THE COMPLETE
TECHNICAL PAPER PROCEEDINGS
FROM:

"SIMULSAT" *
A SIMULTANEOUS MULTIPLE SATELLITE ANTENNA TVRO

Eugene P. Augustin

ANTENNA TECHNOLOGY CORPORATION

Abstract:-SIMULSAT is a Simultaneous Multiple Satellite Antenna Terminal. It was developed by ANTENNA TECHNOLOGY CORPORATION as a result of the demands placed on Cable T.V. operators and television stations to have TVRO systems to view more than one satellite simultaneously without creating an antenna farm. SIMULSAT behaves as a 5-meter antenna over a full 57 degree arc. It is a quasi-parabolic reflector antenna. Gain, radiation patterns, and comparison tests with 5-Meter antennas indicate that SIMULSAT performs very nearly like a typical 5-Meter antenna used as a TVRO. It has the capability of viewing all satellites from Sat Com 4 at 83 degrees to Sat Com 3 at 131 degrees with uniform performance from anywhere in the United States. It has been installed in more than a dozen systems including Teleprompter, Viacom, Heritage and G. E.

I. INTRODUCTION

The demands placed on Cable T.V. operators and television stations to view more than one satellite simultaneously have dictated the need for a multiple satellite antenna. Ideally, such an antenna should provide uniform performance over it's full arc. Indeed, such an antenna exists. It is ANTENNA TECHNOLOGY CORPORATION'S SIMULSAT antenna. SIMULSAT is a quasi-parabolic spherical reflector antenna capable of multiple satellite operation. It covers a 57 degree arc. Degraded performance occurs beyond those limits.

II. BACKGROUND

There are three general classes of antenna to provide wide angle multiple beam operation. These are the Torus, the Offset Spherical, and the spherical which is the class to which Simulsat belongs. In many respects the Torus and the SIMULSAT are very similar. However, a major difference is that the Torus is offset fed in the vertical plane while SIMULSAT is symettrically fed in both planes. Additionally, the Torus is a parabolic contour in the vertical plane and a circular contour in the orthogonal plane. SIMULSAT is quasi-parabolic in both planes. The Offset Spherical Antenna is in reality an approximation to an extremely long focal length parabolic reflector antenna.

III. PARABOLIC SCANNING

In Figure I we consider parabolic beam scanning or parabolic multiple beam operation. A feed placed at the focal point (A.) will produce a beam from the reflector back through the focal point as shown in the Figure. The displacement of the feed in a transverse plane to the reflecting system to (B.) will produce a linear phase shift across the aperture, thus changing the direction of the beam by the angle-θ-. If the reflector were a flat mirror, the beam shift would be linear, and in the opposite direction to the transverse motion of the feed. However, because of the narrow field reflecting system, a coma is introduced which tends to shift the beam in the opposite direction to that of the linear phase shift as well as the introduction of a loss in gain. Thus, a one to one correspondence between angular displacement of the feed and the secondary radiation pattern is not obtained. Further, the decrease in gain increases more or less exponentially as one moves away from the focal point of the narrow field reflecting system. Hence, parabolic multiple beam antennas produce maximum gain only on axis. As one moves off axis, directivity is reduced, the beamwidth broadens , and coma lobes increase. The coma lobe increases on the side of the beam toward the focal point. With an $\frac{F}{D}$ of one; that is, the focal length equal to the diameter, approximately nine or ten beamwidths can be scanned with 1 dB loss in gain.

* SIMULSAT is the Reg. T/M of A.T.C.

However, the sidelobe degradation is significant. With an $\frac{F}{D}$ of .5 such as that found in conventional earth terminal antennas, one can displace about 4 or 5 beamwidths for 1 dB degradation.

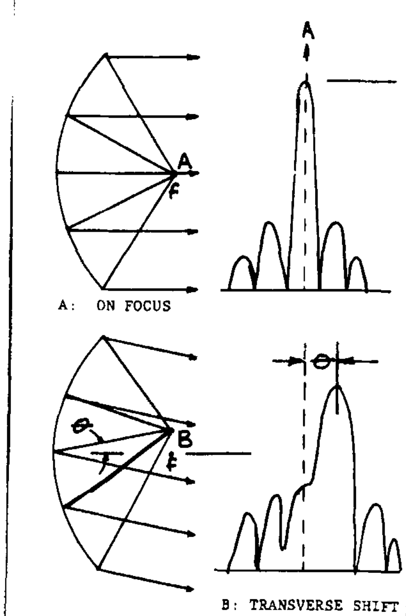


FIGURE 1:
PARABOLIC BEAM SCANNING

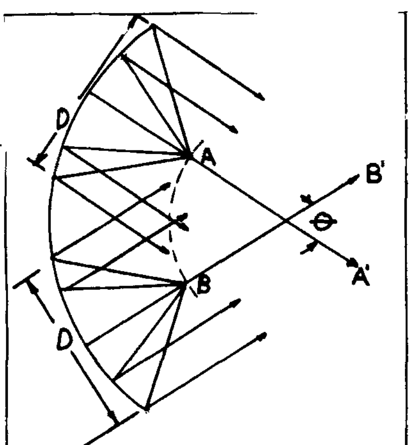


FIGURE 2: SPHERICAL BEAM SCANNING

IV. SPHERICAL SCANNING

Spherical beam scanning or multiple beam operation is shown in Figure (2). Here a feed illuminates only a portion of the reflector , the area represented by the aperture. The feeds are placed along an arc such that the aperture is scanned along the reflector to the various locations. A feed looking at reflector segment A, produces a beam in the A direction while a feed looking a reflector segment B produces a beam in the B direction. Here the feed illuminates the reflector consistently for all beam positions and thus performance is the same for all beam positions until one starts to actually look over the edge of the reflector. Scanning is only limited by the physical size of the reflector and that point at which the opposite edge of the reflector begins to block the reflected waves from the operational zone of the reflector.

V. SIMULSAT SCANNING

SIMULSAT utilizes the on-focus beam principle in the elevation plane and the Spherical Beam Scanning principle in the azimuth plane.

One can determine the angular arc coverage of SIMULSAT. As feeds are moved from Position A to Position B along the feed arc, the beam moves through the angle Theta. Thus, the angle Theta is the maximum angle that can be covered without degradation in performance. For a given reflector size, the longer the focal length--the smaller will be the angle Theta. In it's present configuration, the angular arc coverage of SIMULSAT is in excess of 57 degrees.

The 57 degree arc coverage does not mean to imply that SIMULSAT will view all satellites over a 57 degree orbital arc. Figure 3. shows the geometrical relations between the earth and satellites in orbital arc. From the center of the earth as shown in the Figure the angle Alpha depicts the angular coverage required to view an orbital arc. In the Equitorial Plane from the center of the earth it is precisely the longitudinal difference between the satellites. However, as one moves along the polar axis from the equitorial plane, the distance to the satellites increases and hence angular the arc coverage requirement decreases.

As one moves from the polar axis to the surface of the earth as shown in the Figure at point A, the distance to the satellites decreases and hence the angular coverage Beta increases. Thus, the angular arc coverage requirement of an antenna on the earth surface is a maximum at the equator and decreases as one goes North of the equator.

Additionally, the angular arc coverage requirement North of the equator is greatest when the center of the arc is due South and the angular arc decreases as the site location moves east or west.

For the United States, the maximum antenna arc requirements to see all satellites from Sat Com 3,at 131^{o} to Sat Com 4 at 83^{o} is 55 degrees. SIMULSAT currently has more than a 57 degree capture angle. Thus, SIMULSAT is capable of viewing all satellites in domestic arc from Sat Com 3 to Sat Com 4 from any point in the United States.

SIMULSAT CONSTRUCTION

Figure 4 is a photograph of a SIMULSAT installation in California. SIMULSAT consists of the reflector, the feed support structure, the universal mount, and the feed system. The reflector is a composite reinforced fiberglass structure. The reflecting surface is Hexcel Thorstrand aluminized woven fiberglass cloth. The structure is a combination of woven roving and fiberglass chop. The finish is ultraviolet resistant polyester gel coat. The reflector is made on precision tooling such that no field adjustments of the three segments of the reflector are necessary. Preassembly and inspection in the factory prove the surface to be within .150 inches peak deviation. The reflector weighs approximately 2,000 pounds.

The mount is available in two configurations--a high mount and a low. The choice of mount is dictated by the location. Figure 5 is a photograph of a SIMULSAT installation in Orlando, Florida. As can be seen in the photograph, the antenna is rolled approximately 30 degrees. This is so that the feed arc lines up with the equitorial arc at the center of the equitorial arc. Two different locations for a SIMULSAT antenna , one due north of the center of the equitorial arc and the other east only of the equitorial arc center are depicted in Figure 6. When looking due south, the equitorial arc appears to be horizontal with respect to the antenna, as one moves to the east the arc remains the same but the earth curves away from the antenna and thus the antenna must be rolled in the opposite direction to compensate for the curvature of the earth. As one moves further and further east and further and further North the corner of the antenna gets closer and closer to the ground thus necessitating the use of a higher mount.

The feeds are placed on a track in the feed housing that allows adjustment of each individual feed in azimuth, elevation and polarization with respect to the geostationary orbital arc. Precise alignment of the reflector at a location is not critical since the feed support structure has more than four degrees adjustment capability. Dual polarization is provided through a dual othogonal transformer developed by ANTENNA TECHNOLOGY CORPORATION.

This OMT is physically small and has the LNAs parallel to the beam axis. The system will accommodate all major manufacturer's LNAs and LNCs.

SIMULSAT has the performance characteristics of a typical 4.6 to 5-Meter antenna for each and every beam position across it's 57 degrees of arc.

RADIATION DATA

In order to substantiate the performance claims on SIMULSAT, ANTENNA TECHNOLOGY CORPORATION measured the radiation patterns on a typical production SIMULSAT antenna. The tests were conducted on Comtech Antenna Corporation's range in St. Cloud, Florida. In addition, these tests were witnessed by Comsearch to verify their authenticity. A typical close-in radiation pattern of the mainlobe and close-in side-lobe structure is shown in Figure 7. Also shown are the FCC guidelines for small aperture antennas and the 6 dB averaging limit. The radiation pattern for the far-out side-lobes on a different azimuthal scale is shown in Figure 8. It has the same guidelines and 6 dB limit shown. As seen in these radiation patterns, SIMULSAT does not exceed the averaging limit and meets the general requirements of the FCC guidelines.

We recommend frequency coordination on any antenna be done to the averaging limit. The justification for this is that should an antenna have a sidelobe that exceeds the guideline but is within the averaging limit and that sidelobe happens to be in a direction of a terrestrial interference source, then averaging it with adjacent sidelobes will not reduce the energy content of that sidelobe. An interference condition could exist if one coordinated to the FCC guideline rather than the averaging limit. By coordinating to the averaging limit you are taking the worst possible case and generally the system will behave much better than the coordinated prediction.

The radiation pattern tests were performed with 6 feeds in SIMULSAT--two feeds were located at the left edge of the antenna; two feeds were located in the center of the antenna; two feeds were located at the right edge of the antenna. This was so that adjacent satellite interference levels could be checked on the antenna range. The maximum angular arc between the two feeds within the housing was 57 degrees. Thus, SIMULSAT has the capability of operating over 57 degrees. The measured gain on all beam positions was 44 dB. Thus, SIMULSAT has the gain of a typical 5-meter antenna.

The radiation patterns are such that they can be coordinated for FCC licensing.

PERFORMANCE COMPARISON TESTS

Gain and sidelobes are not the only criteria for the performance of an antenna. One also has to consider the noise temperature. Noise temperature is the most difficult perameter of an antenna to measure, but quite a bit of work has been done on 5-meter antennas. Antenna Technology Corporation performed comparison tests between SIMULSAT and a 5-Meter prime focus antenna at the same location. Carrier to noise measurements were made on several transponders on several satellites in a short time frame on both antennas. The same electronic equipment was used for all tests. The only change was the substitution of SIMULSAT for the 5-meter antenna. In all cases the carrier to noise measurements indicated between 0.5 and 1 dB; better carrier to noise ratio for the 5-meter antenna than was achieved with the SIMULSAT. Noise floor measurements showed SIMULSAT to have .1 to .2 dB higher noise floor. Thus SIMULSAT has about 10 degrees higher noise temperature than a typical 5-meter antenna. If one considers that the 5-meter antenna under test had 44.5 dB gain as opposed to the 44 dB gain for SIMULSAT and the .1 to .2 dB difference in noise floor for SIMULSAT, then good correlation exists with the indicated .5 to 1 dB difference.

In addition to the test conducted by A.T.C. at it's facility, Viacom Cablevision conducted side by side tests on SIMULSAT and on a 5-meter Scientific Atlanta Cassigrain antenna. Both antennas are located on a mountain top located near Pittsburgh, California and within site of the Microwave tower installations on Mt. Diablo. Viacom conducted tests on Sat Com 1, Com Star D2 and Anik 3. Their measurements also indicated an average of 1 dB better performance in the 5-meter than SIMULSAT. Thus, we have correlation between two 5-meter measurements and SIMULSAT to show that SIMULSAT behaves very nearly like a 5-meter antenna.

Table I is a Performance Survey for SIMULSAT.

Frequency:
3.7-4.2 GHz
Gain (4GHz):
44 dBi
Beamwidth:
1.0 degrees
Minimum Satellite Separation:
3 degrees
Maximum Beam Separation:
57 degrees
Polarization Isolation:
25>dB
Adjacent Satellite Isolation:
25>dB
Feed Flange:
CPR 229-G
Size:
16' x 28'
Reflector:
Universal
Mount:
3 piece fiberglass
Wind:
125 Miles per hour-12 cubic yard foundation.

TWO DEGREE SPACING

Recently the FCC proposed a change in Satellite spacing from the current 4 degrees to a future 2 degrees spacing for 4/6 GHz satellites. At the present time we don't know whether or not this will become a reality. A decision won't be available from the FCC until June or July of 1982. The industry has been asked to comment on a technical and cost impact of such a proposal. If the FCC does decide to go to 2 degree spacing, it is my feeling that such a change would not and perhaps could not be implemented prior to 1988 or 1990. This would give manufacturers time to redesign their equipment. At that time operators with 5-meter antennas may have problems. Most typical cassigrainian antennas have a first sidelobe on the order of 12 to 15 dB below the mainlobe. This first sidelobeoccurs almost universally at two degrees from the mainlobe on either side of the mainlobe; hence, the first sidelobe is looking directly at the adjacent satellite when the mainlobe is looking at the desired satellite. The radiation pattern isolation is 12 to 15 dB. For an equal level of ca-rier on adjacent satellites on either side, the carrier to interference ratio would be about 9 dB. This would most likely result in interfering video in the desired signal or "sparklies" may be present, making an undesirable signal. Thus, the antenna will have to be reworked.

SIMULSAT behaves very much like a cassigrainian antenna at 2 degree spacing in it's present configuration. SIMULSAT would have the same relative isolation and carrier to interference problems as a typical cassigrainian 5-meter antenna.

A.T.C. is currently working on the development of a new feed for SIMULSAT which will be retrofitable to the present system. It will cost about the same as a spare feed presently costs and preliminary indications are that it will meet the new proposed antenna guidelines for 2^{o} spacing. This feed system should be available in mid-1983. In any event the change proposed by the FCC would most likely not be implemented prior to 1988 or perhaps 1990. Thus an operator investing in a system today has about 8 years of operating life over which to amortize that system and wait until new developments in the antenna field are available which would make the FCC specification a reality.

COST COMPARISON

In considering SIMULSAT for an operation one must compare the true cost and not the purchase price of SIMULSAT versus the purchase price of several 5-meter antennas. There is a hidden value arising from the fact that there is only one foundation to design, only one foundation location, and only one time that the crew has to go out and perform the installation. Additionally, an antenna farm is not created, less real estate is taken and the environmental impact of one antenna is not compounded by the environmental impact of several antennas in an antenna farm. Again, only one building permit has to be obtained, only one planning commission involvement and the myriad of other hindrances associated with the installation of a TVRO are performed only once with SIMULSAT. Up to 20 feeds can be placed in the feed housing. An operator can always have a spare feed on the shelf so that he can add a live feed at any time without disruption of service. This is an inexpensive method of obtaining additional services.

CONCLUSION

For an antenna for today, SIMULSAT is the most advanced antenna of it's kind. It's a new generation of antenna for today and will be with us for at least 8 years. When one considers that the FCC only opened the industry to small aperture antennas about four years ago, one indeed does come to the conclusion that the advancements made by SIMULSAT truly represent the next generation of antenna. It provides 5-meter performance over a full 57^{o} arc; it is fully FCC licensable, and it is available with more than a dozen currently in operation for single users and MSO's such as VIACOM, HERITAGE, TELEPROMPTER and G.E.

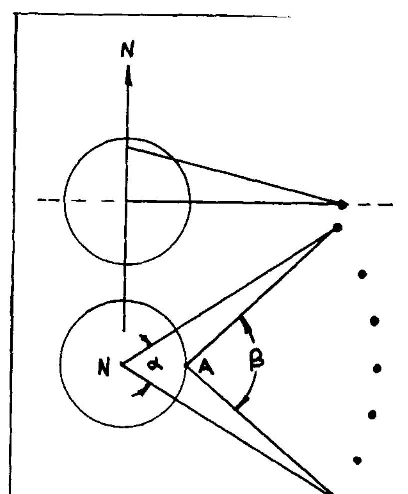
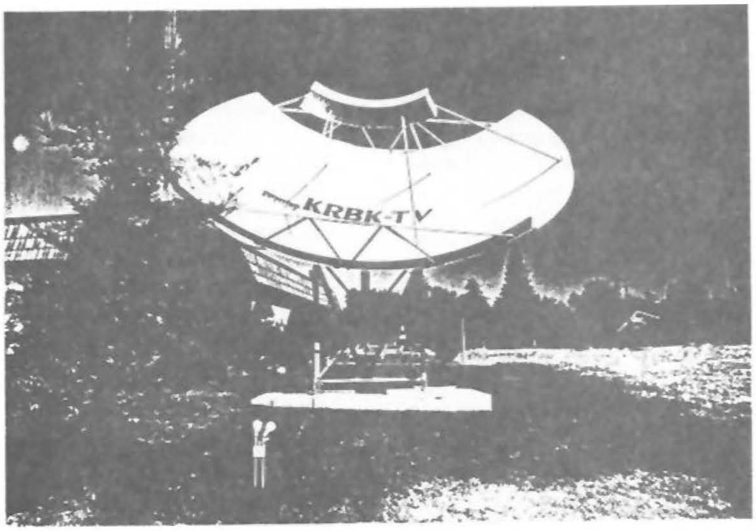


FIGURE 3: ORBITAL AND ANTENNA ARC.

FIGURE 4: WESTERN INSTALLATION
(ANTENNA IS NEARLY HORIZONTAL.)



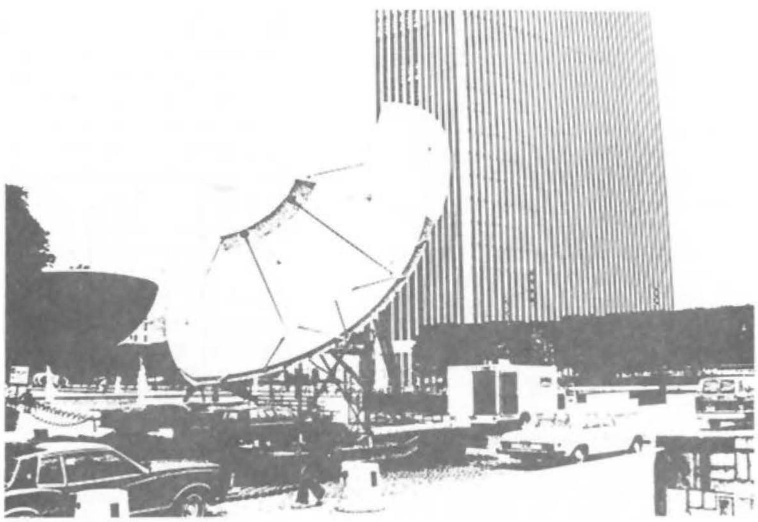


FIGURE 5: EASTERN INSTALLATION (ANTENNA IS ROLLED.)

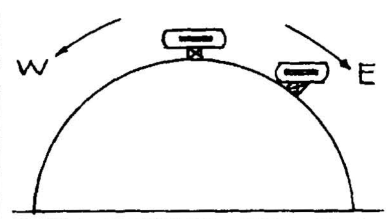


FIGURE 6: SIMULSAT ROLL ANGLE REQUIREMENT

FIGURE 7:

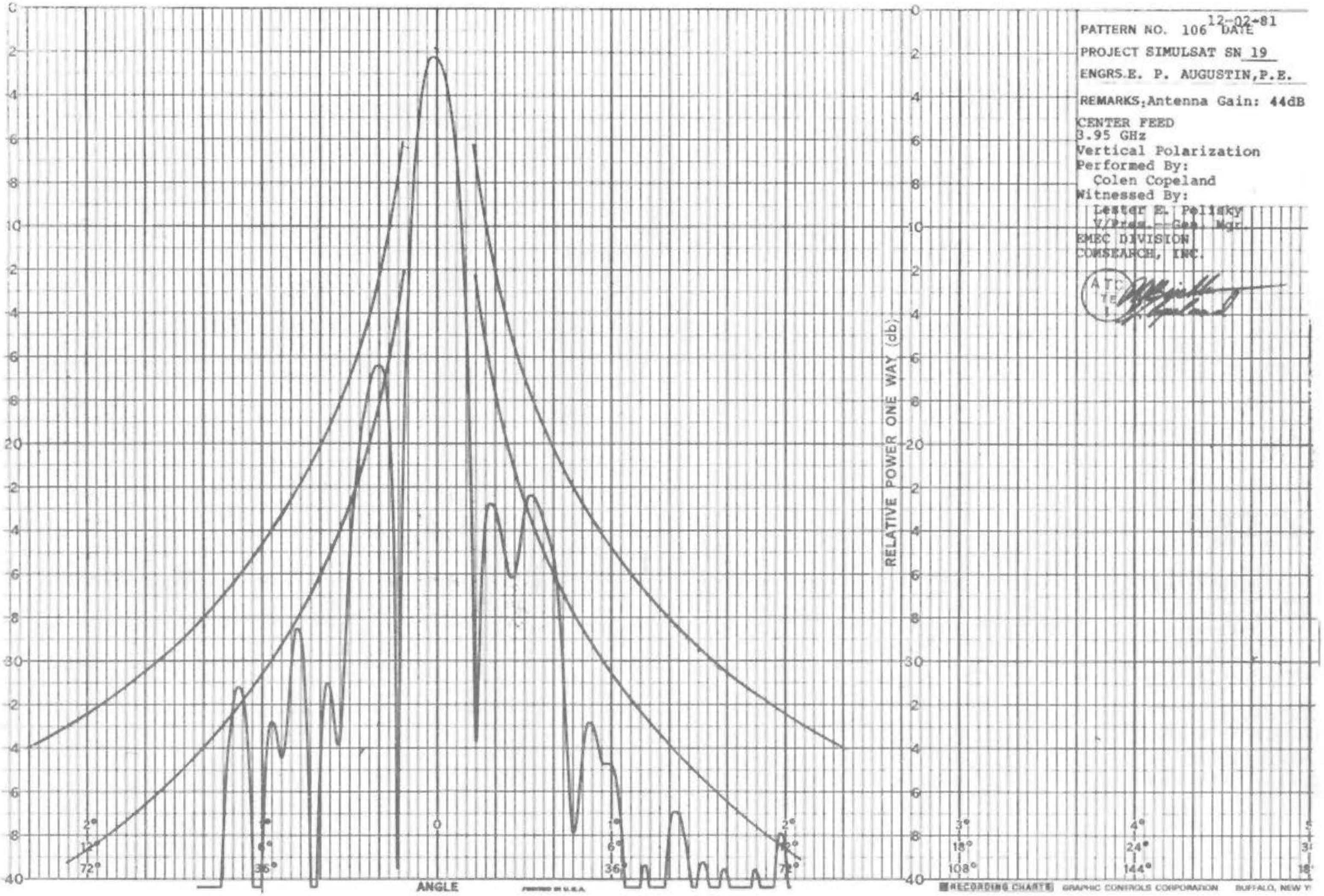
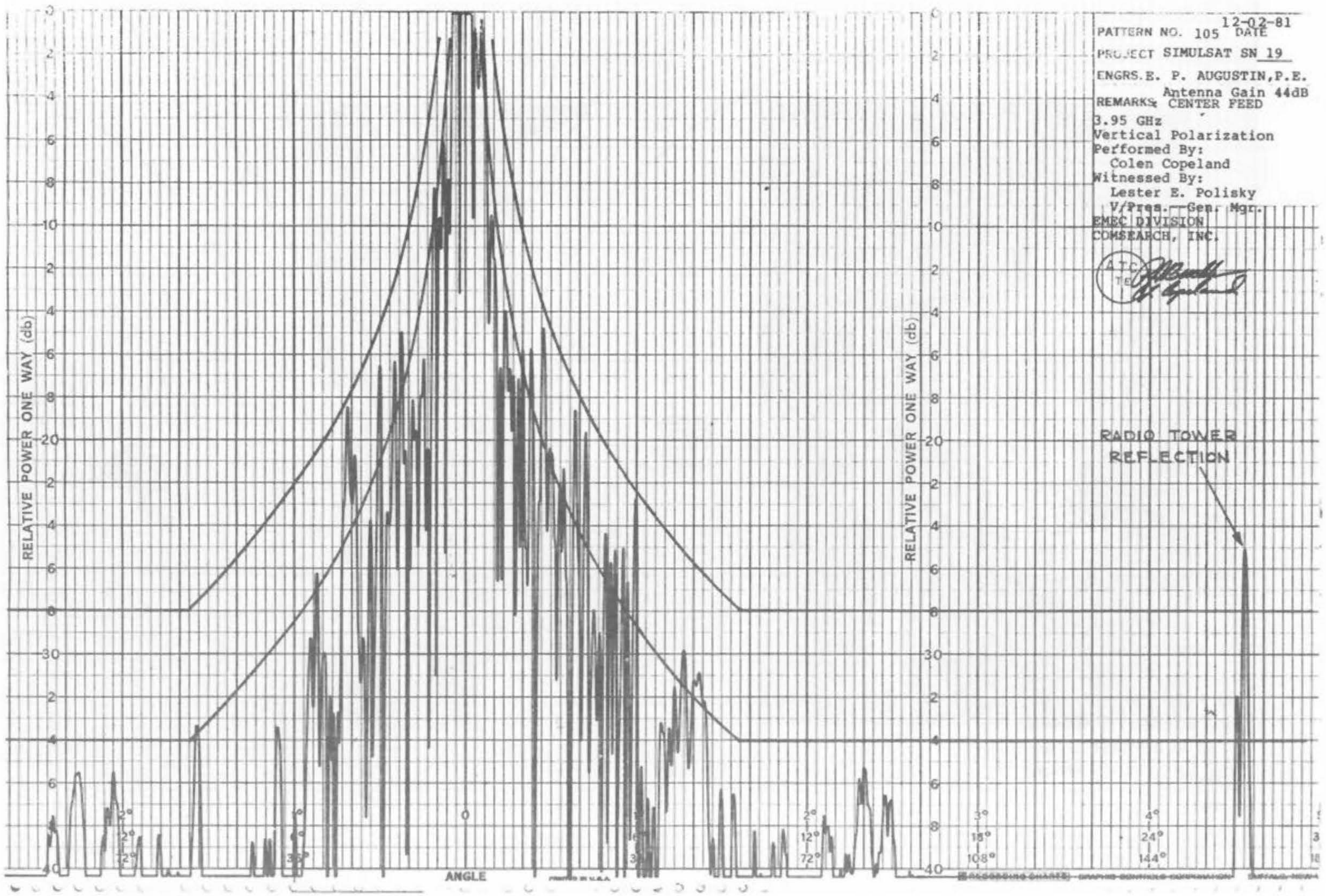

PATTERN NO. 106 DATE 12-02-81
PROJECT SIMULSAT SN 19
ENGRS.E. P. AUGUSTIN,P.E.
REMARKS: Antenna Gain: 44dB
CENTER FEED
3.95 GHz
Vertical Polarization
Performed By:
Colen Copeland
Witnessed By:
Lester E. Polisky
V/Pres.--Gen. Mgr.
EMEC DIVISION
COMSEARCH, INC.
RELATIVE POWER ONE WAY (db)
ANGLE
RECORDING CHARTS GRAPHIC CONTROLS CORPORATION BUFFALO, NEW Y

FIGURE 8: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ENGRS. E. P. AUGUSTIN, P.E.
Antenna Gain 44dB
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Performed By:
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Witnessed By:
Lester E. Polisky
V/Pres. - Gen. Mgr.
EMEC DIVISION
COMSEARCH, INC.
RELATIVE POWER ONE WAY (db)
RADIO TOWER REFLECTION
ANGLE

Abstract of paper entitled

Data Broadcasting: "DIDON" and "DIODE" Protocols

by Yves Noirel, CCETT/Rennes, France

Summary:

A definition of the broadcasting mode is given by using the concepts of *audience* and *programming*. There follows a description of the DIDON protocol and the DIODE protocol. The DIODE protocol is a specialized application of the DIDON protocol, when data is broadcast upon request.

The DIODE concept is explained in relation to the various data retrieval systems, and emphasis is placed on its role in learning about audience structure through the use of new mechanisms in collecting user requests.

The DIODE concept is particularly well suited to teletext systems transmitted via cable networks. It allows efficient use of a return channel to remotely control the downloading of teletext pages into multipage decoders built into television sets.

Paper presented by: Yves Noirel

Born in 1946, graduate of the Ecole Nationale Superieure des Telecommunications/TDF (Telediffusion de France), Senior Engineer/Director of the Data Broadcasting Protocol Laboratory at the CCETT/Rennes in France.

I — INTRODUCTION

In just a few years' time, data broadcasting has gone from the status of a concept greeted somewhat dubiously to that of a technology internationally recognized as very promising. This evolution was brought about by means of a double distinction: first of all, a distinction from the traditional image that radio and television had given to broadcasting; secondly, a distinction from the restrictive image that teletext was beginning to give to data broadcasting.

Avoiding this double pitfall meant providing a definition of broadcasting which would be independent from the type of programs broadcast. This approach was thought to be particularly legitimate in that it constituted a step toward the separation, felt to be increasingly necessary, between information carrier and information provider, between container and thing contained. It thus became possible to build a definition which was no longer focused on one particular presentation of broadcast information, the audiovisual presentation. The specificity of broadcasting is to be found in that particular type of presentation.

That which is specific to broadcasting, and which distinguishes it from other systems of correspondence between two users, is the notion of an audience. The enhancement of the services offered by broadcast systems must therefore take place by broadening the means of configuring this audience. In today's radio and television, programs are established and then transmitted by the press. The schedules indicate, more or less accurately, the time of broadcast, that is, the time when the various products will be available to the users. The influence the user can exert on this programming is one that has a very long response time, by means of surveys that provide a basis for evaluating whether the supply is adequate to the demand. Broadcasting digitally coded information provides a means of broadening the notion of a program, due to the ease with which this type of information can be stored at both transmission and reception end.

The design of a data broadcasting system must therefore be based on two kinds of research, which are complementary: research concerning the set of rules governing the exchange of information between transmitting and receiving equipment, and research concerning the strategies to be implemented in receiving equipment in order to fulfill the requirements expressed by the transmitted equipment. The two types of research result respectively in the definition of broadcasting protocols and transmission guidelines.

II — BROADCASTING PROTOCOLS

The design of broadcasting protocols was guided by the architectural principles applicable to teleinformatic systems, and known by the name of "Open Systems Interconnection". These principles, initially developed within the I.S.O., are now universally used as working tools to design new telecommunications systems. The central notion is the layer, with each layer grouping functions which are similar, either in their nature, or in the technology employed. The functions in each layer are such that the layer can be totally redesigned to take technological advances into account, or to satisfy the needs of a new application, without altering the interfaces with adjacent layers. Every system is described by seven layers, the first four of which concern transmission, and are therefore involved in the definition of broadcasting protocols. Without enumerating the many advantages of this approach, we would nevertheless mention the most perceptible ones:

- the possibility of designing protocols that can be used for various media, with the adaptation of the protocols to the different media taking place at lower layer(s).
- the possibility of multiplexing several digital channels on a single medium, and, within each channel, of carrying different kinds of information to be used together to provide a service.
- the possibility of offering a separate transport service on each digital channel, each transport service being adaptable to the needs of the user (residual error rate, encryption,

amount of information, average and instantaneous data rates).

The DIDON data broadcasting protocol corresponds to the first four layers described in the NABTS (North American Broadcast Teletext Specification). The application of this protocol for broadcasting data on request is called DIODE.

The exact description of the DIODE protocol is beyond the scope of the present paper. We would merely indicate that this protocol defines the dialogue between the transmitting equipment and the receiving equipment in a system of data broadcasting upon request. It is composed of a list of messages which can be exhanged, a description of these messages and the causal relations defining the way they are linked.

The central idea around which the DIODE protocol is built is that the most important characteristic of broadcasting is not that the signals transmitted are one-way, but rather that the information broadcast can be received by a theoretically unlimited number of terminals simultaneously. On the basis of this idea, the transmitting equipment may be said to be like the conductor of an orchestra with regard to the receiving equipment. This idea is also the basis on which the following paragraph develops the ideas enabling us to situate DIODE within the family of information retrieval systems.

III — TRANSMISSION GUIDELINES

3.1 HOW DIODE IS SITUATED AMONG THE DISTRIBUTION SYSTEMS

3.1.1 Resource Sharing in an Information Retrieval System

3.1.1.1 Information Retrieval Systems

An information retrieval system enables the users to retrieve part of the information put into the system by suppliers (who may be the users themselves). The distribution functions of the system consist in offering the users the possibility of requesting information and in supplying each user with the information requested.

In figure 1, k is the amount of information available in the system. The total volume of information available is:

$$v = \sum_{i=1}^{k} Si, \qquad Si \text{ being the size of information } i$$

----------1----------
----------2----------
----information---
----------k----------

DISTRIBUTION SYSTEM

\+ \+ \+ \+ \+ \+ \+ \+

USERS

System for Distributing k Items of Information

Figure 1

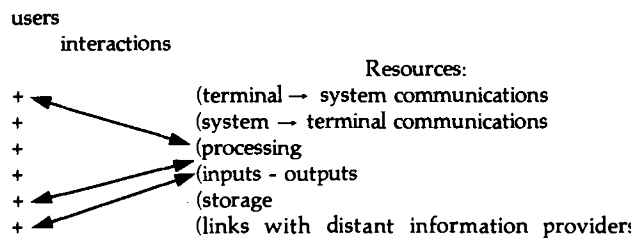
3.1.1.2 Resources of an Information Retrieval System

The user population produces demands for information retrieval which require, if they are to be satisfied, the consumption of common resources of the system:

- terminal → system communications
- system → terminal communications
- system processing power
- system Input-Output capacity
- system storage capacity
- system links with remote suppliers who provide updated information and serve as memory extensions for storage

A request for retrieval is therefore translated as a request for consumption (figure 2). The system's common resources are divided into three groups, corresponding to the different phases of servicing a request for retrieval (this classification is useful for the evaluation and comparison of performances of different information retrieval systems):

- welcome resources (terminal → system communications, processing required to receive and analyse the request, memory for the context of the retrieval session, etc.)
- resources for acquisition and formatting of information (Inputs-Outputs, links with remote information providers, processing, buffer memory, etc.)
- resources for system → terminal communications



Resources of an Information Retrieval System
Figure 2

From this point of view, the design of an information retrieval system falls within the general framework of resource sharing in a system where the consumers arrive at random.

We are taking a "telematic" system with a large number of users as our frame of reference. The process of the arrival of users wishing to retrieve information is presumed to be independent from the number of users retrieving information at a given time.

As system resources are finite, a request for information may, if the system is overloaded, not find sufficient resources to satisfy it immediately. This request will therefore have to wait for service until such time as the resources required become available.

Generally speaking, each resource or set of resources is associated with a resource availability queue.

For an indivisible resource, i.e. one monopolized, at a given time, by a consumer, user consumption is expressed in resource use time, called service time.

As the queue associated with the resource is presumed to have infinite capacity, the sharing of a limited resource means a certain amount of time spent by the consumer of this resource. The time spent is the equivalent of the service time (which is greater or lesser, for a given consumption, depending on the importance of the resource) plus the time spent waiting for the resource to be available (this waiting time depends on the distribution in time of the arrival of consumers).

We shall use the following elementary result, from queue theory, concerning the delay due to sharing a resource (with an infinite queue capacity) in the following conditions:

- the rule is first come - first served
- a consumer's service time is constant, with a value of s
- the law of consumer arrival is Poisson's law with a parameter λ (the time between two arrivals follows an exponential law with an average of $1/\lambda$)

Thus the average time (average service time + average queue time) spent by a user is given by the following formula:

$$(1) \quad W = s + \lambda s^2 / (2(1 - \lambda s))$$

3.1.1.3 System → Terminals Communication Resource

If the system → terminals communication resource is the rarest resource in the information retrieval system, it means that system performance will vary with the load. In this paragraph, we suppose that the system → terminals communication resource is the only limited resource in the system (we are not taking other resources into account) and that, at a given time, it may be totally or partially used (dynamically shared data rate) to service a request for information retrieval.

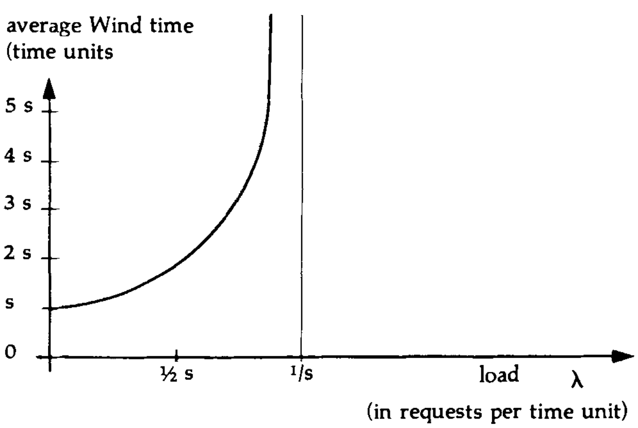
a) The system serves each user independently.

If the system serves each request independently, with the first come-first served rule, the average time (queue + service), called Wind, spent by a user is given by the formula (1) in § 3.1.1.2:

$$Wind = s + \lambda s^2 \ / \ (2(1 - \lambda s)).$$

Figure 3 gives the model for the system with a queue and the Wind curve representing the variations in average time spent according to the average number of arrivals per time unit.

Wind does not depend on k, the amount of information. When the load (described by λ) nears the maximum rate (1/s) admissible in the system, queue time tends toward infinity.



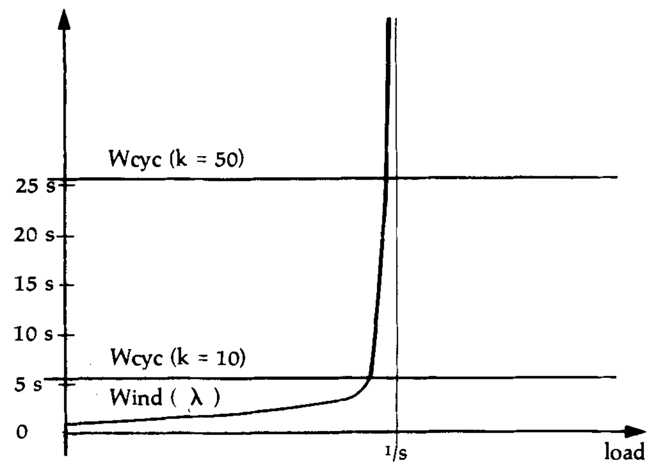
Delay due to resource sharing when the system services requests independently (constant service time)

Figure 3

b) The system broadcasts all information in a repetitive cycle.

If the system broadcasts all the available information in a repetitive cycle, using the totality of the resource, information is broadcast periodically with a period of ks. Requests to retrieve information i are all satisfied simultaneously by the broadcast of information i. The average time spent per request does not depend on λ and is:

$$(2) \quad Wcyc = s + ks/2$$



Information delivery time with independent service and cyclical broadcast for k = 10 and k = 50

Figure 4

c) The system broadcasts part of the information in a repetitive cycle, and services requests independently for the rest of the information.

A fraction p ($0 \leqslant p \leqslant 1$) of the broadcasting resource is allotted to serving requests for retrieval of information not broadcast cyclically. The choice of p and of the information to be broadcast cyclically uses the average rate λ of request arrival, the probability distribution (P1, P2, . . .,Pk), and the criterion of service optimization. We shall give only a numerical example here:

— the system distibutes 200 items of information (k = 200)
— available data rate is 4 Mbits/s
— each item of information takes an amount of time s = 1/5 second to be broadcast at full rate (which corresponds to a volume of 100 Kbytes)
— requests for retrieval of information i ($1 \leqslant i \leqslant 200$) arrive according to Poisson's law with an average rate of λ i (in our model λ i = Pi) with:

$$\lambda i = \begin{cases} 10 \text{ arrivals per second for } 1 \leqslant i \leqslant 10 \\ 1 \text{ arrival per second for } 11 \leqslant i \leqslant 50 \\ 0.01 \text{ arrival per second for } 51 \leqslant i \leqslant 200. \end{cases}$$

It is not possible to service all the requests independently because the average rate of arrival is greater than system capacity, which is 5 services per second.

If the 200 items of information are broadcast cyclically, the period has a value of 40, hence an average queue time of

20 seconds and average time spent (queue + service) of 20.2 seconds.

If we reserve a fraction p = 1/3 of the rate to service requests independently, if information items 51 to 200 are served this way, and if the remaining fraction (2/3) of the resource is allotted to cyclic broadcast of information items 1 to 50, then:

— average time spent for retrieval of one item 51 to 200 of information:

$$s/p + (½)\left(\sum_{j=51}^{200} \lambda j\right)(s/p)^2 / \left(1 - \left(\sum_{j=51}^{200} \lambda j\right)(s/p)\right) = 3.3 \text{ sec.}$$

— the average time spent to retrieve an item 1 to 50 of information is:

$$s/(1 - p) + (½)\ 50\ s / (1 - p) = 7.8 \text{ sec.}$$

With this same division of information between the two types of service, it is possible, by adjusting (diminishing) parameter p, to obtain identical average times (queue + service) whatever item of information is retrieved. This leads to a use rate $(s\sum_{j=51}^{200} \lambda j/p)$ of the resource allotted to the service "by request" which is very close to 1 (this use rate is already 90% in the previous example), which makes the system all the more sensitive to errors in estimation and to load variations (see Wind curve (λ) in figure 3).

By taking the configuration of the audience (characterized here by the probability distribution $(P_i)_{i = 1, 2, \ldots, k}$ and the average rate λ of requests) into account to divide the information to be distributed between the "cyclic distribution" and "individual service per request" modes, it was possible to improve the average information access time, as compared to that necessary for a system operating in only one or the other of these two modes.

3.1.2 Current Systems of Information for Large Numbers of Users: Cyclically Broadcast Teletext, Interactive Videotex

3.1.2.1 Cyclically Broadcast Teletext

Magazines composed of several pages of text are broadcast in a repetitive cycle. Users consult these magazines on their TV sets by means of a keypad. The pages requested are stored and displayed when they are broadcast. Waiting time does not depend on the number of simultaneous users (an additional user does not entail any additional use of the system's common resources), but it is connected with the number of pages available (see §3.1.1). In order to make an additional page available, it must be broadcast cyclically, thus requiring that a fraction of the broadcast rate be allotted to it, which increases the waiting time for the pages which are already programmed.

As the system does not scrutinize audience configuration, resource sharing between items of information to be broadcast (programming) is not dynamic: information no one wants may be broadcasted.

3.1.2.2 Interactive Videotex

Videotex uses the switched telephone network to serve users interactively.

It provides access to large quantities of information - several hundred thousand pages - which can be distributed among independent data bases with which the user dialogues.

Its performances as regards distribution, which are characterized by the response time and the probability that the user may find all access lines busy, depend on the number of simultaneous users (see §3.1.1 for systems servicing user requests independently).

3.1.3 DIODE

3.1.3.1 Structure

DIODE combines a broadcast channel (system → terminal communications) with the return channels of a cable network or the switched telephone network links (terminal → system communications).

Figure 5 gives a block diagram of the system.

Users send requests to a machine called "Delivery Front End". The Front End is located at the interconnection between three networks:

- The telephone network, or the return channels of a cable network, through which the requests are sent.
- The data transmission network used for exchanges with remote information providers. These exchanges enable the Front End to have updated infromation, and to retrieve information requested that it does not have in its memory.
- The DIDON data broadcasting network through which it sends the information to the users.

3.1.3.2 Delivery Front End Functions

The functions of the Front End include:

- the classical functions of a communication node in a teleinformatic system, i.e. transmission procedure management, message queueing, data flow routing
- information retrieval session management: analysis of user request, exchanges with information providers, management of DIODE protocols at transmission, assignment of DIDON digital channels, respecting transmission parameters, etc.
- service performance optimization: regulation of request arrivals (audience structuring), preparation of a program of information to be broadcast on the basis of requests received, optimum location of files in accordance with configuration, etc.

3.1.3.3 Adaptation to Variations in Audience Configuration

The Delivery Front End's role is to enable DIODE to utilize the notion of a broadcast program while taking audience configuration into account.

It is costly, in terms of broadcasting resources and performances, to add infrequently requested information to a system that broadcasts its contents in a repetitive cycle. It is equally costly to distribute frequently requested information in a system that serves its users independently.

To give a numerical example, we may take the following hypotheses:

Considering:

- two information retrieval systems, A and B, with similar size system → terminal communication resources, that resource being the only limited resource in each of the systems; system A serves users independently, and system B broadcasts the information cyclically
- a group of K = 110 items of information, with retrieval of each item taking the same service time s of the system → user communication resource, and user

requests for each item arriving according to Poisson's law with average rates $\lambda 1$, $\lambda 2, \ldots, \lambda 110$, with:

$$\lambda 1\ s = \lambda 2\ s = \ldots = \lambda 100\ s = 0.005$$

$$\lambda 101\ s = \lambda 102\ s = \ldots = \lambda 110\ s = 0.5$$

We want to divide the information between A and B.

By putting items: 1,2, . . . 100 in A
items: 101, 102, . . . 110 in B

we obtain an average retrieval time of:

Wind (λ = 1/2s) = 1.5 s for items 1 to 100

Wycy (k = 10) = 6 s for items 101 to 110

If item 101 is put in A instead of in B, waiting time becomes infinite in system A, which is saturated with requests for item 101.

If items 91 to 100 are put in B instead of in A, with the other items remaining as they were, we obtain an average retrieval time:

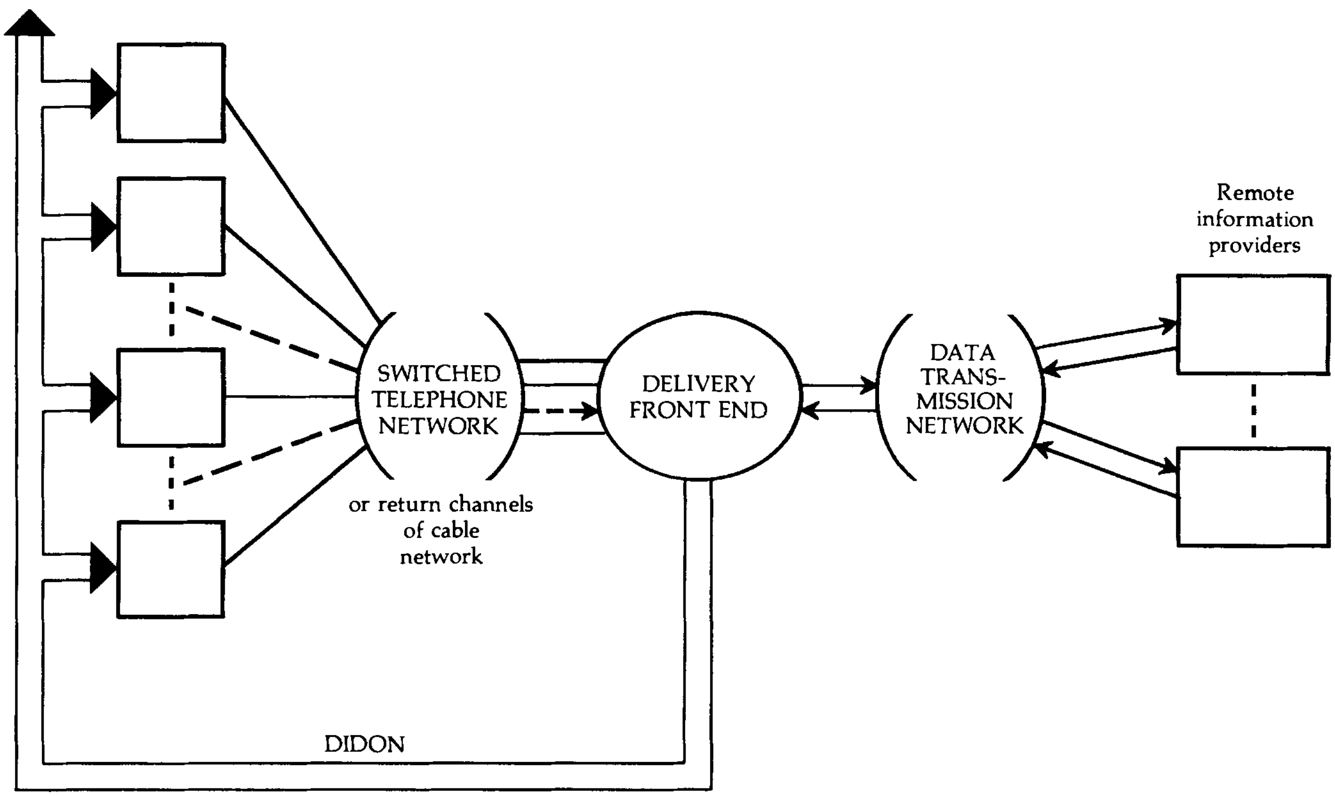
Wind (λ = 0.45/s) = 1.41 s for items 1 to 90

Wcyc (k = 20) = 11s for items 91 to 110

The average retrieval time has increased by about 80% for more than 90% of the requests for retrieval. The gain in time for the others is negligeable.

The above numerical example shows the extra cost in resources and in performances brought about by a bad choice of an information distribution system (cyclic broadcasting or independent service for each user).

One of the advantages of DIODE, which operates on the principles of "broadcast on request with grouping of request for the same information", lies in the flexibility with which it adapts to variations in audience configuration, and in its ability to distribute all information without "cost" distinctions according to the frequency of requests.



DIODE SYSTEM
Block Diagram
Figure 5

ADDRESSABLE CONTROL FOR THE SMALL SYSTEM

Charles Eissler
Director, Market Research

OAK COMMUNICATIONS SYSTEMS
Crystal Lake, Illinois

ABSTRACT

Cost effective addressable control is now available for the small system with as few as 1,000 subscribers. A system that is in the expansion phase of pay can also benefit from cost effective addressable control. The system can utilize the same headend components and home terminals after expansion.

Addressable control can provide improved program marketing techniques, reduced operating costs and enhanced program and equipment security.

The difference between this mini system and one where five to eight thousand or more subscribers are involved is in the control center. The control center is made up of relatively low cost, off-the-shelf components. However, a propriatory software program retains basic addressability and special event capability.

A financial analysis is included. The marginal investment for mini system addressable control, as compared to only hard security, pays back in about two and one-quarter years. Internal rate of return computes to fifty-five percent.

INTRODUCTION

Perhaps you are a small system operator with 1,000 to 3,000 subs who is considering adding one or more premium tiers. However, you need help in marketing, protecting and controlling this more costly product. Or maybe you are associated with an MSO in a small but growing system. You need a configuration that will hold operating costs down in the early growth phase. However, you want a system that will be applicable when you have grown to 10,000 to 20,000 subscribers. Whether you are a small system operator or part of a large MSO, addressable control can help you in all phases of your operation. Control center components and software that will make addressability cost effective in a 1,000 subscriber system are now available.

THE NEED FOR ADDRESSABLE CONTROL

In the past, addressable control was cost effective typically when a system had at least 5,000 subscribers.

Addressable control that is cost effective only in systems of that scale does not meet the needs of the majority of cable operators in this country.

The TV Factbook (1981-82 Edition No. 50) indicates that there are about 975 systems in the country with 5,000 or more subscribers. One can also derive from the data (see below) that there could be 1,715 systems (37% of total) with between 1,000 and 5,000 subscribers. Addressable control which is cost effective in the 1,000 to 5,000 range benefits the majority of system operators.

Subscribers Per System	Systems In Size Range
Over 5K	975 (21%)
1K to 5K	1,715 (37%)
Under 1K	1,889
	4,579

Addressable control can benefit any cable system. It provides the means to deliver and to control premium services including special events. It provides additional security for both program material and equipment. It assists the cable operator in dealing with collections, churn and temporary discounts.

BASIC FUNCTIONS OF ADDRESSABLE CONTROL

We shall refer to this addressable control for the small system as a mini system. This small system alternative will handle basic addressability functions in a cable operation of up to 8,000. Basic addressability functions are the following:

1. Authorization of individual home terminals to operate.
2. Pre-authorization to receive specific programs (including special events).
3. Delivery of the pre-authorized tier or program when transmitted.
4. Changing of authorization on command from the control center.
5. Suspension of all service on command from the control center.

In addition to responding to commands from the control center, the home terminal in an addressable system should be able to disable itself if:

1. The flow of data from the headend is disrupted.

2. It is disconnected from its source of power.

These last two characteristics guard against attempts to steal the home terminal itself. All of these essential functions are continued in the mini system.

OPERATIONAL OVERVIEW

The general operation of an addressable system is retained in the mini system. A key element is the microprocessor which is contained in the home terminal. This microprocessor enables the home terminal to respond to orders from the headend. The home terminal has a unique identity. When addressed, it will react as an individual unit.

The two kinds of data required are address data and program tag data. The address data tells the home terminal to operate and preauthorizes it to descramble programs with a certain tag identity.

The program tag data is sent with the program itself and identifies the kind of program. When the home terminal receives a program with a tag identification that it has been preauthorized to receive, it activates the descrambler and a clear image is received.

The individual home terminal must receive both kinds of data. The address and tag preauthorization must be included in information sent from the CPU. The program tag must be included with the program itself.

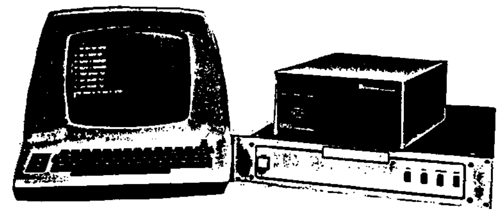
If the subscriber is delinquent or if a home terminal is reported stolen, authorization is withheld in the global address and the box does not function. Addressable home terminals are stored in inventory or carried on the installer's truck in a deauthorized (turned off) state. If a terminal is stolen, it is deauthorized and becomes worthless. The home terminal must be authorized in a system before it will function.

The home terminal used with the small system is common to that used with the total addressable system.

The headend for the mini system is also common to the larger system. It consists of a scrambler (or encoder) for each scrambled channel. Some scrambling systems require a video interface unit to supplement each scrambler. A tag generator is required to identify each program as it is transmitted. Both the headend components and the home terminal can continue to be used as the subscriber base grows and ultimately exceeds the capability of the small system control center. At that point, only the control center needs to be revised.

THE MINI SYSTEM CONTROL CENTER

The control center is where the mini system differs from the larger addressable system. The control center utilizes off-the-shelf low cost components to generate and store the customer file.



However, the software which drives these components is unique. Control center components consist of:

1. A CRT terminal

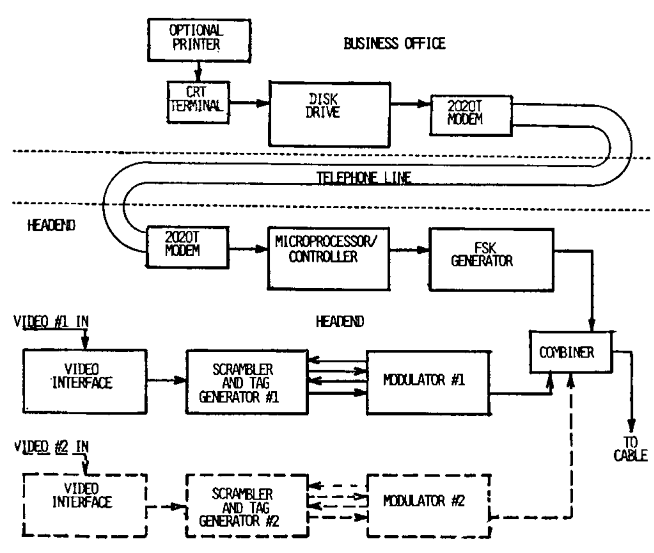
2. A 5¼" floppy disk and drive

3. A CPU microprocessor/controller

4. A FSK generator

5. A printer (optional)

MINI ADDRESSABLE SYSTEM



A CPU and the tag generator can be located at the cable system headend with the CRT terminal, printer, and disk drive located at the cable system control center. These are linked by phone line transmission media.

The system can control 16 tag levels. Tags can be applied to individual channels, groups of channels or program types regardless of channels.

The global file is continuously outputted to authorized service. The cable operator saves this file on a floppy disk and can then re-enter the file into the RAM of the CPU should it ever be lost due to power failure.

The software has six functions. The system prompts the operator throughout the operation.

The system features are:

1. Add a subscriber: The system requests a 4-digit subscriber number. Upon receipt of the number, it conducts a search to assure that it is unique.

2. Change a subscriber: This function provides the means for changing a subscriber decoder address on/off code and tag level authorization.

3. Delete a subscriber: This enables an operator to remove a subscriber from the file and opens the subscriber number and decoder address for reassignment.

4. Printer decoder file: The system can print day-to-day transactions or the entire decoder box file. The print out is useful for auditing and billing from the file.

5. Save decoder file: The global decoder file can be saved on non-volatile memory. This includes all subscriber decoder addresses and authorization levels.

6. Load decoder file: This function provides the means of loading the decoder file from non-volatile media back into the CPU.

If the cable operator wants to provide a special event beyond the scheduled premium services, it can be done. One or more of the 16 tag levels is dedicated to pay-per-view. A channel, the content of which can be preempted by the special event, is selected. At any time prior to the event, authorization data is downloaded to subscribers who have ordered the event. Programming which may be on the channel is not disturbed by the downloading. Then, at the moment the event is to take place, the scrambler is turned on and the channel is tagged with the tag bits previously selected for that special event.

Descrambling immediately takes place on all decoders into which preauthorization was previously downloaded. There is no waiting or transition time between regular programming and the special event.

The small system can handle 8,000 subscribers efficiently. This is the capacity of the 5¼" floppy disk. However, use of the second disk results in some operating delays and inconvenience. Also, one soon encounters the limit of 9,999 which is determined by the 4-digit subscriber number.

The full addressable system becomes cost effective somewhere between 3,000 and 5,000 subscribers which is considerably below the 8,000 practical limit of the mini system.

TRADE OFFS FOR THE MINI SYSTEM

There are trade offs for the mini system. The software menu for the large system details many more business and control functions. Many of these computer software functions provide the added efficiency to operate a larger system. These include such things as:

1. A special installation test sequence
2. Home terminal tracking and audit
3. A history of decoder repair and status
4. Security file
5. Assignment of decoder to installer

FINANCIAL ANALYSIS - GENERAL ASSUMPTIONS

The initial investment in an addressable system is greater than that for a non-addressable system. However, benefits and increased profit can result.

Our analysis assumes that the cable operator has already decided to protect his programs with hard security. However, he is considering whether to install headend addressable control as well.

We will consider the marginal cash outlay and inflow which can be attributed to addressable control. We can then calculate an internal rate of return to determine whether or not the added cost for addressability is a sound investment. Our approach will be to consider the specific cost, revenue increase, or operating cost reduction which will result in a cash outlay or inflow. These will be summarized and the payback period and the internal rate of return will be calculated.

Cash Outlay

Cash outlay is assumed to take place in the first year, the year of construction. It is also assumed that the addressable home terminals are installed in all subscriber homes. By doing so, the system operator can upgrade a subscriber from basic to pay, change premium tiers, deliver special events, demonstrate new tiers, and suspend service by exercising only headend control. Since there is no additional cost to install an addressable terminal, installation cost is not a factor.

Relevant assumptions about the system are summarized in the following table:

System Assumptions
1,000 subscribers (60% pay)
35 channels (300 MHz)
3 scrambled channels

Three premium channels are to be offered by our example system, therefore, three sets of head-end components will be required.

CASH OUTLAY ($1,000)

	Addressable	Non-Addressable	Change In Cash Flow
Control Center (CPU, Term., etc.)	13	Not required	
Headend (scrambler, etc.) - 3 sets	12	6	
Home Terminals, 1,000 units	126	77	
	151	83	
Investment Tax Credit (@ 10%)	(15)	(8)	
Cash Outlay	136	75	61

Cash Inflow

Cash inflow results from a number of items directly attributable to addressable control. Each of these sources of added cash flow will be explained before including it in our table.

There are two direct sources of added revenue, special events and lift.

We assume 6 special events per year are offered and that 50% of the base subscribes. They are included at $10.00 per event with 50% retained by the cable operator as net revenue. Some readers may feel that 6 events per year is optimistic. However, one must consider that 3 special events were offered in 1981 with only a few hundred thousand addressable home terminals in service. By the end of this year more than 2,000,000 addressable home terminals will be in place. Protection of the material while in satellite transmission will be more widely available. The increased market size and the increased program protection will attract more special event promoters.

Lift due to more attractive programming is assumed to add 10% to revenue. The basic and premium revenue (which would be the same for either addressable or non-addressable) is:

Program Subscription And Rate Charged

Service	% of Subs	Subs	Rate/Mo.	Annual
Basic	100	1,000	$7.75	$ 93,000
Pay #1	60	600	8.80	63,400
Pay #2	30	300	4.50	16,200
Pay #3	15	150	8.80	15,800
				$118,400

Lift at 10% equals $18,800

Several items of reduced operating cost and which are attributable to addressable control are included in the analysis as cash inflow. These items are:

-Reduced service costs to handle churn (disconnects/reconnects)

-Reduced service costs to handle tier changes

-Reduction of accounts receivable

-Reduction of box theft

Churn and tiering changes can be handled by entering data on the CRT at the control center. It is not necessary to roll a service truck to accommodate them. Therefore, we used the following assumptions:

-Churn affected 20% of pay subscribers per year

-Tier changes affected 20% of the total subscriber base each year

-Service calls were included at $20 for churn and tier changes

Accounts receivable also appear as an operating cost reduction (cash inflow). The cable operator can demonstrate the ability to suspend service from the control center, thus motivating the delinquent to settle. We included this improved cash flow at $1 per month per subscriber.

Theft of home terminals was included at 5% for addressable units compared to 15% for non-addressable. Based on a survey among cable systems equipped with addressable control in late 1981, the theft rate on addressable terminals was actually running as low as 1%.

Depreciation (seven year, straight line) is deducted from cash inflow. Cash inflow was arbitrarily reduced by 50% in the first year recognizing that a 100% cash flow will not be achieved instantly. The cash inflow for operation is summarized in the table below:

Table of Cash Inflow ($1,000)

	Year 1	Years 2-7
Increased Revenue		
Special Events	7.5	15.0
Lift	9.4	18.8
Decreased Operating Costs		
Churn	1.2	2.4
Tiering Changes	2.0	4.0
Accounts Receivable	6.0	12.0
Theft of Home Terminals	2.7	5.3
Depreciation Expense	(4.9)	(9.7)
Added Revenue + Operating Cost Reduction-Depreciation	23.9	47.8
Income Tax (@ 46%)	11.0	22.0
Net Income	12.9	25.8
Depreciation Add Back	4.9	9.7
Annual Cash Flow	17.8	35.5

Payback and Internal Rate of Return

Cash flow from the previous calculations is summarized:

Cash Flow ($1,000)

Year	Cash Outlay	Cash Inflow
0	61.0	-
1	-	17
2	-	35.5
3	-	35.5
4	-	35.5
5	-	35.5
6	-	35.5
7	-	35.5

Payback is the time required to recoup, in the form of cash flow from operations, the original investment. Payback, calculated from the above cash flow is 2.22 years.

Internal Rate of Return allows one to appraise an investment as compared to other opportunities. One can evaluate the return from a project considering the cost to finance it. Internal rate of return considers the time value of money. Internal rate of return is the discount rate that will reduce the present value of the cash flow over the life of the project to zero. The internal rate of return for our example system is 55.6%.

UPGRADE TO A LARGER SYSTEM

The mini system control center will handle up to 8,000 subscribers. However, long before this number is reached, the system operator may benefit by upgrading the control center. Only the control center need be affected by the upgrade. By doing so, the capacity will be increased directly. Further benefit will result from the more comprehensive software available.

CONCLUSION

The small system operator who is considering adding or increasing premium program offerings, should include addressable control in the plan. Addressable control will enable the operator to market and distribute premium product with greater efficiency. Added program and equipment security will be gained. The marginal investment for addressable control (as compared to hard security) in a 1,000 subscriber system meets the criteria for a good investment. The ability to replace the control center without affecting the headend components or home terminals allows economic expansion at a future date.

Application of Fiber Optics in CATV Distribution Systems

James C. Herman

Times Fiber Communications, Inc.
358 Hall Avenue
P.O. Box 384
Wallingford, CT 06492

INTRODUCTION

There is little doubt that the age of the "wired city" has arrived: CATV trunk and distribution cables are being installed at an ever-increasing rate to provide TV programs as well as security service and other interactive capabilities.

However, as an industry expands into high-rise buildings, the coaxial system becomes more vulnerable to unauthorized taps which escape cable audits. Furthermore, the coaxial system is a potential source of RF ingress and egress.[1] The unanswered question is "Does the high-rise building wired with coax form a large multi-element antenna?"

Fortunately, there is an alternative technical method of TV distribution within a high-rise building.

With the advent of inexpensive fiber optic connectors, large core fiber optic cable, and reliable GaAlAs light emitting diodes (LEDs), a fiber optics distribution network is a reality.

A fiber optic network eliminates unauthorized taps, has virtual freedom from RFI ingress and egress and lends itself to cosmetic installation.

Particularly well-suited to the high-rise building, the fiber optic distribution system is relatively free from electrical codes, meets fire safety standards, eliminates ground loops and reduces the risk to CATV operator.

This paper will review some of the advantages available with the Mini-Hub distribution network for CATV high-rise buildings and compare it to perceived problems expected in coaxial high-rise distribution networks.

FIBER OPTICS IN CATV

Not a new topic, the military and telephone industry have long recognized the advantage of fiber optics to their specialized fields. The advantages of fiber optics over standard coax are overwhelming:

- Lower attenuation - longer runs, fewer repeaters.
- Wider bandwidths - system updating and expansion.
- Freedom from RFI/EMI - no egress or ingress of interferance.
- Security - no unauthorized taps.
- Electrical isolation - no sheath currents or ground loops.
- Safety code - no electrical code, meets fire codes.

The Japanese have demonstrated the viability of fiber optics in their "wired city" project. The Hi OVIS interactive television experiment in Higashi-Ikoma District in Nara Prefecture[2] is an example of the application of fiber optics to a CATV-type distribution environment.

Currently Ma Bell is exploring the use of fiber optics in CATV distribution networks. They have already gained much experience in the use, reliability, and cost effectiveness of the fiber optic technology and seem to be proceding to utilize it where they can.

Several new developments in fiber optic cables and connectors[3] (Reference Dr. Pinnow's paper titled "Optical Fiber Cables and Connectors for Mini'Hub" in this abstract) have provided the catalyst to make fiber optic high-rise networks for CATV reality.

- o The connector is easy to install; it requires no polishing or long cure cycle epoxy solutions; it has low light loss (<<2 dB) and is inexpensive.
- o The fiber optic cable is fabricated in either a drop (two-fiber oval element) or a multi-fiber configuration (many fibers bundled in a tube). Also, it is cost effective. These fibers have large core, low attenuation, and wide bandwidth.

  The small size cables provide neat installation appearance and the light weight of the cable reduces installation labor.

- o A new light emitting diode (LED) is now available. It is constructed as a surface emitting GaAlAs diode packed to focus its high output power into a 200 um fiber core. An inexpensive device, it meets stringent reliability testing and meets its wide bandwidth and low distortion specifications.

These components associated with a unique approach to a Star Network have evolved the best means of distributing CATV signals within a high-rise building.

THE FIBER OPTIC DISTRIBUTION NETWORK

Usually one thinks of a CATV distribution network as a trunk line with directional couplers and splitters providing the signal splitting to feeders and ultimate subscribers. These directional couplers, however, do not have a cost effective counterpart in the fiber optics system. Therefore, the computer, industrial control and other industries have resorted to other means of signal distribution in their communication networks.

The most popular distribution system being applied today is a "Star Network."

The CPU communicates with a remote terminal over a duplex (two-fiber) fiber optic cable system. Like a traffic cop, the CPU can direct that communication from the first terminal to another terminal. Each terminal has the ability

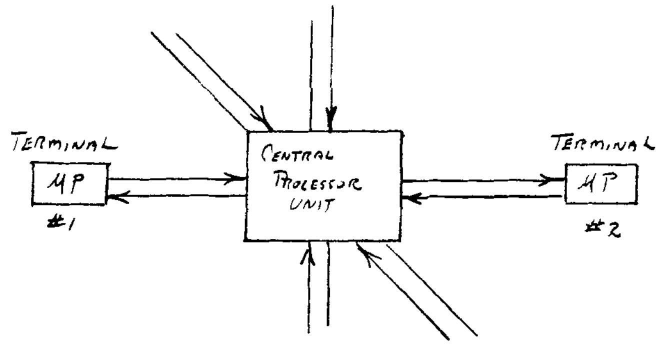


Figure 1.
Star Network

to communicate only with the CPU or with any other terminal through the CPU depending on how the system architecture is designed.

Today this same "Star Network" architecture is available for use in CATV applications. Like the Star Network, the Mini-Hub distribution, designed by Times Fiber Communications, Inc., employs a Central Distribution Unit (CDU) and two-way fiber optics communications to each subscriber as well as with the central operator's office.

Reference an article titled "Mini-Hub Addressable Distribution Systems for High-Rise Application" by M.F. Mesiya and others in this abstract.(4)

A modular system, the Mini-Hub distribution network consists of a Central Distribution Unit housed in a locked metal cabinet. (Figure 2.)

It includes a fiber optic network of dual fiber cable to each subscriber location. (Figure 3.)


The Mini-Hub central cabinet.

Figure 2.
The Mini-Hub Central Cabinet

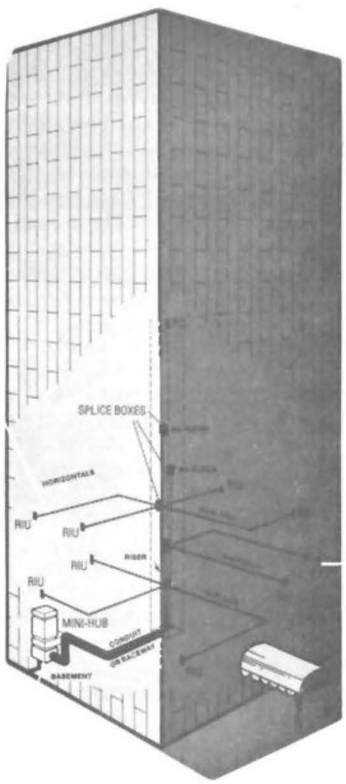


Figure 3.
High-Rise Distribution Network

These fiber cables include bundles of fiber riser cables located in air ducts, elevator shafts, or other installation locations requiring asthetic appearance. Splice boxes are used to distribute these bundled fibers to drop or horizontal single subscriber cables.

The fiber cable is terminated at the Residential Interface Unit (RIU) where the optical energy is converted to normal electrical RF and digital components.


Wall mounted residential interface unit.

Figure 4.
Wall-Mounted Residental Interface Unit

The RIU is a wall-mounted resilient plastic housing with conventional "F: connector outputs for TV (Channel 3 or 4) and FM signals.

A conventional telephone cord connects the RIU to the subscriber set-top Keypad. The Keypad is used by the subscriber to communicate to the CDU. He not only selects his channels with the Keypad, but also interacts with the CATV central office via interactive communications through the CDU.

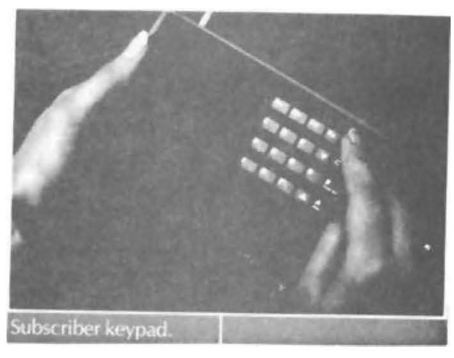

Subscriber keypad.

Figure 5.
Subscriber Keypad

The Mini-Hub system fiber optic network eliminates any problem with RFI ingress and egress. Besides, it is virtually impossible to tap the cable and steal basic tiered signals.

The most expensive item within the subscriber home is the $20 Keypad. This provides additional advantage to the system operator--reduced theft of expensive converters.

The two-way modular, interactive distribution network may be expanded to include many additional services with no subscriber access problem. See Figure 6 for system expansion.

The Mini-Hub effectively eliminates set-top converters and all their associated problems as outlined below:

COMPARISON CHART OF EXCLUSIVE MINI-HUB SYSTEM FEATURES VS ORDINARY SET-TOP ADDRESSABLE CONVERTERS

Features	Ordinary Addressable Converters	Mini-Hub
- Modular Two-way Addressability	No	Yes
- Full Subscriber Access Verification	No	Yes
- Unlimited Program Tiering	No	Yes
- Total Control from Central Office	No	Yes
- Impulse Pay-Per-View	No	Yes
- Signal Leakage Immunity	No	Yes
- Compatible with Other Converters	No	Yes
- Remote Control of Basic Service	No	Yes
- Scrambled Channels Required	Yes	No
- Reprogramming After Power Loss	Yes	No
- Sheath Current Susceptibility	Yes	No
- Transient Surge Susceptibility	Yes	No
- Subscriber Access For Upgrading	Yes	No
- Equipment Theft Exposure	Yes	No
- Signal Theft Exposure	Yes	No

MINI-HUB MODEL	SERVICE AVAILABLE	SUBSCRIBER ACCESS
8100	Addressable Basic channel Tiered 54 levels Diagnostics FM channels Parental lock Cable A and B	One time RIU hook up
8200	Add Pay per view	No
8300	Interactive Store&Forward Impulse Pay Opinion polling Video shopping	No
8400	Interactive(Real time) Security Options Energy Managment	Add sensors
8500	Add Videotex	No

Figure 6
Mini-Hub Expansion Models

WHAT IS EXPECTED OF COAX?

Answering the question, "Are coaxial systems prone to radiation?" is very much dependent upon how these systems are installed; how they are maintained; and the type of components used to assure their continued integrity.

RADIO FREQUENCY INTERFERENCE

RFI is not a new problem to CATV operators. We have learned an expensive lesson in the past with RF carriers interfering with aircraft. Examples of these were[5]

- o Harrisburg, Pennsylvania
- o Oxnard, California
- o Hagerstown, Maryland
- o Wilmington, North Carolina
- o Flint, Michigan

Periodic testing and connector tightening are used to seek out and eliminate the RFI problem within CATV trunk and feeder systems. Performing these tasks is likely to be more complex in the high-rise building.

THE ANTENNA EFFECTS

The Antenna Effects have been reported by amateur radio operators for some time.[7] They interfere with coaxial systems just as readily as with rabbit ears.

The latest issue (March 1982) of QST presents an interesting observation. It suggests that a coaxial cable forms a counterpoise antenna when routed in proximity to AC power wiring. The argument when extended to a multi-floor building could present a serious problem to the CATV operator, if valid.

LONGITUDINAL SHEATH CURRENTS

Longitudinal sheath currents have been accepted as a necessary evil in CATV trunk and feeder cables.[6] Normally thought of as a 60 Hz problem, it is not unreasonable to expect higher frequency transient noise to appear to some extent through the 400 MHz spectrum. Obviously the larger level interference signals favor the lower RF spectrum.

One can model the coaxial system for LSC within the high-rise building and show an argument for the same type of condition prevalent in the trunk and feeder lines.

CONCLUSION

A fiber optic Mini-Hub system is an alternative to a high-rise distribution network of coaxial cable.

We have briefly described the advantages of fiber optics and described it as a mature technology.

It, unlike coaxial systems, provides much flexibility and presents a lower risk to the system operator.

The Mini-Hub is an electronic distribution system with fiber optic network. It is compatible with other converter systems and provides complete subscriber control and diagnostics capabilities from the central office location.

These advantages:

- o Eliminates unauthorized cable taps.
- o Prevents loss of expensive converter.
- o Freedom from RFI egress and ingress.
- o Permits expanded services without access problems.

and others offer the CATV operator peace of mind.

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BANDWIDTH-EFFICIENT, HIGH-SPEED MODEMS FOR CABLE SYSTEMS

Stephen W. Klare
J. M. Rozmus

SCIENTIFIC-ATLANTA

ABSTRACT

Because of recent interest in cable systems for data transmission as an alternative to use of telephone company leased lines, Scientific-Atlanta is introducing the 6402 High-Speed Modem which is capable of transmitting and receiving data at standard telephone system rates of 1.544 Mbps (T1) or 6.312 Mbps (T2). Two features of the 6402 are especially useful for operation on cable systems: high bandwidth efficiency and frequency agility.

The 6402 design is composed of two major parts: the RF section and the baseband processor. The RF section provides modulation, demodulation, frequency translation, and frequency synthesis. The baseband processor recovers both the carrier frequency and the data rate clock from the demodulated baseband signal provided by the RF section using digital processing.

The basic technique used in the 6402 is Quadrature-Amplitude-Shift-Keying (QASK). This method of modulation allows frequency spacing of 750 KHz for T1 channels and 3 MHz for T2 channels with a bit error rate of less than 10^{-9}.

INTRODUCTION

The advent of well-designed coaxial cable networks covering large, metropolitan or suburban areas has led to a high degree of interest in the use of these networks for data communications. Because of the large available bandwidth, in excess of 400 MHz coaxial systems represent an excellent medium for digital communications. With the requirement for commercial systems of $C/N \geq 36dB$, i.e. $C/No \geq 102dB\text{-}Hz$, and the ability for good designs to exceed this by as much as 9dB[1], complex, wideband digital modulation formats can be supported. Because commercial systems are designed to distribute primarily video modulation formats, the transmission system must be maintained in a highly linear mode, thus modulation schemes which may suffer when confronted with the nonlinearities inherent in satellite communications, for example, may be employed with relative inpunity on the coaxial medium. All of the above factors became apparent resulting in the current industry drive to develop data communications capability on existing, planned and future coaxial systems.

In September 1981, Scientific-Atlanta installed a demonstaration data link in order to show the feasibility of providing wideband data services via coaxial cable. This initial installation provided local distribution of 96 voice channels between ISACOM, Inc., operating Satellite Business Systems (SBS) digital earth terminals in Atlanta and Houston, and one of their customers, National Data Corporation (NDC). This link was established with a dedicated cable pair (for redundancy) installed and maintained by South Media, Inc. The link provided NDC with voice and data services between their offices in Atlanta and Houston. Two crucial features of data communications over coaxial systems were demonstrated. The first was that transmission performance was limited only be terminal equipment, the cable medium performed transparently. The second feature involved communication economies. Coaxial cable was unrivalled when cost was a consideration.

Since the installation of this first link a third fundamental principle was uncovered. While the cable offers unparalled cost and performance for high speed data communications its bandwidth must be treated as a highly prized commodity. The installation of wideband full duplex links at T1 (1.544Mbps) and T2 (6.312Mbps) rates employing modulation techniques with moderate bandwidth efficiency, e.g. 0.5 bits/Hz, would only permit 19 T1 links or 4 T2 links on a mid-split coaxial cable network as shown in Figure 1. Therefore, the capacity of the network is greatly enhanced when more efficient modulation techniques are applied. At 2.0 bits/Hz, 76 T1 links or 38 T2 links can be supported. Application of current digital communications technology is essential in order to effect more efficient utilization of the available bandwidth. It was therefore determined that an approach was necessary which would maximize spectral efficiency without driving manufacturing costs to prohibitive levels. A technique satisfying these requirements has been developed and is the subject of the remainder of the paper.

SYSTEM DESIGN

In order to meet the necessary bandwidth efficiency requirements for high speed data transmission, the selection of the modulation format was essential. While spectral efficiences of 0.5b/Hz - 1.0b/Hz are readily achievable it was determined that 2b/Hz could be realized without undue additional manufacturing cost. This was possible due to the ease of implementation of the selected QASK-16 signal constellation, in both the modulation and demodulation processes. QASK-16 is a special case of the Mary Amplitude-Phase-Shift-Keyed (MAPSK) family of signal sets which provide enhanced bandwidth efficiency through efficient signal packing at the expense of bit error probability, P_b, in the noisy enviornment. However, since coaxial systems provide high signal-to-noise ratios, these complex modulation formats are applicable.

A performance goal of $P_e \leq 10^{-9}$ was established for the data link thereby constraining the modulation complexity due to the fixed limit of $C/N_0 \geq$ 102dB-Hz. A large body of literature exists on studies and hardware implementations covering many of the MAPSK signal sets [2 - 11]. After an evaluation of the myriad possibilities it was determined that QASK-16 offered the best compromise of spectral efficiency, P_b, and cost of implementation. The average symbol signal-to-noise ratio, $R_d \triangleq ST/N_0$, is easily found to be $R_d \geq$ 46dB for a coaxial system operating at marginal performance levels or better and a T1 bit rate (QASK-16 transmits four bits per symbol). However, data signals cannot be permitted to operate at power levels in excess of the video signals with which they must co-exist. Therefore, it was determined that the power of each digitally modulated carrier be 15dB below video levels for T1 and 9dB for T2. This results in a total channel power (6 MHz channels) 6dB below a corresponding video channel when the channel is fully packed with T1 or T2 data carriers at .75 MHz and 3 MHz spacings respectively. This requirement reduced the worst case to $R_d \geq$ 31dB for both rates. In order to achieve a symbol error probability, Ps, of 10^{-9}, Rd $\geq$ 26dB is a lower bound when implementation losses are included. Thus, 5dB of system margin exists for the QASK-16 modulation scheme.

The QASK modulation format selected from the family of MAPSK signal sets does not represent the optimum signal set, however it has been shown to be degraded from the optimum by only tenths of a dB [3, 5]. This penalty is insignificant when faced with the complexities of implementation of the alternatives. Through the combination of several decision directed or decision feedback techniques, all of the functions necessary for demodulation of the QASK signal set will be shown to be readily implemented.

System Model

The basic models for the QASK communication link are shown in Figure 2. The incoming data stream, d(t) is scrambled to insure adequate symbol transitions, then taken four bits at a time and differentially encoded [12], then filtered to provide minimum bandwidth and inter-symbol interference (ISI) and impressed on quadrature carriers. The transmitted signal s(t), an M-ary quadrature-amplitude-shift-keyed (QASK-M) signal with a symbol interval of T-seconds, can be represented mathmatically as

$$S(t) = \sqrt{2}[m_i'(t)\cos w_o t + m_q'(t)\sin w_o t] \quad (1)$$

where $m_i'(t)$ and $m_q'(t)$ are scrambled, encoded and filtered pulse trains. These quadrature pulse trains take on equally likely values $j\delta$ with $j = \pm 1, \pm 3, \ldots, \pm (K-1)$ in each channel. Thus for K=4, the case of interest here, $m_i'(t)$ and $m_q'(t)$ are the filtered versions of amplitude shift-keyed (ASK) inputs with equally likely values of $\pm\delta$, $\pm 3\delta$, resulting in the QASK-16 signal set with two amplitudes and two phases in each quadrature channel. The average signal power of the transmitted signal set is

$$= 2/3(K^2 - 1)\delta^2. \quad (2)$$

This transmitter model is depicted in Figure 2a.

The channel shown in Figure 2b is assumed to be an additive white Gaussian noise (AWGN) channel where the noise n(t) has a two-sided spectral density $N_o/2$ W/Hz. In addition the channel adds a random phase shift to the signal s(t) such that the received signal is of the form,

$$\begin{aligned} x(t) &= s[t,\theta(t)] + n(t) + J(t) \\ &= \sqrt{2}\{m_i'(t)\cos[w_o t + \theta(t)] \\ &\quad + m_q'(t)\sin[w_o t + \theta(t)] \\ &\quad + n(t) + J(t)\} \end{aligned} \tag{3}$$

where $\theta(t) \triangleq \theta_o + \Omega_o t$, with θ a uniformly distributed phase shift and Ω_o the frequency shift from its nominal value of w_o. The additional signal J(t) represents additive interence signals which though present in practice are assumed negligible in the discussion to follow.

