TEMPERATURE, TEMPERATURE DESIGN, AND AUTOMATIC LEVEL CONTROL FOR CATV.

BY

James R. Palmer

SUMMARY

The development of a high-output solid-state amplifier has given new dimensions to CATV transmission system design and operation.[1] The application of such amplifiers to trunk lines is discussed in this paper. The inherent advantages of high-output trunk and bridging amplifiers are analyzed. The environment in which a CATV transmission system operates is examined with particular emphasis on temperature. Automatic level control and its operation with temperature change is explained. The overall result is improved system reliability through a great reduction in the number of amplifiers in the system and through improved level control as a result of better design. An important by-product is a reduction in the cost of electronic equipment.

One table and several definitions given in an earlier paper[1] are reproduced here under the heading, "Objectives and Definitions".

OBJECTIVES AND DEFINITIONS

Transmission Design Objectives
12 Channel CATV System
0-4 mc

	Top Quality
Signal to Noise Ratio (SNR), dB	45
Cross Modulation Index, dB	52
Subscribers Signal Level, dBmV at 75 ohms	0 to 10
Echo Rating, dB	-34 dB
Radiation FCC Sec. 15, Par. 15.161-5	
Hum	-60 dB
Gain Stability:	
Short Term	±0.5 dB
Long Term	±4 dB
Differential Gain	±2 dB
Differential Phase	$\pm 3^o$

	Good Quality	Minimum Acceptable Quality
SNR, dB	38	34
Cross Modulation, dB	49	48

Other specifications are the same as Top Quality.

The following quality grade definitions are those used in the above table. "Fine" is the TASO grade No. 2.

Top Quality. 95% of observers viewing pictures at all parts of the system would rate the Picture Quality as "Fine". At least 80% of observers viewing pictures at the extremity of the system would also rate the Picture Quality as "Fine". The picture is of high quality providing enjoyable viewing. Interference is perceptible.

Good Quality. 85% of observers viewing pictures at all parts of the system would rate the Picture Quality as "Fine".

Minimum Acceptable Quality. 70% of observers connected at all parts of the system would rate the Picture Quality as "Fine".

Two definitions used frequently are:

Tilt. Tilt is the ratio expressed in dB between the signal level of Channel 2 visual carrier relative to Channel 13 (or Channel 6 in five-channel systems). Tilt is positive when Channel 2 is at lower level than Channel 13 (or Channel 6). Tilt refers to signal level.

Slope. Slope is the ratio expressed in dB between the gain of an amplifier at Channel 2 relative to its gain at Channel 13 (or Channel 6). By considering attenuation as negative gain, the definition may also be applied to cable or other passive devices. Slope is positive when the gain at Channel 2 is less than at Channel 13 (or channel 6); and is negative for coaxial cable. Amplifiers are generally operated with a slope complementing the slope of the cable span with which it is associated. Slope refers to component of cable characteristics.

TEMPERATURE

In designing a CATV system it is essential to determine the environment in which the system is to operate. The environment has many components, including moisture and precipitation, corrosive elements such as gas and salt water, vibration, and temperature variations. Of these components, only temperature variation is considered in this paper.

Temperature extremes for nine different locations in the United States are shown in Table I, which incorporates maximum and minimum temperature data for the total number of years that the weather bureau stations have been in operation, as well as for a recent ten year period. The temperature ranges shown are for the full year and also for Summer and Winter. This kind of temperature data should be studied by the system designer and the specifying engineer whenever a new CATV system is contemplated.

If a system is designed to truly take care of temperature variations on a year-in and year-out basis, the resulting cost and complexity for, say, Greeley, Colorado, gives a system that definitely overperforms for Seattle, Washington. However, if a system is designed that will take care of

Seattle, Washington, throughout the entire year, it would also take care of Prescott, Arizona, if that system were adjusted twice a year, once for Summer and once for Winter. Temperature statistics are available at the local weather bureau office and should be referred to for the installation of quality television cable systems.

