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

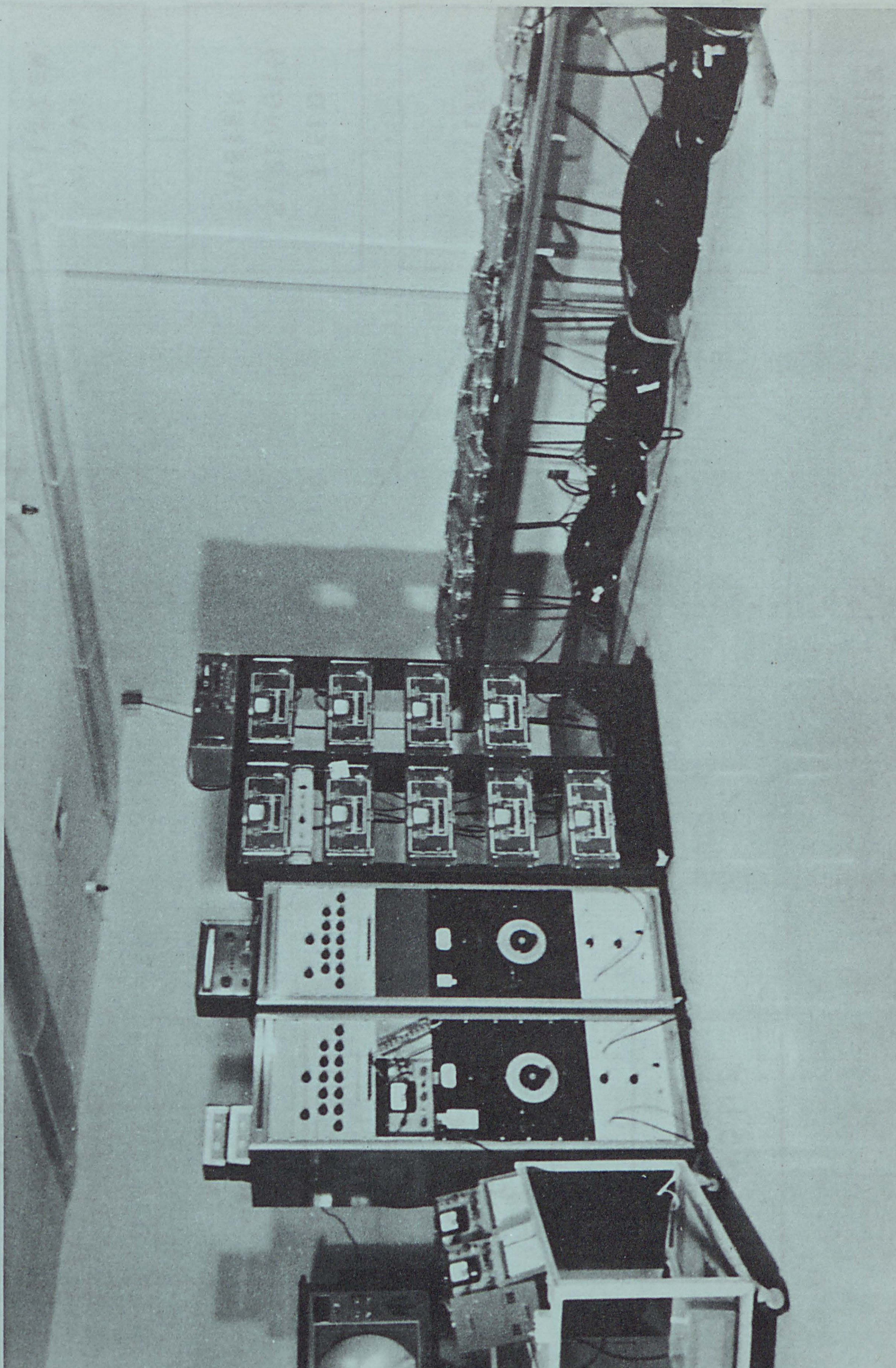


