CATV HEADEND ENGINEERING

Session Chairman:
Walter S. Wydro

Participants:

Steven I. Biro
"Minimum Acceptance Testing of CATV Head-Ends"

George C. Kanen
"In-System Conversion 24 Channels"

Philip D. Hamlin
"Converters and Television Sets as CATV Terminal Devices"

Patrick R. J. Court
"Considerations in the Design and Use of CATV Converters"

Floyd O. Vincent
"The Converter's Place in Today's Modern Cable System"

B. R. Carter
"Solid State Headends"

STEVEN I. BIRO

It is my objective to start a useful dialogue between CATV operators and engineers on the Acceptance Testing Procedures for CATV Head-Ends.

A block diagram of an average (10 channel) CATV Head-End is presented on Figure 1. The ideal Head-End acceptance procedure would encompass the testing of all components shown in this schematic and checking all specifications. It is doubtful that many CATV operators could afford the time, instrumentation and the engineering support required for a thoroughly conducted Acceptance Test.

For all practical purposes, a one-day testing of the Head-End should be satisfactory, demonstrating both Performance of the Antenna System and Performance of the Signal Processing Network. For each of these:

A. PERFORMANCE OF THE ANTENNA SYSTEM

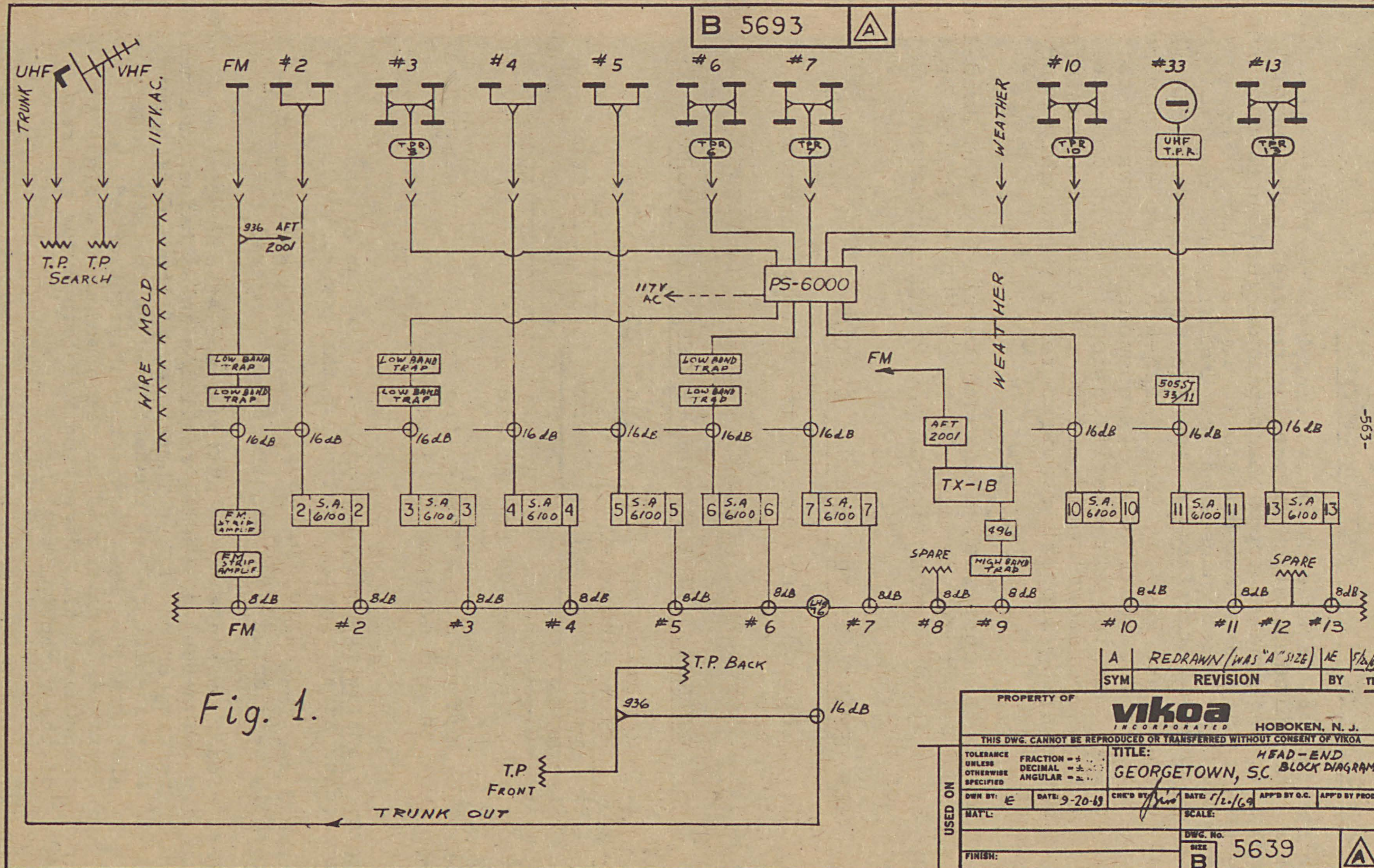
1. Proper orientation of the antenna-arrays.
2. Checking antenna-array gain.
3. A co-channel protection test. (Optional)

B. PERFORMANCE OF THE SIGNAL PROCESSING NETWORK

1. Comparing off-the-air and Head-End test point pictures.
2. Demonstrating the absence of interference beats.
3. Triggering of the substitution oscillators.
4. AGC action of the receiver.

In order to perform above tests, the following minimum test-instrumentation and equipment is required:

1. Field strength meter (FSM)
2. 17" color TV receiver
3. Coaxial switch
4. 3 dB hybrid splitter
5. Step attenuator
6. Search antenna
7. 10/20 kHz tunable B.P. filter (Optional)
8. Audio millivoltmeter (Optional)



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VHF
TRUNK
117V. AC.
FM
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#3
#4
#5
#6
#7
WEATHER
#10
#33
#13
T.P. SEARCH
WIRE MOLD
936 AFT 2001
PS-6000
117V AC
LOW BAND TRAP
FM STRIP AMPLIF
S.A. 6100
16dB
8dB
TX-1B
AFT 2001
496
HIGH BAND TRAP
UHF T.P.R.
505ST 33/11
SPARE
FM
#8
#9
#11
#12
T.P. BACK
936
T.P. FRONT
TRUNK OUT
A REDRAWN (WAS "A" SIZE)
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PROPERTY OF vikoa INCORPORATED HOBOKEN, N. J.
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Fig. 1.

CHECKING THE ORIENTATION OF THE ANTENNA ARRAY

The testing of the antenna arrays cannot be performed without a rotor mounted Search Antenna at the top of the CATV tower. Arranging the proper connections according to Figure 2., the search antenna shall be rotated until the field strength meter shows a maximum reading, and the TV receiver a good, interference free picture.

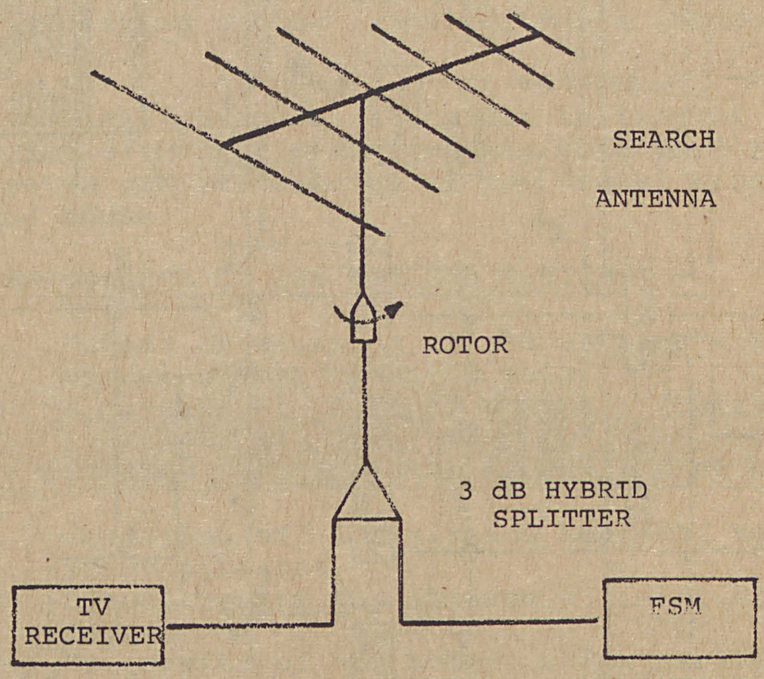


Fig. 2

Compare visually the orientation of the Search Antenna and the antenna array from the bottom of the tower.

If the directions don't agree, the search antenna should be carefully reoriented and the directions compared again.

NOTE: Search antennas have narrower radiation patterns on high-band channels, resulting in a sharper maximum reading on the FSM. Therefore, if low and high-band TV transmitters are concentrated on the same tower (Los Angeles, New York), the orientation of the Search Antenna should be performed on the highest channel and that direction maintained for the rest of the direction testing.

COMPARING THE ANTENNA ARRAY WITH THE SEARCH ANTENNA

Using the Search Antenna as a reference, the signal level and picture quality of the Antenna Array shall be checked channel by channel, using the instrumentation of Figure 3. In this set-up, the coaxial switch has a very important function: It eliminates the time factor when rapidly fading signals of distant TV stations have to be compared. (Switching of the coaxial switch requires only a fraction of a second.)

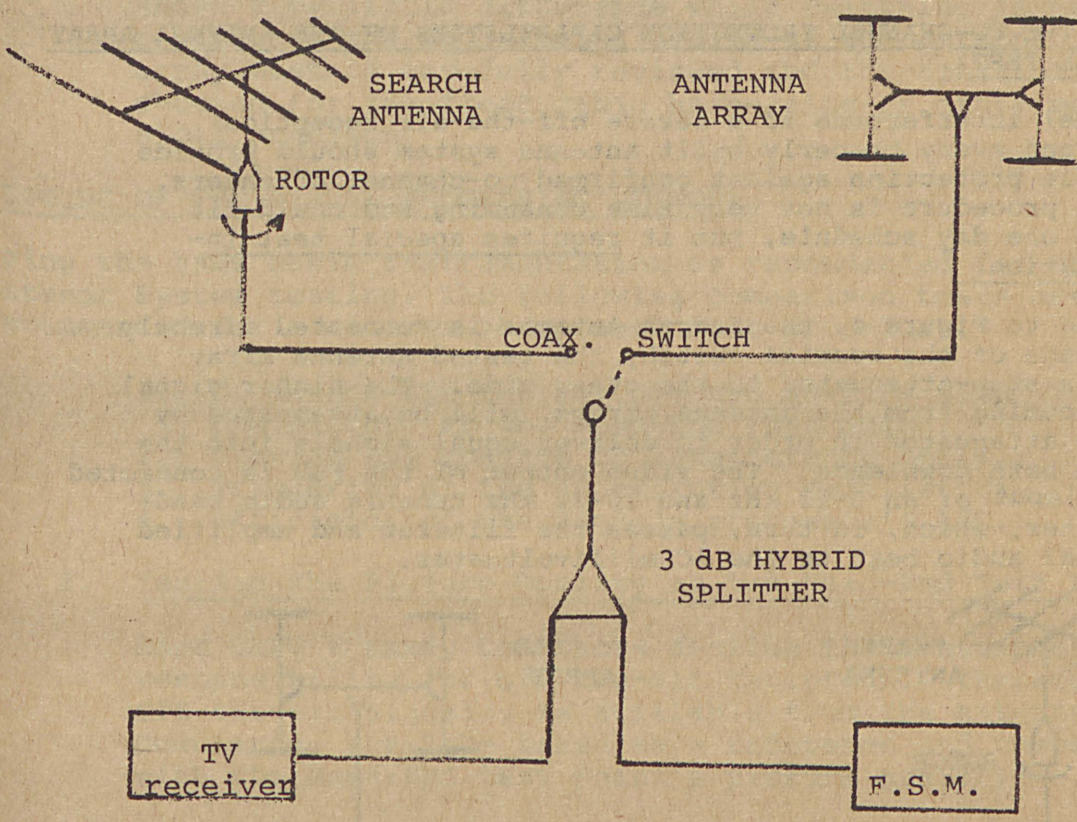


Fig. 3.

Antenna Array Gain testing can be accomplished by switching from the Antenna Array to the Search Antenna. Knowing the antenna gain of the Search Antenna, while compensating both for the difference in the antenna height and for downlead attenuation, the Antenna Array gain can be evaluated. A single channel, several hundred dollar CATV Antenna should out-perform by several dB gain the all-band $ 40 to $ 50 Search Antenna.

The test set up of Figure 3 may be also used for checking off-the-air picture quality and interference protection. Using the Color TV receiver as a reference, and switching from the properly oriented Search Antenna to the Antenna Array, the latter should provide superior color fidelity, more contrast and better picture resolution. At the same time, picture quality may be also judged for absence of interfering signals. The antenna arrays should clearly demonstrate less co-channel beats and less AC or r-f interference. This quantitative testing is fast, straight forward and the required instrumentation makes it feasable even in the less instrumented CATV systems.

TESTING THE CO-CHANNEL PROTECTION CAPABILITIES OF THE ANTENNA ARRAY (OPTIONAL TEST)

Co-channel interference is a severe off-the-air reception problem and every properly built antenna system should provide reasonable protection against confirmed co-channel offenders. The test procedure is not very time consuming and could fit into the one day schedule, but it requires special test instrumentation.

