TWO-WAY CABLE TV TECHNOLOGIES

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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.

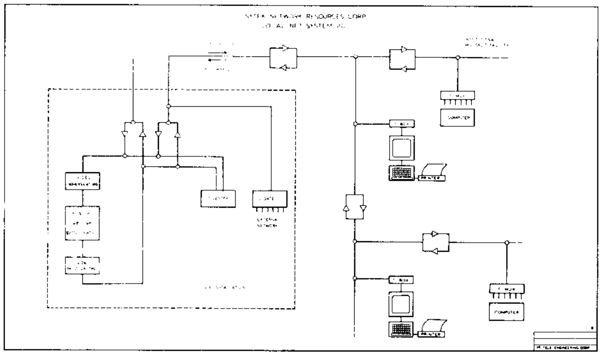
Any terminal can communicate with any computer connected to the system at 9.6 Kbps data rates. The system uses a Carrier Sense Multiplex Access/Collision Detection (CSMA/CO) philosophy and works on RF frequencies.

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)

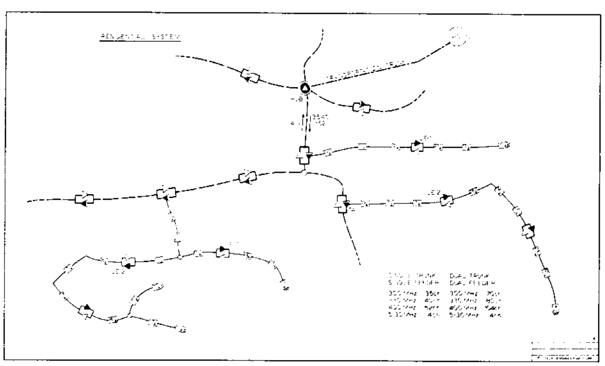
The next chart shows a typical Residential Cable TV Distribution System featuring a Hub location in the geographic center with a number of trunk lines feeding the various parts of town. The more trunks you have eminating from the Hub, the better your position with respect to future data traffic, as we 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.

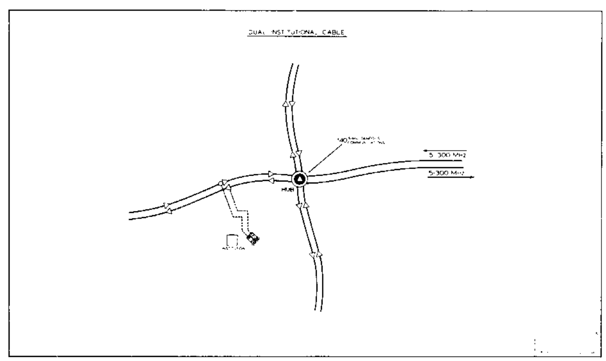
When you look a little deeper into existing installations, you do not find much switching mechanism in the Hub to establish these services.

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 TI	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.

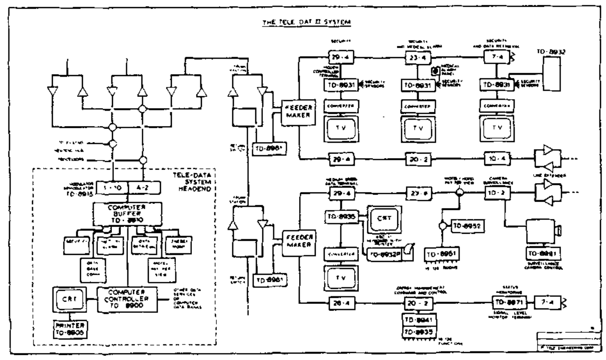
What I would like to do, is to concentrate on one type in each of the equipment categories in order that we can engineer the Level 2 and Regional Level 3 data transmission system.

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.

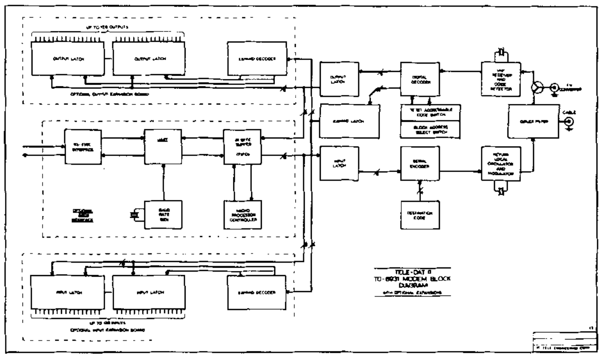
Data terminals talking to each other on the same system are coupled by an interlinking of two RS-232C ports.