TABLE I

MAXIMUM AND MINIMUM TEMPERATURES, °F

LOCATION	PERIOD YEARS	YEAR HIGH	YEAR LOW	YEAR RANGE	SUMMER * HIGH	SUMMER * LOW	SUMMER * RANGE	WINTER * HIGH	WINTER * LOW	WINTER * RANGE
Prescott, Arizona	64	105	-21	126	105	13	92	87	-21	108
	10	100	- 5	105	100	22	78	83	- 5	88
Fairbanks, Alaska	18	93	-59	152	93	-21	114	74	-59	133
	10	93	-56	149	93	-19	112	74	-56	130
Los Angeles, Calif.	83	110	28	82	110	40	70	100	28	72
	10	110	32	78	110	46	64	96	32	64
Greeley, Colorado +	64	107	-45	152	107	- 8	115	84	-45	129
	10	106	-39	145	106	0	106	79	-39	118
St. Augustine, Fla.	68	104	13	91	104	37	67	93	13	80
	9	102	22	80	102	38	64	93	22	71
Kearney, Nebraska o	66	114	-34	148	114	0	114	95	-34	129
	10	113	-21	133	113	15	98	93	-21	114
Keene, N.H. +	68	104	-32	136	104	1	103	85	-32	117
	10	102	31	133	102	13	89	76	-31	107
State College, Pa. +	73	102	-20	122	102	1	101	86	-20	106
	10	98	- 4	102	98	18	80	74	- 4	78
Seattle, Washington +	70	100	3	97	100	29	71	81	3	78
	10	100	13	87	100	35	65	67	13	54

* Summer, May through October; Winter, November through April, unless noted otherwise.
\+ Summer, April through October; Winter, November through March.
o Summer, April through September; Winter, October through March.

TRUNK SYSTEM DESIGN

The important performance criteria affecting the trunk system design are signal-to-noise ratio (SNR) and cross-modulation (Cross-mod). These two characteristics relate to the input and output capabilities of the amplifier. Another important factor interrelated between system design and equipment design is the system length. It has been shown[1] that different amplifier gains should be selected depending on the length of the system. For this reason, C-COR Electronics offers three different models of trunk amplifiers, with gains of 40, 34, and 28 dB, to provide for the different sized systems. Guidelines for selecting these amplifiers as a function of trunk length for various types of coaxial cables are given in Table II.

Transmission characteristics for these amplifiers are shown in Table III.

TABLE II

Amplifier Model	Gain dB	No. of Amps. Cascaded	Total dB	Trunk Length--Miles 1/2" Alum.	3/4" Alum.	0.375 P
TA-40	40	16	640	9.3	13.0	11.0
TA-34	34	32	1090	15.8	22.2	18.8
TA-28	28	64	1800	26.1	36.3	31.0

TABLE III

SPECIFICATIONS FOR TRUNK AMPLIFIERS

OUTPUT: (NCTA Standard) 58 dBmV output level for 12 TV channels at rated gain and full tilt.

RECOMMENDED OPERATION:

AMPLIFIERS	Model TA-28	Model TA-34	Model TA-40
Cascaded, Max. Number	64	32	16
Output level, Channel 13	40 dBmV	43 dBmV	46 dBmV
Amp. Spacing/Operational Gain	28 dB	34 dB	40 dB
Noise Figure			
Channel 13	8 dB	8 dB	8 dB
Channel 2	10 dB	10 dB	8 dB
MANUAL GAIN CONTROL RANGE:	4 dB	4 dB	4 dB

(0, 3, and 6 dB pads available)

AUTOMATIC LEVEL CONTROL: Range is ± 3 dB
Control is ± .5 dB for ± 3 dB input change and includes automatic tilt control. Utilizes Channel 13 picture carrier or pilot carrier.

SLOPE CONTROL RANGE:	22 - 28 dB	28 - 34 dB	34 - 40 dB

Specified as cable length in dB at Channel 13

BANDPASS: 54 - 216 MHz -- ± 0.25 dB

IMPEDANCE: 75 ohms

RETURN LOSS: 16 dB (VSWR 1.38 max.)

HUM MODULATION: -60 dB

TEMPERATURE RANGE: -40°F to 140°F. Unit meets all specifications throughout the temperature range.

POWER: 20 to 32 VAC cable powered.