According to Figure 4, the Search Antenna is connected directly to one side of the coaxial switch, the tested Antenna Array through a step-attenuator to the other side. The higher signal levels, coming from the antenna arrays, will be attenuated by the step attenuator in order to deliver equal signals into the FSM from both downleads. The video output of the FSM is connected to the input of an 8-12 kHz and 18-22 kHz tunable audio band-pass filter, which, in turn, passes the filtered and amplified co-channel audio beat to the AC millivoltmeter.

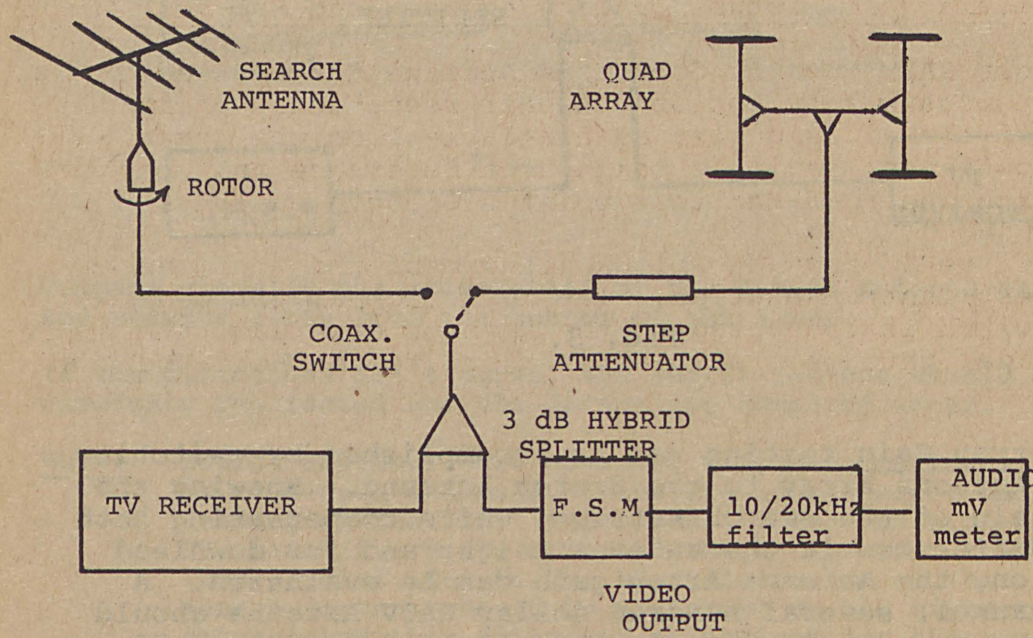


Fig. 4.

Provided the Search Antenna is pointing in the right direction, we obtain a quantitative reading of the co-channel interference from both antenna types. When distant channels are to be checked, the comparison test must be repeated several times to obtain an average value under rapidly fading signal propagation conditions.

NOTE: It is reasonable to expect a 6 to 10 dB improvement in co-channel protection from an antenna array over an all channel search antenna, but 15dB additonal protection should be called excellent. If this test shows very little difference while switching is being performed, the engineering design of the antenna array must be carefully reviewed and the construction checked for incorrect cable harnessing or other mechanical problems.

TESTING OF THE SIGNAL PROCESSING NETWORK

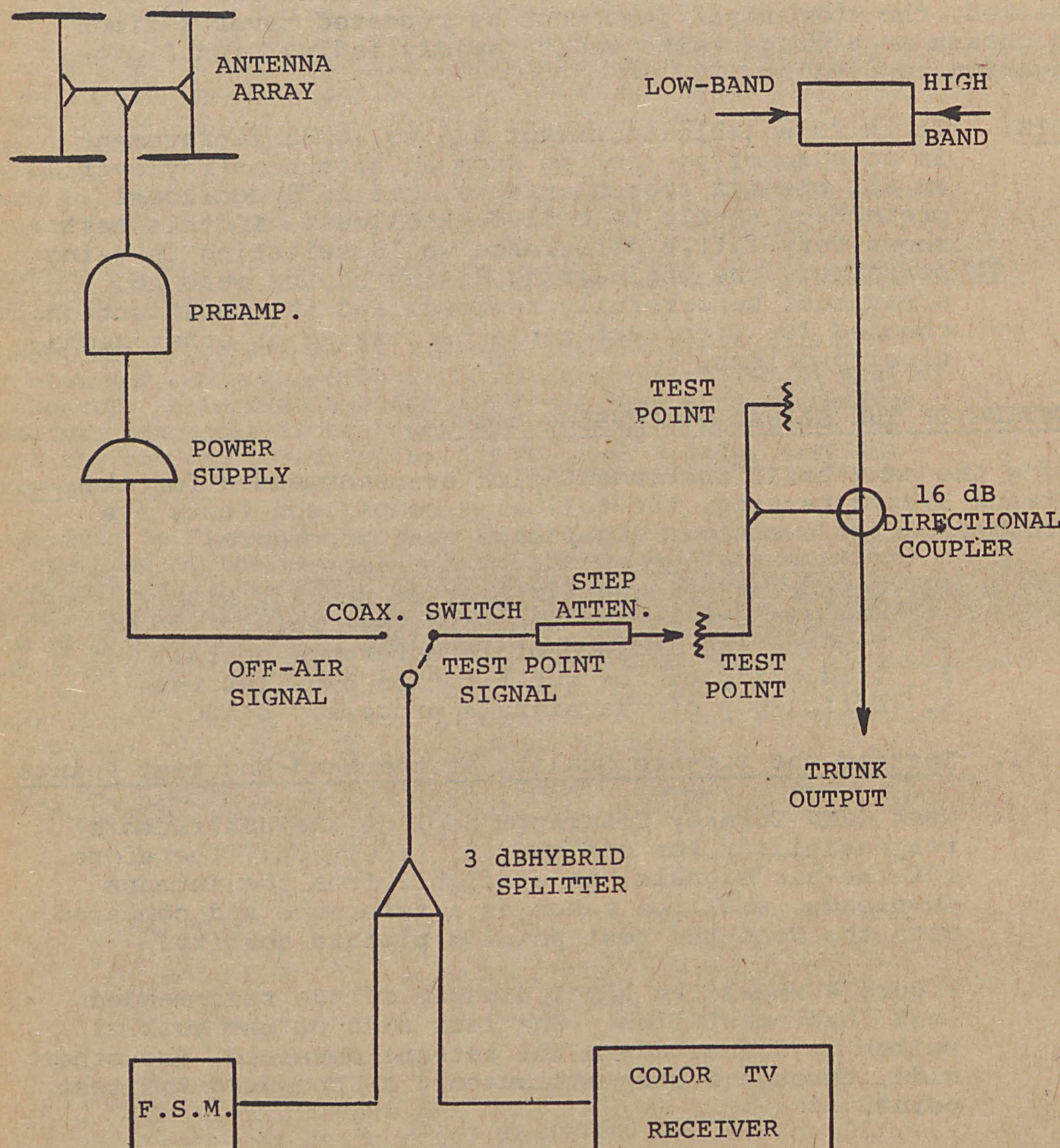
Using the same basic instrumentation as recommended for the Antenna System testing, the following comparison tests are recommended for a minimum acceptance test procedure.

1. Comparing off the air picture quality with the picture at the Head-End Test Point.
2. Proving the absence of interference beats.
3. Triggering of the substitution oscillators.
4. Efficiency of the signals processor's AGC.

1. Testing the Picture Quality at the Head-End Test Points

Most CATV Turnkey Contracts decline the contractors' responsibility for off-the-air reception. Therefore, off-the-air signals, as available from the antenna downleads, shall be taken as a reference and compared with the Head-End test point's picture quality.

Figure 4 shows the block diagram of the recommended test instrumentation. The left side of the coaxial switch is connected to the antenna downlead, the other side, through a step-attenuator, to the Head-End test point.


ANTENNA
ARRAY
PREAMP.
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16 dB
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COUPLER
STEP
ATTEN.
COAX. SWITCH
OFF-AIR
SIGNAL
TEST POINT
SIGNAL
TEST
POINT
TRUNK
OUTPUT
3 dBHYBRID
SPLITTER
F.S.M.
COLOR TV
RECEIVER

Fig. 5.

The step-attenuator must be manipulated to feed the TV receiver with equal signal levels in both modes of operation.

Feeding the TV receiver from the antenna downlead, the TV receiver shall be carefully tuned and adjusted to provide the best off-the air color picture quality. Then, switching the TV receiver to the Head-End Test Point, but without touching it's fine tuning, the picture should not demonstrate any deteoriation in color fidelity or in picture resolution. This procedure must be repeated on every channel and the observations entered into the log-book.

Although this test is quite simple and requires very limited instrumentation, it reveals a great deal about the critical electrical parameters of the signal processing networks, such as frequency response, differential gain and differential phase conditions. The testing of these parameters would otherwise necessitate extremely precise and expensive laboratory type instrumentation, normally not available for CATV field testing.

2. Checking the Absence of Interference Beats

Maintaining the test set-up of Figure 4, the TV receiver shall be properly tuned for best off-the air signal, then switched to the Head-End test point. First, the adjacent channel signal processing units will be turned off, followed later by other units. The TV picture should not demonstrate any change in the background (random) noise, hash or interference beat contents. If there is a sudden change (disappearance) in the interference level, we have evidence that it has been generated within the Signal Processing Network and proper steps shall be taken for the elimination of this problem.

3. Demonstrating the Performance of the Substitution Carrier Oscillators

In the absence of off-the air signals the signal processor should switch automatically into the substitution mode of operation and stay in that mode until the desired TV signal returns on the air. The demonstration should begin with a disconnect of the antenna downleads. The substitution oscillator should trigger within 10 to 20 seconds. Reconnecting the antenna downlead, the signal processor should return instantly to its regular mode of operation.

The measured video carrier levels should not change more than ±1/2dB between the regular and substitution mode of operation. This condition can be easily checked with a FSM at the Head-End test point.

4. Testing the Signal Processor's AGC Action

The specifications of better quality signal processing units call for a ±1/2dB change in the output level if the input signal varies from -14 dBmV to +26 dBmV. For testing the efficiency of the AGC, off the air signals may be used.

A FSM shall be connected through a 20dB pad to the signal processor's output test point. The antenna downleads shall feed the input through a step-attenuator. Reducing the input signal level to the minimum -14 dBmV level or below, the output must be carefully monitored and recorded by the FSM.

Although this testing procedure may not cover the full 40dB dynamic range of AGC action, it will clearly demonstrate the performance of the AGC under practical anticipated fading conditions.

For a full scale AGC testing the application of calbrated signal generators are mandatory.

SUMMARY

It is the author's opinion that a one day testing, using generally available test instrumentation, is only the first but the right step before accepting any Head-End.

Recommendations for a more sophisticated Head-End Acceptance Test will be published in a later presentation.

GEORGE C. KANEN

The desire for increased channel capacity in a CATV distribution system--spurred by the addition of locally originated signals as well as off-air available stations--has created a whole new area of problems for the system operator as well as equipment manufacturers.

Many of us have seen the industry go from a two or three channel system using "strip type" amplifiers as distribution units to the so-called "broadband amplifiers" that boosted the low-band channels allowing carriage of the grand total of five channels, to the now standard twelve channel amplifiers for what was called the "ultimate in CATV equipment." We were barely used to the vagaries and additional techniques required with the twelve channel amplifier when the first twenty channel equipment became available from the suppliers.

The new twenty-plus channel equipment, whether it adds the additional channels in the mid-band between 120 MHz to 174 MHz, the octave approach with twenty channels carried between 120 MHz and 240 MHz, or whether it be a combination of the previous two, the basic problem still is that some or all of the channels carried on the system are non-standard TV frequencies, necessitating that these be converted to standard channels for the individual TV subscriber's set.

A method that exists, and several manufacturers offer this device, is the top of the set converter. This unit, probably familiar to all of us, incorporates a switch and a tuner to by-pass standard channels to the TV set or alternately to convert the non-standard channels to one standard one. Required, quite obviously, is one of these units per television set--a cost that quite rapidly becomes great, particularly if there are quite a few two and three set homes in your community.

If converters or conversion of some form are to be eliminated then, we must of necessity, build a full dual cable system--that is, build two, twelve channel systems side by side, run a drop cable from each feeder to the TV set and use an A-B switch at the set to select one 12 channel system or the other twelve channel system. This, although expensive, certainly does away with conversion. Let's look for a moment at another way to accomplish twenty-four channels, exploring the how and the relative costs involved.

In our system in Newport Beach, we are carrying a full twenty channels of TV signals and employ a specially designed conversion unit placed in the CATV system ahead of the subscriber, to convert back to standard channels.

The system design, with this approach looks like Figure 1.

The trunkline is a single cable carrying all signals basically in an octave configuration. At trunkline locations, where bridging stations would occur, is placed the System Converter. This unit accepts the octave frequency TV signals and electronically converts them to two outputs with up to 12 standard TV channels per output. For example, 24 signals carried on the trunk are converted to separate, isolated outputs for distribution --12 standard TV channels per output. (Figure 2)

Since the converter unit is placed at the trunk amplifier where a bridger would occur in the system, then the In-System Converter functions as a "bridger-converter" and requires the same number of distribution leg outputs as the standard bridger i.e. four except that in this case, because of conversion within the unit, there are eight outputs, two per distribution leg.

A basic block diagram of the in-system converter will serve to clarify the operation of the unit. (Figure 3)

The input from the octave trunkline is coupled to the converter, split through quality and exact filters, combined in mixers with local oscillators to produce standard TV channel frequencies, amplified in separate 12 channel amplifier sections and then four-way split to provide both an "A" and a "B" output--four outputs from the "A" side and four outputs from the "B" side. Distribution legs then from the converter throughout the distribution are dual--one feeder for the "A" side and one feeder for the "B" side.