The receiver model is shown in Figure 2c where the input signal, X(t) is multipled by a locally generated quadrature reference,

$$r(t) = \sqrt{2}\cos[w_o t + \hat{\theta}(t)] \tag{4}$$

where $\hat{\theta}(t)$ is the local estimate of $\theta(t)$. Because the case of interest here is that of very high R_d, the noise will be neglected in further discussions, the case of low-to-moderate R_d is treated adequately in the references.

The quadrature signals multipled by the reference and again Nyquist filtered are represented as

$$z_i(t) = m_i'(t)\cos\phi(t) + m_q'(t)\sin\phi(t)$$

$$z_q(t) = -m_i'(t)\sin\phi(t) + m_q'(t)\cos\phi(t)$$

where $\phi(t) \triangleq \theta(t) - \hat{\theta}(t)$ is the carrier recovery loop phase error. The baseband signals, $z_i(t)$ and $z_q(t)$ are then quantized in an analog-to-digital converter, and processed in order to recover the carrier phase process, symbol synchronization, detect the transmitted symbols, control the gain and detect lock. The algorithms necessary to provide these functions are implemented in a digital processor the details of which are left to a subsequent section. The carrier recovery algorithm employs a decision-feedback technique analyzed by Simon and Smith [13]. The symbol synchronization algorithm is a generalized data transition tracking loop, similar in concept to that analyzed by Simon [14-15]. The AGC algorithm is a decision-directed technique as analyzed by Weber [16], with the lock detection algorithm employing the AGC error signal as its decision criterion. The channel encoding is essentially differential encodng and is necessary in order to remove the quadrant ambiquity in the received symbols. The filtering for bandwidth efficiency, or Nyquist filtering, compresses the transmitted spectrum to achieve the 2 bits/Hz spectral efficiency while minimizing ISI. The filter is partitioned between the transmitter and receiver in order to minimize adjacent channel spillover and adjacent channel interference respectively.

The modem developed for the mid-split cable system is designated the 6402 High Speed Modem. A functional block diagram of the 6402 is given in Figure 3. Each of the elements in the diagram are described in more detail in later paragraphs The salient features are the frequency agility provided by transmit and receive synthesizers, low spurious emissions allowing for reliable coaxial network operation, and a high performance baseband detection technique resulting in $P_b \leq 10^{-9}$

RF SECTION

The RF Processor is comprised of the transmit and receive IF assemblies as well as the transmit power amplifiers, receive amplifiers and the synthesized local oscillators (LO's). A mid-split diplexer is used to interface the transmit and receive assemblies to the cable. While filtering is performed in both the transmitter and receiver of the 6402 none of these filters affects the modulated signal. The spectral efficiency is achieved through baseband filtering in the baseband processor. The design philosophy adopted for the RF Processor was to employ standard components in a way such that highly reliable RF signal processing was possible without generating interference which would affect the performance of other signals on the coaxial network.

Transmitter

The transmitter is composed of several elements: The quadrature modulator, synthesized transmit LO, and power amplifiers. The modulator employs a 145 MHz TCXO as an IF, which is then modulated by the in-phase and quadrature ASK symbols, $m_i'(t)$ and $m_q'(t)$ as described previously. These quadrature signals are summed resulting in the QASK-16 signal. This signal is filtered with a broad IF filter, amplified, and then translated to the transmit frequency by the transmit LO which results in 0.75 MHz channel spacing across the reverse channel, 5-102 MHz. Filtering in the transmitter amplifier stages rejects the TX LO such that the worst case spurious output is -60dBc.

Receiver

The receiver assemblies are composed

of broadband amplifiers, the synthesized receive LO, and the quadrature demodulator. In order to prevent leakage of the RX LO onto the cable, each receiver broadband amplifier is preceded by a compensating attenuation, such that the net gain is essentially 0dB. This inserts the necessary isolation to keep the spurious levels due to the RX LO at $\leq$ -60dBc. The RX LO then provides the necessary conversion frequency, with .75 MHz resolution, to translate the receive channel to the 150 MHz receive IF. In the IF, the signal is amplified and filtered with a broad channel filter with 10 MHz bandwidth to reject undesired channels. A PIN diode attenuator is employed in the receive IF for processor control of the input levels. This signal is then applied to two mixers using the reconstructed carrier references as supplied by the Baseband Processor to demodulate the incoming signals to baseband. At this point the quadrature baseband signals are applied to the Baseband Processor inputs for digitizing.

BASEBAND PROCESSOR

Technology

With careful use of a few state-of-the-art components, it was possible to build most of the baseband processor with standard MSI-TTL technology rather than more expensive ECL. An example of a critical section is the numerically controlled oscillator. The 5 MHz NCO requires the fastest TTl PROM and TTL registers commercially available.

Algorithms

The major functions of the baseband processor are shown in the block diagram of Figure 4. The carrier synchronization section keeps the 150 MHz local oscillator in phase with the incoming carrier by controlling the phase of the 5 MHz NCO output which is mixed to produce the local oscillator. The symbol synchronization section keeps the symbol clock synchronized with the symbol periods of the incoming baseband signals. The automatic gain control (AGC) controls the amplitude of the baseband signals being sampled by the analog-to-digital converters. The lock detection provides a positive indication when the processor is synchronized to a legitimate data transmission. The transmit section consists of a scrambler to ensure a sufficient rate of symbol state changes and an encoder to resolve the ambiguity that derives from the rotational symmetry of the symbol vectors in the I-Q plane. (See detailed explanations below). The decoder and descrambler in the receive section provide the inverse functions of the encoder and scrambler.

The input to all of the algorithms of the baseband processor is the series of 6 bit digital samples of the analog baseband signals of the I and Q channels. The baseband signals are sampled eight times per symbol period. One of the eight samples occurs in the middle of the symbol period. This is the symbol sample. It is a digital measure of the symbol level which is decoded by the symbol detect circuitry. The four levels of a perfect baseband signal produce digital values of +24, +8, -8, -24 for the +3, +1, -1, and -3 levels respectively.

To understand the algorithms of the baseband processor, it is best to visualize the state of the baseband signals as one of 16 vectors in the I-Q plane (See Figure 5). For example, if the I level is +3 and the Q level is +1, then the corresponding vector points from the origin to the point in the lower right hand corner of the (+,+) quadrant. Its phase is $\tan^{-1}(1/3)$.

The carrier synchronization algorithm compares the phase angle of the observed symbol vector with the phase of the expected ideal vector for the current symbol. For example, if the I and Q symbol samples are +27 and -6 respectively, the level detect circuits will detect (I,Q) equals (+3, -1) and the carrier synch circuitry will compare $\tan^{-1}(-6/+24)$ to $\tan^{-1}(-1/+3)$. The difference is scaled and used to control the phase of the 150 MHz local oscillator. The resulting phase-locked loop has a loop noise bandwidth of 50 KHz and a damping factor of 0.6. It is a perfect second-order loop.

The symbol synchronization algorithm is pictured in Figure 6. Samples of the I channel baseband are summed from the center of one symbol period to the next. If a symmetrical transition (i.e., +1, to -1, -1 to +1, +3 to -3, or -3 to +3) occurred during that time the result should be zero. If the result is not zero, then the of the sum, along with the direction of the transition, indicates whether the symbol clock is lagging or leading the received symbol rate. If a number of successive measurements indicates the same direction of clock phase error, a threshold detector will adjust the symbol rate. The symbol clock is generated by the most significant bit of a 4-bit counter that is clocked at 16 times the symbol rate. A lagging clock is adjusted by decreasing the count per symbol period to 15 for one period. A leading clock is adjusted by increasing the count per symbol period to 17 for one period.

The automatic gain control computes the difference between the absolute value for the symbol sample and the absolute value of the expected ideal sample value. This difference is accumulated for 16 symbol periods. The result is summed with the current gain control level to change the gain of the variable-gain amplifier.

The lock detection circuitry computes the same difference as the AGC, but accumulates the absolute value of this difference for 16 symbol periods. If the result is less than a lower threshold, a 3-state counter (i.e. counts 0, 1, and 2) is incremented. If the result is greater than an upper threshold, the counter is decremented. When the counter transitions from 1 to 2, the lock indicator is turned on. If the counter transitions from 1 to 0, the lock indicator is turned off.

The 4-bit symbols are encoded as shown in Figure 7 [12]. The upper two bits are encoded differentially by indicating the change in quadrant from the previous symbol. The lower two bits are coded by position within the quadrant. The differential encoding is necessary because the demodulator cannot distinguish among the four phases of the carrier. For example, if the previous transmitted vector was in the (+,+) quadrant and the current data is 0110, then the encoder will cause a (+1, -3) vector to be transmitted. The receiver may distinguish any of the following combinations:

Previous Quadrant	Current Vector	Quadrant Change
(+,+)	(+1,-3)	$+90^o$
(+,-)	(-3,-1)	$+90^o$
(-,-)	(-1,+3)	$+90^o$
(-,+)	(+3,+1)	$+90^o$

In all four cases, the correct data (0110) is decoded.

The scrambling algorithm [17] is essentially an exclusive OR combination of the 20th previous, 3rd previous, and current data bits. In addition, the polarity of the output is inverted whenever four consecutive 8-bit output sequences are identical.

CONCLUSION

The design of the 6402 High Speed Modem was accomplished using state-space simulation techniques for performance verification. Each of the elements in the receiver and modulator were modelled and tested completely prior to the hardware development. Laboratory tests have provided further verification using Scientific-Atlanta's 400 MHz headend and distribution system. The frequency-agile point-to-point modem represents a strong choice for high-speed communications over cable, with its bandwidth efficiency maximizing the spectral utilization of the coaxial cable system. The modulation scheme, QASK-16, selected for the 6402, is an excellent compromise between bandwidth efficiency and performance without leading to prohibitive manufacturing costs. Through novel design the 6402 achieves 2b/Hz spectrum efficiency using reliable, low-cost components.

ACKNOWLEDGEMENTS

We gratefully acknowledge the work of the staff of the Digital Communications Department at Scientific-Atlanta. The rapid development of the 6402 Modem would not have been possible without their superior team effort.

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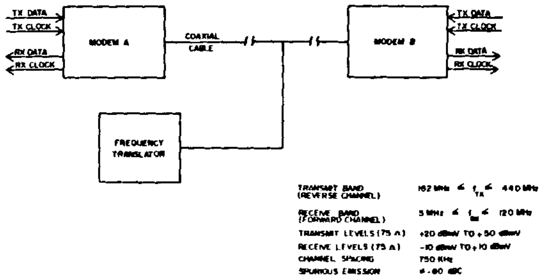


FIGURE 1 COMMUNICATION SYSTEM CONFIGURATION

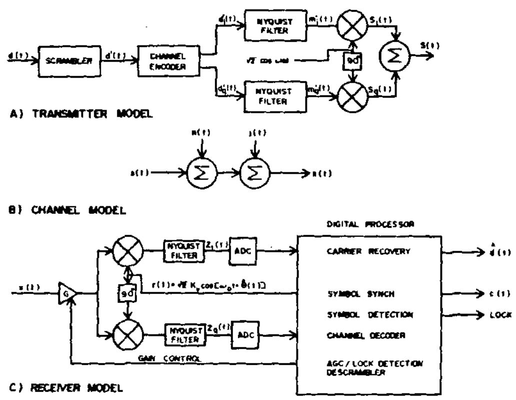


FIGURE 2 SYSTEM MODELS

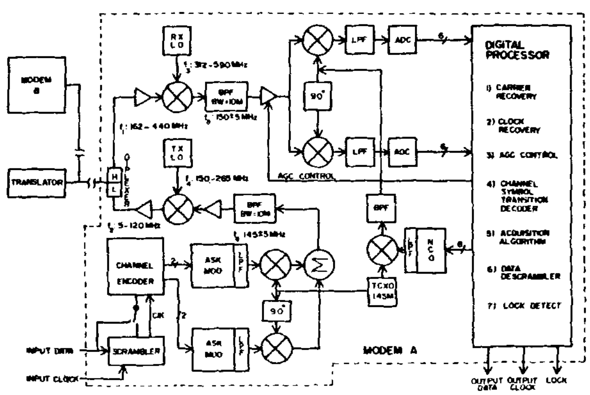


FIGURE 3 QASK MODEM FUNCTIONAL BLOCK DIAGRAM

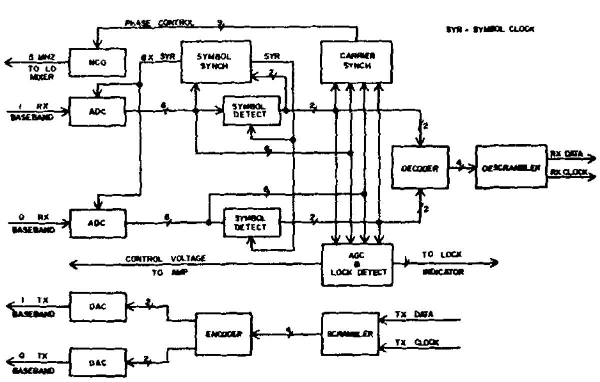


FIGURE 4 BASEBAND PROCESSOR

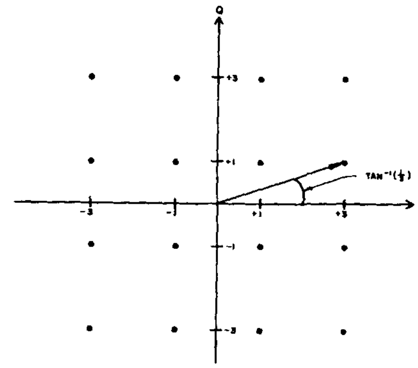


FIGURE 5 SYMBOL VECTORS

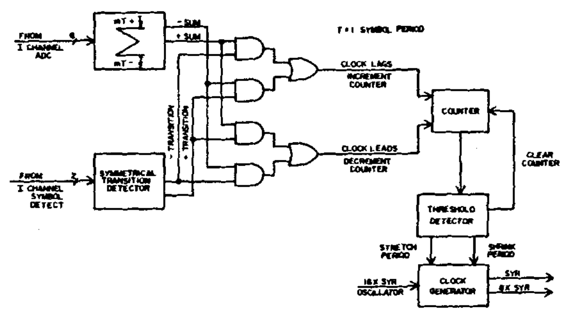


FIGURE 6 SYMBOL SYNCHRONIZATION

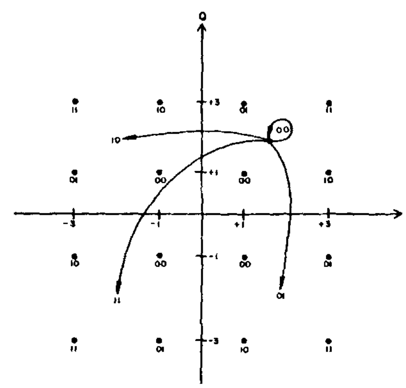


FIGURE 7 SYMBOL CODING

CABLE READY TV SETS - AN OPERATOR'S VIEWPOINT

Gerald L. Bahr

COX CABLE COMMUNICATIONS, INC.

ABSTRACT

The television set manufacturers appear to be creating a new generation of television technology, the cable-ready television. As this technology spreads throughout the industry, the question of its value to the consumer and its impact on the cable industry grow. There appears to be three distinct approaches; the 105-channel set (35 VHF - 70 UHF), the 2-channel set, and the tunerless baseband monitor. This new concept amplifies the need for cooperation by all concerned. The critical areas of agreement include channel designation, frequency format adaptability, retrofit modularity, and probably most important, descrambling and addressability compatibility.

Any of the three approaches the television set vendors have taken, the 105-channel set, the 2-channel set, and the tunerless baseband monitor, can be successful if the set manufacturers and the cable industry will coordinate the effort. If these issues are satisfactorily resolved, cable-ready TV sets can provide new business opportunities for both industries and enhanced value to the consumer. Only through a cooperative effort can the apparent morass of conflict be avoided.

I. INTRODUCTION

A. Why do the TV manufacturer's want to do it?

The question at issue is whether the production of cable-ready television sets is a temporary marketing ploy by the manufacturers or an issue that needs to be addressed over the long term. No one knows for sure at this time and the answer at present appears to be only a function of marketing and financial considerations. One might well ask why the TV set manufacturers are involved in producing cable-ready TV sets. The simple and correct answer, of course, is to make money. The term "cable-ready", it is hoped, will evoke among the buying public an image of a technically superior television set, one able to provide a much greater variety of entertainment services than the dowdy old version of the competition.

All mass manufacturers, whether they be of television sets or automobiles, suffer from a malady known as "follow-the-leader syndrome". When one manufacturer offers a feature not commonly found among the competition, the other manufacturers will immediately follow with their "improved" versions. These improved versions, whether cable-readiness or sun roofs, will always appear to be bigger, better or more cost effective than the original. The cycle continues, feature after feature, in the quest for the consumer's dollar. There is little doubt that this infectious syndrome has found host among the television set manufacturers. This statement is made, not because of the existence of cable-ready television sets, but because of the rather knee-jerk manner of their introduction. I do not impune the integrity of the television manufacturing industry. In fact, I feel that cable-ready television sets are not necessarily a bad idea. Indeed, if certain standards are maintained and coordination between the cable industry and the set manufacturers established, this feature may be a benefit to the consumer, to the television set industry, and to the cable operator.

B. What's in it for the cable operator?

The problem for our consideration here is the effect of this technology on the cable system operator or whether any benefits to be derived are real. If the cable-ready TV set is properly designed and developed, it can be a great benefit to the cable operator. Let's look at a few examples that illustrate this point.

First, if, as a small system operator, you wish to expand beyond your current 12-channel system, you may be hesitant to do so because of the enormous capitalization required for converters. Since your pay services are trapped, you are not concerned with scrambling compatibilities. Therefore, if your customers each had cable-ready television sets with enhanced capacities and which require no converters, you could expand the channel capacity of your plant facilities beyond the 12 channels with a more moderate investment.

Second, if your system is larger with multiple tiers, with the use of bandpass filters, a reasonably sized basic tier could be offered without utilizing converters. Without the capital and operational costs associated with the converters on a basic tier, the subscriber rate could be much lower, thus assisting in achieving a higher basic subscriber penetration.

Finally, consider a cable ready television set of the exact opposite nature from that above: A set that would only tune channels 3 or 4, or perhaps merely a television monitor with all of the tuning and demodulation functions taking place in the converter. In this case, sets could be manufactured and sold at a considerably reduced price to the public. There would be a considerable enticement to the public to purchase these sets. However, their use requires attachment to a cable system and converter. This opens up an entirely new marketing concept for the television set manufacturer and one which has undeniable benefits for the cable system operators. The current embryonic trend toward modular television receivers may facilitate just this kind of a venture.

In summary, then, cable-ready television sets can benefit the cable operator by either reducing system capitalization or increasing penetration, or in some cases, both.

II. CURRENT INDUSTRY STATUS

With this brief overview of the cable-ready television set technology, let's look at the overall industry to see what is currently available. The matrix below denotes the available cable-ready sets. Down the left-hand column of the figure are the various manufacturers who, to our knowledge, currently offer cable-ready television sets. Across the top of each column, the headings indicate some of the features of each set. Let's take a moment to review these currently available items. The data on the chart indicates, though not every set manufacturer is represented, that there is a good start at an industry-wide phenomena.

You will note, also, that not all the manufacturers are going in the same direction. At the present time, competition among the manufacturers has precluded the adoption of any overall standards or procedures for the industry in cable-ready TV set design.

Another fact worth noting is the indication that among the many factors that influence cable ready TV set design, there has been little or no

CABLE-READY TV SETS

Manufacturer	HRC Compatible	Channels Tuned	IF Loop	Video BB Loop	A - B Switch	Comments
Matchmsta	Yes	35 VHF, 70 UHF	No	1983	No	
Sanyo	Yes	35 VHF, 70 UHF	No	Yes	No	Petition FCC to mfg. 2-channel set
Fisher/Sears (Sanyo)	Yes	35 VHF, 70 UHF	No	Yes	No	
Zenith	Yes	42 VHF, 70 UHF	No	Yes	No	HRC automatic; modular TV being considered.
Magnavox	Yes	20 VHF, 70 UHF	No	No	No	
Curtis Mathis	'83?	35 VHF, 70 UHF	No	'83?	No	60 VHF ch. in 1983?
Hitachi	'83?	35 VHF, 70 UHF	No	Yes	No	
Sony	-	35 VHF, 70 UHF	No	Yes	-	Component TV available
Phillips	Yes	35 VHF, 70 UHF	-	-	No	
Wards/Sylvania (Phillips)	Yes	35 VHF, 70 UHF	No	-	No	
RCA	No	23 VHF, 70 UHF	No	No	No	
Quasar	No	35 VHF, 70 UHF	No	Yes	No	BB on projection model only

coordination with the cable industry. Indeed, it appears that about the only coordination has been with the FCC in order to acquire the required waivers to produce television tuners in other than the prescribed format. This lack of coordination is somewhat surprising since many of the television set manufacturers are also involved in the production of cable television equipment, such as RCA, Magnavox, Sylvania and Zenith.

III. TRENDS AND DIRECTIONS

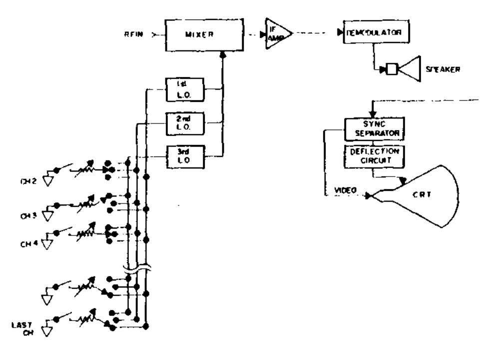
You have seen where we are now, let's look now at where the industry seems to be heading in the near term.

A. The 105-channel set

One of the major directions that many of the set manufacturers are taking is toward the production of 105-channel television sets. These sets are designed to receive the 35 VHF channels of the typical 300 MHz cable system, and the 70 UHF broadcast channels.

Several manufacturers have addressed the issue of HRC vs standard format for the channel placement. Some tuner designs first look at the standard position for a carrier, and if it doesn't find one there, it begins a search pattern to find the HRC carrier. In some TV sets, this is done automatically without the user taking any further action. It would appear that, if the industry adopted as the standard a 105-channel set that could tune HRC, standard, or IRC formats, the cable industry would no longer need to supply converters. However, this scenario would still not resolve the issue of scrambling, tiering, addressability and 400 MHz-plus systems.

MULTI-CHANNEL TV

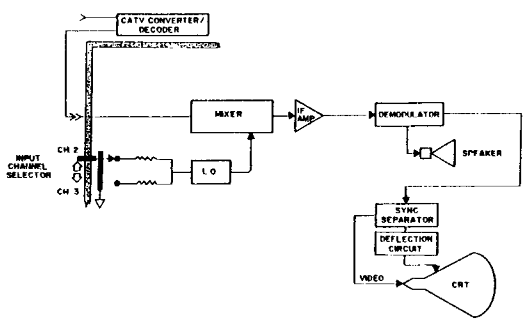


B. The 2-channel set

Another direction which some manufacturers seem to be taking, and which in many ways makes more sense, is the so-called 2-channel set. In this set design, the tuner only tunes channels 2 and 3, or 3 and 4. Sanyo is an example of a manufacturer desiring to produce sets of this design.

Obviously, with cable converters, this is all that is needed. Sanyo feels that they can build a set capable of tuning two channels with a technically superior tuner to anything else available and still sell the set for less money than the competition. Of course, the one major problem with this design is that the set is only usable on these two channels when not used on a cable system, or usable only on a cable system in which converters are used. The owner would need to purchase and install some ancillary means of tuning the television for use without the converter. This device might be an add-on module that the manufacturer has available for those who need it at some later date. A converter might also be available from the cable operator especially for this customer.

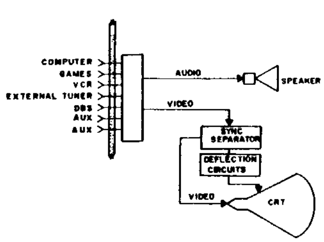
2-CHANNEL TV



C. The "no-channel" set

At least two manufacturers are considering producing modular television sets which, at the purchaser's discretion, may have no tuner at all. It would simply be a television monitor that would depend upon a new breed of converters developed by the cable vendors. These converters would output baseband video and audio rather than the signal modulated on channel 2, 3 or 4, as is used presently. Of course, the advantage of this design would be price. These sets would be inexpensive to produce and, since they are designed to be modular, a tuner (with the associated RF circuitry) could be added at a later date, if desired.

VIDEO MONITOR

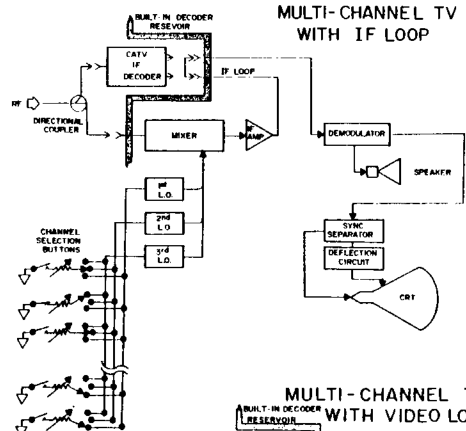


D. Scrambling/addressability

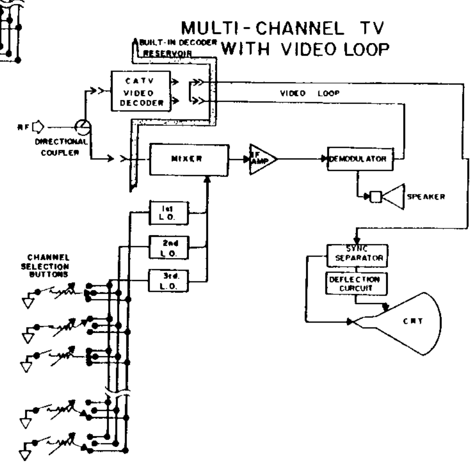
An issue which the manufacturers who desire to turn out the 105-channel sets have not satisfactorily addressed at the present time is the issue of scrambling and addressability. Virtually all of the systems that are 400 MHz utilize scrambling and most of them utilize addressable converters on at least some of the tiers. Since there is little or no standardization in the cable industry on scrambling and addressability, the set manufacturers are not certain which way to turn on this issue. One solution, of course, would be for them to bring out both an IF lead and a baseband lead to the back of the set where the cable company could attach the proper decoder or home terminal unit. This approach would be no problem for the 2-channel or the no-channel set, since they do not propose to provide any cable interface preparation as a part of the set design.

However, with respect to marketing, the 105-channel set or the 2-channel set will require cooperation with the cable industry. The no-channel set requires a great deal of cooperation in that the cable operator must provide a new converter design which outputs at baseband video. The 105-channel set, as mentioned, requires some method for the cable company to include the features of decoding and addressability. There is really no way to tell, at this time, which of these is going to be the dominant direction in the future. However, a manufacturer who designs his television set in a modular fashion will probably be in the best position since his tuner module could accomodate any one or all of the above techniques.

MULTI-CHANNEL TV WITH IF LOOP



MULTI-CHANNEL TV WITH VIDEO LOOP



IV. SOME SUGGESTED INDUSTRY STANDARDS

If all of this is going to work, some standards must be imposed, both upon the set manufacturers and upon the cable industry. I would like to suggest a few basic standards at this time.

A. Channel designation standards

It would seem, at the most primitive level, that at least we should adopt one channel designation as the standard for the whole industry. This would not seem to be too difficult to do but it is amazing the amount of resistance such a thing draws. Whether we adopt the cable nomenclature or the set manufacturer's nomenclature or an entirely new one that is logical and complete really does not matter as long as we are all talking the same language.

B. Channel spacing adaptability

One standard that must be adopted by the television set manufacturers is that all cable-ready television sets must be automatically adaptable between standard, IRC, and HRC formats. Obviously, the set is not cable-ready if it will not tune the cable channels. One manufacturer has already proven that this is not a very difficult thing to do. However, for the 105-channel set manufacturer, it does represent extra cost in manufacturing.

C. Modularity

Another requirement that should be placed upon the set manufacturers is that of modularity, especially in the tuning section. Some manufacturers are designing television sets that look very much like the current component stereo systems. This is the extreme case. However, at the very least, the tuning section of the television set should be easily removable and replaceable with an appropriate replacement module. In other words, the 105-channel set, the 2-channel set, or the no-channel set could be simply a matter of which module is plugged into the tuning section. I believe that this modularily should be standardized, industry-wide.

D. Access for descramblers/addressable converters

As mentioned earlier in the case of the 105-channel set, access must be made for a descrambler/decoder unit or for an addressable unit for those systems that are addressable. Access should be easily found on the back of the TV set and should have both an IF and a NTSC baseband access port.

E. Videotext decoder

Agreement on videotext standards is essential so that we can move forward with the introduction of this service in our industry and allow incorporation of this technology in our systems in the near future.

F. Single and dual cable

Last, but not least, future sets that purport to be cable-ready and either come with 108-channel dual cable tuners or modular such that 108-channel dual cable tuners may be added at some future date need to be ported for dual cable drops. It is hard to say how prevalent the dual subscriber system will be in the future, but at least a number of the later franchises in the larger cities have been won by companies offering a dual 400 MHz system. It is suspected that this will be the trend throughout the balance of the systems and in future refranchising efforts in the larger areas.

V. CONCLUSIONS AND RECOMMENDATIONS

A. What won't work?

What won't work is the cable industry and the set manufacturers going their own ways and ignoring each other or actually setting up adversarial relationships in which only the consumer loses. We talk about wanting less and less government regulation of our industry, but in order to accomplish that, then we must be self-governing and to the benefit of the consumer. This would be a good opportunity for us to show the federal government that we can do it without their bureaucratic intervention, but to do that, we must work together harmoniously to set the standards and directions for this new product.

B. What will work?

What will work, then, is obviously cooperation among all of the parties. At the present time, there is an NCTA/EIA consortium working on setting recommended standards and some directions to solve these issues. As an industry, and I am referring not only to the cable system operators but especially to those vendors who manufacture converters, we must join hands with the set manufacturers in support of this consortium and be willing to abide by the recommended standards that are issued from it. If we do so, I think the advent of cable-ready TV sets can be a positive benefit to the set manufacturers, the cable industry, and most of all, the consumer.

CABLE TV ADVANCES AND TV RECEIVER COMPATIBILITY PROBLEMS

I. Switzer, V.P. - Engineering
Cable America, Inc.
Suite 700 1447 Peachtree Street N.E.
Atlanta, Georgia 30309

ABSTRACT

The new "cable ready" TV sets are not compatible with new cable TV systems that provide multiple PAY TV services using addressable, programmable, converter/descramblers. "Baseband" converters with demodulation, descrambling and remodulation are becoming more popular. Subscriber ownership of terminal equipment would be very desirable but requires a nationally standardized encoding and addressing technique.

TROUBLE!

I am reminded of the lines from the Broadway musical "MUSIC MAN" - "You've got TROUBLE my friends, right here in River City...... With a capital "T" that rhymes with "P" and that stands for POOL!" There is "trouble", my friends, right here in the consumer electronics industry in America, with a capital "T" that rhymes with "C" and that stands for CABLE.

I don't believe that the consumer electronics industry properly appreciates the recent changes and developments in the cable television industry and how they affect consumer electronics. In effect, a new consumer electronics industry - cable television "subscriber terminals" - is growing up outside the present "establishment" . The manufacturers of these products seem to be developing them mostly without the benefit of the engineering experience of established manufacturers of television receivers, although there is some overlap of know-how. The situation is apparent in the nature and the shortcomings of the products being offered to the public.

Many receiver manufacturers are now marketing "cable ready" receivers. These TV receivers are perhaps ready for our cable systems of three years ago. They are by no means "ready" for the cable systems we are designing and building today. Our newest cable systems have dual cables each with 50-440 MHz bandwidth and carry up to 61 TV channels in each of the two cables. All of our new systems have multiple scrambled PAY TV channels. The descrambling is usually built into the tuning converter. Even if our subscriber has what most TV manufacturers call a "cable ready" TV set we cable operators still have to provide the suscriber with our "addressable, programmable converter/descrambler" (APCD). The money and effort that went into the "cable ready" TV set is mostly wasted in our new cable systems. Some of our newest systems use "baseband" converters which:-

tune all channels between 50 and 440 MHz

automatically select between an "A" and a "B" cable drop

have infra-red remote tuning control

have remote audio level and muting control

have programmable descramble functions which are addressable from the cable system head-end

have baseband video and audio outputs for VCR's and video projectors

have built-in "emergency alert" so that they can be turned on, tune emergency channel and turn up audio on command from the cable system head-end

have digital "parental guidance" lock so that subscriber can program the terminal not to descramble "objectionable" channels or programs

have optional RGB output for special monitor functions such as high quality TELETEXT display

have optional built-in TELETEXT decoding

digital clock and tuned-channel display on TV screen

etc.

There is unfortunately a substantial redundancy in all of this which the public is paying for. The cable subscriber has bought a TV set with tuner, demodulator and remote control function. We cable system operators provide him with another very similar set of functions. The subscriber ultimately pays for both. There obviously must be an early accomodation and understanding of who will provide what. It has to start with a thorough mutual technical understanding.

NEW PROBLEMS

The television receiver industry has approached the matter of "cable compatibility" from the standpoint of channel tuning, adjacent channel selectivity, and succeptibility to strong ambient RF fields. These seemed to be the compatibility problems when I first raised the question of compatibility in a paper presented to the IEEE Consumer Electronics Conference in 1971 - more than ten years ago.

The major factor in the changing cable systems environment has been the advent of multiple PAY-TV services and the rapid recent growth in cable television service offerings. Our newest cable systems offer dual-440 MHz cable systems carrying up to 61 channels on each cable. We insist on remote tuning capability in all of our new converters. We refused to buy one manufacturer's converters for many years because they did not offer remote tuning versions of their converters. It is ridiculous to offer a 54 or 122 channel system and then provide only a "set-top" converter which will compel subscribers to get up off their chair every time they want to change channels. The cable industry has sold subscribers on the idea that they would want to change channels often because we offer such a large number and variety of channels. Remote tuning capability is an essential feature of a modern cable service offering. Remote audio control is equally attractive as a subscriber service offering.

I was called some time ago by a senior design engineer for one of the American TV receiver manufacturers. We had just introduced 400 MHz/54 channel cable systems technology. He was designing new "cable ready" tuners and he wanted to know whether 400 MHz would be the end of cable system spectrum development. Just how much tuning range should he build into a new "cable ready" TV set? I wasn't able to give him any assurances about limitations to cable system spectrum usage, in fact 440 MHz equipment had just been announced. After talking about it for a while we decided that it didn't really matter because it was just no longer possible to honestly talk about "cable tuning" as being the basis for a "cable ready" TV receiver. The pressures of PAY TV control and provision of other services has forced us to provide our subscribers with terminal equipment to control PAY TV access and in some cases to monitor PAY TV usage. Inevitably this equipment has become integrated with the tuning function, removing tuning from the function of the subscriber's receiver.

BASEBAND CONVERTERS

"Baseband" converters are now available from several manufacturers. I have given the matter of baseband converters very serious consideration and have discussed them with several cable systems equipment manufacturers. They have been introduced principally to provide more flexibility in "scrambling" techniques and to provide access to information transmitted in the vertical interval.

These are interesting reasons to go "baseband". Although we have made some substantial commitments to baseband converters I still have some reservations. These are some of the potential problems:-

Setting and maintaining proper depth of modulation of the remodulated video carrier.

Setting and maintaining proper visual/aural intercarrier frequency.

Linearity of the remodulator. Most baseband converters use "game chips" - the low cost modulator chips developed for use in mass produced video games and low cost home computers. These modulator "chips" might not have adequate "linearity" for high quality entertainment video.

High cost of a very good IF/video demodulator section.

The use of a particular tuner/demodulator design forecloses any benefits from an improved tuner/demodulator which the subscriber might buy in the future. The displayed picture can not be any better than the baseband produced by the particular tuner/demodulator which the cable system provides. Heterodyne converters are not so limiting.

There are some advantages in a well-designed, well-made baseband converter:-

The IF and video demodulator provided in the baseband converter can be of better quality than that in the average subscriber's own TV set. Adjacent channel rejection could be improved. Proper synchronous demodulation could be provided.

Separate video output can be provided to bypass the internal remodulator. This direct video output can be used in "monitors" and VCR's.

High quality audio demodulation can be provided with separate baseband audio output to similarly bypass the remodulation process.

I believe that the problems of baseband converters are being overcome through intensive development and rapidly growing field experience.

WASTEFUL REDUNDANCY

There is a substantial redundancy in the present system of supplemental subscriber terminal devices provided by the cable system. The subscriber already has a tuner and many have sophisticated remote control systems. The cable system provides, and the subscriber has to pay for, an additional tuner and remote control system. The remote control on the cable system provided terminal is usually not as sophisticated as the remote control provided with the receiver. Sound and color cannot be controlled by most cable system terminal units and the subscriber then finds that he uses two separate remote control units to control one TV set - an obviously unsatisfactory situation. There are other problems which arise. Some remote control TV sets come back on tuned to channel 2 after being turned off. Cable system terminals frequently use channel 3 as their output channel requiring the TV set to be tuned to channel 3 to accept the output of the cable system terminal converter.

In addition to cost problems there are serious picture quality problems inherent in this duplicative system. There is additional signal processing, and sometimes demodulation and remodulation, to affect the quality of the picture which the subscriber finally views on his TV screen.

THE SHIFTING "DIVIDING LINE"

We are seeing at this time a "tug-of-war" between receiver manufacturers and cable systems as to where the dividing line of equipment ownership would be. Receiver manufacturers would like maximum ownership by subscribers, thus maximizing their own participation in the business of supplying this equipment. Cable system operators want the technical flexibility and the increased profit potential of supplying as much of the subscriber terminal equipment as possible. There is a growing interest among cable system operators in moving the subscriber terminal equipment outside the home so as to maintain better control of it. My personal opinion on this issue differs from that of many cable system engineers and operators.

There obviously has to be a change of interface. I don't think that anyone in the cable industry is willing yet to completely standardize the channeling of cable systems. The matter of cable tuning can best be handled by moving the interface from the subscriber tuner input to the demodulator output. Cable subscribers should be able to buy video/audio "monitors". Video/audio interfaces can be readily standardized. The standard input to the subscriber owned equipment should now be baseband composite video (with baseband audio) with RGB optional. Appropriate tuner/demodulators can be supplied by the cable system or could be purchased by the subscriber. Manufacturers could decide whether and which tuners they wish to make and sell. "Off-air" tuners could be offered, as well as tuners for the more popular cable channeling ranges and plans. Tuners might optionally offer RGB outputs as well as standard composite video baseband. New TV broadcast services with stereo audio would require new demodulators with baseband stereo audio output. Further extensions of cable system operating bandwidth would obsolete earlier tuners, but it would be cheaper for a subscriber to replace his tuner with a newer model than to replace the whole TV set just because of an inadequacy in tuning range. These tuners could alternativeely be provided by the cable system who could themselves purchase these units from various receiver manufacturers or from specialized manufacturers. Manufacturers of video devices such as VCR's, video disc systems, video games, home computers, etc. would also benefit since they could then feed the user's video/audio monitor directly, without an RF interface.

"Component" TV sets with separate "tuners" and "monitors" are now available from several manufacturers.

"OUTSIDE" CONVERTER/DESCRAMBLERS

Some cable system engineers would prefer to bring the "dividing line" out from the home and into the cable TV facility. The most commonly proposal is to move the tuning converter from the top-of-the-set outside to a nearby pole or to a utility room in a multiple dwelling unit. This is intended to give the cable operator better control over the converter and associated descrambling equipment since experience has shown that it is often difficult to retrieve this equipment from a subscriber whose service is suspended. This systems approach also gives better control over premium services since only the one channel selected by the viewer actually enters the home. Systems of this type have been demonstrated by at least three manufacturers (C-Cor, Thetacom, Times Wire & Cable) and are no doubt being considered by other manufacturers.

Alternative proposals have been made which delete or "jam" unauthorized premium services in terminal equipment outside the home and then feed only the "clear" channels into the home.

I am opposed to systems of this kind for several reasons:-

1. They place complex equipment in a hostile outside environment with consequent design and operating problems.

2. They are inevitably more costly than the present subscriber terminal equipment.

3. Their placement outside the home creates new maintenance access problems. The problem of maintaining additional equipment outside the home in hard to get to kiosks and/or pole mounted housings should not be underestimated. There is also a problem in providing power for these outside devices.

4. The required outside housings are bulky and create an aesthetic problem.

5. There is a serious problem with multi-set households. The systems being presently demonstrated require a separate drop line for each TV set in the home. There will no doubt be multiplexing of multiple outside converters and remote control links onto a single drop cable, but the requirement for multiple outside terminal equipment for multi-set households aggravates the previously cited problems.

6. These systems do nothing to solve the problem of the costly functional redundancy inherent in duplicating the tuning function in both the cable system and the subscriber's TV receiver.

There may be an interim role for these "outside" converters in apartment buildings where room can be found for the equipment and where environment, power, access and maintenance problems would be manageable.

This arrangement attempts to solve the cable system's main economic problem - control of PAY TV and other special services. Present technology and economic constraints compel the use of scrambling rather than coding techniques and virtually compel integration of the descrambler with a cable tuning device. The basic nature of scrambling requires firm cable system control (usually through ownership) of the descrambler and the development of "outside converter/descramblers" attempts to improve the cable system control of the descrambler.

A MORE SATISFACTORY SOLUTION

I believe that the most generally applicable and satisfactory solution is to move the cable/subscriber interface in the other direction - into the subscriber's receiver - by more realistically defining tuning range, selectivity, and RF field immunity for a "cable-ready" TV receiver and by defining a standardized coding and addressing system for controlling premium TV services. This would allow all the tuning and premium control functions to be owned by the subscriber as part the subscriber's own television receiver, while full control over premium services is retained by the cable system.

Let us distinguish between "scrambling" and "coding" of television signals. "Scrambling" merely modifies the signals so they cannot be received and/or displayed on a conventional TV receiver. Sync' suppression is a common form of scrambling. Video polarity inversion, FM transmission and "jamming signals" are other forms of scrambling. Knowledge of the technique allows "descrambling". You can build a descrambler that will work if you know the scrambling technique. Some systems use very sophisticated scrambling techniques that required more sophisticated descramblers, reducing considerably the risk that average individuals will reproduce or otherwise acquire the required descrambler. There is still very little protection from determined efforts to breach such a security system on a large scale. Another deficiency of such systems is the fact that mere possession of a descrambler often defeats the system. Some systems can address such "lost" descramblers "OFF", receiving some degree of protection, but there are still significant economic problems associated with the loss of descrambling equipment and the theft of services.

"Coding" modifies the signal in such a way that decoding needs both knowledge of the technique and the particular code or cypher that has been used to encode the signal. The technique is analogous to the encryption of high security message traffic. The coding techniques are usually digital but they do not always require digitizing the signal. Coding techniques have appeal because they would allow the subscriber to own the decoding equipment. Nationally standardized decoders could be built into new TV sets. We can then sell the subscriber the decoding equipment because it won't work until we sell him the code required to make the box work right. The code would be unique to a particular program service and to a particular subscriber decoder. We can change the code every day, every week, every month or for every program. The code supplied to the subscriber to operate the box won't work in his neighbor's box for the same program, nor will knowledge of the codes supplied to a large number of subscribers provide a decoding "key".

"Addressing" has been shown to be a very useful adjunct in subscriber terminal equipment. A nationally standardized addressing scheme would also be desirable.

SOME CODING TECHNIQUES

Several STV coding systems have been developed and demonstrated. One such system was developed at Electrohome under contract to Pay TV Corporation. The system inverts the video polarity of the signal in a pseudorandom line sequence, i.e. the number of scan lines in each polarity group is changed in a pseudorandom way. I was impressed with the effectiveness of coding as an alternative to scrambling, but I was not enthusiastic about alternating video polarity as a means of concealing the signal. I believe that there are too many problems in matching the "positive" and "negative" video channels in the decoder. The gain of the inverter must be closely controlled and problems of transmission linearity arise.

I have also seen demonstrations of "line shuffling". I believe that this technique is the most promising and very worthy of consideration as a national standard. Conventional video is read into a digital frame store in regular scan sequence. The lines are read out for transmission in a pseudo-random sequence. A similar store at the decoder reads in the lines as received and then, knowing the code, reads them out of the store in the proper sequence for display. The demonstrations that I saw (by Anderson Labs, a manufacture of digital frame stores), used a full frame digital store (525 lines of storage). This is obviously a very expensive system since decoding requires a similar store. I believe that a system using as few as 8 lines of storage would be adequate. I believe that the prospect for developing low cost consumer versions of such a decoder using either digital or analog storage is very good. "Professional users" could use digital storage for decoding. "Consumer users" could use lower cost CCD's or similar analog video storage devices.

Westinghouse has proposed a system which can be called "line dicing". This cuts a scan line into two parts and swaps the two parts in sequence. The "splice point" is moved along the line in a "pseudo random" fashion, effectively concealing the picture content. I'm not sure how well this works, because cutting a line in two and then rearranging the parts could create a bandwidth discontinuity at the "splice point". The advantage of such a system is that it requires much less buffer storage than a "line shuffling" system. A "line shuffling" system has normal bandwidth because the "switch points" are the beginnings of individual scan lines. Individual scan lines are not changed in any way but sequence.

It is quite practical to handle audio in digitized form, using available encrypting systems. I believe that a suitable digital system can be made to fit within the available aural subcarrier bandwidth without causing impairment of the video transmission. Digital audio transmission will benefit from the introduction of digital audio disc systems for consumers, expected within a year or two. This will make low cost digital audio "chips" available.

RECOMMENDATIONS

The cable system operating industry must go to "coding" instead of "scrambling". We must decide on a particular coding system as a national standard so that the decoders can be built into TV sets and so that low cost decoders can be made available to subscribers on a competitive basis. A nationally standardized addressing system is also important. I believe that subscriber terminal equipment is best made and distributed by the consumer electronics industry. Cable subscribers would enjoy a substantial benefit from a competitive market in subscriber terminal equipment. The beneficial experience with subscriber ownership of telephone terminal equipment has snown that a competitive market-place reduces costs to the user, increases variety and utility of equipment, and creates a wider opportunity for manufacturing and distribution enterpreneurship.

We now know enough about this technology to convene a national committee to recommend a national standard that could be used for satellite, STV and cable distribution. There might even be applications in other distribution technologies such as prerecorded videotapes and discs. One can also visualize more extensive use of program coding in television broadcasting. Some of the European broadcasting systems, e.g. the British Broadcasting Corporation, are completely financed by a compulsory "receiving licence". These broadcasting systems are in fact PAY TV systems operating on a substantial national scale. These systems might in future benefit from a standardized transmission coding and addressing system. One could also visualize public broadcasting in this country using coded transmissions as a means of financing their operations. Transmission coding of both video and audio is potentially as important a standard as is color coding. We must recognize the importance of such a standard and start the technical and organizational work required to develop and adopt national coding standards.

CONCLUSIONS

We don't want to buy, own, maintain and keep track of subscriber terminal equipment. Our company will be buying thirty million dollars worth of this equipment in the next three years. We believe that the public would be best served by technology which allows individual ownership of this terminal equipment. Our company would be best served by technology which allows us to conserve these capital and operating resources and use them for additional distribution plant and subscriber services.

CAN NOISE AND INGRESS COEXIST WITH TWO-WAY SERVICES?

Clifford B. Schrock, Chairman

CableBus Systems Corporation
Beaverton, Oregon

ABSTRACT

As more two-way services are turned on and proliferate on CATV systems, the return path continues to be a limiting factor in the economic viability and reliability of the services.

A practical discussion of the sources and characteristics of noise and ingress in a two-way CATV plant is presented. A number of current practices including bridger switching, filtering, and frequency agility are compared and evaluated.

A technique of using narrowband width transmissions in the return path and other enhancement circuitry at the headend as an alternative to the bridger switching, filtering, and other current methods is described. Test results and comparative data is presented along with a summary of 2 years practical experience using the narrowband techniques.

INTRODUCTION

The dilemma of the cable operators is that they have promised advanced services, but have no cost/benefit justification to do so. Consequently there is no commitment to maintain two-way plant and early experiments are failing, either economically or technically.

We don't know enough about true closed systems in the return direction; in fact, we're just learning about forward "closed systems".

What is presented is a narrowbands technique that lets the CATV operator begin two-way services without having to fight all the traditional problems. Further, the system is compatible with future envisioned services systems by merit of its bandwidth efficiency and may well be just as effective once the return path and its associated problems are understood and solved.

The system presented is formulated around one premise - narrow bandwidth. The baud rate in simply encoded system is roughly:

Baud rate x 2.1 = Bandwidth

For instance 9600 baud will require roughly 25 KHz of bandwidth.

INFORMATION / TIME
is related to
DATA / TIME
is related to
BANDWIDTH

Fig. 1. Relationship between Information, Data Rate, and Bandwidth

To achieve the minimum data rate, each proposed two-way service is analyzed to get to the true information content requirement for a given system. As an observation, I have noticed that the information content is significantly lower than the actual baud rates proposed for use on most systems.

Lets look at some real world examples:

Alarm Systems - the objective is to locate all alarms within 5 seconds. A brute force solution is to poll all customers every 5 seconds for their status.

However, two significant factors are overlooked. The majority of status changes in an alarm system are not alarms; therefore supervision can occur less often - for instance once per minute or (using UL guidelines for alarm operations) once per 90 seconds.

The second factor is that the dispatcher, followed shortly thereafter by the available responsed equipment, i.e. fire trucks and police cars, rapidly becomes the limiting factors. Prioritization is required at the dispatch position to deal with the alarms -

and this prioritization can be established in the system operation by using an interrupt type protocol. This would scan all the accounts slowly (hence in a narrow bandwidth) to supervise or make sure they are on-line, and would be interrupted by alarms at short intervals.

Pay TV Control - the downstream and return (pay-per-view or customer preference) could of course be handled with a rapid, real time data rate. However, in a real world situation, updates can occur slowly, and enabling of special events could be preset on the appropriate terminals, then enabled with a single mass command.

Also, channel authorization decisions can be made within the terminal by comparison to an internal up-dateable ROM.

In the return path, theorists envision overloads could occur in a pay-per-view type event, where within a period of a few minutes, thousands of terminals could request an event. However, again a system of presets that would allow usage for a short period while the system was updated would suffice.

Meter reading - Metering systems generally have 3 requirements - monthly reading, on-line reading (such as when a tenant moves) and demand reading. Demand reading is the most strenuous, although readings per home every 10 to 15 minutes suffices in most instances which can be handled to high capacities with low data rate. Demand reading can be enhanced by only reading the most significant digits which could effectively double the polling rates/hence subscribers served.

Energy management - All proposed systems revolve around customer notification, or system setting in response to factors such as peak demand, or temperature and weather changes. None of the factors requiring control occur instantaneously, nor would a virtually instantaneous (real time) mass command be required. Further, a mass command (such as switching of 10,000 hot water heaters simultaneously) could, in fact, cause significant problems to a utility. Energy management in general can be thought of as a low data-rate type function.

Two-way data systems and Customer Preference Polling - These systems potentially require the highest effective data rates. The downstream requirements are the greatest, with whole pages of data being delivered to each subscriber on the service. Teletext and Video-text systems are already addressing the downstream aspects. Yet the following observations must also be factored:

a. Given the availability of a data system to each home, at any one time, only a small percentage of the population try to use the system. The Bell system has used a factor of 15 to 17% usage for years in planning telephone trunking facilities.

b. A person asking for data is much slower than the data returned. Typically a person will enter a menu select digit or a line of data and receive a page of information back. Rarely can a person deliver data to a system in excess of 110 baud; while, in supplying data back to the subscriber, anything less than 2400 baud "feels" slow.

Much work has already been done in data packeting protocols for networking applications. Systems such as Ethernet, and the Mitre system take advantage of both points "a" and "b" mentioned above to allow efficient packets of data to be sent on a system of much lower baud rate than a cursory glance would suggest.

The author theorizes that other alternatives or adaptations utilizing low baud rate channels and multiple channels could provide efficient solutions.

* * *

The short analysis above was done to bring the reader to a single conclusion: that the actual information content of proposed and envisioned new services on cable is quite low - especially in the return path. Further, if the information content required is low, then the baud rate, and ultimately the bandwidth, is low. This fact can be used to a tremendous advantage by permitting the cable operator to offer advanced service without carrying the overhead in maintenance and associated costs of operating the two-way plant.

A Practical Narrowband Design

The author has designed a narrowband, high-capacity alarm system for cable TV systems that is being used by many cable operators. A detailed analysis is shown to illustrate how the parameters were selected and to show the margins gained over other system approaches.

The system used in this example is the CableBus® Systems Corporation CableAlarm™ system. The design goal was to provide a high-capacity alarm system capable of serving up to 100% of the homes in a cable service area. (Present experience with custom alarms indicates a 5 to 10% penetration; however, significant breakthroughs in price coupled with the increase in crime and decrease in municipal services has the author predicting that we may witness systems with a smoke detector in every home by the mid 1980's.)

The largest block of homes served by a single cable is limited by amplifier spacings to hubs serving 40 to 60 thousand homes. Multiple hubs could utilize the same frequencies to serve different customers. And hubs with exceptions to the maximum proposed capacity could be provided with 2 or more trunk outputs. Therefore, the first premise is that a single trunk area will require a maximum capacity of 40K alarm accounts.

Further dividing, it was felt that a 25KHz bandwidth was the lowest practical value. Factors including the availability of 1F components, frequency stability of the home terminals and cost of obtaining it, and the capability of the resultant data rate (9600 baud) were factored. Two simple modulation options were available: narrow deviation FSK or simple keyed carrier AM. Since narrow deviation FSK has no perceptible C/N advantage over AM, and AM was easy to generate with a minimum number of components, AM was chosen.

Account access times were chosen using UL-611 alarm industry guidelines to arrive at the following:

- Maximum time to check every account for status would not exceed 90 seconds.
- Maximum time between checks for alarms (interrupts) would not exceed 5 seconds (10 seconds required by U.L.) for the first alarm.
- Ability to sort and list multiple alarms would exceed 50 per minute (which would, it should be pointed out, over-run virtually any dispatch center in the U.S.

The limiting factor, therefore, is supervision time (checking to make sure each account is still there). Using a ASCII message format of a header, 4 address characters and 2 command/interrogate characters; a maximum of 77 bits per account would be used. Roughly 11220 accounts could theoretically be covered at 9600 baud using this technique. Allowing for space between transmission, alarms, and other contingencies, a maximum of 5,000 accounts per 25 KHz bandwidth was adopted. To handle 40K accounts, 8 subcarriers of 25 KHz each would be required. The author recommends spacing on 50 KHz intervals, therefore, an entire 100% penetration security operation could be operated in 400 KHz of return bandwidth, with the forward data occupying a similar bandwidth.

Quantifying the Advantages

An analysis of the system advantages over existing schemes is provided. Currently, other manufacturers offer a variety of high baud rate schemes, the narrowest occupying approximately 280 KHz. using an FSK carrier.

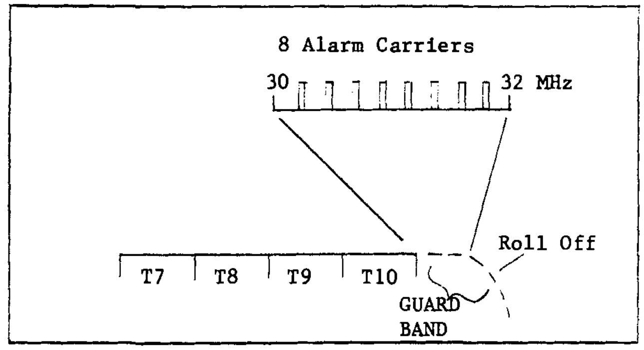


Fig. 2. Typical Return Allocation for 40K Subscriber CATV Alarm System

The CableBus system uses an AM carrier as was described.

The C/N advantage due to bandwidth alone is in the order of a 10 x reduction; approximately 20 dB. A further advantage can be claimed by merit of the simple keyed AM format. A 12 dB C/N is required for reliable performance in a clear (white noise <u>only</u> impaired) noise situation. While it may not be a true advantage in carefully designed equipment, current wideband FSK systems claim to operate only to within an 18 dB C/N.

A third advantage can be obtained by video filtering the data. As shown in the figure, although the bandpass for a given data rate must be 2.1 x the data rate for simple modulation, there are gaps within the bandpass (Figure 3). As shown in the figures, a relatively simple comb filter (Figure 4) can gain an additional 4 to 5 dB of noise reduction.

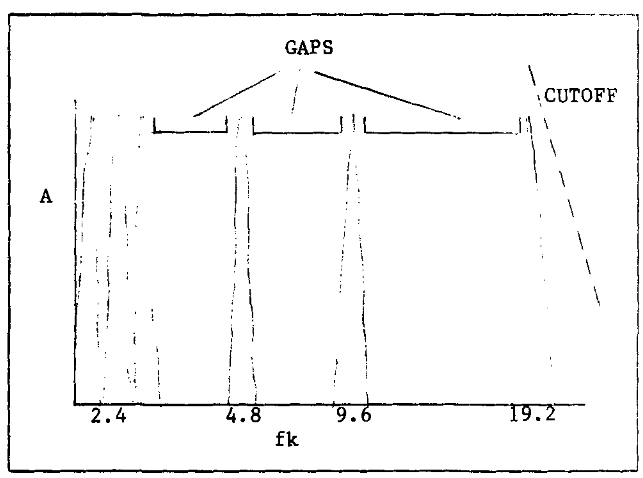


Fig. 3. Fourier Transform Distribution of the Frequency Components in a 9.6 kB Data Transmission

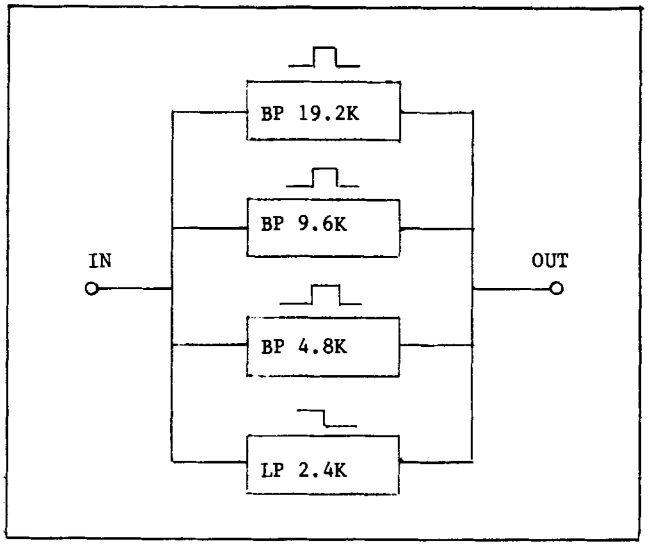


Fig. 4. Comb Filter used to Enhance 9.6 kB Data Reception

A final filtering technique is the "software filter". Random high level system perturbations will always exist on two-way return plants. Lightning strokes and electrical power switching transients are the most violent, although many other sources can "upset" the system. Effective software protection in the form of multiple checks on status and error-correction can enhance a marginal C/N situation. A summary of all these improvements is provided in Figure 5.

Bandwidth reduction to 25KHz	20dB
AM/design improvement	6dB
Video filtering	4-5dB
Software filter	3dB
	33dB

Fig. 5. Summary of Noise Improvements For 25 KHz Alarm System

Alternate Contending Techniques

Other techniques are used to combat return channel ingress and interference buildup. Two of the most popular proposed solutions are bridger switching, and agile frequency control.

Both can provide relief in the areas of operating reliable two-way services, but both add expense and complexity to the system.

Bridger switching is an excellent diagnostics tool for two-way services; however, its use or requirement to make a service functional will ultimately limit the very services we propose to provide. If for instance, it is proposed that the bridger switches be cycled for each security polling cycle (every 5 seconds), we will see about 6 million cycles per year. Other adjacent two-way services must be filtered or time synchronized to the bridger cycles.

Frequency agility, if kept simple, could provide a valuable backup if the primary path is impaired, but in no way should be an excuse for stuck transmitters or as the primary method of handling ingress.

The author submits that cost-effective two-way services must be capable of working independently of each other, and must operate in a "wide open" cable environment (i.e. not sectored or switched).

Equating the Improvement to Dollars and Cents

Up to this point we have been talking about only numbers. The real advantages of a narrowband technique are cost benefits to the operator and the numbers must be translated accordingly. The author feels that the single largest advantage today is gained through a reduction in manpower for trouble calls and maintenance. The two-way plant for a system such as the one described would not be running anywhere close to its maximum potential; therefore, alignment, and ingress problems would be substantially reduced.

The terminal and the central computer equipment benefit from the data rate reduction. In the home terminal, lower baud rates can be very effectively handled with 'bit-crunching' in a single microprocessor, rather than requiring a separate UART or other converter. Further, the home terminal processor can be multi-tasked to handle the other local intelligence required both for a "software filter" and to operate the home alarm system. A single chip home terminal design means lower cost and/or greater performance.

The central computer can also operate using one or more RS-232 ports rather than having to provide a more expensive high speed port.
Another significant advantage is that the narrow carriers can be placed on the cable in places not normally considered by other systems. For instance, most of the CableBus systems so far have operated in the 30 to 32 MHz guard-band. (See Figure 2) While most systems do begin to roll off in this area, the C/N advantage is so great that losses of up to 10dB in the guardband are not a significant factor. Another related advantage is that the narrow carriers can be placed to avoid known

ingress carrier sources. In a marginal or older CATV plant, it is simplest to chose a quiet slot on the cable, a task that is easy if the bandwidth is narrow. (Figure 6)

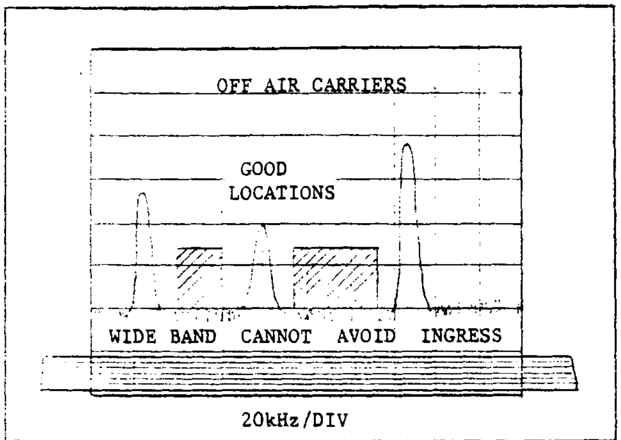


Fig. 6. Choosing a Quiet Return Frequency for a Narrowband Service

A final advantage is that of using a lower return transmitter level from the home. Industry standard is to use +50 up to +60 dBmV for the home terminal return transmitter. The author questions the impact upon factors such as leakage from the cable which is governed by FCC part 15 and part 76.613. Most home drops are marginally effective with downstream signals in the 0 to +10dBmV level range. A return signal of +50dBmV, even of short duration, could be wildly out of spec. on a standard RG-59 drop, especially after the foil deteriorates. Without final supporting data, CableBus has limited its maximum output level to +41 dBmV at the home. A typical worse case flat loss of 47 dB will be encountered between the home and the headend on a well designed two-way plant, resulting in a return level at the headend of -6dBmV. The practical worse case white noise floor (coherent carriers excluded) that we have ever encountered in a two-way plant, across 25 KHz has never been greater than -30dBmV. An additional minor advantage of lower terminal transmit levels is that less filtering is required on the TV leg to the home.

Conclusion

To answer the question posed by this paper - by utilizing narrowband techniques, new services can be accommodated on CATV plants, and need not become a tremendous maintenance and repair burden to the operator. The use of alternate noise reduction techniques such as bridger switching or trunk sectoring should be used only for maintenance or emergency procedures. Frequency agility can provide an enhanced reliability for systems, but should not be the primary method used to make two-way operate.

Narrowbanding, on the other hand, is a method of combating and/or dodging noise and ingress problems. Significant advantages can be gained over wideband systems.

Narrowbanding also forces the user to efficiently utilize the CATV spectrum. To most operators today, bandwidth is not a problem; however, within a few years, after a few successes, the author feels that bandwidth will be at a premium. It is analogous to the pre-1973 gasoline situation. Nobody believed in conservation of gas till they ran out!

Experience gained using the CableBus Alarm System over the past 2 years has proven that less is required of the return path to operate successfully on two-way and marginal plants.

Narrowbanding has significant advantage whether applied as a single carrier or as hundreds of narrow carriers. Someday there may be so many services and revenue sources using two-way that they can easily justify the manpower and equipment necessary to support a very tight high-quality return plant and allow wideband return schemes. Until then, the alternative presented may be the answer.

CARRIAGE OF MULTIPLE ONE-WAY AND INTERACTIVE SERVICE ON CATV NETWORKS

Robert V.C. Dickinson

E-COM CORPORATION
Stirling, N.J.

The concept of the wired city is based upon the facility and capacity of the CATV network. The original concept envisioned "everything for everybody" but progress has been retarded by the lack of economically viable services. Over the years individual stand alone services have been developed as income producers with some degree of success. Addressable control of premium television has been the most successful and profitable and is now being augumented by home security, utility meter reading and pay-per-event TV. The future promises the addition of more sophisticated services including videotex, interactive home shopping and personal computer interfacing plus banking. These business ventures are being fine tuned to be good revenue producers so that indeed the wired city concept is coming into much sharper focus.

With the economic driving forces building, and in some cases firmly in place, it is well to review the technical approach for delivery of these services on the CATV network. Typically, services of this sort are implemented on a stand-alone basis. Manufacturers and program suppliers, experts in their areas, have devised and configured transmission systems including headend subscriber equipment to provide efficient and economical delivery of each individual service. This has resulted in optimization of stand-alone services which in turn has resulted in deficiencies and complexities when multiple interactive services are implemented on a single cable system. The following discussion cites the need for and proposes a multiple service system for CATV carriage of subscriber services.

STAND-ALONE COMMUNICATION SYSTEMS

Let us examine the headend or central control requirement for typical services. Generally speaking each specific service requires some sort of computer to control delivery of status, information or control to and from the subscribers. For instance, in a one-way addressable premium television system it is necessary that the headend computer keep track of the addresses and messages to the subscribers, handle channel authorizations and changes, produce billing information and perhaps prepare the actual billing documents. In a stand-alone system much of the work normally associated with the cable system billing computer is performed by the pay TV control computer. When and if two-way, pay-per-event is instituted, additional control and bookkeeping must be done. Since the control computer for the pay television service is required to control the communications functions, it is necessary that the control computer be on the cable system (usually at the headend) or that high speed data lines be run from the headend to the remotely located control computer. This is a cumbersome situation at best, particularly since system diagnostics are performed at the control computer which should be based conveniently on the cable system for use by the cable technicians.

Should this same cable system desire to offer home security, the classic approach is to add a stand-alone security system which again is controlled by its individual computer. The format of the data transmission is usually unique. The same general restraints apply as in the pay TV system in that network control must be implemented in a convenient place on the cable system while the security central station may well be at some other location. The central station computer, which is associated with the security alarms and the customer data base, is often forced into a location on the cable system rather than being placed advantageously within the community. Some cable operators have chosen to operate their own exclusive security service while others are interested in serving other security operators within the community or even a combination of the two. In the case of multiple security operators, the additional restraints of such a stand-alone security system become obvious.

Due to various economic factors, utility meter reading via cable is gaining new support. If meter reading can be sold to a local utility(s) the cable operator has the distinct advantage of a drop in every home in town. For utility meter reading a headend communications control computer is again required plus a communications link to the utility's billing computer at some location remote to the cable system headend (it is doubtful that the cable company will issue utility bills).

Looking further into the future, the development of profit making banking and shopping services can be predicted. Whereas the services may start locally they can certainly be expected to develop into regional or nationwide ventures. In such a case, a major part of the data base will definitely not be local but will be accessed through satellite, telephone or other communication links. Under these conditions it is likely that a computer will still be necessary for control of the local communication. Situations similar to the above will be encountered in the majority of existing and future cable carried services.

Let us turn our attention to maintenance services which are desirable in the CATV network. Cable system status monitoring has met with varying degrees of acceptance and is certainly desirable if implemented effectively and economically. There has been a great deal of talk about bridger and feeder switching to control the summation of noise in larger systems. Many have concluded that the system architecture can, in most cases, be designed so that the number of subscribers in any section need not be large enough to require feeder switches to reduce excess noise. Noise summation, however, is not the only factor to be considered. In the tree type structure found in most cable networks it is extremely difficult to locate the source of ingress when it does occur. Even though an interfering signal can be seen on the spectrum analyzer at the hub or headend, there is generally little indication as to where the ingress is occurring. If the ingress happens to be at a frequency and amplitude which interferes with one or more of the upstream signal paths, an entire service may be disrupted. It is therefore necessary to have the ability to isolate sections of the system by remotely controlled feeder switches in order to turn off the ingress and allow the remainder of the system to operate properly until repairs may be made.

In a cable system installation where there are several simultaneous stand-alone subscriber services the presence of ingress may have varying effects on each of the services due to their frequency relationship to the interfering signal. When such a condition is encountered on one or more of the services it becomes necessary for the serving organization to refer the problem to the cable system operator who in turn must seek the cause. If the location of the ingress is implemented with feeder switches, it is then necessary to utilize yet another communication system (the feeder switch control system). Since the feeder switch control is not synchronized with the simultaneously operating stand-alone server systems, the process of isolation will cause disruption in all other services even though the ingress does not directly affect them. Of course, if feeder switches are also required to control noise summation, their employment can create intolerable problems due to lack of synchronization so that services are contending with each other to access various sections of the CATV network. In multiservice implementations on CATV the configuration of the subscriber equipment is of great import. In virtually all services subscriber terminal equipment includes special purpose hardware to perform the specific service; security panels, sensors, videotex/terminals, (etc.). On the other hand, in a collection of stand-alone services, a unique modem is required in each home for each service in order to receive and transmit the required information and control functions. The modem function is thereby duplicated for each service. In some services the modems may well be inefficient in use of spectrum, provide poor noise immunity, etc., while in other services higher speed, more expensive units may be required. This diversity is another source of non-uniformity and overall increased cost.

Figure 1 illustrates a typical headend representation of several stand-alone CATV services.

In general it may be said that the stand-alone implementation of multiple CATV services is costly, inefficient and often conflicting in operational requirements.

MULTIPLE SERVICE COMMUNICATION SYSTEMS

Due to the various problems discussed above, a new concept for the delivery of multiple CATV services has been developed. Simply stated, the need is for a "Multiple Service Communications System" (MSCS) which can simultaneously carry many diverse CATV services. The concept reduces duplication, lowers costs, increases capacity and allows for expansion into yet undefined new services.

An MSCS has a single computer which is the "master controller" so to speak, for all service delivery. This computer or System Communications Controller (SCC) transmits to and receives from the remote locations via a built-in master modem. Polling is employed as the system protocol since all control and information passes through this one common point. The SCC does not, however, attempt to perform the various status, control or information functions associated with the individual services. Instead, the SCC is configured with appropriate communications ports which are connected to the specific server computers whether local or remote to the SCC. These ports are normally configured per RS-232, however, virtually any interface, data rate and protocol may be employed. Communication to server computers may be done by wire, telephone circuits, cable carried data circuits, satellite links, etc.

The SCC is arranged to sort and store data as required for each service. In addition, each port is programmed to be protocol compatable with its respective server computer. The only data passed between the SCC and any server computer is that which is required to implement the service but not that required to control communication on the CATV network. In this way data transmission between SCC and server computer takes place at considerably reduced rates compared to the data flow on the CATV system. In addition, there is no interaction between server computers, thereby providing totally independent operation of the services.

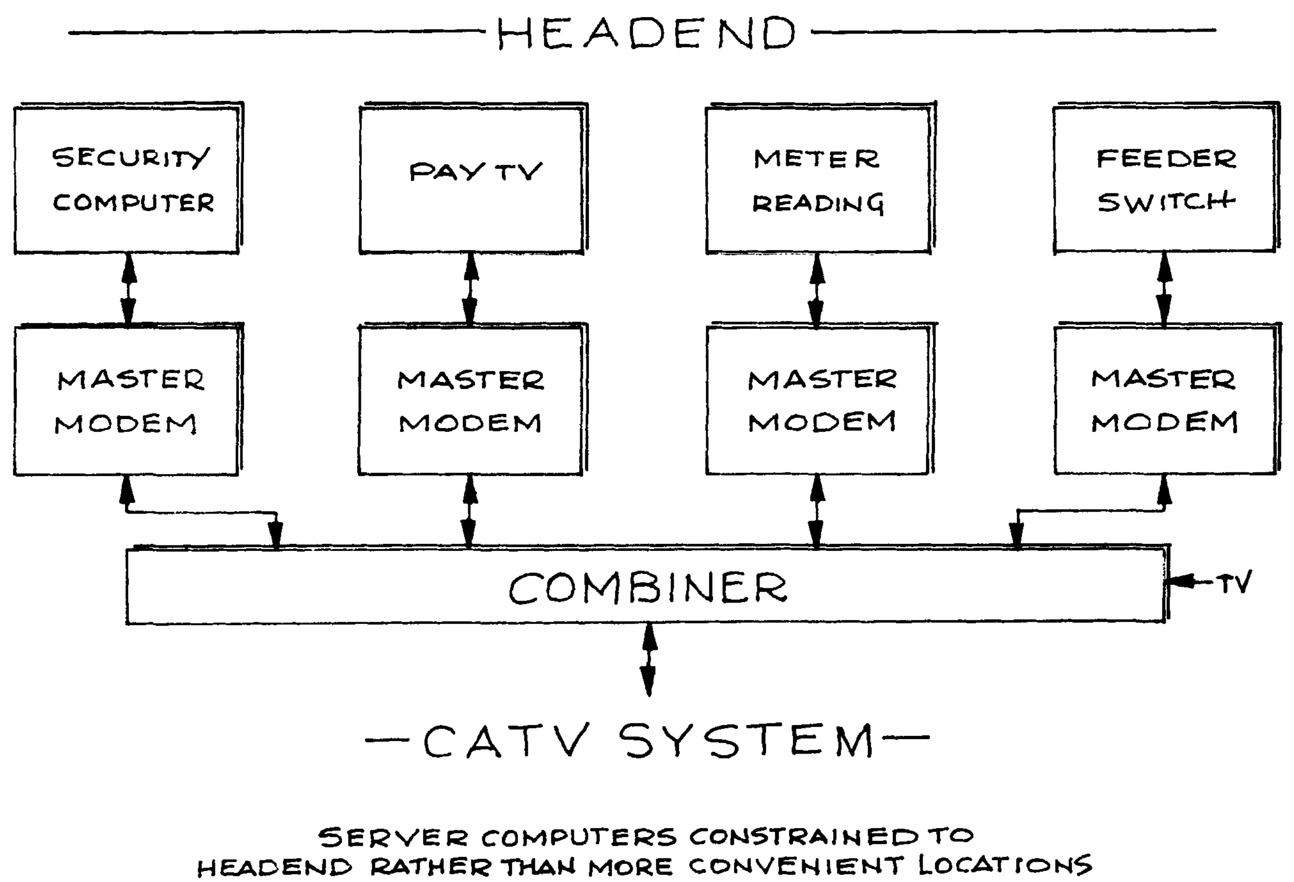


FIGURE ONE: TYPICAL CATV HEADEND FOR MULTIPLE STANDALONE SERVICES

On the CATV system the MSCS utilizes high speed data streams both to and from subscriber locations to implement all services as well as to monitor and control system operation. Since the data rate must be high to encompass multiple services, the cost of the remote modems could be undesirably increased. For other reasons the MSCS employs a communications sub-controller between the SCC and the subscriber modems. This unit has been labelled the Area Control Unit (ACU). The ACU carries on simultaneous communication with the SCC on one side and several hundred customer modems on the other. The communication circuit to the customer modems is also polled but at a much lower rate than the SCC link thereby reducing subscriber modem cost and complexity. The ACU keeps track of status of the customer modems and handles control and information traffic between customer modems and the SCC. Notice that the ACU reports status and alarm functions by exception, i.e.; when there is no trouble and no alarms only a short "all is well" message need be sent to the SCC. The ACU also provides buffering for traffic in order that messages may be properly interleaved in the polled data streams. Since the ACU is a very intelligent communication controller in itself it may, in certain cases, be employed on a stand-alone basis in small systems.

In the MSCS the customer modems assume several forms and, it is well to note that since many simultaneous services may be handled on the system, each service modem requires interface with the same radio frequency data channel thereby utilizing the same data transmission and reception hardware. Interfacing to a variety of individual services requires widely differing connections, formats and functions. In the case of security, medical, fire and other alarm and command requirements, simple on/off inputs and outputs are required. These inputs and outputs can also be programmed to read utility meters. This particular configuration is known as the Customer Service Module (CSM). Installation of the CSM for one of the above functions provides for all of these functions limited only by the actual number of input and output circuits. For these services the SCC is ported to security, fire, medical and utility monitors and computers which supervise their respective services.

Figure 2 illustrates an MSCS CATV implementation.

Home computer and videotex applications for CATV are developing. Interfaces to personal computers and videotex terminals are usually made at RS-232 level. This provides a convenient standard and is quite functional. In these cases the applicable modem is the Videotex/Data Interface (VDI). The same r.f. section is employed as in the CSM, however, the focus is now on the serial transmission of data to and from the computer or videotex terminal. Buffering is required to interface between the polled data to and from the ACU and the specific data rate of the user terminal.

Both upstream and downstream buffers are supplied so that the data stream to and from the computer or terminal appear to be real time rather than polled. SCC porting to VIDEOTEX and other data bases allows an extremely wide variety of important information and functions to be additionally provided.

Other important services can be implemented on the MSCS. Control of premium television viewing with the MSCS is an important application. In order to increase the security, reduce the cost and allow the use of non-addressable converters the Television Control Module (TCM) is mounted outside the residence and employs jamming techniques to control viewing. Jamming signals are applied under SCC control via the ACU to deny viewing of unauthorized channels on a drop by drop basis. The jamming signals are applied in a manner such that trapping is virtually impossible. Since this function occurs outside of the residence, tampering is extremely difficult. The TCM replaces the traditional subscriber multitap and draws power from the distribution cable. The cable system billing computer is connected to an SCC port to input subscriber viewing authorizations. The TCM also provides a remote T.V. disconnect switch for each drop but allows passage of messages between the ACU and customer modems within the residence thereby allowing services such as security and meter reading to function even though TV service may be shut off.

While the TCM module provides control for any premium TV delivery, pay-per-event service may be instituted by use of the Keypad Unit (KPU). The KPU interfaces with the drop within the residence and includes a display and controls for selection of pay TV channel, opinion polling, data base access, etc. If the subscriber desires a remote control for the KPU, it is provided by a wireless link to the hand held unit. The remote unit may be sold to the customer (and permanently retained by the customer) if so desired since its functions do not allow him to defeat the premium product billing. The KPU communicates with the ACU which in turn forwards billing information to the SCC. With this system it is virtually impossible to view the premium TV product and escape the billing function. The KPU may also be used to add the pay-per-event feature with one-way addressable converters thereby avoiding an additional converter changeout. Simultaneous CATV system control and status monitoring are uniquely fitted to the MSCS. In the matter of bridger or feeder switches, control is excercised simply by short commands embedded in the unified data stream. Such commands are absolutely synchronized with the system operation and service functions thereby adding minimum overhead and causing no conflict between services. Status monitoring of CATV parameters such as transmission levels may be performed in spec-

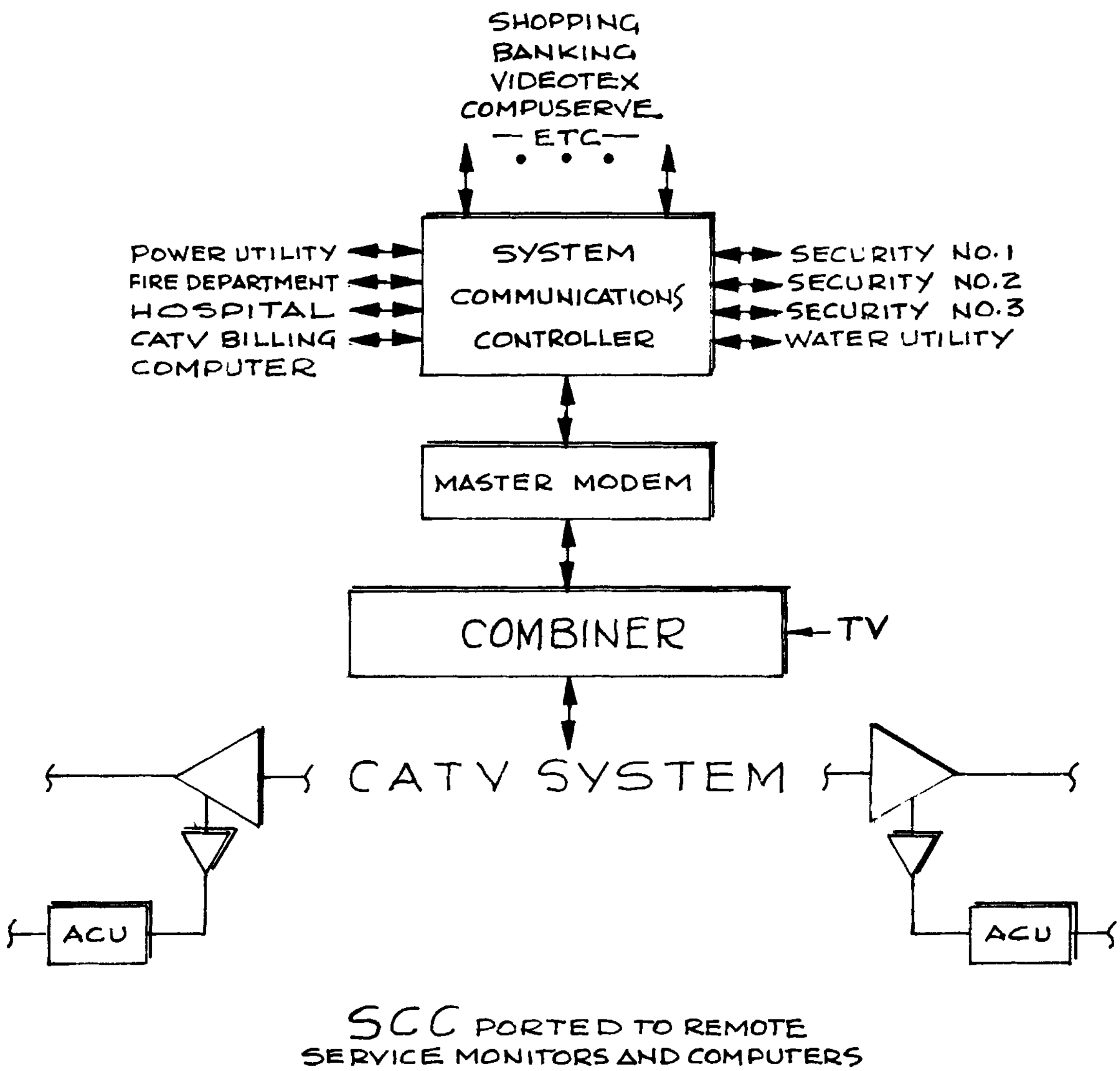


FIGURE TWO: MULTIPLE SERVICE COMMUNICATIONS SYSTEM FOR CATV SERVICES ially designed modules strategically distributed throughout the CATV network. Measurement of voltages, currents, etc. within trunk and distribution amplifiers may be handled in a similar manner; the greatest problem being access to these variables which are not usually available outside of the amplifier housing.

CONCLUSIONS

The MSCS offers many advantages in functionality and cost. Due to the concentration of intelligence in the ACU and the reduction of data rates to the customer modems, the cost of these high quantity items is dramatically reduced. In the provision of simultaneous multiple services the MSCS utilizes appropriate customer modems mixed within the system without penalty. The MSCS may be implemented initially for a single service and later expanded with additional cost savings over stand-alone systems. New services of the future will be implemented with similar, low cost modems as required. Simple services such as security, utility meter reading and pay TV control may be offered to hundreds of thousands of subscribers on a single MSCS channel. Since the MSCS size is limited by the total data throughput, requirements exceeding the systems data rate or expansion of the number of subscribers served may be achieved by utilization of multiple RF channels. This expansion again may be achieved on a minimum cost basis without the requirement for service calls to existing subscribers.

At this critical time in the history of cable television the door is opening for ever increasing revenues from non-TV subscriber services. The ultimate content and form of these services is still unclear. Transmission of these services via a Multiple Service Communications System requires minimum upfront cost and provides maximum effectiveness and performance plus the important ability to encompass new and developing services without conflict, equipment duplication or obsolescence.

CARS BAND CONGESTION

John P. Wong

CARS Microwave Branch
Cable Television Bureau
Federal Communications Commission

ABSTRACT

Cable systems operators are discovering that it is getting more and more difficult to locate spectrum space in the Cable Antenna Relay Service (CARS) band. With the advent of 400 MHz plus broadband technology, the CARS band is saturating at an alarming rate. Practically all of the newer and more sophisticated cable television systems make extensive use of CARS microwave in order to bring in a wider variety of programming. At this point in time, many of the urban and large suburban areas of the country are being wired for cable. The entry of cable into the cities further congest the already crowded CARS band around the metropolitan areas.