TAP	OPERATING VOLTAGE	CURRENT
24V	20 - 26	1.3 A
28V	24 - 30	1.2 A
32V	28 - 33	1.1 A

TEST POINTS: DC Volts, ALC Voltage, RF input and output for measurements with high impedance probe TP-30. (not supplied)

BRIDGER OUTPUT: Output to feed bridger -20/-39 down 20 dB at Channel 2, 34 dB at Channel 13. Equalized to provide +6 dB tilt to bridger.

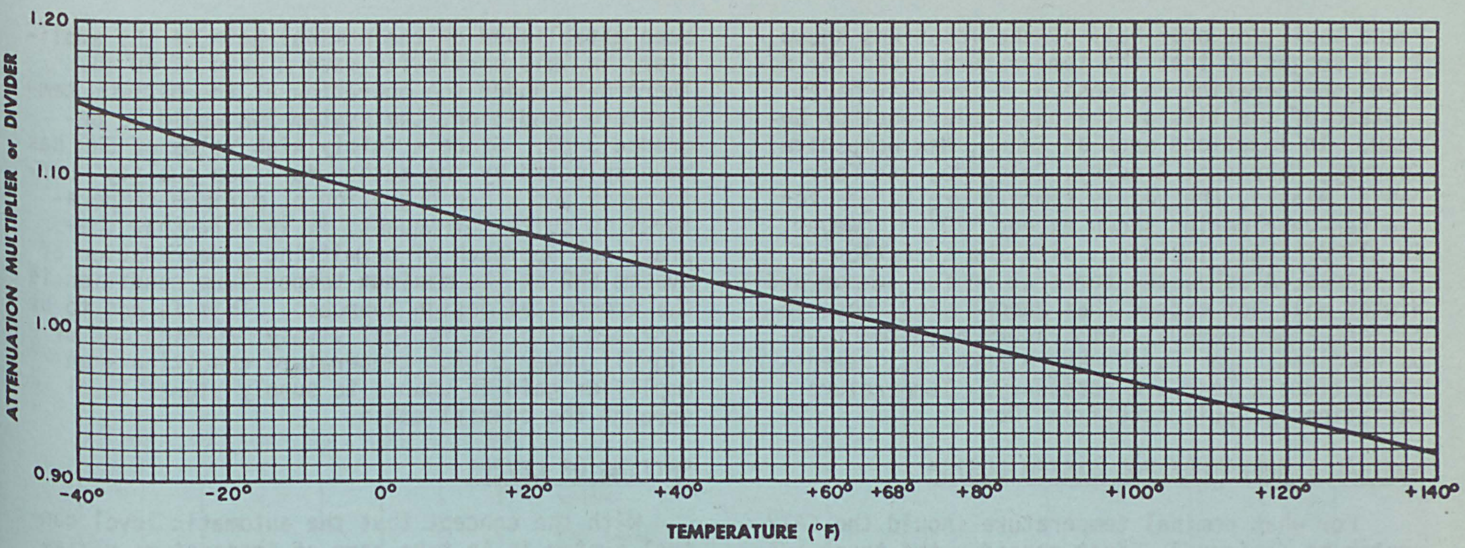
With the high output and low noise of the trunk amplifiers shown in Table III it becomes logical to use a part of this increased dynamic range as increased gain. With the use of a 40 dB gain trunk amplifier instead of a 22 dB gain unit, the reduction in the number of trunk amplifiers is highly significant, approximately 45%. Attendant savings in equipment costs and maintenance costs are readily apparent.

It is estimated that over half of the CATV systems can utilize the 40 dB gain trunk amplifier. These are systems that have maximum trunk lengths of 13 miles of 3/4" aluminum coaxial cable. Contemplated operations in New York City will utilize short trunk lengths from multiple antenna sites. Acceptance and licensing of the 18 GHz microwave service will accentuate this trend. In many metropolitan areas, multiple franchises have been given for different areas of the city--Philadelphia, for instance. In suburban areas contiguous to and a part of a metropolitan area, the fact that adjacent political subdivisions grant franchises to different companies precludes long trunk lengths. Why then, should these situations be saddled with a trunk amplifier that was designed to go a much greater distance?