Let's look at the total configuration from the trunk through a distribution section and analyze costs involved with this method. The next illustration (Figure 4) would be that of a typical bridger/converter distribution section--further assuming that we have a good design, that all four feeder sections from the bridger/converter are utilized, and that we have two (2) cascaded line extenders in each leg. The cost analysis to do then is to calculate the extra cost involved (above the basic 12 channel system) for this method.

Now let's take the individual items which go to make up the second or dual part of the distribution system and see what the additional costs are.

Feeder Cable (10,000')	$ 900.00
Directional Taps (80)	960.00
Line Extenders (8)	1,120.00
Converter (less bridger credit)	1,300.00
Tap splicing labor (80)	200.00
Total Additional Cost	$4,480.00

Now let's count the customers that we can serve from this design using an average of 3.2 customers per tap location--we then have a potential of 256 subscribers. On a dedicated plant basis (service to all subscribers), our per dwelling unit cost is $17.50.

The dwelling unit cost with the top of the set converter system would be $25 per dwelling unit (the cost of the set top converter) if each dwelling unit served had only one TV set. Since our industry average appears to be 1.5 TV sets per home our top of the set cost per dwelling unit would average $37.50 as compared to the $17.50 for the in-system method.

In summary, the in-system conversion method has been proven in our system operation in Newport Beach, the principle and operation of the device is straight forward and relatively simple from a system design and technician maintenance standpoint, and the additional costs above basic 12 channel operation are substantially lower than other existing methods.

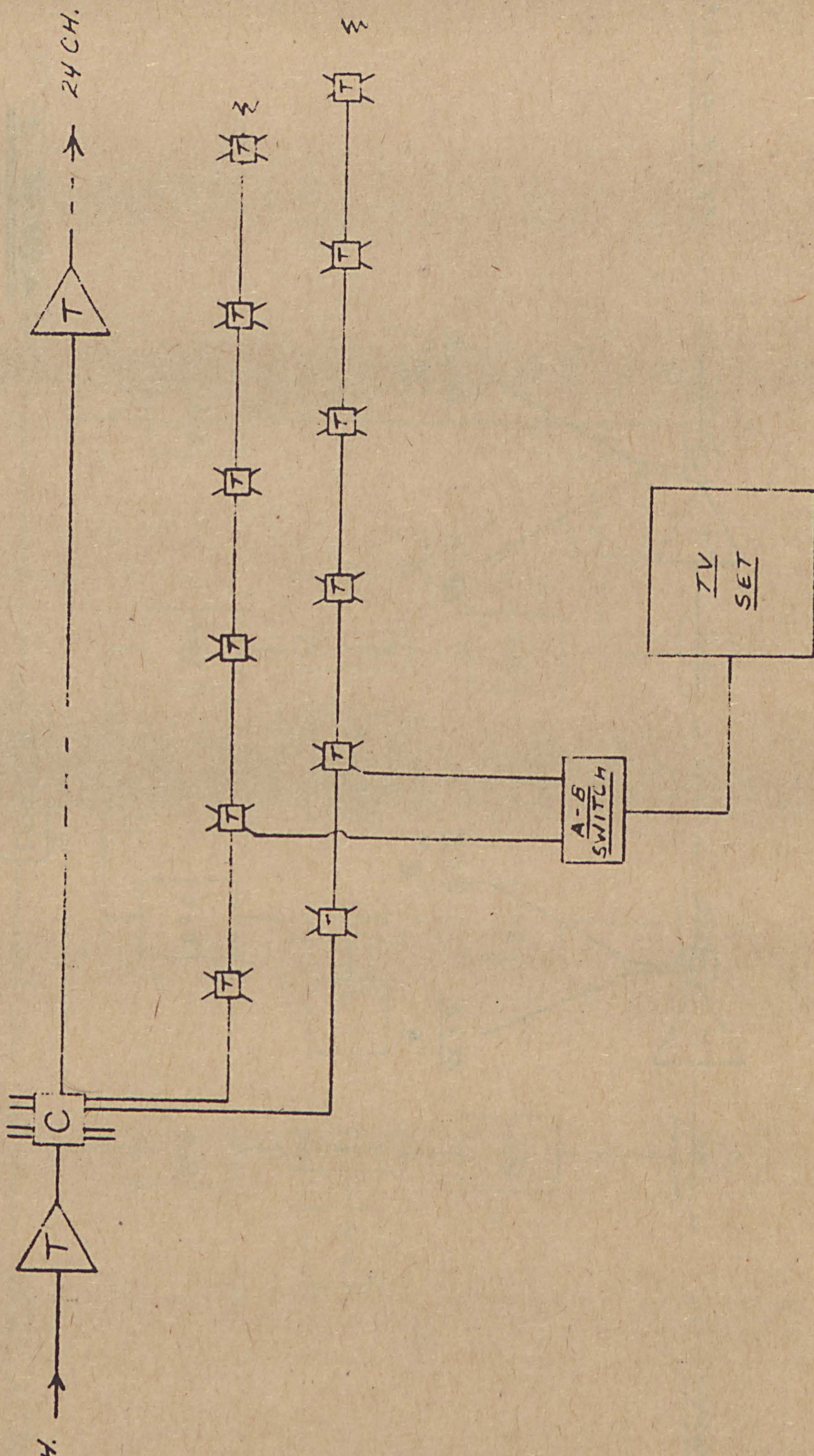


FIGURE 1

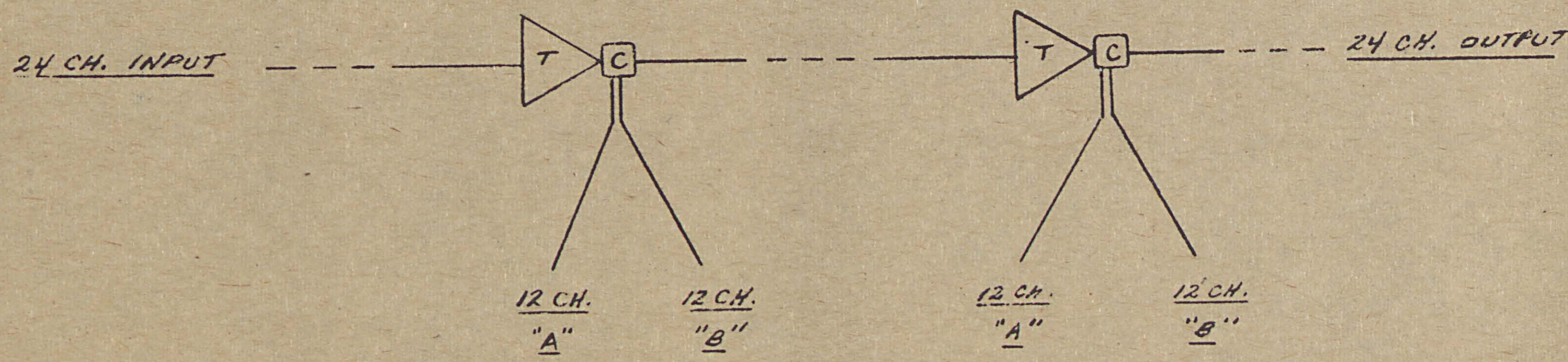


FIGURE 2

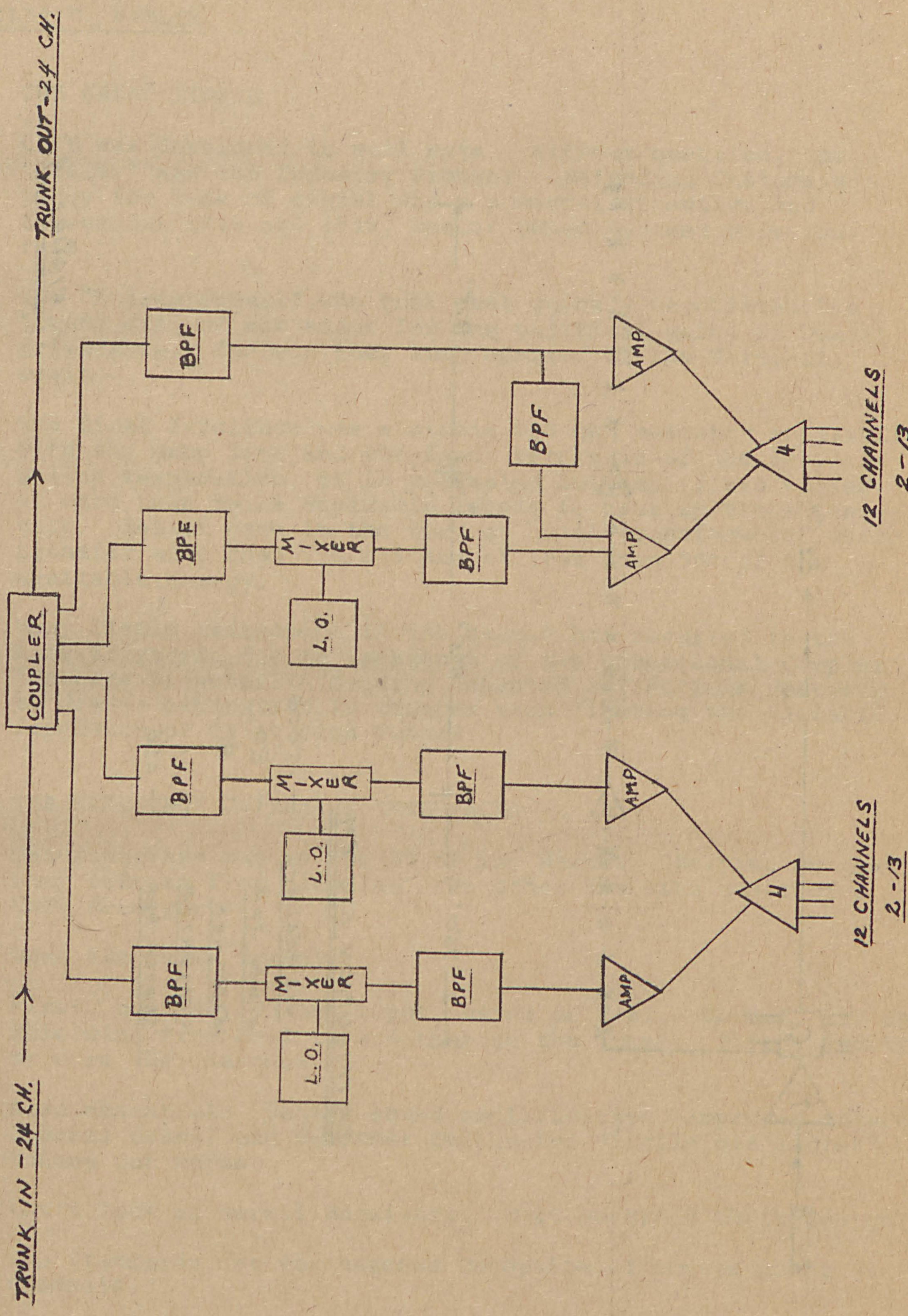
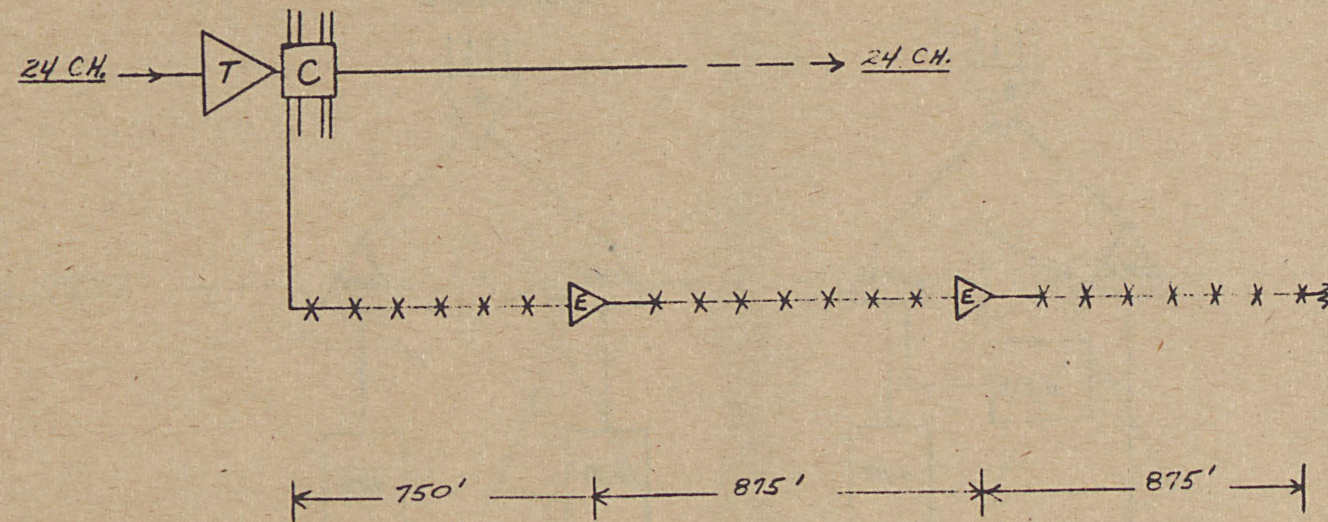

TRUNK IN - 24 CH.
TRUNK OUT - 24 CH.
COUPLER
BPF
MIXER
L.O.
AMP
4
12 CHANNELS
2-13

FIGURE 3



DISTRIBUTION SYSTEM

.412 FEEDER	— 10,000'
4-WAY TAP	— 80
EXTENDER	— 8
CONVERTER	— 1
SUBSCRIBER	— 256

FIGURE 4

PHILIP D. HAMLIN

I. THE GREAT CIRCLE

CATV was developed to sell sets. Without question, the "Dealer" was the Industry Pioneer. Refunding Customers' money for lack of signal was a powerful incentive and throughout 1948 and 1949, Dealer Owned Systems were the rule.