The CARS microwave band allocation scheme, as it exists today, simply cannot accomodate the needs of the cable industry. This paper will suggest an interim solution to help ease the existing CARS band congestion problem. In addition, the author will discuss some of the future possibilities for CARS band users.

INTRODUCTION

One of the biggest problems confronting the cable television industry today is the shortage of channels in the CARS microwave service. The escalating use of CARS band channels by cable system operators in lieu of trunk cable to deliver the various forms of programming has almost evaporated the available spectrum in many parts of the country. Recent technological advancements in coaxial cable channel capacity followed by improvements in microwave equipment design have manifested the wide spread use of large segments of the CARS band by individual cable systems.

As the CARS band saturates, cable television system engineers are beginning to realize the scarcity of channels in the CARS spectrum. They are discovering the increasing difficulties of locating vacant channels in the band. The possibility of frequency interference to existing authorizations are more probable than ever before. And the expenses associated with spectrum search have skyrocketed.

No longer can cable operators simply request frequencies from the Federal Communications Commission (FCC) in the CARS band without extensive interference studies. Advance consultations with neighboring cable systems as well as broadcasters are required since the FCC does not coordinate frequencies for the applicants.

In order to conserve the present CARS band frequency spectrum, collaboration between companies is more of a necessity than ever before, a wiser utilization of the microwave service is a requirement, and other alternatives must be considered. To facilitate for more efficient spectrum usage, choosen industry representatives must attempt to search and to provide for solutions.

Whatever the future of the CARS band maybe, the use of the CARS band frequencies should be created as a privilege and not a right. Finally, the electromagnetic spectrum, of which the CARS band is a part, is a non-renewable resource and ought to be treasured as such.

FCC REGULATIONS

The regulations governing the utilization of frequencies within the CARS band are listed under Part 78 of the FCC's Rules and Regulations (47 CFR 78). Incorporated in this part are the designated frequency channel assignments (47 CFR 78.18) within the frequency band from 12.70 to 13.20 GHz. The breakdown of the band is as follows:

1) Frequencies from 12.70 to 13.20 Ghz are shared between Cable Television System operators and Television Auxiliary Broadcast Stations.

2) Frequencies from 12.70 to 12.75 Ghz are shared with Fixed-Satellite Services.

3) Frequencies within the band from 13.15 to 13.20 GHz are reserved exclusively for the assignment of CARS pickup and Television pickup stations on a co-equal basis within a fifty kilometer radius of each of the top 100 television markets as listed in Section 76.51 of the Commission's Rules (47 CFR 76.51).

The frequency channel assignments for CARS stations are:

1) For FM transmission, allocated are three groups of channels with varying frequencies and differing bandwidths of no more than 25.0 MHz. There are 20 Group A channels, 20 Group B channels and 40 Group K channels. Channels assigned to Groups A and B have bandwidths of 25.0 MHz and Group K channels have bandwidths of 12.5 MHz. Corresponding Group A and Group B channels overlap and are separated by ascending bandwidths 12.5 MHz. Group A and Group K channels also overlap. Two Group K channels correspond to one Group A channel (e.g. the channel boundary of Channel AØ1 is 12.700 - 12.725 GHz, and the channel boundaries for Channels KØ1 and KØ2 are 12.7000 - 12.7125 and 12.7125 - 12.7250 GHz respectively).

2) For vestigial sideband AM transmission (AM) , assigned are four channel groups with bandwidths of 6 MHz or less. There are 42 Group C channels, 42 Group D channels, 42 Group E channels, and 32 Group F channels. Group C and Group D channels overlap and the respective channels in each group are separated by ascending bandwidths 59.2 MHz. Group E and Group F channels also overlap and their respective channels are separated by ascending bandwidths of 60 MHz. Because the fourth and the tenth channels in each AML group are intended for the transmission of pilot subcarriers and narrow band signals, they are allotted bandwidths of 4 MHz and 2 MHz respectively.

The above listed channel assignments are applicable only to CARS stations located outside the 50 kilometer perimeter of the top 100 markets. For CARS stations located with the radii of the delineated television markets, the number of usable CARS band channels are reduced to 18 Group A and Group B channels, 36 Group K channels, 33 Group E channels and 23 Group F channels. This condition further congests the spectrum around the major metropolitan areas.

In order to promote for more efficient use of the spectrum in the CARS band, the FCC incorporated numerous provisions into its rules encouraging spectral conservation measures. These provisions are as follows:

1) Applicants are required to justify the use of microwave channels over trunk cable.

2) Applicants of CARS fixed stations using FM transmission are encouraged to conserve spectral space by alternating Group A and Group B channels such that the adjacent radio frequency (RF) carriers are located 12.5 MHz apart.

3) Applicants for CARS stations are encouraged to apply and fill adjacent channels.

4) Applicants for CARS stations cannot utilize a channel that has a bandwidth greater than 12.5 MHz if the path length is less than ten miles unless sufficient justification is shown.

5) Applicants for Group K channels shall apply for adjacent channels and the requested channels shall overlap the least possible number of Group A channels unless sufficient cause if submitted.

6) Applicants are encouraged to coordinate the proposed frequencies with existing users and other applicants in area.

7) Transmitter peak output power levels are limited to less than 5 watts per channel.

8) Applicants are required to use antenna systems that comply with the Commission's established antenna standards in Section 78.105 of the FCC's Rules (47 CFR 78.105).

Also established in the FCC's Rules are various interference considerations for the CARS service band. They are:

1) Applicants are responsible for the selection of assignable frequencies which will be the least likely to result in interference to other licensees.

2) Applicants shall take full advantage of the latest state-of-the-art technologies to prevent interference to existing users.

3) All applicants, permittees and licensees are expected to cooperate fully and make reasonable efforts to resolve technological problems and conflicts that may prevent the most effective and efficient use of the band. The Commission will intervene only as a last resort.

TECHNOLOGICAL DEVELOPMENTS

The exponential growth of the cable industry fueled by recent technological developments will place an even greater pressure on the users of the CARS band. High capacity trunk cable, interactive cable television, teletext, line sync multiplex technique for data transmission, VHF FM data modems and high definition television are some of the latest developments. To win franchises, cable system operators are compelled to propose maxima services the present state-of-the-art equipment can tolerate. These proposals almost inevitably place a heavy reliance upon the extensive use of the CARS band frequencies. With few exceptions, a large sophisticated cable system cannot be constructed without the wide-spread use of microwave. A typical downstream programming proposal for a 54 channel cable system will require approximately two-thirds of the 80 AM channels in the CARS band. That same proposal will span across three CARS channel groups usually using Channels CØ1 - C42, D33, EØ1 - EØ9 (note, if Harmonically Related Carriers (HRC) or Incrementally Related Carriers (IRC) are used, the Channels CØ4 - CØ9, D33, and EØ4 - EØ9 will be offset from their standard designated channel boundaries.). If upstream paths are also used, perhaps as many as 10 - 12 FM (Group K) or AM (Group E) channels will also be taken up. As one can see, once such a sophisticated cable communications system is constructed, the use of the CARS band in the area will be rendered almost inaccessible to other future users unless enormous coordination and collaboration efforts are made.

CARS FREQUENCY USAGE

The cost-benefits, the topographical requirements, the geo-political restrictions, the convenience as well as the explosion in satellite cable programming has drastically increased the usage of CARS microwave.

A statistical study of CARS band applications indicated that in the year 1977, there were little over eight hundred CARS band applications on file with the Commission. While in the year 1981, that number had more than doubled to approximately seventeen hundred applications. Comparing the same time periods, there were a seven-fold increase in the number of applications requesting 20 or more CARS band channels. In 1977, less than ten applications requested the use of more 20 channels whereas in 1981, that number had increased to approximately sixty. During the five year span from the year 1977 to the end of 1981, the number of CARS authorizations issued by the FCC has increased from about 900 to over 2200.

According to the 1981-82 Television Factbook, in 1980, the number of cable systems in the United States amount to about 4200. Comparing the number of CARS authorizations to the number of cable systems, only approximately half of the systems are presently using CARS microwave. Therefore, a potential for a doubling in users is likely.

Enormous the numbers may seem, we still have not consider future industry growth. Until now, the majority of the industry growth has mainly occurred outside of the large cities. The largest cities, such as New York, Los Angeles, Chicago, Philadelphia, Boston, etc., are still either completely unbuilt for cable or just underway. If past reliance upon the use of the CARS band is a trend. Then an even-more substantial expansion in use of the CARS band is imminent.

MAXIMIZING CARS CHANNEL USAGE

CARS band usage in areas surrounding eighteen of the top twenty five major television markets are saturated or are close to being saturated and cable operators in those areas are confronted with acute interference problems. To facilitate for more efficient utilization, cable companies will have to coordinate with each other. At the present time, coordination groups have been formed or are being formed around the various larger suburbs (New York, Los Angeles, San Francisco, Denver, etc.). The metropolitan New York area, one of the most congested locations in the country, is a prime example of coordination efforts at work. Because the different operators are willing to "talk" to each other, willing to coordinate before adding on new channels, willing to install frequency selective equipment, and are willing to cost-share the expenses, they are all using the CARS frequencies in that area with minimal interference to each other.

Another method to maximize channel usage is to minimize channel use redundancy, this can be accomplished by the use of interconnects between systems. Although one of the original intents of interconnection is to take advantage on the advertising time on local origination channels, a side benefit is the elimination of the redundant use of CARS channels. Interconnects has been operating in various parts of the country including the San Francisco Bay area, the New England area, and the New York Metropolitan area. To promote for more efficient usage, coordination and interconnection can alleviate some of the frequency congestion pains suffered by cable systems operators.

SUGGESTED INTERIM SOLUTIONS

To assist in easing the present congestion problems, the following measures are suggested:

1) Coordination between cable companies before the addition of new CARS channels.

2) Collaboration between cable operators to reduce the probability of frequency interference.

3) Cooperation to maximize CARS spectrum use.

4) Interconnection to reduce channel use redundancy.

5) Selection of higher performance antenna equipment to minimize frequency interferences.

6) Strict adherence of the Commission's guidelines which promote for more efficient channel use and less user interference.

FUTURE OF CARS BAND

The CARS spectrum can only accomodate a limited number of users. And the recent Commission decision to allow the use of the CARS band by Low Power Television (LPTV) operators,on a secondary basis, will exacerbate the present problems. With the possible influx of thousands of additional users (over 6500 applications for LPTV so far), interference within the band is more likely to occur. Expansion of the band into other areas of the microwave spectrum is one of the future solutions.

CARS band equipment manufacturers are or will be capable of making available equipment in the 18 GHz area. As a matter of fact, AML equipment has been originally proposed for and experimented at the 18 GHz area. If the microwave band segment between 17.7 GHz and 19.7 GHz are wholly allocated to CARS users, there can be a possibility for an increase of over 330 - 6 MHz AM channels. A major CARS equipment manufacturer has requested a minimum of 160 AM channels in that area to be alloted for CARS and Broadcast Auxiliary use. Unfortunitely, at this time, no portion of the mentioned spectrum is allocated specifically for CARS use (refer to General Docket No. 79-188, RM-3247, RM-3497). The number of comments filed by the cable industry and CARS equipment manufacturers requesting assignment of the 18 GHz area for CARS use has been disappointing (about 5). Such a lack of interest from the industry can only lead to a conclusion of indifference for CARS expansion in that area. It is apparent that the industry may want to or will be forced to look elsewhere for alternate solutions.

CONCLUSION

The CARS band is congested and will be more so as time goes by. In this era of "Unregulation" the FCC can only oversee and provide limited guidance to the industry. It is the ultimate responsibility of the cable television industry to provide for solutions upon which the future usage of the CARS band is dependent.

ACKNOWLEDGMENT

The author is grateful to Mr. Clifford H. Paul of the FCC for his guidance and assistance in the preparation of this paper.

Note: Opinions and suggestions which were discussed in this paper were those of the author alone, and did not necessarily represent the position of the Federal Communications Commission.

CATV SYSTEM RETURN PATH INTERFERENCE

Harry J. Reichert, Jr.

GENERAL INSTRUMENT JERROLD DIVISION

The usefulness of a viable return signal path associated with an existing forward system signal distribution system is of greater value now than ever before. With this objective in mind it seems worthwhile to review some of the established methods which have been designed to make this objective a technical reality as well as to offer a recently developed technique which will prove to be a valuable addition to any two way system maintenance program.

This new technique was developed to combat COMMON PATH DISTORTION which is a relatively recent addition to the list of distortions which occur in bidirectional cable systems. When the conditions exist in a system that cause this distortion, interference is generated by the forward system signals which impacts the return system frequency spectrum. This potentially interfering energy is ofen misidentified as ingress when the return system is viewed on a spectrum analyzer. The mechanism which causes this distortion and a method to isolate this system problem will be described in detail.

INTRODUCTION

One of the most burdensome problems associated with a bidirectional cable system is the disruption caused by ambient radio frequency energy which enters the system and interferes with the desired return path signals. It is this permeation of undesirable energy, referred to as "Ingress", that has been the subject of exhaustive studies which have been undertaken to define the exact mechanisms that allow this condition to occur and to establish guidelines that can be followed, by those affected, to minimize this problem.

The results of the completed studies indicate that a single qualifiable and quantifiable parameter controls the acceptability of the components, that are used to construct a bidirectional cable system, if they are to provide the necessary shielding required to maintain the return frequency spectrum available for use by the system operator. This parameter, which is called Transfer Impedance, is defined as the opposition to the flow of radio frequency current. Typically, the more resistance or impedance a system component, relied on for shielding, offers to the flow of radio frequency current, the poorer its performance will be as a shield against external energy fields.

Solid aluminum outer conductor cable provides excellent shielding over the frequency spectrum of interest to the cable television industry. It has a uniform and acceptable transfer impedance provided the outer conductor is not violated by a crack or a hole. Therefore, if quality cable and good construction techniques are used, then the majority of the system in terms of physical length will provide adequate shielding. However, the requirement to splice into the cable necessitates cutting the cable and the introduction of connectors and an equipment housing. This is typically when potential ingress problems start. If the connection to the cable by the connectors, the connectors to the housing and the housing itself do not provide a low transfer impedance, then ingress will result.

RADIO FREQUENCY CURRENT DENSITY

The increased surface area of connectors and equipment housings brings a second condition into play which is referred to as current density. Due to the fact that the connectors and housings provide a greater surface area, relative to that of cable, on which the radio frequency current can flow, a slightly higher transfer impedance can be tolerated without degrading the shielding provided by the cable.

EQUIPMENT SUPPLIED TO THE INDUSTRY

In order to minimize the transfer impedance of their equipment, manufacturers have made significant modifications to their products. Integral sleeve connectors, for example, were introduced to eliminate the problem of cable sheath cold flow and vibratory manipulation sustained by the cable sheath inside of the connector. Also, close attention has been given to the housing interfaces. Wire mesh gaskets and other conductive materials are supplied with the primary purpose of minimizing ingress into the equipment housings. Some vendors have gone a step further by constructing the modules that the housing contains so that they will provide adequate shielding without the housing. This is accomplished by using wire mesh gaskets between the module frames and covers.

In spite of the efforts made, ingress still presents a problem. Inordinate ambient field intensities prove to be a challenge. Also, the ravages of vibration and thermal cycling necessitate a constant maintenance effort. Fortunately, there are some methods that have been developed to locate the sources of inadequate shielding.

METHODS TO LOCATE AND MINIMIZE INGRESS

One technique utilizes the forward signal path to transport a test signal to all extremities of the system. A receiver is then used external to the system to monitor the test signal frequency. The rationale behind this technique is that if the test signal can leak out then external energy can leak into the system. The opposite method is also used which entails generating an electromagnetic field external to the system and monitoring the return path culmination point for the presence of this signal. Both of these methods have gained wide acceptance.

A more recent addition to the arsenal of the two-way system operator is return feeder switching which offers two opportunities. The first, from an operations standpoint, is that only the feeder systems requiring continuity at a given interval of time can be switched on, thereby minimizing the magnitude of the ingress. Also, from a maintenance standpoint, the feeder systems which permit unwanted energy to disrupt return path service can be identified by switching each feeder system on,one at a time, and monitoring for the magnitude of the ingress present at the return path culmination point. Both of these locating techniques and return feeder switching provide systèm maintenance personnel with reasonable means by which they can locate sources of ingress.

ANOTHER SOURCE OF RETURN SYSTEM INTERFERENCE

Unfortunately, there is another problem that affects two-way system operation which is relatively unknown. While ingress is associated primarily with the integrity of the outer conductor, this phenomenon is associated with both the outer and the inner conductors. The parameter of transfer impedance that was directed toward the outer conductor must now be considered with respect to both conductors. In addition, the linearity of the transfer characteristic as well as the magnitude of the impedance are important. This phenomenon is referred to as Common Path Distortion.

Common path distortion is a collective term which includes all beat products which are generated within a cable system, that fall in the return path frequency spectrum, excluding the beat energy which is generated by active components. This distortion is caused by a connection which has a nonlinear transfer characteristic. This condition typically develops when two metal members are not making intimate metal to metal contact and an oxide layer develops between them. It is this oxide that causes the nonlinear energy transfer. The beat energy generated that falls in the return system spectrum results when the forward system signals pass over this connection. Obviously, this unwanted energy which occupies the return system can be as troublesome as ingress. It is not suprising that when the return system is displayed on a spectrum analyzer, common path distortion is often misidentified as ingress. For this reason the expression "apparent ingress" has evolved. However, once the nature of this distortion is understood it is relatively easy to determine if common path distortion exists in a system. This is accomplished by inspecting the return system frequency spectrum, as displayed on a spectrum analyzer, for a comb of beat products spaced at six megahertz intervals while the forward signals are being transported by the system. The 6 MHz spacing observed between the return system beat products is due to the spacing of the forward system carriers.

COMMON PATH DISTORTION LOCATING TECHNIQUE

Due to the hetrodyning which occurs at an interface which has a nonlinear transfer characteristic, it is logical to assume that if one of the signals that is applied in the forward direction is coded in some way so as to indicate time interval, then distance could be calculated.

As it turns out this desirable capability can easily be acomplished.

If a continuous wave signal source is modulated by a short duration pulse and this signal is applied to the forward system along with the normal signal load, then the first requirement for a locating technique has been accomplished. Because if a common path distortion generator exists in a system of sufficient severity to cause return path interference, then the beat energy will be modulated with the timing pulses that are being sent out on the system in the forward direction. Therefore, if a receiver is connected to the return path at the same location as the forward pulse modulated signal is applied, then a time difference can be established between when the pulse was received relative to when it was transmitted. Obviously, one half of the total time gives the travel time to the source of the distortion. The conversion of travel time to physical distance can be accomplished by using the following formula:

$$D = T \bullet 984 \bullet VP$$

Where - T is the travel time in microseconds

D distance in feet

VP is the velocity of propagation of the cable

The test equipment required to apply the described technique is determined by the degree of accuracy and resolution that are desired when locating the nonlinear transfer points in a system. Basically, the narrower the modulating pulse is in terms of time the more sophisticated the equipment must be. An important consideration to keep in mind is that the usage of narrow pulse widths which have very fast rise and fall times can lead to subjective impairment of the forward system signals if steps are not taken to minimize interference.

The pulse width and resolution relationship is best explained by converting pulse width expressed in units of time to physical cable system length. A close approximation of this relationship can be seen in the following table.

PULSE WIDTH	PHYSICAL SYSTEM LENGTH
1000 nanoseconds	1000 feet
100 nanoseconds	100 feet
10 nanoseconds	10 feet
1 nanosecond	1 foot

The importance of using the narrowest pulse width possible can readily be appreciated when two sources of common path distortion are physically located close together. If, for example, the distance between two sources was twenty feet then a pulse width of approximately twenty nanoseconds would be the maximum width that should be used for reasonable resolution. Otherwise, the pulse energy which returns to the injection point will be misleading. The block diagram of a transceiver that has been used successfully in the field to locate sources of common path distortion is provided in Figure #1.

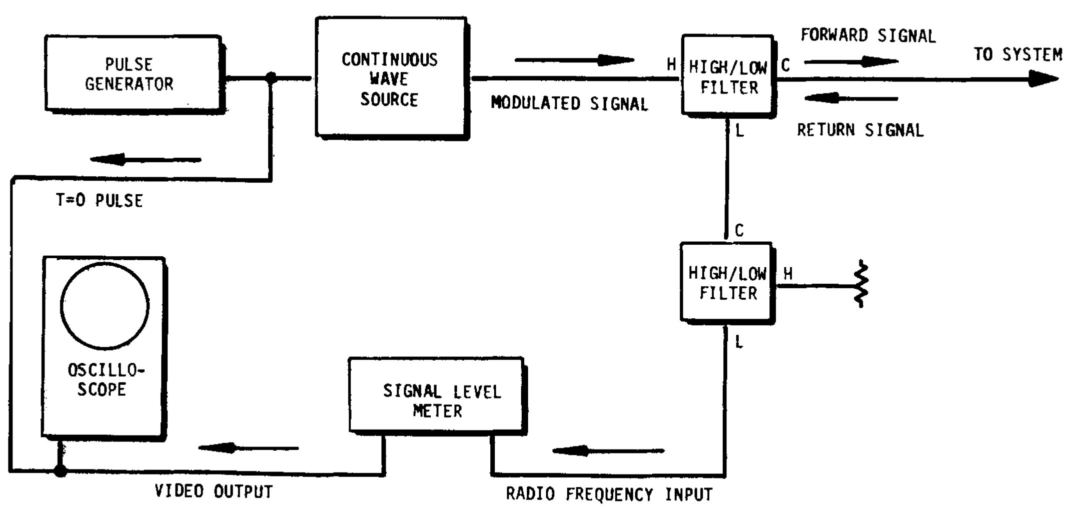


FIGURE 1.

While there are many test equipment configurations that can be utilized to accomplish the objective of locating a source of common path distortion, the method illustrated is one of the most readily achievable in terms of equipment availability to system personnel. With this particular method pulse width and repetition rate are selected via the pulse generator. This signal is then used to synchronize the scope thereby establishing the start time and to modulate a radio frequency source that can be used to fill the gap between channel 4 and 5 or any unused channel allocation that exists in the forward system signal spectrum. The signal level meter is then tuned across the return system spectrum while viewing the oscilloscope. When a member of the comb of beat products that occupy the return system is received, a vertical deflection will occur at the time interval along the X axis which corresponds to the round trip travel time of the applied pulse. The actual travel time is measured by using the graticle and the scan time per division that the oscilloscope is adjusted to.

The pulse repetition rate that is used can be a source of confusing presentations on the oscilloscope. Therefore, it is very important that the minimum repetition rate is calculated and never exceeded. The minimum repetition rate is a function of the round trip travel time that would be required for a pulse to travel from the injection point to the most distant system extremity and back to the injection point. The following formula can be used for this purpose:

$$T = \frac{2D}{984 \bullet VP}$$

Where - T is the round trip time in microseconds

VP is the velocity of propagation of the cable

D distance in feet to most distant system extremity

The value of T found by performing this calculation is the minimum time interval between modulating pulses that should be used. There is no limit to the maximum time interval between pulses. As a matter of fact, when very narrow pulse widths are needed with fast rise and fall times, it is very beneficial to use a storage oscilloscope and manually trigger the pulse generator thereby minimizing subjective impairment that could result due to the wide spectrum of energy which results when pulses having very fast level transitions are used.

THE NATURE OF COMMON PATH DISTORTION

Due to the physical characteristics of the typical common path distortion generator, intermittent amplitude variations will occur. This condition develops due to insufficient pressure between two metal members relied on to carry radio frequency current. The activity of the generator is influenced by temperature changes, vibration and abnormal signal levels. Therefore, it is important to have the locating technique mastered if an efficient maintenance program is to be effected. Field reports indicate that the sources of common path distortion are most active around sunrise, sunset and on days which are relatively wind free. Apparently, as the system is subjected to vibration as a result of wind loading, potential sources of common path distortion are eliminated when one metal member moves across its mating member thereby breaking through the oxide film.

SUMMARY

Clearly, one of the most burdensome problems associated with the return path of a bidirectional system is ingress. It is for this reason that many studies have been conducted to determine the causes of ingress and to develop solutions to this problem. One of the results of these studies is the parameter known as Transfer Impedance which can be used to qualify equipment in terms of the shielding it will provide. Transfer impedance is defined as the opposition to the flow of radio frequency current. Typically, the more resistance or impedance a system component relied on for shielding offers to the flow of radio frequency current, the poorer its performance will be as a shield against ingress. Another consideration that influences shielding effectiveness is radio frequency current density. Because connectors and equipment housings provide more surface area on which the current being carried by the cable can flow, a slightly higher transfer impedance is acceptable without the overall shielding of the system being degraded. In order to minimize the transfer impedance of their equipment, manufacturers have made significant modifications to their products. However, inordinate ambient electromagnetic field intensities, the ravages of vibration and thermal cycling require that an efficient maintenance program is implemented and followed. This objective can be achieved by using the methods that have been developed to establish the locations in a system which are providing inadequate shielding.

Common Path Distortion is another problem which affects return system performance. This distortion includes all of the beat products which are generated within a cable system that fall in the return system frequency spectrum, excluding the beat energy which is generated by active components. Obviously, this unwanted energy which occupies the return system can be as troublesome as ingress. Interestingly enough, when the return system is displayed on a spectrum analyzer, common path distortion is often misidentified as ingress. For this reason the expression "apparent ingress" has evolved. Fortunately, there has been a technique developed to locate the sources of common path distortion.

This technique uses a pulse modulated radio frequency carrier to accomplish the desired objective.

The pulse width is selected based on the degree of distance resolution desired and the pulse repetition rate is chosen based on the time interval required for the pulse to travel from the injection point to the farthest system extremity and back to the injection point. Due to the physical characteristics of the typical common path distortion generator, intermittent amplitude variations will occur. The activity of the generator is influenced by temperature changes, vibration and abnormal signal levels. Therefore, it is important to have the locating technique mastered if an efficient maintenance program is to be effected.

COMPREHENSIVE EARTH STATION FILTERING

William P. Johnson
Chief Engineer, R&D
Microwave Filter Co., Inc.
6743 Kinne St.
East Syracuse, NY 13057

Abstract

Earth stations for Television Receive Only (TVRO) are susceptible to in-band interference from terrestrial common carrier microwave links, out-of-band transmissions such as radar, and spectral noise.

The effects of interference can be minimized or eliminated by proper application of filters in the microwave and/or intermediate frequency signal paths. The proper selection of filters for a system will depend upon the nature of the interference and the effects of the offender on amplifiers and detectors.

Introduction

Stop and listen for just 30 seconds, and make a mental note of what you hear. Is it music, or is it chaos? Is it informative, or is it unintelligible? Is it meant for you, or are you eavesdropping?

In the course of just half a minute, your ears, like the lobes of your satellite earth station antenna, have intercepted many signals from many different sources. Some of them brought desired information, but others were no more than irritating interference. How long you may be able to ignore such interference and concentrate on the signals you <u>want</u> to receive depends a little bit on <u>how</u> determined you are, and a little bit on how strong the interference is. Unlike you, however, your earth station lacks the innate ability to differentiate between wanted and unwanted signals, and therefore it cannot concentrate on one to the exclusion of the other. It cannot, that is, unless it is a filtered earth station....

General Filtering Concepts

There are basically two reasons why filters are used in communications equipment. First, there are applications where the filtered output represents an overall improvement in signal quality as far as the desired signal is concerned. Second, there are applications where undesired spectral energy is removed from the system and the output is now "usable", whereas it was not interpretable by the system previously -- it has been salvaged.

Filtering Trade-Offs

Whenever a filter is employed in either an enhancement or a salvage application, the laws of physics always apply. It is common sense, as well as good technology, to always bear in mind that you never get something for nothing. There are always trade-offs to consider. Sometimes the compromise is such that, as a result of filtering, the system cannot receive signals above or below the band of interest. The price that was paid is in terms of band-limiting of the spectrum "seen" by the receiver. This will improve the signal-to-noise ratio by excluding out-of-band noise. But the spectrum available for use by the receiver, called the bandwidth, is much narrower with a bandpass filter than it was without. The point is, who cares? Out-of-band signals (which aren't part of the adventure of satellite reception, anyway) are omitted, but the signal-to-noise ratio is improved. So, a net system improvement is realized in an enhancement application, even though a small price is paid.

Consider now a salvage application of filters in a communications receiver. If there exists an offending signal whose power is so great or so close in frequency to the desired signal that it prevents the correct reception and interpretation of the desired information, then the offending signal must be removed from the system. The stronger and closer in frequency the offender is, the more likely it is that <u>some</u> of the desired signal's spectrum will <u>fall</u> victim to the filter network removing the offender. However, even if the desired signal is somewhat affected, at least what is left can be used if the filter has been applied correctly. The trade-off here is that desired signal quality may have to suffer if the offending signal is to be removed. Of course, the signal was unusable in the first place.

Understanding Interference in the Satellite Receiver

Now that an understanding of some basic filtering trade-offs is behind us, it is time to get more specfic regarding our discussion of comprehensive earth station filtering.

Interference becomes the issue when a well-designed receiver is fired up and a black picture appears ("wipe-out", as it is affectionately called). Or those sparkles (their pet name is "sparklies") dance all over the screen. Other symptoms may occur as well, such as tones on the audio output, stripes across the screen, or simply a distorted video which one can define as a picture with a bit of imagination.

With some investigative work, the sources of earth station interference can be identified. This is, perhaps, a first step in correcting the problem since the type of interference will dictate which type of filters are required. In some cases, even good detective work will not lead to positive answers regarding the source of interference, but fortunately, in some systems filters can be installed easily and results can be observed which will give clues as to the answers.

Types of TVRO Interference

Let's take a look at where a majority of TVRO offenders originate. This will give us some insight into the problem and will explain some of the filtering techniques associated with their cure.

There are essentially three classes of interference which can gain entrance to the TVRO system through the antenna. There is in-band interference, which is generally the result of common carrier terrestrial microwave links; out-of-band sources, which have spectral outputs near our desired band; and the ever-present spectral noise. The latter will be a problem common to all earth stations, even the ones fortunate enough not to be plagued by the other two.

In-Band Interference

In the allocation of the RF spectrum for the various communications services, the 3.7-4.2 GHz band serves double duty. It is not only allocated for satellite-to-earth transmission, but also for earth-based microwave links. These microwave links are widely used by common carriers for the transmission of voice and data, thus overcoming the high cost of land line systems in many applications. The allocation is summarized as permission to use frequency-shift-keying, a digital transmission technique which is narrow band and centered at a frequency plus/minus 10 MHz from a given transponder center frequency. Theoretically, there could exist 25 link frequencies, but we have gathered extensive information from TVRO installers in the field and we have not experienced more than six terrestrial frequencies and we have not found them closer than 80 MHz in any one local area.

In Figure 1, the FM signal containing the video and audio information on a given transponder will be found at the transponder's center frequency within a 20 MHz bandwidth. At the edge of that bandwidth, 10 MHz either above or below the center frequency, a terrestrial carrier may be present.

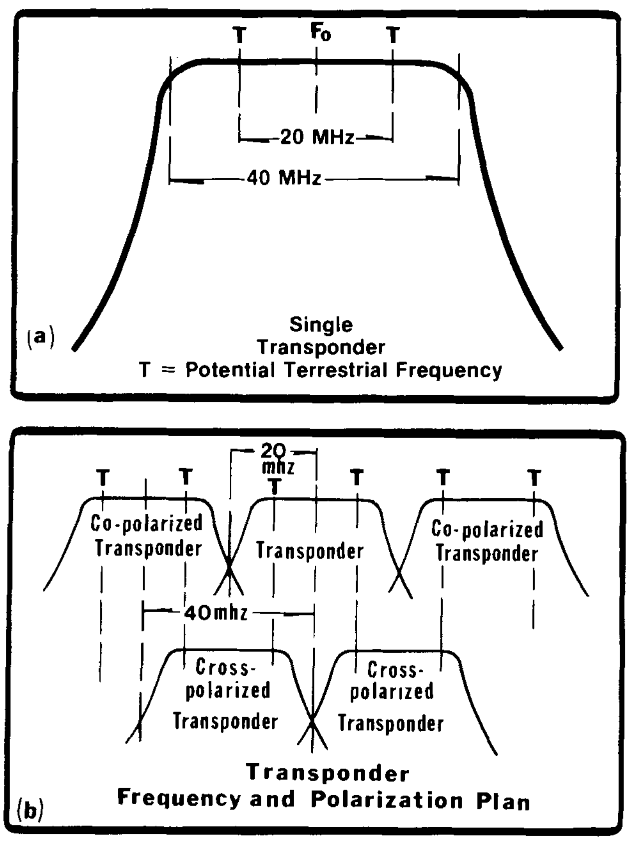


FIGURE 1: (a) Video and audio are located within the 20 MHz bandwidth. (b) Adjacent transponders utilize spectrum sharing techniques. They are cross-polarized.

The degree of ingress the TVRO system experiences from a terrestrial source will occur as a function of the distance from the TVRO dish to the terrestrial source, the bearing of the terrestrial source and its power output. Once it is present, one need only consider the relative powers of the TVRO signal and the terrestrial source to see trouble on the way. The relatively weak signal from the satellite more than 22,500 miles away is poor competition for the terrestrial source beaming into one of the antenna lobes from a few miles away. I like to compare this situation to trying to read a page, such as this one, with a 150 watt spotlight shining in your eyes. Like the pupils in your eyes, the automatic gain control in the satellite receiver may close down the IF gain, making reception of the TVRO signal impossible. In fact, another complication can be the operation of automatic frequency control circuits attempting to center the spectral energy it "sees" on the IF center frequency. This would then shift the weak TVRO signal toward the edge of the IF bandwidth.

Symptoms of and Cures for In-Band Interference

The in-band terrestrials can show their presence in a variety of ways. If they are very strong, the LNA may saturate and hopelessly distort desired inputs. If they are less intense, the terrestrials may cause groups of transponders nearby to "wipe out" or exhibit "sparklies". The object in curing the interference problem is to severely attenuate the terrestrial source while attenuating the desired TVRO signal as little as possible.

The best place in terms of cost and convenience to effect this attenuation is at the final IF frequency. The idea is that if the terrestrial can pass through the LNA and circuitry ahead of the final IF without causing signal distortion, then it is relatively easy to remove it at the lower frequency final IF signal path. If, for example, the final IF was 70 MHz, then a narrow trap at 60 MHz and another at 80 MHz would attenuate the down-converted terrestrial before is disrupted the demodulator. The trap is a filter that will attenuate a single frequency (like 60 MHz) while not severely attenuating nearby frequencies (like 62 MHz).

With traps, there is a design tradeoff that the user should bear in mind. As the trap's notch gets deeper and deeper, the 3 db bandwidth must get wider and wider, with the result that some of the desired signal's spectrum will begin to be attenuated. A good design compromise between notch attenuation and bandwidth is a 25 db notch with plus/minus 1.5 MHz 3 db bandwidth centered at 60 or 80 MHz. If this does not suffice, a deeper notch like 50 db with a wider bandwidth may be required. Again, notch depth is gained at the expense of the bandwidth. The test of picture usability will be the final test of whether or not a given filter will do the job. So, one should carefully monitor the picture to ascertain the notch filter's effect on picture quality.

If filtering at the final IF frequency has little or no effect, filtering at the first IF can be tried if the system is a dual conversion type.

If filtering at the first IF (by placing traps at plus/minus 10 MHz from the IF center frequency) does not work, then correcting terrestrial interference will require a microwave trap for each terrestrial frequency. Typically, this is accomplished by a six-trap waveguide structure with coax-waveguide adaptors installed. This filter would be inserted in the coax signal path after the LNA and before the down-converter, with each of the six-traps tuned to one of the terrestrial frequencies. It is a good idea to have six traps even if fewer terrestrial frequencies are in use since others can be installed as the common carrier loads increase. You can check with local common carriers, especially the local Bell System operating company. With some persistence on your part, they will provide you with site locations (to get bearing and distance) as well as current and planned frequency use.

Out-of-Band Interference

There are, of course, other communications services located above and below the 3.7-4.2 GHz TVRO band. Satellite earth station interference can arise from any nearby service. There are nearby bands in which high power transmitters may be in operation for periods of time. Refer to Table 1 where you can see that an armed forces band and an amateur radio band are adjacent to the TVRO band. While the earth station is attempting to acquire the relatively weak satellite signal, high power RF energy may enter the LNA and be down-converted. Remember that LNAs and down-converters are broad band systems, and sometimes little is done about the possibility of nearby microwave sources getting into the system and degrading performance.

Symptoms of and Cures for Out-of-Band Interference

The symptoms of such out-of-band troubles may take the form of a pulsing interference in the video or audio, or a less periodic fuzzing of sound or picture

TABLE I—Potential Terrestrial Interference Frequencies

FREQUENCY (GHZ)	NATURE OF POTENTIAL OFFENDER
0 960-1 350	Land-based air navigation systems
1 350-1 400	Armed forces
1 400-1 427	Radio astronomy
1 427-1 435	Land-mobile police, fire, forestry, railway
1 429-1 435	Armed forces
1 435-1 535	Telemetry
1 535-1 543	SAT—maritime mobile
1 605-1 800	Radio location
1 660-1 670	Radio astronomy
1 660-1.700	Meteorological—Radiosond
1 700-1.710	Space—research
1 710-1 850	Armed forces
1 990-2 110	TV Pick-up
2 110-2 180	Public common carrier
2 130-2 150	Fixed point-to-point (non-public)
2 150-2 180	Fixed—omnidirectional
2.180-2 200	Fixed, point-to-point (non-public)
2 200-2 290	Armed forces
2.290-2.300	Space—research
2 450-2 500	Radio location
2.500-2 535	Fixed, SAT
2 500-2 690	Fixed point-to-point (non-public) Instructional TV
2 655-2.690	Fixed, SAT
2 690-2 700	Radio astronomy
2 700-2.900	Armed forces
2 900-3 100	Maritime radio navigation
2.900-3.700	Maritime radio location
3.300-3 500	Amateur radio
3 700-4.200	Common carrier (telephone) Earth Stations
4.200-4.400	Altimeters
4.400-4 990	Armed forces
4 990-5.000	Meterological—radio astronomy
5 250-5 650	Radio location (coastal radar)
5.460-5.470	Radio navigation—General
5.470-5 650	Maritime radio navigation
5.600-5.650	Meteorological—Ground based radar
5 650-5 925	Amateur
5.800	Industrial and scientific equipment
5.925-6.425	Common carrier and fixed SAT
6.425-6 525	Common carrier
6 525-6.575	Operational land and mobile
6.575-6.875	Non-public point-to point carrier
6.625-6.875	Fixed SAT
6.875-7.125	TV pick-up
7.125-8.400	Armed forces
8.800	Airborne Doppler Radar

on a number of transponders, all of which are at the same end of the band. When these high power sources ingress, clipping and resulting distortion can occur.

One way to get at the problem is to place a microwave bandpass filter after the LNA and thus place an approximately 15-20 db attenuation at the nearest edges of the offending bands, while causing a minimum insertion loss within the 3.7-4.2 GHz band. This will provide added help in preventing the saturation of receiver circuits due to nearby out-of-band sources.

Even if there is no out-of-band source causing interference problems, there is the signal-to-noise ratio to consider. In any communications system this is an important measure which, in an earth station, will essentially determine picture quality when all other factors are equal. Random noise power is present throughout the spectrum. The received noise will be proportional to the bandwidth of the receiver. Band-limiting the receiver will result in a decrease of noise power, and if the signal power is only marginally affected, the signal-to-noise ratio will improve. The same filter used to rid the system of nearby high power sources will also serve to band-limit the receiver. It will allow clear reception of the 3.7-4.2 GHz band while rejecting out-of-band microwave sources and noise power.

In taking the bandpass filter concept to its most specific application, one could place a single transponder bandpass filter after the LNA. In that case, all interference and noise will be substantially reduced (except perhaps for terrestrials present plus/minus 10 MHz from that transponder center frequency), and the desired transponder will be admitted for processing. The drawback here is that in order to receive another transponder, one must replace the single channel filter with another filter tuned for the desired transponder. This is not a problem, however, when only one transponder is to be received.

If there is a need to place a bandpass filter around a given transponder, and if other transponders are to be received, non-simultaneously, a tunable preselector can be employed. Such a device is a bandpass filter about two transponders wide (about 40-50 MHz bandwidth) with tuning screws which are mechanically field adjustable. It is an easy filter to tune since one simply watches a monitor and adjusts each tuner for the best picture, utilizing a signal strength meter if needed. experiments with a three-pole model indicate great versatility and quick, easy tuning.

As with any filter in the presence of interference, the use of a bandpass device may make a significant difference in picture quality--often it will make the difference between poor reception and a usable signal.

Built-In Types of Earth Station Filtering

Besides microwave bandpass filters and microwave and IF traps-- single channel, preselector and full band devices-- there are other filters in the earth station to enhance its performance.

The LNA is usually housed inside a piece of WR-229 waveguide. Such a structure provides a natural high pass filter response above the waveguide's cutoff frequency, about 2500 MHz. High rejection occurs to out-of-band sources and noise below this frequency. Unfortunately, the access to signals above 2500

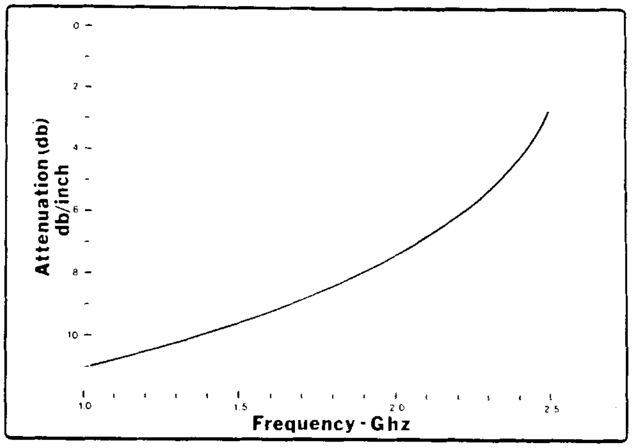


Figure 2: Attenuation [db/inch length] of WR-229 Waveguide

MHz is quite easy. See Figure 2.

The IF section of the receiver is a major section where receiver performance is partially determined. It is here that IF bandpass filters are employed to accomplish the task of image rejection, noise reduction and selectivity.

Some manufacturers build in microwave bandpass filters at the input to the down-converter, saving the user the potential difficulty of out-of-band source interference while at the same time realizing a signal-to-noise improvement.

These "built-in" filters are mentioned simply to call attention to the fact that earth station filtering should begin at the design stage of a system; that is, an earth station system should be designed with the capability to accept filters needed to counter interference discovered after installtion. As a TVRO system operator, one must determine beforehand whether he can add interference rejection filters after the system becomes operational. In some configurations, for example, one cannot readily add a microwave bandpass filter like those described in the out-of-band interference section. That may or may not be critical--the latter, if you are lucky.

Some Parting Words of Wisdom

With regard to earth stations and microwave interference, the best advice comes from the old adage: "An ounce of prevention is worth a pound of cure."

Step number one in the planning stage should be a thorough spectrum survey to identify potential interference. This will reduce chances of unexpected system trouble at a later date.

Step number two should be a careful investigation of potential sources of interference which may not have been operating the day the survey was made. Consider military bases (with high power radar, etc.) and their relative location, and call the phone company to find out where their terrestrial towers are located. Make sure your dish will not be looking into them, and don't forget to take antenna side lobes and reflection off existing structures into consideration.

Step number three should entail identification of well-designed equipment that will allow filter installation if it is needed.

Conclusion

The basic filters used to combat earth station interference are really very simple to use once their operation is understood. And, it is wise to be aware of the common sources of interference that have plagued hundreds of installers and operators in the field.

We have seen how to use these basic filters to combat typical interference problems. All of these solutions lend themselves to field installation without spectrum analyzers or other equipment. This is why, if an interference problem exists, filtering may be the first line of defense. It sure beats relocating the antenna site or building reflective structures around it.

The bad news is that if you are an earth station operator (and who isn't, these days?) there may be a terrestrial or out-of-band source of interference with your name on it. The good news is that hundreds of installers and operators have enlisted the aid of earth station filters of the types discussed here and have solved their interference problems quickly and efficiently. I trust that you will find the same success if you should suddenly find yourself in an earth station interference situation.

CREATING STANDARDS FOR INTERCONNECT SYSTEMS

Dr. Charles Alvord

COMMUNICATIONS TECHNOLOGY MANAGEMENT, INC.

The following article addresses issues of concern to all engineers whose areas of technical interest are in one or more of the many communications transmission technologies. These technologies are converging as a result of the maturing of interactive data retrieval systems. Cable television systems are but one of the more important of these technologies. This article offers the reader an update on the current state of standardization in the field of hybrid interactive data networks. It also introduces system modelling which includes, as an important physical subnode, a two-way CATV transmission system interfacing in a larger hybrid interconnected data-based network.

Hybrid interconnect systems, or systems handling various forms of data from multiple-input ports using multiple transmission media, pose special problems for designers who are concerned about channel utilization, bandwidth efficiency and related control, routing and congestion problems. Global solutions to these design issues remain elusive primarily because of a lack of recognized standards for interfacing such systems. This article will summarize some of the more salient aspects of the standardization problem for a broadband coaxial based interconnect system from a practical viewpoint. It will also relate the current efforts of various international committees that are working toward a solution to the standards problem, describe the components of the problem and the attendant difficulties and conclude by citing recent experience at Communications Technology Management, Inc., in developing an interactive data services network (IDSN).

A DUBIOUS TASK

In communication systems recoupment of original investment and healthy return on investment are important up front considerations. Low-channel utilization, inefficient use of bandwidth and faulty network routing and control schemes are costly. The nonexistence of standards for the complex interconnect systems make predictions for successful system implementation a highly dubious task. Because standards are not readily available, machine-to-machine incompatabilities and non-transportability of system software usually result in inefficiencies in bandwidth utilization and a slowdown in thruput between nodes. Nonstandard interfaces to "foreign" devices must be made transparent to the system software which provides a protocol or handshaking feature for interprocessor communication. In network theory terminology, this amounts to a gateway processor which is an added expense for interconnection. Each buffering operation costs not only dollars but time in terms of thruput. If thruput is diminished, response times suffer and customers begin walking away or reneging from service. So from a dollar and cents standpoint, a universally accepted standard would (a) improve compatability and transportability of hardware interface and system software; (b) minimize the number of intermediate devices, or gateways, which perform speed and code conversion; (c) minimize the reliance on a particular vendor; and (d) provide a common language for data consumers and design personnel.

What form should the standard take? The format should contain a consistent set of rules which govern data communication between any two points in a network. This set of rules often referred to as a protocol has as many facets as it needs to define the procedures for a virtual encyclopedia of data communication related functions. There are various attempts being made at adding some structure to the encycolpedia.

The International Standards Organisation (ISO) has undertaken this monumental task and defined a general protocol structure termed the "Open Systems Interconnection" (OSI) reference model. It used fairly general rules to distinguish the protocol functions performed by each layer using a hierarchical structure. The definition of the protocol layers was developed applying a MINIMAX strategy. The concept is to localize functions to a single layer where significant overlap among the functions existed and thereby minimize both the number and complexity of the interfaces between layers. New layers were created only when either (i) a different "level of abstraction" was needed to distinguish between functions being performed or (ii) the information flow could be minimized. The resulting model contained seven layers as seen in Figure 1. The basic concept is that a user on machine "A" has a "message" to exchange with a user on machine "B". The message may be a task executing in machine "A" which needs to fetch data from machine "B" to complete its transaction. The sender's message unit is decomposed into successively smaller units (packet-frame-bit) as the level of communication service gets closer to the physical transmission level of a binary bit stream and then is reassembled up the line to the receiving application task where it is finally serviced. An example of this process is provided in Figure 2.

A LANDMARK IN INTERFACING

The International Telephone and Telegraph Consultative Committee (CCITT) also is chartered to make recommendations on data communications interfaces. Its work in packet switching standards has helped it pioneer this field. Some of the standards have gained international acceptance. A good example is CCITT V.24, also known as EIA RS232. As far as interconnected broadband data service networks are concerned, the X.25 standard is a landmark for computer to computer interfacing on packet switched public data networks.

Packet switching is an extremely important technology in the data communications field. The traffic characteristics associated with most information services tend to be bursty and the duty cycle for any particular subscriber on the network is extremely low. The implication with regard to network design needs to be fully understood. An analysis of the characteristics of the three basic forms of switching (circuit, message and packet) in view of the traffic characteristics associated with information services clearly favor packet switching. Packet switching will facilitate high transmission facility utilization; a more flexible form of network routing; flexible message handling independent of message type; minimal network transit delay; and adaptive flow control. Most of these advantages are intuitively obvious, as a comparison with circuit switching and message switching will show. Getting back to the CCITT standards work, we cite the X.25 recommendation once again. X.25 consists of three protocol levels: the physical, line and packet protocols. These are conceptually similar to the three lowest OSI model layers. Table 1 summarizes the CCITT recommendations for packet switched networks that are important to large-scale interconnect systems relying on packet switch techniques.

Another important development in the standards arena that has relevance to this article is the work on the IEEE Local Network Standards Committee. This committee is taking on the ISO model one step at a time. Its primary focus thus far has been on layers 1 and 2. The IEEE functional requirements for the IEEE 802 standard addresse transmission line lengths, data rates, media independence features, reliability and freedom from dependence on intermediary devices.

At the physical layer, the IEEE has defined the Media Access Unit (MAU) as the device which will interface to a particular kind of transmission line. Physical layer functions (i.e. coding/decoding, synchronization, and related handshaking signal procedures) will be performed on the data terminal equipment side of the MAU interface.

The layer 2 standard, the link layer, takes the binary bit stream from the physical layer and forms frames. It prefixes the frame with source and destination addressing bits, places additional bits and frame synchronization bits into a control segment of the frame. It also appends the frame with a code that permits the receiving station to authenticate the correctness of the transmitted bit stream.

The IEEE 802 standard is also attempting to address the method of access rights to the transmission line. It is currently investigating contention access and token passing. A significant amount of information is available on these schemes in the literature, and both have their merits. We make no pretense as to which is better. Each network designer should evaluate his network model to select the most appropriate strategy, based upon his traffic statistics and related parameters.

RELATED PROBLEMS

While these committees have addressed the universal need for a set of rules governing intra- and internetwork data communications and have published recommendations for same, a set of related problems confront network design engineers which are even less likely to be solved by a standard. We have summarized the principal technical issues requiring resolution for complex interconnect systems in Table 2 using the OSI reference model layers. Each issue will be defined and related to a generic interactive data services network.

Prior to this discussion we introduce the network topology of our generic IDSN (reference is made in Figure 3). Two primary nodes, A and B. form the backbone of this multi-star network. Two levels of subnodes are shown. The level one subnode A_i and B_i are the primary interconnects to the nodes A and B. The second level's sub-nodes are shown with small letters and are double subscripted, a_{ij} and b_{ij}. The distinction between nodes and sub-nodes is made primarily because of the bandwidth and processing properties at each level. Each nodal entity has the capability to communicate with any other nodal entity in the network. An example of this using the OSI reference model protocol will be shown later.

Let's assume that all second level subnodes are CATV subscribers who are vying for one of the interactive data services shown in Table 3 (the contents of this table will be described later) and, therefore, have some processing capability. Furthermore, assume that the first level subnodes are cable headends (A_3-A_6) when connected to a second level sub-node (a_{31} . . . a_{3n} . . . a_{4n} . . . a_{6n}), or are foreign networks (A_1 & A_2) vying for service through the primary node (e.g., a DEMS system or a TELCO trunk). The physical interconnect involves coaxial cable, digital microwave, and satellite. The generic interfaces are summarized at the physical level in Table 4.

PHYSICAL LAYER PROTOCOL

In order to address issues at the physical layer protocol, we introduce the generic services that we postulate for the IDSN. Table 3 summarizes 19 interactive services and bounds each with the important technical parameters which matter in analyzing the bandwidth problem. Parameters "a-c" and "d-f" are used to compute the upstream and downstream data rates per service and per subscriber. The demand factor, or utilization factor for a channel is computed using parameters "g-j". The utilization factor is then multiplied by the respective upstream and downstream data rate to obtain the average sustained bit transmission rate during some "peak-period" interval on a per subscriber basis. It is clear from an analysis of Table 3 that the upstream data bandwidth consumers are the games, telephony, telewriting and videophone services. This holds true for the downstream data rate as well.

How then is this information used to compute a bandwidth requirement for a system as complex as is shown in Figure 3 ? The answer involves modeling of the network as a whole, at single step intervals. Initially, we need to examine as realistically as possible the true demand placed on the cable headend (A_3 for example). This can only be done by estimating the traffic parameters during the peak period for a nominal subscribership. If we assume the majority of the information of interest is resident in the database maintained at the headend and that one broadband cable channel is used per each direction (say 24-30 MH_z upstream and 220-226 MH_z downstream), we can begin budgeting the channels for a maximum subscribership. Let's assume that headend A_3 is being modeled. We know, given "n" subscribers on that channel, that the total demand for service placed on the headend is the sum of the individual arrivals from the "n" subscribers to the headend plus the arrivals for service coming from A and the locally originated material which requires processing support. If we assume no contention on the channel, or a discipline which effectively orthogonalizes the channel into a set of fixed slots with some sort of token passing, we can compute a maximum subscribership for a processor of size "M" where the average response time is to be no greater than "k" seconds. This is not necessarily the most efficient use of the channel and will certainly limit the ultimate subscribership. Analyzing the channel with contention involves the use of a more dynamic channel allocation model, but this will generally permit a larger subscribership and more efficient use of an otherwise scarce resource.

MODEL PROTOCOL LAYERS

Before expanding the complexity of the network model to analyze the intricacies of the other interfaces and arrival/ service rates, it is instructive to illustrate the interoperability of the OSI reference model protocol layers. Figure 2 overviews this process.

Given a message "m" produced by a task running in the application layer, an information originator in the primary node has prepared a new product data set that he wants inserted into the database of one or more headends (A_3-A_5, B_1-B_2) and is requesting that this change be broadcast to subscribers downstream (a_{31}-a_{3n}, a_{41}, a_{51}-a_{5n}, b_{11}-b_{1n}, b_{21}-b_{2n}). The application layer task passes this data set into a compressed form via a suitable technique to use more efficiently bandwidth and digital storage at each headend and passes a new message "M" to the session layer. The session layer does not modify "M" but simply regulates the direction of flow of messages between the presentation layer and the transport layer.

The transport layer takes the variable length message "M" formed by the presentation layer and decomposes it into a set of smaller fixed length messages (or packets) and prefixes each with a header. The header will include control information, such as sequence numbers, to allow the transport layer on the destination machine to reassemble the data frames (i.e., data frames may be transmitted out of order as a result of retransmission or some other congestion anomoly).

The network layer is responsible for determining which physical line to the destination is to be used as the transmission path. It converts the logical line suggested by the application layer message "m" to the physical line via a communication routing table which lists all physical paths from source to destination. The paths actually selected will depend upon circuit status and traffic statistics, since in a fully connected multistar topology, multiple logical lines between two communicating entities will exist.

In this example, node B routes the packet stream to primary node A and to B_1 and B_2. The network layer will also attach its own header and pass the data units to the link layer. The link layer adds a header and trailer to each packet. The trailer is appended to the packet for purposes of error detection and correction. It passes the augmented packet to the physical level protocol for transmission at the receiving machine (A_1, B_1, and B_2); the packets are serviced; their corrections checked; headers stripped-off; and the message is reassembled by performing a sequence of operations which are the mirror image of those used in going from layer 7 to 1. The servicing of this message will tell the communications tasks executing in A, B_1 and B_2 to retransmit the newly acquired data set after storing. A dispatches this data set to A_3-A_5. The foreign networks A_1 and A_2 will be told that a change to the database has been made when a request by the foreign network is made for some service. The respective cable headends (A_3-A_5 and B_1-B_2) will update their respective databases and dispatch the message to the cable subscribers currently logged on.

An analysis of the network model between A_i and B_i and B requires that soulutions to the congestion, routing, flow control and buffering problems be found. Routing and flow control are often cited as the two most important factors in determining the performance of a network. Inefficient control schemes chew up CPU time and network bandwidth, often resulting in congested networks and deadlock states in buffer pools. Ideally, a routing and flow control mechanism will not consume resources. Today's modern data communications networks all use some form of adaptive routing. That is they use information on the current state of the network to base their routing decisions on. Our generic IDSN is no different. It should include some form of adaptive routing.

An adaptive routing scheme which has good efficiency for a generic IDSN such as we have described was originally proposed by Boorstyn and Livne. It involves the use of two-step heuristic. Step one requires the solution of an assignment problem where there is a search for an assignment of paths. This is made for each pair of nodes that need to communicate, that are "good" in some sense. Rather than employing a possibly exhaustive search for the "best" path, the path selection might be based strictly upon use of low utilization circuits, the minimum number of hops between two nodes, or some other decision criteria. Ties found during this selection process are handed-off to the next step of the heuristic where the departure of a packet from a node is modeled as a multiple choice, chance-constrained queuing problem. A comparison of this method with nonadaptive routing methods indicates that it is possible to reduce the time delay in packet processing by a factor which is roughly the equivalent of the average degree (# of outgoing links from a node) of the nodes in the network.

ROUTING TECHNIQUES

Efficient routing techniques may not be sufficient in a "store and forward" environment since blocking, a particularly disastrous form of contention, can still occur and idle network resources. Kaufman, Gopinath and Wunderlich have proposed the use of a "structured buffer pool with reservation" to eliminate the possibility of node-to-node blocking. In this procedure, packets enter a nodal facility and are placed into the "inboard" queue of the overall buffer pool existing at that node. Each packet is then out processed by the routing and switching processor (perhaps the adaptive routing scheme suggested by Boorstyn). Packets destined for other nodes are placed into an "outbound" queue in the buffer pool. Packets are sent when there is space in the inbound queue of the receiving packet switch and other related network processing (e.g., acknowledgements) has been completed. The analysis by Kaufman et al shows how to set-up the structured buffer pool with reservation, assuming that arrival and service rates are known a priori for the network.

It is hoped that this article has imparted some flavor for the difficulty of fielding complex interconnect systems a problem made worse by the virtual nonexistence of "recognized" standards of relevance. However, based upon the work of the various committees and the lessons being learned by the numerous experimenters today, future endeavors are anticipated to be much less cumbersome and more efficient in general. The more successful ventures will have "solved" the types of problems discussed here.

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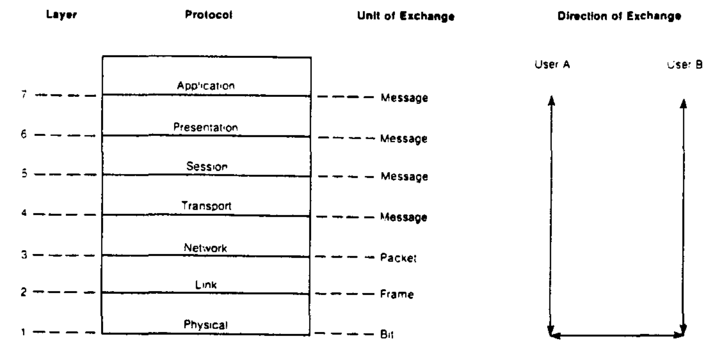


Figure 1 **The Seven Layers of the ISO-OSI Model**

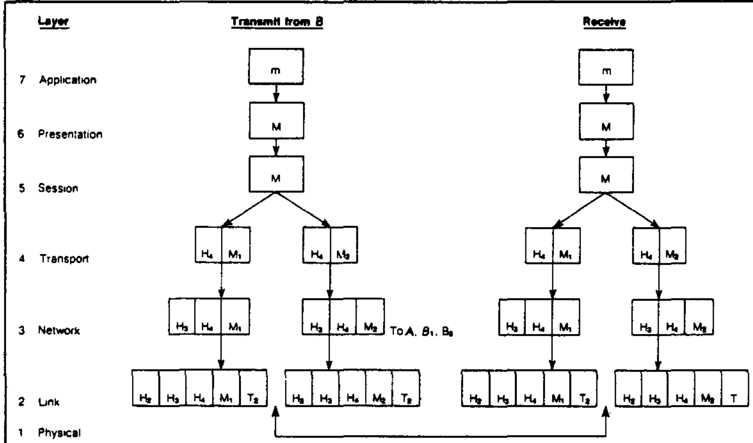


Figure 2 **Tracing the Multi-layer Protocol for a Sample Transaction in ISDN**

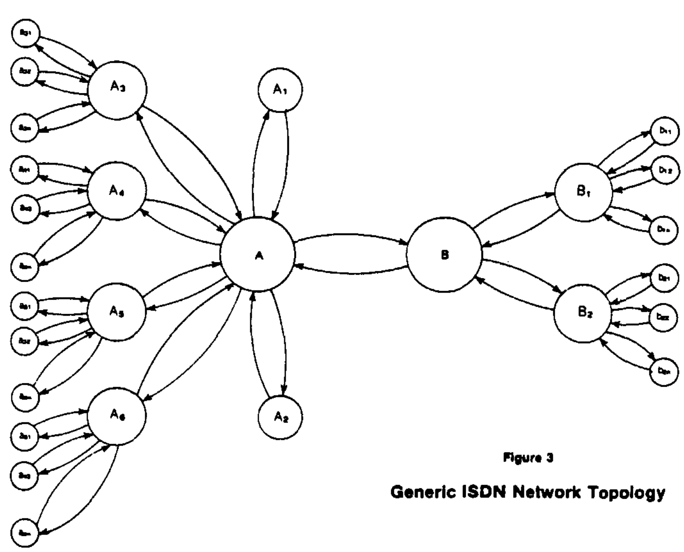


Figure 3

Generic ISDN Network Topology

Table 1

CCITT Recommendations for Packet Switching Networks

X.1	User classes of service
X.92	Hypothetical reference connections
X.95	Network parameters
X.121	International numbering plan
X.2	User facilities
X.3	Packet assembler-disassembler (PAD)
X.96	Call progress signals
X.9x	Architecture model
X.25	Data terminal equipment/data circuit-terminating equipment interface for packet mode terminals
X.75	International inter-change signaling for packet-switched networks
X.28	DTE/DCE interface of start-stop DTE accessing the PAD
X.29	Interworking between a PAD and a packet mode DTE

Table 2:

Key Design Issues in Complex Interconnect System Protocol Layers

Protocol Layers Design Factor	1 Physical	2 Link	3 Network	4 Transport	5 Session	6 Present.	7 Applic.
Bandwidth	X						
BER	X						
Signal levels	X						
Modulation	X						
Framing		X					
Synchronization		X					
Transmission line sharing		X					
Error detection		X	X				
Error correction		X					
Connection establishment		X					
Congestion			X				
Routing			X				
Formation/deformation of packets			X				
Connection to foreign devices				X			
Flow control				X			
Buffering				X			
Network security and privacy						X	
Encoding/decoding						X	
Distribution of data							X

Table 3:

General Services and Key Technical Parameters For an IDSN

	a	b	c	d	e	f	g	h	i	j
Advertising	L	L	L	H	L	L	L	L	B	L
Info retrieval	L	L	M	M	L	M	H	M	B	L
Interest matching	L	L	L	M	L	L	M	L	B	L
Messaging (short)	L	L	L	H	L	L	L	M	B	L
Electronic mail	H	L	L	L	L	L	H	L	B	L
Commerc. trnsctns	L	M	M	L	M	M	M	M	B	L
Questionnaires	L	M	M	H	M	M	M	L	B	L
Auction bidding	L	L	M	M	L	M	M	L	B	L
Pers. database	L	M	M	L	M	M	H	M	B	L
Computation	L	M	H	L	M	H	H	L	B	L
Games	L	H	H	L	H	H	H	L	C	M
Education	L	M	H	H	M	H	H	L	B	L
Telephony	H	H	H	H	H	H	M	H	C	L
Videophone	H	H	H	H	H	H	M	L	C	L
Facsimile	H	L	L	M	L	L	L	M	B	L
Telewriting	M	L	L	L	L	L	H	M	B	L
Home security	L	M	L	L	M	L	L	H	B	L
Remote meter rdg.	L	M	L	L	M	L	L	L	B	H
Energy mgmt	L	L	L	L	L	L	L	H	B	L

Legend:

a— upstream bits/interaction ($a \le 1K = L$; $1K < a \le 50K = M$; $a > 50K = H$)
b— upstream interactions/second ($b \le 0.1 = L$; $0.1 \le b < 0.5 = M$; $b > 0.5 = H$)
c— upstream interactions/call ($c \le 10 = L$; $10 < c \le 100 = M$; $c > 100 = H$)
d— downstream bits/interaction ($d \le 1K = L$; $1K < d \le 50K = M$; $c > 100 = H$)
e— downstream interactions/second ($e \le 0.1 = L$, $0.1 < e \le 0.5 = M$; $e > 0.5 = H$)
f— downstream interactions/call ($f \le 10 = L$; $10 < f \le 100 = M$; $f > 100 = H$)
g— call duration (seconds) ($g \le 100 = L$; $100 < g \le 500 = M$; $g > 500 = H$)
h— call frequency (calls/month) ($h \le 30 = L$; $30 < h \le 100 = M$; $h > 100 = H$)
i— transmission type (B — bursty; C — continuous)
j— penetration (%) ($j \le 25 = L$; $25 < j \le 50 = M$; $j > 50 = H$)

Table 4:

General Physical Level Interface Summary

Interconnect	Example	Transmission
Primary node-primary node	A — B	Satellite
Primary node-1st level subnode	$A - A_1$	Microwave
1st level subnode-2nd level subnode	$A_3 - a_{31}$	Coaxial cable

THE HOME MUSIC STORE

William F. von Meister

DIGITAL MUSIC COMPANY

The Home Music Store system comprises an all digital ultra-high speed satellite based audio distribution network, including an addressable in-home decoder.

SYSTEM DESCRIPTION

The DMC system consists of centralized studio facilities where up to sixteen (16) simultaneous audio and data signals are digitally encoded and multiplexed into single 13.95 MBPS data stream, then transmitted via a standard satellite "up link" facility. Two 800KBPS channels are required for stereo program material, one for monaural (news, index and promotion, etc.).

The broadcast will be received by CATV operators via the shared use of existing earth station facilities or, where necessary, by installing low-cost receive-only earth stations. No additional investment is required at the cable head end.

After exiting the down converter at the cable head, the signal will be transmitted over the cable as a discrete TV channel within the standard 6 MHZ bandwidth.

Each subscriber will be equipped with a low-cost ($100) decoder that will be inserted between the cable entrance and the standard CATV converter. The decoder will contain a key pad and numerical display for selecting the desired DMC channel. Decoder output will consist of low-level (A & B) audio channels. System signal-to-noise ratio will be ≥ 90 DB with a usable dynamic range ≥ 96 DB. Harmonic distortion will not exceed 005% at peak output.

In addition to the basic digital RF conversion function, the decoder will also have the capability to provide additional control and display features:

1. All channels can be disabled for cancellation or for non-payment.

2. Selected channels can be enabled or disabled for receipt of "premium" program material. This feature will allow the user to subscribe to the basic "Music Store" service for a minimum monthly fee and, by calling a toll-free number, to record new albums and releases at a cost that is 40-60% less than comparable retail prices.

3. A contact closure will be provided whereby an external recording device can be activated.

4. With an optional "teletext" decoder, the data channels may be selectively displayed on the subscriber's TV set, enabling him to preview DMC's upcoming selections and features. Capacity (150+ pages per second) is sufficient to provide a wide range of newsworthy, educational and informative material.

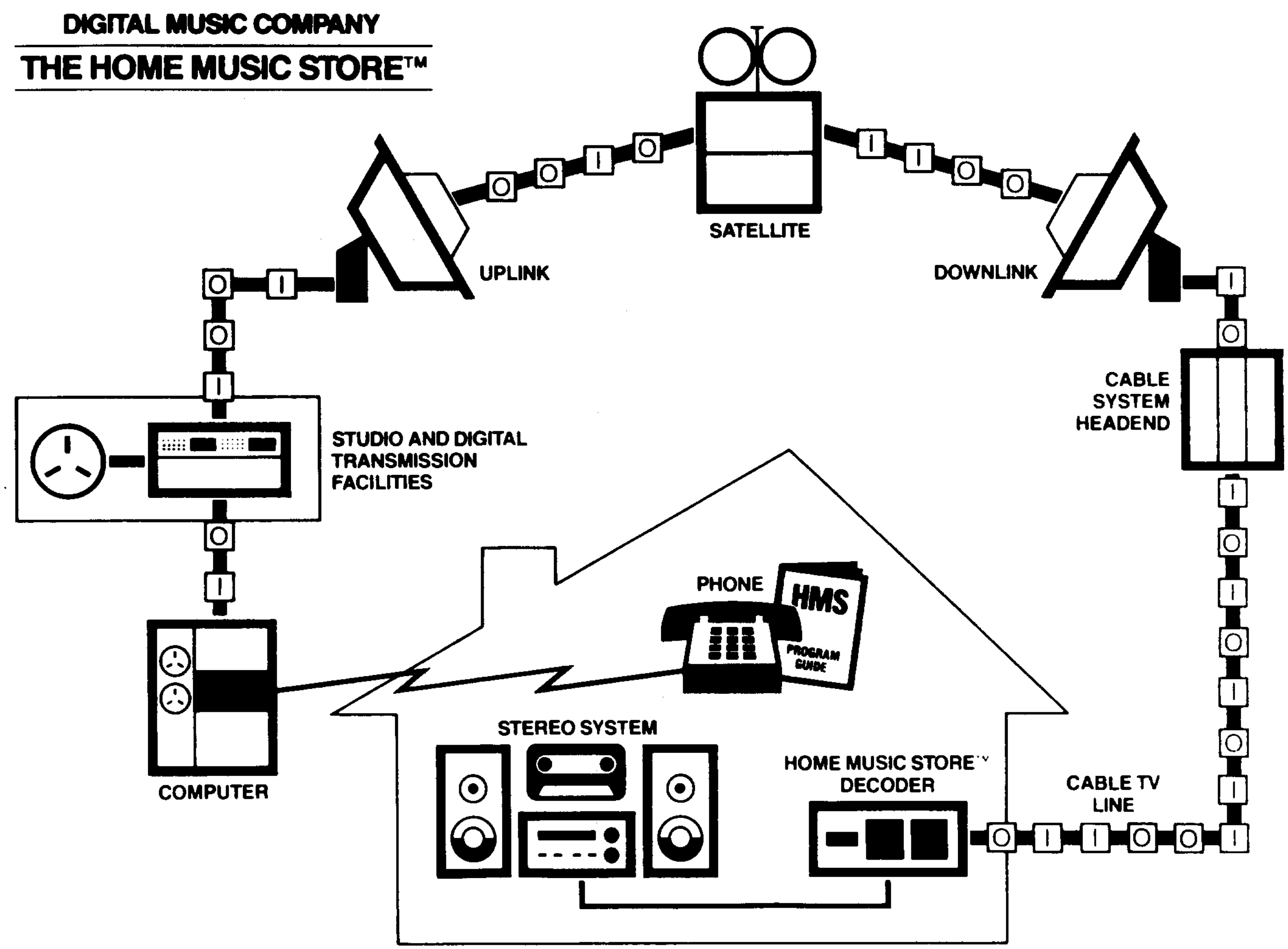
DMC SECURITY

1) All transmissions are digital, encrypted, and very fast. (Approximately 15 million bits of information per second, a data rate far in excess of that manageable by most computers).

2) The decryption algorithums in the decoder ("black box") will use both public and private "keys" as well as a proprietary micro-processor instruction set, i.e., even if the box is duplicated, it can't be used without registering it with DMC.

3) Any decoder can be completely and permanently disabled upon command from headquarters.

4) All selections transmitted for purchase will contain, inaudibly embedded in the music, the serial number of the individual decoder from which the music is transcribed. Appropriate law enforcement agencies will be given access to the equipment necessary to identify these numbers. Even once identified, the numbers cannot be removed without virtually destroying the recording.


DIGITAL MUSIC COMPANY
THE HOME MUSIC STORE™
SATELLITE
UPLINK
DOWNLINK
CABLE SYSTEM HEADEND
STUDIO AND DIGITAL TRANSMISSION FACILITIES
PHONE
HMS
PROGRAM GUIDE
COMPUTER
STEREO SYSTEM
HOME MUSIC STORE™ DECODER
CABLE TV LINE

DESIGN CONSIDERATIONS FOR ADDRESSABLE MULTI-DWELLING TERMINALS

PATRICK J. BIRNEY
MANAGER SYSTEMS ENGINEER

PIONEER COMMUNICATIONS OF AMERICA, INC.

ABSTRACT

In practically every major market franchise being awarded today, the cable system operator must provide his services to the entire community including the ever-growing number of Multi-Dwelling units. Providing cable service to large Multi-Dwelling complexes poses many unique problems which the cable operator must consider.

This paper details some of the practical design considerations in employing Multi-Dwelling terminals for application in apartment, condominium, and high-rise type housing units. Special attention is given to the system interface problems of the Multi-Dwelling terminal to insure co-existability within the vertical service environment of the Cable Television system network.

DETERMINATION AND IMPLEMENTATION OF ACOUSTICAL GOALS FOR BROADCAST FACILITIES

WAYNE V. MONTONE

RICHARD K. MILLER & ASSOCIATES, INC.
ACOUSTICAL ENGINEERING GROUP

This paper addresses the acoustical environments required for good "live" and produced cable and satellite tranmissions. This information is applicable to all individuals involved with cable, television, teleconferencing and videoconferencing.

Discussions of the effects of systems typical to the industry and how the acoustical environment goals are difficult to attain, are included. Typical and common solutions will be discussed based on case histories. The terminology of noise and acoustic descriptors are defined. The basic principles involved in providing noise reduction or to reduce noise within a space are also related. Included are descriptions of how generalized acoustic data can reduce the likelihood of attaining the desired acoustical goals along with a practical acoustical checklist.

INTRODUCTION

The audio portion of broadcasting is fifty percent (50%) of the transmission. Yet the quality of the audio environment, which is affected by noise impact, is constantly overlooked. In understanding noise impact and its adverse effects, first noise itself must be understood.

Technically noise is defined as the combination of a nonharmonious group of frequencies. A more common definition is merely unwanted sound. Any sound can be considered to be noise. Music is after all, only music to the ear of the beholder. Human perception of noise is subjective; there are however analytical methods for noise assessment which remove human judgement errors.

Sound consists of very minute pressure fluctuations in the air, generated by any method that can cause these pressure fluctuations. Sound generation can be divided into three (3) broad categories.

1. **Vibrating Surfaces**
2. **Aerodynamic Turbulence**
3. **Molecular Decomposition**

Vibrating surfaces are the most common and easily understood mechanisms that generate pressure fluctuations. Some examples of vibrating surfaces are strings on guitars and pianos, drum heads, vocal chords, stereo loudspeakers, walls, windows and their support systems. As can be seen, most any solid object has the potential for generating sound. This variety of sources make detailed engineering calculations necessary to determine how noise interacts with the solid structures.

Aerodynamic turbulence is a much more complex type of noise than vibrating surfaces. When air (which may be thought of as a fluid) is moving in stable flow configurations, it does not generate any noise. When the air flow leaves its stable flow configuration and interacts with directive structures (like air changing direction in heating, ventilating and air conditioning ducts), or with ambient air (like at an air outlet grill) a turbulent mixing region is created. The volume, velocity and size of the mixing region determine the amount of turbulence and the corresponding noise generated. This can be complicated even further whenever a solid object is placed in the air flow (t-joint ducts).

The third method for generating noise is molecular decomposition. This type of noise generation is found in electric arcs from welders, furnaces, and flames. It has no architectural application.

NOISE CONTROL

There are four (4) basic concepts for reducing the noise impact architecturally. These concepts are.

1. **Sound Barriers**
2. **Sound Absorption**
3. **Vibration Damping**
4. **Vibration Isolation**

Any of these four concepts can be applied depending on the engineering analysis. It is very important to understand the difference of these noise control concepts. Typical sound barriers consist of sheet rock, gypsum board, concrete, brick, and wood. The materials' noise control quality is due primarily to their mass. They reduce sound by reflecting or resisting its transmission. The performance of the materials is measured as transmission loss, T.L.

Typical sound absorption materials are fiberglass insulation, open cell foam insulation, cloth and even people. Sound absorption theory differs widely, however what basically occurs is acoustic energy is dissipated. Because these materials have very little mass, sound is not reflected or stopped by them. The absorption materials may be used to reduce the noise within an enclosed environment. Surface treatments, such as curtains, ceiling tile, etc. to reduce typewriter or computer noises are a common example.

These first two concepts, barriers and absorbers, work extremely well together as a system in stopping and dissipating noise. The barrier reflects noise and the absorption aids in dissipating the remaining acoustical energy

Vibration damping materials are traditionally rubber or vinyl which are applied to surfaces that are radiating noise created by its own internal mechanisms. Vibration isolation materials are typically rubber or compressed fiberglass which are used to prevent vibrations from being transmitted to another surface. Their common form is machine mountings or floor isolators.

ACOUSTICAL DESCRIPTORS

Units

dB stands for decibel. A decibel is the unit of power ratio equal to one tenth a bel. A bel (named after Alexander Graham Bell) is a power ratio equal to the logarithm to the base 10 of the ratio of any two powers ($B = Log_{10} P_2/P_1$). The early researchers in sound and human perception found that humans perceive sound logarithmically. The bel system of measurement happened to coincide rather well with the experimental hearing data.

By definition a decibel (dB) is a power ratio, but because it is a ratio it can be converted to other ratios. What is normally referred to as a dB in noise work is the sound pressure level (Lp). The sound pressure level is defined as.

$$Lp = 20 \log P/0.0002 \text{ microbars} \qquad (1)$$

Where Lp = Sound Pressure Level in dB
P = Sound Pressure (rms) in Microbars

Since decibels are logarithmic, they cannot be added together like normal numbers. 50 dB + 50 dB DOES NOT equal 100 dB. The long method to add decibels is to work Equation (1) backwards through the antilogs, arrive at the original pressures, add them together and recalculate the Lp dB.

There is however a short cut. If the difference between decibels is known, then Table I can be used to add decibels.

TABLE I

Decibel Addition

Correction Factor to dB Difference Between Sound Levels	Added to the Higher Sound Level
0 to 1 dB	3 dB
2 to 3 dB	2 dB
4 to 8 dB	1 dB
9 dB or more	0 dB

Example. 50 dB + 51 dB = 54 dB

(51 dB - 50 dB = 1 dB, the 1 dB difference is equal to an addition factor of 3 dB. Make this addition to the highest level, 51 dB + 3 dB = 54 dB)

Frequencies

Humans can perceive a large range of discrete frequencies. Normal human hearing has a range from 20 Hz to 20,000 Hz (Hz = Hertz = cycles per second). The lower frequencies are commonly called bass tones and the higher frequencies are called treble tones. For technical analysis it is necessary to consider all the frequencies of the noise impact or sources.

Discrete frequency analyzers are expensive and difficult to use. To simplify frequency analysis octave bands have been developed. Octave bands divide the frequencies into groups. The standard octave bands are listed in Table II.

TABLE II

Center Frequency, Hz	Octave Band Range, Hz
31.5	22-44
63	44-89
125	89-177
250	177-354
500	354-707
1000	707-1414
2000	1414-2828
4000	2828-5657
8000	5657-11313

Because people do not, however, perceive all frequencies with equal acuity, a single number evaluation was created. Humans hear the middle frequencies, around 500 - 4000 Hz, easier than the high or low frequencies. This explains why it is so easy to hear a baby cry. Babies cry at the frequencies that are the easiest to perceive.

To mimic the way a human ear actually hears sound, a system of "weightings" have been developed for sound level meters. A-weighting (dBA) mimics human hearing at low intensity sound levels, B-weighting (dBB) duplicates human hearing at middle intensity sound levels and C-weighting (dBC) is for analyzing the sound at high intensity sound levels to human standards. The weightings to be applied to sound levels for the octave bands are presented in Table III.

TABLE III

	A, B & C Weightings		
Center Frequency, Hz	dBA	dBB	dBC
31.5	-39.5	-17.1	-3.0
63	-26.2	-9.3	-0.8
250	-8.6	-1.3	0
500	-3.2	-0.3	0
1000	0	0	0
2000	+1.2	-0.1	-0.2
4000	+1.0	-0.7	-0.8
8000	-1.1	-2.9	-3.0
16000	-6.6	-8.4	-8.5

The dBA weighting is most commonly used because of its similarity to human hearing. However, engineering analysis does not require this weighting. This and other systems are used for generalized comparisons or discussion only. The difficulties of using dBA data, or any other single number rating system for engineering analysis will be discussed later in the paper.

Barrier Performance

A noise reducing system, such as an architectural wall, performance is measured in dB and the measurement is referred to as sound transmission loss, T.L. The sound transmission loss class, STC, is a single-number rating of a wall's sound transmission loss performance. The sound transmission loss class rating method procedures are specified in the American Society for Testing Materials (ASTM) annual book of standards. The sound transmission loss of a wall is measured or calculated at 16 third-octave bands with center frequencies from 125 to 4000 Hz. To determine the standard transmission loss class the transmission loss values are plotted and compared with a reference contour. The rating is easily determined by using a transparent overlay on which the contour is drawn. The contour is shifted vertically relative to the test data curve to as high position as possible according to the following conditions:

1. The maximum deviation of the test curve below the contour at any single angle shall not exceed 8 dB.
2. The sum of the deviations at all 16 frequencies of the test curve below the contour shall not exceed 32 dB - an average of 2 dB.

The sound transmission loss class will "hide" deficiencies, therefore full frequency sound transmission loss data should be used for engineering analysis. A wall or building membrane's sound transmission loss characteristics are affected by its coincidence effects (resonance), mass (pounds per square foot) and leaks (perforations or openings). The coincidence effects describes the frequency at which a material resonates. This effect greatly reduces a material's ability to stop sound at that particular frequency. The material's mass in part defines its ability to prevent sound from being transmitted through its body.

Before complex or double wall constructions can be evaluated, each layer of the wall must be examined for its own coincidence effects and mass characteristics. Double walls with layers of different materials will perform superior to those walls with layers of similar materials because the coincidence effects (frequency at which the noise reduction capabilities will be less than expected) will not occur in the same frequency. The air space within a double wall provides a decoupling effect between the two layers in a wall. This air space effect is also reduced at its natural resonant frequency which is a function of air space thickness (inches). The addition of sound absorption materials that do not cancel the decoupling effect will enhance the noise reducing qualities even further.

It should be realized that detailed composite sound transmission loss calculations must be performed if the membranes of a room do not have similar characteristics. This is because weaker wall membranes sound transmission loss performance will cancel out superior qualities that may be present.

Sound Absorption

Sound indoors is affected by the room shape, volume, and the interior surfaces. In most cases the room shape and volume are fixed by other design criteria and processes. Except in the case of special facilities where speech projection is the focal point of the design, the surface treatments are the controlling factor of the interior environment. The sound absorption qualities of surface treatments are delineated by their sound absorption coefficients.

Sound absorption values vary with frequency, and are dependent upon porosity and thickness. Material facings, have a large effect on the sound absorption values. Where two or more materials are considered within a room, all surface treatments or the lack of it must be used when determining the interior effects. The room's sound absorption characteristics affect the amount of time sound will be reflected about in the closed space. The reflected sound is called reverberation.

CRITERIAS

Recommended acceptable interior noise levels, or as they are more commonly known "Noise Criteria Curves," have been compiled for a large scope of interior uses. The noise criteria values are presented in dB and octave band sound pressure levels. The various interior uses (speech, working, reading, etc.) and their corresponding noise criteria level goals are presented in Table IV.

The octave band sound pressure levels of the Noise Criteria Curves are shown in Table V. They are used to establish the background or ambient noise levels in a given environment. The ambient noise level is the sound present in a facility when it is not in use and only the support systems are in use. By designing a room to particular Noise Criteria Curve levels excellent signal to noise ratios and proper microphone keying may be achieved for appropriate broadcasting conditions. The recommended Noise Criteria Curve levels should not be exceeded. If the recommended Noise Criteria Curve levels are exceeded, the ambient levels may mask or drown out the intended activities, by being within in ten dB of the broadcast signal. This can manifest itself as a problem in speech intelligibility. Any noise sources whether from inside the facility itself or external sources (intrusive noise) must comply with the Noise Criteria Curve guidelines.

Normally a NC 15 is desired for a broadcasting facility whether for cable, television, telecommunication or vidoecommunications. It would be necessary to reduce any potential intrusive noises to approximately 10 dB below Noise Criteria Curve 15 values, while the interior sources should not exceed Noise Criteria Curve 15. This will avoid the decibel addition factor of 1-3 dB, raising the noise level above the Noise Criteria Curve goals.