The equipment designer has considerably more flexibility in the design of a high-gain amplifier than he does in the design of a low-gain amplifier. In the multistage amplifier, the multiple interstage networks can be used for equalization and automatic level control. Solid state devices with high output inherently have higher noise levels than low level devices. To be able to separate an input stage from an output stage with other stages gives the designer the latitude to select a low-noise, low-level input transistor at the input and a high-level output device at the output of the unit without one device affecting the other device to any marked degree.

TEMPERATURE DESIGN, TRUNK SYSTEM

Barring an accident and assuming good design, the only thing to change the signal level in a CATV transmission system is temperature. This, of course, assumes that the signals at the antenna site delivered to the transmission system are stabilized through the necessary equipment. Further, it assumes that the power voltage supplied to the amplifier is regulated and that transistors are reliable and do not fall off in gain as they age.



To correct attenuation to 68°F, use figures at left as multiplier. For example: 2db @ 100°F is known factor. To calculate attenuation @ 68°F, locate 100°F at bottom of chart, follow 100°F line to point of intersection with curve, move left to obtain multiplier of .96. 2 db x .96 equals 1.92 db @ 68°F.

When attenuation @ 68°F is known, use figures at left as divider to calculate attenuation at other temperatures. For example: 2 db @ 68°F is known factor. To calculate attenuation @ 120°F, locate 120°F at bottom of chart, follow 120°F line to point of intersection with curve, move left to obtain divider of .94. 2 db divided by .94 equals 2.13 db @ 120°F.

(Copper loss correction only; assuming dielectric losses constant with temperature)

FIGURE 1 ATTENUATION TEMPERATURE CORRECTION FACTOR

Temperature causes the loss in the coaxial cable to vary. Curves showing the coaxial cable attenuation temperature correction factor are given in Figure 1. In addition, the amplifiers themselves may have a variation in gain with temperature, although the designer attempts to eliminate or minimize this variation. An automatic level control system, therefore, should be designed to take care of temperature variation. Such a system will also tend to take care of "accidents" if they should occur. These will not be designed for, however, since they are of an unpredictable nature.

An intermediate design goal is to hold signal levels constant. (The primary design goal is to deliver good pictures to the subscribers all of the time). If levels are too low at an amplifier input the pictures go into the snow (system SNR is reduced). If amplifier output levels are too high the picture shows windshield wiper effects of cross-modulation. Without some sort of control system, temperature fluctuations will cause snowy pictures in hot weather and "cross in the pictures" in cold weather. An automatic level control system is therefore desirable to hold signal levels at the output of an amplifier at a constant value.

In order to effect signal level control it is desirable to utilize a closed loop control system adjusting the gain of the amplifier. The output signal level is sensed, referred to a reference and adjusted. Some systems utilize a system that senses a temperature and attempts to make a proportional adjustment based on that temperature change. This is an open loop control system. However, it is logical that the signal level itself should be measured and controlled since this is the desired goal. Since the temperature change causes the greatest variation at the highest frequency, the highest frequency signal should be used as a yardstick to control the level. The logical selection is Channel 13 picture carrier (with a standby oscillator at the antenna site) as the pilot signal for automatic level control operation. Further, since the temperature effects on the coaxial cable produce twice the dB change at Channel 13 as at Channel 2, the automatic gain function should change 2 dB at Channel 13 for every 1 dB at Channel 2. Any residual errors in the slope can be adjusted manually on a seasonal basis.

It has been found practical and economical to design an automatic level control system with C-COR's Model TA series amplifiers with a range of ±3 dB. With the Model TA-40 and with cable spacing of 40 dB, this ±3 dB range will accommodate 120°F temperature range (±60°F). With the Model TA-34 and the TA-28, with ±3 dB ALC range, the temperature ranges are ±70°F and ±80°F.

With reference to the maximum and minimum temperature chart of Table I a range of 120°F can accommodate the temperature variations on a yearround basis for over half of the locations shown. It is suggested that the temperatures used for design consideration be those of a ten-year period instead of the life of the particular weather bureau. In locations such as Keane, New Hampshire; Kearney, Nebraska; Greeley, Colorado, and Fairbanks, Alaska, the yearly temperature ranges for the ten-year period shown exceed 120°. However, in all of these locations with the exception of Fairbanks, Alaska, the temperature for Summer and Winter will not exceed that range. For these locations a semi-annual temperature adjustment will be required. For Fairbanks, Alaska, adjustments three times a year are necessary. Temperature variation in April itself is 106°.