The "Entrepreneurs" who took over quickly negotiated the "trade off" of set sales for the political gains of Dealer friendship. Therein they lost control of the Terminal Device.

The first Interface was a simple 100 ohm resistor in parallel with the drop line and the input terminals of the Set. As a line termination, it is unequaled but amplifiers worked at more than twice desirable levels to heat up those resistors. Relief came in the form of balun transformers, which transfer more than 90% instead of less than 50% of the available energy.

Very little refinement in the baluns has occurred in the last 15 years, due to emergence of the Directional Coupler "Garbage Disposer." Sending unwanted reflections upstream to die of exhaustion is cheaper than fighting the variable impedance of Television Tuners.

II. THE EMERGENCE OF ACTIVE INTERFACES

Manufacturers say we are 2% of the Market. Relying on that, they refrain from "loading" the other 98% with costs of a CATV Receiver.

What are those costs?

First, coaxial, 75 ohm input, using an F-61. Second, 100 dB Shielding from F-61 to-and-through the Tuner. Third, twenty or more VHF Channels.

Also essential: Better sound amplification, improved adjacent channel traps, and smoother tuning for "little old ladies" tuning out worms.

Let's look at normal Receivers. What governed their design?

The Standards set for Antenna Reception of non-adjacent channels.

.........so let's look at the Antenna.

The standards dictate horizontal dipoles, with or without parasitic elements for directivity. This energy collector must be broad band over at least the channel of interest and frequently over two octaves. This encourages folding the dipole and gives a 300 ohm nominal impedance.

Twinlead is a cheap and efficient downspout for this energy, and is readily made 300 ohms.

A problem develops at the set. Single ended Tuners require unbalanced lines. To match the Tuner, a balun transforms 300 ohm twinlead to 75 ohms.

Easiest mounting for the balun is the Tuner. The Tuner is behind the Knobs, on the front of the Set, necessitating more twin lead from balun to screw terminals on the back of the set.

This arrangement is satisfactory for Antennas. The folded dipoles intercept lots of energy and pour it down the efficient twin lead. Reflected energy from indifferent to very bad match at the Tuner input is squirted back up and reradiated to oblivion by the reciprocal antenna.

.......but connect the same set to a CATV System.

The nominal 75 ohms we want is buried inside the cabinet. Between our 75 ohm cable and that Tuner is the barrier of the 11¢ balun. Hurdling this obstacle requires a $1.00 transformer, carrying our impedance upstairs to 300, from whence the set balun brings it back down to 75.

Losses are multiplied and reflections abound. Far worse, the 15 to 30 inch interconnecting twin lead is an exposed jugular, vulnerable to all ambient signals and a positive guarantee of "direct pickup."

III. UNDERSTANDING DIRECT PICKUP

Assume two signals traveling a parallel course for 20,000 feet. One travels by air, the other by cable paralleling the air path.

Arriving at the Television Set, the Air Signal cuts across twinlead from set back to balun, the balun itself, and the almost wide-open Tuner. This develops a signal.

The Cable signal also arrives. It develops a picture too ....but there is a difference. The difference is time. Assume the Cable to have a velocity factor of .6666 that of free space. Assume the Air Signal travels 900 feet per microsecond, giving the Cable Signal a speed of 600. For every 1000 feet the Cable Signal is delayed .5 microseconds and accumulates 10 microseconds of delay.

Assume again the Tuner "sees" a +20 Signal from the Air Signal, which arrives first. The Cable Signal hits the same input with +15.

The horizontal sweep line is visible for 53 microseconds. It syncs on the first signal. The second signal, with identical information arrives later and weaker. Its sync is not enough to "seize" the horizontal oscillator but all mathematical sequences of the first signal are duplicated.......ten microseconds later. It therefore appears about one fifth of the screen to the right.

In practice, there are many differences. Airplanes provide "dancing ghosts", in which the flutter makes the direct pickup alternately stronger or weaker than the cable and control leaps from one to the other. The "direct pickup" is also plural, with numerous air paths via reflections, making variable delays visible as extra smears and ghosts.

There is infinite variety but all degrade reception.

IV. CURES FOR DIRECT PICKUP

Ghosts are invisible if down 30 dB from the desired signal. They are occasionally unnoticed at -25 dB and even tolerated close to -20.

Propagation conditions vary throughout day and night, and with weather. The objective should be -30.

This is achievable with an even start. Let the Direct Pickup be +15 and the Cable Signal +15. Wire the drop directly to the Tuner, ground braid, by-pass powerleads, pray a little, and you can barely see the ghost.

Often they come back to haunt you.

Cure depends upon degree. If System Layout permits hitting the Set Terminals with +15 dB, and Direct Pickup is +15 before the cure is attempted, success is barely possible. The undesired signal must be reduced to -15 dB for complete cure but -10 is generally acceptable. Elaborate bypassing of the balun, soldering calle to the Tuner, and other expedients will effect the cure.

In many areas, no cure can be effected at reasonable cost. This led to the "active interface."

V. CONVERTERS AS "ACTIVE INTERFACES"

Converters are the oldest active device in CATV. Most 1948 Systems converted a single channel to i-f, through a modified Television Tuner, then ran high level 25 Megacycle signals directly to sets, without intermediate amplification. The first amplifiers were developed for this i-f distribution.

Later Systems converted the available signal to Channel 2, for least line loss. With the advent of three channel Systems, all were heterodyned to Channels 2, 4, and 6. "Direct Pickup" was cured on a single channel Seattle System constructed in 1949 by Home Convertors, converting the single channel 5 to i-f, then back to Channel 2. "Block conversion," heterodyning 5-6, later solved the problem at the Head End.

All Big City Systems solved this problem at the Head End until they ran out of channels.

The next move was from Head End to Home. Using a scaled down Channel Commander permits delivering the set any convenient "clear channel." One hundred dB Shielding permits processing the clean cable signals to i-f and back to the channel chosen for delivery.

VI. PROBLEMS IN DESIGNING AND MAINTAINING CONVERTORS

First, the problem. We need a thousand dollar Signal Processor, sized for the home, priced at $25.00.

The budget necessitated some deletions. Stricken are AGC, AFC, and Crystal Control.

AGC is sorely missed. With manual gain control, we adjust the potentiometer for best compromise between Noise Figure and Cross Mod. It controls the voltage at the base of the r-f Stage and what is best for one is not healthy for the other. AGC would permit setting the minimum signal condition for best noise, then provide the necessary voltage to improve the overload when the signal was high enough that Noise Figure was not the item of interest.

AFC and Crystal Control elimination has simply forced the design of more stable oscillator circuitry. Mrs. Jones, if she likes the Network's Offerings, can cry her way through a full day of Soap Operas in Color, without retuning her Converter.....assuming the necessary stability in the Television Set.

Maintenance is not a problem. Our Twenty Five Channel Tuner has been independently tested by three Laboratories. It withstands accelerated life tests of 25,000 complete cyclings. Neither discernible contact wear nor appreciable oscillator shifting resulted. More than 32,000 have been manufactured.

Pilot Error is a serious problem. The Subscriber lines up two holes to hit a bullseye. Frequently he forgets and tunes the set, shifting the bullseye out of range. A Service Call results. Corrective action in the form of a "feed through" switch is under consideration. When the Set is "detuned," the Subscriber can throw the switch and by-pass the Converter. Using the same channel in the Cable, he can "retune" his own set.

Biggest problem with installation is dynamic range. Large City Systems are laid out with very high signals at Subscriber Terminals. Converters are built for the range 0 to 12 dB.

Our original units provided no access to the manual gain control. The Operator had to pad where signals exceeded 12 dB.

A screwdriver adjustment with easy access through the case eliminated this problem.

A Public Relations problem is Remote Control. Few Installers can "field" the angry reaction of a Subscriber who has paid fifty dollars or more for a "Pinger".........but a really good salesman can teach him to fine tune subtle color changes with the remotely placed Converter, using the "Pinger" for other controls.

VII. THE ULTIMATE TERMINAL DEVICE

The Customer Owned Set is a "Terminal Disease." We pamper its deficiencies and when the going gets too rough, feed it "Pablum" through the Converter. Always we sustain the frustration of delivering a product without control over its final display.

The Subscriber owned 19" Color Set costs him more than $18.00 monthly to buy, finance, and repair. In addition, he pays for the Cable.

An Operator can Lease a CATV Color Receiver of better quality, with multi-channel capability, 100 dB Shielding, and periodic preventive maintenance, for $12.00. Present Operating Margins can be maintained or equalled.

Both Parites to such an arrangement stand to gain. I predict the "ultimate terminal device" will revolutionize our Standards and enhance our Service to Subscribers.

VIII. SECONDARY SERVICES POSSIBLE WITH LEASED RECEIVERS

The twin problems of the Newspaper Industry are Paper Supply and Delivery. Disposal of the discarded waste is a headache to the Homeowner.

Delivery of all Printed Media is within the grasp of CATV. Storage devices can receive entire newspapers and circuits are within reach to permit scanning a whole page, then "zooming" in to fill the screen with a paragraph or a single picture.

The passing of the indifferent, affluent Newsboy, and the Mother who drives him around his route, will not long be mourned.

Dual payment plans are entirely practical, with the "free television" advocates suffering "fade-in fade-outs" of intermittent advertising superimposed on the copy. Subscribers would pay for the privilege of uninterrupted News.

IX. HOTEL/MOTEL SERVICES

Hotels provide a unique opportunity for "in house" programming. If your field of interest lay in the next speaker and you wanted to relax in your room until he appeared, a channel tied to a Camera aimed at this stage would be a genuine convenience.

Cameras showing the wares of local Department Stores could likewise fill vacant channels and permit shopping by telephone, with same day delivery to your Hotel Room. All equipment utilized could generate Lease Revenue and someone would, of course, derive income from the Advertising.

X. CATV TELEVISION SETS OF THE FUTURE

The form of present Television Signals guarantees the addition of noise and distortion on each successive reamplification. Encoding signals to pulse modulation and using amplifiers that regenerate the pulsed input without noise is prevented by the necessity for decoding back to the standard form for Television Set processing.

Under the Wired City concept, the CATV Receiver can be built to accept superior methods of distribution.

END OF AN ERA

Obviously we have completed the "Great Circle." The TV Dealer started the business to sell Sets. He passed the torch to us, we built a better mousetrap, and vast new areas were opened to Set Sales. In twenty years we have exceeded the capabilities of the Terminal Device. We need more channels. We need shielding. Most importantly, we need control of the Quality of the final picture.

To accomplish this we must offer the "Ultimate Terminal Device" ....The CATV Receiver!

Thank you.

PATRICK R. J. COURT

INTRODUCTION

The basic purpose of any CATV converter is to allow an increase in system channel capacity, either by eliminating direct pick-up problems or by permitting the utilization of additional spectrum space on the cable (which is normally beyond the reach of a standard TV receiver), or both. Despite the fact that these devices perform a valuable function, and do it very efficiently, they remain the subject of much controversy within our industry. The author hopes that a full discussion of the considerations in their design and utilization will help dispel some of the misunderstandings and misgivings which presently surround them.

SOME EARLY HISTORY

The invention of the CATV converter was stimulated by the movement of cable TV into the major U.S. metropolitan markets, in particular New York City. It came as an unpleasant surprise to the operators who were developing these markets, to discover the phenomenon of the "Right Handed Ghost." In central Manhattan, for example, there are seven powerful VHF transmitters and the local radiated field strengths are phenomenal, being measured in volts per meter. While it is possible to build a cable distribution which is adequately shielded against these powerful radiations, nobody had previously reckoned with the amount of signal that can be picked up by the exposed antenna circuits, or induced by ground currents, within the TV receiver itself. The receiver, under these circumstances, is presented with two signals on each of seven channels -- one direct from the transmitter and the other, somewhat later, through the cable. Hence the right handed ghost. In view of the fact that the basic motivation for building CATV in New York in the first place was to offer service free of the familiar and distressing left handed, multipath ghosts which had haunted New Yorkers for so long previously, the discovery was a depressing one indeed. A right handed ghost is no more saleable than a left handed one!

The stratagem of connecting the coaxial cable directly to the tuner was not very successful in New York, invalidated the UL approval of the receiver and, furthermore, presented the operators with the prospect of a less than satisfactory relationship with their subscribers in the matter of future responsibility for his receiver maintenance.

Necessity is the mother of invention and the concept of the shielded VHF to VHF converter to eliminate ghosting arose in the West in response to the anguished cries from the East. The converter was born, in fact, in the laboratories of International Telemeter Corporation in Los Angeles in late 1965. It was born not entirely for altruistic reasons, but in the hope that an honest dollar might be made from so elegant a solution to so vexing a problem. Sterling Information Services and Television Presentations have since acquired the exclusive patent and marketing rights to this invention with the same reasonable expectation.

Almost coincidental with the emergence of metropolitan CATV came the pressure for more channels and it was logical to incorporate additional tuning capacity within the converter enclosure, and hence the evolution of the non-standard frequency converter.

DESIGN CONSIDERATIONS

In spite of its inherent simplicity the design considerations of a CATV converter, if not complex, are quite diverse. As with any other consumer-type product, the requirement of low cost (and where else can one buy so much for so little these days?) complicates the design problem. Let us first consider the standard 12 channel VHF to VHF converter. Its purpose is to remove the tuning function from the TV receiver and to enclose it within a heavily shielded environment which is immune to direct pickup. All channels are then converted to intermediate frequencies and thence to a single VHF channel, not shared by a local station, to which the TV receiver can then be tuned and lo -- the ghosting problem is solved.