Reverberation from sound buildup within the facility is measured as a function of time. Reverberation time is the time that would be required for the mean-square sound pressure level to decrease to 60 dB after the noise source has stopped.

TABLE IV

Designs Goals For Indoor NC Levels in rooms with various uses

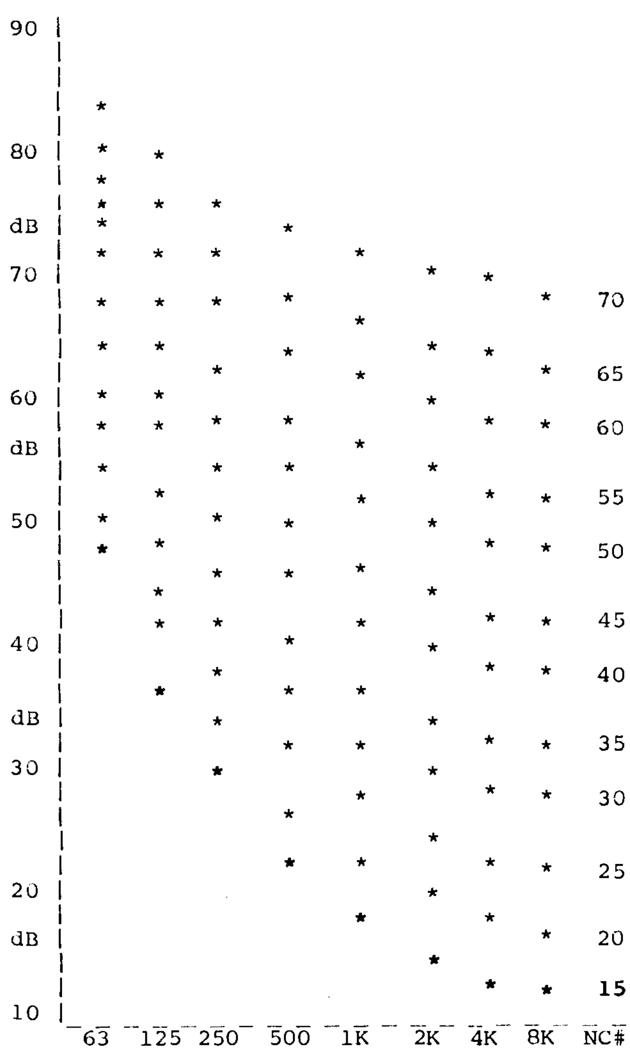
Type or use of space	Noise Criteria Level
Concert halls, opera houses, recital halls, drama theaters, **broadcast**, television and recording studios (excellent listening conditions)	**15 - 20**
Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels (for sleeping, resting, relaxing)	20 - 30
Small auditoriums, small theaters, small churches, music rehearsal rooms, large meeting and conference rooms (for very good listening)	20 - 30
Private or semiprivate offices, small conference rooms, classrooms, libraries, living rooms and similar spaces in dwellings (for good listening conditions)	30 - 35
Large offices, reception areas, retail shops and stores cafeterias, restaurants, etc. (for fair listening)	35 - 40
Lobbies, corridors,	

laboratory, work spaces, drafting and engineering rooms, general secretarial areas, maintenance shops (moderately fair listening conditions)	40 - 45

Speech intelligibility has a direct correlation with the time it takes the sound to decrease. If a lecturer's first spoken word continues to travel within a room even after he has spoken his fifth word, the audience will not be able to understand what is being said. This affects speech intelligibility. Table VI presents building uses and ideal design reverberation times. Extremely low design goals are used for broadcasting uses. This minimizes activity noises of the room and allows for clear understanding of the spoken word at relatively close distances.

TABLE V

Noise Criteria Curves
Level, dB v.s. Frequency, Hz



PROBLEMS IN PRACTICE

Single Number Rating Systems

As previously presented single number rating systems such as dBA and STC attempt to average or generalize the sound spectrum so the information can be easily handled. Unfortunately this causes design deficiencies where weighting factors or performance dips are disguised and the full impact is not realized. For example, the speech range is considered to be 500 HZ to 2000 HZ with the peak frequency at 1000 HZ. This is true when considering only speech intelligibility, but the normal human being is capable of producing sound levels as low 125 HZ. A voice outside a facility may intrude at low frequencies if the dBA weighting was used.

TABLE VI

OPTIMUM REVERBERATION TIME at 500/1000Hz

Use versus Time, seconds
(building size range = xxXXxx)

Use	Time (0.2 – 0.5 – 1.0 – 1.5 – 2.0 – 2.5 – 3.0)
Liturgical	XXXXXXXXXXX>
Symphonic	xxXXXXxx
Secular	xxXXXxxx
Opera	xxXXxx
Orchestra	xxXXxx
Classical	xXXXXxx
Musicals	xxXXxx
Bands	xxXXxx
Churchs	xxXXXXXXXXXXXXXXX>
General	xXXx
Theater	xxXXxx
Cinema	xxXXXXxx
Lectures	xxxXxxx
Drama	xxXxx
Classrooms	xxXXxx
Recording	xxXXXxx
Broadcast	**xxXXXxx**
Nightclub	xxxXXXXxxx

Axis: 0.2 0.5 1.0 1.5 2.0 2.5 3.0

Without that information the

engineered wall would not be sufficient to stop or reduce the noise impact at that frequency. In addtion, the lower frequencies are much more difficult to stop and would require elaborate high mass walls.

When designing a telecommunications facility that uses microphones with actuation levels, which would include all the frequencies from 31.5 - 8000 Hz, a wall with certain a standard transmission loss class value may provide a corresponding Noise Criteria Level that appears satisfactory. However, the sound transmission loss value at 125 HZ would be significantly less than expected and would not provide the proper environment. This would cause the microphone to activate and be continuously "open" or on.

Either the fan, motor, ducts or the supply grills can be the source of the problem. All parts of the systems must be considered, especially the supply grills which can create high frequency "whistling" noises.

The vibration levels within modern buildings are another source of the designer's concern. Structure borne vibrations have several sources, the primary ones are fixed machinery and foot falls of the building's occupants. Here we see the heating, ventilating and air conditioning system hardware come into play. Its location and mounting techniques can directly effect any critical facility within the building.

The vibration levels are transmitted to all rigidly attached membranes which all have the possibility of becoming acoustical radiators or "speakers". This effect can cancel out the effort of stopping the airborne intrusive noise by allowing the vibrations to pass through the very systems themselves. The noise from footfalls (peoples foot steps) from floors above in an average slab building can reach levels above the Noise Criteria Curve of 35. This prevents reaching the extremely low Noise Criteria Curve goals required for cable or broadcast facilities. There can also be undocumented effects on camera optics and picture quality.

In combating the noise and vibration levels typical solutions used for large on-grade studios are just not applicable. The solutions usually involve massive walls and doors which are not feasible in multi-level structures that many teleconferencing, videoconferencing and cable facilities are being installed in today. The point source building loads typically are in the range of 8 - 10 pounds per square foot. At these low levels high mass wall solutions can not be used and radical acoustical wall membrane design is necessary.

SOLUTION SYSTEMS

Detailed Research and Measurements

It is extremely important to have fully researched the peak (maximum) noise levels, as well as the ambient levels, that exist in the building. This must include the variety of building modes the building is used in, such as lunch hour, high load air conditioning demand and late night operation. The potential impacts that can happen any time must be considered. This includes employee disagreements, high traffic conditions, such as building tours and uncontrolled wall impacts from doors. Every second your broadcast facility is in operation it should not be interrupted.

When considering the ability to hear clearly, the signal-to-noise ratio is critical. Signal-to-noise ratio is the difference between the ambient noise levels as compared to the speaker's voice level. If the ambient noise level is high due to design deficiencies, the speaker may have to speak abnormally loud to be heard properly, or not heard well at all.

Impact Determination

A very common problem is underestimating the impact of the intrusive noise (exterior noise) that will be affecting the facility. The origin of this problem lies in accurately determining the type of activities that will be present. The noise levels of raised speech or yelling can be very loud and be surprising low in frequency. The designer may use the generalizing dBA equivalent of the expected noise level for an activity outside the facility. This will invalidate all further goal calculations. It is essential that the maximum level that may occur, within reason, be used in computing the sound transmission loss necessary to provide the desired acoustical environment.

Typical Building Construction

The typical or average building provides a multitude of problems for the acoustical designer of a broadcast facility. Making use of every square foot of building space does not sound like a problem, but this usually leads to having many types of spaces with different acoustical goals improperly placed. Careful planning or space zoning is necessary and can save a multitude of problems and dollars in the future.

The heating, ventilating and air conditioning system is a cronic problem because of the various types that can be used. Open plenum return systems render a facility acoustically useless without expensive return air silencers and ceiling treatments. The sound produced in one area of the floor can travel to any facility area where the air flows to. Many systems utilize unlined trunk lines that link facilities together in very short distances. This allows sound to reflect in the ducting directly into the next facility. The heating, ventilating and air conditioning system hardware itself leads to the next building concern.

When the noise from the heating, ventilating and air conditioning system itself is too loud, it too can be broadcasted along with the speakers voice. In addition the signal-to-noise ratio may be improper and the audience will not be able to distinguish between the two sounds, therefore masking the message.

Having to stop production or retape in your facility is defeating its special purpose. These costly "down times" are often accepted as the cost of doing business or passed along to the production staff as their problem to overcome.

Full Frequency Analysis

When making the base line building surveys include measurements throughout the octave band sound pressure levels of 31.5 to 8000 Hz. Any predictions of potential noise sources or impacts should be calculated throughout the same frequency range. This data should be used to determine the acoustical design goals. No single number rating systems or evaluations should be used, especially with the sound transmission loss class. This will prevent an unforseen deficiency in the designed wall at any particular frequency resulting in an improper acoustical environment.

Multiple Building Membranes

The determined sound transmission loss goals must apply equally to all membranes that are part of the facility. This includes walls, floors, ceilings, windows and doors. The composite or overall sound transmission loss will only be as good as the weakest membrane. This weakness is proportional with the entire surface area.

Sealing

An illogically large deficiency in the sound transmission loss can result from very small areas, including miniscule gaps. The sound transmission loss of a wall system with air gaps in and around receptacles and doors equal to 1% of the total surface area will be limited to just 10 dB.

This limitation results from poor sealing. The need of designing the facility to be "airtight" is essential. Anywhere air or light can travel so can sound. This basic principle must be translated into practical construction practices. The sealing of all perforations through the acoustical membranes that surround the facility must be carried out by the installation crew. A quality control system with caulking examples and check points in the process should be created for the contractor or the subs. To be most effective the system is to have the acoustical designer carry out the quality. However, a sealing quality control system can be designed and construction or building owner employees can be trained for implementation.

CONCLUSIONS

To provide a superior acoustical environment the common problems presented in this paper must be dealt with. The following Table VII presents a suggested check list that you or your acoustical designer should always take into consideration.

With is practical checklist of critical points in the acoustical design process of a critical space the common pitfalls can be avoided. For complete design services rely on a qualified acoustical consulting firm.

TABLE VII

Acoustical Design Checklist

I MEASUREMENT

1. Ambient Levels
   - Morning [ ]
   - Lunch [ ]
   - Afternoon [ ]
   - Night [ ]
2. Peak Levels
   - Voices [ ]
   - Cleaning [ ]
   - Walking [ ]
   - Impacts [ ]
   - Office Equip [ ]
   - External [ ]
3. Flanking Paths
   - Electrical [ ]
   - Phone Lines [ ]
   - HVAC [ ]
   - Chases [ ]
   - Construction [ ]
   - Other [ ]

II ASSESSMENT

4. Zoning
   - Traffic Pattern [ ]
   - HVAC [ ]
   - Usability [ ]
   - Noise [ ]
   - Other [ ]
5. Full Frequency Data [ ]
6. Microphone Cutoffs
   - Overall Level [ ]
   - Frequency [ ]
7. Signal to Noise Ratio Goal [ ]
8. Noise Criteria Levels
   - NC-15 [ ]
   - NC-20 [ ]
   - NC-25 [ ]
9. Acoustical Environment Goals
   - Ambient [ ]
   - Privacy [ ]

TABLE VII (cont)

Acoustical Design Checklist

III ANALYSIS

10. Transmission Loss Goals [ ]
11. Transmission Loss Data
    - Floor [ ]
    - Ceiling [ ]
    - Walls [ ]
    - Doors [ ]
    - Windows [ ]
12. Transmission Loss Calculations
    - Mass Law [ ]
    - Coincidence [ ]
    - Air Resonance [ ]
    - Double Wall [ ]
13. Surface Areas
    - Floor [ ]
    - Ceiling [ ]
    - Walls [ ]
    - Doors [ ]
    - Windows [ ]
14. Reverberation Time Calculations [ ]
15. Composite Transmission Loss [ ]

IV SPECIFICATIONS

16. Wall Schedule
    - Thicknesses [ ]
    - Air Spaces [ ]
    - Insulation [ ]
    - Stud Distances [ ]
    - Stud Type [ ]
    - Isolation [ ]
    - Membrane Number [ ]
17. Door Schedule
    - Weight [ ]
    - Frame [ ]
    - Seals [ ]
    - Number [ ]
18. Finish Schedule
    - Product [ ]
    - Amount [ ]
    - Thickness [ ]
    - Nightime [ ]

TABLE VII (cont)

Acoustical Design Checklist

IV **SPECIFICATIONS (cont)**

19. HVAC

System Type	[ ]
Lining	[ ]
Duct Size	[ ]
FPM	[ ]
CFM	[ ]
Grill Type	[ ]
Grill FPM	[ ]
Silencer	[ ]

20. Installation

Methods	[ ]
Sealing	[ ]
Perforations	[ ]

V **CONSTRUCTION**

21. Materials Checks

Membranes	[ ]
Insulation	[ ]
Isolation	[ ]
Studs	[ ]
Doors	[ ]
Windows	[ ]
Ducting	[ ]
Gaskets	[ ]
Caulking	[ ]
Glue	[ ]

22. Sealing

Caulk Location	[ ]
Caulk Width	[ ]
Glueing Locat.	[ ]
Glueing Width	[ ]
Perforations	[ ]

23. Transmission Loss Testing

Walls	[ ]
Walls & Doors	[ ]
Windows	[ ]
Complete	[ ]

24. Reverberation Testing

Surface	[ ]
Furnished	[ ]

DOWNLOADING AND ADDRESSING VIA TELETEXT

Gary W. Stanton

Southern Satellite Systems

ABSTRACT

A teletext signal has been continuously transmitted on the vertical interval of Satcom I, transponder 6 since the NCTA show in 1980. The original purpose was the video dissemination of cable news services. Recently, the system has been modified to incorporate data transmission which emulates a standard telephone line, but with far higher data reliability. In addition, the modified teletext system for data transmission incorporates an addressability function with over five million addresses possible. A priority scheme for national, regional, local and individual addressing is described. A description of the system, including data from reliability tests is presented. This will also define several key technical requirements for successful teletext data reception.

General Information

The cable and communications trades have been full of news about the up and coming information invasion of the home. With the British, the French and the Canadians, among others, the battle lines have been drawn about whose system is the best for delivering various videotext or teletext services into America's wired cable homes. Unfortunately, there's so much talk and so little really happening that it may be time to sit back and take a look at where this revolution really is, what's really happening and what's just in the testing, a few years down the road.

One problem in all the talk is the fact that the generic jargon of the alphanumeric information industry is confusing. Are videotext and teletext the same thing? What about viewdata? And why do some people leave the "t" off of videotex(t)? Do they have lazy typewriters, or not a large enough supply of "t's" at their printer? These questions aside, let's deal with what's really happening.

There are some cable systems in the U.S. delivering "videotext," which for the purposes of this paper will be considered two-way and interactive. There are some broadcast stations test marketing their "teletext" services, which in this article will mean strictly one-way. UPI, Reuters, Dow Jones, and Quotrader are all delivering their services, which are "teletext", to cable systems, today and in the case of Quotrader, to private users. UPI and Reuters began satellite testing of the service in July 1980, and service to cable TV headends in October 1980.

But one-way teletext services aren't really what all the excitement is about. It's the interactive services that are getting all the attention, and precipitating the hue and cry of the future of communications. The Warner-Qube system in Columbus, and other such ventures like The Source in Virginia, are the kinds of things that the cable and communications industry have been talking about so much.

Unfortunately, few of the things being talked about are ready to happen on a national basis today. That's why, if teletext isn't going to remain a thing of the future, the industry needs to use what's available today to its full capacity. That means using the existing means of teletext, one-way delivery, and make it two-way, in effect, by using telephone lines as the means of "upstreaming."

Videotext is basically two-way communications, using a telephone line to "call up" specific information, which is then delivered to the person who requested it, using the same phone line. It's "narrow stream," two-way delivery, which is interactive.

Teletext, on the other hand, is a one-way "stream" of information (channels or pages), delivered as a "wide stream." Phone lines, the standard means of most operating text delivery today, do not permit wide streams of information, whereas broadcast or cable delivered teletext does. Two-way videotext is selective and slow. One-way teletext is non-selective and fast. It takes a lot of transmission space to provide streams of information for the general public. Because of the various limitations inherent in both videotext and teletext, there is need for both wide stream teletext, as well as interactive videotext.

The major drawbacks to interactive videotext services are the long distance phone charges, the cost of the receive equipment, and the fee for the information service itself. The downloading scenario outlined previously enables users to accomplish most of the same things they could accomplish using a two-way system, for less cost. Downloading with satellite delivered teletext information, as done by CableText, and upstreaming via phone lines means teletext for specialty users is not a thing of the future. It's being done today and can be done by any kind of information supplier who wishes to do so.

In this application, subscribers will be continuously "on-line," with their printer or computer storage device receiving the information transmitted for them.

While a satellite delivered teletext system can be delivering hundreds of different specialized types of information, individual subscribers will receive only the information they want and need, because the teletext decoders will be "addressable." A Teletext decoder will feed the data into a user's printer or computer with storage. Though the information may be delivered at 3 a.m., the user can still "call it up" when he or she is ready to use it, either by instructing the computer to display it, or by simply reading the printed copy. If a subscriber needs to use the information for a transaction, a simple telephone call will make a technically one-way system two-way in effect. Downloading the information via teletext makes the system interactive only when needed, with information being delivered 24 hours per day.

The key to this application of existing, in-use today technology, is in what's called an "RS-232 decoder." RS-232 is an EIA defined standard computer serial data interface used for interconnection of many different devices. A printer or home computer can be attached to a RS-232 decoder, as well as a cable system's character generator as it's being used by UPI, Reuters, Dow Jones, and View Weather today. The delivery of teletext information into businesses and homes of "specialty" users is one of the two markets soon to be tapped by the common carrier Southern Satellite Systems, through its teletext system called CableText.

Let's look at the "downloading" application of teletext. An example is being accomplished today by Quotrader, a commodities service which utilizes a specially equipped computer along with the RS-232 decoder. The decoder interfaces with the microcomputer, feeding the information into the computer for use in analyzing the commodities information. The software provided as part of Quotrader's monthly fee also enables users to receive buying and selling recommendations. Buy/sell orders are placed by a phone call to a user's broker, or by attaching the computer to a modem which permits the user's computer to talk directly to the broker's computer.

That scenario, starting with 1) downloading information into a home computer, or in some cases a printer, 2) storage of the information on the computer storage device or on a printed page, 3) viewing of the information at the convenience of the user, and finally 4) the use of the information for a phone transaction (upstreaming), is one application that is ready for the marketplace today.

Existing System Formats

There are a number of teletext and videotext systems either proposed or in existence in either test or operational modes. Some are very similiar, differing only in minor detail, however, just different enough as to be incompatible. Others are significantly different in one or more respects.

For background purposes, a brief description of the various systems is in order.

1. The first teletext systems and by far the most widely used is the United Kingdom (U.K.) system and its variations. The teletext version is called Ceefax in Great Britain and the videotext version is called Prestal. This system is also used in Australia and several other European countries. Several variations of it are in use in the United States, such as Field Communications' "Keyfax" system and Southern Satellites' "CableText" system. KSL in Salt Lake City and WGN in Chicago also experimented with variations of the U.K. system. Reportedly, 1.5 million LSI chip sets have been sold for the U.K. system.

The U.K. system features a mapped video screen system where each screen alphanumeric character or mosaic graphic character's screen position is defined by its position in the transmit stream. After the necessary page address or header information is transmitted, subsequent consecutive transmissions contain screen row numbers and the information to be displayed on that row. For example, the 10th character transmitted with a row 4 address will be displayed in the 10th screen position in row 4. In practice, it's not quite that simple, but in essence, that is how it works.

2. The remaining major systems use a free format where there is not a fixed relationship between transmit screen positions. This means screen positions must be defined in the transmitted data, as well as line feed/carriage return at the end of each line. The major systems using variations of this protocol are:

a) Antiope: The French teletext system. Technically, Antiope is the screen language and "Didon" is the transmission protocol. The French pioneered the non-mapped concept for teletext/videotext usage.

b) Teledon: The Canadian system. This system is quite similar to the Antiope system, however, it also included a set of picture description instructions (PDI's) which gives the ability to draw circles, lines, and other geometric figures.

c) CBS system: CBS originally adopted the Antiope system to the NTSC television system. They added the necessary transmission protocol to make the system work properly in the 525 line 60 cycle television system currently in use in the U.S.

d) North American Presentation level protocol or "PLP". AT & T combined the Antiope, Teledon, and CBS systems into a single system. The PLP format does not specify transmission format, only presentation level, i.e. viewable level format. This means the CRT and printer presentation codes have been defined by the PLP format, but not the transmission scheme.

Since AT & T conceived the PLP format, Teledon and CBS have ammended their display system protocol to be compatible. At this point there are basically two major competitive incompatible systems in existence, the U.K. system, which includes both teletext and videotext definitions, and the PLP presentation system with the CBS videotext transmission definitions.

Advantages/Disadvantages

Much has been written on the comparative advantages of each system. However, the engineering community must stand back and realize that the end user, whether a home owner, business, or cable system really does not care what technical system is in use. All the end user is really interested in is:

1) Obtaining the desired data or information
2) Reliability
3) Lowest possible cost

It is apparent that each of the two major systems has certain advantages and disadvantages. The particular application should dictate the specific system chosen.

Transparent Data System

SSS has been using an early version of the U.K. teletext system for transmission of the UPI and Reuters news services. There was not a U.K. defined protocol for data transmission only, or for addressability greater than the 800 page numbers defined in the U.K. protocol. Therefore, it was necessary to define a system protocol and have appropriate hardware fabricated.

In the basic U.K. system, a header row is transmitted, which contains the page addresses, various control codes, and 22 free bytes usually used for the first part of the displayed text. Subsequent transmit rows contain the hundreds digit of the page number as the row number and the data for display. All transmit rows have a three byte preface consisting of two bytes of clock run-in and a single byte framing code. These three bytes synchronize the decoder for data recovery. The control and addressing codes in both the header and rows are Hamming code protected, while the data is transmited with odd parity.

Standard Transmission Mode

Examination of the Header row reveals a number of options. The first option is to use the last 22 bytes in the header row for transmission of the required data. To implement this system, the computer needs to store incoming data until 22 bytes are collected, then insert these bytes on the next available vertical interval line. The decoder will receive these 22 bytes and store these in RAM. A microprocessor controlled UART then spools the data out to the RS-232 interface at whatever data rate the UART has been set for. As long as the UART is set to transmit at a speed equal to or greater than the incoming rate for new data, reliable data recovery is obtained.

Since the effective vertical interval transmission speed is 5.554 megabits/second for two or three vertical interval lines, many standard 300 to 1200 baud services can be multiplexed together. The basic U.K. Teletext chip set has capacity for 800 descrete addresses. For practical purposes, one vertical interval line will support forty-four 300 baud services in this mode.

Multiple Transmit Mode

It has been recognized that a need exists for a higher level of data integrity than may exist in a single transmission. In two way telephone line service, the receive device can send a negative acknowledge (NAK) upon failure to receive intelligible data. For one-way transmission this is not the case; therefore, depending on the reliability required, it may be necessary to retransmit the identical block of information.

To implement the multiple transmission mode, two additional control bytes are defined, thereby leaving 20 bytes for information data. The first control byte is a mode definition which alerts the decoder of the multiple transmission mode. The second control byte is a continuity index which is incremented each time new data is sent, but is not incremented on a repeat of the old data.

The decoder is double buffered. In its receive buffer only data with correct parity is retained. Subsequent transmissions will not replace previous correct parity information, but will fill in missing information. Therefore, the data will integrate upward on subsequent transmission. Upon receipt of a new continuity index, the data in the receive buffer is moved to the output buffer for spooling out to the RS-232 interface. The input buffer is cleared for a new block of data.

For ultra high reliability, it is possible to transmit three or more times, with the decoder selecting the best of the transmissions in a voting process.

Additional Addressability

Examination of the control code structures reveals 13 bits that can be redefined without jeapordizing needed control functions. Using these 13 bits a three tier subaddress mode was constructed. The tiers contain 64, 16, and 8 levels, respectively, with each tier operating independently of each other.

For example, the group of 64 can be defined as states, the group of 16 could be regions in a state, and the last tier group as individual decoders within the region. Alternatively, the 8 tier group could be used for regions in the U.S., and work downward in the opposite direction. A third option is to use the bits for discrete decoder address instead of a tier system. This gives a total of 6615 discrete addresses per page, or a total of 5,292,000 discrete possibilities.

The zero address in each tier is not included in the above address possibilities. The zero address is reserved for mass addressing. If a zero address is sent for a given tier address all decoding units in that tier respond to the data in that pocket. This gives the flexibility of mass addressing of decoders without sending identical data to units with different address codes.

Data Error Test

A number of tests have been performed and are continuing to quantitize reliability at a TVRO, and subsequent transmission on a cable system. Although measurements are continuing, various preliminary results are reportable. It is apparent that considerably different factors are involved in cable system data integrity than those which affect TVRO integrity.

At a TVRO, impulse noise appears to be the greatest source of errors. The amount of impulse noise is related to the usual known factors such as dish size, LNA, etc. In other words, the higher the carrier to noise ratio, the better the data integrity. Tests were made using a 3.65 meter dish with a

90 degree LNA, with the measured c/n = 11. Byte error rates of 1×10^{-5} in the dual transmit mode were measured. The dual transmit mode uses the technique described earlier, with two transmissions in the same TV field. Tests with a 10 meter antenna indicate error rates of 1×10^{-6} are obtainable in the single transmit mode.

There are numerous factors that affect performance of teletext via the cable TV medium. A complete analysis is beyond the scope of this paper; however, several comments are in order. One observation is that transmission errors tend to appear in large groups, rather than singularly as is typical at a TVRO. Various investigators have found many causes.

It has been shown that the modulation process is critical in passing teletext data. One study by a reputable manufacturer has concluded that adjustments of modulation levels is of critical importance, as over modulation is disastrous for teletext data recovery.

Conclusion

An economical, addressable, teletext system has been developed for downloading data to various types of home/business data equipment such as computers and printers. The system features transparent data communication as well as a flexible addressable format. The system is based on the reliable and available U.K. teletext chip sets for implementation in today's marketplace, using high speed one way data downloading and low speed selective return path via the existing telephone system.

EARTH STATION SITE LOCATION
AN EVOLVING TECHNOLOGY

DOM STASI
DIRECTOR OF ENGINEERING

WARNER AMEX SATELLITE ENTERTAINMENT COMPANY, NEW YORK

ABSTRACT

Selection of an earth station site whether for transmission or reception of TV programming is rarely, if ever a simple process. Selection criteria such as ownership of a tract of land or colocation with existing headend or office facilities usually renders one site a very strong first choice. Conditions such as a downtown location, which render a site desirable for an office or those such as a hilltop, which are attractive for a headend generally, unfortunately, represent the worst locations for earth station facilities due to interference.

A short couple of years ago, interference effects would have negated most of the type location we are discussing. That situation is changing. As earth stations for CATV proliferate, the experience each designer encounters in solving his particular interference problem adds to the collective pool of knowledge for the benefit of the next.

LOCATION

In selecting a site location for the Warner Amex Satellite Entertainment Company Network Operations Center, numerous signal problems needed to be solved. All were. Some conventionally, others not so conventionally, using and developing methods heretofore untried. Several techniques are applicable to any site location and are treated in technical detail.

Selection criteria may be categorized as those we impose upon ourselves, such as ownership of a tract or colocation with existing facilities (offices, studios, etc.), and those largely outside of our control, which are imposed upon us by others, such as environmental impact or compatability with other frequency users in the very crowded 4 and 6GHz bands. Keep in mind, regarding the latter, as a station builder you are the newcommer and often not a very welcomed newcommer at that. Thus, you must conform to whatever conditions exist, in the spirit of community imposing minimal negative impact upon the established order. This is a wholly fair and equitable set of circumstances developed for the common good, despite what in a projects early stages seems weighted against your progress. Quite the contrary is true. The rules encourage the proliferation of new services, however, protection of existing channels (which you will become upon licensing) is a higher order of priority. Allocation or denial of frequencies will be predicted upon that. The commissions rules clearly state, when applying for transmission frequencies, your allocation must bear minimal interfering potential not only to any and all licensed existing carriers, which is fairly common knowledge, but to those not yet licensed whose application bears an earlier filing date than your own as well.

In other words, if a carrier determines that your transmissions will cause him interference, he is free to block your application. It's then incumbent upon yourself to either withdraw your application, (and find another site), or prove to the objecting carrier (with the F.C.C. as arbiter) that he can (or must) live with your signal. Too often an applicant will choose the former and abandon a site based upon an objection without further argument. This is unfortunate since in virtually all instances, many objections can be cleared through site engineering during the prior coordination stage of an application. Keep in mind, since your route is only proposed and not yet existing, the carriers objections are not measured, witnessed phenomena but only postulations. And at that, are calculated against a set of worst case parameters.

Optimizing your own calculations, and modifying the physical properties of your site can yield surprising results. How extensive this activity will be depends, of course, upon the desirability of the site. In the course of coordinating a Smithtown, Long Island location for Warner Amex Network Operations Center no fewer than 66 objections were posed, and ultimately cleared. What's more, this level of determination has become common practice. One year ago not a single transmitting video earth station existed within 35 miles of New York City. By late '82 there will be no fewer than ten operational or under construction. It's a safe assumption that all faced large numbers of objections, and obviously resolved them. These resolutions may take many not readily apparent forms, for example assume you've filed for transmitter facilities and encountered objections something not so commonly known is having satisfied the commissions criteria, no existing or future carrier may object to your application, and if it is shown that you indeed will impose objectionable interference to existing facilities, you may learn that the responsibility for eliminating the interference, surprisingly, rests not with you, but with the carrier who is being interfered with!

Consider that no efficiently engineered system utilizes more sophisticated (i.e., expensive) antennas than necessary. In the case of the common carriers, when most routes were built, satellite communication was not sufficiently developed to constitute a significant interference source. Consequently, and prudently, antenna systems installed by common carriers prior to 1978 were often of a type providing high gain and low wind loading, but poor off axis discrimination. The familiar periscope antenna is one example of such a system.

The commission in what must be considered extraordinary foresight, provided in the rules that such antenna systems would be permitted until such time as they inhibited future communications systems growth. (By being interfered with by those future systems), at which time the effected carrier must upgrade the system, or accept the potential interference and not impede the interference application! But, don't expect the affected carrier to volunteer this sort of information. You must go to the rules, and in such matters a good communications attorney in concert with a frequency coordination firm is a valuable resource. But beyond these legal and negotiable actions, the most effective and self determined measures one can take are the scientific.

It's axiomatic in designing satellite earth station facilities that, if it works in terrestrial systems, do the opposite in a satellite system. (i.e. put a tower on a hill; put an earth station in a hole.) The extent of this simple philosophy is very surprising. All of those physical obstacles which were so troublesome when path profiling microwave links and those properties of electromagnetic waves which conspired to make point to point reliability seem unachievable, will almost without exception work to the advantage of the satellite system planner.

SOME BASIC EXAMPLES

Shielding both natural and man-made has been shown to be a highly effective method of eliminating interference. Microwaves do not substantially penetrate mineral substances and are virtually devoid of ground wave components. Thus, fences, walls, buildings or earthen mounds can serve as highly effective shields when located between interference source and receiver. When a carrier objects to your application, the objection is generally a computer spit out based upon a flat earth model. Careful examination of USGS contour maps and great circle calculations will go far in reducing interference impact. After a tentative site has been selected and interference sources identified, a path profile may be undertaken. The objective being to determine the extent of terrain shielding existing between your site and the interference source(s). In the case of transmitting earth station interference is both received and generated. Given antenna reciprocity theory, however, both may be handled similarly. A path profile is best plotted on rectilinear graph paper with obstacle information taken from USGS topographical charts of 1:7500 scale. Draw straight lines on the topos between your site and the interference sites, identify obstacle elevations between them and transfer this data to the graph paper in the 'y' axis.

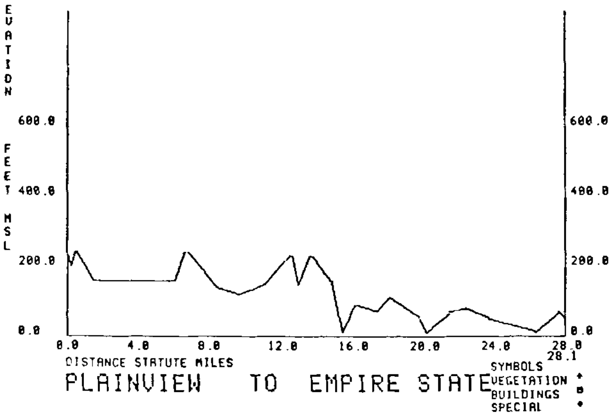


Fig. 2

Mark the midpoint between the two objects. This is maximum earth bulge and should be considered an obstacle. Transposing all major vertical elevations from the contour map to the 'y' axis graph sheets will yield a vivid representation of your line of site situation. Earth curvature (bulge) should be added to each obstacle height as it effectively raises those obstacles higher into the path. Earth bulge (h) may be calculated as follows:

$$h = 0.677\ (d_1 d_2) \qquad (1)$$

where:

d_1 = distance from near end of interference path to obstacle.

d_2 = distance from far end of interference link to obstacle.

Determination of actual relative obstacle heights is probably the single most important factor under the control of the designer as it will affect a parameter known as "takeoff angle" between the interference site and the candidate site. Every degree of takeoff angle we build into our model will contribute about 12dB of attenuation between interference source and sink, and can be controlled to considerable degree by site engineering.

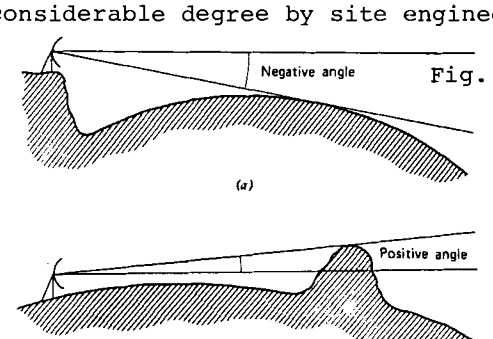


Fig. 3

DIFFRACTION & REFRACTION

Radio waves travelling through the atmosphere do not follow true straight lines, even at microwave frequencies, they are actually refracted, or bent. More importantly, they may also be diffracted. In designing the Warner Amex Smithtown site the phenomenon of ray diffraction was applied extensively. To make the equation for earth bulge (Eq-1) more effective, it may be modified to include the effects of departure from straight line propagation, which is assumed in (Eq-1).

Refraction

Refraction may cause a transmitted wave to be "bent" toward or away from the earth. If it is bent away from the earth, it is effectively the same as if earth bulge were increased. The effects of refraction may be determined mathematically through the inclusion of a K factor to (Eq-1) as follows:

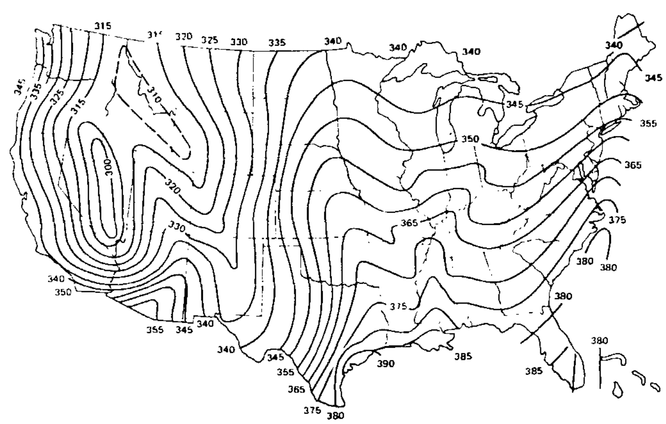
$$d(ft) = \frac{0.667\ d_1 d_2}{K} \qquad (2)$$

where:

$d_1 d_2$ are expressed in miles

$$K = \frac{\text{effective earth radius}}{\text{true earth radius}}$$

The standard K factor is 4/3 and as such, will yield negative results in most cases. This should not, however, be accepted carte blanche when optimizing a candidate site. Refer to the sea level refractivity chart below.

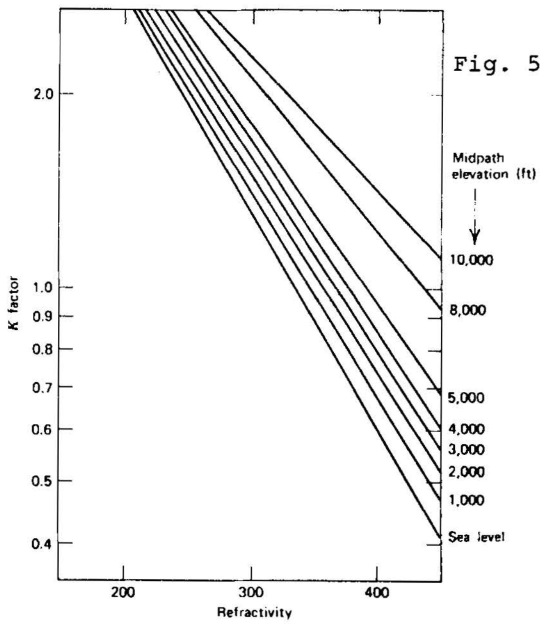


Sea level refractivity (N_0) index for the continental United States—maximum for worst month (August).

Fig. 4

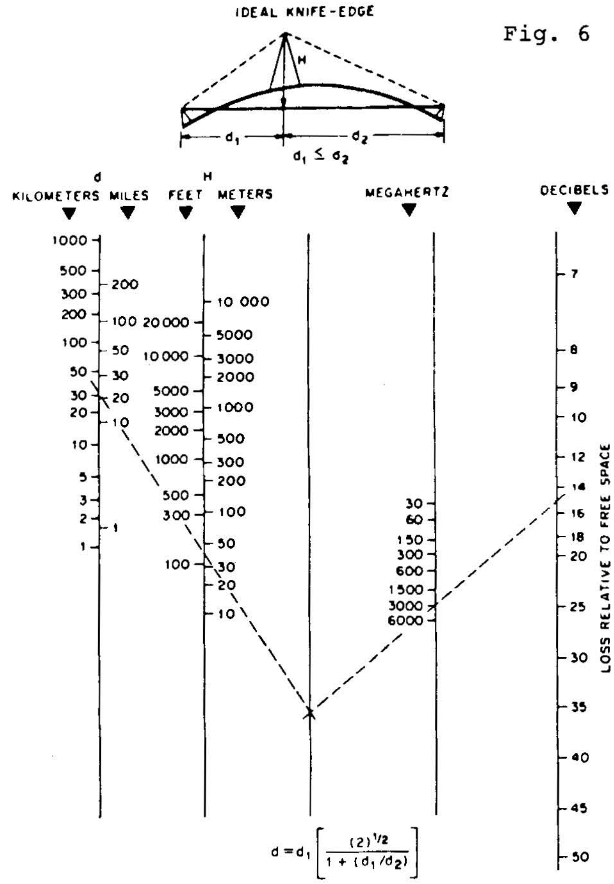
Find the refractivity index for the area of interest. Apply this to the chart of Figure (5) to determine K factor, and subsequent effect upon midpath earth bulge. As can be seen, for K factors of less than 1, a significant improvement in terrain blockage can be achieved.

Fig. 5



K factor scaled for midpath elevation above mean sea level.

Fig. 6



Diffraction

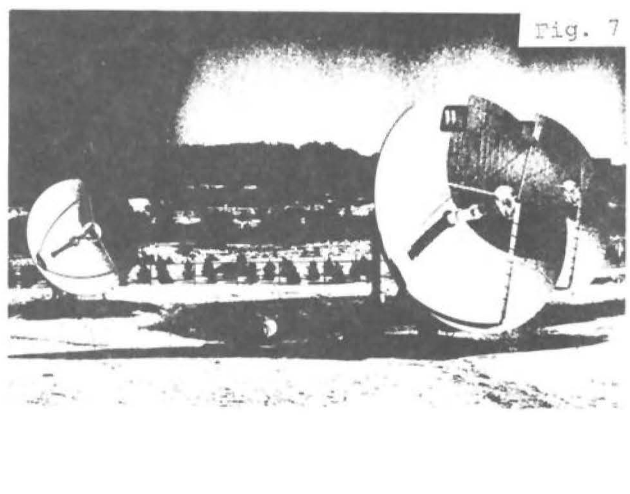
The other factor which must be added to obstacle height when optimizing shielding pertains to the effects of diffraction. A wave front exhibits expanding properties as it travels through space. These result in phase transitions and reflections as the expanding wavefront passes over obstacles.

As with refraction these properties, known as fresnel effect, result in increases or decreases in signal strength, relative to free space propagation. The graph of figure (6) approximates the diffraction effect to a propigating wave when fresnel clearance is disrupted by an obstacle. In this case, an ideal knife edge. First fresnel zone clearance may be estimated by the formula:

$$R = \frac{13.58\sqrt{\lambda d_1 d_2}}{D} \qquad (3)$$

where λ = wavelength of signal (ft)
d_1 = distance from transmitter to path obstacle (statute mi)
d_2 = distance from path obstacle to receiver (statute mi)
$D = d_1 + d_2$ (total path length in statute mi)

If fresnel zone clearance is not present between your antenna centerline and that of the interference facility some diffraction loss exists, and may be considered in your optimal model. Surprisingly effective results may be obtained by deliberate injection of diffracting apparatus into the interference path. These may take the very substantial form of an earthen mound or be as simple as metal fencing, properly placed. In the case of a new building facility, such as Warner Amex at Smithtown, interactive location of antennas



and building contributed a diffraction. When coupled with terrain modification and diffraction fencing all of which are minimally visible figure (7) resulted in diffraction losses in excess of -60dB to interfering signals.

Contrary to advice that the site was not clearable and using the above mentioned techniques it was determined that a strong possibility of natural and artificial interference attenuation could be brought to bear at this site. Once this evidence was gathered three days were spent by both myself and the building architect at Compucons computer in Dallas. Various combinations of building size, location, and elevation were tried and fed to the computer along with antenna locations and elevations in an effort to achieve optimum diffraction losses. After what seemed inumerable postulations and the application of an unorthodox double diffraction fence atop the building, (not visible) the right combination was found and ultimately cleared the site to the satisfaction of all carriers and the commission.

CONCLUSION

We've discussed one aspect of a very large project, the successful completion of which was an industry first.

Two factors were above all responsible for that success. The skill and resources of the Compucon Corporation, whose willingness to apply unorthodox techniques in a sustained effort, finally worked. And, the complete design freedom enjoyed under a very courageous and farsighted management at Warner Amex Satellite Entertainment Company.

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ELECTRICAL SAFETY CODES

Henry Kallina
Walnut, Iowa 51577

Cable Communications of Iowa

The cable television industry has improved our television viewing for many millions of people. Our industry has contributed to the high technology of the world we live in. We now deliver TV signals of many varied program sources, and we also transport digital signals in our cable systems in both directions. We now use computers in our everyday working on our systems; i.e. doing our billing, system design, and addressing converters. We spend many hours maintaining our systems so that our subscribers have 24 hour service. The various jobs which we perform all have a basic underlying motive-to operate a profitable business and do it safely.

We have built most of our cable systems using the finest equipment available. We phase lock our head inns, provide interactive two-way transmission, and even turn on and off the TV signals at the subscribers TV from the office with a computer. We have accomplished this under an ordinance called a franchise, which the city fathers grant us. We all have read our franchises and in them we find that we must abide by various codes; i.e. National Electrical Safety Code, National Electrical Code, and others. Most system engineers have copies of these code books, most not current, but why should we have current ones when the ones we have don't make any sense? When we try to read them we wonder if a lawyer who didn't know who Volt was, or which end of a piece of copper wire was positive or negative, wrote these code books in his spare time!!!!!

When you ask someone about the code, they usually give you a strange look and either change the subject or bluff their way through the answer. Everyone seems to have some idea what the code is, but are just not quite sure as to what the code actually says!!! I will try to clear some of the mystery concerning the safety codes and hope that cable operators will begin to pay more attention to this most important subject.

This paper will concern itself with only two of the many codes which we might operate under. The first is the "National Electrical Safety Code" which concerns itself with our physical outside distribution plant. The second is the "National Electrical Code" which concerns itself with the installation of our cable drops into buildings and homes.

Both codes have one main primary objective--electrical safety to our personnel who work on the cable television plant and electrical safety to the subscribers who we have hooked up to our cable television plant. "Safety" is the key word and if we use this as our main goal in providing cable television service to our subscribers, we will accomplish the following:

1. Make our cable television systems safe from electrical shock hazards to our company personnel.
2. Make our cable television systems safe from electrical shock hazards to our subscribers.
3. Reduce our liability to the general public and to ourselves.
4. Ensure that our cable television plant is at the same "ground potential" as the telephone plant and the power system.
5. Reduce our system down-time because of better grounding paths for electrical disturbances with no difference of potential between our system and the phone or power systems.
6. Reduce converter/descrambler failures because of better ground paths and equipotential systems in homes and buildings.

It is now becoming clear how important it really is to pay much attention to the mysterious code books and begin to use them as a good source and foundation to build an effective and grounded cable television plant. The small costs of bonding strands together, bonding to existing verticles and even driving ground rods is insignificant compared to the potential costs of system down-time. Subscriber grounding and bonding is also small in cost compared to the replacement and repair of converters costing $80-150.

The utilities have had much experience in the field of being liable for damages caused directly or indirectly by their plants to the property of others. The cable television industry has had little experience in this field, and as we begin to provide services to subscribers in areas of protection of both life and property, we will be forced into situations where we are going to be held accountable for our actions. Sound engineering practices based on existing codes will benefit our cable television plant and reduce our liability.

The code books have order to them in the way they are written and once that is understood then making some sense of the code becomes clearer. The codes are written ambiguously and are subject to interpretation and that is what makes them hard to understand. The best hint for understanding the code books is that they are written like a novel one would buy at the book store. You have to start at page one and build and progress on previous sections until you arrive at the section or topic which interests you. Unlike an encyclopedia, in which one can pick a particular subject, turn to that page and read and understand with no reference to prededing chapters and sections. One example of this in the code is the definition of "Electrode" which one possibly considers a simple ground rod. This is not the case and one must search for the exact definition and also be aware that there are heirarchies of "Electrodes". A 3, 4, or 6 foot ground rod does not constitute a grounding electrode anywhere!!!!!! A manufacturer produces these lengths of ground rods because someone wants to buy them. Nothing less than an 8 foot rod will meet code, of specific material and diameter, and shall maintain at least 25 ohms to ground at all times. In other words, if in the winter time the frost level is deep enough to increase the ground resistance to more than 25 ohms to ground, then a longer rod is required or you do not meet code. The same applies in sandy soil. But, of more importance, if you do not maintain low resistance paths to ground, where do you think that surges go if your electrode resistances are too high...they propagate down the cable into your amplifiers and then you have an outage.

Another example is the grounding of our strand. The NESC says that no less than 4 connections per mile, which translates to about every 1st, 10th, and last pole in our plant, are necessary. This is not good enough in this day and time. We should bond and ground everywhere we can at every pole we can, as this reduces the differences of potential between us and the other utilities. It is the difference of potential that causes failures in 99 per cent of the outages, and not defective transistors. Remember that every time we double the number of ground paths we cut the resistance to ground in half. An effective ground has to be less than 2(two) ohms to ground. A 25 ohm ground is ineffective in shunting lightning to ground...again one must be concerned with bonding conductor size, bonding materials, and proper methods of bonding and grounding. Old wives tales which have been passed down through the ages from grunt to grunt, lineman to lineman, and technician to technician have no place in todays cable television plant.

A word of caution--if the power company uses a delta distribution system in changing from primary AC to 120/240 AC you should not bond the cable TV strand to the power company vertical grounding wire...install your own grounding system on the poles and protect the last 8 feet of your grounding vertical with a mechanically strong insulated guard securely fastened to the pole. The ground rod must be equal or below ground level and must provide at least 25 ohms of resistance (or less) to ground in its most adverse condition.

The National Electrical Code prescribes the method in which a home or building should be grounded. A device such as a grounding block is needed to ground the outside shield of our coaxial cable. A green wire, not smaller than #18 is now used to connect the ground block or device to the grounding electrode system of the home or building. In order to sustain the least liability, the attachment point is where the power company attaches their neutral to the grounding electrode system of the building or home. This point can be more difficult to locate than you think, but if you find the grounding conductor out of the fuse panel, then you can connect anywhere along this grounding conductor. Using the same grounding point the phone company uses does not constitute an effective ground according to code...the phone installer may have used the wrong point of con ection...and two wrongs do not make a right! If this is not readily available then your own grounding electrode can be installed (not less than 8 ft. in length made of the required material) and must maintain less than 25 ohms to ground in worse condition.

I hope that this paper sparks interest in this most difficult subject and that we will begin to follow code. It not only reduces our liability to the general public, it even helps prolong longetivity of our cable systems.

Code books have committies and the people on the committies have names and phone numbers and should be called when one has a question about the code. The power company and phone company are also very good and informative sources as to questions, but be weary of "wives tales". Undertaking the task of understanding the codes is not an easy project, and it will take many hours even before daylight is seen at the end of the tunnel...but it is worth the time and effort.

The latest edition of the "National Electrical Safety Code" can be obtained from the Institute of Electrical and Electronics Engineers, Inc. 345 East 47th St., New York, NY 10017.

Latest editions of the "National Electrical Code" can be obtained from your electrical wholesaler in your community.

I want to thank our Chief Engineer, Mark Bowers, and the manager of the Atlantic Municipal Utilities, Dick Stevens for their help in this report.

FIBER OPTICS MYTHOLOGY

Archer S. Taylor
Senior Vice President, Engineering

Malarkey-Taylor Associates, Incorporated
Washington, D.C.

Signal transmission on a tiny glass thread is a technological development with vast implications for telecommunications. Fiber optics could even have as revolutionary an impact on the future of our society as solid state technology itself.

But if the cable television industry is to realize the very real promise of fiber optics technology in its special corner of the telecommunications universe, it must carefully distinguish between fact and fancy. The real facts are great enough; but opportunity could pass us by if we waste our time and capital on the dreams.

Five myths about fiber optics keep recurring, in the trade press as well as in magazines and newspapers of general circulation. The critical question for evaluating these claims of the superiority of fiber optics is:

"compared to what?"

MYTH NUMBER ONE.
Optical fiber has enormous, almost unlimited bandwidth.

Certainly, compared to a 4 kHz pair of telephone wires, an optical fiber does have "enormous bandwidth". But, optical fiber technology is presently limited to 4 or 5 TV channels because of dispersion in the glass, and non-linearity in the optical devices. FM is better than AM, but requires several times as much bandwidth per channel. Digital, PCM is almost impervious to dispersion and non-linearity, but requires very great bandwidth per channel.

So, compared to coaxial cables, capable of carrying up to 55 or 60 TV channels, the "enormous bandwidth" of fiber optics systems simply is not now a fact. Undoubtedly this will change, just as the channel capacity of coaxial cables increased dramatically from 27 up to 55 or 60; but it will be a long, long time before a single fiber can match the channel capacity of a single coaxial cable.

MYTH NUMBER TWO.
Low loss in optical fibers means very few amplifiers.

Optical fibers are routinely available today with certifiable losses of 0.18 dB per 100 feet (actually 6 dB per kilometer). This is equivalent to the loss in a 3-inch diameter coaxial cable at 400 MHz. With such low loss, repeaters with 20 dB gain could, in fact, be spaced 2 miles apart.

Unfortunately, since the fibers can only carry 5 TV channels, it would take 11 or 12 fibers to match the 55 or 60 channel capacity of coaxial systems. Each fiber would require its own photodetector, repeater, and laser or LED light source. Every 2 miles, then, there will be 11 or 12 repeaters; that is, an average of one repeater for every 880 to 960 strand feet. The old 412 cable would do better than that.

Of course, it is much easier to maintain 11 or 12 repeaters at one location than 8 or 10 repeaters at 8 or 10 locations. Moreover, the wide repeater spacing means shorter cascades. This is quite important because of the non-linearity of the light sources which must also be cascaded.

MYTH NUMBER THREE.
Optical fiber is cheap, and will greatly reduce the cost of systems.

Next to water, sand is probably one of the most plentiful and easily obtained materials on the face of the earth. However, only particular types and grades of silica sand are suitable for making optical fibers; and other, more expensive chemicals must be added to the silica to achieve the necessary refraction index. Moreover, fabrication of the hairlike fibers, with precise physical dimensions and optical characteristics is a sophisticated process that would not even be possible without elaborate computer control.

Thus, although sand is cheap, fiber fabrication isn't.

Because of limited channel capacity, 11 or 12 fibers are required to carry 55 or 60 channels. If one fiber costs 10 cents a foot, the bundle must cost more than $1 a foot, two and a half times as much as 3/4-inch coaxial cable. The fiber system requires more, not fewer, repeaters, than the coaxial system, and each repeater requires a photodetector and light source not necessary with coaxial cable.

Finally, because of the non-linearity, most fiber optics TV projects have been based on FM, baseband or PCM techniques. Each of these requires a single channel modulator and demodulator for each of the 55 or 60 channels, at a cost of $3,000 to $5,000 per channel. Such systems do perform much better than VSB/AM coaxial systems. But until VSB/AM becomes feasible for fiber optic systems, they will remain much more expensive, though better, than AM coaxial systems.

In fact, development may already have reached the stage where 4 or 5 VSB/AM channels can be carried as successfully on long fibers as on coaxial cable.

MYTH NUMBER FOUR.
Optical fibers are so small and light they can easily be installed anywhere.

Each optical fiber is, of course, very small and light in weight. However, each fiber must be loosely encased in its own protective plastic sheath, and for comparable channel capacity, 11 or 12 of these sheaths must be cabled together, with an overall outer jacket. In addition, special strength members must be included to relieve the tiny fibers of the mechanical stress of installation and other hazards. The resulting fiber cable may be only slightly smaller and lighter in weight than the customary coaxial trunk and feeder cables.

Even the inherently small size and weight of optical fibers are almost entirely offset by the practical requirements.

MYTH NUMBER FIVE.
Glass is a non-conductor, so fiber optics does not have to comply with electrical codes.

Glass is a non-conductor of electricity. It will not transmit lightning or power line surges. It does not present a shock hazard; and it cannot be short-circuited.

But the steel strength members required to protect the fibers are conductors, and present all of these hazards. Unless glass or plastic strength members are used instead of steel, and the optical fiber cable is installed on plastic messenger strand instead of galvanized steel, the non-conducting feature is of little value.

Most of the limitations of fiber optics today derive from the present limitations of the optical systems. Optical dispersion, which shrinks the bandwidth as the length of the fiber increases, has already been improved. Maybe it will get even better. The non-linearity of the light sources (not to mention their short life) is probably also subject to improvement.

These developments will be slow, however, unless a crash program is demanded by circumstances such as precipitated the recent 400 MHz development.

For the present, it appears quite safe to recognize that optical fiber is not a practical substitute for coaxial cable in the conventional tree-type distribution systems being built today.

However, fiber optics does have some valuable applications in today's cable television industry. A few channels transmitted over short enough distances that repeaters are not required, can provide higher technical quality and reliability than would be possible with coaxial cable, and at realistic cost. This is particularly useful for the critical TVRO and local off-air signals. FMTV provides exceptionally high transmission quality for hub interconnections, where the high cost can be widely shared. Fiber optics can be used in this application without unduly increasing the cost, and with the advantage of having fewer locations requiring maintenance of active devices.

These are only the sideshows, however. The main event really lies ahead when cable TV systems change from tree-type distribution to star-type, the "switched system" as it was called a dozen years ago. Instead of concentrations of only 4 or 8 or 16 or even 24 off-premises converters, each switching or processing center will serve 300 or 400 or maybe even 1,000 subscribers with fiber service drops, carrying one TV channel to each subscriber, perhaps as much as 2,000 feet or more away.

The small size of a bundle of 200 fibers, compared with the size of 200 RG-59 coaxial drop cables, makes this feasible. With only one channel, bandwidth and intermodulation are well within the capability even of the low-performance grades of fiber.

The set-top converter will be banished, forever. Scrambling will no longer be necessary. Three-fourths of the system will be passive--no power, no amplifiers, no splices, no leaky connectors. Perhaps even the teletext decoding, storage, and character generating facilities could be located in the switching or processing centers instead of expensive individual home terminals.

It is not ready yet; and probably a rather long evolutionary period will be needed to adapt present business practices, marketing methods, and personnel training to the new concepts, as well as to optimize the hardware configurations, installation techniques, and operational practices.

The advantages in maintenance costs, unlimited channel capacity, management flexibility, superior technical performance and reliability, especially in two-way systems are so great that it is bound to happen; but that is another story for another panel. In any case, it is only possible because of fiber optics.

MALARKEY-TAYLOR ASSOCIATES
1301 Pennsylvania Avenue, N.W. Suite 200
Washington, D.C. 20004

FULL FIELD TIERED ADDRESSABLE TELETEXT

William L. Thomas

Zenith Radio Corporation
Glenview, Illinois 60025

Tiering and addressability are not new concepts to the cable television industry. However, the application of these concepts to full field teletext presents an exciting new service which can be offered. The ability to subscribe to specific categories out of a large, instantly available, data base is both technically feasible and affordable. The capability of full field tiered, addressable, and scrambled teletext to offer a profitable service today is further enhanced by future expansion possibilities into the areas of two-way interactive services, home games and computers.

INTRODUCTION

Many teletext systems are under consideration for use in both broadcast and cable applications. All these systems have been defined in a way which allows full field operation. However, very little has been said about how such a system would operate. Presented in the following discussion are some ideas which form the framework for a successful application of full field teletext.

Full field teletext offers tremendous throughput of data into the home. Coupled with addressability and tiering concepts already being widely used in the industry, a system that offers selective subscription to large amounts of information can be offered.

Using the North American version of the British teletext system as a model, a calculation of the system throughput can easily be made. Assuming a 40 character 24 row page display format, it takes 30 horizontal scan lines to transmit a full page. If 250 lines per field are allocated for text, the full field throughput will be 500 pages/sec!

$$(250 \text{ lines/field})/(30 \text{ lines/page}) * (60 \text{ fields/sec}) = 500 \text{ pages/sec}$$

In a system designed for a worst case wait of 10 seconds to receive a page, a 5000 page data base could be available. With such a data base the average wait for any page would be only 5 seconds. If a longer average access is tolerable, such as 10 seconds, a 10,000 page data base could be offered. For purposes of this discussion a 5000 page data base will be assumed. Although the British teletext system was used in this calculation, the other teletext systems under worldwide consideration have similar average page lengths, leading to a similar result.

One of the exciting characteristics of electronic data bases is the ability to have the information instantly updated. For example, if 250 pages of a data base are assigned to the latest news, weather, and sports information, continuous updates in these categories could account for thousands of pages of information presented in a day's time. Hence, the amount of information that could be passed through a "5000" page data base in a single day is almost unlimited. The main reason for having 5000 pages becomes the ability to assign sections of pages to specific information services.

Tiering allows these sections of a large data base to make sense from a customer point of view. A sufficient number of tiers, say 40, will allow for a considerable selection of "programs" to be offered. It is not the purpose of this paper to point out the programs that could be delivered via teletext, however, some categories are: news, weather, sports, entertainment, professional information, business information, television guides for the cable system, classified advertising, shopping information, etc... By having 40 independent tiers of programming it is felt that a profitable (for the cable operator) and interesting (for the customer) service would be offered.

Along with tiering comes the concept of addressability, where each customer has a unique subscriber code that he is identified by. The tiering authorizations could then be sent specifically to each decoder as part of the overall teletext data stream. To keep the headend equipment simplified, it is proposed that this data be sent as specially coded teletext pages, as part of the normal full field transmission.

As a necessary part of any tiered, addressable system, whether it carry video or teletext programming, a scrambling method is required. In the case of video, it is a system design concern as to what extent the scrambling can be beaten by "pirate" decoders. For digital transmission of data there is considerably greater freedom in designing levels of scrambling, all the way from simple inversion of the data (similar to video inversion) to encryption which requires a digital key to unlock. As a minimum, some scrambling is required to prevent a decoder designed for receiving normal broadcast teletext from having access to the subscription portion of the data base.

DECODER FEATURES

Not all subscribers will be interested in receiving subscription teletext information. As a result, it is not appropriate to include a text decoder of the required complexity in the cable converter itself. This leads to the concept of a modular add on teletext decoder. In this case, the converter must be manufactured with a provision to connect modules of this type. With some thought, other modules may also be defined that would be connected at this interface. The specifications that are desired for such a system architecture are as follows (assuming a baseband remote controlled converter):

1) Video signal input and output.
2) Remote control input and output.
3) Audio signal input and output.

All these signals could be made available on a single connector with a shorting plug installed for normal operation of the converter.

The teletext decoder would include only the required circuitry to grab pages, check authorization information, respond to user requests and generate the teletext video in a compatible form with the mode of operation (text or caption mode). The display format would be 40 character rows with between 20 and 24 rows per page. Graphics modes would also be available depending on their cost benefit ratio. Certainly the mosaic type graphics would be offered since they "come for free." Various color choices would be available such as the eight combinations of red, blue, and green.

A typical user session might involve the following steps:

- User selects text mode.
- A system welcome page is presented.
- Emergency information pages are identified.
- Personal or group messages are noted as being available, with optional viewing.
- The system index page is displayed, without page selection ranges.
- (Decoder acquires user tier authorization information.)
- A modified index page is shown with valid page ranges.
- User selects valid pages and continues session.
- (Decoder continues to monitor status for authorization or system changes.)

The last two items are where the majority of the time will be spent in a typical session. User page requests will be "delivered" with an average wait of only 5 seconds. The decoder will also periodically check the system and user status, making any changes known to the user during the session. This is important since some users may leave a single page selected for a long period of time, say, for the purpose of monitoring their favorite stock information.

Special features which a system such as this could offer are numerous. An obvious use is as the downstream channel for two-way interactive actions. Also, an enhanced version of this teletext decoder could form the basis of a home TV game or computer, where games and programs are sent as part of the teletext data stream. The tiered addressable aspect of the decoder would be an essential ingredient in delivering these kinds of services.

HEADEND REQUIREMENTS

The equipment and personnel requirements at the headend will vary depending on the amount of service provided to the subscribers. Let's take a look at what is required for a minimal system installation, where most of the information is delivered to the cable operator from outside information providers:

Equipment	Estimated $
Headend computer/software	20,000
5 Mbytes of memory	35,000
Channel inserter	10,000
Local editing console	6,000
Remote entry modems	2,000
Contingency	2,000
Total	$75,000

The cost of this 5000 page system can be reduced by roughly $25,000 if one starts with only 1000 pages. Hence, a $50,000 investment is sufficient to start. At any time, the system could be expanded with additional pages of memory.

The headend computer is the "traffic controller" of the system. It takes incoming information from the billing computer (tier authorizations), from the outside information providers (via the remote entry modems), and from the local editing console (local information, emergency alert information, customer messages, etc...). The memory store of 5 Mbytes holds the currently active 5000 pages; these are loaded from the computer and backed up on disk storage devices. The channel inserter takes information from the memory store and generates the full field teletext. Note that the computer is not directly involved in the rapid recirculation of the 5000 pages, instead the channel inserter works directly with the memory store on a continuous basis. The local editing console is used for creation of the local part of the data base. This console could also be used for entry of customer tier authorization information, although the preferred method is from the master billing computer.

One of the interesting tasks of the headend computer could be to format the incoming information providers copy into the appropriate display format that is required in the system. However, many sources of information will come preformatted, since there is reason to believe that unique editorial styles will develop as teletext becomes more popular.

SUMMARY AND CONCLUSIONS

A full field, tiered, addressable, and scrambled teletext system has been described. This system could be implemented based on a variety of current teletext technologies such as 1) British teletext, 2) French teletext (Antiope), 3) Canadian teletext (Telidon), or even 4) AT&T PLP teletext. Decoder characteristics from both the system and user perspective have been discussed. Headend costs have been estimated for two system configurations. Known technology allows text services to be offered in a cable system which will far exceed the scope of competitive services soon to be available from standard broadcasting. Furture extensions of a system such as this can cover such topics as two-way interactive services, home games and computers.

The availability of hardware and information providers in the next year will initiate what promises to be an exciting application of text delivery into the home.

IMPROVING CATV SYSTEM RELIABILITY WITH AUTOMATIC STATUS MONITORING AND BRIDGER SWITCHING

John Skrobko

SCIENTIFIC-ATLANTA INCORPORATED

ABSTRACT

Insight into the extent of status monitoring systems and their impact on cable systems is required by cable operators. While these systems have been suggested as a means of providing early warning and failure location to improve maintainability, their usage is yet to be widespread.

An approach to a status monitoring system with reverse disconnect features will be discussed. Design tradeoffs will be examined. System results will be studied to relate benefits and possible disadvantages.

With the extension of cable system usage beyond entertainment services, reliability and ease of maintenance have increased in importance. Marketability of cable services can be enhanced through proper monitoring of distribution plant.

INTRODUCTION

Status Monitoring Systems had been around all through the seventies while never genuinely becoming popular. Due to them being niceties rather than necessities, interest waned while cable systems grew. This growth and increasing concern in efficient maintenance has seasoned the serious developments seen in the past few years. The fact that many leading equipment manufacturers offer Status Monitoring Systems is evidence that the necessary technology and interest is here.

JUSTIFICATIONS

A cable operator locates a system fault by responding to customer complaints followed by a station to station search for the problem. His maintenance costs, personnel requirements and records of unhappy subscribers explode as his system expands. He needs a Status Monitoring System.

Status Monitoring minimizes fault location to the nearest station or cable span. It provides pre-fault detection by uncovering non-fatal yet out of tolerance conditions. In addition, since the system is automatic, it provides an around the clock vigil, detecting possible intermittent problems. With the advent of Data Business Communications over cable, what better way is there to monitor perfect transmission of data than by a system based on those principles?

Supplemented with reverse switching capability, Status Monitoring can isolate points of ingress to the reverse band. Noise can be limited by turning off unused feeders.

Naturally, all of this does not come easily. There are initial constraints which must be met. Nevertheless, there is testimony to the resulting success with the proper installation of a Status Monitoring System.

CABLE SYSTEM REQUIREMENTS

A station with both forward and reverse capability is required for the installation of Status Monitoring. All amplifiers must be set at correct operating levels. Otherwise, you will begin with faults. This may seem to be a simplistic point, but has however, significance. A system ordinarily appearing in top notch condition, relies heavily on the forgiveness designed into distribution electronics. By the nature of Status Monitoring, these areas of reprieve will be questioned and duly noted on the Status Report.

Margins must be allowed for the additional power requirements of Status Transponders in each Trunk Station.

Available bandwidth must be provided for both a forward and return data carrier. This varies among all equipment manufacturers and can significantly impact programming versatility. While some limit bandwidth to several hundred kilohertz, others occupy a full television channel bandwidth of six megahertz.

STATUS MONITORING COMPONENTS

In the headend, there are three major building blocks to a Status Monitoring System: Input-Output display and interface, Processor Controller, and Digital to Analog cable system interface or simply RF Subsystem. In the distribution plant are the many modules referred to as Amplifier Status Transponders.

The Input-Output display and interface is easily achieved through the use of a CRT display and keyboard. This connects to the Processor by a standard interface allowing flexibility and remote locatability if desired. The typewriter keyboard input eases operator interface.

The Processor is basically a "bit-pusher" providing parallel input and output. Data bits are available for output and ports are open for input at times specified by the internal software of the Processor. Commands and responses need to be written in simplified language to minimize operator confusion. The hardware must be reliable and provide non volatile memory for retention of important information in the event of a power failure. The advantage of a separate Processor permits the flexibility for future growth and expansion of a system.

The RF Subsystem can be subdivided for ease of explanation and maintenance. These separate modules are as follows: POWER SUPPLY, parallel to serial data converter or ENCODER, serial data TRANSMITTER, signal combiner or DIPLEX FILTER, serial data RECEIVER, and serial to parallel data converter or DECODER. The purpose of these modules is to take data from the Processor, transmit it to the Transponder, receive information from the Transponders and supply it as information to the Processor. In addition, they check to be certain that the polled address is indeed the same as the received address. Figure 1 is a block diagram showing the headend connections.

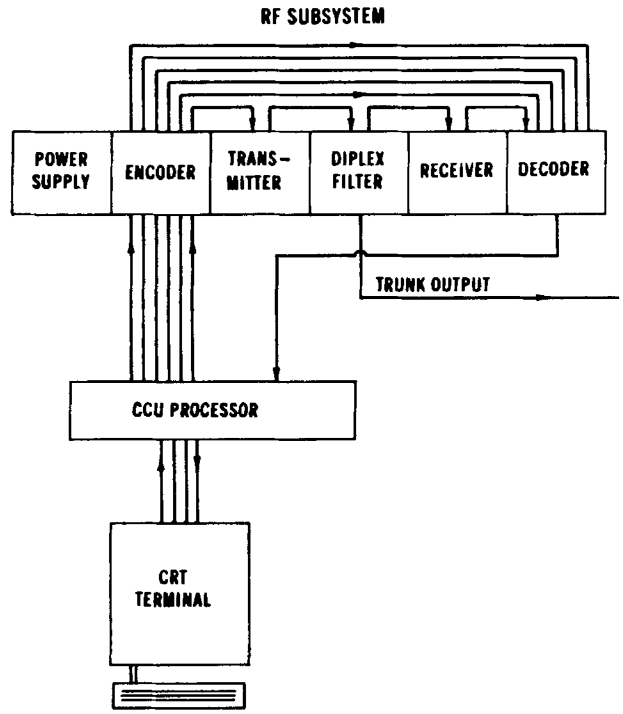

Figure 1: Block diagram showing signal connections of the Headend portion of the Status Monitoring System.

The Amplifier Status Transponders are basically small RF Subsystems with limited intelligence. The building blocks of these may be listed as: receiver, decoder, acknowledge determination, status determination, encoder and transmitter. A possible scheme for connecting RF to a transponder is shown in Figure 2.

PHILOSOPHY OF DESIGN

There are various tradeoffs which become apparent in the specification of a Status Monitoring System. Response time to a change in status should be as fast as possible while not sacrificing reliability. The amount of status data should be sufficient to provide an effective system while not causing operator confusion. Circuit simplicity is of paramount importance for reliability considerations but limits the capabilities of the system.

System timing is based on available bandwidth and software. Minimum signal bandwidth is preferable in order to limit infringement on revenue gathering signals. Elements leading to increased bandwidth are: increased data rate to speed up system response, and increased carrier deviation to desensitize receiver drift with temperature.

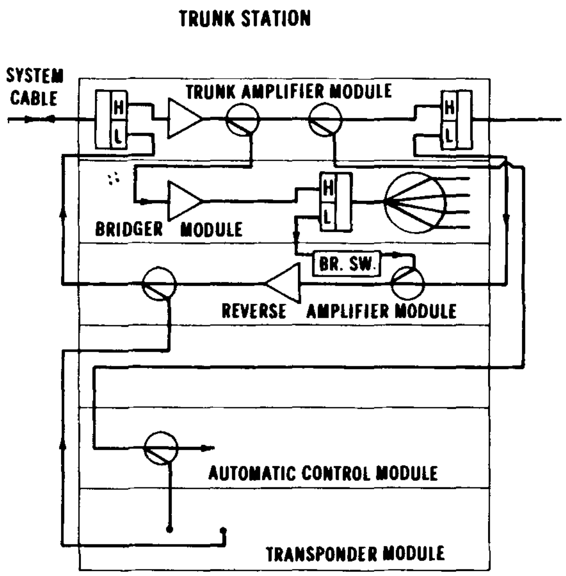

Figure 2: Block diagram showing RF signal through a trunk station with a Transponder module installed.

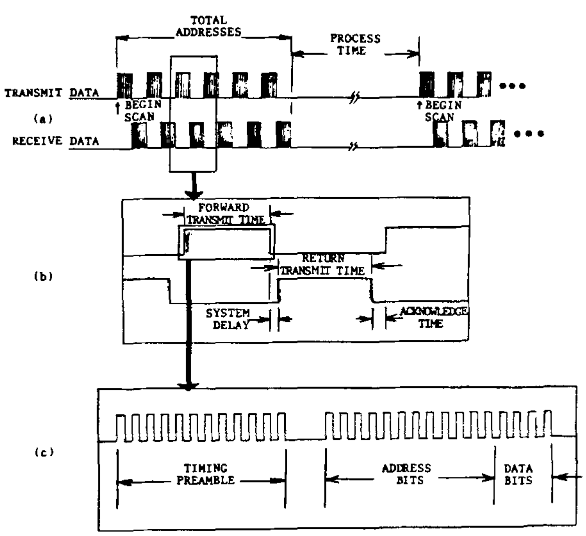

Figure 3: Timing Diagrams of Serial Data. A complete repetitive scan is shown (a) and relates process time to total address scan time. An expanded portion (b) uncovers contributions of system delay and headend acknowledge time compared to transmit time. This transmit time is expanded (c) to detail the makeup of this data stream.

Further understanding of timing constraints can be acquired from Figure 3. Figure 3(a) represents a portion of the continuous serial data streams output from the Encoder and input to the Decoder at the headend. The total number of activated addresses will lengthen the time for each cycle. In figure 3 (a) only six addresses are activated.

With a data rate of 7.5 KBPS, each address burst is approximately 4.2 msec. For this example, the total address time would be 4.2 msec repeated 12 times, or 50.4 msec.

The process time is governed by the speed and complexity of the software. Basically, this is the comparison between past and present status to determine if a change has occured. A time for this processing would be 280 msec.

Figure 3 (b) is an expanded portion of 3 (a). The system delay (possibly .3 msec worst case) and acknowledge time (typically 1.5 msec) are shown relative to the transmit time (4.2 msec as previously indicated). Other than the scan time for the total number of addresses, and the process time of the software, the next largest contributor to system timing is the data burst transmit time. Figure 3 (c) expands Figure 3 (b) further and indicates the various contributors to transmit time. The timing preamble is used to establish a clock frequency for the following data. The total number of address bits determines the largest number of possible activated addresses. In this system it is eleven bits, or 2048 addresses. The following four data bits complete this data burst. As a result, one can recognize the tradeoffs involved in address and data handling capability as well as total data burst time.

Other contributors to scan time delay are error prevention schemes. Reliability is significantly increased when two consecutive changes in status reports are received before updating the status record. Therefore, report of a change is delayed by an additional scan cycle.

Software complexity can both add and subtract cycle time. Those subroutines that add to the frills of a system naturally delay the system if they are in constant use. Those that permit limited scans for the aid of distribution fault troubleshooting can significantly add to the flexibility and speed of operation. If a situation of numerous intermittent faults developed, the operator would be overwhelmed with continuous changes in status. The ability to scan the entire system yet monitor a small portion is a time saver. Observing individual or blocks of station data in a large system becomes a mandatory software tool. In systems with reverse switching capability, automatic rather than manual switching control can add to the value of a more complex software package.

In both designing and specifying a Status Monitoring System, all of these aspects must be considered to optimize that system for the particular operation.

INSTALLATION

Perhaps never before have instructions been so important to the cable operator.

Access to a two-way cable and visibility of all distribution trunk stations requires a headend origination of Status Monitoring signals. Remote terminal location is possible through the use of modems.

A multiple hub site system requires hub bypassing for both forward and return carriers. The simplest approach is a dedicated bypass cable with bandpass filters for the carriers. This scheme is shown in Figure 4.

Amplifier status transponders need access to both forward and return RF paths as well as AC and DC powering and reverse switch control. Locating the transponders in the station housing is most convenient. Otherwise, strand mounting an additional housing and interfacing all these connections is required.

In this system, since these transponders are factory preset, and merely plug into the trunk station housing, installation is simple. The only requirement is to set the proper address for that station.

A map is a necessity to maintaining order to address numbers. Assignments should begin at the origination site and be in sequence for each trunk run, not to be interrupted until the complete length of trunk terminates. Splits can then be accommodated in the same manner. Confusion arises when an rf failure in one station is corrected by the following automatic station thus driving it out of its normal operating windows. This would indicate a failure of both stations. Repairs need to be directed starting at the first reported station, which is easily recognized in an efficiently numbered system.

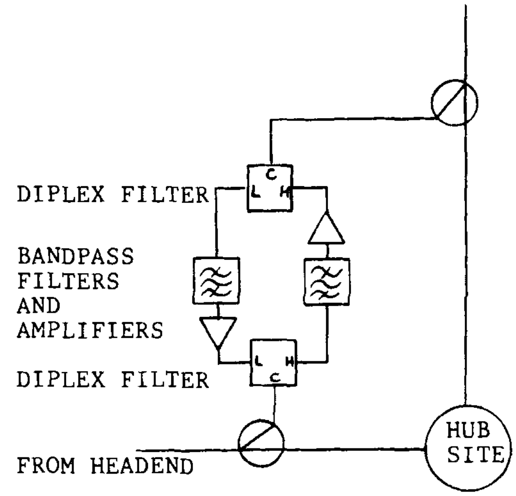

Figure 4: Block diagram showing scheme for bypassing a hub site for Status Monitoring.

CONSEQUENCES

Installed in an existing system, Status Monitoring will uncover faults in what seemed to be a working distribution plant. Intermittents, unbalanced stations out of AGC ranges, and out of tolerance powering are some possible faults previously left undetected. Initially, the process of eliminating these problems will cause additional burdens on a staff of field technicians. Only those who can use the system after the installation will appreciate the effectiveness of it.

There is a long term consequence which must be accepted with this system. This individual module adds to the complexity of the trunk station. The different and unfamiliar technologies of digital and high impedance circuitry will initially frustrate the field technicians' seventy-five ohm rf concept of cable distribution. Normally, failure does not interrupt service, but does prevent monitoring capability, and must be serviced.

Another potential cause for concern is the ultimate integration of the headend and distribution plant. Faults will be detected and reported to headend personnel. In large systems where the two are indeed segregated and approach factions of competition, the teamwork required by the Status Monitoring System will be thwarted.

Nonetheless, Status Monitoring has the capability of providing a means of perfect system maintenance. The operator is furnished with advanced warnings and immediate fault locations. There is nothing quite like the warm feeling radiated by a CRT displaying no faults in an entire cable system.

CONCLUSION

Various aspects of a Status Monitoring System have been described. Justifications, requirements, components and installation have been treated. Some insight into the philosophy behind design tradeoffs has been given. Hopefully, the reader is in a better position to not only pass judgement on various manufacturers versions of equipment, but better assess the impact of such a system on any particular cable system.

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INTER BRIDGER TRUNKING FOR INFORMATION SERVICES

Robert R. Brown Jr.

Cima Telephone and Television

ABSTRACT

The challenge of CATV interactive services may require a new plant topology. A circuit switching network that bypasses the headend for information flow, while using the existing tree structure of CATV plant for supervision and control, is proposed.

The method involves the installation of a "dumb" switching node at each bridger and interconnecting these nodes within a hexagonal mesh overlaying the city. The node will route signalling upstream to a supervisor in the headend. The supervisor will activate nodes downstream according to a routing algorithm. In this fashion subscriber terminal information from one bridger can be trunked through the mesh to a subscriber terminal off another bridger.

Introduction

The techniques used to develop this network were originally derived as a method to interconnect several remote telephones with a single cable pair. Two minima problems, minimum spanning and Steiner's Problem, were studied. Minimum spanning offered the most economical path between points, but Steiner's solution suggested adding additional points for further economy. The geometry of Steiner's solution, with its many 120 degree angles and tree forming a nearly hexagonal structure, could conform to a routing arithmetic. Demand for not only two way, but point to point wideband communication on CATV plant makes some form of switching network prime for consideration. A brief look at some general properties of telephone and CATV plant will show the kinds of communication available now.

Sharing subscriber communications from each bridger station into a distributed coaxial switching network can be accomplished now. While numerical analysis of traffic loading is beyond the scope of this work, the proposed network has sufficient flexibility and bandwidth to outperform present CATV plant.

Communication

First we must define what is meant by communication. There must be a source of information, a sink for information, and a path to transfer the information from source to sink. This simple process, illustrated in figure one, becomes the objective of the proposed network.

FIG. I

The Desired Communication

Demand for new services has resulted in video, computer, teletype, and alarm information, among others, sharing spectrum with home entertainment on CATV plant. Some of these new services are point to point communication - a single source wishing to transfer a block of information to a single sink. This information could be private and some means must be provided that only the desired sink receives the information. The reverse can also be true, some sinks only wish to receive information intended for them.

When sources or sinks are computer terminals, large bandwidth is required for timely transfer. The standard TV channel has large amounts of information when compared to other forms of communication such as voice. The paths for these new services must be able to pass this information. Up to circuit limits, increasing the signal to noise ratio of a channel will allow more information to pass in a given time. However, large blocks of information required for video or computers ultimately require large bandwidth for efficient operation. Another kind of communication, between computers, requires a large block of information to be transferred in a short time with only an acknowledgement of reception in return.

Suitable plant should provide short duration, high band width, one way, secure point to point communication with provision for acknowledgement in return. Given this kind of communication, what options are now available to the average industrial consumer, or experimental user? Two large communication networks, telephone and cable television, already have much of the country wired.

Telephone Plant

Basically a multicenter multistar network, telephone plant provides two way point to point communication. Several subscribers are connected by separate cable pairs to a central switching office, the configuration resembling a star.

Important parts of the communication or call, are supervision, signalling, and information. These parts are not isolated. Going off hook, a supervisory signal to the switching center, starts the call. The dial tone signal informs the subscriber as to the progress of the call. The subscriber responds by dialing a control signal which some offices store in a register. The switching center uses the address in the register to connect the calling and called cable pairs. Finally the called subscriber hears the ringing signal, answers the phone and the talk path is completed.

The communication involves a single source to a single sink along a temporarily dedicated path within the central office. The connection is two way, or full duplex, the dedicated path providing a margin of security. When calls are made to subscribers not serviced by an originating office, interoffice trunks are used. When required interoffice trunks are busy, calls are routed to higher offices in the hierarchy until a connection can be made. This alternate routing provides great flexibility.

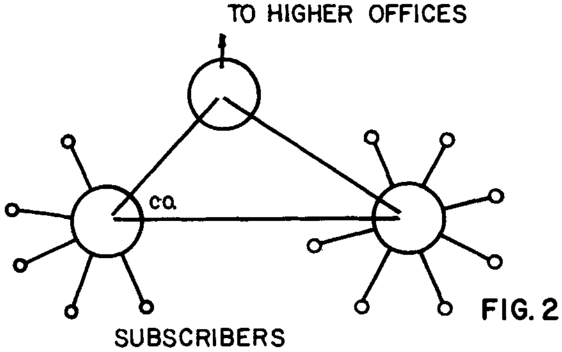


FIG. 2

While quite versatile in forming a great number of paths the star arrangement has drawbacks. A call to a subscriber across the street can require the use of several miles of cable to the central office and back to the called subscriber. To conserve this excessive use of cable, multiplexing, time or frequency division, can be used on a link to the central office. A method named concentrating relies on the property that most lines are idle much of the time and a few links to the central office can service several subscriber lines with a remote switch as shown in figure three.

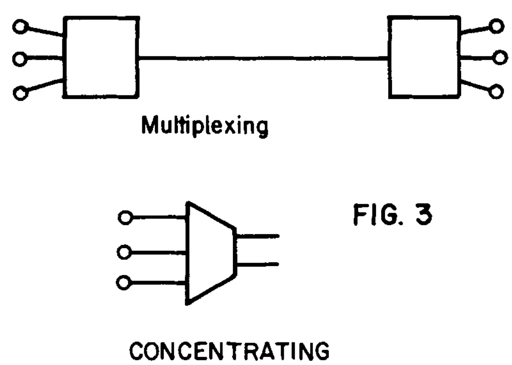


FIG. 3

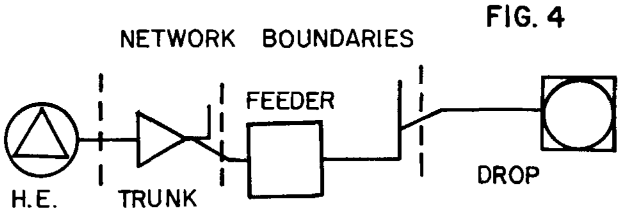
Another drawback, bandwidth of the subscriber line is small. For a fee, the line can be conditioned to provide greater bandwidth but nowhere near the six megahertz required for a standard television channel. Cost presently prohibits the installation of large bandwidth cable for subscriber lines. Telephone plant with its inherent switching has the versatility required for point to point data communication but is lacking in bandwidth.