NOMINAL TEMPERATURE FOR SYSTEM DESIGN

For what nominal temperature should the CATV system be designed? First consider the trunk system and more specifically a system using the Model TA-40 trunk amplifier. This amplifier has a nominal 40 dB gain for 40 dB cable spacing. The automatic level control has a rated control range of ±3 dB. The amplifier meets all of its performance specifications at the limits of the ALC operation, 37 dB and 43 dB gain. It is necessary to have sufficient gain so that the signal level does not get progressively lower under hhe maximum temperature conditions. We could, therefore, design with 43 dB of gain and 43 dB of cable spacing at the maximum temperature. The level control range of ±3 dB corresponds to ±60°F of cable attenuation change at 216 MHz. A 70°F ambient with ±60°F change gives temperature extremes of 10°F to 130°F. Since 130°F is almost always a maximum design temperature, one can design with the nominal gain and the temperature at a nominal ambient of 70°F.

The author believes that this is a satisfactory design approach. There is one limitation, however. The system design criteria for SNR have been established on the nominal gain of the amplifier, in this particular case a gain of 40 dB. Therefore, under the operation at the maximum temperature condition, the system SNR would be degraded 3 dB. Since a fairly high value of SNR has been selected by the author for "top quality" performance and since operation at maximum temperatures is quite infrequent, it is felt that the practical approach of permitting a degradation of system SNR at the maximum temperature condition is the economical design approach. This is not to be confused with the typical simply "running out of signal" under a high temperature condition when amplifier gain is unable to supply signal level through the coaxial cable.

SETTING OF LEVELS

With the concept that the automatic level control system is to take care of temperature variations, the level control operating position must be set in the field as a function of temperature. If it is desired to have the ALC function over a temperature range of 10 to 130°F then the ALC operating point must be adjusted so that it is at one extremity of its control range at 130°F and at the other extremity at 10°F. The manufacturer must provide the service technician with a temperature-ALC setting chart so that the technician, upon checking the ambient temperature, will set the level control system operating point at the correct point.

FEEDER SYSTEM DESIGN

The high-output bridging amplifier operational characteristics are shown in Table IV.

TABLE IV

SPECIFICATIONS FOR BRIDGING AMPLIFIERS

Models BA-2 & BA-4

OUTPUT: (at each output port) (NCTA Standard) 53 dBmV output level for Model BA-2 and 50 dBmV output level for Model BA-4 for 12 TV Channels with 12 dB output tilt at maximum gain and 0 dB slope.
GAIN: BA-2 -- 42 dB, BA-4 -- 40 dB typical. 40 dB and 38 dB guaranteed minimum @ channel 13 with gain control at maximum.
GAIN CONTROL RANGE: 4 dB continuous, 0, 3, 6, 9 and 12 dB pads available. (Zero dB pad supplied).
BANDPASS: 54 - 216 MHz ±0.5 dB
ISOLATION BETWEEN OUTPUT PORTS: 20 dB minimum
IMPEDANCE: 75 ohms
RETURN LOSS: 16 dB (VSWR 1.38) all ports
TEMPERATURE RANGE: -40°F to 140°F
Temperature compensation provides stabilization of gain to better than ± 1 dB over total temperature range. Unit meets all specifications throughout the temperature range.
HUM MODULATION: -60 dB
POWER: Full isolation "power saver" tapped transformer.