Dual Conversion

Implicit in the conversion of all twelve standard VHF input channels to a single one of these is the use of dual conversion. Single conversion results in an impossibly difficult range of oscillator frequencies and almost insurmountable image problems.

At one particular channel, single conversion becomes mathematically impossible.

Dual conversion implies the conversion of all input channels to i-f and the use of a second mixer to convert the i-f carriers to the chosen output channel. The frequency inversion which occurs in the first mixer must be canceled by a second inversion in the output mixer. Thus the output oscillator is "high-side," as indeed is the input oscillator.

Choice of Intermediate and Output Channel Frequencies

Whenever multiple conversion is employed, great care must be taken in design to avoid spurious interferences. Certain combinations of carrier and oscillator frequencies can give rise to problems if not guarded against. Potential third order problems also exist when considering that a third conversion occurs in the TV receiver itself. At one particular channel, for example, all three oscillators are operating at the same nominal frequency. Note nominal, not actual.

The choice of i-f was largely dictated by economic considerations. In order to make the converter economically feasible in a then uncertain market, it was decided to employ a basically standard, high quality, television tuner. These are manufactured in huge volume from unbelievably costly tooling and have been refined over years of engineering and manufacturing experience. They are consequently available at relatively low cost. It was a sound decision, because the market was not only unpredictable, but the total potential could not possibly justify anything radically different from a standard tuner. Even if every known CATV subscriber eventually had a converter, this would represent less than half the annual tuner production of Oak Manufacturing Company, which was selected as the source of the TPI converters.

For excellent reasons, the TV industry has standardized the band from 41 to 47 MHz for i-f and all tuners are currently manufactured this way. It therefore made all the sense in the world to retain this i-f for converter use.

The choice of output conversion channel frequency was not so circumscribed, but again economic considerations precluded offering a wide choice. Technical considerations excluded the use of the low VHF band, particularly channel 6 which happens to encompass the second harmonic of 41.25 MHz (i-f audio). The other low band channels make it difficult to achieve adequate "feed-through isolation," which will be reviewed later.

It is desirable to restrict the choice of output channels to two frequency-adjacent ones, the logic being that in any one city, one or the other will be unoccupied by a local channel. At locations midway between two adjacent frequency transmitters, their field strengths will not pose a co-channel interference problem.

From an economic standpoint it is preferable to use frequencies as high as possible so that the ratio of bandwidth to center frequency is small, then the same physical components can be used for both channels. The only difference at the factory is then one of alignment and tracking. Alternative channels 12 and 13 were therefore chosen.

Choice of Tuner and Modification for CATV Use

A systematic evaluation of available tuners led to the Oak four-circuit incremental switch type, largely because of its excellent characteristics, dependability and low oscillator radiation. As good a tuner as it is, it is not suited, without modification, to CATV use. For example, it is designed with 300 ohm input, has substantial gain and is optimized for use with agc. It is economically unfeasible to provide agc in a converter, and with adjacent channel operation the normal transistor tuner does not fare too well without it, largely because of cross-modulation. With the collaboration of Oak engineers, its electrical characteristics were carefully tailored for CATV use with fixed bias operation. In particular the input was redesigned for 75 ohms, and the gain was reduced from 40dB to 10dB by the use of degenerative feedback and other techniques. A compromise was found between noise, gain and cross-modulation which ideally suits CATV adjacent channel requirements. The resultant noise figure of 12dB maximum yields scarcely perceptible noise at -6dB input, while cross-modulation is better than -57dB at +6dB input. In practice this means that cross-modulation is invisible at input levels up to +12dB and scarcely visible with normal picture content at levels up to +18dB. In addition the gain taper across the spectrum was confined to less than plus or minus 3dB. All of this was accomplished without degradation of any of the excellent mechanical and other design characteristics of the generic tuner.

Beyond this, a further refinement was added, to overcome an intrinsic problem which exists when receiving channels 5 and 6 adjacently, and which many CATV engineers have undoubtedly observed with standard receivers. When tuned to channel 5, the tuner oscillator frequency is 123.00 MHz. The second harmonic of adjacent channel 6 video is 166.50 MHz, and the difference frequency is 43.5 MHz which happens to fall in the i-f band as a highly visible beat. The tuner was modified to incorporate a special switched trap which attenuates channel 6 video when tuned to channel 5 and the beat is thereby eliminated.

Adjacent Channel Rejection

Many receivers in the low to medium price class, particularly the transistorized variety, do not operate comfortably with adjacent-channel CATV input. Many exhibit cross-modulation and every CATV engineer is familiar with the adjacent sound beat and the need to reduce audio levels on the system, to the point where some marginal receivers can scarcely reproduce audio at all! In spite of the extra cost, the TPI converters incorporate adjacent channel traps, with minimum attenuation of 20dB. These completely overcome both problems at the receiver, and in fact if every receiver were equipped with a converter, the audio levels in the system could be raised to the normal FCC specified level of -10dB instead of the meager -15 to -20 which most systems struggle with.

Output Channel Filter and Attenuator

As the converter bandshaping is principally governed by the tuner and i-f circuits, the output filter can be relatively broadband. The principal consideration is attenuation of the output oscillator, both to meet FCC radiation specifications and to avoid a possible beat with the receiver oscillator, which operates at nominally the same frequency. A triple tuned filter provides the desired bandwidth and skirt selectivity and reduces oscillator output to less than 1000uv. A 3dB, L-attenuator helps maintain output VSWR at better than 2:1.

Fine Tuning

The considerations surrounding fine tuning are quite complicated and the arrangements provided in the TPI units, while they add to the cost, are in the judgment of the author the best that can be provided. In theory, if the converter oscillators were perfectly stable, there would be no need to provide fine tuning in the converter at all. However, this does not take into account the fact that most TV receivers themselves have a warmup drift or the differences in transmission from channel to channel, particularly with color. The situation therefore arises that the subscriber is selecting channels at the converter and fine tuning at the receiver -- not a particularly convenient arrangement, especially if the converter is installed as a remote control device.

At the other extreme it is possible to furnish a conventional front-end fine tuner in the converter and thus avoid the problem and expense of providing highly stable oscillators and a fully-regulated power supply. This is the inexpensive way out and unfortunately the results are consistent with the old adage "you get what you pay for." The subscriber is now confronted with two, wide-range, fine tuning adjustments and can get totally lost in his attempts to correct one with the other. The i-f carriers can become completely misplaced with respect to the passband and traps and in fact, both receiver and converter can become totally misaligned. Bear in mind that on some channels, the fine tuning range can exceed one channel width, so the prospects of difficulty are considerable.

This situation has been roundly and justly criticized by CATV operators and probably represents one of the basic reasons for resistance to the use of converters at all.

The approach taken in the TPI converters was to take the best and reject the worst of both alternatives. Both oscillators are designed to have excellent long-term stability (combined drift less than plus or minus 200 kHz over 30°C rise above ambient). A fully regulated power supply completely eliminates dependence upon line voltage between 100 and 130 VAC. The tuner incorporates a high quality memory detent tuning mechanism with re-set accuracy within plus or minus 50 kHz. Thus the overall frequency dependability is within about plus or minus 150 kHz and it is possible to withhold the tuner oscillator adjustments from the subscriber entirely -- even the installer. The memory tuning adjustments are intended for factory and service use only and all frequencies are precisely adjusted at the factory with crystal controlled calibrators, using the audible beat method (therefore within plus or minus 10 kHz). We are therefore assured that the i-f carriers remain correctly positioned within the passband.

For the convenience of the subscriber a fine tuning adjustment is provided which affects only the output oscillator over a limited range (plus or minus 0.75 MHz), and which compensates for TV receiver warmup drift and transmission variations. This is accomplished through a 300° rotation potentiometer, which electronically controls the output oscillator. The subscriber can now precisely fine tune the channel at the converter without getting lost and it is rarely, if ever, necessary for him to touch his TV receiver tuning controls once they are set. It is also very easy for him to do so should it become necessary, as he merely has to visually index the converter tuning knob to approximate mid-range and then fine tune the receiver. Thereafter he is in business.

Gain

Many people seem to be under the misapprehension that a figure of merit for a converter is overall gain and wonder why our units have only 6dB plus or minus 3dB. This is not a consequence of poor design; in fact the figure was deliberately chosen. With too much gain, some receivers will overload with maximum input from the drop cable. With too little gain or a loss, the noise contribution from the TV receiver can be significant when the input is at a minimum. The gain figure of 6dB plus or minus 3dB assures that neither of these things will happen.

Bandwidth and Bandshape

CATV people are of course calibrated to the idea of plus or minus 0.25dB from 50 to 250 MHz, and wonder why a typical converter does not meet this standard. Well, plus or minus 0.25dB is necessary for amplifiers which have to be cascaded and is to be expected in a unit costing $500/800 per copy. At the prices people expect to pay for converters, however, it is economically unfeasible to achieve such a specification, and at the same time meet all of the other requirements, including satisfactory phase response. As a practical matter there has to be a compromise and we have found the best to be the "3dB rectangle" whereby all points in the response curve between picture and sound are within 3dB. No visible picture degradation results, even to the most critical trained observer; in fact the picture quality is usually improved because of elimination of cross-modulation and adjacent sound beats.

VSWR

Here again, CATV engineers have grown accustomed to figures like 1.2:1 and 1.5:1, and are not happy with the idea of 4:1 which is the design figure for the current TPI converters. Until now the state of the art has not permitted an improvement without consequent degradation of noise performance.

Frankly we have not been happy with this figure either, although it is better than most receivers which operate on CATV, apparently successfully. We have also yet to be shown a situation in which improved VSWR would perceptibly improve the end result. However we recognize this figure should be reduced, if just to avoid any argument, and are looking to improved technology to achieve this.

Shielding

The shielding requirements are severe and should not be less than 100dB. This means that in a field of one volt/meter the output of the converter, with its input terminated and shielded, should not be greater than 10 uv. This would put any potential ghost signal approximately 46dB below the desired converted signal output, with input at 0dB, and is substantially better than the best drop cable currently available.

To accomplish this, the r-f circuits are totally enclosed in a rugged, plated steel compartment, and the power supply circuits are mounted externally to this compartment. The only connection other than the coaxial input and output cables, which enters this compartment is B+, and this is through a filtered terminal. Thus there is no prospect of pickup on the power cord being induced inside and no need for complex power line filtering. Figure 1 shows the chassis construction of the TPI Focus 12 VHF to VHF twelve channel converter.

Power Supply

Some economy might have been effected by the use of a transformerless supply, but in the interests of absolute subscriber safety a transformer-type supply is used. Also in spite of the extra cost, a fully regulated supply is used rather than simple zener stabilization in order to maintain oscillator stability. Twelve volts B+ is used and there is no measurable change of B+ with line voltage.

Miscellaneous

The internal circuits of the converter tend to offer a natural, direct path to the output channel frequency. Hence a phenomenon known as "on channel feedthrough" whereby channel 12 on the cable input can possibly interfere with the converted channel 12 at the output, particularly if the converter is tuned to channel 12. The direct channel will differ slightly in frequency from the converted channel, so careful attention to the internal layout and circuit design is necessary to avoid the problem. Feed-through isolation must be maintained at 70dB minimum.

To assure absolute subscriber safety, the converter should be fully approved and listed by Underwriters' Laboratories. In some cities it is illegal to install such equipment in the home without the UL seal or city equivalent.

Devices of this kind must also be certified to meet Part 15 of the FCC Rules and Regulations regarding direct and line-conducted radiation.

Aesthetics

With a single design you cannot please all of the people all of the time, but if you try hard enough, you can please most of them most of the time. Economics presently weigh heavily against offering too much choice of style or color, so a conscientious effort must be made to achieve something which is aesthetically pleasing to most people. As with the familiar telephone, clean contemporary styling and color appear to be the best choice. Figure 2 shows the TPI Plus 13 converter.

Non-Standard Channels

The development of converters for non-standard channel frequencies has consistently been ahead of the distribution equipment for transporting them. While the amplifier people are still lagging, they are catching up fast.

In the early state of development of expanded channel operation, it was quite out of the question to commit the elaborate and costly tooling and engineering required for a tuner having more than 13 positions, and retaining the same proven mechanical and electrical properties. (The 13th position is of course for UHF.) The approach taken therefore was to design a 13 position tuner using the same mechanical parts as used in the standard 12 channel unit, and retaining the same basic circuit design except for the inductive tuning elements. Historically, that is how the 25 channel concept began -- a converter containing a 12 channel tuner and a 13 channel tuner can obviously receive up to 25 channels. The VHF allocation plan also helped because it is possible to arrange nine new frequency-adjacent channels between the aircraft navigation band (which it is prudent to avoid) and channel 7. Four more can be positioned above channel 13 with only a 10% increase in total bandwidth. These 13 new channels were designated A through M (to avoid confusion with the UHF channels), which terminology has become standardized. It is also remarkable that if we momentarily forget the five low band V's and consider only the remaining 20, we find them contiguously arranged from 120 MHz through 240 MHz which happens to be one octave. The converter people foresaw the probable earlier development of single-octave distribution equipment, which is inherently free of second harmonics and second order beats, and the later development of mid-band techniques followed by all band equipment, perhaps using push-pull. In any event the converter itself could care less and was prepared for any eventuality.

The Gamut 25 converter therefore contains two tuners and a function switch to select either the number channels or the letter channels. It affords full shielding against direct pickup in all of them.

The Plus 13 contains only the non-standard tuner and a bypass switch to permit tuning the regular twelve channels at the TV receiver. It was devised as a more economical method of adding up to 13 new channels in areas not particularly bothered by direct pickup from local TV stations.