CATV Plant

Basically a tree network, CATV plant provides one way single source to multisink communication. The reverse path provides multisource to a single sink communication. Examples of these communications would be a baseball game on the forward path to homes. On the reverse path, home security alarm information would be sent to a common point in the headend.

The outside plant has trunklines for information to reach an area, feeder lines that bridge off trunklines to cover an area, and subscriber drops for the final connection on the forward path. Each of these lines has their own character or properties. The transition from one part of plant to another crosses a network boundary.

FIG. 4



Typical plant has headend switching for source or program material but no provision for subscriber point to point communication. A subscriber can originate a message to the headend on a given channel by sharing total upstream plant for brief intervals. By selectively energizing a premium addressable tap downstream, a message can be routed to a single subscriber and blocked to all other subscribers. Thus, by using total physical plant for brief intervals point to point communication is possible.

Bandwidth is large, anywhere from two to four hundred megahertz systems can be found. Bandwidth in any part of the plant is typically the same. CATV plant has the necessary bandwidth for point to point data communication but is wasteful by sharing all cable for each communication.

What Kind of Plant?

Starting from basics, it is desirable that every subscriber have the possibility of communicating with any other subscriber. Direct paths between all subscribers would be physically impossible. Routing individual subscriber coaxial cables to a central switching office is physically impractical.

For switching schemes that route messages through the headend-trunk boundary, total plant is tied up for the duration of the communication. This sharing of plant would be impractical for large systems with heavy traffic requirements. If traffic demands are small, sharing the headend-trunk boundary would be an efficient use of plant.

In CATV plant the trunk-feeder boundary concentrates several subscribers to a common point, it also distributes from a common point to several subscribers. The proposed network would pickoff and insert messages at the trunk-feeder boundary. Contention onto the network could be resolved with a polling scheme. Addressable premium taps and addressable terminals could be used as security to prevent "bridgercasting." Using this boundary minimizes shared plant per call while still taking advantage of already having the subscriber connected.

Setting the constraint for an information network interconnect at the CATV trunk-feeder boundary, what form should it take? Given tree, mesh, and star networks the mesh will be investigated here.

There are three regular tiling patterns in the plane, triangle, hexagon, and square. To create a switching mesh each of these would have their vertices assigned to irregularly located bridger stations and their edges deformed to accommodate a primarily rectangular street grid. Of these, the hexagon would use the least cable to connect all stations. This occurs because the triangle mesh requires six edges per vertex, the square would require four, and the hexagon only three.

Every bridger will have a switching node assigned to its location. These nodes will be interconnected with trunks forming a hexagonal mesh. Information from a subscriber will bypass CATV trunk, enter the node, travel through the mesh, be upconverted to enter a bridger, and finally reach a subscriber. The communication will be controlled and supervised from the headend.

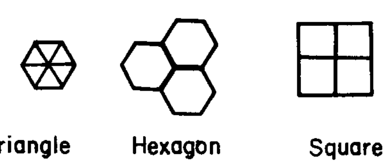


FIG. 5

Sample Communication

The speed with which a call takes place requires the user to assemble all information into a device and let the call proceed automatically. The standards by which terminal equipment access a network are outside the scope of this paper. The more the headend supervisor conforms to preferred standards the less equipment the system operator will have in the home to maintain.

Assume the subscriber has an information send/receiver. The sender would transmit both signal and message information. Likewise the receiver would be required to take in both signal and message information. In figure six, T7 and an arbitrary VHF 2 are standard CATV channels but T10 and VHF 1 need only occupy a narrow part of a standard channel.

Signalling routes through CATV trunk between the headend supervisor and subscriber. Messages remain on the path between subscribers. It is advantageous to look at the network from a signalling and message viewpoint. For subscriber "A" calls subscriber "B", figure seven shows signalling and message paths. The sequence of major events of a call without contention are detailed in Table One.

The headend supervisor connects the node trunks only after source and sink have been confirmed. This prevents unnecessary construction of paths. The method to build paths depends on a routing algorithm.

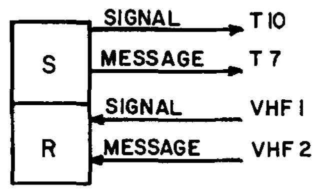


FIG. 6

SUBSCRIBER SEND/RECEIVER

Table One

A node is polled on VHF 3
OFFHOOK ENABLE sent on VHF 1
OFFHOOK ENABLED sent on T10 by A
DIAL TONE sent on VHF 1
A sends address signals on T10
B node is polled on VHF 3
B terminal polled on VHF 1
B sends RECEIVE ENABLED on T10
B addressable tap opened by VHF 4
Required nodes connected by VHF 3
TRANSMIT ENABLE sent on VHF 1
A sends info burst on T7
B receives info burst on VHF 2
Circuit times out
B terminal polled on VHF 1
(N)ACK sent on T10
(N)ACK sent on VHF 1
Call completed

A CALLS B

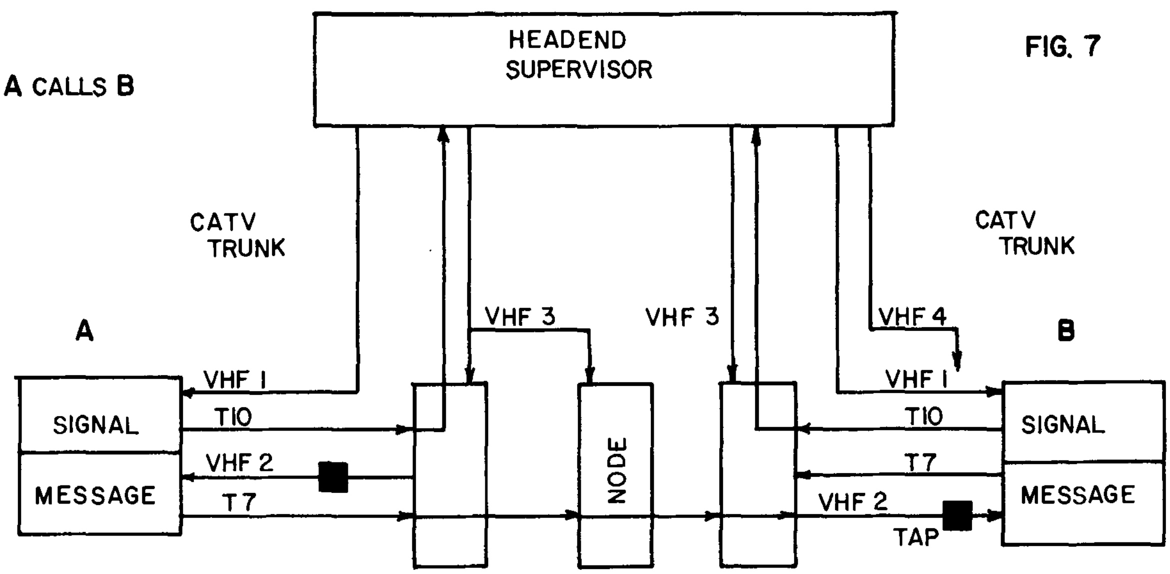


FIG. 7

Vector Space Switching Arrays

Vector space switching arrays assign position vector numbers to equipment located at a vertex. Each trunk connecting equipment becomes a unit edge.

Three unit vectors in the plane, ($\underline{r}0$, $\underline{r}1$, $\underline{r}2$), make it possible to generate paths between any two vertices of the triangular mesh shown in figure five. Creating a path from any calling party A to any called party B resolves the switching problem.

These unit vectors have the properties that their exponents add according to addition modulo three and:

$$\underline{r}0 + \underline{r}1 + \underline{r}2 = 0 \qquad (1)$$

which leads to:

$$-a\underline{r}^{n} = a\underline{r}^{n+1} + a\underline{r}^{n+2} \qquad (2)$$

For n=0, in abbreviated form:

$$(-a, 0, 0) = (0, a, a) \qquad (3)$$

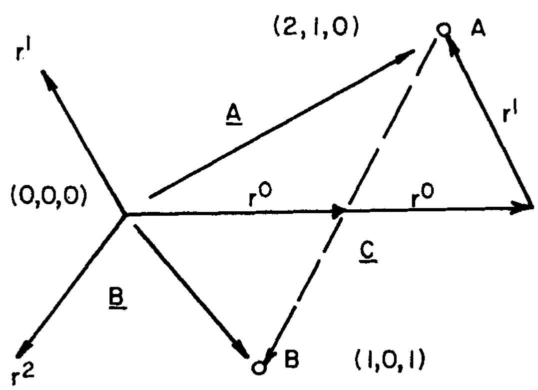


FIG. 8

Assume party A at position (2, 1, 0) wishes to call party B at position (1, 0, 1). The calling path from A is vector $\underline{C}$ such that:

$$\underline{A} + \underline{C} = \underline{B}$$

or,

$$\underline{C} = \underline{B} - \underline{A} \qquad (4)$$

For example,

$$\underline{C} = (1, 0, 1) - (2, 1, 0) \qquad (4)$$

(1, 0, 1)	
(0, 2, 2)	(3)
+(1, 0, 1)	(2)
= (2, 2, 4)	
= (0, 0, 2)	(1)

The calling path must include A, B, and all points necessary to reduce vector $\underline{C}$ to 0. A strategy for generating those points starts with the largest component of $\underline{C}$ in a counterclockwise order. Add a unit of this component to $\underline{A}$ and decrement $\underline{C}$ accordingly. Table Two summarizes this process.

Table Two

A register	C register	Path Node
INPUT $\underline{A}$,		
(2, 1, 0)		(2, 1, 0)
CALCULATE $\underline{C}$,		
	(0, 0, 2)	
ADD LARGEST OF C TO A, DECREMENT C		
(2, 1, 1)	(0, 0, 1)	(1, 0, 0)
ADD LARGEST OF C TO A, DECREMENT C		
(2, 1, 2)	(0, 0, 0)	(1, 0, 1)
STOP, C = 0.		

The unit vectors as defined cannot generate a hexagonal path. Rotating the unit vectors 180 degrees will produce new unit vectors, ($-\underline{r}0$, $-\underline{r}1$, $-\underline{r}2$). Alternating these new unit vectors every other point with the regular unit vectors will produce a hexagonal path. See figure nine.

The path from 0 to A is simply:

$$\underline{r}0 + (-\underline{r}2) = \underline{A}$$

but,

$$-\underline{r}2 = r0 + r1$$

by substitution,

$$\underline{r}0 + (\underline{r}0 + \underline{r}1) = \underline{A}$$

$$2\underline{r}0 + \underline{r}1 = (2, 1, 0) = \underline{A}$$

As all points of a hexagonal unit mesh coincide with points of a triangular unit mesh, all hexagonal points can be expressed with triangular unit vectors.

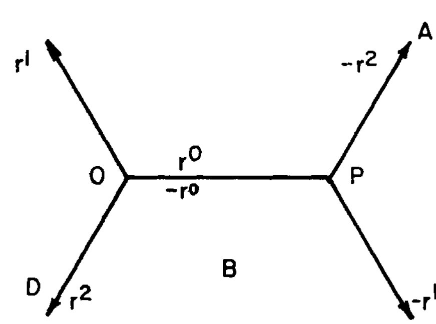


FIG. 9

The routing strategy must be changed to compensate for the negative vectors. Also some vector positions are positive, some negative, and some are omitted from the array. With the origin at (0, 0, 0) and positive, the test for position vector status is:

sum of components	= 0 mod 3	positive
"	= 1 mod 3	negative
"	= 2 mod 3	excluded

The routing algorithm for the headend supervisor is illustrated in figure ten. Table Three summarizes this process for party A calls party D.

Table Three

A register	C register	Path Node
INPUT A,		
(2,1,0)		(2,1,0)
CALCULATE C,		
	(0,1,3)	
A POSITIVE		
ADD LARGEST OF C TO A, DECREMENT C		
(2,1,1,)	(0,1,2)	(1,0,0)
NEGATIVE		
DECREMENT SMALL OF C TO A, SUM C		
(1,1,1)	(1,1,2)	(0,0,0)
POSITIVE		
ADD LARGEST OF C TO A, DECREMENT C		
(1,1,2)	(1,1,1)	(0,0,1)
STOP C = 0		

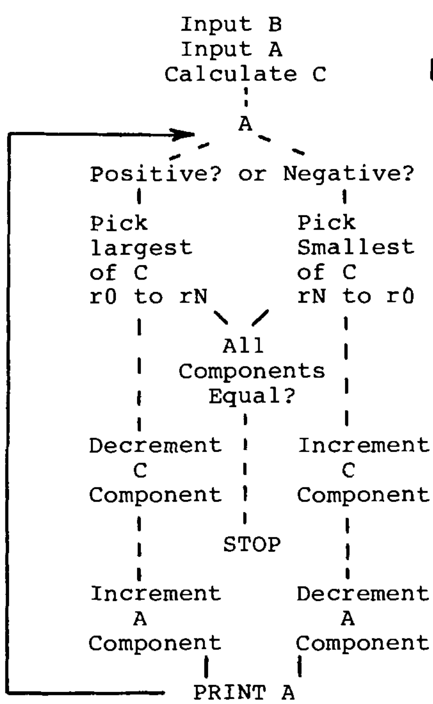


FIG 10

The Node

The node makes connections required for a call. It must provide amplification for line losses and conversion of a reverse path channel to a forward path channel.

On commands from the headend supervisor, a tone decoder selects crosspoints for connection. With reference to figure eleven, only one crosspoint on a horizontal line may be enabled. All vertical lines remain unbroken, passing through the crosspoint.

A local call (involving just one bridger) would go through crosspoints "A" and "C". An interbridger call initiated from this station would go through crosspoint "A" and for example "G". An internode path would involve, for example, crosspoints "D" and "I".

For internode paths that encounter a busy node, the supervisor merely skips forward one component. Two crosspoint connections of a given channel are not possible on the same trunk.

A single channel node was shown; more channels are required for greater capacity.

System Growth

As traffic on the network increases blocking of long calling paths will become a problem.

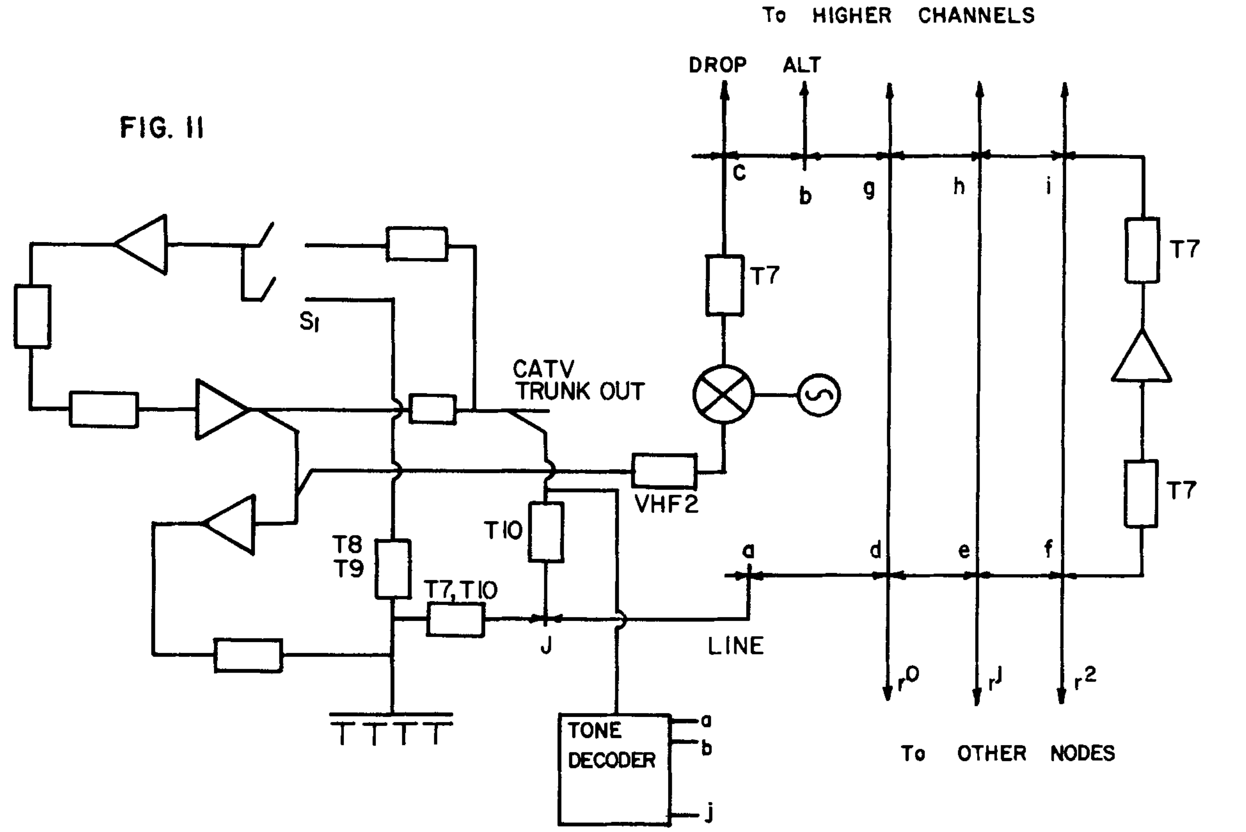
When the mesh was constructed each trunk line could carry more than one channel. The concept of dedicated forward and reverse channels no longer applies. Putting higher channels on the trunk means they all must be able to travel opposite directions. Allowing a 30 megahertz channel spacing makes the single trunk equivalent to eight or ten tiers of trunk.

As channels are added in selected portions of the mesh, a map of the system will start appearing like a honeycomb with hills and valleys.

It is also possible to build dedicated trees on higher tiers of the mesh for high volume, constant path, subscribers. Dedicated drops from these tiers direct to the subscriber will prevent these users from overloading the network.

As the system grows, cascadability will become a problem. Alternate routing outside the mesh will become necessary. The problems are complex enough to require a continuing traffic study and most design by a vendor.

FIG. 11



CONCLUSION

The concept of constructing a hexagonal interbridger trunk mesh appears lucrative. The resulting network can outperform existing CATV plant for point to point wideband communication. The network allows existing CATV plant, technology, and personnel to make the transition to a new communication.

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INTERACTIVE SPLIT SCREEN TELECONFERENCING

Don Langley and Jerry Richter

UNIVERSITY OF CINCINNATI AND RICE-RICHTER ASSOCIATES

****

ABSTRACT

Broadband interactive teleconferencing is a programming technique that can be interesting and enjoyable for both participants and viewers alike providing a useful feature to your cable communications system while enhancing the public's image of the cable firm. Briefly, this involves the interconnection of two or more remote locations anywhere along the cable television system allowing participants at these locations to carry on face-to-face conversations on a television screen.

While this method of programming may sound complicated, the technical configuration is actually quite simple and the required equipment is probably already available in your community programming studio. The procedures outlined will allow you to produce live, split screen teleconferencing with minimal problems.

****

"Interactive cable" is a term which has come into wide use in recent years to describe the capability for a narrowband signal to be transmitted upstream from a computer terminal in a subscriber's home to a central computer, usually located at the headend.

Of course, cable also has the capability of providing broadband interactive services such as video teleconferencing among several locations although this service is not as highly publicized as narrowband consumer applications. However, broadband teleconferencing on a community level is perceived by educators, government officials, social service agenecies and others as being particuarly desirable when they are made aware of its possibilities.

The basic purpose of broadband teleconferencing is to permit two parties to an interaction, a speaker and listener, to be mutually present to each other while engaged in a dialogue. The capability for teleconferencing within a community can have significant social implications. It can break down the increasing isolation of the elderly, handicapped and institutionalized. It can open new channels of communication between individuals and groups who would, ordinarily, not have a common meeting ground. It can also increase the dialogue between elected officials and citizens and increase the perception of responsiveness of local government. It can also strengthen the position of the cable company in the community by providing a dynamic community communication network which can become the basis for community involvement. In other words, it can change the perception of the cable company from that of a marketer of programming services to that of a basic community resource.

The objective of providing a simultaneous image of the speaker and listener to each other can, of course, be accomplished by several means. However, research conducted by the Alternate Media Center of New York University in Reading, Pennsylvania under a national science Foundation grant in 1975[1] indicates that the most flexible configuration is a centralized switching point and combination of the speaker and listener's images on a split screen. If this switching point is located at the headend, the interactive objective is fulfilled using only one downstream channel. With appropriate headend equipment any number of interactive locations can be split on the downstream channel in any combination to effectively provide face-to-face communication between any two points.

Several technical problems are inherent in split screen, broadband teleconferencing. First, two cameras at locations which are several miles apart must be phased in order for the split screen image to hold. Second there must be sufficient return capacity to permit the most flexible combination of originating sites. Third, the potential for audio feedback is significant and must be provided for. Finally, easily portable live origination equipment must be available to permit the establishment of temporary interactive sites in neighborhood locations such as libraries, government buildings, schools, etc.

In addition to a cable system capable of two-way transmissions, the minimum equipment required for live, split screen teleconferencing is as follows:

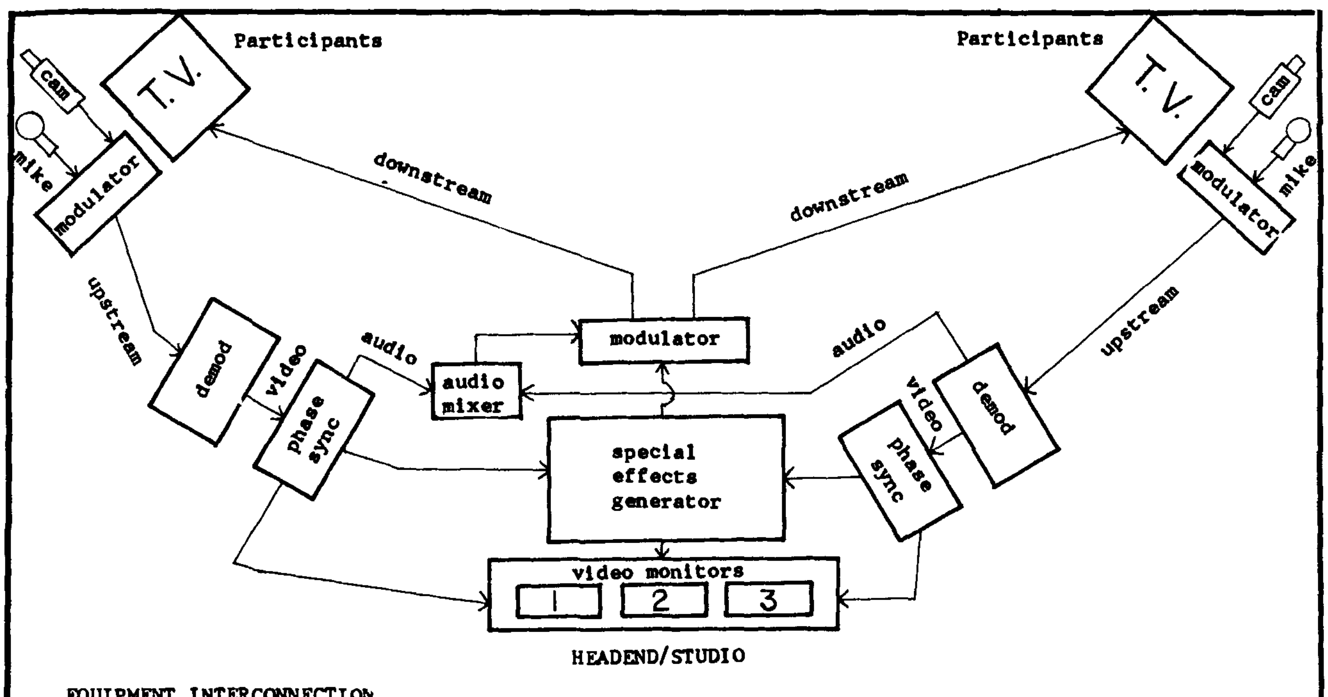
2 Video Cameras
2 Directional Microphones
2 Television Receivers
2 Modulators for Upstream Transmission
2 Demodulators
2 Phasing Synchronizers
3 Video Monitors
1 Special Effects Generator
1 Audio Mixer
1 Modulator for Downstream Transmission

You may wish to include additional cameras, microphones, and television receivers. Additional modulators, demodulators and routing switchers will be required for more than two remote locations. A video tape recorder may also be included for a permanent record of the conference.

Fancier productions may be accomplished with full switching capabilities, chroma key generators, character generators, or other specialized production tools. But the object of this type of programming is the interaction of the parties involved and the lack of fancy production equipment should never stand in the way of that fundmental objective. The simplest of production equipment can provide quite adequate split screen programming.

The technical configuration and interconnection of equipment is actually quite simple[2] (see diagram below). The camera(s) and microphone(s) outputs are connected to the upstream modulator video and audio inputs at each remote location. This signal is transmitted to the system headend, usually on a sub low band channel, and demodulated. The demodulated video signals are then phase synchronized and fed into the special effects generator to achieve the split screen effect. Both of the upstream video signals and the combined split screen signal should be monitored with separate video monitors in the headend location.

The demodulated audio signals are routed to the audio mixer. The audio



EQUIPMENT INTERCONNECTION

to each other's profiles rather than conducting a face-to-face conversation. In addition, the standard camera shot should be a medium close-up of the participants in order that all facial features are clear.

From a technicial viewpoint, the audio portion of a split screen teleconference can present more problems than the video portion. In order to maintain the conversational aspects of the programming, it is important to keep microphones open to all participants. This allows the participants to interrupt each other as in a normal conversation. However, since the participants hear each other over the speaker of the television receiver, a potential for feedback exists.

The potential for feedback is directly related to the audio level of the television receiver; to the pick-up range of the microphone; and to the number of microphones or television receivers at the remote location. In order to minimize feedback problems a number of techniques are used. The audio level of the receiver should be loud enough for all participants to hear yet low enough to minimize feedback. All microphones should be of a directional type rather than the omni-directional type and participants should hold the micro phones close to their mouth rather than using table stands. If more than one speaker is present at a location, the speakers should share microphones as much as possible.

As long as the cable system return amplifiers are properly aligned and each remote location has a cable drop readily available, the set-up time for a split screen production should not require more than an hour or two depending on the number of locations involved (if additional lighting is required at the location, allocate more time for this purpose). Setting up for this type of production does require more coordination than a studio production however.

When setting up, audio should be installed first in order to have contact with the headend and/or other locations. Have the headend give a count and adjust the television receiver audio level at the remote location. Remember to keep the audio level as low as possible but yet audible throughout the remote location. Once this audio level is established, do not change it. Next, send a test tone to the headend and set the VU meter level on the audio mixer at 100. After removing the test tone, check each microphone with a test count from the location that it will be used.

This is when you will find out if feedback will be a problem. If feedback is a problem, work with the headend to correct it. Leave all microphones on and in place.

Adjust each camera to be used and check for proper camera angle and lighting for each possible shot. Once one camera is adjusted properly, it can serve as a "model" for the other cameras. Remember to have the cameras located adjacent to and shooting over or across the television receivers to reduce parallax.

With these procedures completed, you are ready to produce interactive, split screen programming. The following diagrams[3] illustrate alternative set-up positions and some important points relating to television placement and camera shots. An interactive program is more successful when all locations follow the same conventions.

Remember, this programming technique can provide an interesting diversion to your normal programming day as well as providing a beneficial communications tool for the community that you serve. Yet it does not require any extensive or unusual equipment and can be accomplished in a matter of hours. The next time you are looking for a new programming format, try an interactive, split screen program. Both you and your community will enjoy the results.

[1]Mitchell and Mose, "Two-way Cable Television: An evaluation of Community Uses in Reading, Pennsylvania." Final Report, National Science Foundation. (Reading, Pennslvania: NYU Reading consortium, New York University, The Alternate Media Center School of the Arts, Graduate School of Public Administration, 1978).

[2]Rice-Richter Associates, "Basic Techniques for Interactive Television." detailed description of set-up procedures based on copyrighted manuscript, 1981.

[3]"Ibid, redrawn from manuscript."

IMPORTANT POINTS

1. Camera must be positioned to get a face on shot when speaker is looking at the monitor.

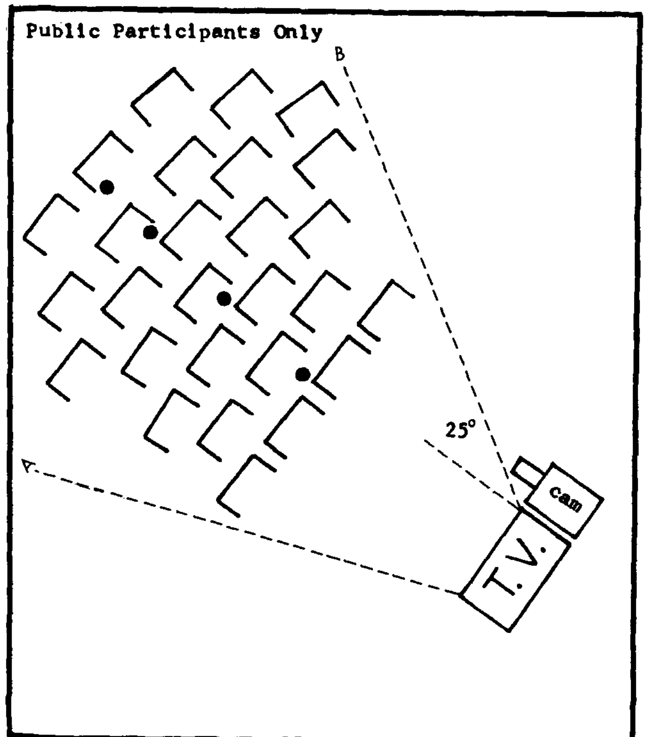
2. All camera shots must clearly show speakers facial features.

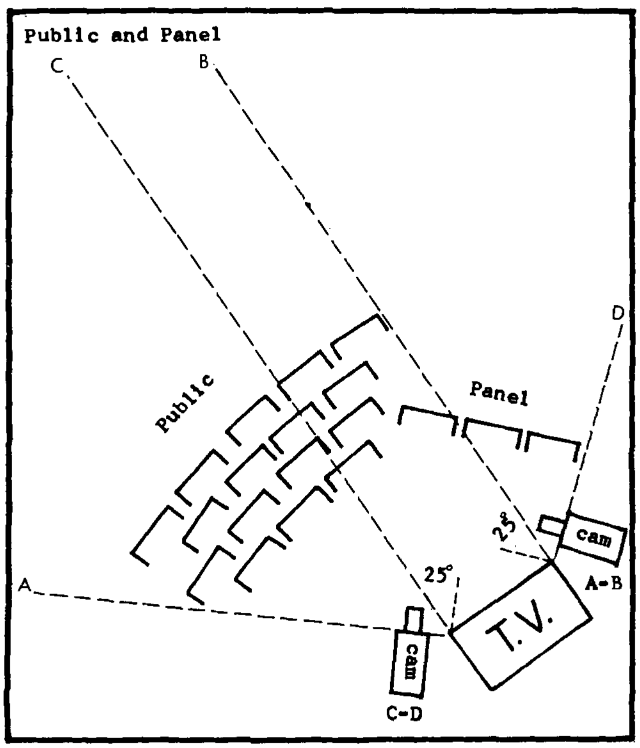
3. Shots including more than two people are not useful since, at that point, facial recognition decreases: Show the group with a two shot pan.

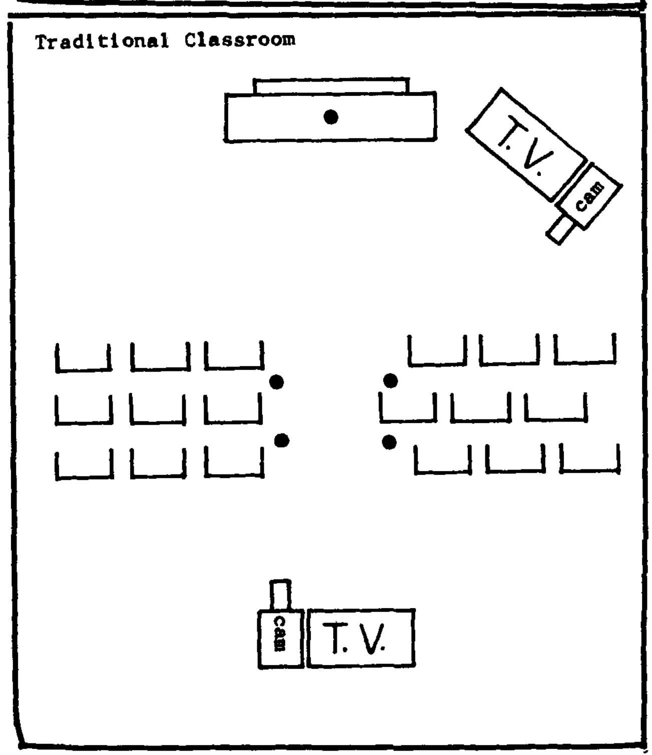
4. If more than two people are involved at a site, seating should be arranged so that the group can be shown without excessive head and foot space or long panning distance.

5. Regard the monitor as another group of people to whom the people in your site will be speaking face-to-face.

THE MONITOR IS THE FOCUS OF THE SET-UP.







LOCAL ORIGINATION STUDIO
BALANCE BETWEEN COST AND FUNCTION

Tom Garofalo

VIDEO IMAGES

Almost every cable T.V. franchise carries the responsibility of supplying the hardware and space needed for a Local Origination (LO) Studio. As a showpiece of your system, the LO Studio is characterized by its more sophisticated productions of newscasts, talkshows and commercial spots. Preconstruction planning of this facility is usually initiated by asking the following two questions:

1) What site preparation should we consider before deciding on the studios physical layout and,
2) Compare the production equipment's performance with its price and usefulness.

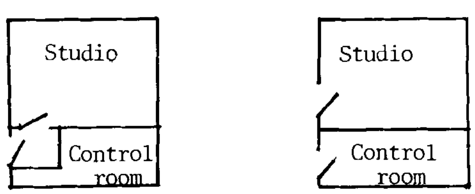
Focusing on a multi-camera studio with special effects and editing, this paper will outline areas of special interest in site preparation and equipment choice.

SITE PREPARATION

A. Floor Plan Generally regarded as an area reserved for architects and their ideas of space conservation, the intelligent video designer will approach a studio floor plan with a critical eye. Traffic flow must be contained within specific boundries in order to assure the least amount of interruption and the maximum use of the space available.

Since the studio is usually designed to have access to the control room and rest of the building, some ideas of door placements are in order.

For low traffic patterns, use one corner of the control room to locate an entrance from a hallway and mount your studio door on the adjoining wall. Higher traffic patterns dictate a seperate entrance to the studio. (Figure A)



LOW TRAFFIC HIGH TRAFFIC

This free flowing traffic pattern will assure the least amount of temptation to those individuals who might otherwise pass close enough to "tweak" on knobs and buttons.

Any engineering or production function that a window serves is better off left to a low cost black and white security camera mounted in the studio. Locating racks, consoles, and other hardware along the windowed wall often becomes an aesthetic dilemma, with the rear of the equipment being exposed to the studio.

A good comprimise is a three by three foot window located as close to the control room/studio door as possible.

B. Production Personnel Locate all equipment controls with thought to the number of production personnel available. Common sense dictates smaller more compact control areas for those of you with smaller staffs.

Group the video, audio, and editing controls within a three bay area if only one or two people are available. With a larger crew, control areas are separated into engineering, audio, editing, graphics and video switching.

C. Acoustics Whether your studio was built from the ground up or carved from existing office or warehouse space, pay special attention to acoustics.

Use your architect's input to arrive at a sound insulation factor of 60 or better. However, once insulated from the outside world, avoid the "hollow" or "echoing" sounds by using a cyc curtain ceiling panels and wall coverings.

D. HVAC "High volume, low velocity, low noise" is the key phrase when specifying HVAC requirements.

Cooling loads are largely determined by the number of studio lights in use at any one time. Leave this estimation to the experts but remember: studio ceilings and HVAC ductwork do not have to look pretty, they just have to be quiet and efficient.

E. AC Power Plan now for your ultimate power needs. This can generally be estimated from two areas: Lighting and Equipment.

Varying the intensity of the studio lights has more than just aesthetic appeal. Local codes usually require more feeder capacity for a box full of 20 amp circuit breakers than for a lighting dimmer capable of handling the same number of lights.

Expect that your equipment power needs will double and possibly triple within the next ten years. This is not an overestimate, but a time proven reality in our industry.

Be adament about two variables. One, insist that all AC power to the equipment racks and to any other devices that are connected to these racks (headends, modulators) are on the same AC phase. This will prevent the all to often occurance of AC ground loops or "hum".

Two, a good, solid ground connection to a reliable source is essential to prevent disturbances generated by the dimmer panel or outside sources such as motors, copiers, etc.

PRODUCTION EQUIPMENT

The following catagories will outline the price and performance range of the products available for you to use in your Local Origination Studio.

A. Cameras Generally, three types of color cameras are available in today's market: a) single tube convertible cameras, b) multi-tube convertible cameras and, c) multi-tube studio cameras.

The convertible camera addresses both studio and portable applications. Affixed with a 1.5" viewfinder and battery, the convertible camera connects easily to a portable recorder for location taping. For studio operation, a 5" viewfinder, remote operation panel and rear lens controls are used.

The studio camera usually offers larger 7" viewfinders, larger pick-up tubes (for better resolution), larger yokes (for better registration) multiple intercom circuits and a camera head that handles the larger zoom lenses.

Figure B compares studio and convertible cameras with 10:1 lenses, engineering remote controls and studio viewfinders.

Figure B

Class	Specs.	Price
Convertible single tube	300 lines/48db	$6,000.00-$7,000.00
Convertible multi-tube	550 lines/53db	$8,000.00-$18,000.00
Studio multi-tube	600 lines/54db	$25,000.00-$35,000.00

B. Special Effects Generators Special effects generators (more commonly referred to as "Switchers or SEG's) represent a large product group to choose from.

Features to consider are:

A. Number of special effect patterns
B. Number of mix-effect amplifiers
C. Colorizing options
D. Key options
E. Number of inputs
F. Syncronization to the total system

Figure C compares single mix/effect SEG's:

Figure C

Features	Price
6-inputs, internal sync and color bar generator, 6 effects	$2,100.00
10-inputs, internal sync and color bar generator, 10 effects, positioner	$4,000.00-6,000.00
10-inputs, external sync, colorizer, positioner, 10 effects	$3,900.00-4,600.00

Figure D compares dual mix/effect SEG's:

Figure D

Features	Price
9-inputs, external sync, colorizer, positioner, 12 effects, pattern modulators, chroma keying, shared mix/effects bus	$8,000.00-9,500.00
10-inputs, external sync, colorizer, positioner, 16 effects, pattern modulator, chroma keying, seperate mix/effects bus	$17,000.00-20,000.00

C. Tape Machines The most common video tape recorders that are used in the LO studio are of the 3/4" U-Matic variety. When properly maintained these VTR's will produce acceptable results to third generation tapes.

For comparison, we have listed editing systems which consist of one source VTR, one editing VTR and one controller (Figure E).

Figure E

VTR Format	Price
1/2" VHS or Beta	$ 8,750.00
3/4" U-Matic	15,000.00 - 17,500.00
3/4" Broadcast U-Matic	25,000.00 - 30,000.00
1" Type "C"	132,000.00 - 150,000.00

Video tape recorders may be treated as syncronous inputs to the special effects generator with the addition of a vertically locked time base corrector. This will allow special effects and dissolves, as if the prerecorded material was "live in the studio".

Figure F illustrates TBC's and their approximate costs:

Figure F

Specifications	Price
V-locked only 1/2"-3/4" VTR's	$ 5,000.00-10,000.00
V-locked with image enhancement and noise reduction 1/2"-3/4" VTR's	8,000.00-12,000.00
V-locked for use with 1" VTR's	22,000.00-26,000.00

D. Audio Basic components of the audio system are:

a. mixer board for mics and VTR's/ATR's
b. Turntable w/cartridge and preamplifier
c. cartridge recorder
d. reel to reel recorder
e. processing devices such as equalizers, limiters, reverbs, etc.

Generally, we keep the LO Studio wiring in a two wire shielded unbalanced mode. This is generally dictated by the expense of an all balanced in and out mixing board (usually $10 - $15,000.00 more for the same features). If the area surrounding the control room is not exposed to RFI or EMI, the unbalanced audio mixer provides a convenient and in-expensive means of combining your audio signals.

Audio processing or "sweetning" is viewed on a one by one basis. The production personnel may desire more fullness, shaping, reverberation, etc. A multi-point patch panel is usually installed to accomodate the insertion of these devices into the audio flow.

Figure G is representative of audio components and their costs:

Figure G

Features	Price
Mixing boards- 6 inputs - unbalanced	$250.00 - 600.00
Mixing boards 10-16 inputs - unbalanced	2,000.00 - 5,500.00
Turntable	250.00 - 500.00
Cartridge recorder	2,000.00 - 2,500.00
Reel to Reel recorder	700.00 - 1,800.00
Processing equipment	1-2,000.00 per item

E. Lighting The success of your production is largely dependent on lighting. Even the most expensive camera cannot substitute for the mood or feeling that a well lit set can create.

Figure H lists portable lighting systems that are transported in a knocked down configuration:

Figure H

Features	Price
3 light kit	$ 600.00 - 900.00
4 light kit	1,000.00 - 1,300.00
5 light kit	1,100.00 - 1,500.00

To enhance productions in the LO Studio, larger ceiling supported lighting instruments can be used:

"Backlighting" will seperate the subject from the background and give an illusion of greater studio depth. Smaller four to six inch fresnels are used here so as to concentrate on specific objects rather than general areas.

Focusable fresnels, eight to twelve inches, allow individual subjects to be highlighted. This "key lighting" creates the subtle suggestion to the viewer that this is an area of main interest.

Twelve to sixteen inch scoops provide broad illumination for the entire set. These "fill" lights increase the average illumination level without calling attention to any one specific area.

Complete lighting systems are shown in Figure I. Included are an adequate number of instruments, plug strips, the dimmer panel and patch panel to match the studio size shown to the left.

Figure I

Size of Studio	Price
10' x 15' (non dimmed)	$4,000.00
15' x 20'	16,500.00
18' x 25'	24,000.00
20' x 30'	33,000.00

SUMMARY

Outfitting a local origination studio can be a real learning experience!

Make the decision process a lot easier by visiting expositions like the NCTA, talking with your fellow members and, most importantly, listening close to the person who has done it before!

MetroNet: An Overview of a CATV Regional Data Network

R. P. McNamara
Sytek, Incorporated

P.E. Morse
Jerrold Division, General Instruments

Abstract

MetroNet is a low cost, high performance data communications network which is based on a synergistic combination of broadband analog, digital and packet switching communication technologies. MetroNet is seen as a means of providing a cost effective, data communications link to the small business and residential consumer market over currently deployed cable systems.

A description of the marketing and network communication requirements for MetroNet, along with general architectural considerations - both hardware and software, are discussed.

1. Introduction

The evolution of new services offered by cable operators is being driven by the demands of users and franchise authorities for additional value added services and the need of MSOs to generate new revenue streams. An area of active investigation by many MSOs is the provisioning of a two way data communication link over the cable network. This data link is the backbone over which many of the contemplated services will be provided.

Two market segments would appear to have significant need (in terms of traffic volume) for a data communications backbone; the business market and the residential consumer market. The business market contains users having a substantial data communication need and who would welcome the capacity, topology and cost saving potential of a CATV network as an alternative to the Public Switched Telephone Network (PSN). This market is being driven by the attempts of many companies to improve white collar worker productivity by deploying "Office of the Future" enhancements. The second market segment is that of the residential consumer. Unlike the business market, the residential consumer market does not yet exist and will have to be developed.

The telecommunication services which are being developed for the home consumer environment are usually consolidated under the umbrella of Videotex Services. It would appear safe to assume that the cost of providing network access and transport will have a strong bearing on the ultimate penetration of Videotex services in the residential market. This paper will describe a network which directly addresses the needs of the residential marketplace and will focus on describing a general architectural overview of MetroNet, a CATV regional data network.

It is projected that the consumer market will provide combinations of audio, textual and graphical information to the home subscriber. To many experts, the emergence of this market during the decade of the 80's is a certainty. The only question which remains is whether the market will evolve as an extension of plain old telephone service (POTS) or whether it will be provided by an alternate local distribution system, the cable. [1] It is our contention that the nature of the service (data), the traffic characteristics of the service (bursty transmission and long holding times), the type of plant the service is provided on (circuit switched, analog) and the recent movement of local telephone companies to cost based pricing (designated Universal Measured Service) will make the provision of Videotex services over the currently deployed Public Switched Network (PSN) a costly and unattractive offering. As a cost effective alternative, Videotex Service could be provided by local CATV franchises.

MetroNet is a low cost, high performance, data communication network and is a synergistic combination of broadband analog, digital and packet switching technologies. Utilizing standard cable TV facilities, MetroNet will provide a transparent, high performance, communication system incorporating distributed network intelligence. For the residential consumer market, MetroNet will be compatible with all existing (subsplit and midsplit) cable systems. Unlike other proposed CATV data networks, MetroNet makes no assumption as to where in the network control and service nodes are located. As such, MetroNet is completely generalized as to service node deployment. The MetroNet system architecture will provide the interconnection of a wide range of subscriber and service nodes, configuration flexibility, and the ability for a low cost phased introduction of service.

One of the underlying design goals of MetroNet is that it must provide today's Videotex services inexpensively yet still have the flexibility required for future network growth and applications. The generality of the system enables it to effectively service a wide range of user applications - from control and security monitoring systems to packetized LPC voice and data.

This paper will provide an overview of the MetroNet System. Among the areas discussed will be:

- Residential Market Requirements
- Network Requirements
- MetroNet's Network Architecture

2. Residential Market Requirements

This section begins by addressing the home telecommunication market and extrapolating the consumer network requirements by examining the range and types of service which will be deployed. The intention here was not to study all possible future services in great detail, but rather to forecast general trends in the development of this market and to estimate their impact on the telecommunications network that will transport these services. These projections were used to create a network traffic model in an effort to evaluate the network performance.

Forecasting service demands for the residential marketplace is not a straightforward undertaking. Indeed, many studies conducted during the last decade have predicted rapid development of this market. [2] Generally, these forecasts came as a result of anticipation of the results of the integration of new computer technology and advances in both telephone and cable television communication service. It was expected that this integration would make possible and, indeed, substantially lower the cost of a wide variety of services that previously were not handled electronically.

However, in many cases changes have been slower than expected. Except for a broader variety of television programming, increased use of video games, and some custom calling features, the home telecommunications market is not appreciably different from that of ten years ago.

Many reasons could be offered for this belated development. Primary among these is the requirement that many actors in the marketplace have to undertake activities simultaneously. Generally, there is not one driving force but many. The offering of a service such as electronic funds transfer necessities significant resource allocation on the part of banks, communication companies, information processing firms, and residents. Market signals have to be very clear before this investment will be forthcoming. Individuals or firms that may lose market share should conditions change, e.g. sellers of paper, may delay through legislative or judicial means. Finally, regulatory uncertainty has also resulted in reluctance on the part of market participants to make the required investments.

Many of the forces which would tend to expand the home telecommunications market still exist today , but counter forces are also present. Thus, one of the fundamental design criteria for MetroNet was that the network architecture had to be modular and allow for either rapid or slow development of the consumer marketplace.

The potential range of these new services encompess such diverse areas as energy management, home security, bank and shop at home, video games, electronic directories and personal data storage, to name a few. While the projected market for these services is expected to be significant, the most difficult issue at this time is identifying those services which form the base or "critical mass" for the development of this marketplace. Unlike the Business Marketplace, which is being driven by a need for greater productivity in the office market, the residential consumer is motivated by a different set of needs. Most consumers acceptance of a new service (or set of services) will be based on the savings or perceived savings that the service offers to the subscriber. Table I summarizes the key services, their traffic characteristics, and their market penetration by 1990. The peak traffic was developed from a model of each prospective service. It should be emphasized that these services were used as an indication of the core or critical mass of services and formed a baseline for the network traffic model.

TABLE I

SERVICE	Peak Traffic Bits/Sec/ Residence	Penetration (Total) Households
1) Home Banking	2.6	30%
2) Home Shopping	11.35	25%
-Comparison Shopping	7.1	50%
-Reservations	.12	20%
3) Electronic Mail	2.66	2%
4) Electronic Newspaper		
- News	15.5	20%
- Public Notices	.16	30%
- Classified	1.6	30%
- Financial	1.75	10%
5) Information Services		
- References	15.5	30%
- Traffic Conditions	6.5	20%
- Software Packages	.77	10%
6) Security Services	.3	5%
7) Energy Management	.14	10%
8) Education Program	37.	5%
9) Medical Monitoring	.3	1%
10)Entertainment Services		
- Video Games	1.68	30%
- Gaming	.20	15%

3. <u>Network Requirements</u>

MetroNet will act as the integrated data communications backbone for all value added services to the home. This role places some rather unique requirements on the network implementation. MetroNet must support a wide range of applications, many of which have not been identified (in Table I above) or developed. In the design of MetroNet, it was realized that the network should provide a wide range of performance, customized to the needs of each application. Wideband, low delay applications should coexist with narrowband, delay tolerant applications without requiring the latter to pay the cost of the former. Furthermore, as more data traffic, users and applications are migrated to an integrated, regional data communications network, an increasing number of them will require privacy and security features to safeguard their data from other users. These features should be modularly included so that users not requiring these services do not pay for them and, further, that the full interconnectivity of the network is not compromised. Stated another way, a secure user should be able to optionally invoke the security and privacy services of the network.

A summary of the network design assumptions and requirements is shown in Table II. These assumptions and requirements were used to define the MetroNet system architecture and discuss such issues as Network topology, bandwidth, connectivity and control.

The choice of a network architecture was most strongly affected by the following network requirements:

- The network would have to support bursty, data type traffic.
- Network bandwidth is assumed to be a scarce and valuable resource.
- The network will be deployed in a hostile environment.

The first two requirements could be met by a network similar in design to SYTEK's System 20 LocalNet product line, that is, a distributed intelligence, packet switched network. However, the third requirement mandated that some form of centralized network administrative control be provided to prevent fraud (both of the network and of other users).

In the development of the MetroNet architecture, it became apparent that consideration must be given as to how the services depicted in Table I are provided. Specific issues considered with respect to service provisioning, included: who provides the service, the location of the service node, the size of the service node - among others.

A comparison was made between centralized vs decentralized service node deployment. A centralized service node was characterized as being located at (or trunked to) the cable system headend. In this scenario, all services are provided by the MSO. A decentralized network architecture would allow service nodes to be physically located anywhere in the network. Services may or may not be provided by the MSO - that is, many service nodes would be provided by outside vendors or entrepenuers. The non- MSO service nodes would still generate a revenue stream for

TABLE II

Network Requirements

Assumptions

♦ Market - The network will be designed to suport the small business/ residential market

♦ Traffic - The network will be designed to support digital data type traffic

♦ Topology - The network will be implemented over a broadband CATV network which exhibits a "tree" type physical topology

♦ Bandwidth - Network bandwidth is assumed to be a scarce and valuable resource. It is assumed that the network will be implemented in a subsplit cable system with a maximum of 25 MHz (one way) allocated for data services

♦ Environment - The network will be deployed in a hostile environment and be subjected to both accidental and premeditated attacks.

♦ Standards - The network architecture will not necessarily conform with IEEE (or other standard organizations defined standard network. The network, however, will conform with the ISO seven level protocol architecture and will present standard interfaces to connecting nodes and networks.

General Requirements

♦ Capacity - The network will be capable of supporting a subscriber base of at least 50,000 subscribers. More complex systems of multiply interconnected networks may be deployed.

♦ Cost - The network will be cost effective for the consumer marketplace.

♦ Planning Cycle - The network should not exceed allocated RF spectrum capacity for at least a 10 year period after initial deployment and provisions for expanded growth must be included in the basic architecture.

♦ Adaptability - The network will be flexible extensible and will support current and future services

♦ Access Time - Under maximum loading conditions, the network will accept and transmit 99% of the packets it receives within 100 milliseconds.

♦ Geographical Extent - The network will be able to support traffic within a 20 mile radius of the network head end or some other centralized network node collection point. Provisions for expanded geographic coverage must be included in the basic architecture.

Connectivity

♦ Connectivity - The network will allow for the logical interconnection of any two nodes.

♦ Node Location - Nodes, both subscriber and server, may be physically located anywhere in the network.

♦ Communication Services - The network will provide a full range of communication services

♦ Connection Throughput - Subscriber nodes will have a throughput of at least 19.6 Kb/s

♦ Internetworking - The network will allow for the connection to and from off network nodes provided the proper interfaces and connections exist.

Network Control

♦ Access and Authorization - The network will be able to identify, authenticate and grant or deny access of any node to the transport services of the network. This implies that the network will posses an enforcement mechanism which can deny network access to unauthorized nodes.

♦ Security - The network will be able to protect itself against vandalism (both physical and electrical) theft (both from the network and authorized users) and attacks against user data privacy

♦ Monitoring - The network will posses digital and analog monitoring capability for maintenance,traffic allocation, and accounting purposes

Reliability

♦ Reliability - The network will be reliable such that the entire system downtime is less than three minutes per month

♦ Network Control Nodes - The network control nodes will be configured in such a fashion so as to meet the network reliability requirements.

the MSO in the form of traffic on the network, more services for the consumer, node access charges, etc. Furthermore, the MSO could provide billing support for these service nodes so that the consumer receives just one bill, not multiple bills, for Videotex Services.

Another area which was investigated was the issue of service node reliability, complexity and size. The last area to be considered was the regulatory impact on a centralized vs decentralized serving arrangement. For regulatory reasons alone, it is projected that a centralized service node architecture will leave the MSO open to long term legal entanglements and regulation. This reasoning is based on a projection of "creeping" regulation. Noteworthy examples which come to mind are recent mandates requiring the CATV industry to provide two way capability (FCC), interconnection of franchises (various state PUCs), and some censorship of CATV offerings (various franchises). This concern appears to be substantiated by a recent M.I.T. report on regulation of the CATV Industry [4].

To further pursue the issue of centralized vs decentralized service node deployment an examination of the effort and time needed to add new services and features to a system was performed .A summary of these findings are shown in Table III and clearly favor decentralized serving arrangements.

Based on the assumptions and network requirements from Table II and the requirement that service nodes be distributed throughout the network, it is apparent that the needs of the regional area data network could be provided by a distributed intelligence, packet switched network. However, it was decided that a centralized network control function which allowed the network administrator to control network access, subscriber node deployment, and distribute traffic was also necessary. The resultant hybrid network is MetroNet. It is felt that MetroNet provides an optimum mixture of decentralized network intelligence and reliability with centralized control. Additional flexibility is provided in that MetroNet will allow for the deployment of either centralized or decentralized service nodes.

TABLE III

NETWORK ARCHITECTURE - CENTRALIZED VS DECENTRALIZED
-SERVICE RELATED ISSUES-

	Central	Decentral
Effort to add new services	Harder	Easier
Effort to increase service capability	Harder	Easier
Effort to develop service	Harder	Easier
Time to develop new service	Longer	Shorter

4. MetroNet Architecture

MetroNet is a packet switched data network which provides communication via the CATV distribution network. The network consists of three generic types of nodes - network control and monitoring nodes, user nodes, and network interface nodes. The network architecture for MetroNet is outlined in Figure 1. A network consists of the following elements:

Cable Distribution Systems
- o Data Channel Access Monitor (DCAM)

Network Control Nodes
- o Network Access Controller (NAC)
- o Network Traffic Monitor (NTM)
- o Network Resource Manager (NRM)

User Nodes
- o Subscriber Node
- o Server Node

Network Interface Nodes
- o Intranetwork Links (optional)
- o Internetwork Gateways (optional)

The core network consists of the cable distribution system, the Data Channel Access Monitor, the Network Access Controller, the Network Resource Manager, the Network Traffic Monitor, and two nodes which want to communicate with each other.

A typical session in MetroNet is initiated when a subscriber node signals the Network Access Controller (NAC) and is allocated channal bandwidth. The subscriber then initiates a session with the Network Resource Manager which authenticates the session request and assigns a specific network channel for the subsequent session.

Information flow in the network would be from each node toward the head end. The headend receives each upstream transmission and rebroadcasts it on a specific downstream channel. The headend contains the enforcement mechanism which prevents network access (that is - it prevents network packet retransmission) of unauthorized packets. Authorized packets are rebroadcast downstream toward the network nodes. All session transmissions are monitored by the Network Traffic Monitor (NTM) which gathers network usage statistics for load management and accounting purposes. If MetroNet extends beyond the local geographical area, the network can be connected through either an Intranetwork Link or an Internetwork Gateway. The function of these components are summarized in the following sections.

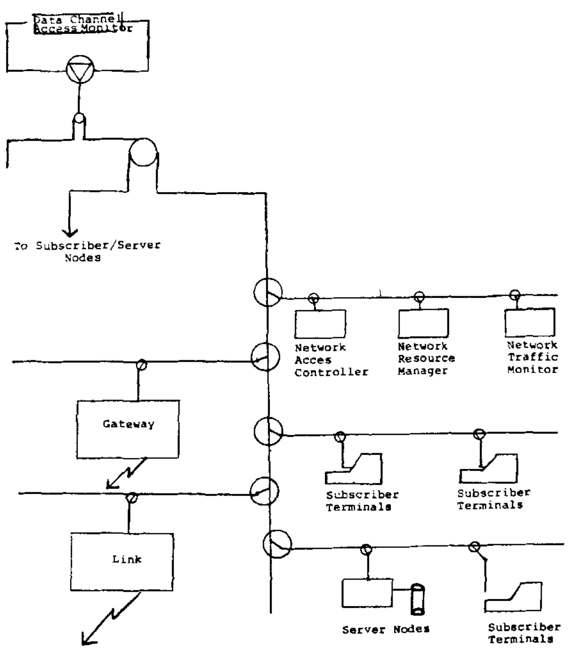


Figure 1

4.1 Cable Distribution Network

MetroNet utilizes broadband coaxial CATV cable as its physical communication medium. Analog video applications can share the same cable as the MetroNet data network. Since broadband CATV is a directional broadcast transmission system based on a single, rooted tree, physical topology, each network node can broadcast their transmission in one direction, up the tree towards the CATV head-end. The head-end contains a frequency translation device (DCAM) which rebroadcasts the transmission from the root of the tree downstream to all attached nodes. MetroNet exploits the directional aspects of the CATV transmission system to achieve full connectivity. MetroNet transmissions are contained in two frequency bands: an upstream (low frequency) and a downstream band (high frequency) and are compatible with either subsplit or midsplit cable systems. In a subsplit CATV system the band from 5 to 30 MHz is typically used for transmissions towards the cable head end. The outbound directory will be contained in a 25 MHz band somewhere in the 54-400 MHz region. It should be pointed out that the actual frequency allocations of the inbound and outbound bands are unimportant in the MetroNet architecture.

The MetroNet architecture divides the upstream and downstream bandwidth into multiple logical channels through the use of Frequency Division Multiplexing (FDM). Frequency Shift Keying (FSK) is used to modulate RF carriers to create individual data channels. Each MetroNet data channel will have a throughput of 128 Kb/s and is capable of supporting hundreds of users because of both the CSMA/CD access mechanism and the packet switched format.

As was previously specified, one of the requirements of MetroNet will be to provide access to network transport facilities and user accountability. Both of these requirements will be met through the use of a semi-intelligent head end - the Data Channel Access Monitor (DCAM)

The DCAM at the CATV system headend will perform two functions:

- It will receive the upstream channel transmission (data packets) and rebroadcast these transmissions from the headend in a specified downstream channel to all attached user devices, and

- It will, under direction of the Network Access Controller (NAC), examine every data packet passing through each headend channel. Packets from unauthorized network users will not be rebroadcast to the network. This strategy will prohibit unauthorized network access and misdirected billings by "spoofing" of the Network Traffic Monitor.

The network headend will be organized on a per channel basis. Each network data channel consists of a (low band) demodulator, a packet verification unit, and a (high band) modulator. Each group (~10) of DCAM modules (one module per channel) will have a "hot" stand by in case of failure of the online unit. Reliability is provided through 1 for N redundancy in DCAM units. It should be noted that even if there were a failure in both a front line and back up DCAM module, the remainder of the network would be unaffected and continue to operate. The network protocol architecture will be configured in such a way that if a DCAM module were to fail, the user nodes would default to their home channel and the Network Resource Manager would then reassign nodes to other data channels. The majority of users probably could recover and be reassigned to other data channels without detection of a network fault. (It is anticipated that the only discernible effect to a user would be a short delay or dead time before the network would reconfigure and it is suggested that such a delay might be difficult to discern from a server node slowdown).

Network growth would proceed on a channel by channel basis. Cable systems which require more data channels would be outfitted with more channels while smaller systems could be sized appropriately.

It should be pointed out that the network is organized so that nodes can be located anywhere in the network. Network control nodes, subscriber nodes or server nodes may be located physically anywhere within the network. The only centralized network component will be the DCAM located at the headend which is under the NAC's control, and except for monitoring of packet verifiers, its operation is passive.

4.2 Network Control Nodes

There will be three types of network control nodes in MetroNet- the Network Access Controller, the Network Traffic Monitor and Maintenance Node, and the Network Resource Manager.

The Network Access Controller (NAC) is under control of the network administration and will allow it to restrict unauthorized users access to network resources. The major resource protected is that of network transport services.

The basic function performed by the NAC is to provide network channel access. The Network Access Controller will maintain one or more data bases containing a list of valid user addresses, and user node ID's. The Network Access Controller can be located anywhere in the network but will be connected by a set of out of band channels to the head end. The use of out of band channels between the NAC and DCAM will prevent attacks on the DCAM by malicious network users that would prevent the DCAM from being out of communications with the NAC. The major purpose of the NAC is to give the MSO control of the network. This "centralized" control function though, may be located anywhere in the network.

The next major network control node is the Network Traffic Monitor and Maintenance Node. A Network Traffic Monitor (NTM) will be assigned to each network data channel. The network traffic monitor will collect information on:

* source/destination node traffic statistics - these statistics will be used for accounting purposes

* data channel throughput and utilization. This information will be transmitted as necessary to the NAC for traffic load leveling.

Furthermore, it is expected that the NTM will be able to monitor individual node status and collect information about:

- o node up/down status
- o node throughput
- o node response time distribution

The actions of the NTM will be passive (except for its interactions with the NRM). It is anticipated that during non peak business hours the NTM could consolidate user usage and generate network billing information. A second function of the NTM will be to perform analog measurements of individual channels, cable and amplifier quality. Network Monitoring probes will be situated throughout the network and interrogated as necessary (over the data channels) by the NTM. This should allow the network administrator to detect network system faults both before and after occurrance. It should be noted that these network probes could be used to detect acts of vandalism (both physical and electrical) against the network. The centralization of network status will permit cost effective, implementation of network maintenance policies.

The last function to be performed by the NTM node will be diagnostics of network equipment - both network control nodes and user nodes. If administration costs are to be minimized, automatic remote diagnostic checks of equipment attached to the network will be necessary. In some cases, the NTM will only be responsible for interrogating other network components or generating test signals. However, the NTM will be charged with the responsibility of accumulating network diagnostic information, cataloging it, disabling faulty network equipment as required, and reconfiguring the network to minimize the effect of failures or damage caused by vandals. Like all MetroNet control nodes the NTM can be located anywhere within the network.

The last control node to be discussed here is the Network Resource Manager (NRM). The NRM, like both the NAC and NTM can be located anywhere in the network. The NRM is accessed directly by a network user node, and will allow:

* Network users to set up connections by symbolic names without knowing the destination address.

* Network users to interact directly with the NRM, ie - directory look up

It is expected that the network administrator will be responsible for the NRM data base. The NRM will provide the basic tools allowing network users the ability to build their own directory data bases for session set up through the use of symbolic address names.

4.3 Network User Nodes

The network user nodes will consist of two types, subscriber access and server nodes. The subscriber access nodes, (terminal), will be the most common in the network. The subscriber nodes will perform the following functions:

* Communication Interface to MetroNet

* Data terminal

It is expected that the display portion for the terminal will be the standard home television receiver. The attachment of the data terminal will transform its function from a simple TV receiver to that of a small personal computer which can call upon the data and information services attached to MetroNet.

The communication interface in the terminal will provide the following functions transparently to the user:

* Interact with the NAC for channel access

* Interact with the NRM for session initiation

* Interact and select, under network management control, a data channel on which to operate for this particular session

* Maintain and disconnect sessions as necessary

* Format and address packets using an internal MetroNet communications protocol suite

* Control access to assigned data channel band- width during a session using a CSMA/CD network access mechanism.

* Control the local and global flow of data over the MetroNet channel to prevent congestion and data loss during a session

* Detect errors through the use of Cyclic Redundancy Checks (CRC) and correct errors through retrans mission of lost or damaged packets.

It is anticipated that the terminal will be supplied by the cable MSO to the subscriber, just as current descramblers are provided. Each terminal will contain (either as a separate system, or integrated into the terminal node) a Network Access Unit (NAU). The NAU contains the RF modem and digital circuitry which implements the necessary protocols used to interface the user's terminal equipment to the network, The RF modem will be designed to be frequency agile over the entire data network spectrum. Each NAU contains a Network Access Unit Identification Number (NAU ID) which is in permanent storage within the unit. The NAU ID is unique for every network node and is the mechanism by which the NAC recognizes a particular billable user. It should be pointed out that the NAU ID is separate from the unit address and is never broadcast to the network. Tampering with the NAU ID is designed to give an attacker no real benefit. Theft of an NAU ID is roughly analogous to the theft of a credit card. Also, NAU ID space is very sparse. NAU ID's could be sixty four bits resulting in over 10 ** 19 different NAU ID's. Hence the probability of guessing a valid NAU ID would be very small. These precautions, together with the special equipment and knowledge needed to set a NAU ID into a unit make it relatively difficult for a user to falsify his identity to the NAC.

The subscriber node will be able to receive combinations of video, data, graphics, and audio. The specific format of the audio will be specified later but it is anticipated to require a throughput of $\leq$ 1.2-1.8 Kb/s. The subscriber terminal will be able to respond and transmit data and graphics. (It is not expected or required that the Terminal be able to formulate audio. If this capability were to exist, there is nothing to prevent its transmission over MetroNet, however.)

The second type of user node is the network server node. Like all other types of nodes it can be located anywhere in the network. In most all aspects, Server Nodes are identical to Subscriber Nodes in the communication services that are provided to the node. Service nodes will perform the following functions:

- Communication Interface to MetroNet
- Server applications

The communication interface to MetroNet will vary from looking similar to the subscriber node (for the smaller nodes) to being able to access multiple data channels concurrently (for the larger server nodes). Three generalized interfaces to MetroNet are envisioned at this time.

- A server node which has a single NAU and can support one session at a time.
- A server node which has two modems. In this node, one of the NAU's is always tuned to the home channel and the other NAU is (after the first session) tuned to a specific data channel. Subsequent sessions are transferred to this channel after the first session is initialized. The data channel modem and packet communication equipment is capable of handling multiple sessions on a single data channel. Ideally the limit of the server node to handle concurrent sessions should be the rate limiting step for the number of concurrent sessions the Network Access Unit can process. Further requests for sessions directed at this node by the NRM over the home signaling channel will be met with "node busy" response, or the NRM may provide call queuing services.
- A server node which has multiple modems. In this configuration, one NAU is always tuned to the home channel while other NAUs are distributed across various MetroNet data channels. Each separate NAU will be capable of handling multiple sessions.

4.4 Network Interface Nodes

Network Interface Nodes are units which either allow user devices to interface to the network or provide connectivity to other network channels, remote network sites (or subnetworks) and foreign networks.

User Network Access Nodes (UNAN) will provide access to the network to users who care to provide their own subscriber terminals or server nodes. The UNANs provide the same communication function as the subscriber/server nodes. The UNAN will contain a Network Access Unit ID (NAU ID) and at least one network address (server nodes will probably have multiple or rotary network addresses). The UNANs allow all the communication functionality of network provided server/subscriber nodes along with a range of standard interfaces.

The second class of network interface nodes provides connectivity between MetroNet "subnetworks". In the connotation to be discussed, MetroNet will be a group of subnets (and connecting nodes) which share a common address space, independent of their physical location. Separate cable systems are physically interconnected and this is accomplished through the use of a Link.

In its simplest form, the MetroNet Link will perform a one to one mapping of specific packets from MetroNet subnetwork channel to another MetroNet subnetwork channel. The link will be responsible for channel access at subnets and flow control of the transmitters if the destination channel is operating under heavy usage. The link channel size (that is the size of the channel between two links) will have to be sized to carry intranet packets with a minimum of delay. The size of this channel will be a function of the amount of traffic between subnetworks. The link channel could vary from a dedicated TDM or packet switched channel, but in all cases will be dependent upon the particular traffic patterns between subnets. It should be noted that subnets could be connected by links with low speed channels (possibly common carrier).

Since the MetroNet Link will be a network node, it will operate both automatically or under direction of the NAC and NRM. The last class of network interface node will be the Gateway. Gateways will provide interconnection between MetroNet and foreign networks. Foreign networks are meant to include MetroNet systems not under the control of the network administration, the PSN, public data networks (Telenet, Tymnet) and OCCs. Initially Gateways will be able to interface with the PSN and X.25 packet data networks. Gateways will be able to handle both incoming and outgoing sessions.

Gateways will be under the control of the NAC and NRM. Sessions addressed to nodes off of MetroNet will be directed to a Gateway. The gateway will serve the equivalent function of a tandem or class 4 office. Signalling to the remote nodes, session initiation, and, where possible, reliable data transmission via error detection and recovery protocols with foreign networks will be handled by the Gateway unit. Gateways will also be able to handle inbound session request from remote nodes. This will require that the portion of the session carried by MetroNet be negotiated through the NRM. It should be noted that sessions which are initiated offnet will probably be billed (for the MetroNet portion, at least) to the destination node, However, as metropolitan area networks proliferate this practice may revert to those currently governing telephone calls over the PSN.

4.5 Communication Protocols

MetroNet implements a common packet-switched protocol architecture throughout its component elements. The protocol suite is designed to be extensible, offering new:

- internal services,
- transmission media, and
- user device access methods.

with only localized changes to the architecture and implementation.

Transmission bandwidth on a channel is allocated in a distributed manner using a carrier-sense multiple-access with collision detection (CSMA/CD) access method. This technique permits each packet communications unit to contend independently for transmission access on one of the data channels. The minimization of centralized network control provides for high system reliability, low transmission delay, and high channel utilization. Each MetroNet channel is independent from all other channels with respect to transmission access, thus supporting simultaneous transmissions on each configured channel.

The protocol architecture for MetroNet is based on the ISO Open Systems Interconnection Reference Model [3] with modifications and extensions for the regional network environment. The seven protocol layers are:

- Application- Provides specific services to user devices
- Presentation- virtual terminal, format translation, end -to-end encryption services
- Session- name to address mapping, network monitor and control services
- Transport- flow and error controlled virtual circuit and transaction services
- Network- end-to-end addressing, routing and datagram services
- Link- per channel addressing, datagram services, error protection, transmission control (CSMA/CD) and Network Access Control
- Physical- multipoint, half-duplex communications with distributed access control.

It should be noted that the Applications layer is usually not provided by the network.

5. Summary

MetroNet will offer an integrated data communication system through the deployment of a sophisticated packet switched network. This network will allow the use of existing CATV systems to provide the residential consumer with a wide range of value added services in a cost effective manner. This network will not only meet the current projected communication needs of the residential market, but provide the extensibility and flexibility required to meet future growth and new services.

6. References

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MICROWAVE DATA TRANSMISSION USING AML TECHNIQUES

A. H. Sonnenschein P.E, I. Rabowsky, and W. C. Margiotta

HUGHES AIRCRAFT COMPANY
MICROWAVE COMMUNICATIONS PRODUCTS

This paper discusses the characteristics and relative merits of some of the alternate signal modulation methods which are employed to transmit various forms of data and voice over AML microwave systems.

AML systems have during the past 10 years become widely accepted as the dominant means for the local distribution of multiple video signals in the CATV industry. The reasons for this extensive use of more than 20,000 video channel paths worldwide are tabulated in Figures 1 and 2. In a nutshell, these reasons are that AML systems are more cost effective, spectrum efficient, and reliable than any of the available alternatives.

- **ECONOMICAL FOR MULTIPLE CHANNELS**
- **SPECTRUM EFFICIENT – HIGH CHANNEL CAPACITY**
- **CABLE COMPATIBLE – VHF IN/OUT**
- **GOOD PERFORMANCE**
- **HIGH RELIABILITY**

1. Why AML?

- **INCREASED CHANNEL CAPACITY REQUIREMENTS & DUAL CABLE SYSTEMS**
- **SHORTER AMPLIFIER CASCADES (MORE HUBS)**
- **ESCALATING COST OF HEADENDS**
- **FREQUENCY RE-USE TECHNIQUES**
- **ACCELERATING CASH FLOW BY LEAPFROGGING TO PROFITABLE AREAS**

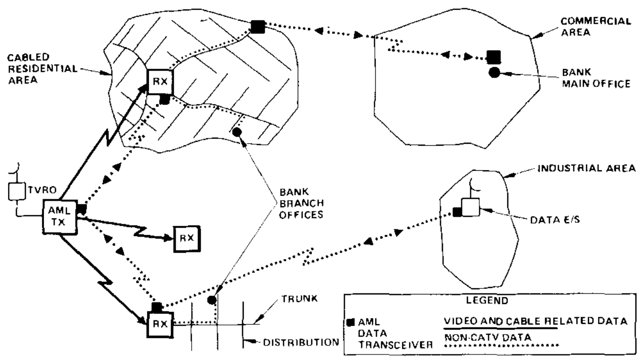
2. Further reasons for recent proliferation of AML in major urban markets.

The trend towards the use of AML hub distribution systems has further accelerated in recent years, as a direct consequence of the dramatic increase of channel capacity of major market franchises. This increase in channel loading has the following effects: 1 - A shortening of permissible amplifier cascades, 2 - A major increase in the cost of sophisticated headends to an extent that the cost of duplicating headends at various hubs becomes prohibitive, and 3 - A further strain on limited frequency allocations. All the factors have intensified the necessity for the use of AML systems in suburban as well as rural areas. Channel capacities as high as 160 channels are frequently necessary to accommodate all upstream as well as downstream transmission requirements.

More recently, various forms of data transmission requirements have been added to the prior video and FM broadcast traffic requirements. Some of these new requirements are CATV related, for instance security alarm signals, subscriber addressable control signals, interactive service signals, etc. An even larger growth area however is represented by opportunities for carrying signals for unrelated non-CATV entities on a leased channel basis. Potential customers include various kinds of institutions as well as commercial and industrial establishments.

Thus there are two major reasons why we have had to implement the data transmission capabilities of AML systems. First is the obvious fact that where the AML system forms the backbone of a CATV system, it must be capable of transmitting all required cable related as well as all leased channel data traffic. More importantly however is the fact that many potential commercial and industrial customers for data transmission services are in non-residential areas that are not cabled now, and that will be the last to be cabled - if they are ever cabled. Thus, a hybrid transmission system, as illustrated in Figure 3 is the only practical means of serving such potential data transmission customers. As the illustrations indicate, microwave relays are used to complement the CATV system, extending service to uncabled areas.

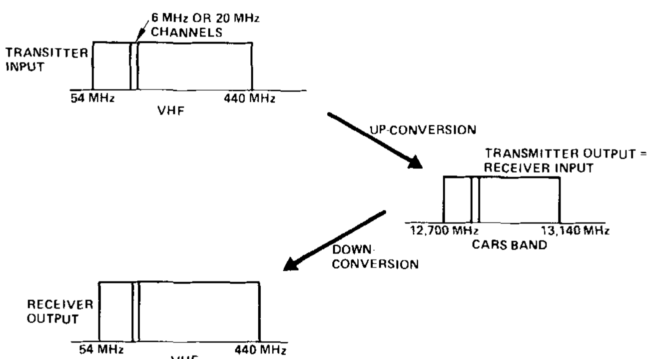
Before proceeding on to the various different data modulation methods, it is useful to briefly summarize the principle of operation of an AML system, from a broader perspective than is common in normal CATV video usage (see Figure 4). It can be seen that the AML system is essentially a frequency translating device. It simply upconverts any signals that lie in the VHF band to the 12 GHz band, transmits these signals from one place to



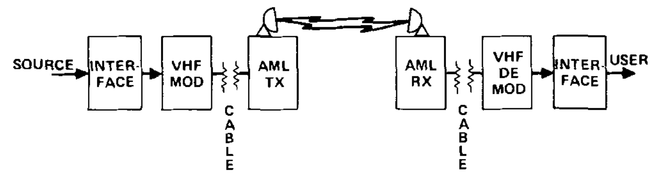
3. Hybrid data network.

another and then downconverts the received signals back to VHF again. In this process, it fully preserves all incoming modulation forms and spectral relationships. Thus the acronym AML no longer only denotes an "Amplitude Modulated Link" for VSBAM video signals, but rather a faithful and transparent microwave transmission system for any or all modulation forms, be they digital or analog. It has only half jokingly been suggested that AML really means "Any Modulation Link" and it is with this broadened scope that we wish to deal with here, bearing in mind that all the previously mentioned cost and bandwidth saving attributes of AML systems recognized for video traffic apply equally well to data transmission.

As illustrated in Figure 5 a typical block diagram of an AML one-way data link consists of an appropriate interface with the transmitting data equipment followed by a modulator which provides a modulated VHF carrier at its output. The VHF modulator output is connected to the input of an AML transmitter which then upconverts the VHF signal to the authorized microwave frequency. The signal received at a remote site by the AML receiver is downconverted to VHF and fed to a VHF demodulator. The output of the demodulator provides the appropriate interface with the receiving data communications equipment. Two-way communications is obtained by duplicating the equipment shown, with the exception of the antenna systems, at each data



4. AML - principle of operation.



5. Block diagram.

communications site and by providing frequency distinction between the upstream and downstream paths.

The modulators and demodulators may be remote from the AML equipment, being interconnected with standard CATV cable links.

There are a number of standard data communications interfaces which may be required to interconnect the data equipment to the modulator-demodulator (modem) equipment. Data processing standard interfaces such as RS-232C, RS422 and V.35 are readily available. Bell standard interfaces such as DS1, DS2 are also available.

There are five modulation methods that are being widely used for transmission of voice and data. They are tabulated in Figure 6. As you can see from the table, the familiar VSB and FM modulation methods can be used for either video or data transmission.

Each form of modulation has its own particular advantages and disadvantages to be considered when designing a data communications system for a particular application and for transmission through a broadband cable system.

Figures 7, 8, 9, 10 and 11 tabulate some of the characteristics of VSB, FM, SSB, FSK and QPSK modulation in relationship to the transmission of voice and data. These charts describe the applications and relative merits of the various modulation methods for different types of message traffic requirements.

MODULATION	TECHNIQUE	APPLICATION
VSB	VESTIGIAL SIDEBAND AM	VIDEO/DATA
FM	FREQUENCY MODULATION	VIDEO/VOICE & DATA
SSB	SINGLE SIDEBAND SUPRESSED CARRIER AM	VOICE & DATA
FSK	FREQUENCY SHIFT KEYING	VOICE & DATA
QPSK	QUADRATURE PHASE SHIFT KEYING	VOICE & DATA

6. Modulation techniques for data transmission.

APPLICATIONS	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
• VIDEO & PROGRAM AUDIO	NTSC STANDARD COMPOSITE VIDEO 6 MHz BANDWIDTH	• SPECTRUM EFFICIENT • CABLE COMPATIBLE • ECONOMICAL	NO FM IMPROVEMENT
• LOW SPEED DATA	3 CHANNELS 600 b/sec	• INEXPENSIVE	VERY LOW DATA RATE
• LINE SYNC MULTIPLEX	ANY COMBINATION OF NTSC VIDEO, OR DATA TO A TOTAL OF 6.3 Mb/sec	• POTENTIALLY LOW COST IN LARGE VOLUME • TDMA • FREQUENCY SHARED • TELETEXT COMPATIBLE	NOT YET COMMERCIALLY AVAILABLE

7. VSB.

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
• VIDEO & PROGRAM AUDIO	STANDARD NTSC VIDEO & AUDIO	FM IMPROVEMENT OF SIGNAL TO NOISE	REQUIRES 20 MHz
• BROADCAST AUDIO FM	16 CHANNELS @ 15 KHz AUDIO @ 75 KHz DEVIATION	LOW COST, FM IMPROVEMENT	REQUIRES 20 MHz
• VOICE-ANALOGUE	600 CHANNELS OF FDM @ 4 KHz EA	MODERATELY HEAVY DENSITY	REQUIRES 20 MHz
• VOICE-DIGITAL	192 VOICE CHANNELS, T1 COMPATIBLE	COMPATIBLE WITH DIGITAL SWITCHING	SPECTRUM INEFFICIENT, COMBINED ON ONE STREAM
• DATA-ANALOGUE	600 FDM CHANNELS EACH CHANNEL 14.4 Kb/s	FM IMPROVEMENT EDP COMPATIBLE	LIMITED DATA RATES, REQUIRES DATA MODEMS
• DATA-DIGITAL	12 Mb/sec IN T1 FORMAT	FM IMPROVEMENT, T1 COMPATIBLE.	EXPENSIVE MULTIPLEXERS, SELECTIVE FADING SENSITIVE

8. FM (20 MHz).

Upon review of a specific application, it should be possible to narrow down the selection of equipment to a preferred choice. For example, if you are to transmit data during daylight hours and entertainment video at night, you would most likely choose VSB and use line sync multiplex equipment to transmit the data. Line sync multiplex equipment is designed to convert standard data formats into teletext format and to transmit up to 525 lines of data at the rate of 9600 BPS for each line.

If the application calls for subdividing a 6 MHz channel into many standard 4 KHz voice channels and thus serve many users of voice and data, then you will use Frequency Division Multiplex (FDM) equipment together with a single sideband modulator.

If the application calls for a data network to connect a few hundred data terminals to a computer center, and if available spectrum on the cable is not in short supply, you will use an economical FSK data communications system.

Finally, if you have a mix of high speed data requirements such as 1.544 MBPS T1 lines for digital telephone switching systems, or 1 MBPS lines for high speed graphics terminals, then you will use the QPSK RF data modems. Because a 1.544 MBPS data modem requires a bandwidth of about 1.1 MHz it is possible to subdivide the 6 MHz channel and by utilizing FDM techniques isolate T1 data streams from one another, thus providing security between applications and preventing intersymbol interference from interrupting the entire data transmission in the channel.

The data communications network designer should become thoroughly familiar with each of the modulation methods listed above, and the wide

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
VOICE	≤ 960 CHANNELS OF FDM @ 4 KHz EA	• SPECTRUM EFFICIENT	NO FM IMPROVEMENT
DATA	≤ 960 CHANNELS @ ≤ 14.4 Kb/s	• COMPATIBLE WITH STANDARD EDP INTERFACES, • SPECTRUM EFFICIENT	NO FM IMPROVEMENT

9. SSB (6 MHz BW).

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
DATA	≤ 56 CHANNELS @ 56 Kb/s	LOW COST CABLE COMPATIBLE	VERY SPECTRUM INEFFICIENT

10. FSK (frequency shift keying).

variety of interfacing data communications equipment. This information together with the knowledge that the AML microwave link is equivalent to a short length of broadband coaxial cable makes it possible to design cost effective, reliable data communications networks.

In conclusion, we would like to reiterate the following points.

1. Message traffic in general, and data traffic in particular, offer one of the most promising and profitable enhanced service opportunities for CATV operators.

2. Data transmission requirements consist of CATV related traffic (such as interactive services or station monitoring) as well as traffic for institutional, commercial and industrial customers.

3. Such data traffic requires high transmission reliability and spectral utilization efficiency.

4. Commercial and industrial customers are frequently not in cabled areas and can only be reached by hybrid systems combining cable compatible microwave and cable elements.

5. AML microwave techniques offer advantageous means of accommodating virtually any analog or digital signal capable of being carried on conventional cable systems. In such applications, the AML system becomes a virtually transparent link which completely avoids the distortions and other technical and financial costs inherent in microwave systems that require demodulation of the cable-carried signals to baseband and subsequent remodulation to cable compatible formats.