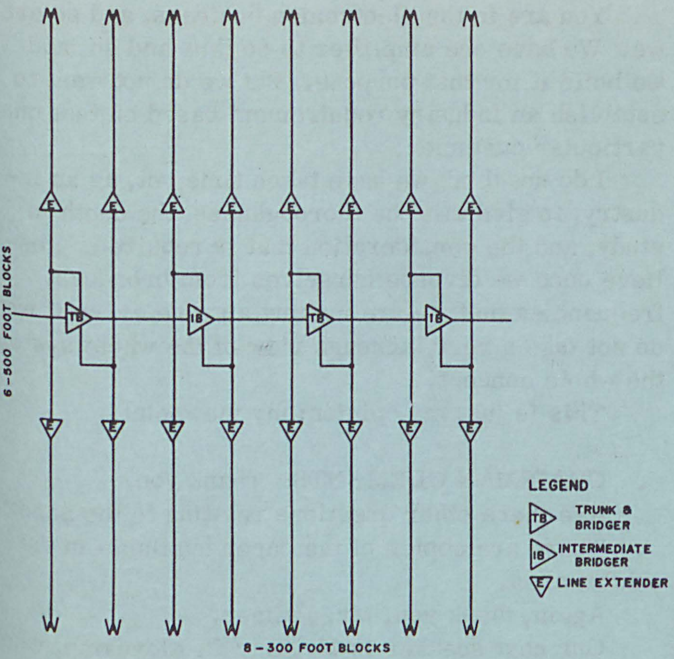


FIGURE 2 CONVENTIONAL 22 dB GAIN AMPLIFIER

The output of 53 dBmV for each port of a two-port bridger or 50 dBmV for each port of a four-port bridger allows feeder lengths over 40% longer than were previously possible (without line extender amplifiers). In fact, the high-output bridger has greatly reduced the number of line extender amplifiers necessary in a system and as a result has concentrated more of the amplification at fewer locations, resulting in easier maintenance and higher reliability.

Therefore, it is extremely important that the bridging amplifier itself have a gain-temperature characteristic that does not aggravate the situation. With C-COR bridging amplifiers, the gain-temperature characteristic is flat. With the bridger output (operational) of 47 dBmV (each of 4 ports) and the resulting long feeder lengths, temperature variations in the typical situation nal level variations in the typical situation at the end of the feeder of ±1.5 dB to 2 dB. It is felt that this range can be adequately taken care of with the AGC of the television receiver itself, particularly since the design criterion has limited signal level variation at the receiver of 0 to 10 dBmV under nominal conditions. However, it is readily apparent that another 2 dB change due to bridging amplifier gain change may aggravate the situation to the point of causing picture degradation.

TYPICAL SYSTEM LAYOUTS

Two systems layouts are displayed in Figures 2 and 3 showing an idealized section of a system. The system shown in Figure 2 utilizes conventional 22 dB gain amplifiers. The system shown in Figure 3 utilizes C-COR's high-output trunk and bridging amplifiers. For a forty block area

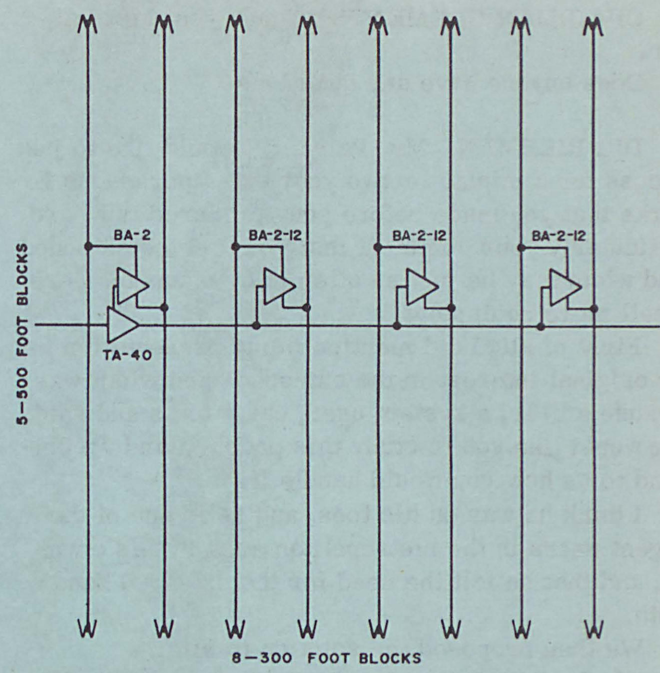


FIGURE 3 C-COR SYSTEM

C-COR uses five amplifiers while the 22 dB system uses sixteen amplifiers. In this case the cost reduction for amplification is 25%.