The same basic design considerations applied to these two units as to the Focus 12, with a few additional tricky problems thrown in.

RELIABILITY

A considerable amount of misinformation has circulated around our industry concerning converter unreliability, instability and so forth. As a result many operators are reluctant even to consider using them. Some of this misinformation is based upon experiences with very early models, since discontinued, some made by people no longer in the business. Perhaps the best rebuttal to this is the experience of Manhattan Cable Television which is by far the largest user of converters in the business. MCTV has substantially more than 15,000 Focus 12 converters in operation and is experiencing a trivial annual failure rate. It is therefore in no way discouraged from its conviction that converters offer the only practical solution to its problems.

USES FOR CONVERTERS

Apart from simply allowing increased channel capacity, converters offer the prospect of additional revenues for operators who can now consider offering a dual class or even a multiple class service. In fact, in the long run, this seems to be the only way of justifying the provision of an ever-increasing number of channels. Using the same cable, it is possible to offer up to 12 channels for one price and beyond 12 for a higher price. Beyond that, it is possible to direct specific channels to selected business communities, schools, doctors, etc., in return for additional separate monthly fees. It is not particularly difficult to arrange for converters to be inoperative at specific channels, thus denying say the doctors' channel to the schools and vice versa, and both of them to the public at large.

Converters can be installed as remote control devices, perhaps not as elegant as wireless remote control, but functional. At least two systems are doing this as an inducement to obtain additional subscribers and have many satisfied customers as a result.

ALTERNATIVES

Alternatives of course exist to the problem of providing more than 12 channels, the most notable being the two cable system. The main disadvantage seems to be higher cost and certainly higher initial investment. The dual plant has to be installed even if there is only one subscriber, whereas investment in converters is proportional to the number of subscribers. Furthermore, many buildings are difficult to wire with two cables, particularly high-rise apartments. The dual cable system, moreover, does not have inherent protection against direct pickup at the receiver and each local TV transmitter can now knock out two channels instead of one, one with a simple ghost, the other with co-channel beats, dual images and venetian blind effects.

Another method is the hybrid system employing pole-top converters. In this arrangement a single trunk cable is used carrying say 20 channels, single octave. Elaborate converters then manipulate the channels around so that they can be carried the rest of the way dual cable, standard frequency. The economics of this arrangement would seem to be not too far different from the all-dual system and the problems of dual wiring in homes, direct pickup, etc., seem to be the same.

Block converters from VHF to UHF have also been proposed both for indoor and outdoor installation. Unfortunately, block converters are prone to all kinds of beats and UHF receivers don't take too kindly to adjacent channel operation. It is almost impossible to find the channel one is looking for on the average UHF dial, and nearly impossible to tune it when it is found. Direct pickup from UHF stations can disable certain channels and many receivers are still around which cannot receive UHF anyway.

WHAT OF THE FUTURE?

Many operators have expressed the view that the TV receiver industry will soon come forth with shielded multi channel receivers which will make converters unnecessary. This may happen over the very long range but the fact is that the total number of subscribers now served by CATV represents but a fraction of the 60/70 million television homes in the U.S. This does not presently justify the attention and investment required by the industry to manufacture special CATV receivers or to increase the cost of all receivers sold so that they are compatible. Even if they started today and sold nothing else but these ideal sets, it would take at least ten years to turn over the present inventory of sets in use. Clearly the CATV industry is not going to wait that long to furnish the additional channels and services that are presently possible through the use of converters.

What of a special CATV receiver to be leased to subscribers as part of the service? The problem here is to convince the owner of a $500 color set which matches his French Provincial or Danish Modern decor, and which has the features and screen size he likes, to accept some kind of standardized CATV receiver instead, presumably at extra cost. Such an arrangement was tried in Montreal, Canada, in the early 50's and it fell flat on its face. Besides, does the CATV industry really wish to get into the receiver business, and does it really wish to alienate the dealers?

Many operators hope for some dramatic breakthrough or miraculous development which will eliminate the need for converters entirely. Miracles are unlikely but there will undoubtedly be breakthroughs in price, although they may not be as dramatic as we would all like to see. Prices must eventually bottom out as they have with TV sets and autos, once maximum advantage can be taken of volume production. Already, mass production techniques are being used as much as possible, designs are economical and markups are modest. Improved technology will gradually enhance performance even beyond present standards and at the same time allow prices to remain competitive.

For our company's part, we expect converters to find increasing acceptance and are examining every avenue to improve the product and reduce prices. Our new model Gamut 26, just announced, embodies the results of an 18 month program wherein radical new techniques have achieved these two conflicting objectives. Perhaps the Gamut 26 qualifies as a "breakthrough."

Varactor tuning may eventually supersede present methods, when the economics of the interface mechanisms have been resolved. Here the converter manufacturers are largely dependent upon the technologies developed by the receiver and tuner industry which presently enjoys a much larger volume over which to amortize the considerable investment in engineering and tooling involved.

The converter as we see it today, or even tomorrow, may be only a forerunner of more sophisticated subscriber terminal equipment of the future. Future devices may allow for many different kinds of service, beyond simple television entertainment. Some of these services may involve two-way transmission, may allow purchases to be made in the home in response to advertising messages, rating services, surveillance systems in conjunction with outgoing burglar and fire alarms, two way facsimile, etc., etc. The horizons are unlimited -- who knows they may one day dispense Green Stamps.

CONCLUSIONS

The CATV converter is here now, today, in practical, reliable, economical form and with a proven track record. The distribution equipment manufacturers are hot on our heels. The pressure for more channels is with us and additional revenues are waiting to be gathered through their use. What are we waiting for?

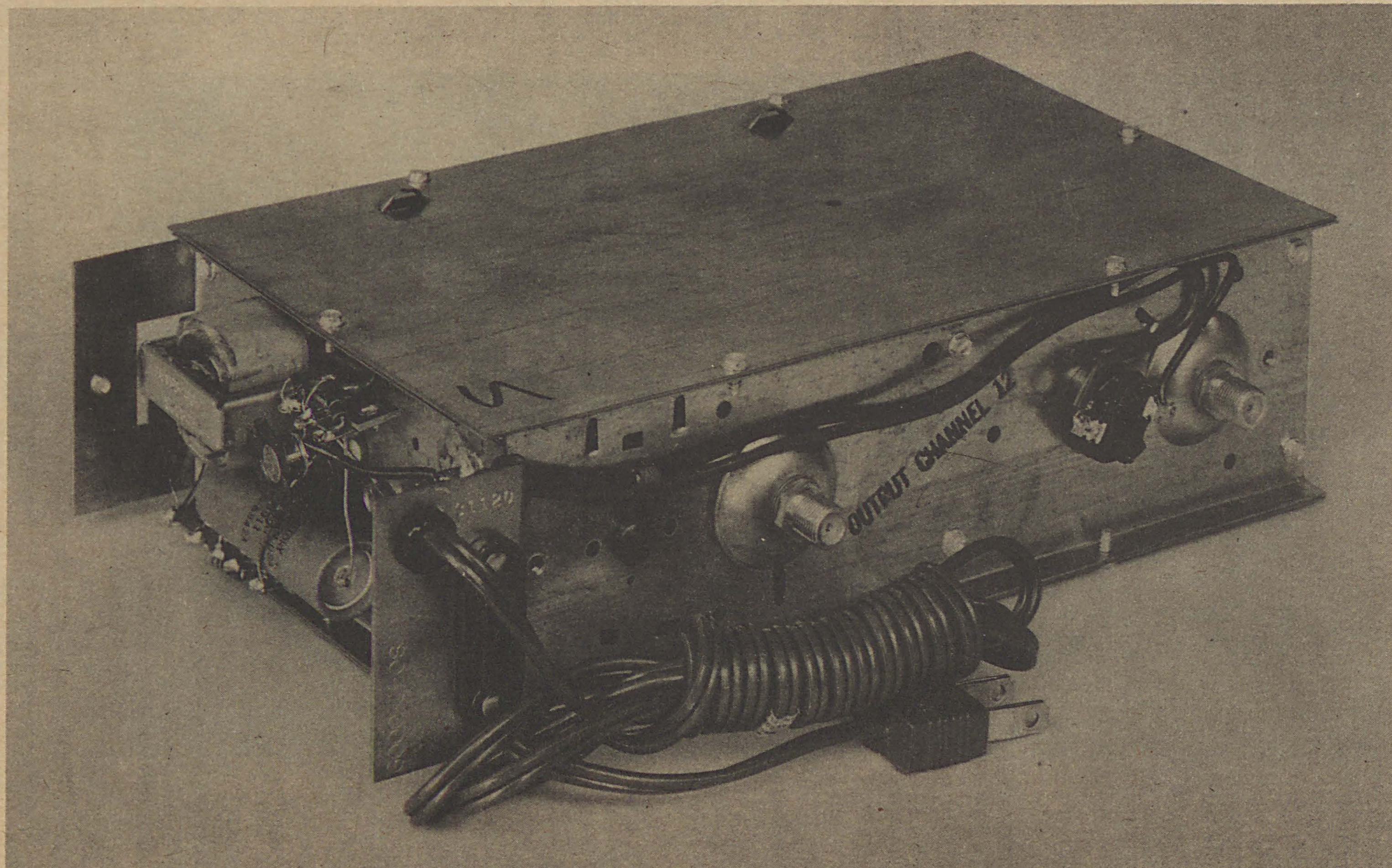


Figure 1. Chassis Construction of the TPI Focus 12 Converter.

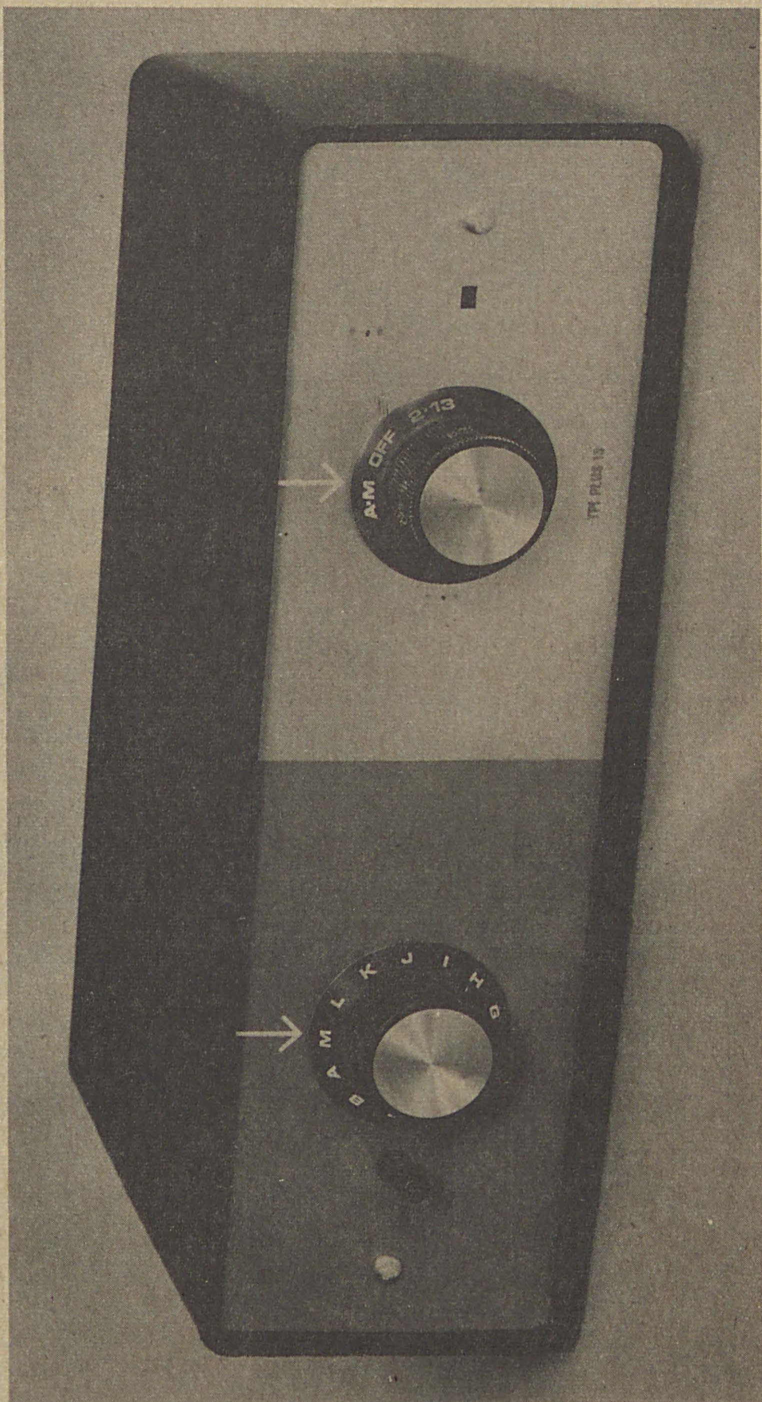


Figure 2. TPI Plus 13 Converter.

FLOYD O. VINCENT

The need for a multichannel system has created the need for a converter. The converter in today's modern systems must accomplish many things in addition to producing more channels. It must be a compatible partner of the cable system.

When I say "compatible partner", I refer not only to today but with an eye to the future expansion and growth of the CATV industry. Right now many persons are busting their brains trying to figure how additional services and, I might add, additional revenue can be utilized by the system and the system operator. It is upon this premise that I say, "Keep your system clean."

The only clean system is a set-top converter. It is an appendage not an integral part; therefore, 2-way communications are still possible all the way from the customer's house. Another point of fact, there are no other parasite frequencies generated in the system. The only other clean system is two cables or systems all the way from the head end.