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
VOICE	144 T1 COMPATIBLE VOICE CHANNELS	• SPECTRUM EFFICIENT, • CABLE COMPATIBLE • PARTIONABLE USING FDM TECHNIQUES	REQUIRES HIGH C/N RATIOS FOR LOW BER COMPARED TO FM OR FSK
DATA	10 Mb/s IN A 6 MHz BANDWIDTH SLOT	• SPECTRUM EFFICIENT • CABLE COMPATIBLE • PARTIONABLE USING FDM TECHNIQUES	REQUIRES HIGH C/N RATIOS FOR LOW BER COMPARED TO FM OR FSK

11. QPSK (quadrature phase shift keying).

MINI-HUB ADDRESSABLE DISTRIBUTION SYSTEM
FOR HI-RISE APPLICATION

M.F. Mesiya
G.E. Miller
D.A. Pinnow

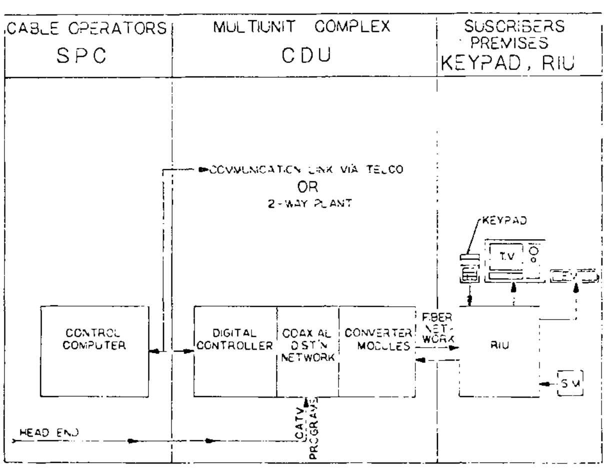
Times Fiber Communications, Inc.
358 Hall Avenue
P.O. Box 384
Wallingford, CT 06492

INTRODUCTION

Mini-Hub is a micro-computer controlled local distribution system to provide cable television and other services for urban high-rise environment in major metropolitan areas. The system is fully addressable and uses state-of-the-art fiber optic technology to provide improved security and signal quality.

The block diagram of the basic Mini-Hub system is shown in Figure 1. It consists of five major components:

1. Keypad
2. Residential Interface Unit (RIU)
3. Central Distribution Unit (CDU)
4. Fiber Network
5. Subscriber Program Controller (SPC)



Block Diagram of the Mini-Hub System
Figure 1

In operation, the subscriber selects a channel. A digital signal is generated at the keypad which corresponds to the selected channel and is transmitted optically by the RIU via the fiber network to CDU. The CDU is the central node of communication and signal distribution for the star network architecture used in the present system. It determines service authorization in response to a channel change request, and if valid, just that channel is sent to the subscriber.

Addressability can be achieved locally by using a Field Programming and Diagnostic Unit (FPD). Alternatively, the CDU can be addressed from the operator's office using the SPC. The cable system operator has the capability to enter or request information from the CDU. The interface allows the operator to update/reduce the service menu; enable or disable service; run diagnostics; carry instantaneous polling and other services.

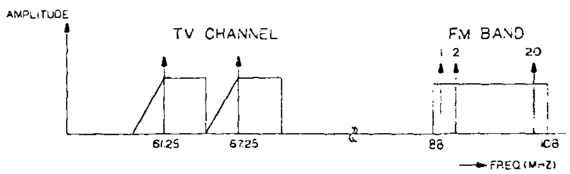
The organization of the paper is as follows: Section 2 summarizes the performance and system design objectives which guided the development of the Mini-Hub system. The key features of the subscriber's keypad are described in Section 3. In Section 4, the RIU is described. Section 5 gives a description of the CDU. The optical fiber network is described in Section 6. The SPC and system's communication network that provides full addressability to the cable operator are considered in Section 7. Section 8 concludes the paper by outlining the advantages of the Mini-Hub System from the cable operator's point of view.

SECTION 2. SYSTEM DESIGN OBJECTIVES

The following objectives guided the development of the Mini-Hub system:

Transmission Format. One TV channel assigned either on channel 3 or 4 and FM band consisting of 20 carriers in 88-108 MHz range are transmitted to the subscriber on uplink fiber. The digital data from subscriber's Keypad or Sensor Interface Module (SIM) is transmitted downstream at 9.6 kb/s using NRZ code. The frequency plan for the uplink is shown in Figure 2.

Addressable Control. The cable operator exercises total control over the service delivered to each subscriber from the SPC at his central office. The CDU not only operates under the software control of the SPC, but also sends clear confirmation of the commands being executed. The cable operator, as part of routine operational procedure, can confirm the integrity of the control mechanism by verifying the service status of each subscriber.



Frequency Assignment of Uplink
Figure 2

Performance. The performance requirements adopted for delivery to the subscriber are as follows:

TV	
Level	10 dBmV, typical
CNR	43 dB, minimum
FM	
Level	-8 dBmV, typical
SNR (mono)	65 dB, minimum
(stereo)	55 dB, minimum

The guaranteed performance, of course, sets certain minimum requirements on quality of the drop acceptable from cable system.

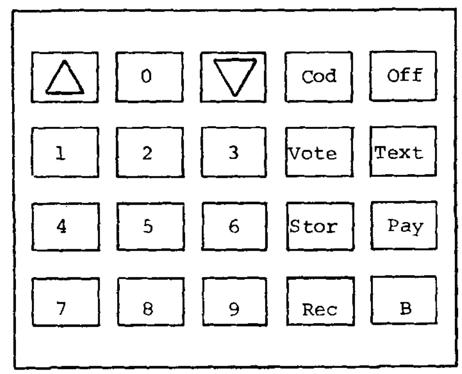
Modular Expandability. One of the major design goals in developing the Mini-Hub system architecture was to incorporate flexibility to provide subscriber access to new cable services as they develop without making the current hardware obsolete. Whereas the basic Mini-Hub system features full addressability (including opinion polling), it is possible to expand to other interactive services, such as

Impulse Pay-per-view
Catalog Shopping
Fire/Medical/Panic/Intrusion
  Alarm
Videotext

This can be accomplished by adding plug-in services modules and/or firmware changes.

SECTION 3
KEYPAD

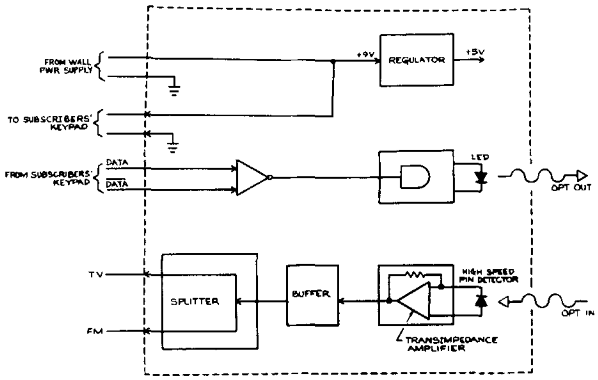
The Keypad provides the necessary interface between the subscriber and the CDU to furnish two-way interactive cable TV service. Included in the Keypad is an 8-bit microcomputer which, in addition to performing the necessary local control and diagnostic functions, receives (from remote IR unit) and encodes 6he data in serial format. The Keypad allows tiered access to over 100 channels, opinion polling, pay-per-view parental authorization codes plus other interactive services. The layout of the push-button keyboard is shown in Figure 3.



Block Diagram of the Keyboard
Figure 3

SECTION 4.
RESIDENTIAL INTERFACE UNIT (RIU)

The RIU is a permanently mounted wall unit which acts as an interface between the subscriber and the CDU via the fiber network. The block diagram of the RIU is shown in Figure 4. It contains a highly reliable digital LED transmitter and a low-noise wideband optical receiver. The transmitter converts the digital command words from the Keypad into a stream of on-off optical pulses. The optical receiver uses a low voltage, high speed PIN detector packaged to provide optimum coupling to 200 um core fiber without using any pigtail. A low-noise, wide band transimpedance amplifier performs the necessary current-to-voltage transformation. TV and FM signals are then made available at separate F connectors via a buffer stage and power splitter.



Block Diagram of the RIU
Figure 4

SECTION 5.
CENTRAL DISTRIBUTION UNIT (CDU)

The CDU is the focal point for all communications and signal distribution. It consists of three main sections:

1. Coaxial Distribution Network
2. Digital Controller
3. Converter Modules

Coaxial Distribution Network

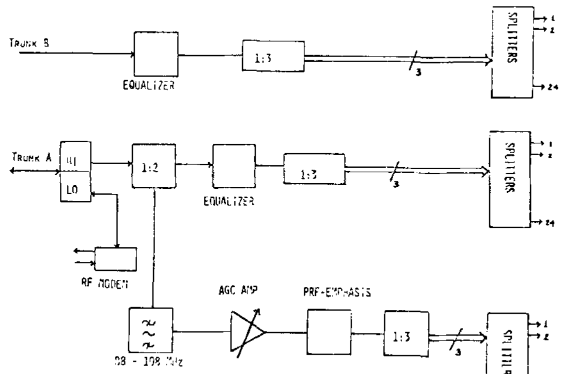
The coaxial distribution network interfaces with 2-way cable distribution plant to perform the following functions: (i) Condition and distribute TV signals on A and B trunks to all converter modules; (ii) Extract, AGC, preemphasize, and distribute FM carriers in 88-108 MHz band to all converter modules; (iii) Combine RF modem's response signal with the return trunkline signals.

The block diagram of coaxial distribution network is shown in Figure 5.

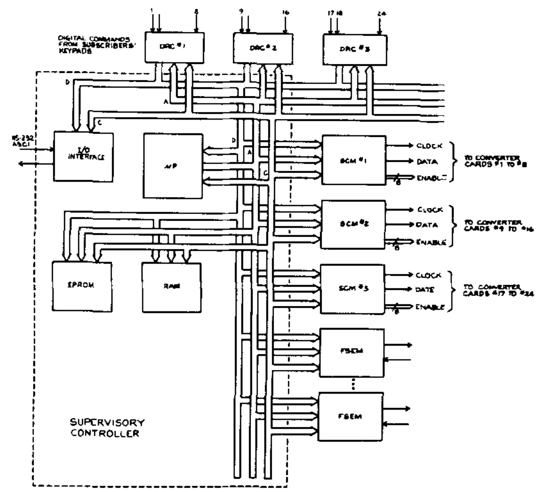
Digital Controller

The digital controller communicates with subscribers as well as cable operator's SPC to exercise necessary control towards delivery of authorized levels of TV and other services. The functional diagram of the digital controller is shown in Figure 6. The major components of the digital controller are

(i) Supervisory Controller
(ii) Data Receiver
(iii) Subscriber Control Module



Block Diagram of the
Coaxial Distribution Network
Figure 5



Block Diagram of the Digital Controller
Figure 6

The Supervisory Controller provides the necessary control over data flow to implement various services as well as supporting the many diagnostic functions designed into most areas of the system.

The Data Receiver is used to receive serial data from the subscriber's Keypad or Sensor Interface Module (SIM). Each data receiver card supports 8 subscribers and up to 3 cards may be installed in a CDU, therefore allowing up to 24 subscribers to be serviced. Each subscriber's receiver IC is individually addressed by the supervisory controller and data placed on bus for further processing by either respective Subscriber Control Module (SCM) or one of the Future Services Expansion (FSE) modules.

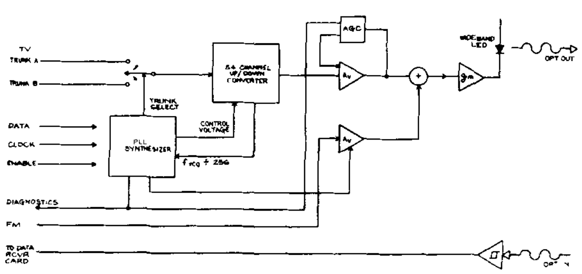
The Subscriber Control Module is a microcomputer based channel selection control unit. One module services up to 8 subscribers and acts upon commands which are routed to it by the Supervisory Controller. Commands include channel change requests from subscribers and SPC's tier enable/disable authorizations.

Following receipt of a channel change command, the microcomputer in the SCM compares the command word to those stored in Electrically Alterable Read Only Memory (EAROM) to determine subscriber's status. If the service has been made available, the SCM sends the appropriate data word to phase locked loop (PLL) circuitry in the converter module to change channel. The contents of the EAROM are remotely alterable by the cable operator using the SPC, thus providing complete control over tier enable/disable functions.

The Converter Module

The Converter Module is a programmable channel selection unit which delivers one subscriber requested cable channel as well as FM band to the uplink optical fiber. One module is required per subscriber. The up/downconverter is switched between trunks A and B on command from subscriber's Keypad. Channel select and other commands to the module originate from the SCM and are sent in serial form. The converter module also regulates delivery of FM service upstream under the control of cable operator's SPC.

The block diagram of the Converter Module is shown in Figure 7. The PLL synthesizer generates the necessary control voltage to set up/down converter's VCO frequency in response to channel select command on its data input line. The up/down converter used in the present system is of improved design as evident from key specifications summarized in Table I.



Block Diagram of the Converter Module
Figure 7

TABLE I

Noise Figure	10dB, max.
Return Loss - Input	14 dB, min.
Output	14 dB, min.
Flatness	±0.5 dB
Output Frequency - Accuracy	±5 kHz
Drift	±50 kHz
Cross Modulation (at 13 dBmV input/channel)	-56 dB, max.
Adjacent Carrier Rejection	30 dB, min.
Temperature Range	0^o to 50^oC

AGC control of LED drive assures specified modulation depth and performance level in spite of certain extent of channel-to-channel level variation. The LED used to transmit multiplexed TV and FM signal on frequency upstream is state-of-the-art performance device. It has excellent linearity and coupled power-bandwidth product. In addition, the inexpensive GaAlAs surface emitter has proven reliability in excess of 10^5 hours.

The converter module uses a schmitt trigger detector to perform optical to electrical conversion of downlink data headed for the Data Receiver.

SECTION 6.
FIBER AND CABLE NETWORK

The fiber developed for Mini-Hub is of a special large core design to efficiently collect light emitted from an LED. The core diameter at 200 um makes the cross-sectional area 16 times greater than that of the 50 um diameter international standard fiber used in telecommunications. Light collection from an LED is directly proportional to the core area. Another advantage of the large core is that it substantially reduces the tight tolerances and thus the cost associated with optical connectors. The fiber is made with a pure silica core and a binary borosilicate cladding. The low cost of the silicon and boron starting materials makes this fiber particularly attractive for consumer applications.

A star network of large core glass-clad-glass step index dual fiber optic cable links the subscriber's RIU with the CDU. The downlink fiber carries digital signals from the RIU to the CDU. The uplink fiber transports TV and FM optical signals from the CDU to the RIU. The major segments of the fiber network are

1. Distribution Box
2. Vertical Riser
3. Junction Box
4. Horizontal Home Runs

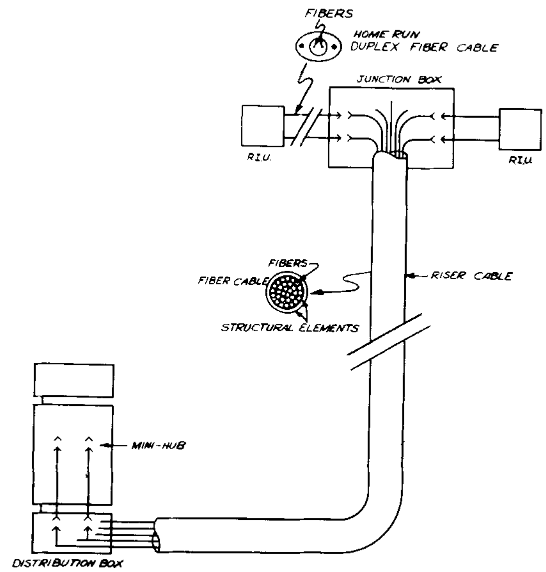
Figure 8 shows the fiber optic network configuration for high-rise application. The optical fiber jumpers from each converter module terminate on the optical connectors in the distribution box. Vertical Riser cable originates at the distribution box and terminates on the junction box at each floor. The Riser uses multiple-fiber cable design and may contain 8, 12, 16 and up to 24 fibers. The overall dimensions of this cable are on the order of 1/4". Thus, a single riser cable, with dimensions comparable to RG-59 coax, can serve up to 12 subscribers. This multifiber cable is available with a polymer outer sheath or in a seamless aluminum jacket where re- quired by fire codes. The home runs to each subscriber begin at the junction box and terminate in the RIU. The dedicated fiber pair cable used in these runs is packaged in single oval element reinforced with two steel wires. The characteristics of optical fiber used in the network are summaried in Table II.

TABLE II

Fiber Dimensions	200 um core dia. 250 um clad dia.
Type	Step index
NA	0.15
Bandwidth	45 MHz-km
Attenuation	8 dB/km
Home Run Cable Dimensions	Oval, 0.100 in. x 0.150 in.

This cable is particularly well-suited for termination with optical connectors. The first step in terminating the cable is to use a knife or razor blade to cut into the jacket about 6 to 8 inches from the end. The blade is then glided along steel reinforcing wires to strip away the polymer and expose the fibers. In completing the connector assembly, the steel wires are fastened to the backshell of the connector so that axial pull forces are not directly transmitted to the fibers. The fiber can be terminated with a rugged connector assembly in less than 5 minutes under field conditions.

Using state-of-the-art device and fiber network technologies, the system can achieve a transmission distance of 1/2 km. The link budget accounts for not only worst case connector and cable losses, but includes margin for temperature and aging effects.



Fiber Network in Hi-Rise Environment
Figure 8

SECTION 7. SUBSCRIBER PROGRAM CONTROLLER (SPC)

The SPC is a minicomputer system designed to support the programming of Mini-Hub system CDUs in field installations. The smallest version of SPC supports from 20,000 to 30,000 subscribers. This is determined by a combination of equipment and storage strategies. The SPC utilizes advanced minicomputer technology which can be upgraded to provide greater subscriber capacity and to add real-time processing. Additionally, the SPC supports production of CDU subscriber programming on magnetic media or battery backed RAM. This media can be used with Field Programming and Diagnostic Unit (FPDU) to program the CDU or to execute diagnostics at site. The SPC employs Digital Equipment Corporation's (DEC) PDP-11 system hardware. Software support for SPC includes an RT-11 operating system, a communications controller and Mini-Hub system application software. The application software package includes the following modules:

Service
These programs are used to create Master and Site Files which detail what services subscribers are authorized to receive. The site files are outputted to various field installations via cable operator's plant or telco network. The

functions include addressability operations such as subscriber channel authorization/verification, upgrading/downgrading, and connect/disconnect.

Diagnostics
These programs are used to exercise various diagnostic functions built into the system. The operator selects diagnostic options desired and defines the scope of test.

Transactions
These programs are used to provide "impulse" pay-per-view programming, opinion polling, teleshopping and personal transactions in a batch-store and forward mode. To implement these functions, supervisor controller memory at site is used as temporary storage media. The information is collected by SPC in a polling operation, concurrently clearing site storage for new transactions.

Real Time
These programs support functions such as fire, security, etc. which require two-way real-time processing.

SECTION 8
ADVANTAGES

1. Signal Security. The Mini-Hub system eliminates signal theft completely because it sends only one authorized channel at a time to the subscriber's apartment. Even FM service can be remotely switched on or off. The F/O network is virtually impossible to tap and thus provides an added measure of security.

2. Elimination of Equipment Theft. Since the keypad in the subscriber's apartment is inexpensive, equipment theft is essentially eliminated. Further, the motivation for theft of the keypad does not exist because it cannot provide service unless authorized by the CDU which is remotely located in a secure area of the building.

3. Lower Connect/Disconnect Costs. Disconnect costs can be totally eliminated. Addressable control allows disconnect or back-pay reconnect instantly from the home office. An apartment visit to retrieve the expensive set-top converter is not required.

4. Flexible Control of Premium Programming. With the Mini-Hub system, premium programming can be provided on impulse pay-per-view or regular basis quite flexibly.

5. Expandability to Provide New Services. The system is designed to provide new services such as fire/intrusion alarm, and other enhanced services by adding plug-in modules or replacing the firmware without making the system obsolete.

6. Improved Signal Quality. The system design is performance driven. The improvement in signal quality delivered to the subscriber has been achieved by using state-of-the-art up/down converter, fiber optic and microcomputer technologies.

7. Compatibility with Other Addressable Systems. In a mixed single/multi-unit dwelling environment, the Mini-Hub system can coexist with other addressable converter systems. A modified version of the SPC, acting as a database controller, can provide the necessary interface with cable operator's control computer.

8. Electrical Isolation. The fiber optic network provides electrical isolation between the subscriber and the Mini-Hub. Sheath currents common to coaxial systems are eliminated as well as any potential egress or ingress of RF signals. Static discharge transients cannot enter the Keypad and damage microprocessor circuitry.

Acknowledgments

The Mini-Hub System is the culmination of a major development effort at TFC involving more than 50 people. M.F. Mesiya acknowledges the contributions of J. Barton, T. Batko, N. Bunker, J.Curreri, J. Heath, W. O'Neil and F. Williams.

The development of the SPC represents efforts of S. Westall's team. Development of the fibers and fiber cables was due to the efforts of W. Hanley, J. Lanoue, P. Levin, D. Munson and F. Noble. The connector work represents the efforts of L. Engdahl, R. Strait, and R. Ziltz..

The authors thank J. Herman for critical review of the manuscript and constructive comments.

NEW SERVICES: AN INTEGRATED CABLE NETWORKS'S APPROACH

Michel Dufresne

VIDEOTRON COMMUNICATIONS LTEE

SUMMARY

Over the years cable television systems have shown their growth capabilities by offering a widening range of new services. Several systems have expanded this way to meet the specific needs of viewers. The VIDACOM™ system described in this presentation is an integrated communications system based on broadband digital transmission. This system's design enables it to support a whole range of new services from which an individual viewer can elect to receive only those of personal interest. The numerous services offered include special information, inter-personal communications, transactions, video games and software, pay-television addressing and decoding functions, opinion polling, monitoring functions, as well as hybrid services combining video, audio and informations. The VIDACOM™ system is now being introduced by Vidéotron a major Canadian cable television system. A functional description of the system and its services follows.

INTRODUCTION

The Vidéotron cable television system serves more than 600,000 subscribers in Québec, out of a potential 1,100,000 homes. Vidéotron offers its subscribers programming on 35 cable television channels since 1975, with new services being steadily added.

Principal services offered include retransmission of programmes from Canadian, American and Québec broadcast television stations. There is also a special channel that offers Québec viewers programming from France. Proceedings of the House of Commons in Ottawa and the Québec National Assembly are carried on two other channels.

Regional community channels with studios in different localities are also available for use by the public to present its own programmes of special interest.

Local programming of varied kinds is carried on specialized or thematic channels providing wide coverage of sports, arts and entertainment, science, and programming for children. Additional services include self-programming or television on request. Subscribers can select a programme from among more than 7,000 subjects offered, and see this selection inserted in the schedule of one of the channels made available for this purpose. The request is made by telephone and automatically listed in the schedule as soon as there is a time slot available.

A "Contact" information channel for subscribers allows animators to speak directly to viewers about ways to improve the quality of technical service or programming, or simply to explain the new services available. A special weekly programme called "Tne Wired City" informs subscribers about latest developments in services and new technology.

In addition to these video programming services, various channels carry alpha-numeric information on general subjects, programming schedules, weather reports, and other similar services.

A classified advertising service is available to subscribers who have articles they wish to sell. A photograph and a caption are shown on the screen while an announcer describes the article for sale.

Another entertainment service gives subscribers access to video or computer games. Using a touch-tone telephone, the subscriber can request a particular game and then have the computer designed graphics transmitted by cable for viewing on the TV screen at home. Various subscribers can experiment with these games 24 hours a day on few cable channels.

Finally, a news and information system has been introduced, so that a local daily newspaper can provide the cable viewers with an electronic "newspaper". This service is just one of the interesting possibilities offered by TELIDON, the Canadian videotex system. In this way, several news columns are presented to all our subscribers 24 hours out of 24.

On the technical side, these various network systems are linked by satellite (provincial); long-range micro-wave networks (inter-regional); high-capacity micro-wave systems (regional); and star / tree structured cable systems based on coaxial cable technology (local). These local infrastructures also have two-way capacity.

NEW DEVELOPMENTS AND SERVICES

In addition to the services already offered, Vidéotron is now setting up a communications system capable of supporting a new range of services. The approach used is based on broadband digital communications technology adapted to cable television systems. An integrated approach making efficient use of the coaxial cable network structure makes it possible to transmit these communications services simultaneously and concurrently. It also avoids the proliferation of non-compatible communications protocols, especially the over-abundance of equipment that would otherwise be required for the user to receive these widely varied services.

This system is oriented towards the use of well known digital computer and telecommunications protocols.

In addition to the use of this integrated approach, the system is so designed that it permits progressive introduction of system functions and the ability to carry new services from time to time, as needed, based on modularity principles.

An important aspect of this system is that it has been designed in harmony with broadband cable television system characteristics based on communications models that are defined taking into account this inherent structure. This enables communications to be directed as desired, either to all subscribers, to special groups, or to individuals.

The subscriber or communications interface has basic electronic functions that permit the user to receive or access various services. Most of these services are managed and offered according to optional models or categories of services. The various interface functions are activated or deactivated as required, based on the user's options.

Some less universal services are supported by the addition of a basic interface module or by the use of peripheral terminals linked with the communications interface (ex.: personal micro-processor).

An important principle followed in developing the system was to establish relations between the video, audio and information functions. This hybrid usage makes it possible to define new communication models adapted to cable system capacities.

In establishing the system, two complementary models were defined; one-way and two-way. An important new range of services can be offered with the one-way model. Later, when the system possesses the two-way characteristic, a second category of services fully compatible with the first category can be added.

This document describes the kinds of services that the VIDACOM™ system can support, based on the two phases to be introduced: the one-way mode and the two-way mode. Technical aspects will not be covered here, but by presenting its several characteristics it will be possible to grasp the system's capabilities.

VIDACOM™ SERVICES

The one-way communication mode is introduced in a cable system which does not have two-way transmission characteristics. This is the situation that exists in most systems that were set up essentially for the retransmission of broadcasting station signals. In this version, new services can be offered over the one-way system structures, while providing the possibility for further expansion when these systems are modernized to support two-way transmissions.

On the services level, it should be pointed out that the VIDACOM™ approach offers the user an interactive mode to access new services from the moment a one-way mode is structured into the system. Later evolution to a two-way mode increases the services that can be accessed by user, while these two modes remain transparent for the user.

a) Information and communications services

Depending on the transmission mode introduced, the VIDACOM™ system permits information to be distributed selectively, either to the majority of users, to special interest groups, or to individuals. The system has a technical capacity to transmit more than 1,000 pages/second, with the possibility of carrying more than 20,000 pages of information in a single cycle. These information pages are prepared from material stored in the computer data bank; the pages in each information magazine are linked for retrieval in a specific pattern.

The user can access these pages by pushing buttons on a numeric keyboard, or keypad, to call up "menus" or lists of items, indexes, or selected pages, in order to retrieve the desired information. Retrieval is rapid, taking an average of less than 2 seconds depending on the links used, and regardless of the number of active users.

Certain information categories or magazines can be accessed only by those users who have subscribed for the services in question. This information addressing procedure makes it possible to direct specific material to users in various interest groups.

The information contained in each of 20,000 pages can be changed or updated continuously to respond to the needs and interests of users. In this way, more than 200,000 pages of information can be transmitted in a single day to all subscribers or users with access to the cable system.

A third usage mode involves communication of specific information to an individual user. A message system can be set up for selective delivery of desired content to each user, by inserting these pages in one of the cycles at the proper time. The basic information cycles of 20,000 pages are affected very little, if at all, in this type of communication.

The information thus transmitted is displayed on the user's TV screen by the VIDEOTEX presentation module, after being encoded by TELIDON Videotex process. The display is made compatible with the TELIDON encoding system, by using a sub-set called MINI-TELIDON. This approach was selected so that a decoder could be integrated in the subscriber interface at low cost.

The display decoder's features, which represent a sub-set of TELIDON possibilities, allow the information to be displayed in an alpha-geometric format which provides visual resolution and choice of colours far superior to those possible with existing alpha-mosaic systems.

Key words search can be used to access information based on alphabetical indexes provided as pages of the information pages cycle. The keypad is used for the entry of the request.

The one-way operational mode can therefore be described as a selective videotex function mode, because information can be selected without the need for two-way transmission capability. The user interacts with a data bank of 20,000 active pages in the same manner as if connected directly with a computer. It is important to note that when the interactive mode is added to the system the pages returned to each user are added to one of the cycles, but addressed specifically to each user. This is the videotex mode.

Communications services added to this interactive mode include such varied ones as inter-user electronic mail, transaction services such as access to remote data banks or computer services (commercial tele-transactions).

b) Selective video and audio services

Cable systems already carry numerous television and FM radio frequency signals. These systems now have the capacity to support more than 50 television channels.

Addressing and tele-loading functions permit remote management of access to selective services such as pay-television. The presence of TV converter and signal descrambler functions within the VIDACOM™ interface makes it possible to offer various video services such as Pay-TV in particuliar.

Using the same technological base, selective services can be provided to specific groups of users. Tele-education programmes or business conferences can be organized by selectively distributing certain content on a definite programming and scheduling basis. These video signals, which are normally scrambled, can be received only by authorized users.

A complementary service offered is stereophonic sound for Pay-TV channels. This optional interface function permits the user to link the subscriber interface with a stereophonic reproduction system to receive high fidelity sound compatible with the video quality.

c) Hybrid video / information services

The user interface has built-in electronic functions for simultaneous reception of video and information, along with mixing of the video and information content.

Included in the first group of services in this category are video captioning for the hearing handicapped, or to provide translations from another language. The system has the capability for captions to be either window displayed or superimposed on the image. The positioning of the captions is defined when the programming is being prepared.

This type of captioning is also used when the user operates the terminal. Thus, at the user's option, the lower portion of the picture on the screen can be replaced by a "menu" of available services to permit to the user to make a choice.

When desired, the time, date and station selected can be displayed superimposed on the screen.

When certain information is desired, this can be displayed in full page format (videotex mode) at the bottom of the screen or superimposed on the image. The user is thus able to consult the information without missing anything in the video programme being watched.

When specialized video services or documentaries are being transmitted, this hybrid mode can be used to complement a video programme making information available to the user on request. This information can be superimposed, either partially or completely over the video picture.

d) Telematic services

The user interface has other communications functions as diversified as the information and communications services described here. By adding an external communications module, this interface can communicate with peripheral units and transfer certain service content to these external units.

One example of these peripheral services involves the use of a teleprinter to printout certain information when the content format is compatible. A user can retrieve information for display on the TV screen, and then have the information he wishes to retain printed out for a permanent record.

Another application involves providing access to software programmes for use with personal micro-computers. A user so equipped could consult a diversified software "library" accessible by either the one-way or two-way mode, as the case may be. This software would be available in different types and formats to conform with the model of personal micro-computers used by the subscriber. These software programmes could have uses as varied as desired, including computer games, management models, tele-education, word processing and other functions.

This mode of communications by means of an interface access port enables various peripheral units to be linked with a high-capacity communications system to access various telematic services.

e) Video games and internal functions of user interface

The VIDACOM™ user interface capacity is based on its internal programming. This programming is dynamic in the sense that it can be modified or adapted with changing and growing operating needs.

This interface programming makes it possible to offer the user self-programming services for utility functions. Some examples of these functions are: selection of preferred TV channels, useful information packages, controlled access (by password) to certain programme, and programme listings by channel and viewing times.

This self-programming capacity at times can also serve other purposes, such as the tele-loading of special software in the user interface to perform certain special functions. In view of the residual capacity available in the interface, it is possible to load programmes or software to make video mini-games of attractive quality available to the user. When the self-programming functions described in the previous paragraph are temporarily eliminated, the allotted capacity can be augmented to accomodate games of average complexity. In this mode, the graphics generator is used to produce the necessary images on the television screen. This graphics generator has specific functions enabling it to produce the special animations used to play these video games.

f) Tele-command and tele-reading services

These services group all the communications transactions involved in the remote control of certain functions. Among these is tele-loading of options related to services accessible to an individual user. The remote authorization for access to certain information magazines or material depends on whether or not the user has subscribed for these services (tiers).

Another group of tele-loading services comprises special addressing transactions for the management of energy usage, by electric utilities for instance. This provides the energy companies with a method for controlling energy consumption in their systems by making load shedding during peak load periods. In another application, electric utilities can adjust meter rates by remote control during peak demand periods to encourage users to make a personal decision to cut power consumption.

These services use the one-way transmission mode that permits telecommand functions, but not the capability to verify receipt of the command.

When the two-way mode is added, a tele-reading can be made following the tele-command, or tele-readings alone can be made, as desired. This latter operational mode is used for fire, burglar and security alarm systems, as well as for monitoring functions of various kinds.

Whatever the nature of these various services, certain tele-command transactions can be provided as complementary services (teleprinter operation).

CONCLUSION

Information services enter a new era with the advent of VIDACOM™ system broadband communications. This integrated system can provide services of varied kinds, by using an exploiting the special features and capabilities of the cable systems.

The Vidéotron System in Montréal will be conducting experiments with this technology and introducing the services described, starting in July 1982, with the help of 250 user interface prototypes. After the necessary adjustments have been made following these experiments, Vidéotron initially plans to install 100,000 of these interface units during the first year of operation, starting in September 1983. Integration tests are now in the final stages for all procedures related to transmission of these services on the cable systems and communications management from the head ends.

Several large North American cable systems are now evaluating this system and the services it will carry. It can thus be anticipated that VIDACOM™ will quickly be adopted by several cable companies. It should be pointed out here that this technology is also applicable to cable systems of average size.

OPTICAL FIBER CABLES AND CONNECTORS FOR MINI-HUB

Douglas A. Pinnow
Ross W. Strait, Jr.

Times Fiber Communications, Inc.
358 Hall Avenue
P.O. Box 384
Wallingford, CT 06492

INTRODUCTION

New large core fibers, special cable constructions, and associated optical connectors have been developed in support of a major system effort to distribute television signals within a high density area or high rise apartment buildings. This new system, known as MINI-HUB, has a star configuration with dedicated fiber pairs connecting each apartment to a Central Distribution Unit (CDU). One of the fibers is used to transmit a single modulated TV channel from the CDU to the subscriber while the other transmits a digital channel select signal from the subscriber back to the CDU. A more detailed description of this system is given in a paper entitled "MINI-HUB Addressable Distribution System for Hi-Rise Application," which is presented by M.F. Mesiya et al in the session on New Developments in Addressable Hardware. This paper deals with the optical fibers, cable constructions and optical connectors developed for the MINI-Hub system.

FIBERS

The development of fibers for this system was guided towards the most cost effective design that would satisfy the following technical requirements:

- Low loss: less than 10dB/km.
- A bandwidth length product sufficiently large to transmit TV signals at the Channel 3 or 4 carriers (60 or 66MHz) for distances up to 500 meters.
- A sufficiently large core that inexpensive connectors (approximately $1 per fiber end) could be used with insertion losses of no more than 2dB per connection.
- A large enough core and numerical aperture to accept more than 100μ Watts of light from state-of-the-art LED sources.

The preferred fiber design which economically satisfies all of these requirements has a 200μm core of pure silica and a 25μm thick cladding layer of borosilicate glass which builds up the outside diameter to 250μm. The core diameter at 200μm makes the cross-sectional area 16 times greater than that of the 50μm diameter international standard fiber used in telecommunications. This is a significant advantage since light collection from an LED is directly proportional to the core area. Another advantage of the large core is that it substantially reduces the tight tolerances and thus the cost associated with optical connectors.

Low fiber cost is realized through the use of the inexpensive binary borosilicate glass system: a low refractive index borosilicate cladding deposited over a pure fused silica core. This simple step index doping scheme enables tight process control. Processing time is minimized through the use of pre-sintered silica start rods of high optical quality, upon which a substantially constant composition of borosilicate glass is deposited. The cost of the materials used to make this fiber is only a fraction of the cost associated with the alternate germanium doped silica type fibers. The difference is due to the abundance of the boron dopant as compared to germanium, which is now considered a strategic material by the U.S. Government. The numerical aperture of this waveguide is targeted at 0.15. This produces an intrinsically large bandwidth-length product, atypical of higher numerical aperture step index waveguides, with the result that the highly practical value of 45MHz is achieved. Over short distances of 1/2 kilometer or less, single channel video bandwidths fit well within the capacity of these fibers.

CABLE

Two basic cable constructions have been designed for MINI-HUB. The first is a dual fiber construction for "home runs" directly from the CDU to a subscriber's Residential Interface Unit (RIU). The dedicated fiber pair cable construction used in these runs is packaged in a single oval element reinforced with two steel wires to give it a pull strength of over 80 pounds. A cross section of this cable is shown in Figure 1. Its area is only a fraction of that of RG-59 coax, yet its durability and flexibility are comparable to coax.

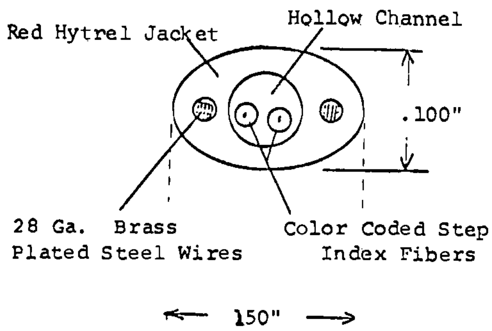


Figure 1

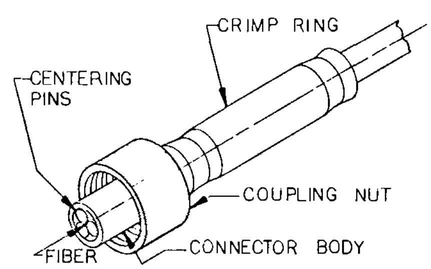


Figure 2a

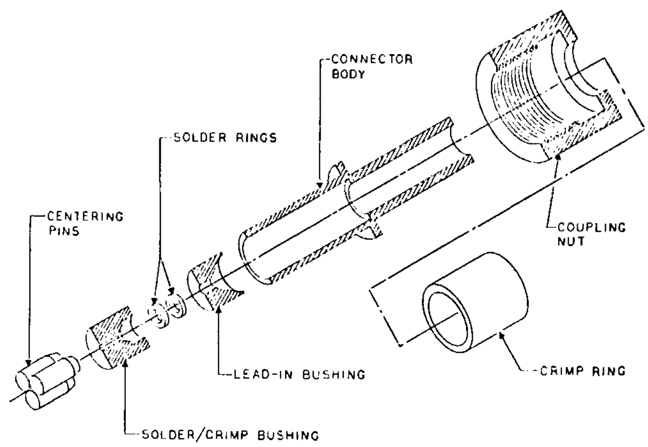


Figure 2b

The other type of cable that has been developed for MINI-HUB is a multi-strand construction that will typically be run in vertical risers where space is at a premium. The riser cable may contain 8, 12, 16 and up to 24 fibers. The outside diameter of this cable is approximately 1/4 inch. Thus, a single riser cable, with dimensions comparable to RG-59 coax, can serve up to 12 subscribers. This multi-fiber cable is available with a polymer outer sheath or in a seamless aluminum jacket, where required by fire codes.

These cables are particularly well-suited for termination with optical connectors. The first step in terminating the oval element is to use a knife or razor blade to cut into the jacket about 6 to 8 inches from the end. The blade is then glided along steel reinforcing wires to strip away the polymer and expose the fibers. In completing the connector assembly, the steel wires are fastened to the backshell of the connector so that axial pull forces are not directly transmitted to the fibers. The fiber can be terminated with a rugged connector assembly in less than 5 minutes under field conditions using the connectors described in the following section.

CONNECTORS

Experience gained early in 1980 with our first MINI-HUB installation established that available connectors were not well suited either due to their high cost or long installation time. Installation was protracted by the curing time of the epoxy glue used to secure the glass fiber to the connector body and by the time to polish the fiber end. As a consequence we set the following objectives for our current MINI-HUB connector development:

- Installation time: less than 5 minutes per fiber end.
- Cost: approximately one dollar per end.
- Minimum reliability: comparable to a coax F-connector.

These objectives have been met by an internal development at TFC and are being in parallel by several other connector manufacturers. The TFC connector is shown in Figure 2a and Figure 2b.

There are three key features in this connector design. First, the fiber is aligned and precisely centered along the axis of the connector body by three precision ground pins. Secondly, the glass fiber is rapidly secured to the metal body of the connector by a unique soldering technique. Brief application of external heat with a soldering pliers causes the solder preform rings inside the connector barrel to melt. Upon cooldown the fiber is permanently fused in place with a direct pull strength of several pounds. It should be noted that the glass fiber is not subject to such a high tensile load in actual use because the load is transferred to one of the steel wires in the cable jacket which is secured to the connector backshell. The final feature of this connector relates to the elimination of the necessity to polish the fiber end. Rather than polish, we have developed a compatible cleaving tool which can be used to prepare the end of the fiber in a fraction of a minute.

CONCLUSION

In conclusion, a low cost, high quality glass optical fiber, associated cable constructions, and connectors have been optimized for use in high volume, short to medium distance applications. These items have passed through a complete development-cycle and are now in manufacturing. Fiber parameters have been chosen to match the objectives of a new video distribution system in a cost effective fashion. Although the fiber, cable and connectors were specifically tailored for MINI-HUB, similar system objectives tend to guide the fiber selection for most short to medium distance analog and digital links.

ACKNOWLEDGMENT

Development of the fibers and fiber cables was due to the efforts of W. Hanley, J. Lanoue, P. Levin, D. Munson, and F. Noble. The connector work represents the efforts of L. Engdahl and R. Ziltz.

PACKETCABLE:
A NEW INTERACTIVE CABLE SYSTEM TECHNOLOGY

PAUL BARAN

PACKETCABLE INC.
10411 BUBB ROAD
CUPERTINO, CA

ABSTRACT

A new interactive two-way cable system technology is described. Alphanumeric text and graphic capability is provided for all users. A new architecture head end computer supports a large number of simultaneous data users. Full two-way remote addressable converter capability is provided for single and dual cable systems.

INTRODUCTION

Few expectations have been held as long and with such fervor as the advent of interactive two-way services on cable. It is our belief that the economic viability of new two-way services has been delayed by a "chicken and egg" predecessor problem.[1] New services can pay their own way only if the public has purchased the hardware required to deliver them. This is unlikely to occur, however, until after the services have been made available. Information providers, on the other hand, are reluctant to develop new services until enough potential users have the delivery hardware in place to form an economically viable constituency. Of course, test demonstrations can be run, and are being run today. But, the new industry can't take off until this chicken and egg problem is solved.

I would like to discuss ways to break this deadlock by providing the needed data delivery capability at a near zero cost to the cable operator. Most large new cable systems will need addressable converter capability to control pay TV delivery anyway. The new services support could come along as byproduct -- almost a free ride.

I would like to talk to you today about a system now in development that is called PacketCable.[2] This is a new digital control and communications system intended to support high speed, interactive broad band computer communications on both present and future cable systems. PacketCable will provide the functions of the addressable converter as well as the capability to support a wide range of new services including:

- Videotext (Teletext and Viewdata such as required to deliver Electronic Yellow Pages)
- Panic Alarm Type Services (Police, fire, medical aid)
- Electronic Mail
- Electronic Game Support
- Transparent Digital Communications
- Electronic Shopping
- Home Appliance Monitoring & Control

In the following description, it will be helpful to think of neither a single unit, nor a collection of units. PacketCable is better thought of as a distributed computer communications system, tying together geographically separated units to create a new set of capabilities. The tightly interconnected overlay structure of digital processes appears to make feasible the delivery of a range of sophisticated new services which, in the past, too often were called "blue sky."

To allow the television viewer access to new services without purchase of additional hardware, alphanumeric/graphic text generation is built into the basic system. Although two-way data based services are provided, initial emphasis is on pay TV control, including support for impulse pay-per-view for any channel. The full two-way communications and control capability could support an almost infinite variety of tiering and billing combinations. The addressable converter function is controlled by a remote wireless hand-held keyboard for 400 MHz or 50+ channel single or dual cable systems. Baseband decoding is used for remote control of sound volume. The system design seeks to be significantly less vulnerable to signal theft than conventional one-way addressable converters by such design features as inbuilt electronic serial numbers. These can be used to pinpoint the location of each unit within the cable system if stolen.

SYSTEM DESCRIPTION

Figure 1 is a simplified block diagram of the system.

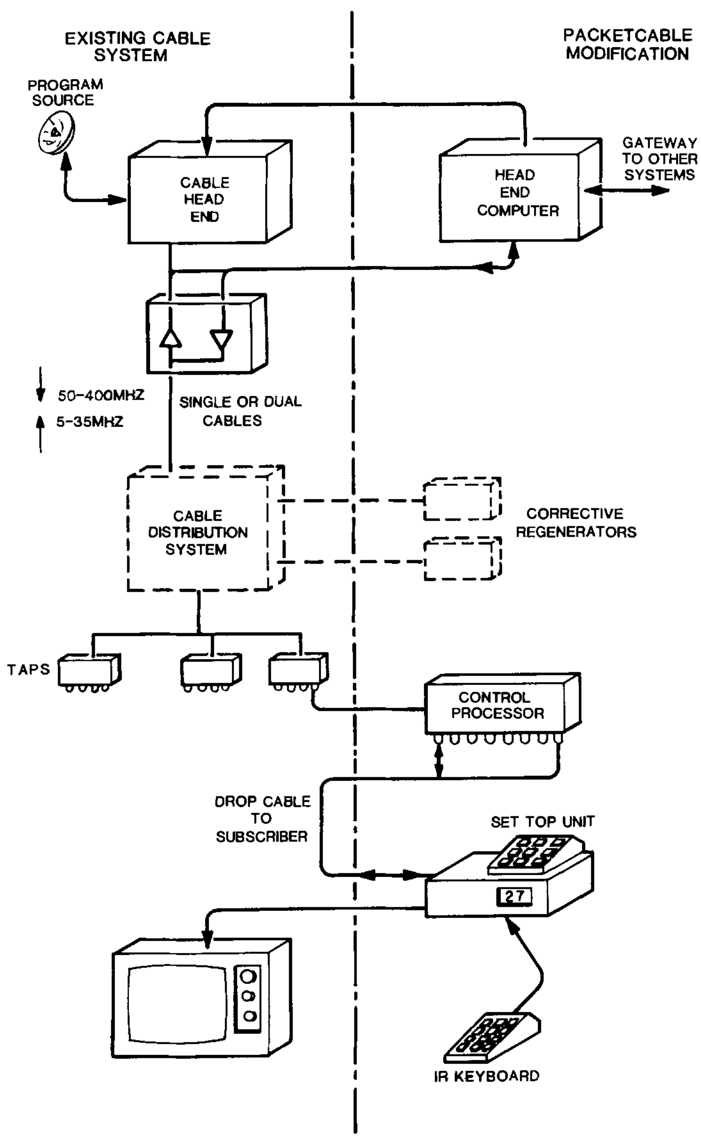


FIGURE 1. THE PACKETCABLE SYSTEM

On the left is a conventional single or dual TV cable system. On the right are shown the major new units that form the PacketCable system.

IR Keyboard

Starting upward from the bottom of the figure is an infrared keyboard. This wireless hand-held keyboard is used by the TV subscriber for remote stations or enhanced service selection. The user's TV set is most often initially tuned to channel 2, 3 or 4. Once tuned, the user's set forever operates as a totally electronically controlled set. This includes channel selection, sound volume and power on and off. TV signals can be selected from either of two 50+ channel cables. The same keypad used to select stations can select videotext frames. A local data base of up to several hundred thousand frames can be selected by the user, generally within two seconds. About 900 of these frames are sent in teletext fashion with a response time of under one second.

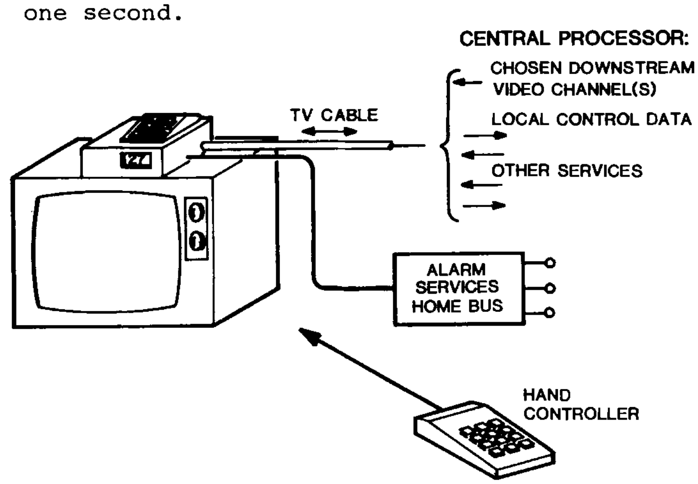


FIGURE 2. SUBSCRIBER TERMINATION

Aside from a slight difference in response times, the use of a common tree selection protocol permits these two modes to be indistinguishable to the user. An optional keyboard, including a full alphanumeric keypad is available for sending electronic mail. The basic PacketCable system contains an inbuilt alphanumeric generating capability, so some minimum text and graphic services are available to all users without need for additional hardware. The very short response time required by a fast keyboard user results in a high data rate in the data communications subsystem and the need for rapid processing in the data handling portions of the system.

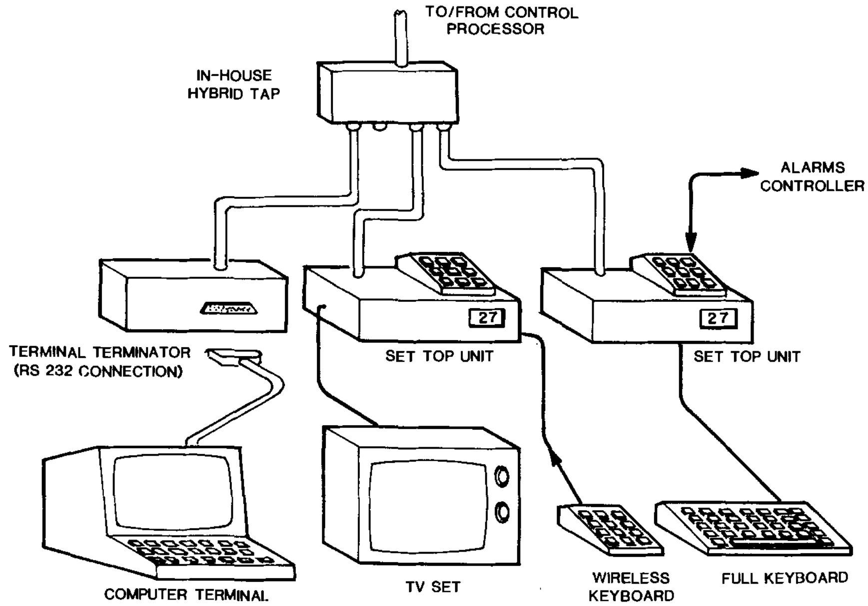


FIGURE 3. EXTENDED SUBSCRIBER SERVICE

Set Top Unit

The interconnection point between the subscriber's drop cable and the remote keyboard is the Set Top Unit. (See Figure 2, Subscriber Termination.) The Set Top Unit uses a pair of LED displays to indicate the channel number being watched, or else time. The Set Top Unit also contains an interface plug for connecting alarm sensor circuits, downloading games and controlling appliances. Provision is made for later inclusion of a "home bus," if and when there is industry agreement on an interface standard. The Set Top Unit intercommunicates with the remote Control Processor using short packets sent on the same drop cable as the selected TV signals.

Other Terminating Devices

Other optional interface terminators which may be used in lieu of or in addition to the Set Top Units are shown in Figure 3.

One example of another type of device used for terminating professional or home computer devices or terminals is imaginatively called a "Terminal Terminator" (TT). This TT unit contains a standard 25 pin RS232 connector and can connect a standard data terminal or similar standard computer to the system using standard ASC11 characters. Speeds of up to 19.2 kilobits per second are possible with this unit using a clear-to-send protocol arrangement.

Control Processor

The Control Processor is a strand mounted unit that controls up to eight TV sets, each of which may have one or two TV channels per drop cable. The Control Processor has primary responsibility for transmitting and receiving data packets via the cable system. It connects between the house drop cable and the usual directional coupler tap. Parenthetically, it is never necessary to cut a distribution cable for installation or removal.

Data Transmission

Data transmission requires at least one 6 MHz downstream channel and one 6 MHz upstream channel. A gross data rate of approximately 2 Megabits per second downstream, and about 1 Megabit per second upstream is used. All data is organized as packets containing full routing and addressing data. Each packet contains a cyclic redundancy check field. Every packet requires an acknowledgment of correct reception, otherwise it must be re-sent. The communications protocols are designed for fast, error-free performance, including compensation and correction of any upstream noise problems.

Upstream Noise

Several different techniques are used in PacketCable to reduce the effects of spurious upstream signals:

1. Most 5-35 MHz upstream noise leaks in via the drop cables. Since the upstream transmitter is in the Control Processor, this source of noise is effectively removed.

2. Proprietary devices, which we call Corrective Regenerators, prevent defective packets from propagating upstream in the cable system.

3. Frequency agility is reserved for use in disastrous situations to change the upstream frequency.

4. If upstream noise does occur, the ingress point of noise is precisely determined and pinpointed for removal.

Head End Computer

The Head End computer is an unusual communications switch and information processor. It takes upstream packets, and then processes them to create downstream packets. The Head End Computer also supports gateway connection to other systems in the outside world. These gateways allow connection to a remote diagnostics computer as well as to remote data bases and data networks. The Head End Computer has local storage for a few hundred thousand pages of alphanumeric/graphic text. The Head End's heaviest processing load is in the pay-per-view billing, data communications, customer records maintenance and data retrieval.

Because of its central role in the system, the Head End Computer must be extremely fast and reliable, and we seek a maximum two second response for most subscriber data retrieval requests. Given a hypothetical "average" cable system of 10,000 users of which 20% of the users might simultaneously want data base services, the Head End Computer will face a throughput load ten times greater than today's largest time-sharing computers. Since no existing or shortly forthcoming computer could meet these performance requirements, plus meet the reliability and cost constraints, it was necessary to create a new computer architecture, tailored to the unique requirements and constraints of this application.

A New Computer Architecture

The challenge was to design a time-sharing computer capable of handling more users than the largest computer today, and to do so at an affordable price. Part of the solution was to utilize the remote processor capability distributed throughout the Control Processor portion of the system. A second factor was in the packetization of all data. This meant designing a computer to process standard form packets instead of 8, 16 or 32 bit words as in today's small machine practice. Another necessary simplification was to remove the provision for general purpose computation found in today's time-sharing systems. This provision is not needed in our application where subscribers do not present number crunching loads. The users who want such services can always get them by being connected to a remote computer. This reduction of function allowed tailoring the computer to handle the remaining tasks faster. This allows a quicker response time to more users for a given amount of hardware.

The decision to design a special purpose computer was not lightly made. It meant designing a new form of processor from the ground up, including all boards. One obvious alternative is to use one or a pair of off-the-shelf general purpose computers which could simulate some features of the system for the initial set of users. This alternative was rejected, however, because it punted on the critical issue: Can a composite hardware, firmware and software system with the properties required be built to serve thousands of simultaneous users in a wholly reliable manner? And, can it be built in a cost effective manner? Our objective was to solve the real longer range problem. We did not want to settle for a simple test demonstration system.

System Reliability

The single most important consideration in the PacketCable design is reliability. An unreliable two-way interactive system is nearly useless for most future high value services, such as electronic mail, alarms and data communications. This view of the importance of reliability is new in the cable industry. In the early days of cable, keeping capital costs to an absolute minimum was the single overriding consideration in achieving profitability. This is changing rapidly, and importance must now be particularly placed upon achieving the absolute highest reliability of any system element shared by many users.

Head End Reliability

The Head End Computer, for example, has been designed to be relatively immune to the effects of component part failures. When Head End hardware failures do occur, the affected parts are effectively bypassed. As the failed components do not go away by themselves, a remote monitoring capability is being implemented.

The Head End Computer software is being designed so that transitory failures cannot cause loss of billing data, nor create duplicate billing records. No single hardware failure will affect operation of the system. Duplicate boards exist in all sections and replacement boards may be plugged in, and removed while the power is on, without causing transient errors.

Dual Cables

The PacketCable equipment is designed at the outset for use with either single or dual cables. The critical data channel can be received and transmitted on either cable if one should fail. Dual cables have the inherent possibility for greater system reliability, but only if failures in the A cable and the B cable are statistically independent. Ideally, different power feeds should be used for each of the two cables. While the failure characteristics of dual cables are better than those of single cable, their failures rarely will be statistically independent. If Cable A and B were statistically independent and each had a reliability of 0.999 or 8.76 hours outage per year, then the probability of both not being out of commission would be $(1-.999)^2 = .001^2 = .000001$. Thus, the annual down time changes from 8.76 hours to 31.5 seconds per year.

This concern with reliability is academic today. But, providing that it match or better the reliability of the telephone subscriber's line, cable could one day become the major transmitter of high value information. There is no reason, other than cost, why cable must be the unreliable network it is today. This cost tradeoff is changing, however, and the PacketCable system has been designed with this longer term system evolution in mind.

CRYPTOGRAPHY AND SIGNAL SECURITY

Digital Security

Any system used to convey highly personal electronic mail must be secure from the curiosity of a would be eavesdropper. Cable TV systems are particularly vulnerable to such "eavesdropping" since the upstream branches of the distribution tree concentrate near the Head End. Here, all contents of the system are exposed unless they have been fully protected. Safeguarding confidentiality also has an economic rationale. Any system that does not assure the privacy of information transmitted is nearly worthless. Sensitive private matter such as electronic mail is, as a rule, transmitted in digital form. Hence, cryptography can be effectively applied. While simple cryptographic schemes exist, we have chosen the U.S. National Bureau of Standards DES Algorithm. This is a certified security code for most U.S. governmental agencies, so there is no question as to its reliability. The drawback to the DES code is that it imposes a heavy processing load. Consequently, DES is used only with personal and highly sensitive information.

Video Security

Video encryption is a different matter. Theoretically, a good cryptographic scheme can be devised by using alternating, concatenated, reversible transformations.[3] This is easy in the digital domain where long keys can be derived from short key bases. As digital signals regenerate perfectly, irreversible distortion does not occur. This is not so in the analog world where few reversible transformations exist and imperfections become irreversible noise.

The difficulty with analog signal encryption is that the redundancy of the NTSC video makes it possible to undo the analog coding scheme with some cleverly designed post processing. More specifically, the NTSC video signal always contains:

1. the color burst
2. horizontal synch
3. vertical synch
4. line-to-line correlation, and
5. frame-to-frame correlation.

Having access to this tremendous amount of known or *a priori* information is tantamount to sending a key along with the lock. Any system that is to remain in the field for a decade or more, and which generates high revenues is begging to be ripped off by a smart computer freak or an innovative entrepreneur. As revenues on cable's high value services increase, the "breaker box" becomes an economic alternative.

In Silicon Valley where I live, designing and building devices to defeat protection schemes is not immoral. Rather, it is a high-status art form. The January 24, 1982, edition of the *San Francisco Chronicle* carried an interview with Mr. Steven Wozniack, the young cofounder of Apple Computer Company -- now a $330 million/year company. Wozniack describes his last business venture prior to forming Apple Computer -- designing and building blue boxes to defeat the telephone company's billing scheme for long distance calls.

Once a descramble defeat circuit is described, a large population is generally interested in its use. *Radio Electronics Magazine*, for example, reported a 40% increase in newsstand circulation for its January 1981 issue, which featured an article on an off-the-air descrambler. The major difference between the use of blue boxes and one-way descramblers is that, with the blue box, there is a high risk of being caught, while a descrambler can be built and used in the privacy and immunity of one's own home. As the Chinese fortune cookie says: "He who trusts a TV scrambler is like man who believes in Chinese fortune cookies."

REMOTE DIAGNOSTICS

One feature of the PacketCable system is the use of remote diagnostics for all units. Thus, we always know the status of every unit in the field. Faults, including intermittent failures, are detected and noted at the Head End. Given that a fault is found remotely, we wanted the fastest possible swapout arrangement for a defective unit. The unit is fixed only where an automated diagnostic unit is used -- at the depot maintenance point. The Control Processor unit is designed so that it is not necessary to break into any cable -- only some F-type connectors need to be unscrewed for fast exchange. With a proper "cherry picker" vehicle, the swapout time will probably be about the same as for an indoor unit. Given that the subscriber is often not home during the day, it may be less.

Underlying our decision is the assumption that, with increasing social pressure to hire marginally competent workers, an ever greater percentage of service technicians will be incapable of handling even simple assignments. Some will manage to foul things up if given half the opportunity to do so. Therefore, our concept of servicing electronics is changing. We don't want a technician poking probes into a digital electronic unit. He'll often never find the problem -- and may just as often create new ones. We prefer to confine service work to depots equipped with proper test jigs and where the tasks can be routinized. It takes a computer to fix a computer. And that's what we have.

In light of this maintenance philosophy, we have designed an electronic serial number which will be built into each unit for on-line service use. This digital code tells us:

1. Who is the registered lessee?
2. History of manufacture - date, modifications, serial number,etc.
3. Features

This information is available through interrogation by the Head End.

Since different units can be plugged together by common F-type connectors, mistakes will occur. It is desirable for the Head End to know which unit is connected to what. This arrangement catches "screw-ups" made by service technicians who have connected the wrong units together. Many other defects can also be detected and pinpointed by this Head End Computer monitoring arrangement.

This option is useful not only for spotting misconnected units, but also for pinpointing the location of stolen units. Reconnecting a stolen PacketCable unit will not be the wisest thing to do. Monitoring arrangements guarantee detection of the stolen unit. The temporary owner never receives any services.

STATUS

The work reported here is a snapshot of a development program now underway. As such it is subject to the usual changes and modifications as the project evolves. The hardware is in laboratory prototype stage at present and an intensive shakedown period is envisioned prior to field testing.

FOOTNOTES

1. See P. Baran, "Broad-Band Interactive Services to the Home: Part II - Impasse," IEEE Trans. on Communications, January 1975, pp. 178+.
2. PacketCable is a trademark of PacketCable Inc., Cupertino, CA.
3. C. E. Shannon, "Theory of Secrecy," Bell System Technical Journal, 1949, pp. 656-715.

PRESENT STATUS OF FIBER OPTICS TECHNOLOGY AND ITS IMPACT ON THE CATV INDUSTRY

Dr. Paul Polishuk
President

Information Gatekeepers, Inc.
167 Corey Road
Brookline, Massachusetts 02146

ABSTRACT

This paper will review the present status of fiber optics technology and its impact on the CATV industry. Major broadband programs in Canada, France, Germany and Japan will be reviewed. Applications such as satellite earth station to headend, electronic news gathering, local area networks, teleconferencing, master antenna systems and local distribution will be reviewed. Major incentives or disincentives to fiber optics applications in each major country will be covered.

INTRODUCTION

Fiber Optics has reached the level of acceptance as a technology whose time has come and now the only questions are of refinement of components and applications. The telephone companies around the world have realized that the economics of fiber optics has been proven. Major parts of the telecommunications networks are now being wired with fiber as evidenced by the Bell System with the Northeast Corridor and Pacific Telephone, the Japanese Nippon Telephone and Telegraph, the British Post Office, the French and German administrations. In some countries, determinations have been made to use fiber optics instead of coaxial cable in future plans for long haul requirements.

Most of the major developments and attention are now in the local plant from the last switching center to the consumer. Although almost every country has either political or legislative problems of providing integrated voice, order, and data directly to the consumer, major experiments are underway to develop the technology, design architectures, and implement field trial to show the economics of providing integrated services directly to the home. This paper will review the experiments presently underway or planned around the world and then assess the important factors in the U.S. environment that will effect the provision of integrated services.

FIBER OPTICS EXPERIMENTS

At the present time, the major fiber optics programs providing fiber directly to home include:

a. Japan - Hi-OVIS and NTT
b. Canada - Eli Manitoba
c. France - Biarritz and Lille and Montpellier
d. U.K. - Milton Keyes
e. Germany - Bigfon, Berlin, Heinrich Hertz institute
f. Denmark
g. U.S.

The following is a short description of each of these systems:

Japan - Highly Interactive Optical Information System (Hi-OVIS)

The Hi-OVIS system is the first and oldest fiber optics experiment system designed to provide services directly to the home. Basic design and preparations were done from 1973 to 1977. Operation started in 1978 and has been in experimental operation since then.

Hi-OVIS was installed in the new town district in the neighborhood of NARA City, NARA prefecture 156 homes were wired with fiber optics and eight other terminals were located in schools, fire stations, and other public institutions.

The Hi-OVIS Program is being managed by the Visual Information System Development Association under the support of the Ministry of International Trade and Industry (MITI). Figure 1 shows the system outline. Table 1 lists the development schedule.

JAPAN - NTT Field Trials

In addition to the Hi-OVIS program, Nippon Telephone and Telegraph (NTT), has been conducting field trials of fiber optics subscriber loops since April of 1980 in Yokosuka near Tokyo. The purpose of the field trials is to examine the feasibility of existing fiber optics subscriber loop technology and to determine problem areas that need to be researched in future developments.

Tables 2 and 3 list the services for fiber optics subscriber loops and classification of fiber optic subscriber loop systems. Figure 2, shows in schematic form the layout of the system.

Canada - Elie Manitoba

Elie Manitoba field trial started in operation in late 1981 and will continue through March 1983. The trial is a rural fiber optics subscriber loop system, the joint venture of the Canadian Department of Communications in cooperation with the Manitoba Telephone System. It provides integrated services to 150 subscribers. The services provided include single party telephone with up to four extensions, and choice of seven stereophonic fm-band radio channel, access to 9 one-way television channels with expansion up to 12 channels, and one full duplex 50 kilobit data channel for additional digital services.

Approximately 110 subscribers will be fed by LED driven circuits using two fibers. Almost 40 subscribers will be fed by laser driven circuits.

The subscribers are served over fiber optic loop circuits which emanate in a star configuration from two distribution centers. The Field Trial Center in Elie and a remote distribution center near St. Eustache. These centers are connected by a nine kilometer unrepeated fiber trunk cable. The longest subscriber loop is 5 kilometers. Figure 3 is a block diagram of the system.

France - Biarritz

In September 1979, the French Government announced plans to wire the city of Biarritz, population 30,000 with fiber optics. In December 1979, four firms were awarded design contracts. In November of 1980, Societe Anonyne de Telecommunications (SAT) was selected as the main contractor for the Biarritz project.

The project has been designed to connect up to 5,000 subscribers. The first step will include 1,500 subscribers. Each subscriber will be provided the following services:

a. two-way videophone
b. two television programs, simultaneously selected out of 15 programs (30 programs later)
c. 12 stereophonic high quality radio channels
d. miscellaneous narrow band data/electronic directory, teletext, etc.

The system outline is shown in figure 4.

In order to provide two way interactive videophone connected to the standard telephone network, a separate broadband switching system is being developed, thus two switching systems are connected to the local network, voice switch and broadband switch. The two switching networks are situated in the central exchange controlled by their respective command units. A third contact unit is in charge of distributed services.

The system will be put into operation in early 1983. The experience gained during the following two years will be used for the development of future systems. In addition, this will be an important step in the development of optical component technologies and also should result in substantial reductions in component prices.

Lille and Montpellier

Experimental optical fiber cable T.V. networks are planned for the cities of Lille and Montpellier, as well as an experimental urban network for the distribution of video communications and computerized information services to 1,000 subscribers.

U.K. - Milton Keynes

British Telecom initiated a trial to 18 homes in the new town of Milton Keynes. After two years of study, the system has been installed to provide CATV services by the end of 1981. Its main purpose is to utilize fiber optics in the local networks. It will employ a new type star network other than the conventional tree structure, and a microprocessor controlled wideband switch to route the required program to the customers.

Each subscriber has two fibers into the home. The aims of the Milton Keynes trial can be summarized as:

--to demonstrate and stimulate interest in wideband services to the customer
--to assess the performance of existing optical communication technology for this application and to identify critical problem areas
--to gain technical and field experience
--to assess customer reaction to the system

Figure 5 is a schematic of the Milton Keynes Trial.

Germany - Bigfon

The Deutsche Bundespost envisages using fiber optics economically in the local exchange area beyond the 1985-86 period. The first step is a prototype system of a broadband integrated optical fiber local network call Bigfon. Seven different demonstrations are planned in the Federal Republic in the 1982-83 time period. These include:

City	Suppliers
Berlin	Krone, SEL, SIEMENS
Hamburg	TEKADE/FGF
Hanover	AEG-Telefunken
Dusselforf	AEG-Telefunken
Nurnberg	TEKADE/FGF
Munich	SIEMENS

The performance requirements have been specified as follows:

--Telephone (64 hbps)
--Data, Text, facsimile (8 or 64 kbps)
--24 VHF Stereo (digital or analogue)
--2-4 T.V. channels (digital or analogue, T.V. multiple access switching system)
--Picturephone (digital or analogue, 5 MHz/ color)

Figure 6 shows the various services being planned and network interconnection contemplated.

Berlin

In 1980, one of the first broadband optical communications systems to go into operation in Europe has been installed in 25 Berlin households. A single fiber delivers any 2 of seven 5 MHz T.V. channels, plus any 2 of 14 FM stereo channels to each subscriber, who can receive all four simultaneously. The network was built by AEG Telefunken for the German Bundespost at a cost of $3 million. The system is analog, and can be used for telephone, T.V. and viewdata and videotext services. System uses star configuration with loops up to 2.5 km without repeaters.

Heinrich Hertz Institute

Over the past several years, an experimental system of an integrated broadband fiber optics communications system has been developed using links of 8Mbps, 34 Mbps, 140 Mbps, 280 Mbps, and 560 Mbps. In addition, a 2.32 Gbps link has been developed. Thirty two T.V. channels have been multiplexed over a single made fiber link.

The experimental system consists of two broadband networks, a fully digital one with a decentralized exchange functions, and time division multiplex transmission. In the digital network, subscribers are connected by fiber optics loops, in the conventional network the subscribers are connected to the central public branch exchange by a star shaped fiber optic subscriber lines.

Denmark

In the spring of 1979, the Jutland Telephone Company decided to install and operate a main distribution system for CATV. The first phase of the system was installed and in operation by the spring of 1980. System distributes seven T.V. channels, six stereo channels, and twelve AM radio stations by digital PCM. The overall system is shown in figure 7.

U.S.

The introduction of fiber optics into CATV has been limited until recently to supertrunk applications and satellite to head end links. In mid 1981, Times fiber introduced the minihub system for distribution of T.V. signals to apartment buildings using fiber optics. These are no comparable experiments in existence or planned comparable to those described previously. (See figures 8, 9).

The telephone companies have seen the importance of this technology and have interested heavily in its application mainly for long haul and between central offices. They are a also developing the technology and experience with fiber optics. The Bell System has developed the SLC™ -96 system, that provides digital service to suburban and rural customers. This system is currently undergoing tests at Bell Laboratories in Chester, New York. This prototype long wavelength systems used light emitting diodes that operate at 1.3 micrometers.

Regulatory and legislative changes, will open up further the local distribution market. There is increased activity in the development of local area networks that will produce further impetus. It is not difficult to see that there will be a very competitive struggle for the local distribution market.

CONCLUSION

It appears that the following may occur:

a. Future local distribution using fiber optics will be provided either by the Telephone Companies or foreign manufacturers.
b. Fiber optics technology for local distribution will not be provided by U.S. Manufacturers.
c. Future CATV systems that can not accommodate the use of fiber optics will be technologically obsolete by the end of the decade.

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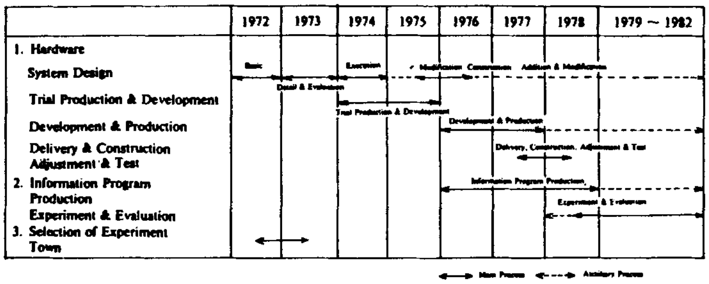


Table 1

Service Types		Content
End-to-End Service		Telephone Data Facsimile Video phone TV conference
Center-to-End Service	Broadcast	CATV Hi-Fi Stereo Still picture High-definition TV
	Interactive	Video Response System Captain
Leased Line		ITV High-speed data (1.5 ~ 6.3 Mb/s) High-definition ITV

Table 2

System	Service contents	Research items	Expected introduction period
Home-use subscriber system	· TV broadcast service · Telephone · Home facsimile · Video phone · VRS · Captain	· Cost reduction · Network construction · Video software and hardware technology · Market creation	10 ~ 15 years or more
Business-use subscriber system	· Telephone · PBX · High speed data · Still picture · ITV · TV conference · VRS	· Cost reduction · Strategic introduction	5 years or more
On-premises system	· Telephone · Data · PBX · TV conference · ITV	· Cost reduction · Network optimization	3 years or more
CATV distribution system	· TV broadcasting · Interactive TV · High-definition TV	· Cost reduction · Network construction which can lead to general subscriber loops · VHF-TV transmission · Video switching technology	3 ~ 5 years or more

Table 3

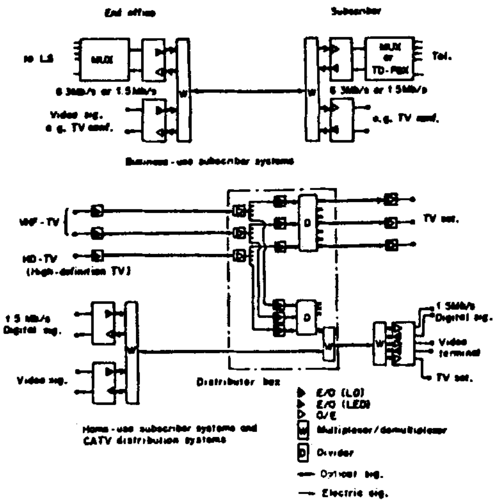


Figure 2

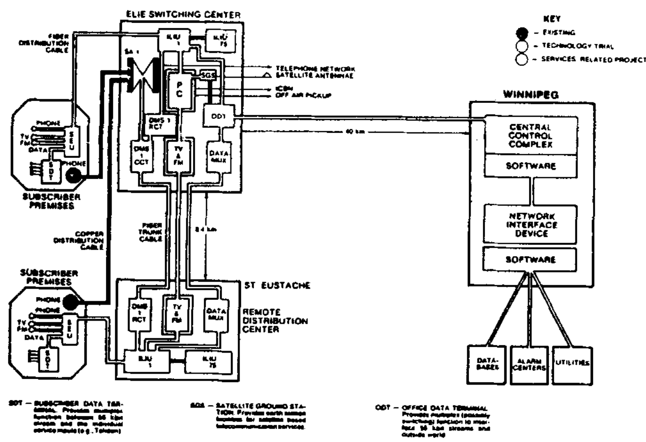


Figure 3

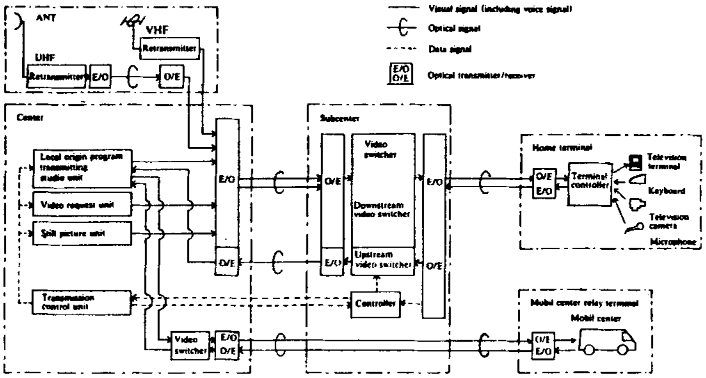


Figure 1

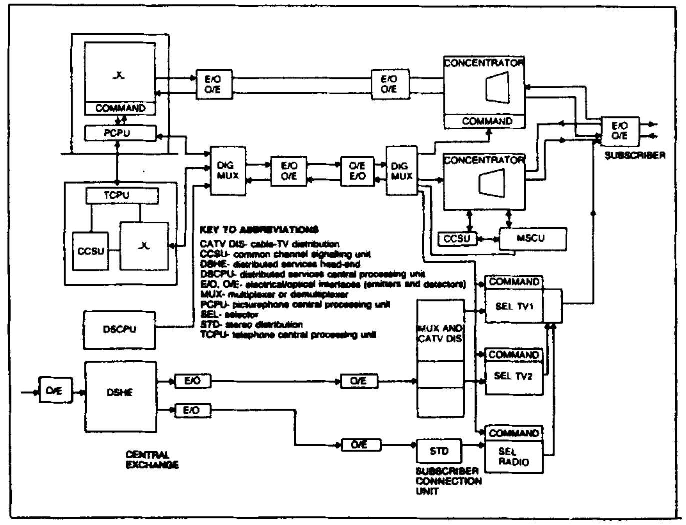


Figure 4

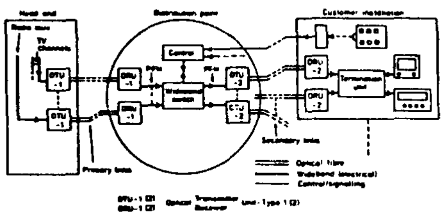


Figure 5

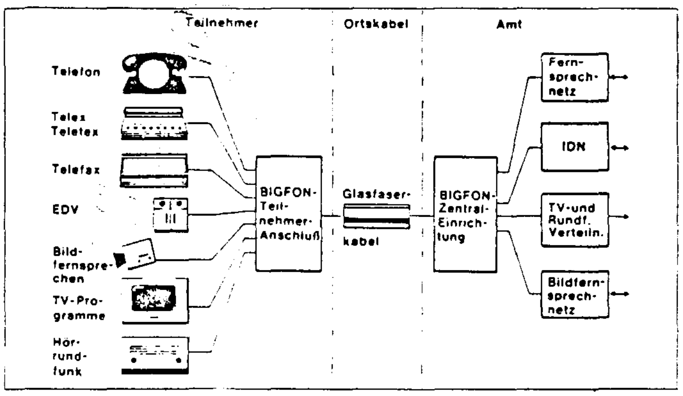


Figure 6

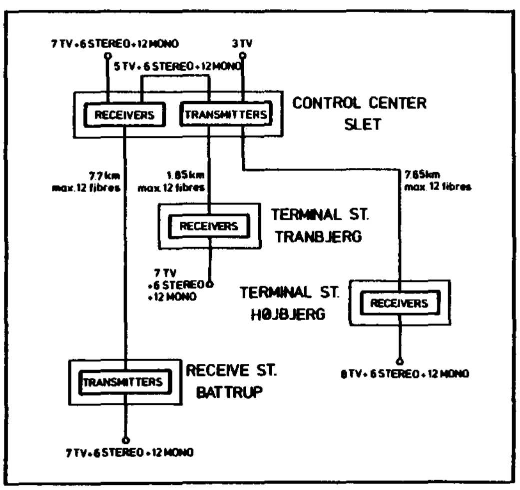


Figure 7

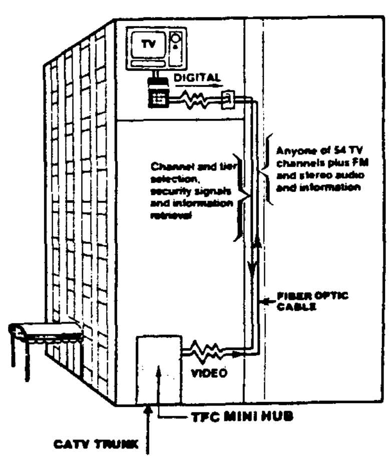


Figure 8

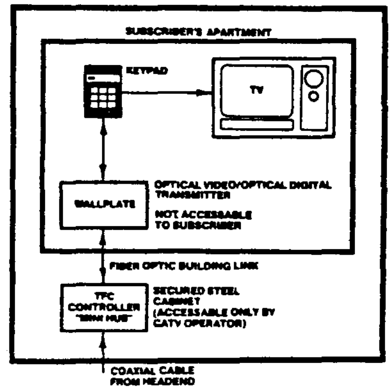


Figure 9

Profiling Microwave Paths Using a Microcomputer and Printer

Marvin H. Mason, Jr., Staff Engineer

MetroVision, Inc., Atlanta, Georgia

ABSTRACT

With the advent of metropolitan CATV systems utilizing expanded bandwidth, the area covered by a single headend is reduced. Consequently, to cover the required area, sub-headends or hubs are established. Microwave radio (particularly AML) is one of the more cost effective ways to transport signals to hubs. However, in most metropolitan areas, several paths must be considered before a final selection can be made. The path profile is perhaps the most tedious task of the preliminary engineering, taking one to two hours of an engineer's time per path. The BASIC computer program described uses a microcomputer with 16K bytes of memory and a DOT MATRIX printer to generate path profiles in minutes rather than hours.

INTRODUCTION

Faced with the task of determining the feasibility of inter-connecting several widely spaced communities in a major metropolitan market with AML microwave radio, I quickly determined that no less than twelve path profiles would be needed to make an informed decision. The work was an obvious task for the engineering department's Radio Shack computer. Since at that time I had little programming experience, I made a call to Lorri Kauffman, Application Engineer, at Hughes Microwave who provided a program that calculated earth curvature and Fresnel Zone clearances. Lorri offered the Hughes plotter program but we did not have a plotter and I felt the job should be done with existing resources.

Although calculating the clearance heights was quicker, the manual plotting of the profiles on graph paper continued to be drudgery of the worst sort. A remembered converstion with the boss about plotters and a close inspection of the printer sitting idly in the corner quickly brought forth the realization that a printer, after all, was a course plotter with a funny pen.

Checking the printer's character set revealed that graphics could indeed be coaxed from it with a few LPRINTCHR$ statements. With Lorri's program as a sound foundation I finally emerged from the quagmire of the BASIC language with the program described in this paper.

I have adapted the program to operate with two printers and have no reason to doubt that others could not be incorporated into the program. The program listed is for the Okidata Microline 83A printer and Radio Shack Level II BASIC. The Radio Shack model VI printer was also adapted. Tables 1 & 2 list the printer character codes and corresponding characters used in the program.

TABLE 1
MICROLINE 83 A

CODE	CHARACTER	USE
181		LEFT VERTICAL AXIS
176		LEFT VERTICAL AXIS
180		LEFT VERTICAL AXIS
151		RIGHT VERTICAL AXIS
131		RIGHT VERTICAL AXIS
135		RIGHT VERTICAL AXIS
140		TREE CHARACTER
166		TREE CHARACTER
179		TREE CHARACTER
157		TREE CHARACTER
149		HORIZONTAL AXIS

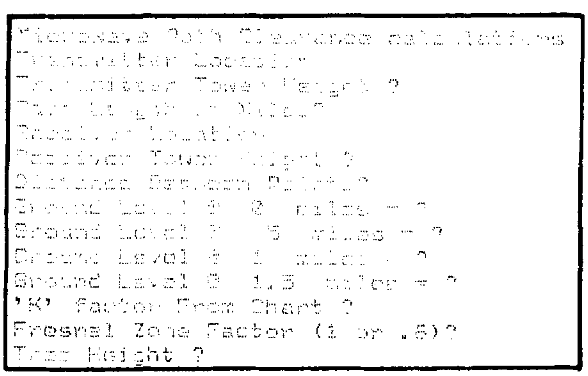
TABLE 2
RADIO SHACK MODEL VI

CODE	CHARACTER	USE
250	+	VERTICAL AXIS
241	—	VERTICAL AXIS
248	┴	LEFT VERTICAL AXIS
243	┬	RIGHT VERTICAL AXIS
239	■	TREE BODY
245	|	HORIZONTAL AXIS

OPERATION OF THE PROGRAM

Using the program to create a path profile is simple. You draw a path centerline on a 7.5 minute map in the same manner as a manual plot, check the proposed path for obstructions, calculate or measure the distance between the transmit and receive locations, decide on the spacing for the intermediate points and list ground elevations at transmit, receive and intermediate points. Maximum possible tower or antenna mounting heights should be selected next. Refer to a sea level refractivity chart and determine the "K" factor for your location. Using this value for "K" is recommended as it most closely represents the earth curve plus the bending of the radio "beam" due to climatic conditions. However, the program allows you to check the profile with different values of "K" so a worse case of K=2/3 may be used initially, and refined later.

Once you have completed the above steps the program is simple to operate. Enter the information when the program prompts as shown in figure 1. Your profile will be printed in the format shown in figure 2.



SCREEN FORMAT
FIGURE 1

After the profile is printed you will have to use normal techniques in using a straight edge to find the critical points and if you have a viable path. Figure 3 depicts a completed profile showing earth curvature, ground height, tree height and fresnel clearance. The two paths shown represent two possible antenna mounting locations on each tower.

PROGRAM DESCRIPTION

The program is listed in Radio Shack Level II BASIC at the end of the paper. The comments included in brackets () are not part of the program and should not be entered when you load the program. To change the scale of the plot, line 40, variables VS and HS would have to be reset. If you use several scales, you may wish to change this line to:

```
40 INPUT "VERTICAL SCALE"; VS
   :INPUT "HORIZONTAL SCALE";HS
```

To adapt the program to another printer lines 470, 480, 510, 530, 540, 650, 660, 680 and 690 will have to be changed to include the unique printer character and control codes. For instance, for the Radio Shack Model VI printer line 470 is changed to:

```
470 Bs = CHRs(250) + CHRs(241) + CHRs(248)
    + CHRs(241)
```

Table 2 provides a description of this printer's characters. A profile using the Radio Shack Model VI printer is shown as figure 4.