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.

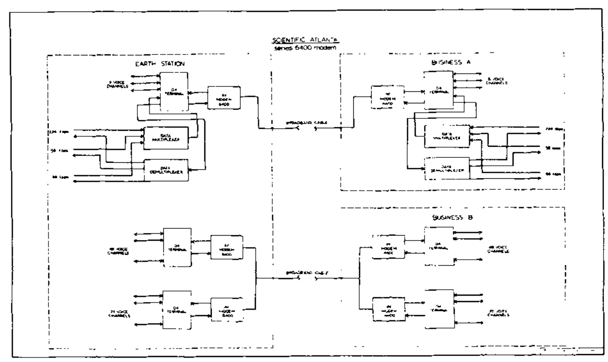
This system incorporates the flexibilities that are dictated by the cable TV industry. The operator can offer one service category and add other service categories as they become available, or when they appear to be revenue producing.

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.

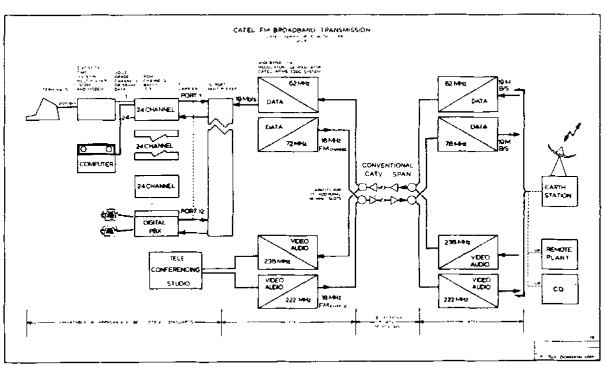
Multiples of 1.2 Kbps	**1.2; 2.4; 4.8; 9.6; 19.2 Kbps**
Multiples of 56 Kbps	**56, 112, 224, 448 Kbps**
T1	**1,544 Kbps = 24 voice**
T1C	**3,152 Kbps = 48 voice**
T2	**6,312 Kbps = 96 voice**

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.

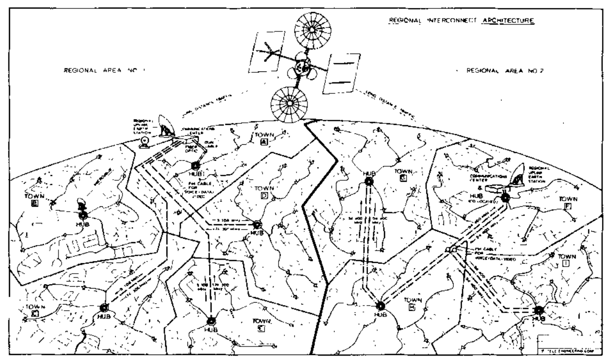


REGIONAL INTERCONNECT SYSTEM ARCHITECTURE (LEVEL 3)

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)

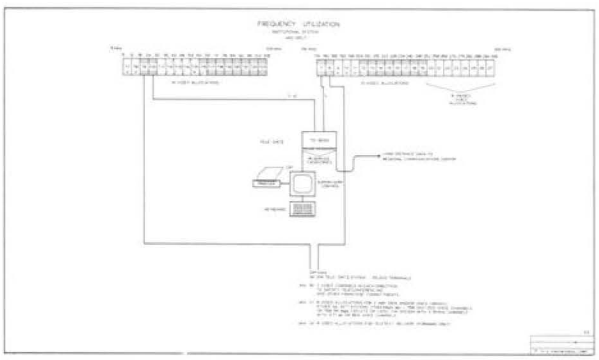
Level 2 is the local hub area cable TV system consisting of the Residential and Industrial cable systems.

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.