CONCLUSIONS

A considerable reduction in amplifiers can be made in a CATV system utilizing high-output units. System costs are also lower. An automatic level control system utilizing a closed loop control system results in higher quality performance. Careful consideration of temperature is important in good CATV system design.

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1 Palmer, James R., "CATV System Design Philosophy and Performance Criteria as the Basis for Specifying Equipment Components", Paper presented at the 16th Annual Broadcast Symposium, I.E.E.E. Group on Broadcasting, Washington, D.C., September, 1966.

CHAIRMAN CLEMENTS: Thank you, Mr. Palmer.

Does anyone have any questions?

DR. RIEBMAN: Mr. Palmer, I would like to just discuss for a minute or two your extemporaneous remarks that you made before your prepared talk, and particularly your comment that you feel the extended band width may be just an attempt by manufacturers to sell more equipment.

First of all, I did mention in my presentation that our original interest in the extended band width was because a user, a system user, came to us and said, "We would like you to study this problem and recommend to us how you would handle it."

I think he was on his toes, and he is one of the largest users in the metropolitan area in this country, and that he felt the need for the extended band width.

We then proposed the solution to him.

I feel the manufacturer has a responsibility to his customers to look ahead and try to make his equipment compatible with what future needs might be, and several questions came from the floor about the concern of, "Are we going to buy equipment now and then next year have to replace it?"

Our company, AEL, is making an effort, every effort that we humanly can, to protect our customers against obsolescence. In fact, we are trying to make our equipment compatible with future expected needs. We are recommending for the future.

We are indicating that 300 megacycle cable should be utilized now. It costs you nothing. We have made our system modular. I think we have pioneered the modular concept for the very purpose of minimizing the cost in changing the system in the future.

Rather than be criticized I think we should be commended for trying to help the users and save them future expense.

Now I would just like to raise a question to you in these metropolitan areas, which I think are concerned with this problem first, although it is spreading all over the country. What is your answer to the difficulty of how to attract a subscriber who can already get nearly 12 or more than 12 channels off the air; or 12 channels?

MR. PALMER: I agree with you that we ought to install coaxial cable that goes up to 300 megacycles.

For the rest of your comment, all I can say is that I disagree with you for the reasons I have stated. I just, pure and simple, do not agree. I think it is wrong to take the solution to a particular problem for a particular customer, and offer it as an industry solution.

You are in the electronics business, and so are we. We have one amplifier to do thus and so, and we build it for that purpose. But we do not want to establish an industry requirement based on that one particular customer.

I do not think we have taken time yet, as an industry, to give this the thoroughness, the depth in study, and the consideration that is required. I believe once we divorce ourselves from broadcast frequencies that we are making a grave error if we do not take a very thorough view of the whole system, the whole concept.

This is just my opinion; my viewpoint.

CHAIRMAN CLEMENTS: Thank you.

Are there other questions relating to the paper?

There are copies of the paper available in the exhibit area.

Again, thank you, Mr. Palmer.

Our next speaker is Mr. Gay C. Kleycamp, who is going to address us on the subject of MID-BAND USE IN CATV SYSTEMS. (KAISER CATV)

Mr. Kleycamp. (Applause)

MID-BAND USE IN CATV SYSTEMS

BY

GAY C. KLEYKAMP

INTRODUCTION

This is a report on a series of tests and simulated as well as actual CATV system operation with the application of additional TV channels in the 120 to 175 MHz frequency spectrum. This region is generally referred to as the "mid-band". Standard production unmodified Phoenician Series trunk line amplifiers (KAISER Model Nos. KGAA and KGMA) were used with normal 22 dB spacing.

In assigning the frequencies for the various mid-band channels, it was considered practical to use 6 MHz separation between each of the video carriers with the lowest mid-band channel (Channel "A") at 121.25 MHz. No attempt was made to use mid-band frequencies above 157.25 MHz (Channel "G") in order to avoid interference with the 166.5 MHz pilot carrier used in the KAISER equipment. The lower frequency limitation of 121.25 MHz was selected in order to avoid any possibility of interference with aircraft navigational radio devices.

LABORATORY TESTS

All KAISER Phoenician Series amplifiers are tested for a +50 dBmV, 12-channel plus pilot carrier