Formulas used to calculate earth curvature and Fresnel Zone are found in lines 240 and 250. In ordinary form they are:

Earth Curvature

$$h = (d1 \times d2) / 1.5\ K$$

Where h is earth curvature in feet, d1 is distance from the transmitter in miles, d2 is distance from the receiver in miles and K is the factor for the curvature of the earth. K = 1 is the true curve of the earth, K = infinity is a flat earth, K < 1 is the case when the radio beam bends away from the surface and K> 1 is the case when the radio beam bends toward the surface.

Fresnel Zone

$$F1 = 72.1 \sqrt{\frac{d1 \times d2}{F \times D}}$$

Where F1 is the first Fresnel Zone in feet, d1 is distance from the transmitter in miles, d2 is distance from the receiver in miles, F is frequency in GHz and D is path length in miles.

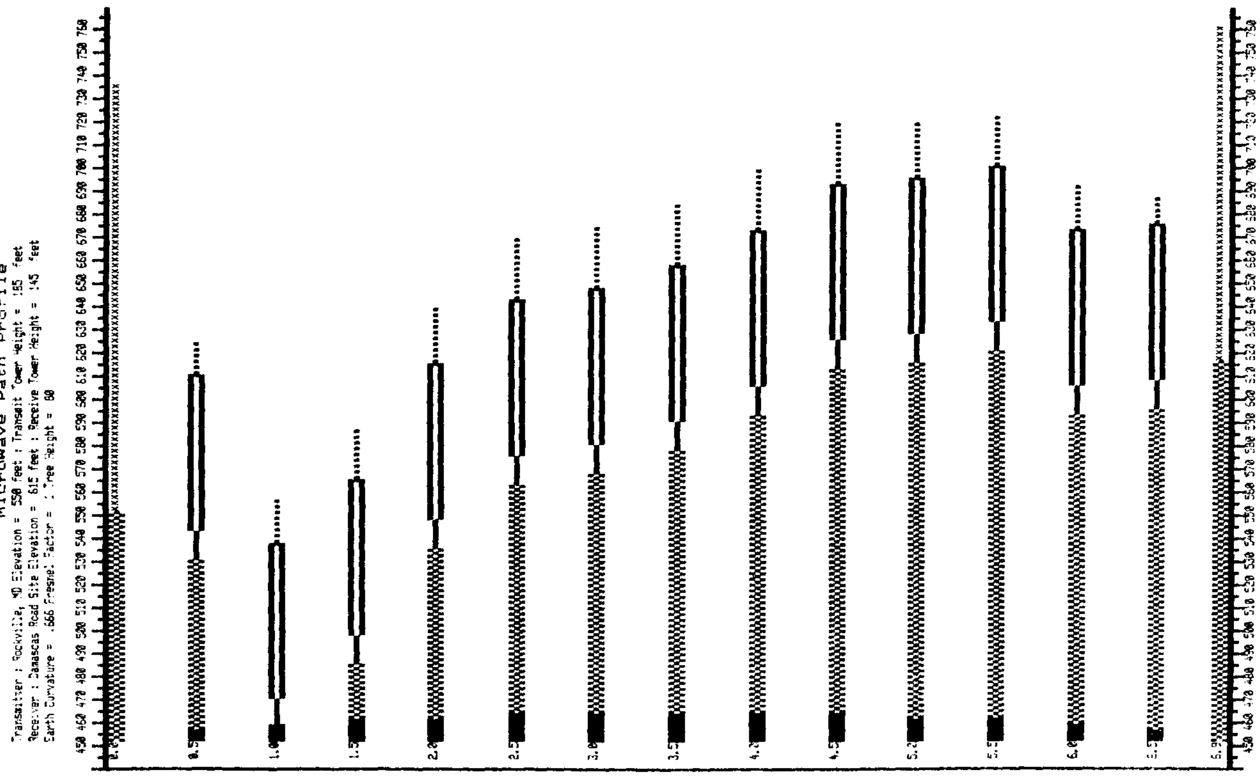


FIGURE 2
OKIDATA MICROLINE 83A

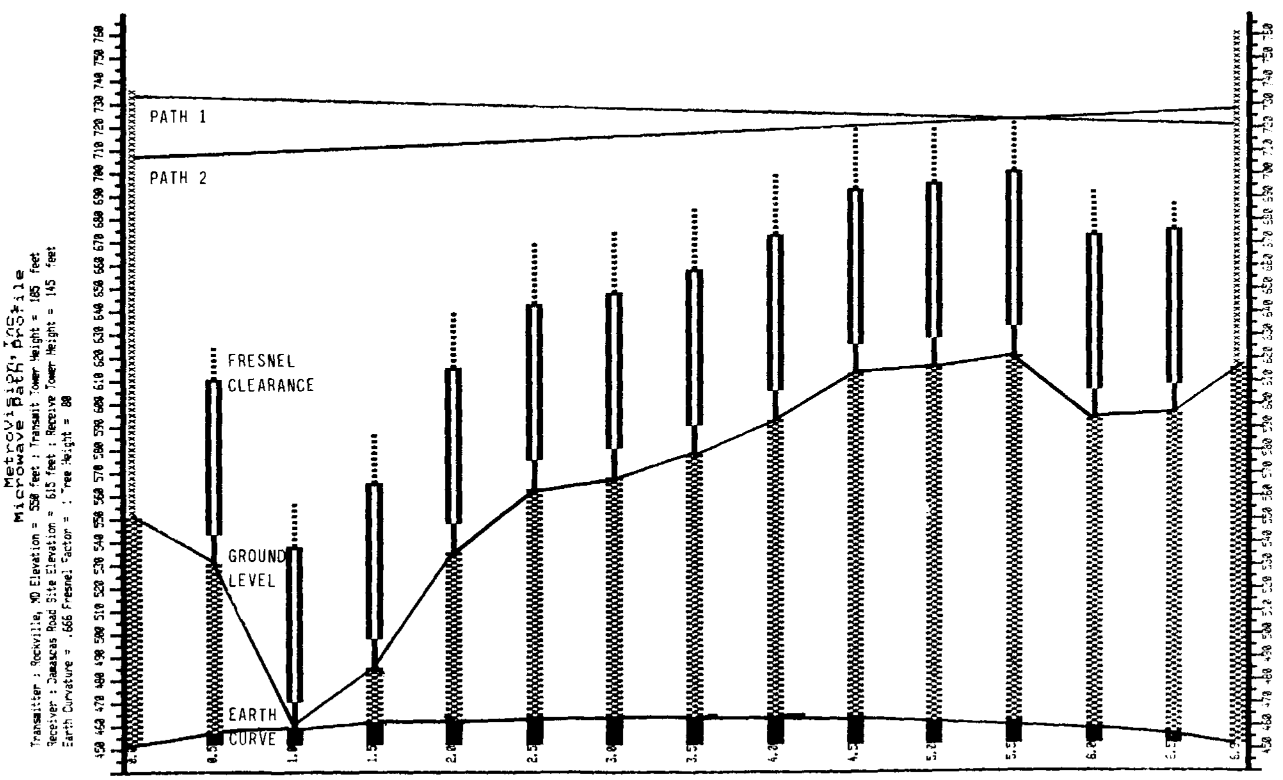
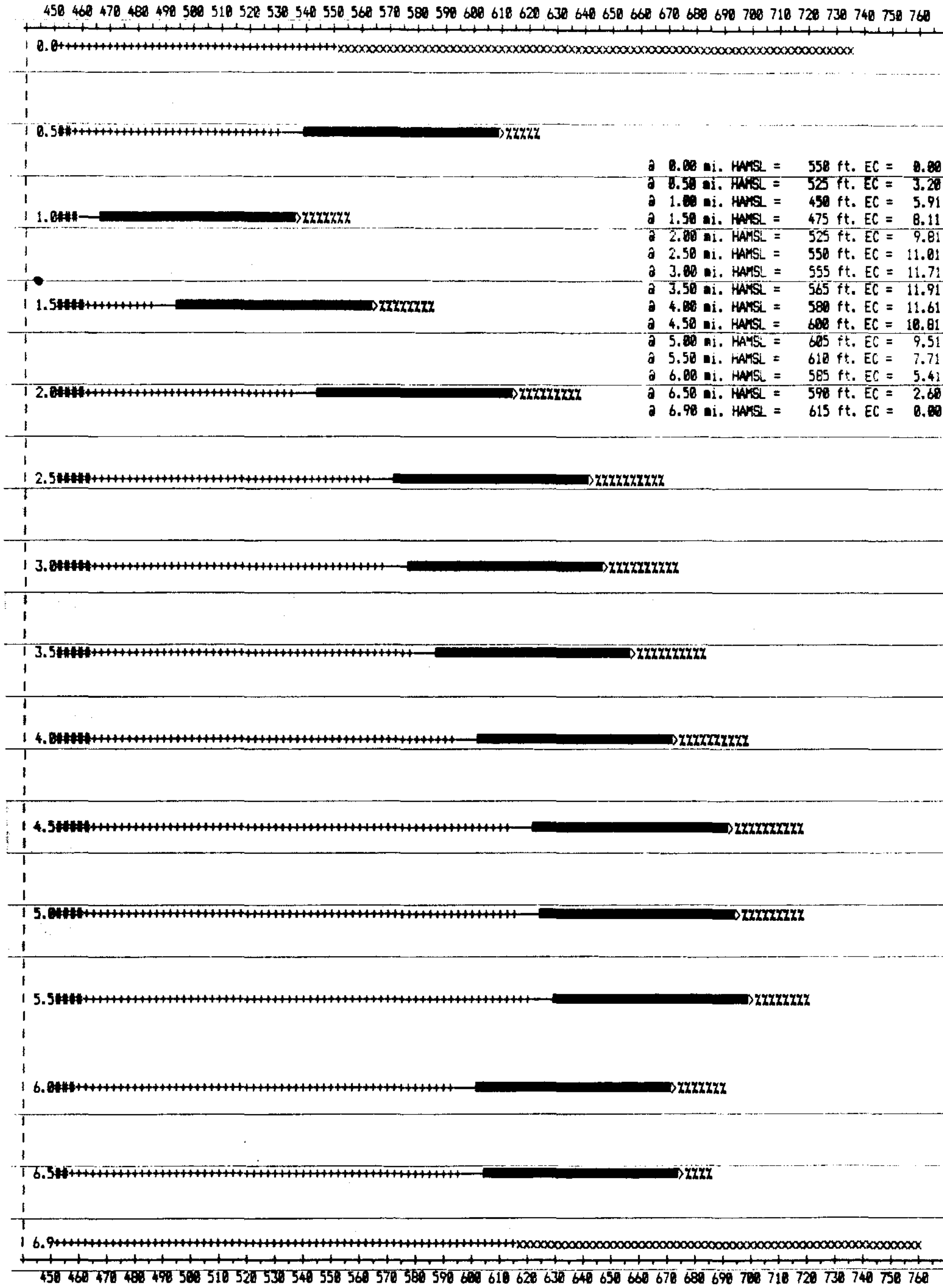


FIGURE 3
OKIDATA MICROLINE 83A

MetroVision, Inc.
Microwave Path Profile

Transmitter : Rockville, MD Elevation = 550 feet : Transmit Tower Height = 185 feet
Receiver : Damascas Road Site Elevation = 615 feet : Receive Tower Height = 145 feet
Earth Curvature = .666 Fresnel Factor = 1 Tree Height = 80



@ 0.00 mi.	HAMSL = 550 ft.	EC = 0.00 ft.	FC = 0.00 ft.
@ 0.50 mi.	HAMSL = 525 ft.	EC = 3.20 ft.	FC = 13.78 ft.
@ 1.00 mi.	HAMSL = 450 ft.	EC = 5.91 ft.	FC = 18.71 ft.
@ 1.50 mi.	HAMSL = 475 ft.	EC = 8.11 ft.	FC = 21.92 ft.
@ 2.00 mi.	HAMSL = 525 ft.	EC = 9.81 ft.	FC = 24.11 ft.
@ 2.50 mi.	HAMSL = 550 ft.	EC = 11.01 ft.	FC = 25.54 ft.
@ 3.00 mi.	HAMSL = 555 ft.	EC = 11.71 ft.	FC = 26.35 ft.
@ 3.50 mi.	HAMSL = 565 ft.	EC = 11.91 ft.	FC = 26.57 ft.
@ 4.00 mi.	HAMSL = 580 ft.	EC = 11.61 ft.	FC = 26.23 ft.
@ 4.50 mi.	HAMSL = 600 ft.	EC = 10.81 ft.	FC = 25.31 ft.
@ 5.00 mi.	HAMSL = 605 ft.	EC = 9.51 ft.	FC = 23.74 ft.
@ 5.50 mi.	HAMSL = 610 ft.	EC = 7.71 ft.	FC = 21.37 ft.
@ 6.00 mi.	HAMSL = 585 ft.	EC = 5.41 ft.	FC = 17.90 ft.
@ 6.50 mi.	HAMSL = 590 ft.	EC = 2.60 ft.	FC = 12.42 ft.
@ 6.90 mi.	HAMSL = 615 ft.	EC = 0.00 ft.	FC = 0.00 ft.

FIGURE 4
Radio Shack LINE PRINTER VI

PROGRAM LISTING

The notes in the program listing explain the purpose of the lines. Adapting the program to other types of BASIC is beyond the scope of this article. However, it should present no problem for microcomputers that use Microsoft "BASIC". The command "PRINT USING" may be unique to Radio Shack but can be easily replaced with "PRINT TAB" statements.

```
10  REM "Computerized path profile using a
    printer as a plotter"
20  CLS          (clear the screen)
30  CLEAR2000 (clear 2000 bytes for string
              space)
40  VS = 2.5
    :HS = 10 ([VS] vertical scale: Used as
              a divisor in calculating the
              number of feet to be
              displayed as one character
              space on the printer.
              [HS] horizontal scale: Used
              as a multiplier in calculat-
              ing the fraction of a mile to
              be displayed as one line
              feed. 1/HS (ie. if HS =10
              then the scale is .1 mile to
              one line feed.).)
50  PRINT @200,"Microwave Path Clearance
    calculations"
60  LINEINPUT "Transmitter Location ";TL$
70  INPUT "Transmitter Tower Height (to
    nearest 5 feet) ";TT
80  INPUT "Path Length in Miles";PL
90  LINEINPUT "Receiver Location ";RL$
100 INPUT "Receiver Tower Height (to
    nearest 5 feet) ";RT
110 INPUT "Distance Between Points";DD
120 I = INT(PL/DD) ([I] counter used to
                    set space between
                    calculation points)
130 IF PL/DD = I THEN J = I
    ELSE J = I+1 (This line deletes the
                  additional space created
                  on the graph if the path
                  length is integraly divi-
                  sible by [DD]
140 DIM GH(J),GH$(J),GL(J),EC(J),EC$(J),
    EL(J),FC(J),FC$(J),FL(J),DT(J)
                (DIMENSIONS [VARIABLES]
                 [GH] ground height;
                 [EC] earth curvature;
                 [FC] fresnel zone
                 clearance; [DT]
                 distance from the
                 transmitter;
                 [GH$] ground height
                 display character;
                 [GL] temporary variable
                 used in calculating
                 [GH$] from [GH];
                 [EL] temporary variable
                 for earth curvature;
                 [FL] temporary variable
                 for fresnel zone;
                 [EC$] earth curvature
                 character;
                 [FC$] fresnel zone
                 character)
150 FOR X = 0 TO J (lines 150 to 190 are a
                    loop for inputing
                    ground height at the
                    interval you desire to
                    create the path
                    profile.)
160 DT(X) = DD*X
170 IF DT(X)>PL THEN DT(X) = PL
180 PRINT "Ground Level @ ";DT(X);" miles
    = "; :INPUT GH(X)
190 NEXTX
200 INPUT "'K' factor From Chart ";K
210 INPUT "Fresnel Zone Factor (1 or .6)
    ";FF
220 INPUT "Tree Height ";TH
230 FOR X = 0 TO J (this loop calculates
                    the earth curvature and
                    fresnel zone clearance
                    from the formulae in
                    the text.)
240 EC(X) = DT(X)*(PL-DT(X))/(1.5*K)
250 FC(X) = 72.1*FF*SQR((DT(X)*
    (PL-DT(X))/(12.7*PL)))+10
260 NEXTX
280 LH = 15000 (lines 280-340 calculate
                the lowest ground height
                and sets that figure as a
                baseline for the graph. The
                variable is [LH] & [LI].
                [LT] is temporary.)
290 FOR X = 0 TO (J-1)
300 IF GH(X)> = GH(X+1) THEN LT = GH(X+1)
    ELSE LT = GH(X)
310 IF LT< = LH THEN LH = LT
320 NEXTX
330 LH = INT(LH/10)*10
340 LI = LH
360 FOR X = 0 TO J (lines 360 to 460
                    convert [GH], [FC] and
                    [EC] to scale and
                    creates the display
                    strings.)
370 GL(X) = INT(((GH(X)-LH)/VS )+.99)
380 GH$(X) = STRING$(GL(X),"+")
390 NEXTX
410 FOR X = 1 TO I
420 EL(X) = INT((EC(X)/VS)+.99)
430 EC$(X) = STRING$(EL(X),"#")
440 FL(X) = INT(FC(X)/VS)
450 FC$(X) = STRING$(FL(X),"%")
460 NEXTX
470 B$ = CHR$(181)+CHR$(176)+CHR$(180)
    +CHR$(176)
480 C$ = CHR$(151)+CHR$(131)+CHR$(135)
    +CHR$(131) ([B$] and [C$] are the
                border characters between
                tic marks. They must be
                created from the printer's
                character set.)
```

```
490 S = (DD*HS)-1 ([S] counter for line
                  feeds between
                  measurement points.)
500 TS = INT(TH/VS) (lines 500 and 510
                    create the character
                    for displaying
                    trees.They must be
                    created from the
                    printer's character
                    set)
510 TH$ = STRING$(4,CHR$(140))+CHR$(166)
    +STRING$((TS-6),CHR$(179))+
    CHR$(157)
512 TA = INT(TT/VS)
    :TT$ = STRING$(TA,"x")
                    (lines 512 and 513
                    create the character
                    for the transmit and
                    receive towers. [TT$]
                    transmit tower; [RT$]
                    receive tower.)
514 RA = INT(RT/VS)
    :RT$ = STRING$(RA,"x")
520 REM "####PRINT ROUTINE#####
                    (lines 530 to 610 are
                    the header.)
530 LPRINT CHR$(31)(expanded
    print);TAB(26)"MetroVision, Inc."
540 LPRINT TAB(22)"Microwave Path
    Profile";CHR$(29)(16.5 CPI)
550 LPRINT TAB(5)"Transmitter : ";TL$;
    " elevation : ";GH(0);"feet";
560 LPRINT "Transmit Tower Height : ";TT;"
    feet"
580 LPRINT TAB(5)"Receiver : ";RL$;
    " elevation:";GH(J);" feet ";
590 LPRINT "Receive Tower Height : ";RT;"
    feet"
610 LPRINT TAB(5)"Earth
    Curvature:";K;"Fresnel Factor:";FF;
    "Tree Height:";TH
                    (lines 620 and 630
                    print the vertical
                    scale.)
620 LPRINT " "
    :LPRINT "  ";
    :LPRINT USING "####";LH;
    :FOR X = 1 TO 30
    :LH = LH+(VS*4)
    :LPRINT USING "####";LH;
    :NEXTX
    :LH = LH+(VS*4)
    :LPRINT USING "####";LH
630 FOR X = 1 TO 32
    :LPRINT B$;
    :NEXTX
    :LPRINT B$
 640 LPRINT CHR$(149);"   ";GH$(0);TT$
                    (line 640 prints the
                    transmit site.)
650 FOR X = 1 TO (J-1)
    :FOR U = 1 TO S
    :LPRINT CHR$(149)
    :NEXTU
                    (lines 650 to 670
                    print the body of the
                    graph.)
660 LPRINT CHR$(149);
    :LPRINT USING "##.#";DT(X);
    :LPRINT EC$(X);GH$(X);TH$;FC$(X)
670 NEXTX
680 FOR X = 1 TO
((INT((DT(J)-DT(J-1))*HS))-1)
    :LPRINT CHR$(149)
    :NEXTX          (line 680 prints the
                    space to the receive
                    site .)
690 LPRINT CHR$(149);USING "##.#";PL;
    :LPRINT GH$(J);RT$(line 690 prints the
                       receive site.)
700 FOR X = 1 TO 32
    :LPRINT C$;
    :NEXTX
    :LPRINT C$ (lines 700 and 720 print
              the right vertical scale.)
710 LPRINT "  ";
    :LPRINT USING "####";LI;
    :FOR X = 1 TO 31
    :LI = LI+(VS*4)
    :LPRINT USING "####";LI;
    :NEXTX
    :LPRINT " "
    :LPRINT " "
720 FOR  X  =  0 TO J
    :LPRINT USING "@ ##.## mi.
    HAMSL =  ##,### ft. EC = ###.## ft.
    FC = ##.## ft. ";DT(X),GH(X),EC(X),
    FC(X)
    :NEXT X (line 720 prints the data used
            to create the graph.)
730 LPRINT CHR$(12)(form feed)
740 CLS
    :PRINT @200,
   "P R O F I L E   C O M P L E T E ! ! !
    If you want to run another profile for
    this path type 'Y' ;  Otherwise type
    'N' . Press<ENTER>"
750 INPUT A$
760 IF A$ = "Y" THEN GOTO 200
770 IF A$ = "N" THEN END
    ELSE PRINT "Answer 'Y' or 'N' only."
    :GOTO 750
```

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ACKNOWLEDGEMENTS

I am grateful to Mr. Richard C. Hickman, Vice President, Engineering, MetroVision, Inc. for suggesting this paper be written and for his support in its preparation. I also wish to acknowledge the aid of Ms. Lorri Kauffman of Hughes Microwave Inc. who supplied the original program from which this was adapted.

RF SYSTEM DESIGN FOR CABLE TV
A NEW APPROACH

Allen Koch

COMPUCON, INC., DALLAS, TEXAS

ABSTRACT

The high demand for cable TV systems with more channel capacity and two-way communications has caused increased congestion in the CARS frequency band, and a need for new microwave system planning techniques.

Compucon has developed a new computer program which can quickly scan a computerized data base and identify available channels in designated directions. This paper discusses how this new system planning technique may be applied in the early planning stage to select a feasible cable system configuration.

In addition, ideas are presented to combine earth station and CARS band planning to help design an integrated system for program reception and distribution.

Cable TV systems are experiencing unprecedented demands for more channel capacity, more capability, and more flexibility from communities both large and small. The demand for cable systems has caused increased congestion in the CARS frequency bands and has created a need for more sophisticated microwave system planning techniques. The expanded requirements for cable systems have forced the development of new system configurations to more effectively utilize the allocated frequency spectrum.

Most cable systems can be categorized by three design configurations (Refer to Figures 1, 2, and 3). The star system design is the most common with the principle flow of traffic from the hub to the individual headends. A headend can be a repeater location to other outlying headends. An application of this design is the "Master Headend" concept being planned and implemented for many large metropolitan areas. The two transmitter site system design allows double channel capacity over the star design but greatly increases the intra-system frequency interference considerations. The solution to these considerations involve more complex antenna systems and antenna cross-polarization. The colocated dual transmitter system design has the same capacity as the previous system and similar considerations. The tradeoffs between the two designs are the number of hubs and the number of headends. In all three system designs, the upstream channels to the hub must be separated by frequency from the channels downstream. A different frequency band may be used for upstream channels depending on the channel application; an example is the 12 GHz private microwave band for local government use.

A general review of the CARS system planning cycle will point out the need for a preliminary CARS band frequency analysis (Refer to Figure 4). After a cable company has responded with an interest in providing a system proposal, the local market analysis study begins. The technical feasibility study follows and evaluates whether the system should be FM or AML, approximate antenna sizes, tower heights, approximate hub and headend locations, need for a receive-only (TVRO) earth station or microwave interconnect, system capacity, and system capability. This step in the cycle is where a preliminary frequency analysis would assist in determining frequency availability, site selection, antenna sizes, and the probability for a TVRO earth station clearance. After the market analysis and technical feasibility studies prove to be viable, a full proposal is submitted followed hopefully by a franchise award. Now the implementation steps occur with final site selection, detailed frequency analysis and system engineering, construction permit and license, system installation and distribution of programming.

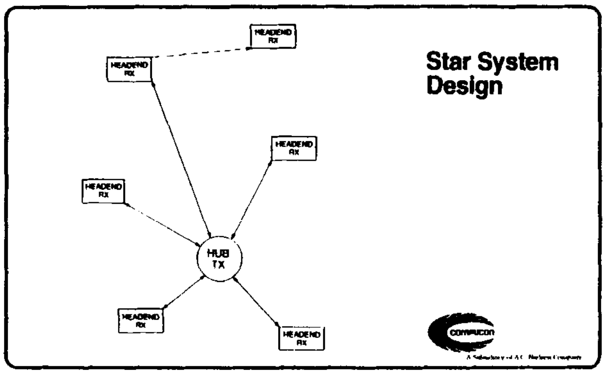


FIGURE 1

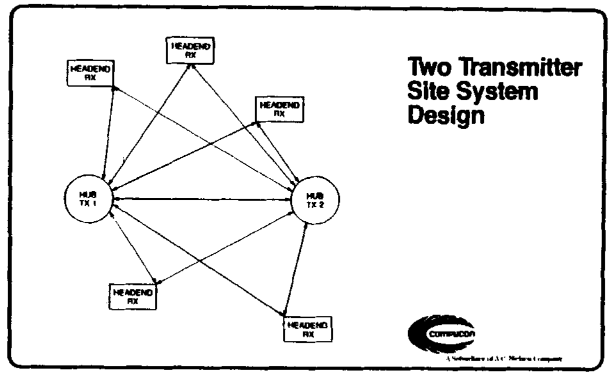


FIGURE 2

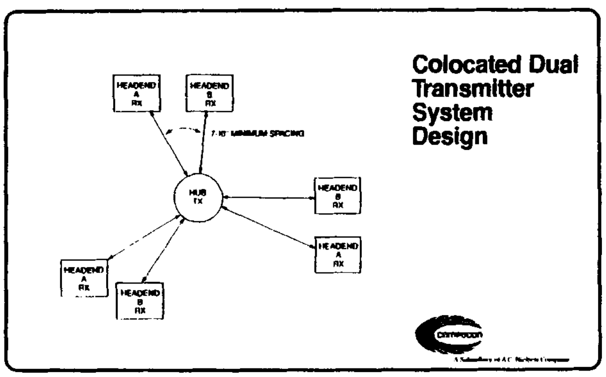


FIGURE 3

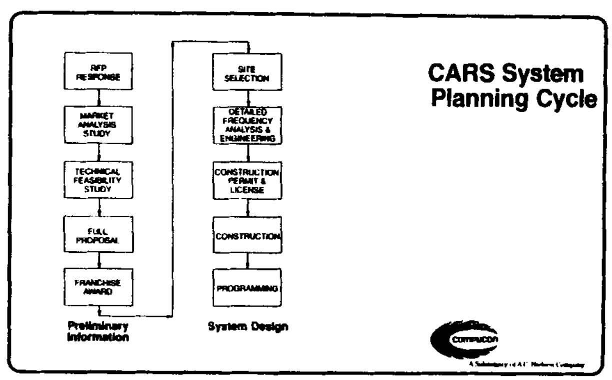


FIGURE 4

Performance of a preliminary analysis requires a computer system which can access an extensive terrestrial database of all existing and planned CARS systems as well as antenna, equipment, and interference criteria databases (Refer to Figure 5).

The computer program design concept is based on a central hub site transmitting in 10 radials to potential receiver locations equidistant from the hub (Refer to Figure 6). The half-duplex analysis will evaluate interference resulting from the hub transmitter into outside receivers and interference into each potential headend from outside sources. The full duplex analysis will also consider interference from each headend location into outside receivers and interference into the hub receive antennas.

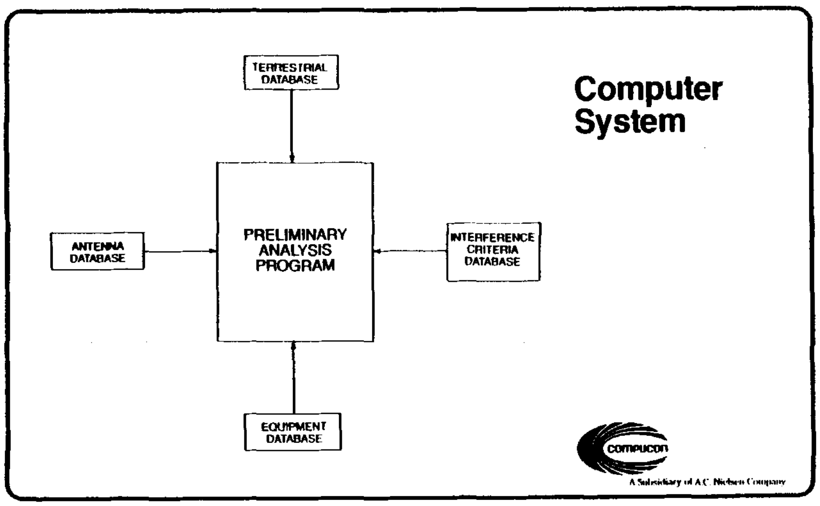


FIGURE 5

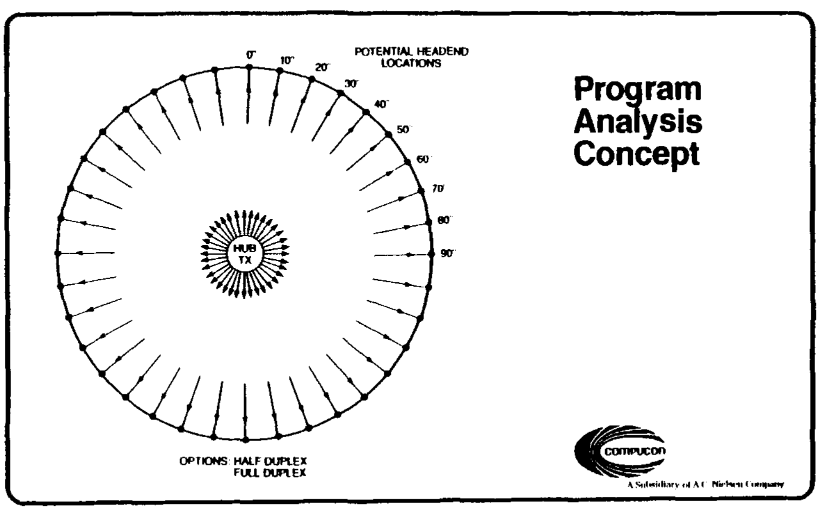


FIGURE 6

All of the program input parameters and options are listed on the report data sheet (Refer to Figure 7). The minimum required input information is the site name, latitude, and longitude. The remaining items: antenna, transmit power, margin, coordination distance, colocate distance, receiver distance, azimuth step size, half or full duplex, and modulation type are variable, but will also default to the values listed when different values are not supplied. The program can be used in all configurations mentioned and would be applied to each hub transmit site.

The Preliminary Frequency Availability Report provides a summary of the clear frequencies from and into the hub and headends (Refer to Figure 8). The interference is evaluated at each listed azimuth and the program prints the number of clear frequencies in each group of the CARS band at each end of each azimuth path. Both polarizations are evaluated with the total combined number of clear frequencies printed. An evaluation of the computer printout provides information in making the following decisions: optimum locations for headend sites, maximum channel capacity based on interference, choice of frequency groups, recommended antenna sizes and types, and the probability of the hub site being the best location.

If not all of the factors have given the required results, then the variables can be changed and the program rerun. The major items to change would be the choice of antennas, transmit power, receiver distance, and hub location.

CARS / STL

COMPUCON — PRELIMINARY FREQUENCY AVAILABILITY REPORT — 04/21/82

DALLAS, TEXAS

HUB NAME : SAMPLE SITE, IL

CUSTOMER : HUGHES

SYSTEM PARAMETERS

1.	HUB NAME		: SAMPLE SITE, IL
2.	LATITUDE	(DMS) :	39 - 00 - 00
3.	LONGITUDE	(DMS) :	89 - 00 - 00
4.	ANTENNAS		
	FCC CODE		: A03222
	MANUFACTURER		: ANDREW
	MODEL		: P6 - 1220
5.	MAXIMUM TRANSMIT POWER	(DBM) :	30.0
6.	MARGIN	(DB) :	10
7.	MAXIMUM COORDINATION DISTANCE	(MI) :	125.0
8.	CO-LOCATE DISTANCE	(MI) .	0.1
9.	NOMINAL HEADEND DISTANCE	(MI) :	10.0
10.	AZIMUTH STEP SIZE	(DG) :	10.0
11.	HALF OR FULL DUPLEX		: FD
12.	MODULATION TYPE		: AM

FIGURE 7

CARS / STL — 04/21/82

COMPUCON — PRELIMINARY FREQUENCY AVAILABILITY REPORT

DALLAS, TEXAS

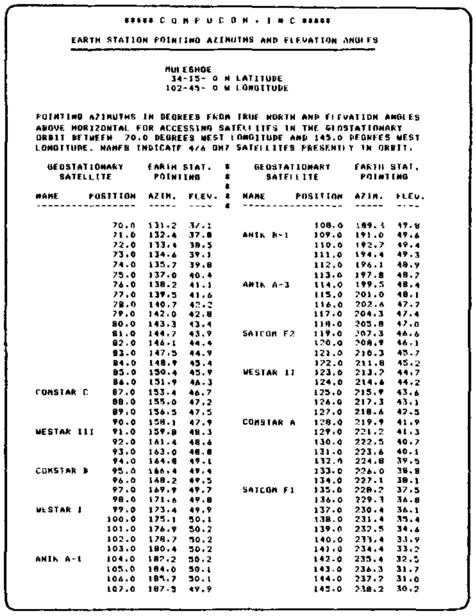
HUB NAME: SAMPLE SITE, IL — MODULATION: A M

HUB TO HEAD END AZIMUTH (DEG)	TRANSMITTING AT HUB / RECEIVING AT HEAD END — CHANNELS (TX)/(RX) — C	D	E	F	SUMMARY KEY	TRANSMITTING AT HEAD END / RECEIVING AT HUB — CHANNELS (TX)/(RX) — C	D	E	F	SUMMARY KEY
0.0	29/32	29/30	29/28	22/22	***	29/30	26/30	27/38	19/28	***
10.0	31/31	33/29	30/42	23/32	****	42/29	39/30	28/30	19/22	****
20.0	2/42	2/42	32/42	25/32	****	37/31	36/31	29/32	20/22	****
30.0	19/42	21/42	31/42	25/32	****	30/29	29/26	3/31	2/23	***
40.0	14/42	14/42	42/ 7	28/ 5	**	42/42	42/39	2/42	2/29	*****
50.0	42/33	41/33	29/ 2	21/ 2	****	42/42	41/41	5/42	3/31	*****
60.0	32/31	32/28	31/30	20/22	****	31/42	31/39	3/27	3/22	****
70.0	42/29	42/27	27/30	18/22	***	42/42	42/40	4/27	4/20	*****
80.0	42/42	39/39	42/30	32/22	*****	42/42	41/39	4/42	3/31	*****
90.0	35/42	33/40	42/30	28/23	****	42/33	41/33	42/32	32/25	****
100.0	28/27	26/29	42/27	32/20	***	42/13	42/11	30/42	24/30	****
110.0	42/42	42/39	42/42	32/32	*****	42/26	41/25	42/42	30/32	*****
120.0	42/30	41/27	32/42	26/32	****	31/ 6	32/ 8	30/30	23/24	****
130.0	42/28	40/25	42/27	31/18	***	4/16	2/13	42/35	32/26	****
140.0	30/38	32/40	42/42	32/31	*****	3/ 6	2/ 7	30/30	20/21	****
150.0	42/31	42/28	32/42	24/32	****	3/ 2	2/ 2	42/ 6	32/ 3	*
160.0	42/42	41/42	33/38	22/26	*****	6/ 7	8/ 4	29/ 8	21/ 4	*
170.0	27/42	24/39	28/31	23/22	***	42/ 3	40/ 2	31/ 8	25/ 5	*
180.0	42/42	42/42	42/27	28/22	*****	36/42	35/42	42/27	32/19	****
190.0	32/32	29/34	28/28	19/21	****	42/31	39/29	28/42	20/31	****
200.0	42/27	42/24	30/39	25/27	****	42/32	42/29	42/42	32/31	*****

FIGURE 8

One of the major sources of programming for a cable TV system is a receive-only earth station. During the technical feasibility stage, it would be advantageous to know if a TVRO could be co-located at the desired hub site. A separate preliminary TVRO analysis can be performed to provide that information (Refer to Figures 9, 10, and 11). After supplying the site name, company name, and coordinates, the program will calculate the potential interference into the earth station, and print out each source of interference and a figure of merit analysis summary. The figure of merit will state the estimated percent probability of successful placement of the earth station.

In conclusion, the preliminary analyses that were described can be an economical design tool to be used in the planning of a cable system. They provide technical insight at a low cost, provide an integrated design package, are easy to perform and analyze, are flexible to an application, and can save money in a system design by selecting the right equipment configuration early in the planning cycle. The programs have a limited capability and were not designed to replace the full detailed analyses that are required. The ancillary services to CARS and TVRO planning, detailed frequency analysis, earth station coordination, FCC applications, field services, and interference alert protection, are available through Compucon.



***** C O M P U C O N , I N C *****

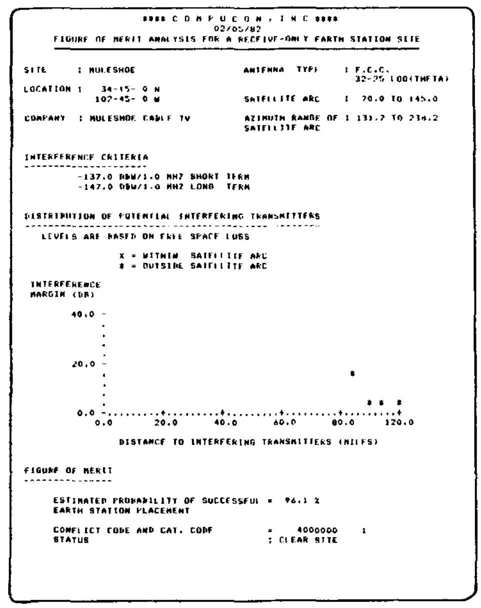
EARTH STATION POINTING AZIMUTHS AND ELEVATION ANGLES

MULESHOE
34-15- 0 N LATITUDE
102-45- 0 W LONGITUDE

POINTING AZIMUTHS IN DEGREES FROM TRUE NORTH AND ELEVATION ANGLES ABOVE HORIZONTAL FOR ACCESSING SATELLITES IN THE GEOSTATIONARY ORBIT BETWEEN 70.0 DEGREES WEST LONGITUDE AND 145.0 DEGREES WEST LONGITUDE. NAMES INDICATE 4/6 GHZ SATELLITES PRESENTLY IN ORBIT.

GEOSTATIONARY SATELLITE NAME	POSITION	EARTH STAT. POINTING AZIM.	ELEV.	GEOSTATIONARY SATELLITE NAME	POSITION	EARTH STAT. POINTING AZIM.	ELEV.
	70.0	131.2	37.1		108.0	189.3	49.8
	71.0	132.4	37.8	ANIK B-1	109.0	191.0	49.6
	72.0	133.4	38.5		110.0	192.7	49.4
	73.0	134.6	39.1		111.0	194.4	49.3
	74.0	135.7	39.8		112.0	196.1	48.9
	75.0	137.0	40.4		113.0	197.8	48.7
	76.0	138.2	41.1	ANIK A-3	114.0	199.5	48.4
	77.0	139.5	41.6		115.0	201.0	48.1
	78.0	140.7	42.2		116.0	202.6	47.7
	79.0	142.0	42.8		117.0	204.3	47.4
	80.0	143.3	43.4		118.0	205.8	47.0
	81.0	144.7	43.9	SATCOM F2	119.0	207.3	46.6
	82.0	146.1	44.4		120.0	208.9	46.1
	83.0	147.5	44.9		121.0	210.3	45.7
	84.0	148.9	45.4		122.0	211.8	45.2
	85.0	150.4	45.9	WESTAR II	123.0	213.2	44.7
	86.0	151.9	46.3		124.0	214.6	44.2
COMSTAR C	87.0	153.4	46.7		125.0	215.9	43.6
	88.0	155.0	47.2		126.0	217.3	43.1
	89.0	156.5	47.5		127.0	218.6	42.5
	90.0	158.1	47.9	COMSTAR A	128.0	219.9	41.9
WESTAR III	91.0	159.8	48.3		129.0	221.2	41.3
	92.0	161.4	48.6		130.0	222.5	40.7
	93.0	163.0	48.8		131.0	223.6	40.1
	94.0	164.8	49.1		132.0	224.8	39.5
COMSTAR B	95.0	166.4	49.4		133.0	226.0	38.8
	96.0	168.2	49.5		134.0	227.1	38.1
	97.0	169.9	49.7	SATCOM F1	135.0	228.2	37.5
	98.0	171.6	49.8		136.0	229.3	36.8
WESTAR I	99.0	173.4	49.9		137.0	230.4	36.1
	100.0	175.1	50.1		138.0	231.4	35.4
	101.0	176.9	50.2		139.0	232.5	34.6
	102.0	178.7	50.2		140.0	233.4	33.9
	103.0	180.4	50.2		141.0	234.4	33.2
ANIK A-1	104.0	182.2	50.2		142.0	235.4	32.5
	105.0	184.0	50.1		143.0	236.3	31.7
	106.0	185.7	50.1		144.0	237.2	31.0
	107.0	187.5	49.9		145.0	238.2	30.2

FIGURE 9



**** C O M P U C O N , I N C ****
02/05/82
FIGURE OF MERIT ANALYSIS FOR A RECEIVE-ONLY EARTH STATION SITE

SITE : MULESHOE
LOCATION : 34-15- 0 N
102-45- 0 W
COMPANY : MULESHOE CABLE TV

ANTENNA TYPE : F.C.C.
32-25 LOG(THETA)
SATELLITE ARC : 70.0 TO 145.0
AZIMUTH RANGE OF : 131.2 TO 238.2
SATELLITE ARC

INTERFERENCE CRITERIA
-137.0 DBW/1.0 MHZ SHORT TERM
-147.0 DBW/1.0 MHZ LONG TERM

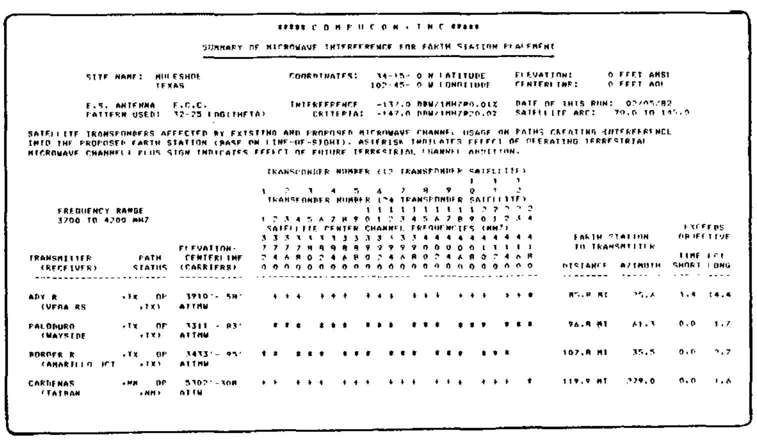
DISTRIBUTION OF POTENTIAL INTERFERING TRANSMITTERS
LEVELS ARE BASED ON FREE SPACE LOSS
X = WITHIN SATELLITE ARC
* = OUTSIDE SATELLITE ARC

FIGURE OF MERIT

ESTIMATED PROBABILITY OF SUCCESSFUL = 96.1 %
EARTH STATION PLACEMENT

CONFLICT CODE AND CAT. CODE = 4000000 1
STATUS : CLEAR SITE

FIGURE 10



***** C O M P U C O N , I N C *****

SUMMARY OF MICROWAVE INTERFERENCE FOR EARTH STATION PLACEMENT

SITE NAME: MULESHOE TEXAS
COORDINATES: 34-15- 0 N LATITUDE, 102-45- 0 W LONGITUDE
ELEVATION: 0 FEET AMSL
CENTERLINE: 0 FEET AGL
E.S. ANTENNA PATTERN USED: F.C.C. 32-25 LOG(THETA)
INTERFERENCE CRITERIA: -137.0 DBW/1MHZ@0.01% ; -147.0 DBW/1MHZ@20.0%
DATE OF THIS RUN: 02/05/82
SATELLITE ARC: 70.0 TO 145.0

SATELLITE TRANSPONDERS AFFECTED BY EXISTING AND PROPOSED MICROWAVE CHANNEL USAGE ON PATHS CREATING INTERFERENCE INTO THE PROPOSED EARTH STATION (BASE ON LINE-OF-SIGHT). ASTERISK INDICATES EFFECT OF OPERATING TERRESTRIAL MICROWAVE CHANNEL; PLUS SIGN INDICATES EFFECT OF FUTURE TERRESTRIAL CHANNEL ADDITION.

FREQUENCY RANGE 3700 TO 4200 MHZ

TRANSPONDER NUMBER (12 TRANSPONDER SATELLITE) 1–12; TRANSPONDER NUMBER (24 TRANSPONDER SATELLITE) 1–24; SATELLITE CENTER CHANNEL FREQUENCIES (MHZ) 3720–4180

TRANSMITTER (RECEIVER)	PATH STATUS	ELEVATION-CENTERLINE (CARRIERS)	TRANSPONDERS AFFECTED	EARTH STATION TO TRANSMITTER DISTANCE	AZIMUTH	EXCEEDS OBJECTIVE TIME (%) SHORT	LONG
ADY R (VEGA RS ,TX)	,TX OP	3910'- 58' ATTNW	+ + + + + + + + + + + + + + + + + *	85.8 MI	25.6	3.4	14.4
PALODURO (WAYSIDE ,TX)	,TX OP	3311 - 83' ATTNW	* * * * * * * * * * * * * * * * * *	96.8 MI	61.3	0.0	1.7
BORDER R (AMARILLO JCT ,TX)	,TX OP	3433'- 95' ATTNW	* * * * * * * * * * * * * * * * *	107.8 MI	35.5	0.0	2.7
CARDENAS (TAIBAN ,NM)	,NM OP	5302'-308 ATTN	+ + + + + + + + + + + + + + + + + + *	119.9 MI	229.0	0.0	1.6

FIGURE 11

SATELLITE SPACING - THE NO PARKING SIGN
A Report On The Problems and Some Solutions

Gil Hodges

President
SAVAC International, Inc.

Abstract

The text describes a novel optical design, featuring innovative reflex plates for small aperture (3m) antennas along with new technology in feed horn design and application.

When used as a microwave antenna system, the design forces the antenna to assume the performance and radiation pattern characteristics of a much larger aperture, opening the door for small aperture use at 2° orbital spacing.

The design also incorporates a new combination of materials and manufacturing processes which have greatly expanded the operating frequency range, service life, and field maintenance of the system.

Space communications is the newest frontier; to suggest, at this early stage, that our industry is incapable of solving a corridor crowding potential may be irresponsible. Satellites are now allotted 4° parking slots across the Geostationary parkway; the FCC is suggesting that the allocated separation be reduced to provide for more growth. We can, and must, anticipate that 3° spacing is both inevitable and temporary - followed by 2° spacing.

Accordingly, this report will address itself to these problems and to some solutions for satellite communications.

Reduction of satellite spacing means different problems to different sections of our industry, but the common thread which binds us all is "interference". To reduce the effect of the anticipated interference on earth stations, the FCC has proposed a change to Part 25.209 to read $29 - 25 \log_{10} \theta$ for 1° - 7°. This proposal effectively reduces the field of view of the antenna so that it sees less angular space at 22,300Nm. Good, large aperture antennas (5m+) now enjoy this view restriction per the inverse relationship between aperture size and beam width.

Small aperture antennas, however, have not been noted for narrow field of view, especially the rapidly expanding 3m sector of our market. The conventional 3 meter antenna has the widest field of view of the classic parabolic configurations so should suffer the most at 2° orbital spacing. To make a small aperture antenna work, and work superbly at 2° spacing, will involve an unconventional approach to design and manufacture, though the objectives are simple:

1) Develop a 3m reflector configuration which narrows the 3_{db} beam width and the peak beam.
2) Develop a feed system which significantly increases gain and suppresses side lobes.

We will first examine the reflector. Let's establish a photographic analogy to better understand antenna optics. Let's define our antenna as a camera and a distant satellite as the subject to be photographed - not forgetting that it is an invisible target. We know its general location in space and that it is generating an infinitesmal amount of light. Logically, we select the largest aperture lens at our disposal for maximum light gathering potential, understanding that there is an inverse relationship between "big" and "good". We aim our camera into the designated area in space, use our light meter to better pin-point our aim, take a few test shots and suddenly we have an exposure of the invisible subject. But we never know where the subject is relative to our field of view; we receive the same exposure when the subject is in the corner of our viewing field, as is the case when it is centered within our lens. To make matters worse, our field of view is 1,860 miles, and our target only 10 feet in diameter - our margin for sighting error is more than modest.

Now, let's switch to a super telephoto lens and halve our field of view (now 930 miles) though we all know that this lens change will reduce our speed which lessens our exposure, so we have lost more than we've gained. True, we could construct a telephoto lens of sufficient aperture and speed to restore the loss, but that would cost dearly - yet we are still confronted with a potential sighting error of 930 miles.

Why is it so important to have good composition (a centered subject) and a restricted field of view? The answer should now be obvious for without the ability to discriminate and sight a specific subject, the addition of other closely spaced subjects could make your camera useless: But don't throw your camera away yet!

In that we are not photographing a discrete subject, only recording all its available light, we can optically restrict what your camera sees without effecting its speed or distorting the energy creating the exposure. Let's add a long black tube over your lens that extends out into space 12 inches, 12 feet or 12 miles. Suddenly, this blinder forces you to pin-point your target or the lens will not see the subject. Because your subject is a speck in space, and all of its energy is traveling parallel to your tube, no light is lost once the tube is pointed at the subject - so you have the necessary exposure and your aiming accuracy (field of view) is directly proportional to the length of the tube extended over the lens. And, most importantly, this tube prevents your lens from seeing other subjects that are moving closer to your primary subject, so unwanted light is rejected.

A satellite antenna, fortunately, is optically very different from a lens; a lens is refractive (transparent) and an antenna is reflective (opaque). As a reflector, our antenna responds to the law of reflection (all energy will reflect from its surface at its angle of entrance). By using this ancient and immutable law of physics, we can now easily construct an equivalent version of the blinder tubes by the use of optical reflex plates within the concavity of our antenna.

If these optical reflex plates are positioned or aimed perpendicular to the satellite, the emitted energy from the satellite is unobscured by these plates and a full signal is recorded. However, any error in the aim of the antenna will cause a corresponding change in the reflex plate's reflection angle; if the satellite is off-axis to the optical center of the antenna, its reflection angle will be off-axis to the reflex plates of the antenna, and the incoming signal is now obscured or shadowed from the detector.

Technically, we have constructed a metal maze in which there is a restricted and narrow entrance. As with the tubes, we now have the ability to pin-point our target and to reject the light being emitted from neighboring satellites. As with the blinder tube, the degree of rejection and the field of view is a function of the size and termination point of the optical reflex plates and the focal length of our antenna. Using conventional optical equations, a 2° field of view is an easy task; it is now theoretically possible to mass produce small aperture ($\leq$3m) antenna systems with a viewing angle of under 2°.

To understand the problem of 2° spacing with respect to 3m or smaller apertures will call for a quick primer in optics and the determination of the field of view for a specific aperture size. In optics, a parabola is classified as a "Diffraction Limited Optical System" (1) and as such, exhibits a Fraunhoffer diffraction distribution for a circular aperture. To determine the field of view of the aperture we must know the central angular radius of the peak beam at the base. This radius is given by the following formula: (2)

$$\text{Radius } \emptyset = 1.22 \times \frac{\text{Wave Length in Meters}}{\text{Diameter in Meters}}$$

To translate this to field of view we simply multiply this angle by the distance between the earth station and the satellite. In our case, for geostationary use, it's 22.3Knm. Knowing this we can now predict the base angular radius of any aperture at any frequency and determine its field of view in miles. Remembering that 2° spacing is roughly 930 miles point to point between satellites, this sets our maximum field of view at 1860 miles as the go/no go field of view limit for 2° reception. Determining the field of view for a 3 meter aperture at a wave length of 8.11 cm ($3.7GH_z$) we have;

$$\emptyset = 1.22 \times \frac{\text{Wave Length in Meters}}{\text{Diameter in Meters}}$$

$$\emptyset = \frac{1.22 \times 8.11 \times .01}{10' \times 12'' \times .0254}$$

$$\emptyset = \frac{1.22 \times .0811}{3.048} = \frac{.099}{3.05} = .0324 \text{ Radians}$$

Converting that resultant to degrees we have: $.0324 \times 57.3 = 1.86^{\circ}$

This is the angular field of view in degrees either side of zero for the peak beam. To determine the full field of view for the aperture at that frequency double the angle, convert it to radians and multiply by 22,300nm.

$1.86^{\circ} \times 2 \times .0174 \times 22{,}300 = 1443.7$ miles
According to this equation a 3m aperture at the designated frequency should have a field of view of less than 1860 miles which should satisfy part of the requirement for 2° reception. So what's the problem?

In reality a 3m antenna, or any antenna, is, optically speaking, quite poor. We must remember that these mathematical equations are assuming 100% accuracy throughout all aspects of reflector design, manufacture, and assembly. Figure A is an example of a conventional 3m antenna at a frequency of $3.7GH_z$ vertical pole. Its base angle is 6.5°. Converting the base angle to field of view we have $6.5^{\circ} \times .0174 \times 22{,}300 = 2{,}522.1$ miles. Now, the real problem is in better focus--the peak beam is 662 miles wider than our limit of 1860 miles. Fig. B is a typical vertical pole pattern for our own SAR 10.3 at $3.7GH_z$, using a commercially available scalar feed. Here we have a base angular dimension of 4.19°. Converting this to field of view we have: $4.19^{\circ} \times .0174 \times 22{,}300 = 1625.7$ miles. Now our peak beam field of view is almost 235 miles under our limit which more than satisfied the 2° requirement. The 3db beam width on this pattern is 1.65°.

Fig. A Scale: 1° Per Division

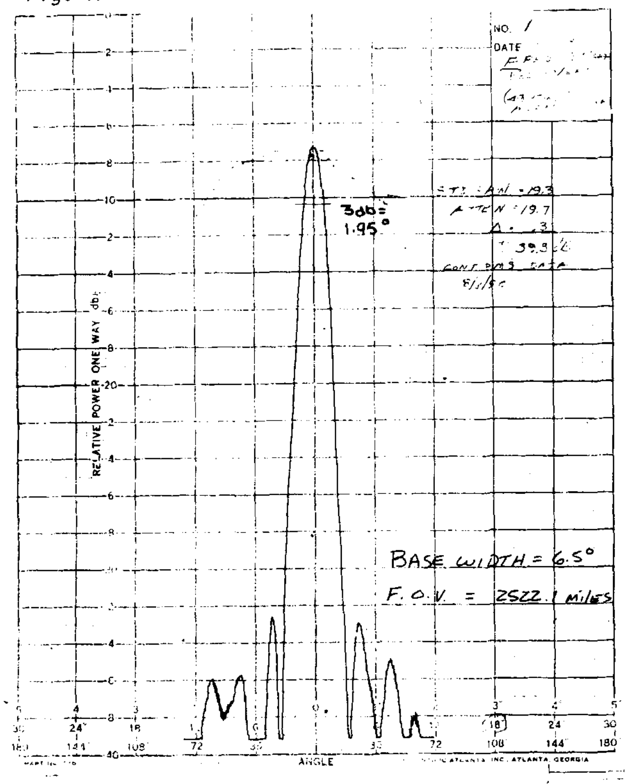
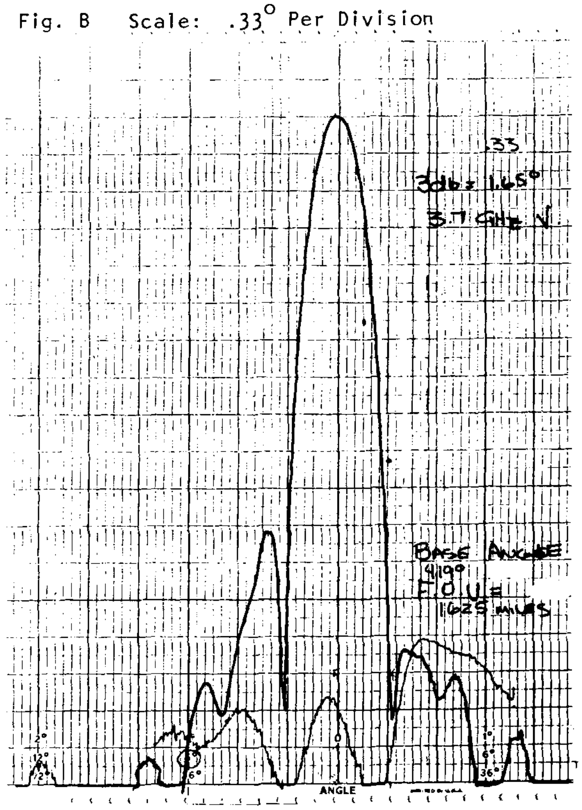


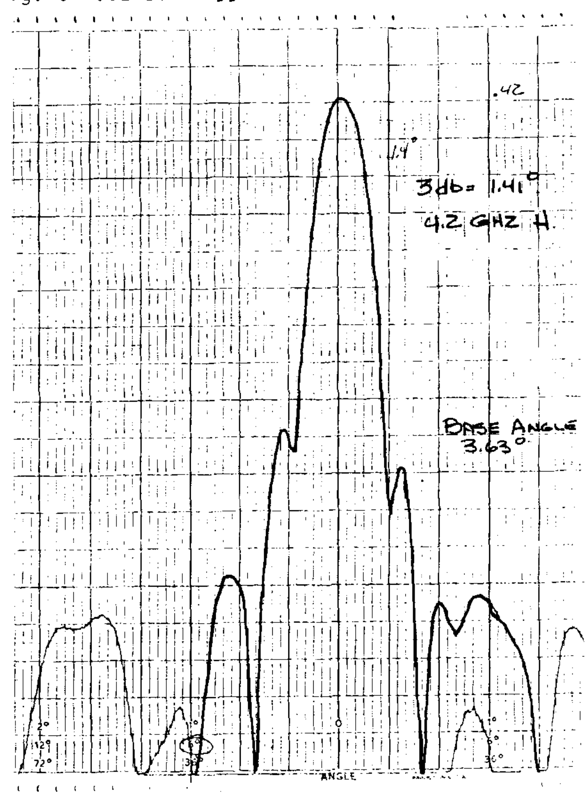
Fig. B Scale: .33° Per Division



We at SAVAC achieve this restricted field of view partially through the use of our optical reflex plates within the concavity of the antenna. The plates cause the distribution of energy per degree of angle to roll off the peak much faster than would normally occur in a conventional unobstructed parabolic reflector. By increasing the height of the plates, further reductions of beam width can be achieved.

Fig. C is a pattern of the SAR 10.4 at 4.2 GH_z H. pole. (again using a commercial scalar feed). The 10.4 system had a 3 db beam width of 1.4° and a base angle of 3.63° (1408 f.o.v.). While there are many other functions of our reflex plates, their main optical function is to achieve the reduced base angle and 3db beam width of the aperture so that it sees one and only one satellite at 2° spacing. Now that we have developed a reflector with a field of view that meets 2° spacing, the remaining challenge is side lobe control to minimize interference.

Fig. C Scale: .33° Per Division



Side lobes can be manipulated by either one or both of the following techniques:

a) Side lobe position
b) Side lobe magnitude

SAVAC has chosen to influence both parameters to insure more trouble free reception at 2° spacing. Side lobe position is largely controlled by the F/D of the dish. For example, Fig. D is a breakdown of the 1st side lobe position at 3 frequencies for the SAR 10.3 and 10.4 using a ratio equivelent reflex plate height. The side lobes on the .42 are on the average 1° nearer the peak beam than the .33. While both will work at 2° spacing the .42 provides a more comfortable margin.

Side lobe magnitude is altered by developing a new concept in feed horn design which significantly increases net gain, allowing for extremely low edge illumination tapers, while maintaining a 41+dbi gain figure--and secondarily, the suppression of near in lobes. SAVAC has filed patents on just such a feed. It incorporates a precision scalar configuration which exhibits superior beam width equalization and phase center control but most importantly, incorporates a new concept in transition from circular to 229 guide.

Fig. D

10.3	39"Focus	10.4	51"Focus
F/D = .33		F/D = .42	
Freq.	Position	Freq.	Position
3.7	3.74°	3.7	2.4°
4.0	2.47°	4.0	2.28°
4.2	2.23°	4.2	2.80°

As this new feed was incorporated into our reflector, the overall antenna efficiency increased 15%, yielding an antenna gain unparalleled by any other 3m antenna.

This designed increase in gain permitted us more freedom in the use of the new feed system, to further refine our performance:

1) To significantly under illuminate the antenna for the suppression of far out lobes.
2) To selectively illuminate the balance of the antenna for near in lobe suppression.

It is well known that different degrees of edge illumination tapers can be achieved by controlling the primary radiation patterns of a horn. One can achieve as wide as 180° or as little as 15° by altering the number, size, spacing, and flare angle of the convolutions in the horn. SAVAC selectively illuminated areas of the antenna for the control of near in lobes.

The face of a feed horn can be "mapped" to pin-point those areas of the reflector most influenced by a given sector of the feed. Once the secondary radiation patterns are cut, one can determine the angular position of the lobes by inspection, and relate it to a physical region of the antenna.

The remaining job is to identify that sector of the feed which illuminates that region of the antenna and modify it so that it under illuminates that region. The net result is suppressed near in lobes.

Since the side lobes are fixed as a function of the aperture size and F/D, all horns are factory set and are interchangeable to any SAVAC antenna of common F/D.

The SAR 10 antenna is the industry's first entirely vacuum formed, optically graded reflector. Typical reflector RMS is approximately .003". The reflector consists of two parts.

1) Vacuum formed optical substrates formed from high impact ABS.
2) A 100% R. F. reflective film which is secured to the reflective side.

By virtue of our cold lamination process, the surface RMS provided by the parent tooling is preserved throughout all phases of manufacturing which allows us to offer an RMS which could only previously be obtained via a costly spun aluminum process.

When the manufacturing process is complete, the ABS substrate is sandwiched between UV and IR stablized films. This combination of polymers protects the substrate from the most harsh outdoor environments for a period which should exceed 10 years.

Vacuum forming is by no means a new art but it has many advantages when used as a manufacturing tool for satellite antennas. For example, the tooling required is cost effective; molds can be quickly modified or repaired with a minimum of time and money.

Process parameters such as shrinkage can be controlled to within .020" from lot to lot throughout the year. This uniformity guarantees the end user two major benefits:

1) Repeatable and predictable performance from all units.
2) Stocked and off the shelf replacement reflector segments for the antenna.

Factory replacement parts are not limited to the reflector segments only. In fact, all components of the antenna are field serviceable and replaceable.

SAVAC is currently developing a retro fit kit for conventional small aperture antennas which will include 3 items.

1) RF reflective film
2) Optical reflex plates
3) SAVAC feed, less the provision for near in lobe control.

When an antenna is retrofitted using the above mentioned kit, it will improve efficiency 8-15% and will exhibit a related increase in gain on the order of 1 to 2 dbi.

The near optical grade reflector surface on the SAR 10 boasts the widest available frequency range of all small aperture antennas on the market today (well in excess of $30GH_z$).

Due to the optical reflex plate configuration the antenna has consistently demonstrated lower wind loading and noise temperature specifications.

Perhaps the most important advantage is with respect to shipping logistics.

The SAR 10 antennas require less volume to ship as a result of the "nesting" of the parts. Because of weight to volume ratio of the package, the antenna is inherently cheaper to ship on a commercial carrier than other 4 piece or 1 piece fiberglass counterparts, which represents a considerable cost savings to all buyers.

It has often been said that necessity is the mother of invention and the SAR 10 is a good case in point. The antenna for the future will have to contend with a number of new problems not prevalent in the past, including:

A) Decreased orbital spacing
B) Increasingly noisier ambients, and
C) Reception from hybrid dual frequency satellites -- to name a few.

The SAR 10 antennas in our opinion are the only small aperture antennas which were designed in anticipation of the known spacing problems, as well as other.

The 80's hold a virtual renaissance in technological advances for satellite communications. The SAR 10 antennas and feeds represent only a small part of the wonders to come. Almost unbelievable advances in LNA's, receivers, and transmission line are just around the corner.

We at SAVAC are proud to be a part of this communications revolution, and hope to share with you still more improvements when we meet again.

ACKNOWLEDGEMENTS

The author wishes to thank the following people for their contributions and help in preparing this paper:

1) Marvin P. Hodges: Director, SAVAC Int., Inc
2) Dr. Richard Buchroeder: President, Optical Center, Tucson, AR.
3) Tony Sciarrino: President, Space Machine & Design, Consultant - SAVAC Int., Inc.
4) Carl Schmitt: Manager Spectrum Engineering, Comsat General

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SELECTION OF AN OPTIMUM MODULATION SCHEME FOR CATV DATA TRANSMISSION

Jon P. GrosJean
Consulting Engineer

DataVision

Two-way data transmission on CATV cables is growing rapidly. Unfortunately, TV and FM signals occupy most of the available frequencies in current cable systems leaving very little for data signals. Return channels, however, are usually vacant but often very noisy and suffer from outside signal leakage. Most, if not all, current CATV data systems use FSK because of its inherent signal-to-noise improvement properties. This is helpful in the return path but not necessary in the path into the home where signals are very good quality. Furthermore, if signal-to-noise improvement is desired, FSK must have a deviation greater than the signal bandwidth so it uses up the available spectrum with fewer data channels. A better approach would be to use different modulation schemes in different directions while choosing them to keep both the home unit cost and data error rate low.

INTRODUCTION

Some general requirements for a two-way CATV data transmission system serving a large number of homes are:

1. Reliability-low data error rates.
2. Low cost of home unit.
3. Ability to serve a large number of homes on an existing cable system.
4. Minimum use of additional frequency spectrum.
5. No interference with television signals.

A low data error rate necessitates either a good signal-to-noise ratio or a complex modulation scheme. Since the TV signal into the home is generally much better than that required for very good data transmission at reasonable data rates, it should be possible to use relatively simple modulation scheme in this direction.

It would also be desirable to keep the frequency used for data transmission into the home relatively low so expensive filtering or complex frequency conversion schemes are not needed.

Assuming the use of the existing two-way cable arrangements, transmission of data out of the home must be between 5 and 30 MHz. However, unlike in the other direction, the return path is usually noisy because the summing effect of noise from the reverse channel amplifiers and pickup of external signals is often quite severe especially around the 27 MHz CB frequency. Thus, return signals must lie between approximately 5 and 25 MHz. This is a bandwidth of 20 MHz, and, if a large number of homes is to be served, there will necessarily be a trade-off between data rates and occupied bandwidth. For example, if 300,000 homes are served and each channel frequency selected serves 3000 homes, 100 channels will be needed. This leaves 200 KHz for the channel spacing. Filter selectivity requirements will reduce the allowable channel bandwidth to about 150 KHz. It will be shown later that this channel bandwidth puts a severe restriction on the maximum data rate depending on the type of modulation selected.

Thus, if it were easy to generate in the home, a relatively complex modulation scheme requiring a sophisticated central receiver which performed well in the presence of noise should be used. It would, as mentioned above, still have to operate within the channel bandwidth constraints. Since each central receiver-transmitter will serve a large number of homes, its cost and complexity in relation to the whole system is relatively unimportant.

MODULATION POSSIBILITIES

Basically, there are only 3 ways an RF carrier can be modulated: Its amplitude, frequency, or phase can be changed by the modulating signal. Since only modulation with pulses is being considered here, these would be referred to as OOK (on-off keyed), FSK (frequency-shift keyed) and PSK (phase-shift keyed). OOK is referred to here as AM (amplitude modulation) because in reality the modulation can be anything from a 80% to 100% change in the carrier amplitude.

The bandwidth required to transmit a pulse depends on its minimum width and the type of modulation used. A pulse of width t seconds has a bandwidth of approximately 1/t hertz. However, when this pulse modulates a carrier, the occupied bandwidth is always equal to or greater than 2/t hertz because the modulation process translates the frequency spectrum of the pulse from being centered at zero frequency to being centered at the carrier frequency. PSK modulation in which the pulses shift the carrier phase by 180° and AM both produce an occupied spectrum bandwidth of 2/t hertz. (1) In data transmission terms, the bandwidth would then be equal to twice the baud rate since the minimum pulse width is 1/baud rate. FSK, on the other hand, produces an occupied bandwidth which depends on how much the carrier is shifted. A commonly used expression for the occupied bandwidth B is:

$$BW = 2\Delta f + 2\ B \qquad (1)$$

$$\text{or} \quad BW = 2\Delta f + 2\ (\text{baud rate}) \qquad (2)$$

(Δf = peak frequency deviation)

FSK usually is used because it offers a signal-to-noise improvement over AM, but this is only true if Δf is large enough. A commonly used criterion is that for $\Delta f/B = .6$, FSK is approximately equal to AM. (2) Thus, in order to gain any significant improvement in signal-to-noise ratio using FSK, the occupied bandwidth must be greater than the bandwidth of an AM signal. If $\Delta f/B = 1$, the occupied bandwidth of FSK is 2 times that of AM and the signal-to-noise improvement is about 5 dB. This is true, however, for carrier-to-noise power ratios above approximately 2 dB. Almost the same performance can be obtained at this level by using AM with a synchronous (phase locked) demodulator. Another comparison can be made by comparing the calculated bit error probabilities for the different types of modulation. (3) AM has the poorest performance and an error probability $P_e = 10^{-8}$ requires a carrier-to-noise power ratio C/N of 18 dB. FSK with incoherent detection (not using a phase locked loop detector) achieves the same P_e for C/N of 15.5 dB. PSK, however, is 3.5 dB better than FSK and requires a C/N of only 12 dB. The problem is that PSK is sometimes difficult to demodulate especially when a large number of non-coherent signals must be detected. This occurs when a receiver using a phase locked loop (PLL) acquires the PSK signal. The PLL cannot tell if the phase it starts with is 0° or 180° unless some method of determining this is built into the data. Complicating things further is the problem of acquiring a signal rapidly and then being able to remain at 0° when a long 180° data pulse is received. If only one signal such as that from a space probe is being received, this is not a problem because, for these applications, the phase locked loop can have a very long time constant. When a new signal of unknown phase must be locked on to every few milliseconds, however, the loop must be relatively fast and so will also change phase and lock onto the 180° datapulse when it occurs. These factors make PSK demodulation somewhat more difficult than other schemes.

HOME RECEIVER POSSIBILITIES

As was mentioned earlier, low cost is the most important requirement for the home receiver. Its performance specifications are not severe because of the large signal level and good signal-to-noise ratio into the home. If the 108 to 120 MHz band is used, the home receiver should be able to operate reliably with signal levels which would usually satisfy the FCC limitation of 10^{-5} watts anywhere on the cable system in this band. Another consideration mentioned earlier is that home receiver frequency should be kept relatively low to keep costs down. If it is crystal or synthesizer controlled and only L-C filters are used, 300 MHz is about the upper frequency limit. Unfortunately, this lies in the middle of the TV band, and, if it is undesirable to use up TV channels for data transmission, the 108 to 121 MHz frequency range is all that is available. This works out well, however, because most cable systems would have a problem with the FCC limits if they used these frequencies for TV signals.It is a relatively small band, but if modulation and data rates are carefully chosen,any practical numberof homes can be accommodated.

HOME TRANSMITTER POSSIBILITIES

As with the receiver, the home transmitter should also be low cost. It is probably desirable to set its frequency also with a crystal or synthesizer arrangement. If a crystal is used, FSK becomes difficult or expensive. If a synthesizer is used, it is not as difficult, but a problem occurs because the "0" output frequency must be on one side of the channel center frequency and the "1" frequency on the other. This is more likely to result in adjacent channel interference problems between unmodulated and modulated carriers because the receiver must be tuned to the center of the channel.

AM and PSK, on the other hand, are very easy to generate. AM is generated by simply turning the carrier on and off either with a gate or by turning the RF amplifier stages on and off. PSK can be generated by switching between a 0° and 180° signal from the oscillator or phase inverter. Thus, from the standpoint of the home transmitter, AM or PSK are the easiest to generate.

CENTRAL RECEIVER POSSIBILITIES

As was mentioned earlier, cost is not an important consideration in the central receiver. It should have the best possible performance in the presence of noise and its received signal must not occupy too much bandwidth because of the limited frequency range available. Unlike with the signals going into the home, the available frequency range is limited to 5 to 25 MHz and the possibility of using a TV channel for data doesn't exist. The Central Receiver has another unique requirement in that it must rapidly demodulate signals which last only a few milliseconds from many homes in succession. These signals may also have levels which vary as much as 15 dB at the receiver. The level variation occurs because it is almost impossible to set and maintain several thousand homes on a given frequency so they all produce the same level at the Central Receiver. This complication just about precludes the use of AM in the return path: If the AGC system must settle in less than 2 ms, then the longest data pulse must be much less than 2 ms. If no AGC is used, then the 15 dB level variation would cause quite a problem with a preset threshold. The most obvious solution to the level variation problem is to use a receiver containing a limiter and to use either FSK or PSK modulation. A phase locked loop could be used to demodulate either with good results, but the PSK is better in terms of lower error probability and uses up less bandwidth. As was mentioned in the paragraph on types of modulation, PSK may present some difficult problems in polled systems where signals must be rapidly acquired and demodulated. It could be assumed that since the Central Receiver's cost is not important, these problems could be overcome and PSK would be the best choice.

CENTRAL TRANSMITTER POSSIBILITIES

The Central Transmitter must provide a good signal with very low spurious outputs, but it is the least constrained of all the systems by modulation limitations. FSK would be the most difficult to generate and AM the least difficult. However, it must be concluded that the Central Transmitter would not have any influence on the selection of a modulation scheme.

CONCLUSION

The following tables summarize the preceding discussion (the lowest number indicates the most desirable).

A. Occupied BW

1 AM or PSK
2 FSK

B. Noise Performance

1 PSK
2 FSK
3 AM

C. Home Receiver Cost

1 AM
2 FSK
3 PSK

D. Home Transmitter Cost

1 AM
2 PSK
3 FSK

E. Central Receiver Performance

1 PSK
2 FSK
3 AM

When factors A, C, and D are considered, AM seems to be the best choice for signals going into the home. When factors A, B, D, and E are considered, PSK seems to be the best choice for signals going from the home to the Central Receiver.

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SLOPED-GAIN HYBRIDS

G.G. Luettgenau

TRW Semiconductors
14520 Aviation Boulevard
Lawndale, California 90260

ABSTRACT

All CATV hybrids currently on the market operate with flat gain. Recently an interest was shown in devices with an up-slope in gain from 14.5 to 18.5dB. Experimental circuits of this kind were assembled and measured. The performance in terms of trunk reach was calculated. Comparisons were made relative to flat-gain hybrids and a hypothetical device with 8dB gain slope. It was found that significant improvements in reach could be obtained, provided that tilt and interstage equalization were optimized.

DISCUSSION

Hybrids in CATV Trunks

The maximum length of a trunk depends primarily on two parameters: The noise figure and the composite triple-beat of the amplifiers used. The length or reach is often expressed in decibels which may be converted into miles once the cable losses/100 feet are known. Although the spacing of the amplifiers has a major influence on the reach (with the theoretical optimum being 1 Neper = 8.69dB), for a number of practical reasons a spacing of 25dB has become widely used practice. The following equation describes the relationships mentioned.

Reach = SP * 10exp (((-CTBB-CTB)/2-CNR-ENB+ET)/20) (1)

where:

SP = Amplifier spacing (dB)
CTBB = Composite triple-beat performance at the end of the trunk.
CTB = Amplifier CTB measured at a level of ET dBmV.
CNR = Carrier-to-noise ratio (dB) at the end of the trunk.
ENB = Noise voltage (dBmV) at the output of the amplifier.
ET = Output level (dBmV) at which CTB is measured.

In subsequent calculations trunk criteria are set to -63dB for CTBB and 43.5dB for CNR.

Since trunk amplifiers usually contain two hybrids, the amplifier performance is a function not only of the hybrid characteristics but also of the circuit employed and of the operating conditions. In the following analyses, an amplifier with these details is assumed:

- Frequency range 50 to 400 MHz
- Gain 25dB at 400 MHz
- Two identical hybrids with 18.5dB gain at 400 MHz
- Input equalizer with 2dB flat loss
- Interstage equalizer, gain and tilt control with 10dB flat loss

The cable slope is assumed to be:

Slope = 25 * (1-SQRT(F/400)) (2)
which results in about 16dB for F = 50 MHz.

The noise figure and the composite triple beat of the hybrid gain-blocks vary with frequency. The changes are approximated by:

X(F) = X(400) - DELTA * (400-F)/350 (3)

where:

X(F) = NF or CTB at frequency F
X(400) = NF or CTB at 400 MHz
DELTA = Difference in NF or CTB between 400 MHz and 50 MHz.

In this paper it is assumed:

NF(400) = 6dB, DELTA (NF) = 2dB
CTB(400) = -62dB, 52CH, flat, 46dBmV
DELTA (CTB) = 8dB

Another factor entering into the performance equation is the output spectrum tilt with which the hybrids are operated. While there is agreement that tilt improves composite triple beat, there is no consensus on the exact relationship. Theoretically one may argue, that tilting the output levels reduces the total output power and that therefore two dB in CTB should be gained for every dB drop in average power. Integrating the power for a 6dB tilted spectrum with 0dB 400 MHz reference, results in a value of -2.21dB for the average power. A theoretical CTB improvement of 4.42dB can therefore be predicted. The tilt was assumed to follow an inverse cable slope according to equation 2. The improvement differs somewhat for other degrees of tilt. It was calculated:

Tilt	CTB Improvement
1dB	0.82dB
6dB	4.42dB
10dB	6.74dB
16dB	9.34dB

In real life it is reasonable to expect less improvement. One reason for this lies in the fact that the higher frequencies contribute more to the overall CTB than the lower ones. In tilting the signal the higher frequencies remain fairly strong and maintain their influence.

In the literature one finds an empirical relationship, which states that a CTB improvement of 0.6dB is gained for every dB of tilt. This. value, which agrees fairly well with theory, was used in the calculations in this paper.

Flat-Gain Hybrids

It is the objective of this study to assess the influence of hybrids with substantial upslopes of gain on trunk performance. Before this case is analyzed, the base line, given by the performance of flat-gain hybrids, is established. Reference is made to Figure 1.

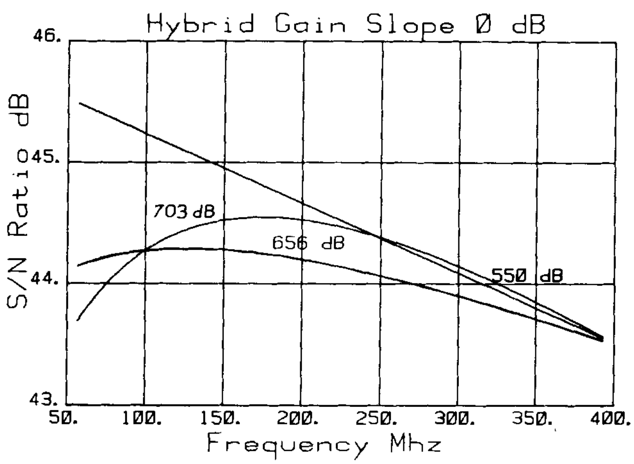


Figure 1. Trunk Reach for Flat-Gain Hybrids.

The top curve of Figure 1, labelled 550dB (trunk reach) relates the signal-to-noise ratio to frequency for an amplifier operating with flat spectra for both pre-amp and post-amp. It is seen that the C/N ratio at the low frequency end is unnecessarily good. Operating with 6dB tilt for the post-amp and 0dB for the pre-amp the reach is increased to 656dB. Finally, the computer was allowed to find optimum values of tilt for both input and output hybrids. A reach of 703dB was calculated for 9dB post-amp tilt and a down tilt of -3dB for the pre-amp. This somewhat puzzling result becomes understandable if one consideres the following: The tilt values obtained require an interstage equalizer of 11dB (and an input equalizer of 4dB for a total compensation of 16dB). The large value of interstage equalization loss at low frequencies reduces the noise contribution of the pre-amp. Therefore the low frequency output voltage levels may be reduced while still maintaining an acceptable CNR. As mentioned before the pre-amp operates with a down-tilt. This actually worsens its CTB performance relative to the flat output condition. It is apparent that increasing the amount of interstage equalization reduces the overall amplifier noise output, but increases the combined hybrid distortion. There exists, for every condition of post-amp output tilt, an optimum value of interstage equalization, resulting in maximum trunk reach.

Application of some of the operating conditions calculated may pose difficulties in practice. It is beyond the scope of this paper to ponder the practicality of all study results.

4dB Gain-Slope Hybrid

Industry inquiries seemed to show interest in a gain-block with a 4dB inverse cable equivalent slope. Experimental versions of such chips were constructed and measured. It was found that CTB and noise figure values were essentially equal to those obtained from equivalent flat-gain parts. Tilted output CTB performance agreed with the impirical relationship mentioned earlier.

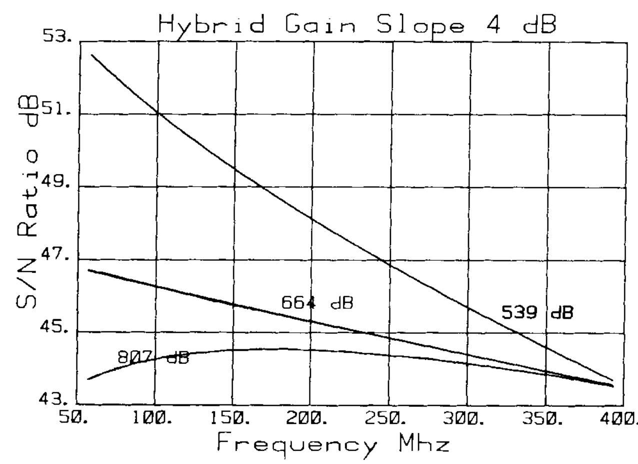


Figure 2. Trunk Reach for Hybrids with 4dB Gain Slope.

The operating conditions are summarized below:

Reach	Tilt	Interstage Equalization
539dB	0dB	0dB
664dB	6dB	0dB
807dB	13dB	7dB

The maximum trunk reach has increased 104dB over the best value obtained from the flat-gain parts. This is due to the fact that the noise output of the sloped-gain devices is 4dB lower at the low-frequency end. Therefore better distortion performance can be achieved by increasing the output tilt. Note however that there is practically no difference in reach between sloped and flat hybrids, if both are operated at 0 or 6dB tilt. CNR at low frequencies is better for the sloped-gain device, as one would expect.

8dB Gain-Slope Hybrid

To further investigate the subject, a hypothetical hybrid with 8dB gain-slope was examined.

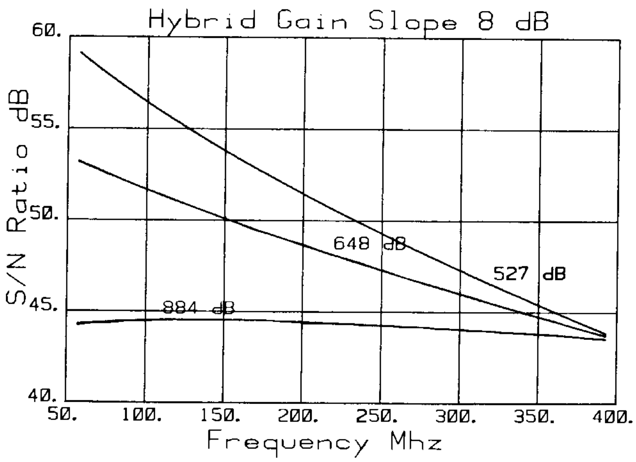


Figure 3. Trunk Reach for Hybrids with 8dB Gain Slope.

Reach	Tilt	Interstage Equalization
527dB	0dB	0dB
648dB	6dB	0dB
884dB	15dB	0dB

The reach improvement is now 181dB over the best performance of the flat-gain devices. It is up to the equipment designer to decide whether such a hybrid would be desirable.