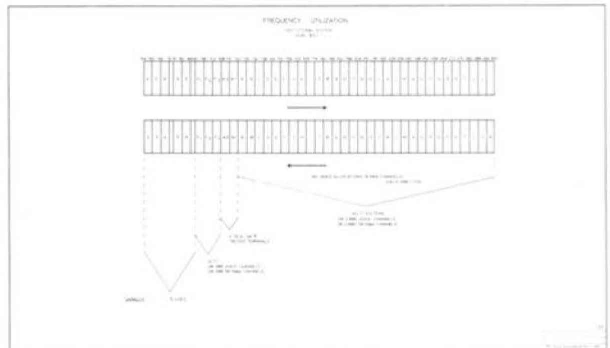
The lopsided nature of the mid-split cable is further enhanced by the fact that transmission around IF frequencies is not feasible.

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.

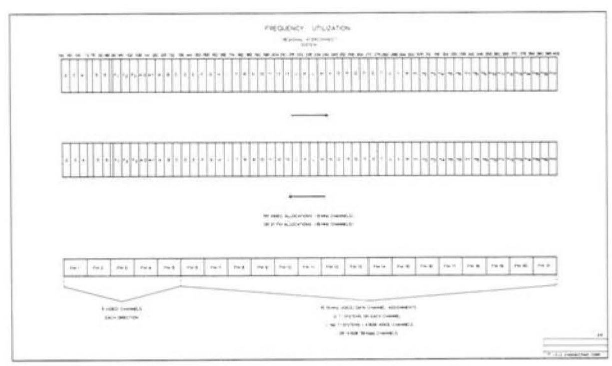
Setting aside 5 channels for video teleconferencing and program origination, a total of 33 video channels are available for voice/data traffic. Using S.A. Series 6400 modem equipment, a total of 132 T1 systems with 3,168 digitized voice or 56 Kbps channels can be accommodated.



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.

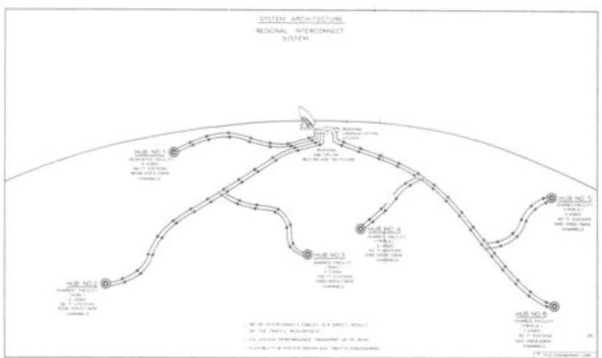
There are 55 video channel allocations in each direction. Because of the length of this dual .750 transportation trunk, we will use CATEL FM, Series 3000, modems and divide our frequency spectrum into 16 MHz slots.

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.

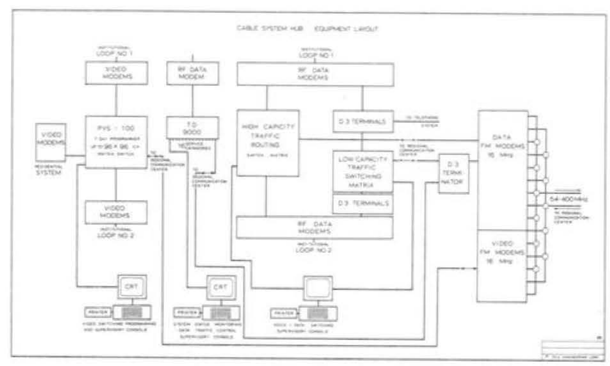
I have covered the transmission properties of both Level 2 and Level 3 broadband systems to some extent in the foregoing. Let us now have a look at the equipment complement that will be required at the various locations.

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.

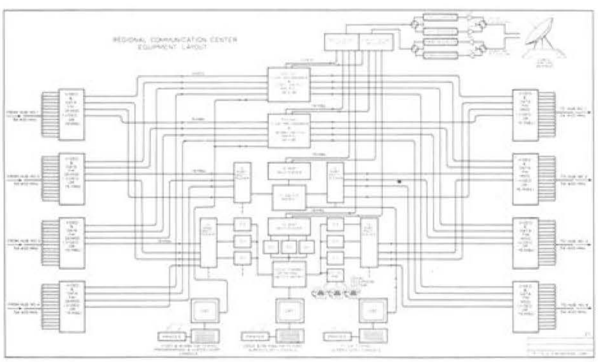
A CRT with keyboard and printer acts as system status monitor, supervisory control console and record keeper for billing. All of this equipment is available now.

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.