In the dual cable case, a cursory glance at cost may be illusionary and the costs would be in labor, due to extra care needed to avoid leakage or cross talk between the two systems which would have to be in the order of 60 dB all the way from the head end, plus the fact that a switch would be needed at the customer's set.

Any new devices on the drawing board now or in the future could not possibly be compatible with all the schemes that have been broached forgetting more than 12 channels to the customer; and, if the various schemes I have heard of do take place, we have lost what is now known as the basic system concept and created something which would limit future growth or expansion, except to get more than 12 channels on a one-way path to the customer in which case each system would become a unique entity in itself and components for some would be custom-designed. With no possibility of a future device being compatible with all systems economically or practically, no system or supplier could survive this expense.

The set-top converter does not alter the basic concept of any system now in existence and will not impair its future growth. It will, in fact, enhance the operation of any basic system now operating as far as selectivity, direct-air pickup rejection, and return loss causing ghosts by double travel on lead-in.

The set-top converter has the additional feature of not being exposed to the elements which include high temperature excursions, humidity, and corrosion which should overshadow the fact that it could be stolen or there would be service calls, plus the additional cost factor of producing more than 12 channels any other way.

The set-top converter is the only scheme that will increase the selectivity of the TV set. Any other scheme can only place the frequencies at the right place in the spectrum, and the adjacent channel selectivity will be at the mercy of the TV set. Even a behind-the-TV-set converter cannot do this.

Let me further expand this concept. Any converter, no matter where it is placed in the system, unless the customer tunes it to select his channel, will only place a specific channel at a specific place in the spectrum with equal amplitude, and the TV set alone has the job of selection of this channel while the converter that the customer tunes essentially preselects a channel and therefore has the additional selectivity of the converter and the TV set combined for adjacent channel rejection.

The ideal set-top converter has these additional qualities:

(a) Gain - It has gain which will help to avoid direct-air pick-up problems. No other converter can put this gain on a specific channel of the TV set, the AGC of the set thereby helping to reject a direct-air pick-up channel.

Let me further clarify. While a behind-the-TV-set converter could presumably also have gain it would not have the selectivity plus gain function for adjacent channel selectivity.

This preselect quality would be of necessity if we are going to hit the almost barefoot r-f amplifier of the TV set with a +30 dBmV signal level to avoid crossmod being generated in the r-f amplifier of the TV set.

(b) This converter has a better input match than any standard TV set -- in fact a return loss in the order of 10:1, while most TV sets are in the order of 3:1 or worse. This means that no ghosts can be produced on the input lead-in cable from the tap which could be produced from a poorly matched TV set. How this comes about is, when the TV set has a very poor match and the lead-in cable exceeds 40 to 50 feet, the signal is reflected back up the cable, re-reflected from the tap and back to the TV set, producing a displaced image. With a well-matched intervening converter, this would not be possible. Since the line from the converter to the set is fairly short, no noticeable ghost could be produced there even with a poor TV set match. Let me add here that this feature could also be maintained by a behind-the-set converter.

In addition to the above, the well-designed converter should exhibit the following qualities which would allow it to be coupled to any system and be an asset to same.

(a) Constant gain from 50 to 250 MC

(b) Ability to handle a fairly large input dynamic range -10 to +10

(c) Exhibit a good noise figure

(d) And have output attenuator pads for the sets that have limited AGC

Let's take a look at the system and see what the converter at the set can do or has to do. In the first place the noise power in a 4 MC bandwidth in dB referenced at 1 Milliwatt is -107.57, or 10 log KTB = -107.57 dBm.

On top of this basic number, the system noise figure must be subtracted. For instance 32 amps cascaded with 10 dB noise figure each would yield a 25 dB system noise figure at the output of the 32nd amp.

If we subtract (with all signal levels referenced to dBm)

-107.57	= 10 log KTB
25.00	= Noise figure of 32 amps in cascade
- 82.57	= Effective system noise level
- 48.75	= 0dBmV signal level
33.82	= Signal-to-noise ratio at the set if the set were to

receive an 0dBmV signal level, or 43.82 dB if the set were to receive a +10 signal level.

The above numbers assume no other adverse system conditions like temperature on the cable which is not completely cured with equalizers and AGC. In such case the signal-to-noise ratio is further degraded.

If the amps had been 8 dB noise figures, we would only have increased the signal-to-noise ratio by 2 dB.

Therefore, the signal would have to be at least +10 for an acceptable picture.

Earlier in the system after 16 amps the same signal-to-noise ratio would be achieved with a +7 dBmV signal at the customer's set.

This means that the converter so placed in a system after 16 or 32 amplifiers must be able to handle a +7 to +10 dBmV input signal without saturation in order to preserve the signal-to-noise ratio and not produce crossmods at this signal magnitude.

Most TV sets would be able to handle this plus the converter's gain due to the AGC action within the set; however, the converter's output stages must be able to cope with a +30 dBmV signal linearity.

The converter's gain would have to be fairly constant from channel to channel, otherwise there would be either noise figure or saturation problems. Where the gain dropped, the noise level would raise. Extremely high level excursions would limit in the TV set.

With an ideal signal input level of +10 dBmV and 10 to 20 dB of gain the converter will help suppress most direct-air pick-up problems.

However, if the converter does not receive an adequate S/N ratio, there is no way it, or any device, can recover the S/N ratio. Gain in a converter can only help suppress direct-air pick-up problems, and its noise figure can only help minimize the noise contributed by the converter to the system. No matter what the noise figure of the converter, it cannot recover a degraded signal-to-noise ratio.

Conclusion:

The converter will not only eliminate off-the-air pick-up, but with constant gain across the band will truly give your system a 25-channel capacity.

B. R. CARTER

Advantages of Solid-State Circuitry

The many advantages of solid-state circuitry are commonly known. Among these are low power requirements, low maintenance due to long life of transistors, and small physical size.

The physical size of transistor circuitry lends itself favorably to modular construction. Let us examine the versatility of this type construction.

On Channel Conversion

The simplest requirement of a CATV heterodyne type head-end is an on channel conversion. This requires a down conversion to i-f, an i-f band pass, i-f amplifier with AGC, a standby carrier, up-converter and power supply.

Referring to Figure 1, Channel A is fed to the down converter where it is mixed with the oscillator and converted to an i-f. For on channel conversion, the oscillator is common to both the down converter and up converter. It is then passed through a bandpass filter to the video i-f amplifier where an AGC voltage is developed to control the i-f amplifier. The AGC voltage is also fed back to the down converter in the form of a delay AGC voltage to keep the AGC amplifier in the center of its dynamic range.

A sound trap should be provided in the i-f amplifier to adjust the sound level. The i-f is fed from the i-f amplifier to the up converter where it is mixed with the oscillator frequency and converted back to Channel A.

There should also be a means of switching to a standby carrier when the off-air signal is lost. This can be accomplished by switching between two supply voltages, utilizing a Shmitt trigger to sense the AGC voltage level. When the standby carrier is turned on, signal from the i-f amplifier should be blocked by turning off the output stage. The AGC stages must remain on in order to develop an AGC voltage when the input signal is restored.

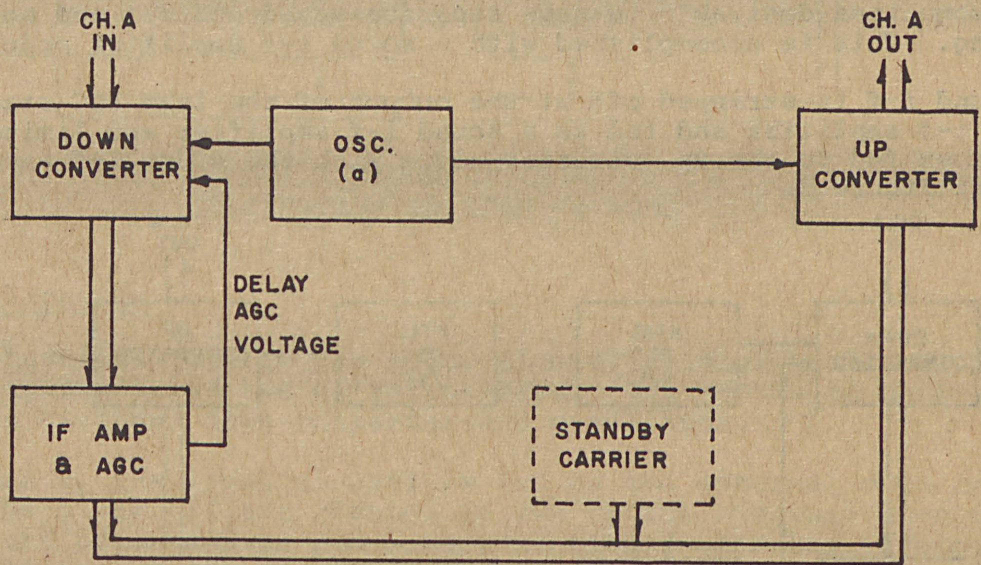


FIGURE 1

ON CHANNEL CONVERSION

Off Channel Conversion

For off channel conversion, (Ch. A. - Ch. B) another crystal controlled oscillator is required to drive the up-converter. (Figure 2)

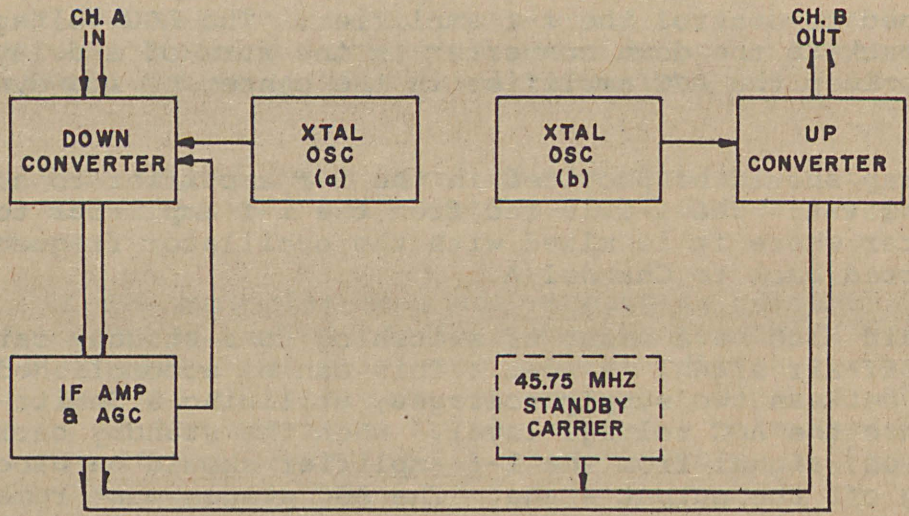


FIGURE 2
OFF CHANNEL CONVERSION

Sound Control

It is sometimes desirable to have separate sound control and sound limiting. This is accomplished with a sound i-f amplifier module.

The sound i-f is stripped off at the output of the last AGC stage in the i-f amplifier and fed to a sound i-f amplifier and limiter. It is then fed to the up converter along with the video i-f as shown in Figure 3.

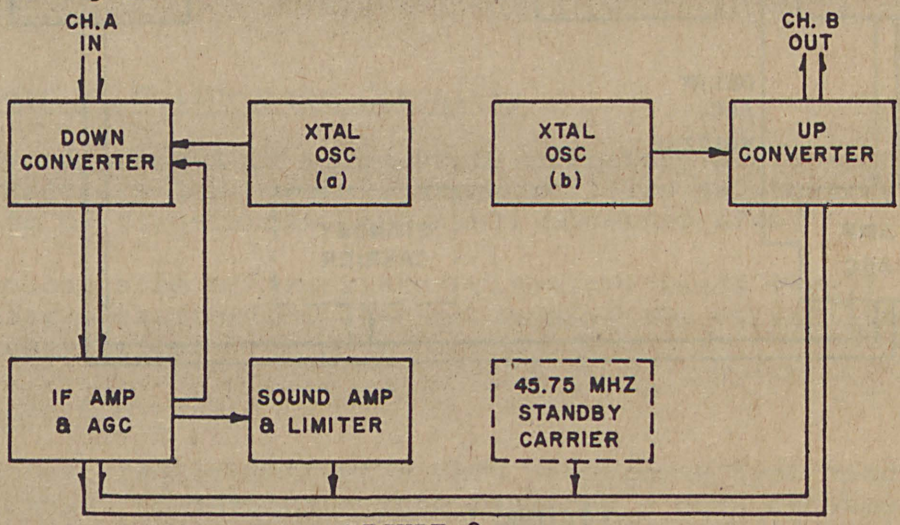


FIGURE 3
SEPARATE SOUND CONTROL

Origination

By adding a video modulator and vestigial side band filter to the standby carrier module, we have the capability of originating video. (Figure 4)

With an addition of an FM modulator to the sound i-f amplifier (Figure 4), we have provisions for local origination in the standby mode of operation. The output of the video i-f amplifier is cut off and the FM modulator and video modulator are enabled. The modulated i-f carriers are fet to the up converter and converted to the desired channel.