METHOD OF ANALYSIS

A printout of a small computer program used to make the calculations for this study is shown at the end of this paper. The language is FORTRAN as used for a PR1ME computer. The example analyses one specific condition of tilt and equalization. By changing

DO 500 KTILT   0,20

DO 600 KEQNT   0,K

the program will scan a range of conditions for tilt and equalization.

CONCLUSION

It was shown that considerable improvements in trunk reach can be obtained by sloped-gain hybrids. In order to realize the theoretically possible performance, it is necessary to operate with appreciable output tilts.

```
.NULL.
      TRACE TILT,EQUAL,REACH,CNR
      REAL FSLOPE(67),AGAIN(67),ATT1(67),ATT2(67)
      REAL TB(67),RNF(67)
      REAL CTB1(67),CTB2(67),CTBB(67),ENB(67)
      REAL E2(67),E1(67)
      REAL CTB1T(67),CTB2T(67),CTBBT(67),RNFT(67)
      REAL FREQ(67)
      GAIN=18.5
      GSLP=4.
      TOTSLP=25.*(1.-SQRT(9./67.))
      K=INT(AINT(TOTSLP-2.*GSLP+.5))
      RNFHI=6.
      RNFLOW=4.
      CTBHI=-62.
      CTBLOW=-70.
      AFIX1=-2.
      AFIX2=-10.
      TILTFA=.6
      DO 500 KTILT=13,13
      DO 600 KEQNT=7,7
      EQFR=TOTSLP-2.*GSLP-FLOAT(KEQNT)
      DO 100 J=9,67
      I=76-J
      FREQ(I)=6.*FLOAT(I)
      FSLOPE(I)=(1.-SQRT(FLOAT(I)/67.))*25./TOTSLP
      AGAIN(I)=GAIN-GSLP*FSLOPE(I)
      ATT1(I)=-EQFR*FSLOPE(I)+AFIX1
      ATT2(I)=-FLOAT(KEQNT)*FSLOPE(I)+AFIX2
      TB(I)=CTBHI-(CTBHI-CTBLOW)*
     +(67.-FLOAT(I))/58.
      RNF(I)=RNFHI-(RNFHI-RNFLOW)*
     +(67.-FLOAT(I))/58.
      CTB2(I)=TB(I)-TILTFA*FLOAT(KTILT)
      CTB1(I)=TB(I)-(GAIN+AFIX2)*2.-TILTFA*(FLOAT
     +(KTILT)-GSLP-FLOAT(KEQNT))
      CTBB(I)=20.*ALOG10(10.**(CTB1(I)/20.)+10.**
     +(CTB2(I)/20.))
      ENB(I)=20.*ALOG10(SQRT((10.**((-59.+AGAIN(I)*
     +2.+RNF(I)+ATT2(I))/20.))**2.+(10.**((-59+RNF(I)+
     +AGAIN(I))/20.))**2.))
      DBS=(-63.-CTBB(67))/2.-43.5-ENB(67)+46.
      E0=43.5+ENB(67)+DBS/2.
      E2(I)=E0-FLOAT(KTILT)*FSLOPE(I)
      E1(I)=E2(I)-AGAIN(I)-ATT2(I)
      CTB2T(I)=CTB2(I)+2.*(E2(67)-46.)
      CTB1T(I)=CTB1(I)+2.*(E1(67)-46.)
      CTBBT(I)=CTBB(I)+2.*(E2(67)-46.)+DBS
      RNFT(I)=E2(I)-(ENB(I)+DBS/2.)
      IF(I.EQ.67) GO TO 100
      IF(CTBBT(I).GT.CTBBT(67)) GO TO 600
      IF(RNFT(I).LT.RNFT(67)) GO TO 600
100   CONTINUE
      REACH=10.**(DBS/20.)*25.
      CNR=RNFT(9)
      TILT=FLOAT(KTILT)
      EQUAL=FLOAT(KEQNT)
600   CONTINUE
500   CONTINUE
900   CALL EXIT
      END
BOTTOM


QUIT

OK, SEG *TILTAMP
 REACH=         807.1316
 CNR=          43.63605
 TILT=          13.00000
 EQUAL=          7.000000

OK,
```


Reference

The Future of CATV Hybrids
G. Luettgenau and J. Powell, "SCTE Spring Engineering Conference" Boston, 1982.

TECHNIQUES FOR IMPROVING CONTINUITY OF SERVICE IN A CATV DISTRIBUTION SYSTEM

John Dahlquist

JERROLD DIVISION
GENERAL INSTRUMENT COPRORATION

ABSTRACT

No longer is the only purpose of a CATV Distribution System to be a very reliable vehicle for providing interference free, entertainment television programming to the residents of a community. Today's modern CATV Distribution System is now being defined in proposals to municipalities as nearly 100% reliable communications network; capable of delivering non-entertainment services (i.e. security, electronic fund transferring, data base access, etc.) to CATV entertainment and institutional subscribers in a more timely fashion, displayed in a more conveniently used medium, and at a lower cost to the user.

With this being the functional objective of modern CATV Distribution Systems, it is clearly seen that the need for the system to provide uninterrupted service, in both the forward and return signal transmission paths, has increased dramatically.

This paper discusses techniques to improve the continuity of service from the overall system design viewpoint and from an amplifier configuration viewpoint. Separately, particular focus will be placed on forward and return transmission paths. The paper will present various methods of implementing the techniques, the potential cost impact of each, and the expected improvement in the continuity of service.

THE TORUS ANTENNA

Marvin D. Shoemake

SATCOM TECHNOLOGIES, INC.

ABSTRACT

Today there are 16 satellites in orbit in the 70-143° arc, three Canadian domsats and thirteen U.S. domsats. Only two U.S. domsats operate at 12/14 GHz. Within the next three years the number of satellites in the 70-143° arc could be increased to 27, more than doubling in-orbit satellite transponder capacity. Presently, six 12/14 GHz satellites and four dual C/Ku-Band satellites have been approved by the FCC.

By 1985 the total U.S. domsat capacity in orbit will probably exceed 400 transponders as compared to the present approximately 250 transponders. The prudent earth station owner should consider a satellite earth station antenna capable of interfacing with multiple satellites in multiple frequency bands. Simultaneous accessing of these satellites will become more important as more and more services and programming sources are available from a number of satellites.

Several multibeam antenna configurations are available which can access multiple satellites. This paper will provide a technical treatise of the multiple beam Torus antenna. It includes technical details, specifications and test data on the SatCom Technologies 4.5 meter Torus antenna.

TWO-WAY CABLE TV TECHNOLOGIES

ERNEST O. TUNMANN

TELE-ENGINEERING CORPORATION

Two-way Cable TV Technologies covers the broad range of uses of state of the art coaxial cable transmission systems for Integrated Video, Voice and Data Transmission.

The paper describes the four levels of a nationwide broadband coaxial tramsission system that would permit the transfer of high speed data, voice and video.

The Regional Interconnect System Architecture Level 3 - "the missing link" - is discussed in detail relative to frequency spectrum, capacity and equipment requirements.

INTRODUCTION

I welcome the opportunity to address this assembly of industry leaders on the subject of Two-way Cable TV Technologies and its application as the transmission media for video, voice and data in a Regional/Local Carrier Network environment.

My peronal background has been in transmission engineering all my life.

In 1955, as Transmission Engineer for the Bell of Canada, I had my first exposure in broadband transmission. At that time, 5 channels of video was the limit.

I founded Tele-Engineering Corporation in 1973 with the following long range objectivities:

a) to enhance the quality of cable transmismission system engineering and implementation
b) to develop ancillary products for data transmission on cable and broadband switching
c) to transform one-way cable distribution systems to two-way broadband transmission systems for video, voice and data transmission.

Since then, over 1500 miles of cable distribution plant have been designed and implemented on a turnkey basis. We enjoy a backlog of 1500 miles of system and have introduced programmable broadband switching and data transmission equipment for cable.

It is my firm belief that the business transmission system of the future must combine high speed data, voice and video. Anything short of such a network will ultimately fail.

It is my firm belief that both cable operators communication managers throughout the business community must learn the basics of broadband communications, PCM multiplexers and broadband switching.

What we have before us is a merger of computer technology with broadband transmission and switching technology.

It is also my belief that the cable operator of the future must become familiar with common carrier regulations and set up common carrier subsidiaries for business communications, or be bypassed by more agressive enterpreneurial organizations.

My presentation will take you through the nuts and bolts of broadband communications and will

- **describe the REGIONAL INTERCONNECT SYSTEM ARCHITECTURE**
- **analyze the SPECTRUM EFFICIENCY of the Regional Interconnect Cable**
- **describe the REGIONAL COMMUNICATIONS CENTER of the future**
- **and leave you with some THOUGHTS, MILESTONES AND RECOMMENDATIONS on how to get from here to there**

HIERARCHY OF NATIONWIDE BROADBAND COMMUNICATION SYSTEMS

The following chart describes the various levels of broadband communications.

There are four levels -

Level 1: The in-plant broadband network, also called the local area communications network or the office of the future. It provides high speed data, voice and video communications throughout a building or a group of buildings. Traffic to the outside world, or interplant communication, cannot always be established by business-owned earth stations and, therefore, requires a broadband cable connection.

Level 2: The broadband cable connection is the Cable TV Distribution System and the Institutional Cable that will develop into the Industrial Cable. Transmission of voice, data and video will arrive at the Hub of the local cable company. Distribution to locations within the franchise area will be performed by the cable company. Regional and long distance traffic will be grouped and switched to Level 3, the Regional Interconnect System.

Level 3: The Regional Interconnect System, or "the missing link", collects broadband transmissions from a group of local cable companies and forwards the traffic to the Regional Communications Center. The RCC will be the switching center for regional and long distance transmissions. Regional transmissions will go to other cable company hubs. Long distance transmissions will be forwarded to the operating satellite communications carrier of your choice.

Level 4: The satellite communications carrier will complete the nationwide long distance connections and route all broadband communications to the appropriate Regional Communication Center.

Level	Broadband voice/data/video	Transmission Medium	Operator
1	- In-plant - Intra Business - Local Area Network	- MW - Video Cable - RF Cable	Business and Industry
2	- Inter Business - Intra Town	- RF Cable	Cable Company
3	- Inter Town - Intra Region - Long Distance	- RF Cable - MW - Fiber	unknown Specialized Common Carrier
4	- Inter Region	- Satellite	SBS MCI SPC AT&T WU

As you know, Level 4 is well established and is waiting for you to close the gap of Levels 2 and 3. The level revolution is just getting started to interlink in-house computers and rebuild the internal telephone system using digitized voice.

Large industries will not wait for you to make up your mind on Levels 2 and 3. They will establish their own communication center and go directly from Level 1 to 4 (MACOMNET). Medium size and small businesses with the need for regional and long distance high speed data will be the best target.

LOCAL AREA COMMUNICATION NETWORKS (LEVEL 1)

There is an ongoing parallel development to Cable TV Distribution systems in the business community. Intra and Inter-Plant Communication Systems are going broadband.

Some examples of these services are given on the next chart.

Ethernet	**Xerox**
Arc	**Datapoint**
Primenet	**Prime Computer**
Mailway	**Wang Laboratories**
Wise	**Wang Laboratories**
Mitrenet	**Mitre Corporation**

Local Area Communication Networks

These systems are mostly baseband systems and handle speeds from 9.6 Kbps, and 56 Kbps to 10 Mbps

In all cases and related developments, the goal is to develop an integrated voice/data communication system that can deliver 56 Kbps data and digitized voice to every office desk, and to permit high speed communication between terminals and computers integrated with digitized voice PABX systems.

Tele-Engineering Corporation just completed a dual mid-split facility at Brown University in Rhode Island.

The system will be used for video, camera surveillance, security, energy management and data transmission.

To satisfy the University Campus' needs for multi-terminal to multi-computer interconnection, a SYTEK Local Net System 20 has been chosen.

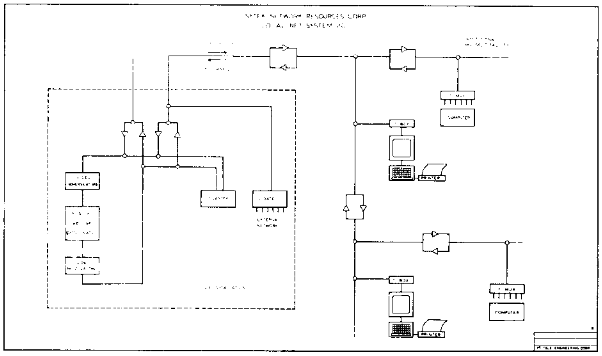
Any terminal can communicate with any computer connected to the system at 9.6 Kbps data rates. The system uses a Carrier Sense Multiplex Access/Collision Detection (CSMA/CO) philosophy and works on RF frequencies.

All stations listen to the circuit. If the link is idle, the station requiring to transmit proceeds and listens for its own signal (echo) to confirm the transmission.

Should two stations transmit simultaneously, the transmissions collide and each station attempts to retransmit after a random delay.

20 stations can be handled in a 300 KHz assignment, or 400 in a 6 MHz video channel.

Collision detection lives in the environment of small systems such as Local Area Networks. In large cable TV distribution systems long delays are to be expected due to cable propagation to reduced data transfer rates.



PRESENT CABLE TV DISTRIBUTION SYSTEM ARCHITECTURE (LEVEL 2)

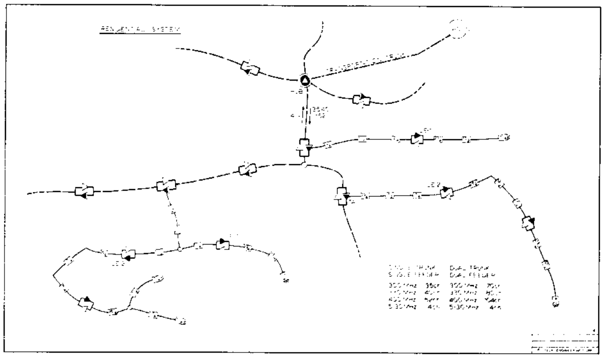
The next chart shows a typical Residential Cable TV Distribution System featuring a Hub location in the geographic center with a number of trunk lines feeding the various parts of town. The more trunks you have eminating from the Hub, the better your position with respect to future data traffic, as we will see in a little while.

Old-fashioned tree systems will require rebuilding.

Present Distribution System Architecture includes:

Single	Dual
300 MHz - 35 ch	300 MHz - 70 ch
330 MHz - 40 ch	330 MHz - 40 ch
400 MHz - 55 ch	400 MHz -110 ch

All the above features, when equipped, a sub-low transmission band in the reverse direction which can carry 4 video, or 6 MHz assignments between 5-30 MHz on each cable.



In newer systems we also find an institutional loop, typically a mid-split Institutional System. Originally designed as a simple school interconnect system, it became a tool to obtain franchises - a give-away to the town. It is commonly pictured as the town's communications system for teleconferencing, city computer interconnect and city, or countywide telephony.

The spectrum consists of 21 channels in one direction and about 14 channels in the other direction.

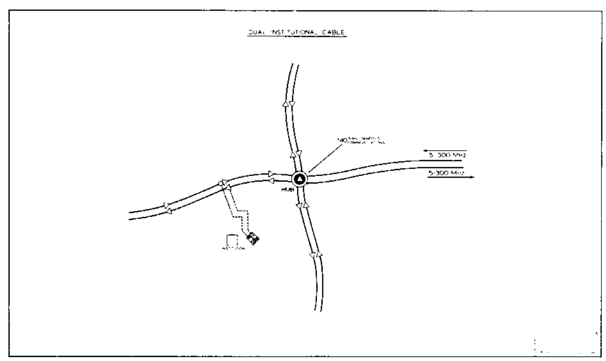
When you look a little deeper into existing installations, you do not find much switching mechanism in the Hub to establish these services.

Tele-Engineering Corporation developed the PVS-100 Programmer for 7-day switching of up to 96x96 video matrices, and up to 10,000 switching functions per week. We only sold a few so far.

But if the Institutional System would be extended into the industrial areas in town, it will become a powerful tool for voice, data and video.

The next slide shows a more powerful version of the institutional interconnect cable. It features 2 cables, 54-300 MHz, or 35 channels in each direction.

As we will see later, this cable arrangement seems to be the desirable architecture for high density traffic within the franchise area of a town or hub area.



DATA RATES AND DATA COMMUNICATION EQUIPMENT

What kind of transmission rates can we then expect to handle in interconnecting Level 1 with Level 2 over cable TV distribution systems?

Also, what kind of transmission rates can we expect to handle from single residencies?

All data rates from homes are essentially low or medium speed.

Service	Data Rate
Home	
Security Energy Management Meter Reading Data Inquiries Home Banking/Shopping	300 bps
Computer Terminal Electronic Mail	1,200-9,600 bps
Business	
Security Energy Management Data Inquiries	300 bps
Data	9.6-57 Kbps
Digitized Voice	64Kbps
PCM Combined T1	1.544 Mbps

There may be a high speed requirement in the forward direction to the home such as video or page selection. For this purpose, separate video channels can be set aside without affecting the return data requirement.

What kind of equipment is available to carry these data rates on the Level 2 residential and institutional networks of a cable distribution system?

There are many equipment developments in existance that I could not begin to describe because of lack of time.

Just to name a few:

Pioneer, E-Com, AMDAX, Tele-Engineering Corp., Scientific-Atlanta, CATEL

and many more are entering the market every day.

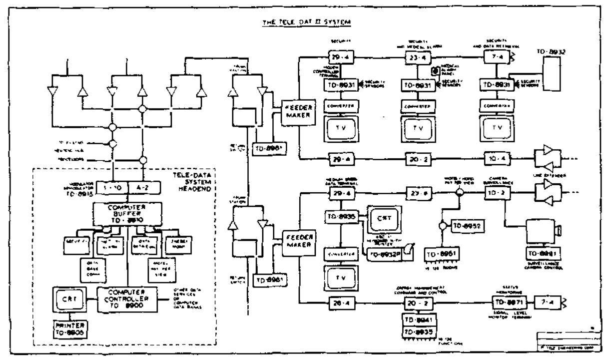
What I would like to do, is to concentrate on one type in each of the equipment categories in order that we can engineer the Level 2 and Regional Level 3 data transmission system.

There are two basic categories of data transmission:

Manufacturer Model	System	Level
A. Distribution Scanning Systems		
Tele-Engineering Tele-Dat II TD-8900	Residential System	Level 2
Tele-Engineering Tele-Dat II TD-9000	Institutional System	Level 2
B. Point-to-Point Systems		
Scientific-Atlanta Series 6400	Institutional System	Level 2
CATEL Series 3000	Regional Interconnect System	Level 3

DISTRIBUTED SCANNING EQUIPMENT

A distributed scanning system as the TD-8900 can handle up to 65,000 low speed terminals anywhere on the residential system. With 1 Mbps scanning rate, all terminals are addressed and have responded in less than 2 seconds.



The slide shows the general purpose of the TD-8900 design and its usefulness for a variety of data services such as security, energy management, camera surveillance, data inquiries and home computer data transmission.

There can be up to 16 different service categories within one system. Each category has a separate RS-232C port through which the data stream can either be connected to the telephone net or to PCM multiplex equipment for Level 3 (Regional Interconnect) transmission.

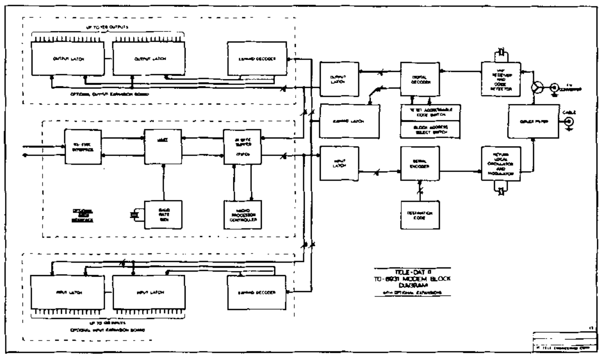
Data terminals talking to each other on the same system are coupled by an interlinking of two RS-232C ports.

The front end computer is used for system status monitoring and billing records.

The Tele-Dat II, TD-8900, system transmits an address of 16 bits and an 8-bit command signal to any terminal. In turn, the terminal answers, when addressed, with a 4-bit category code and 8 bits of information. The TD-8900 scans each terminal in the sequence of near to far on each trunk station area and expects an answer in accordance with a precisely measured delay time.

Should a terminal fail to respond, an instant alarm is noted on the first scan cycle. Each terminal is equipped with a communication bit, a power standby bit, tamper switch bit and a converter disconnect bit. The alarms are registered in the system computer front end and alert to immediate maintenance and follow-up action. In the forward direction, up to eight commands are available for pay-per-view, energy management or other forward messages.

A terminal modem controller can be expanded to a medium speed data terminal by multiple addressing. Speeds up to 9,600 bps can be accommodated in one unit.



For data applications, an RS-232C interface module is added permitting a direct interface with an ASC II terminal. The beauty of this design is the multi-purpose use of a Modem controller terminal. At the same time, it can serve as a security modem, an energy management controller, a slow speed data inquiry unit, a pay-per-view controller and a medium speed data modem.

This means that 5 or more categories of service can be accommodated in the same unit and all separately billable. The unit is of rugged construction, designed for garage or basement installation and features a 4-hour power standby battery.

Multiple security services can be provided on one system, simply by assigning appropriate category numbers.

Medical alarms can go directly to the operating ambulance service or hospital.

Multiple energy management control systems can also be established on the same system. Competition is invited.

The cable operator is the transmission company and provides the opportunity to operate energy management services to any new local venture that desires to do so.

Data base computer connections can be offered to any subscriber with a home terminal. The RS-232C interface is a part of the modem controller. Various data base and home computer-to-home computer connections can be accommodated on the same system.

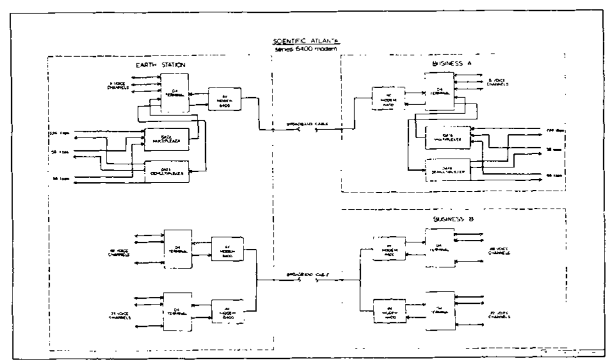
This system incorporates the flexibilities that are dictated by the cable TV industry. The operator can offer one service category and add other service categories as they become available, or when they appear to be revenue producing.

The Tele-Dat II, TD-8900 system, operates with pulse width modulation in order to assure a high resistance to ingress noise. Noise tests have been conducted and indicate error-free transmission at signal-to-noise ratios of 16 to 18 db. The use of pulse width modulation, however, reduces the spectrum capability of the system limiting data transfer speeds to 9600 bps.

The Tele-Dat II, TD-9000 system, is in design for use on the institutional network. Here, ingress noise is not a problem and better signal-to-noise ratios can be assured. Utilizing phase modulation, a much improved handling capability will be achieved. Speeds up to 56 Kbps can then be handled with the same distributed scanning concept.

POINT-TO-POINT DATA TRANSMISSION EQUIPMENT

The Scientific-Atlanta Series 6400 point-to-point modem can handle T1 speeds of 1544 Mbps in a small portion of a video channel assignment.



This slide shows the direct connection between 2 businesses requiring voice and data over broadband cable using the Series 6400 RF modem.

Scientific-Atlanta features Model 6402 modem transmitting data rates of 1.544 Mbps in a 750 KHz band. Model 6403 modem features data rate of 1.544 Mbps in a 500 KHz band. The goal is a T2 modem carrying 4 T1, or 1.544 Mbps data streams on one video channel. Modulation is coded amplitude phase shift keying requiring signal-to-noise ratios of better than 30 db.

This equipment is then ideally suited for point-to-point applications over mid-split or dual 300 MHz (Level 2) institutional network. It is not a good approach on sub-split residential systems with high ingress noise contributions.

One comment has to be made relative to the D4 terminal equipment shown. The D4 channel bank can derive 48 voice channels out of a T1C (3.152 Mbps) circuit. The D4 channel bank belongs to a family of commercially available PCM multiplex equipment. T1 carriers at 1.544 Mbps can transmit 24 voice channels using a D3 channel bank.

Commonly used data rates for information and digitized voice are shown in the next slide.

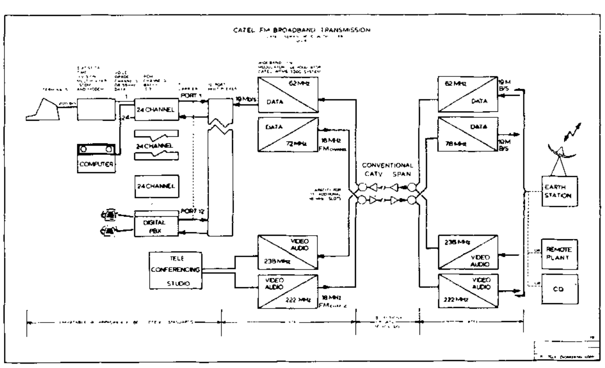
Multiples of 1.2 Kbps	**1.2; 2.4; 4.8; 9.6; 19.2 Kbps**
Multiples of 56 Kbps	**56, 112, 224, 448 Kbps**
T1	**1,544 Kbps = 24 voice**
T1C	**3,152 Kbps = 48 voice**
T2	**6,312 Kbps = 96 voice**

Common Data Rates

The next slide shows the block diagram of a CATEL, Series 3000 FM, modem in combination with a TRW/Vidar, DM 12A, PCM multiplexer. The Vidar equipment combines 12 T1 circuits, or 12x24 voice channels (288) into a 19 Mbps data stream that is fed into a 15 MHz CATEL FM modem.

At the earth station, the 19 Mbps bit stream is demodulated and fed to either earth station or central office. This concept is compatible with Bell PCM hierarchy and broadcast quality video signal.

The utilization of FM technology makes this transmission system an outstanding tool for Level 3 transmissions. FM technology permits the cascading of cable TV amplifiers without inherent cumulative noise effect. This means that transportation trunks interlinking cable system hubs can be designed and will transport integraded video voice and data streams over long distances without signal degradation.

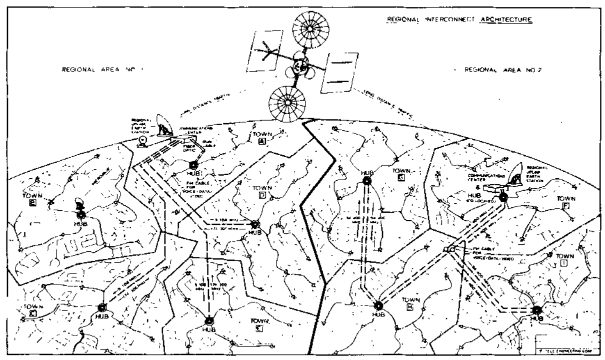


REGIONAL INTERCONNECT SYSTEM ARCHITECTURE (LEVEL 3)

Now, that we have taken a look at the available building blocks for data and voice transfer on coaxial cable, we can model the broadband transmission system of the future.

We see the long distance segment of the broadband voice/data/video network accomplished by satellite transmission.

A geographical region will feature a Regional Communications Center (RCC) that becomes the Central Office for regional broadband communications. Coaxial 0.75" transportation trunks are connecting the RCC with the individual cable system hubs (Level 3).



The cable system hubs are the collection and routing point for local broadband transmission within the cable system area (Level 2). Level 1, the in-plant broadband communication systems are not shown, but can easily be visualized.

Microwave and fiber optic links can be used for some applications in the Level 3 regional interconnect. As we will see in the following, however, it appears that microwave has inferior traffic capacity handling properties if compared with coaxial cable.

Fiber optics, on the other hand, is a technology that may be considered for short distances. The state of the art is such that many years will go by before fiber con truly be recognized as a broadband long distance medium and compete in a cost effective manner with coaxial cable.

Let us take a look at the spectrum efficiency of coaxial cable transmission systems to prove this point.

FREQUENCY UTILIZATION AND SPECTRUM EFFICIENCY (LEVEL 2)

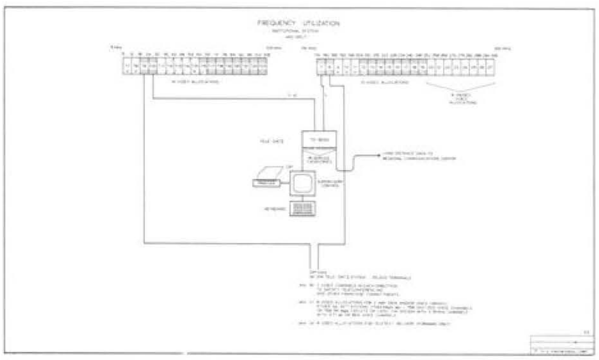
Level 2 is the local hub area cable TV system consisting of the Residential and Industrial cable systems.

The forward spectrum of the residential system is predominantly reserved for entertainment video. There are, however, two unused video assignments that qualify for data transmission. In our example, A-1 and T-10 are used for Tele-Dat II, TD-8900, Distributed Scanning System Transmission.

Due to marginal signal-to-noise conditions on the sub-low return spectrum, this transmission may not be feasible without the use of feeder branch switching equipment at trunk amplifiers.

Proper hub design calls for 3 or 4 trunk lines serving separate segments of a town. Assuming such an architecture, a total of 8 Tele-Dat II systems and up to 520,000 low speed terminals could be accommodated.

For voice/data transmission, the frequency spectrum of the Industrial Cable in a mid-split configuration is more appropriate.



One channel assignment has been used for Tele-Dat II distribution scanning system.

Video needs for teleconferencing and video origination programs are covered by reserving 3-channel allocations.

This leaves us with 8 video allocations or 48 MHz that can be used for voice/data systems. Using the S.A. Series 6400 modems, 32 T1 systems or 56 Kbps data circuits can be accommodated.

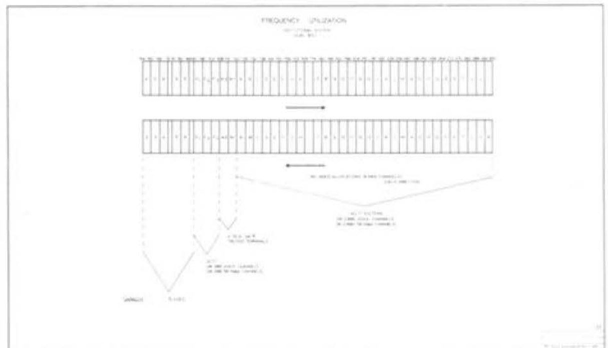
The lopsided nature of the mid-split cable is further enhanced by the fact that transmission around IF frequencies is not feasible.

As a result, there are 8 unused forward video channel assignments that may be used for forward high speed data or teletext.

Next, we have the dual 300 MHz Institutional/Industrial System.

Here, we find a total of 40 two-way video channel assignments. Assuming that we set aside 2 channels for Distributed Scanning Systems (Tele-Dat II, TD-9000), we could serve 130,000 low and medium speed terminals on each trunk.

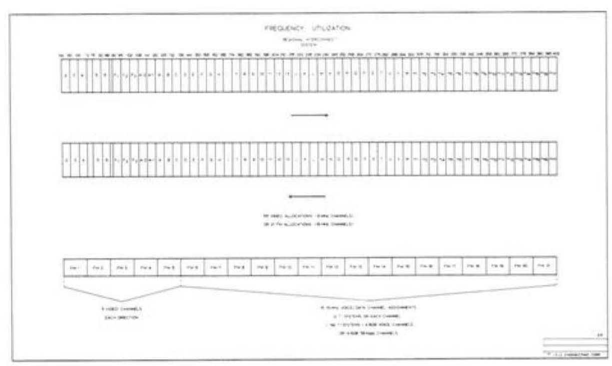
Setting aside 5 channels for video teleconferencing and program origination, a total of 33 video channels are available for voice/data traffic. Using S.A. Series 6400 modem equipment, a total of 132 T1 systems with 3,168 digitized voice or 56 Kbps channels can be accommodated.



This is a powerful voice/data and video transmission system that certainly could satisfy all voice and data needs within the Level 2 community for many years to come.

FREQUENCY UTILIZATION AND SPECTRUM EFFICIENCY (LEVEL 3)

Traffic engineering dictates that a substantial number of communications conducted by businesses are of regional and long distance nature. Unless a company has located all its facilities within a cable system area, it will require communications to locations outside the system area.



Substantial traffic requirements then exist between the Hub and the RCC. This slide indicates the powerful capacity of a dual 400 MHz system.

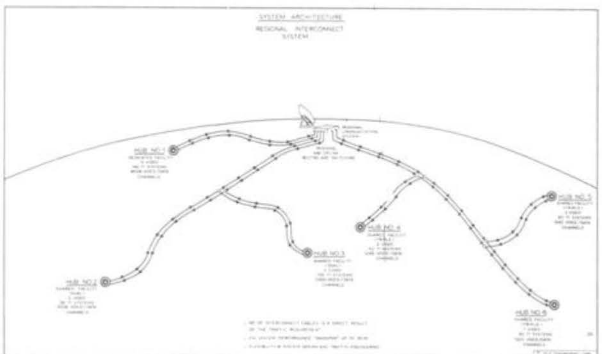
There are 55 video channel allocations in each direction. Because of the length of this dual .750 transportation trunk, we will use CATEL FM, Series 3000, modems and divide our frequency spectrum into 16 MHz slots.

The result is 21 FM video assignments that could be arranged as follows:

5 video plus 16 voice/data channels
This choice will produce 192 T1 systems with a total of 4,608 digitized voice or 56 Kbps circuits.

THE REGIONAL INTERCONNECT SYSTEM (LEVEL 3) - THE MISSING LINK

As we see in the next slide, it is not necessary to run a dual 400 MHz cable between each hub and the RCC.



The number of interconnect cables is a direct function of the traffic requirement.

The slide shows a single, a dual and a triple regional system with shared spectrum utilization.

Even in the case of the triple shared system, an average of 60 T1 systems (1440 voice) and 2 video channels can be accommodated for each of the three hubs. There is complete flexibility in system design and traffic engineering. Standard cable TV design practices apply.

Shared facilities can be upgraded to dedicated links by overlashing 2 more cables in the shared section.

Both microwave and fiber optics would have a hard time to compete with such a simple architecture. It appears that coaxial broadband facilities are the correct choice at this time and for many years to come.

One word of caution with respect to reliability. It appears essential to keep outages of such a facility to an absolute minimum. An availability of 99.99 percent is recommended. Such a reliability can only be assured by employing standby power supplies with no-break features and fully redundant trunk amplifiers. In addition, sophisticated status monitoring equipment should be used that will provide a computerized evaluation of signal levels and carrier-to-noise ratios measured at all amplifier stations.

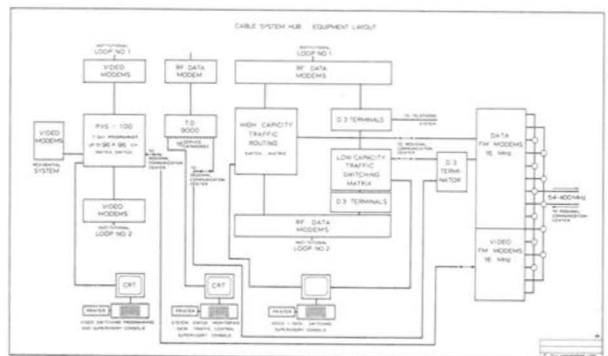
I have covered the transmission properties of both Level 2 and Level 3 broadband systems to some extent in the foregoing. Let us now have a look at the equipment complement that will be required at the various locations.

EQUIPMENT COMPLEMENT OF HUB SITES (LEVEL 2)

The Level 2 hub site presently may incorporate some modulator and alphanumeric generators for automatic news channels, local origination and public access.

The equipment layout of the future will require routing and switching equipment for video; routing and switching equipment for distributed scanning systems such as the Tele-Dat II, as well as data multiplexers and routing/switching equipment for point-to-point data transmission.

The slide indicates these 3 separate routing and switching categories. On the left, we see the equipment arrangement for video channel switching. Utilizing a standard PVS-100 7-day programmer with video switching matrices, video channels can be switched on a programmed basis between institutional loops, between institutional loops and residential system as well as between the Residential /Institutional systems and the Regional Communications Center (RCC). All programming is controlled and recorded from a CRT with keyboard and printer. All equipment is available now.



In the middle, we see the Distributed Scanning System Computer with 16 RS-232C outputs that can be arranged for loop back into the system, connected to the telephone line or transferred via D3 PCM terminals into the high capacity bit stream to the RCC.

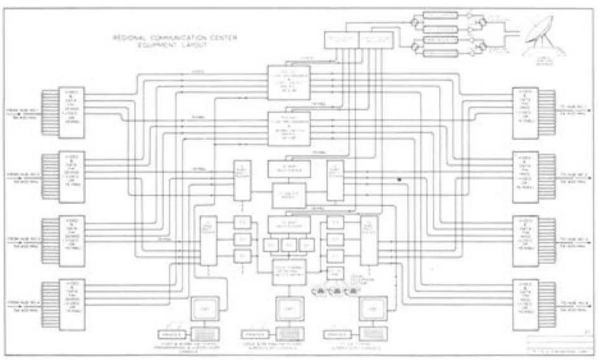
A CRT with keyboard and printer acts as system status monitor, supervisory control console and record keeper for billing. All of this equipment is available now.

To the right, we see voice/data modems (S.A. Series 6400), D3 or D4 PCM multiplexer banks, T1 routing switch matrices as well as 56 Kbps switches to provide switched traffic between two institutional loops, as well as from the institutional loops to the RCC. The supervisory and record control console is shown at the bottom. 16 MHz FM modems (CATEL 3000) are shown on the extreme right to transfer voice/data and video to and from RCC. All of this equipment is available now.

The cable TV system Hub will become the communication center for (Level 2) switched broadband traffic within the Hub area, as well as for regional and long distance traffic (Level 3 and 4).

EQUIPMENT COMPLEMENT AT REGIONAL COMMUNICATION CENTER (RCC) (LEVEL 3)

The Regional Communication Center (RCC) acts as the switching point for regional and long distance broadband traffic. Its equipment complement is similar to that of the Hub center except more powerful.



This slide shows coaxial cable facilities entering on the left from four different hub sites. Each of the broadband transmissions received consists of video and voice/data. The video channels are routed to PVS-100 video matrix switches that arrange for the circuit switching to either or both distant hub sites (regional traffic), or to the earth station facility (long distance traffic). In a very similar manner, 19 Mbps data (12 T1 channels) are switched between regional and long distance traffic.

Lower speed voice/data transmissions are switched at the 56 Kbps level (voice channel) after going through 12-port PCM multiplexer and D3 channel banks.

It can readily be seen that good compatibility between video and voice/data exists and that there is total flexibility in circuit routing and traffic grouping.

The detailed design of a Regional Communication Center only depends upon initial traffic requirements and growth projections.

SUMMARY AND CONCLUSIONS

In summary, it is concluded that two-way cable TV technology, as it is presently used for the delivery of entertainment video, can become a powerful voice/data and video carrier.

The equipment technology also is commercially available to form local, regional and long distance segments for high speed data and digitized voice transmission. Broadband switched networks can and should be developed now to satisfy the information transfer requirements of the 80's.

The cable operator has to familiarize himself with the technology of broadband data/voice communications in order to be able to partake in the ongoing communication explosion. The rewards are many times those that can be derived from the delivery of entertainment services.

The following milestones should be followed to assure a successful broadband communications venture:

- **Technology Investigation**
- **Market Research**
- **Traffic Engineering**
- **System Engineering**
- **Business Plan**
- **Investigation of Regulatory Environment**
- **Establishment of Traffic Routes**
- **Common Carrier Filing**
- **Implementation**
- **Marketing**
- **Operation**

Milestones for Development of Local Carrier

This does not mean 59 wires stapled to trees. This business is high quality communications engineering. It is not for amateurs, but for knowledgeable professionals dedicated to the long term.

Tele-Engineering Corporation is committed to take part in this merger of technologies. As system engineers and turnkey contractors, we are ready to assist in design and implementation of any voice/data/video communication system that may be conceived. As supplier of Distributed Scanning Systems and video/data/voice switching matrices, our company is dedicated to the integration of voice, data and video and the implementation of broadband networks.

VIDEO REMOTE TRUCKS - DESIGNING YOUR OWN

Peter M. Rafalow
Director, Local Origination

Valley Cable TV, Inc.

This section will explore the whys and hows of designing and building a video remote truck for local production. It will cover the building process from production needs to final installation, along with interior and exterior construction, the bid process, personnel needs, power needs and meeting the franchise requirements.

OUTLINE

I. Designing Your Own Truck

   A. Advantages

      1. Personalized
      2. Control
      3. Cost

   B. Disadvantages

      1. Time Consuming
      2. Constant Adjustments
      3. Follow up

II. Truck Use (Plus Franchise Requirement)

   A. ENG
   B. EFP

      1. Sports
      2. Music
      3. Live productions

III. Type of Vehicle

   A. Van
   B. Box Van
   C. Step Van
   D. Trailer

IV. Restrictions

   A. Vehicle

      1. Interior Room
      2. Weight limitations

   B. Available Budget

V. Power

   A. One or two systems

      1. Isolation of equipment (from air conditioning)
      2. Gas consumption (generators)
      3. One or two gas tanks
      4. Weight of generators
      5. Room needed for generators

   B. Monitoring

      1. Meters
      2. Protection circuits (from equipment)
      3. Regulator and isolation (noise in monitors)

   C. Distribution

      1. Number and types of circuits
      2. Shore power
      3. Shore power selection (auto switcher)
      4. 12v system (work lights)

VI. Equipment Lists

   A. Figure out needs
   B. Costs
   C. Compatibility
   D. Equipment bid process

VII. Internal Environment

   A. Amount of air conditioning needed
   B. Heating?
   C. Isolation (Sound and temperature)
   D. Interior finish (carpeting)

VIII. Layouts

   A. Audio location (seperation?)
   B. Generator location(s)
   C. Rack space needed
   D. Location of major equipment
   E. Outlet locations (everywhere!)
   F. Guttering locations
   G. Access ports

IX. Construction Bids

A. Go over in detail with them

1. In person

B. Get their ideas

X. Construction (personally supervised)

XI. Installation

A. Wiring

1. Full flow charts
2. Flexibility (patch bays, routing switchers)

B. Equipment timing

XII. Maintenance

A. Engineer needs to know truck

1. It helps if it is designer

B. Back-up supplies

VIDEOTEX ON TWO-WAY CABLE TELEVISION SYSTEMS - SOME TECHNICAL CONSIDERSTIONS

Efrem I. Goldberg

GTE Laboratories Incorporated
40 Sylvan Road
Waltham, Massachusetts 02254

ABSTRACT

An interactive videotex system for two-way cable television is technically feasible today. This discussion focuses on characteristics of cable television systems that influence their performance as data networks and data communications concepts as they apply to this use of cable. It is intended for those considering the merging of the two technologies. Network topology, signaling, and protocols are covered in the cable TV context.

INTRODUCTION

Today's cable television systems technology is capable of providing much more than improved reception and additional channels of TV. A number of experiments on two-way interactive CATV services have been underway since the mid 1970's. The Viewdata and Teletext concepts have been under development for a decade. Combining cable TV and videotex into a fully interactive two-way data communications link for consumers and small businesses is a logical next step in the progression of both technologies.

The gap between what can be and what is on cable TV is mainly the result of economic factors. Until recently cable operators, equipment manufacturers and others evaluating the business were not convinced that an investment in advanced systems would pay off. This is changing.

A number of factors are combining to motivate the cable television industry to use the two-way capabilities required by the FCC since 1972.

- Home Box Office and other premium offerings distributed by satellite have made cable TV attractive to urban and suburban dwellers.
- Cable operators have promised to provide two-way services in their proposals to help win franchises.
- The number of personal computers is increasing rapidly along with public sophistication about computers and computing.
- Social factors such as the increase of two-income families and the perception of the home as a refuge from the stress of modern life make an interactive communication capability in the home attractive to the consumer.
- QUBE and some other experiments have proven that it is technically possible to provide a variety of two-way services on cable.
- The utility of the telephone for data communications in the home is limited by the certainty of increased cost for telephone service in the future and the reluctance of consumers to tie up their phones for long periods of time while they access data services.
- Cable operators want the additional revenue that provision of new services will bring.

Consequently, establishing low cost, reliable data channels has become a high priority goal for multiple systems operators (MSOs), cable TV equipment manufacturers, communications and computer companies, and potential service providers. Videotex is a very attractive vehicle for many of the proposed services, therefore, an optimal adaptation of this technology to the cable TV environment is needed.

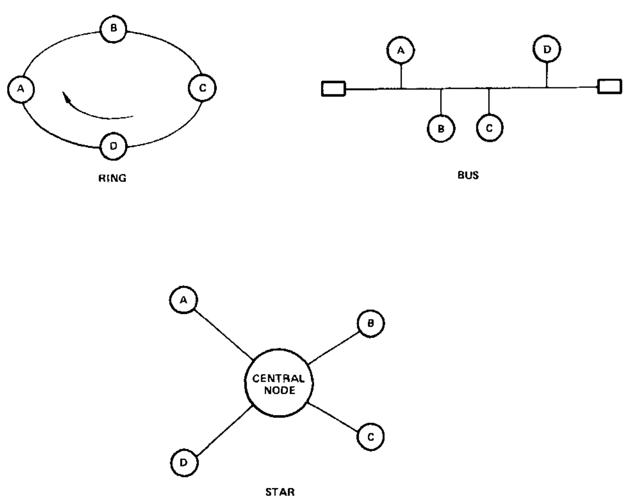
The exact nature of this optimal adaptation is not yet clear. The existing interactive offerings provide a rather limited degree of interaction. QUBE, for example, can support a tree search of a videotex database with its "multiple choice" buttons, but its response is slow and the upstream channel is limited to a few characters at a time.

A genuine two-way interactive system must provide the means to send as well as to receive lines of text. For subscribers to realize the full potential of consumer data services on cable TV they need something rivaling the performance of the acoustically coupled telephone modems sold in computer stores for about $175. I will focus on that level of capability in this paper. I am convinced that anything less between the subscriber and the host computer is not enough to make two-way videotex on cable a viable service offering in the long run.

First, I will describe the physical aspects of CATV Systems - their topology and electrical characteristics. Next, I will discuss ways of transmitting data signals in the CATV environment. Finally, I will briefly explain the concept of communications protocols and describe two types of protocol that can be used in these systems.

PHYSICAL CHARACTERISTS

In general, there are three types of communications network topology.[1] They are the ring, the bus, and the star. They are illustrated in Figure 1. A single point-to-point line can be classified as a special case of the bus or star. The common elements of all three are a transmission medium, two or more nodes or stations communicating over the medium, and a set of rules for interchanging information called a protocol. The medium can be wire, optical fiber, radio or even pneumatic tubes. The nodes can be data terminals, voice terminals, host computers, or any other device capable of sending and/or receiving signals. While a particular configuration may favor a particular type of traffic, in principle, any type of traffic could be carried on any of the three.



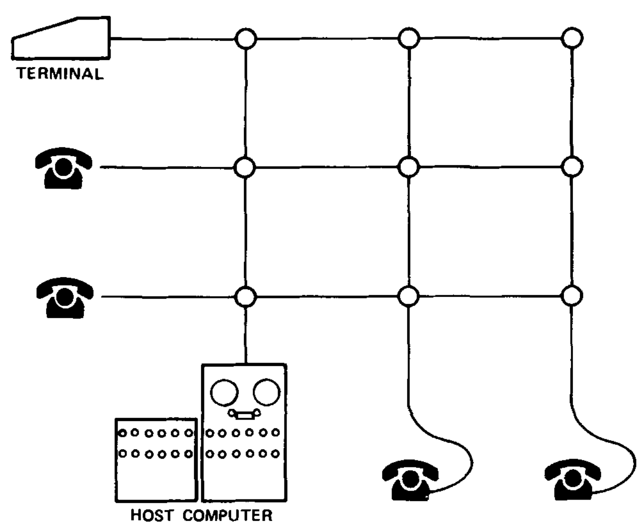
1. Three Types of Data Networks

All traffic on a ring network travels in one direction. If A wants to send a message to C, it must first be received by B and then relayed to C. One function of a protocol is to indicate how a station can recognize a message intended for it since each station on the ring sees all messages. Usually a ring is designed so that a message started by A will go all the way around the ring and finally return to A for removal. This way A knows its message got all the way around the ring. The ring works fine as long as all the stations are working properly, but, since each station is an active repeater, when a station fails, the ring is broken until the failed station is located and repaired or bypassed.

On a bus network each station is a passive listener. When A sends its message to C it travels along the bus in both directions. All stations hear the message and, again due to a protocol, C can recognize that the message is intended for it. C copies the message and acts on it, the others recognize that the message is not for them and ignore it. This configuration is somewhat similar to a CATV system in that all stations hear all messages. The difference is that a bus has no central node. All nodes have equal access to all other nodes. A CATV system is more properly considered as a type of star network.

In a star network A's message to C first goes to a central node and then from the central node to C. In one class of star network the central node contains a switching system that connects A's line directly to C's. This is called circuit switching. The public switched telephone system is the prime example of a circuit switched star network. In the other class of star network, all messages from the stations go to the central node, and all messages leaving the central node are broadcast to all stations in the star. This is exactly what happens in a two-way cable TV data link system.

In a switched system like the telephone network there is a direct, exclusive physical connection between two stations for the duration of their communication. A schematic of a switched system is shown in Figure 2. Any subscriber can connect to any other subscriber by joining lines together with switches represented here by circles at the intersections. Whole hierarchies of switches exist permitting worldwide connectivity. Most technical considerations for implementing a data communications system on a cable TV network stem from the fact that it is not a switched system.

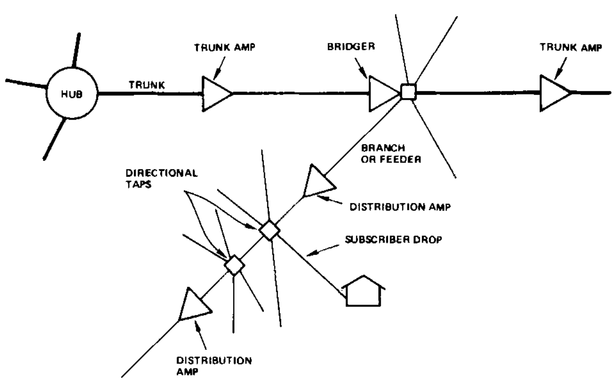


2. A Switched System

The central node of the CATV star is the head end or hub. The lines radiating from the hub are called trunks. The trunks are not single lines but complex systems in their own right. Amplifiers are placed at intervals along the trunks to maintain signal levels. Since attenuation is greater at higher frequencies, and since the signal level varies with changes in temperature, the amplifiers are equipped to compensate for these factors. There is a limit to the number of amplifiers that can follow one another along a given path and this number decreases as the system bandwidth increases. The permissible distance between amplifiers also decreases as bandwidth increases.[2] In a 400 MHz system the maximum length of cable is about 4 or 5 miles. Systems covering areas of larger radius must have multiple hubs connected by "supertrunks."

This length limit has an important implication for data communications. The time it takes for a message to travel from the outermost user terminal to the hub is determined by the distance from the hub. This delay influences the performance of a data link and is an important consideration in the design of protocols. In a 400 MHz cable system this delay is held to a reasonable upper bound. In systems of lower bandwidth the delay can severly limit performance and may even prevent many older systems from being used for two-way interactive services even if they are equipped with return channels. More will be said about the effects of delay in the section on protocols.

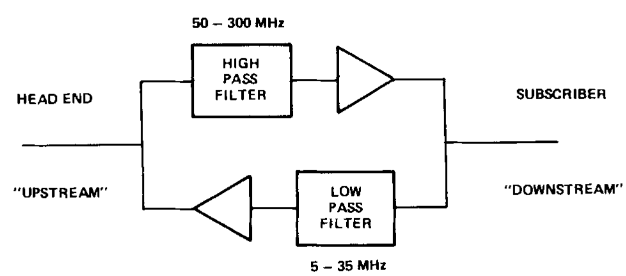
Amplifiers located at points where branches leave the trunks are called bridgers. In some systems the bridgers are equipped with remote controlled switches so a technician at the hub can isolate sections of a trunk, bridger by bridger, to find a source of interference or other fault. The signal level on a feeder is maintained by distribution amplifiers. Groups of subscriber drops are connected to taps inserted along the feeders between amplifiers. Figure 3 is a schematic representation of a trunk line and feeder segment.



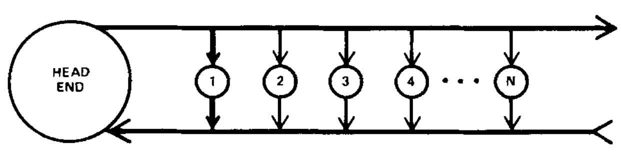
3. Schematic of Trunk Line and Feeder Segment

What we have then is a one to many structure with a hierarchy of nodes ranging from a main hub/head-end at the top followed by subhubs, trunk ends, bridgers, distribution points and subscriber drops. There is a natural division into physical subgroups. The subgroups can be treated as logically separate systems for data communications purposes and assigned dedicated controllers. This way a system can gradually grow larger as demand for service increases. Moreover, many relatively inexpensive devices can take the place of a large high performance processor.

The return channel is implemented by assigning part of the band to upstream traffic. The band is split by filters in each amplifier housing (Figure 4). Then two seperate amplifier modules send their portion of the band along the cable in the appropriate direction. The taps that couple signals into the subscriber drops are directional taps designed to pass signals only from the head-end to the individual drop and back. One drop cannot communicate directly with another. An upstream and a downstream channel are paired so the signal path can be represented schematically by Figure 5, with each station receiving on the downstream line and sending on the upstream line. A processor located at the head-end can control all communications or the head-end can simply retransmit what it receives on the upstream channel back out on the downstream channel. If that happens every user receives what any user sends after a delay proportional to its distance from the hub. The former case is centralized control and the latter distributed control. Both of these broad classes of control will be discussed further in the protocol section.



4. Basic Amplifier System for Two-Way CATV (Backfeeding)



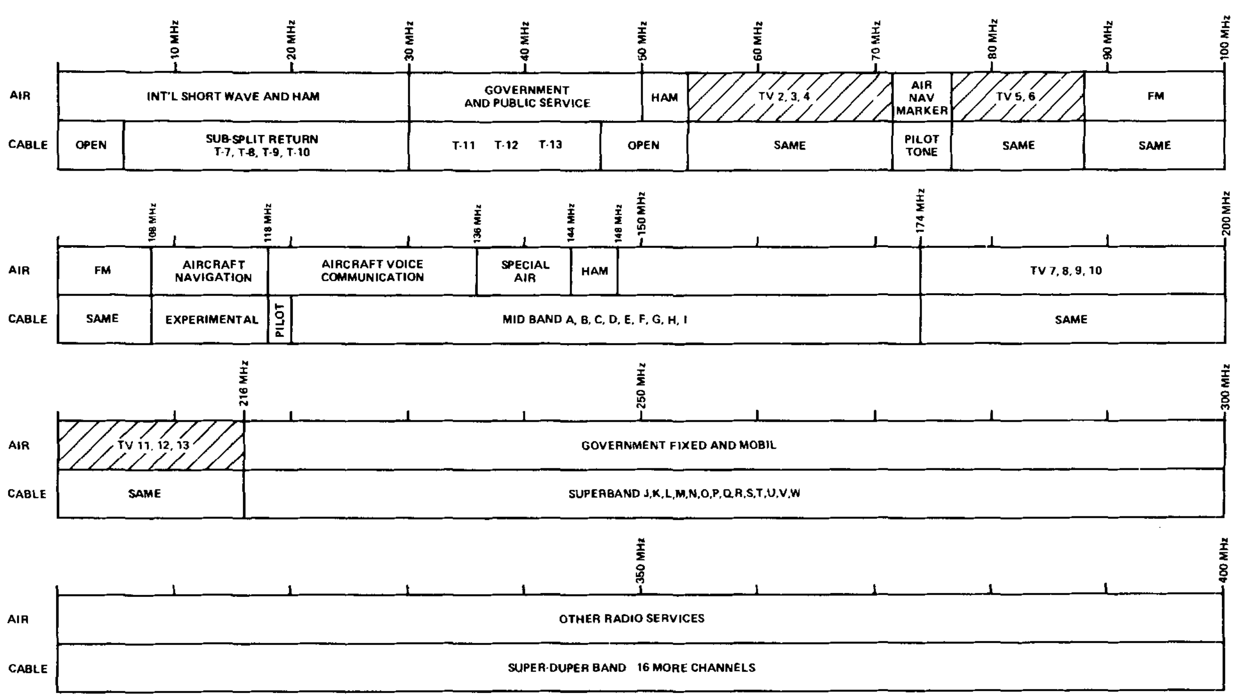
5. Two Way Signal Path

Each subscriber contributes a small amount of noise to the upstream channel resulting in a large amount of noise at the trunk end. When this is added to the noise from other sources on and off the cable, the return channel can be quite noisy. It is essential to keep noise ingress down to a minimum on a two way system through proper maintenance of lines, connectors and terminations. Even with proper maintenance the noise accumulation may interfere with upstream data transmission. One way to limit the effect of noise buildup is to switch off all but one bridger at a time on a trunk, permit access only to those users on that branch group during that time, then go on to the next group and so on in cycles. Another solution is to place active repeaters at each bridger to reconstitute the data signal before the noise can overwhelm it. The bridger switching method is slow and the repeater scheme is expensive. If the return data rate is sufficiently low so that a bit interval is long relative to the period of the noise, it may be possible to tolerate the ambient noise of the system. One other step that can be taken to reduce noise ingress is to block the return path from subscribers not set up for two-way data with inexpensive line filters.

BANDWIDTH AND CHANNELS

In the United States, a television channel - picture and sound - occupies 6 MHz of bandwidth. This number was chosen in the early days of television development and reflects the tradeoff between picture definition, spectrum availability, and the state-of-the-art of electronics at that time. There will probably be a wider bandwidth channel assignment set up in the near future to accommodate high definition television (definition is a function of bandwidth), but the 6 MHz slots will continue to be the basic divisions.

The cable spectrum runs from 5 MHz to about 400 MHz. Most older systems stop at around 220 MHz with 12 to 24 channels. The newest wideband systems have as many as 58 channels. Even more are possible by going beyond 400 MHz. At higher frequencies, however, distortion and other problems increase, so channels beyond the 58th are usually put on a second cable. A chart of the spectrum from 5 MHz to 400 MHz is shown in Figure 6. The lower half of each segment shows the assignments on the cable and the upper half shows some of the transmissions that are "on the air" at those same frequencies.



6. The CATV Spectrum

Channels T-7 through T-10 are used for upstream transmission in what is called a subsplit. The other three channels in the T group are attenuated by the filters separating the upstream from the downstream channels and are not suitable for video. T-11 can possibly be used for data. In some cases a midsplit is used. Here the T group 2-6 and the FM band are used as upstream channels, 7 and up go downstream and A-I are lost due to filter crossover.

A practical data link system will most likely use a total frequency allocation equal to one or more 6 MHz channels in each direction. Given such an allocation one can assume that anything done within the allocated channels is acceptable as long as it will not interfere with the other channels in the system. The choice for allocation within the 6 MHz band is between a single high-speed channel with sufficient guardbands, two or three channels of about 1 Mb/s each or many slower channels with frequency agile tuners at subscriber terminals able to tune to the least active available channel upon starting a session. The ultimate choice will be a tradeoff between system performance and hardware cost.

Cox Cable Company has chosen a multiple low speed channel approach for their INDAX system. They divide the main channel into a number of slots 300 kHz wide with a 28 kb/s signaling channel in each slot. This arrangement can be built at low cost because a low-speed microprocessor can be used as a communication controller along with other parts made in large quantities for other consumer applications. Faster signaling demands higher performance components.

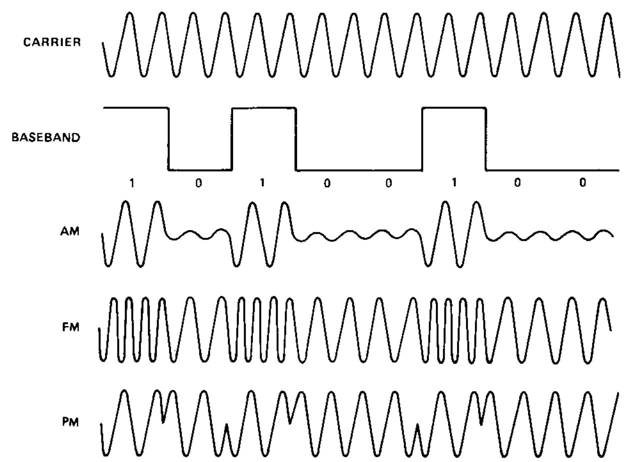
DIGITAL SIGNALING

Morse code represents all characters of the alphabet with three symbols - dot, dash and space. Similarly a digital code represents all information by combinations of two distinct states- "on" and "off" or 1 and 0. Therefore, a digital system need only recognize two distinct levels. An analog system, in contrast, is required to reproduce a continuous range of levels. Thus, a television signal is made up of a rapidly changing voltage or current where the signal varies in proportion to the picture brightness. The latter task is more vulnerable to distortion than the former. So, in a given channel, it is easier to transmit digital information.

A digital pulse train will travel along a wire, as will an analog signal, for a limited distance without distortion. Signals must be modulated for longer distances, for combining many independent signals on a wideband cable, or for radio transmission. The popular buzzword MODEM refers to a device that performs MOdulation and DEModulation.

There are three basic types of modulation- amplitude (AM), frequency (FM), and phase (PM). All methods work by modifying a characteristic of a single frequency carrier [Figure 7(a)] in response to changes in an information bearing signal called the baseband signal [Figure 7(b)]. The examples in Figure 7 illustrate the digital case. The analog case is the same in principle, but intermediate values are represented as well as the maximum and minimum.

In amplitude modulation [Figure 7(c)] the peak to peak value, or amplitude, of the carrier is altered in response to the baseband. Binary 1 is maximum and binary 0 minimum. In frequency modulation [Figure 7(d)], binary 1 is twice the frequency of binary 0. This is indicated by the larger number of transitions of the carrier under the ones in the figure. Finally, in phase modulation [Fgure 7(e)], the order of occurrence of the swings of the carrier is altered.



7. Types of Modulation

A variety of techniques combining phase and amplitude modulation are used in the digital radio equipment intended for high capacity microwave transmission applications and in high-performance telephone modems. These schemes permit data rates greater than the frequency rate of the carrier. This is referred to as getting more than 1 bit/Hz. Some day it will be economically feasible to use these techniques in subscriber systems. For now, modems operating at less than 1 bit/Hz will suffice. They can be produced, in quantity, in a price range that a consumer can afford. Bandwidth, which from a data communications point of view is cheap on cable, is traded for modem complexity.

The most common modulation technique for low-cost data modems is frequency shift keying (FSK). It is a form of FM where the carrier is always at either one of two distinct frequencies. The 300 bit/s modems that attach to a telephone handset use FSK. FSK can be implemented with simple circuits and performs well in a noisy environment. AM can also be implemented inexpensively, but it suffers more from noisy line conditions. A noise burst can easily be interpreted as a transition from low to high amplitude.

A cable TV data modem should do the following:

1. Receive a modulated carrier from the cable at one or more frequencies.

2. Detect the modulation and pass the baseband information on as a bit stream.

3. Tell when it is receiving a carrier and indicate that to the terminal.

4. Generate a carrier at one or more frequencies accurately.

5. Accept a baseband bit stream and use it to modulate its carrier.

6. Switch its carrier onto and off the cable when required.

Clearly, operating an end to end digital communications path requires more functions than those performed by the modems at each end. These additional functions are performed by special purpose computer peripherals under control of software. The hardware devices are called communications processors and the software programs are called interfaces and protocols.

PROTOCOLS AND INTERFACES

Webster defines protocol as "A rigid long-established code prescribing complete deference to superior rank and strict adherence to due order of procedure." The connection between this definition of protocol in human interaction and the definition in machine interaction is the phrase "due order of procedure."

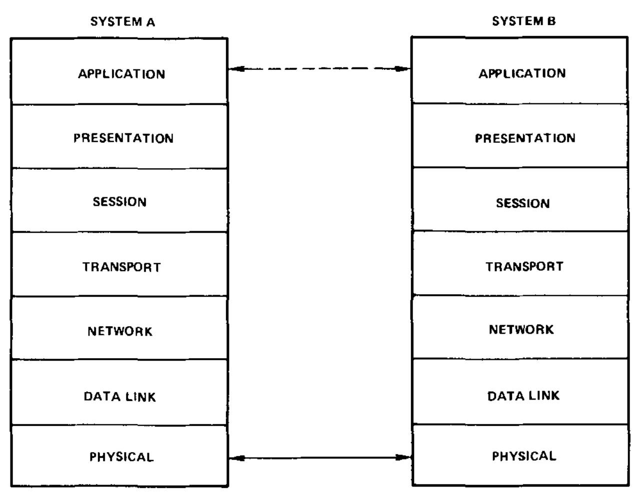
Communication protocols are sets of rules governing information flow in a communication system. Among the specifications included in protocols are:

- Procedures for establishing and altering relationships between devices in a system
- Formats for messages sent in a system
- Means for identifying devices
- Means for allocating permission to transmit among devices sharing a line
- Means for recovery from errors or failures
- Means to control the flow of data when a station is temporarily unable to process more

Protocols and interfaces are functionally similar. Protocol refers to a set of rules for communication between similar devices or processes while interface refers to rules for communication between dissimilar devices and processes. Thus two host computers communicate using a protocol, and a terminal communicates with a host using an interface. The word interface is also used to refer to the physical connections between devices. Cables, connectors and circuits make up the interfaces in this context.

To simplify matching in this world of diversity, the International Standards Organization (ISO) has developed a set of recommendations for interconnection[3] called Open Systems Interconnect (OSI). The OSI model divides systems into seven levels or layers based on functions. If these functional divisions are maintained in the design of a system, and all communications pass through the layers, two systems can interconnect by passing messages between themselves at a matching layer.

The layer concept is illustrated in Figure 8. It shows two independent systems and their seven layer structures. Suppose A is a computer running a program at its application layer that generates a report and it requires some numbers from a database system running as an application on B. Computer A passes its request down through its functional layers using its interfaces. The request is sent to B where it is received and passed up through B's layers. B's application layer gets the requested information and passes it back down in a message to A. The information is eventually passed up to A's application. The application layer can be either an application program, a person using a terminal, a peripheral or a combination of any of the three.



8. ISO OSI Reference Model Applied to Two Systems in Communication

It is beyond the scope of this paper to deal with any but the physical and data link layers in detail. In videotex the definitions of character sets, screen formats, and graphics facilities are specified in the presentation layer as in Bell's "Presentation Level Protocol." The details of the other layers depend on the characteristics of the systems and access media involved. The OSI model is only a recommendation and things do not split neatly into the layers in most real systems. It is still a good design and discussion aid. Some newer protocols such as X.25 have been designed explicitly to follow the recommendation.

The apparent connections between processes at each level are called logical or virtual connections. The passage through the layers is said to be transparent to the communicating layers. Many virtual connections can exist over a single physical circuit. Connecting and disconnecting these virtual circuits is called virtual switching. In a cable TV data system, virtual switching takes the place of the physical switching of the telephone network.

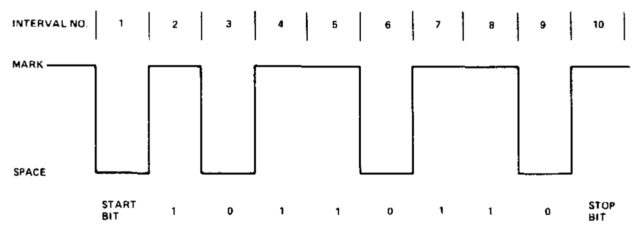
The two layers of protocol needed to transmit data over Cable TV lines are the physical and data link. There are several defined standards for the physical layer. One of them, RS-232, in one of its several variations, can be used for this application. There is no data link standard yet although some are under development.

The function of the physical layer is to send and receive data bits without regard to their format or meaning. The formal specification[4] defines an interface, in the physical sense, between a Data Terminal Equipment (DTE) and a Data Communication Equipment (DCE). DTE is a generalized term for any device that sends and/or receives data. DCE is a generalized term for a modem capable of transmitting bits over a medium. Neither the medium nor the transmission technique is specified.

The specification document for RS-232 is mainly a description of a 25 wire connection between a DTE and a DCE. It defines the electrical and mechanical characteristics of the hardware components of this connection. It also defines the function of each circuit involved and a list of standard groups of these circuits required for some general application cases.

One important distinction among the many variations of RS-232 is whether they are intended for synchronous or asynchronous operation. Adjacent bits are distinguished from each other by their time of occurrence with respect to a time reference or clock. In a synchronous channel the timing information is transmitted along with the data, while on an asynchronous channel each station has its own clock running as close as possible to a specified rate. Thus a synchronous RS-232 is wired with circuits to pass clock signals to and from the DTE.

Asynchronous communication is simpler to implement than synchronous. It is used with most microcomputers and so called "dumb terminals" communicating over the public switched telephone network. It is also known as start/stop communications. Each character is represented by an 8-bit code preceeded by a "start" bit and followed by a "stop" bit (Figure 9). The line is held in the high or mark state between transmissions. When a character is received the "start" bit causes the line to go to the low or space state. The receiver recognizes the transition as the start of a bit and sets the local clock to sample the line at the center of each bit interval. If the transition is due to noise, the line will be high at the sampling instant and the receiver will reset itself. If the transition is a real start bit, the line will still be low and the receiver will sample the next 8 bit intervals, and store the results in a memory or buffer. At least one interval of mark, the "stop" bit indicates the end of a character. The process starts over when the line goes low again at the next "start" bit.



9. Asynchronous Data Representation for One Character

The same version of asynchronous RS-232 used to couple low cost telephone modems to terminals will serve as the physical level for connecting videotex decoders, terminals, and microcomputers to a cable TV modem. To accommodate terminals without their own microprocessor, a microprocessor based communications processor will be included with a modem and tuner in a typical cable data converter. The data converter may also be included in special versions of addressable cable TV converters as a single package sharing a common power supply, microprocessor, and other components. Both of these converters will also have a read only memory programmed with the cable TV data link protocol that will control its interactions with the rest of the system.

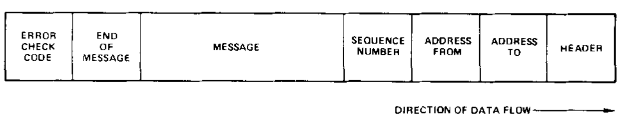
The task of the data link layer is to take a raw transmission facility and turn it into a reliable line that can move data from one location to another. Part of this task is formatting raw data in the form of bits into units suitable for transmission. A second part of the task is to verify successful receipt of data. In a cable TV environment the data link layer must also set up and maintain a virtual circuit between two communicating devices since the physical circuit is shared by all stations on the network.

A user dialing into a host computer on the telephone has exclusive use of a line during the session. The data link protocol degenerates to almost nothing in this case and is often considered part of the physical layer. In a typical dial-up videotex terminal, the unit of transmission is the single start/stop character of Figure 9. Upon each keystroke the selected character is sent to the modem. It travels over the line to the host where it is stored in a buffer. The host also sends the character back on the return channel (echo). This echoed character is received at the terminal, stored in the display memory and displayed on the screen. When the user hits the carriage return or enter key, the host acts on the data and responds by sending information to the display memory by the same return path. The echo serves as verification of successful receipt at the host.

The data link level on cable must get the data to the right place at the right time. This is a virtual switching task. Getting data to the right place is accomplished by assigning a unique address to each station. A message is sent to a particular station by attaching the station's address to the message. The address of the sending station can be included also if the message could have come from more than one place. Each unit on the network checks all messages and copies those that have been addressed to it.

Allocation of transmission time to insure that only one valid message is on the line at a time is the function of an access scheme. Polling and contention are two types of access schemes that are being applied to cable TV videotex systems. It is beyond the scope of this paper to evaluate the relative merits of the two. The right choice in any instance depends on the goals of the system designers.

The unit of data transmission in both polling and contention is a block of characters rather than a single character. Figure 10 is a representative message format. The block is divided into fields. The header is a control character or group of characters that unambiguously indicates the start of a block. The two address fields identify the destination and source of the block.



10. Typical Message Format

The sequence number permits detection of the loss of a block from a series of blocks that belong together. The receipt of each block is verified by an acknowledge message (ACK) from the receiver back to the sender. If a block is missing from a sequence or arrives in a damaged condition, a not acknowledged message (NACK) is sent instead and the block is retransmitted. Each block is saved in a buffer at the sending station until it is acknowledged, and its buffer space can be safely rewritten with a new block.

The message field holds the actual data that is being transferred. In this case it is delimited by an "end of message" control character. Fields in a format can be delimited by control characters or by character count. In the later case, a character count field will be located ahead of the message field.

Error check codes of various types are used to determine if an error occurred during transmission. Some error coding methods can correct errors; others only detect them. If an error is detected a NACK can be returned and the erroneous message retransmitted.

In polling, a central processor controls all access to the line. In its most elementary form, role call polling, the processor goes through a list of all stations in a system and sends each station a polling message. If the polled station has something to send in its buffer, it sends it. If not, it sends a message indicating it has nothing to send. Even if no data is sent, each transaction takes an interval of time equal to the sum of the duration of the polling message, the time it takes to reach the polled device (propagation time), the duration of the response, and the propagation time for the response. In a system with a large radius and many terminals the polling cycles are very long. QUBE has a 6s polling cycle in the Columbus system. This may not seem like much, but it can be painfully slow to someone searching a large tree structured videotex database or reading a multipage electronic message.

Polling can be speeded up dramatically by only polling those terminals that are actually in use. Newly active stations can be brought on line by issuing a "free poll" once or twice in each cycle and adding the newcomers address to the roll call list. Terminals logging off are removed from the list.

Further improvement is possible by taking advantage of the fact that most of the users on line at any instant are not sending or receiving data; they are typing or reading. Group or generalized polling[5] only polls those terminals that have something to send. The users are divided into groups based on the digits of their addresses. The polling processor polls each group. If a station in that group wants to send, it transmitts a burst of carrier or other signal. The processor responds by polling a subgroup of that group and listening for a reply. If there is none, it polls a second subgroup and so on until it isolates the requesting station. The process continues until all terminals ready to send in that cycle have been polled and then a new cycle begins. The statistics of terminal use are such that the number of steps in each cycle will be much less than in rollcall polling.

In contention, all stations on a network compete on an equal basis for the right to transmit. The entire channel capacity is available to all users, and, usually, any user can send a message directly to any other user. When two or more users attempt to transmit at the same time it is called a collision. Upon detection of a collision each user involved waits for a randomly determined interval and retransmits.

There are four types of contention. In the first type, called Aloha, users transmit at will. Receivers can recognize overlapping messages so, upon collision, no acknowledgments are sent. The transmitting stations, hearing no reply within a predetermined time, wait for an additional short interval and try again. The short interval is different at each station so the likelihood of a second collision is small. This form of contention can achieve 18% efficiency. It was originally intended to be under control of a central processor but works in a distributed environment as well.

Slotted Aloha is an improved version of Aloha. All stations are synchronized to conform to intervals or slots of time. A transmission can begin only at the beginning of a slot so, if a collision occurs, one slot is lost. Without the slots the beginning of one message could collide with the end of another causing the loss of nearly twice as much time. By limiting the time lost per collision, slotted Aloha can be 37% efficient. Keeping the stations synchronized requires a central clock controller, and if the stations are at various distances from the control clock, maintaining sync is impossible.

In Listen-before-talk or Carrier Sense Multiple Access (CSMA) each station listens to the return line and sends only when the line is quiet. Collisions do occur, however, because there is a finite propagation time. When the line appears quiet there may be another message coming up the line that will collide with the one just sent. For long messages this method achieves 90% efficiency.

The ultimate contention scheme is Listen-while-talk or Carrier Sense Multiple Access with Collision Detection (CSMA-CD). Here a station that is transmitting continues to listen to the return line. It can recognize its own message, so if it hears anything else, it knows a collision has occurred and it stops sending instantly. The time wasted by unsuccessful transmissions is kept to an absolute minimum. This method can reach an efficiency of 95%.

CSMA and CSMA-CD are particularly sensitive to the size of a system. If two stations start transmitting at the same time their transmissions must reach each other before they detect a collision, stop sending, and free the line. Because a cable TV system is a star its area of coverage increases with the square of its radius. Thus, the average round trip delay is weighted towards the maximum delay.

If the round trip delay is small compared to the duration of the message, the time a message is exposed to the possibility of a collision is small. That is why these systems favor long messages. The minimum delay to message ratio for good performance is about 5%.[6] The maximum message length must be set to break very long transmissions into smaller units to prevent stations with a lot of data to send from dominating the system.

CONCLUSIONS

In summary, all the technical elements for setting up high performance videotex links on cable TV systems are available. Two-way capability is well understood and already in place in many areas. Consumer grade integrated circuits and discrete components are on the market for all the necessary hardware functions. Low-cost microprocessors have sufficient power to handle the protocols. What remains is the task of combining these elements into a reliable, economical system. Now is the time to experiment to determine the right combination of components; attractive and useful information offerings; and managerial skills required to operate a consumer-oriented data service that will compete successfully in the coming information marketplace.

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WANGNET, A CABLE-BASED LOCALNET

Jay Jubert

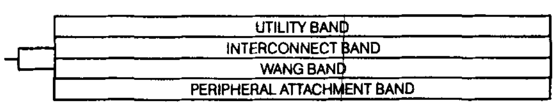
WANG LABORATORIES, INC.

ABSTRACT

WangNet is a hybrid office network which includes data, video, audio, and facsimile. WangNet was designed to meet the growing demand in all forms of data transmission. The design can be configured to be a complete local area, multivendor, computer communications network--down to a point-to-point application.

Wang Laboratories, Inc., as a manufacturer of computers and data transmission equipment, is dedicated to the efficient utilization of information through broadband/coaxial cable.

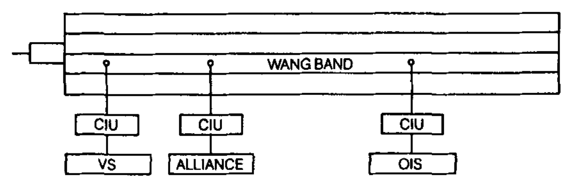
WANGNET'S MULTIPLE SERVICES



Information takes many forms--Video, Data, Audio and Facsimile. In the modern business environment the many different types of equipment used in handling information should be connected to share resources--this connection is WangNet. WangNet can be characterized as a private cable system for office use. WangNet is designed in a tree configuration, like many cable systems, and can be the size of a room, a high-rise or a campus and gatewayed to a cable TV system for Metro transmissions to other WangNets or to individual information users. WangNet is a broadband, frequency multiplexed network as opposed to baseband, which restricts only one user to a cable.

According to the U.S. Department of Commerce figures, by 1985 data transmission will represent about $22.5 billion in domestic telephone company revenues, which is an increase of 642% over those of 1979.

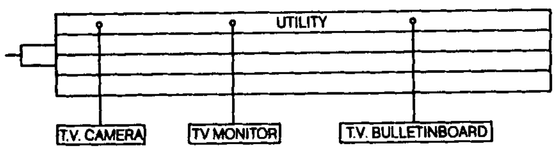
WANG BAND



WangNet is designed to help accommodate this enormous data requirement by utilizing standard reliable cable TV components with a spectrum allocation of 340mHz, divided into four major groupings. The utility band is for video and is transparent for many RF users--the Wang Band is for the interconnection of Wang computers and word processors. The interconnect band is utilized for the connection of equipment of many different manufacturers such as IBM and Digital. Finally, the peripheral band is used to connect printers and remote workstations to host computers. Each band accommodates different data speeds, protocols and line utilizations providing an extremely flexible network.

Wang studies of office information flow have concluded that a dual cable systems offers the most efficient design to handle present and future office needs, with one cable dedicated for upstream traffic, the other downstream. This dual cable design is actually a one cable design looped back over itself or in other words an elongated "U", which is terminated at the ends, with all amplifiers aligned up in the same direction.

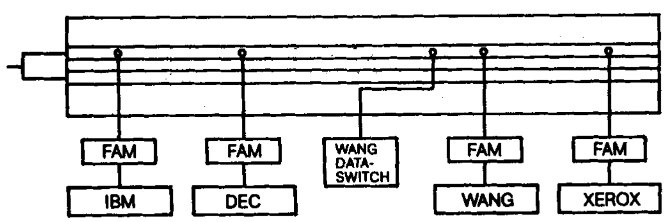
UTILITY BAND



The utility band has a 42 mHz slice of the spectrum broken up in 7 TV channels, corresponding to VHF TV channels 7 through 13. This spectrum is for non-Wang RF devices such as closed circuit TV, teleconferencing, video security, training or any devices which can use CATV spectrum.

INTERCONNECT BAND

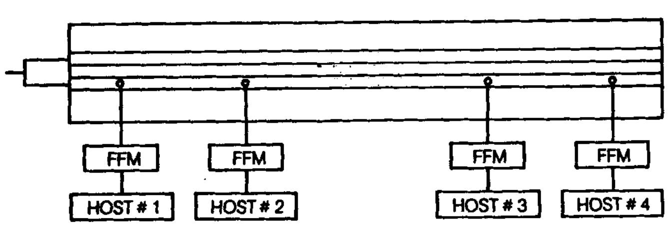
• **SWITCHED SERVICE**



The interconnect band has three sub-divisions. Two groupings are comparable to telephone leased lines and the third is for switched channels. All interconnect band channels are protocol independent and support virtually any manufacturers equipment. The switched band has 256 channels which are available at speeds of up to 9600 bps by using a Wang frequency agile (FAM) modems. This switched capability provides point-to-point or multipoint information transfer. Each frequency agile modem is controlled by a Wang data switch which selects available frequencies and addresses, by continually polling all FAMs to keep track of their status and the availability of each channel. The two dedicated interconnect sub-bands include 64 channel allocations at speeds of up to 9600 bps and 16 channels for speeds up to 64,000 bps. Both dedicated channel groups require Wang fixed frequency modem (FFMs) to be used between compatible pieces of equipment.

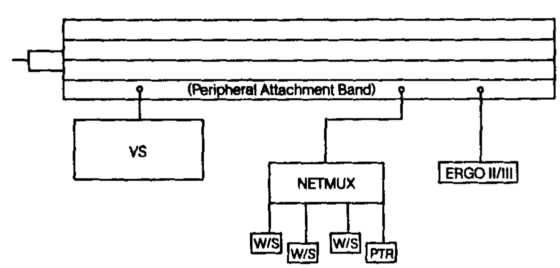
INTERCONNECT SERVICE

• **DEDICATED SERVICES**



The Wang Band is composed of a 12 megabit channel for the use of Wang Word Processing and Data Processing equipment. The Wang Band uses CSMA/CD contention protocol and a variable length HDLC packet protocol. Network connection is accomplished through a Wang cable interface unit (CIU) which is a general network processor that also has extensive diagnostic and network administration capabilities. Wang Band Facilitates data base file and document transfers, electronic mail as well as many shared resource functions. Up to 16,384 devices can be connected to the Wang Band.

PERIPHERAL ATTACHMENT BAND



The peripheral attachment band is a means to attach thousands of work-stations and printers to larger systems on the network in order to increase productivity through resource sharing.

In its announced form, WangNet addresses the need for simultaneous flow of highly diverse information forms within a facility. However, recent studies indicate that while up to 80% of the information generated stays within this facility, this still leaves 20% destined for branch and regional offices. As a result, capabilities to be announced in the future include high speed "gateway" services between facilities, perhaps using in-plant CATV cable for these purposes. We believe that the choice we made several years ago of broadband technology for local networking will allow us the flexibility of using this technology to meet the communication challenges of the eighties, for both local and remote communication networking.

I would like to acknowledge Bill Rosenberger and Mark Stahlman for their input.

ISBN 0-940272-01-6; 0-940272-08-3; 0-940272-10-5; 0-940272-11-3; 0-940272-12-1; 0-940272-14-8; 0-940272-15-6; 0-940272-16-4; 0-940272-18-0; 0-940272-19-9; 0-940272-20-2; 0-940272-21-0; 0-940272-22-9; 0-940272-23-7; 0-940272-24-5; 0-940272-25-3; 0-940272-26-1; 0-940272-27-X; 0-940272-28-8; 0-940272-29-6; 0-940272-32-6; 0-940272-33-4; 0-940272-34-2; 0-940272-35-0; 0-940272-36-9; 0-940272-37-7; 0-940272-38-5; 0-940272-39-3; 0-940272-40-7; 0-940272-41-5; 0-940272-42-3; 0-940272-43-1; 0-940272-44-X; 0-940272-45-8; 0-940272-46-6; 0-940272-47-4; 0-940272-48-2; 0-940272-49-0; 0-940272-50-4; 0-940272-51-2; 0-940272-52-0; 0-940272-53-9; 0-940272-54-7