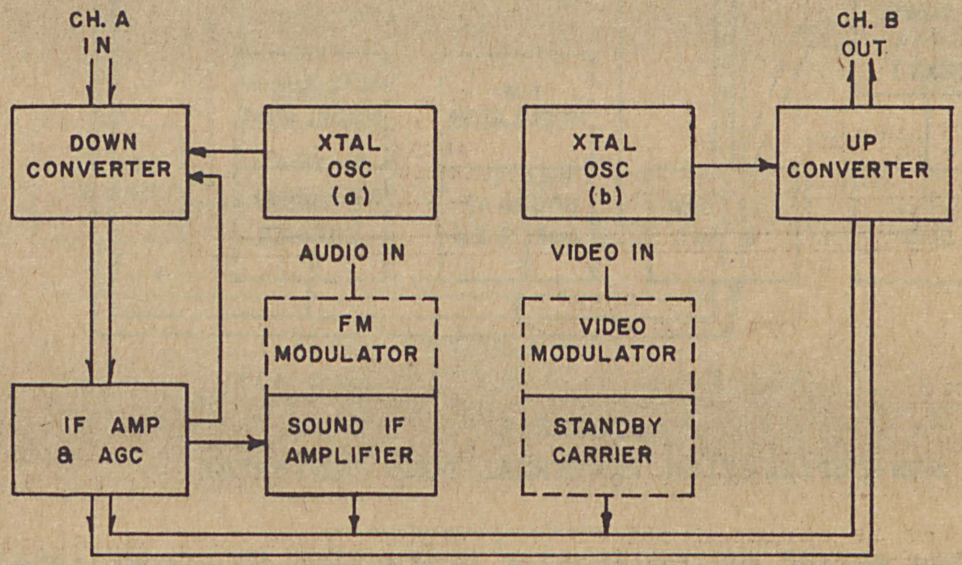


FIGURE 4
ORIGINATION IN STANDBY MODE

Non-duplication

Some situations require the protection of a local station. This can be accomplished two different ways. One way is to have a separate external down converter and oscillator.

In Figure 5, the local channel is fed to the external down converter. The other off-air channel is fed to the internal down converter and processed as previously mentioned when the internal down converter is active.

When the external down converter and oscillator are turned on, the internal down converter and oscillator are turned off.

The i-f is then fed from the external down converter to the i-f amplifier and is processed as previously described.

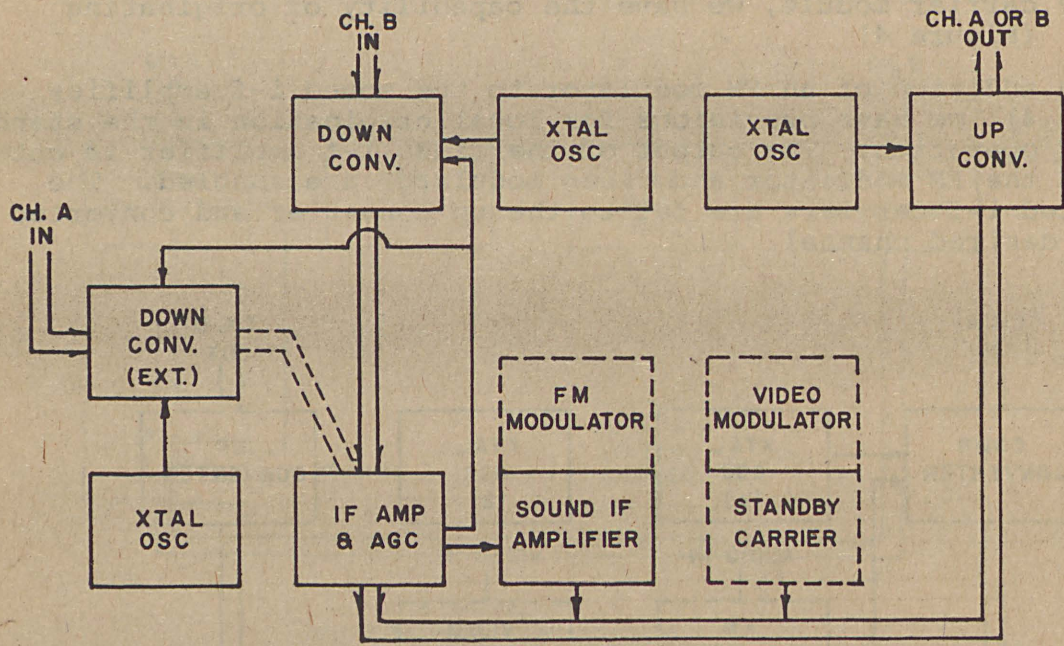


FIGURE 5
NON-DUPLICATION (EXTERNAL DOWN CONVERTER)

An alternate method of duplication protection is accomplished by substituting an i-f amplifier for the standby carrier and feeding the i-f from another head-end unit to the i-f amplifier input as shown in Figure 6. A pad is used to provide isolation between the two i-f's when the units are operating in their normal modes.

When Channel B is switched to standby (Figure 7), the i-f amplifier is enabled and the i-f from Channel A is fed to the up converter of Channel B. Then, when Channel A goes off the air and the standby carrier comes on, it feeds both the Channel A and Channel B up converters.

This switching may be accomplished remotely. This is also useful in situations where an educational channel or some independent channel has a limited broadcast schedule. Rather than having a blank carrier on the channel, another channel can be substituted.

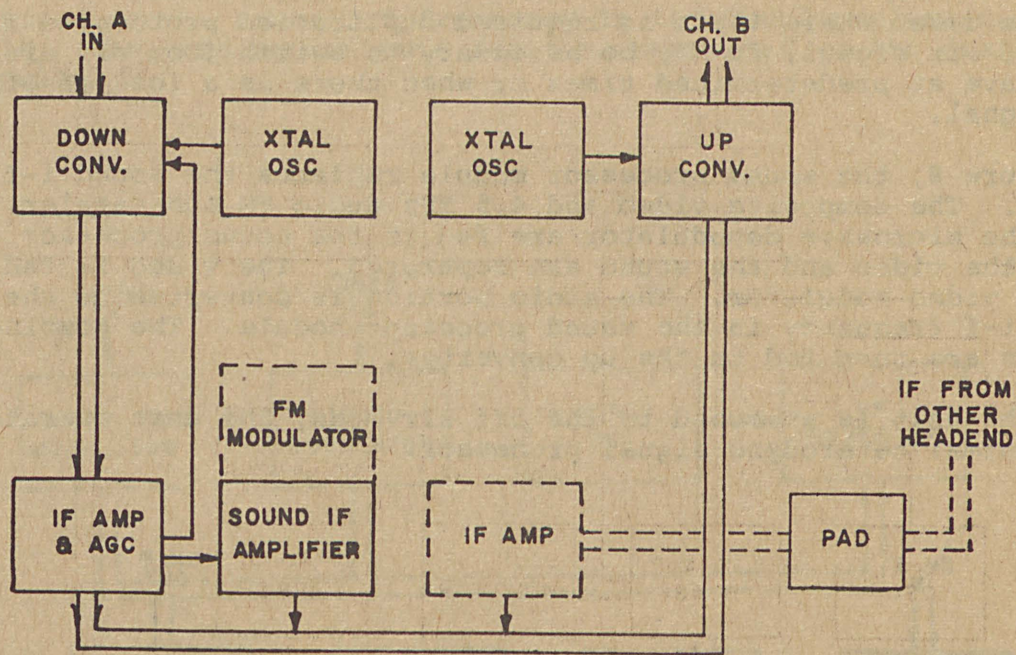


FIGURE 6
NON-DUPLICATION (i-f AMPLIFIER)

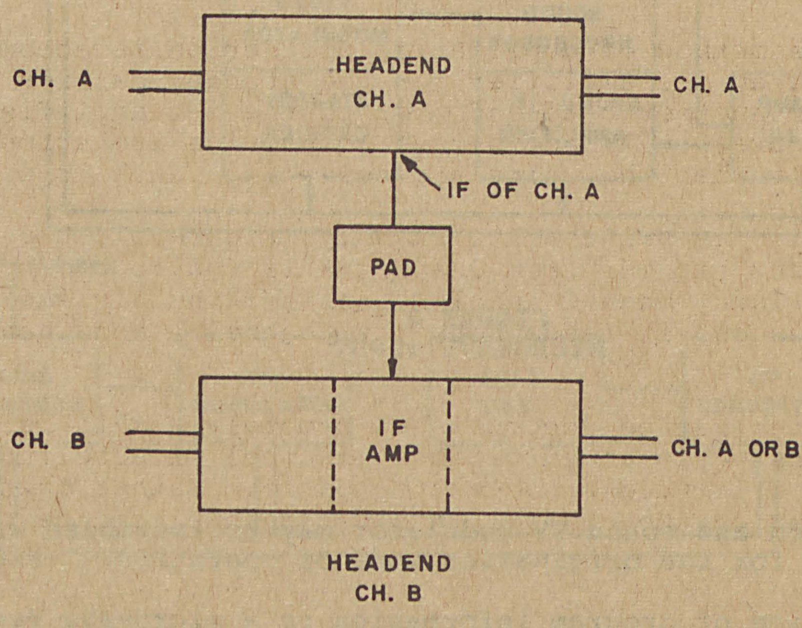


FIGURE 7
NON-DUPLICATION (i-f AMPLIFIER)

Switching From Off Air to Microwave

In some cases where there is required duplication protection from the off air signal, it may be necessary to switch from off air to microwave at predetermined times or when there is a loss of off air signal.

In Figure 8, the sound processor module replaces the sound i-f module. The composite video and 4.5 MHz audio FM sub-carrier from the microwave demodulator are fed to the sound processor where the video and the sound are separated. The video is fed to the video modulator. The audio portion is converted to the sound i-f frequency in the sound processor module. The combined outputs are then fed to the up converter.

When the unit is switched to the off air mode, the unit operates as a normal heterodyne signal processor.

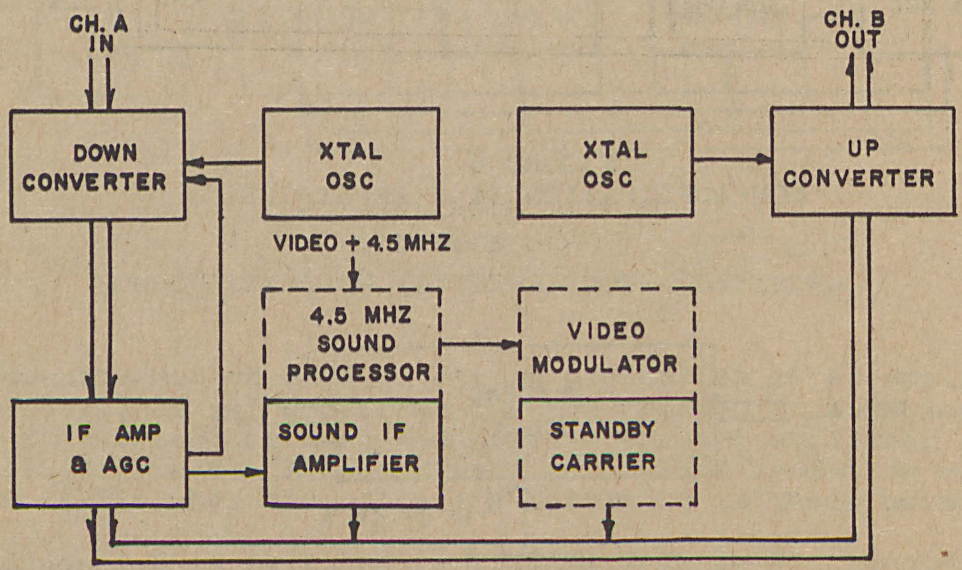


FIGURE 8
MICROWAVE INPUT

TV Modulator

A normal video and sound TV modulator may be assembled with the modules used for the origination mode of operation. (Figure 9)

When the source of program information is a microwave feed, (Figure 10) the composite video and 4.5 MHz audio FM sub-carrier from the microwave de-modulator are fed to the sound processing unit where they are separated. The video is fed to the video modulator where it generates a video i-f. The audio portion is converted to the sound i-f frequency in the sound processing module. The combined outputs are then converted to the desired channel.

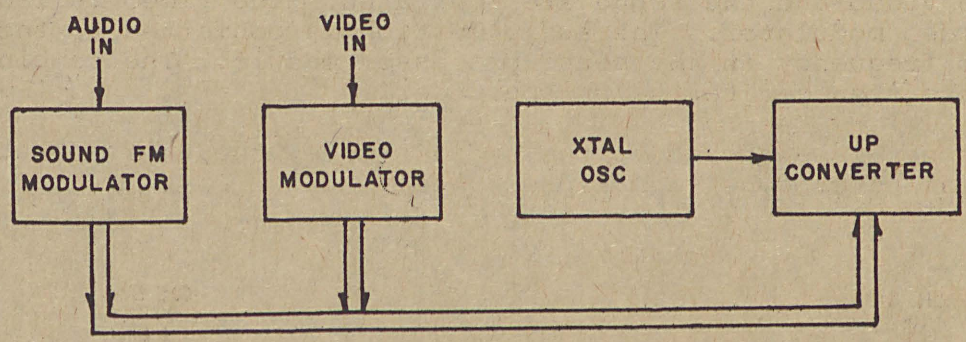


FIGURE 9
TV MODULATOR

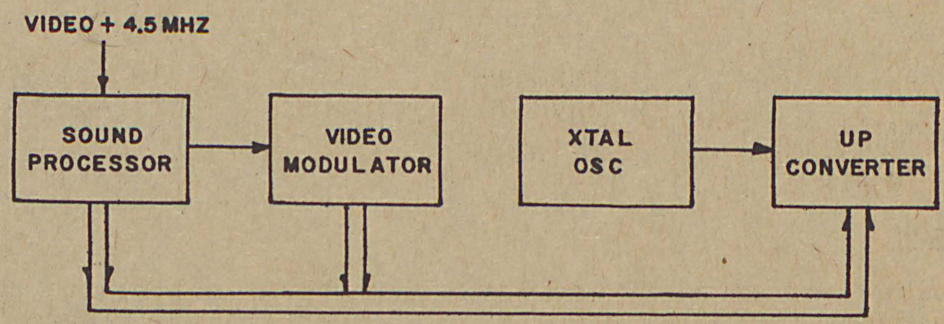


FIGURE 10
TV MODULATOR MICROWAVE FEED