FIGURE 1 - LABORATORY TEST SET-UP

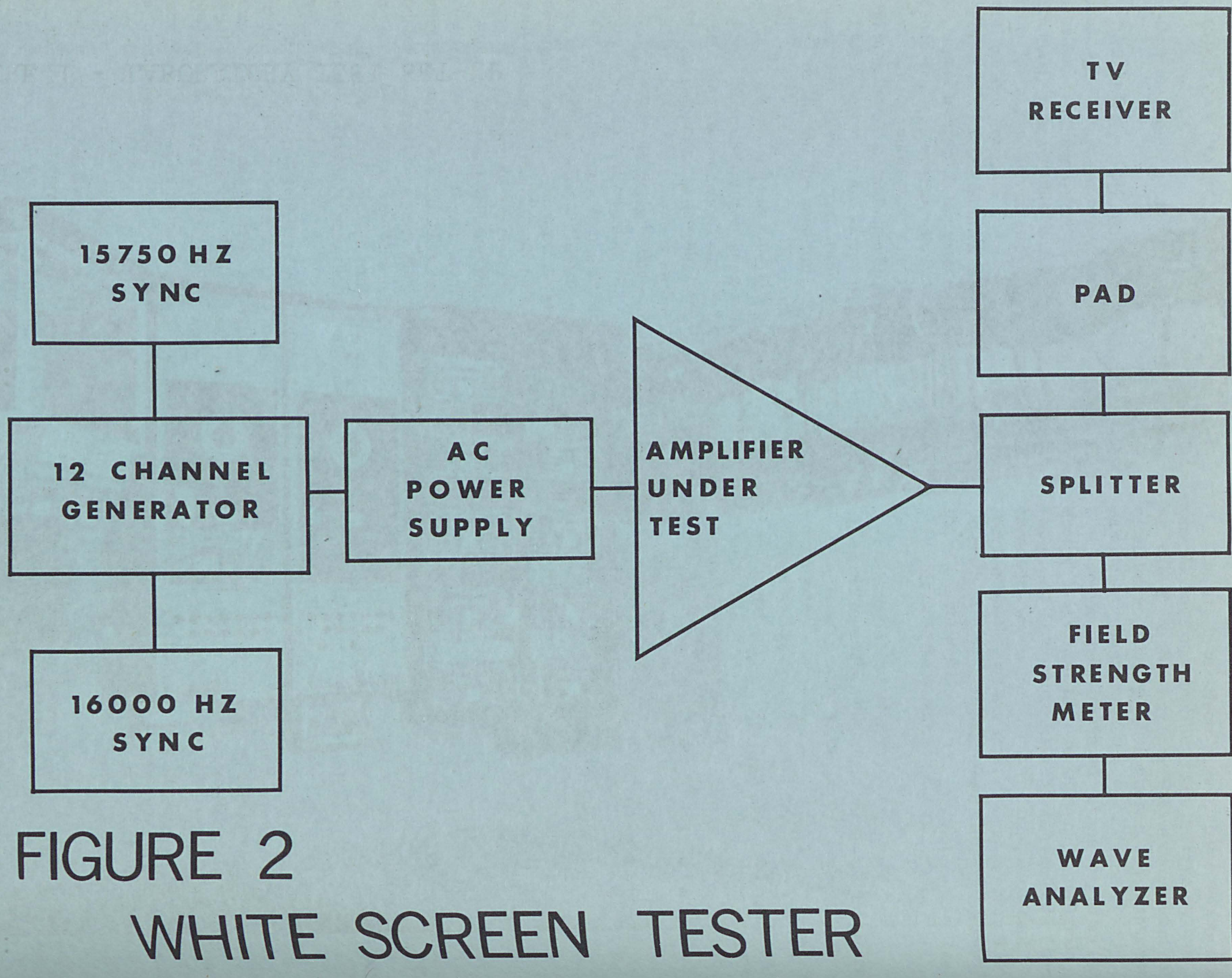
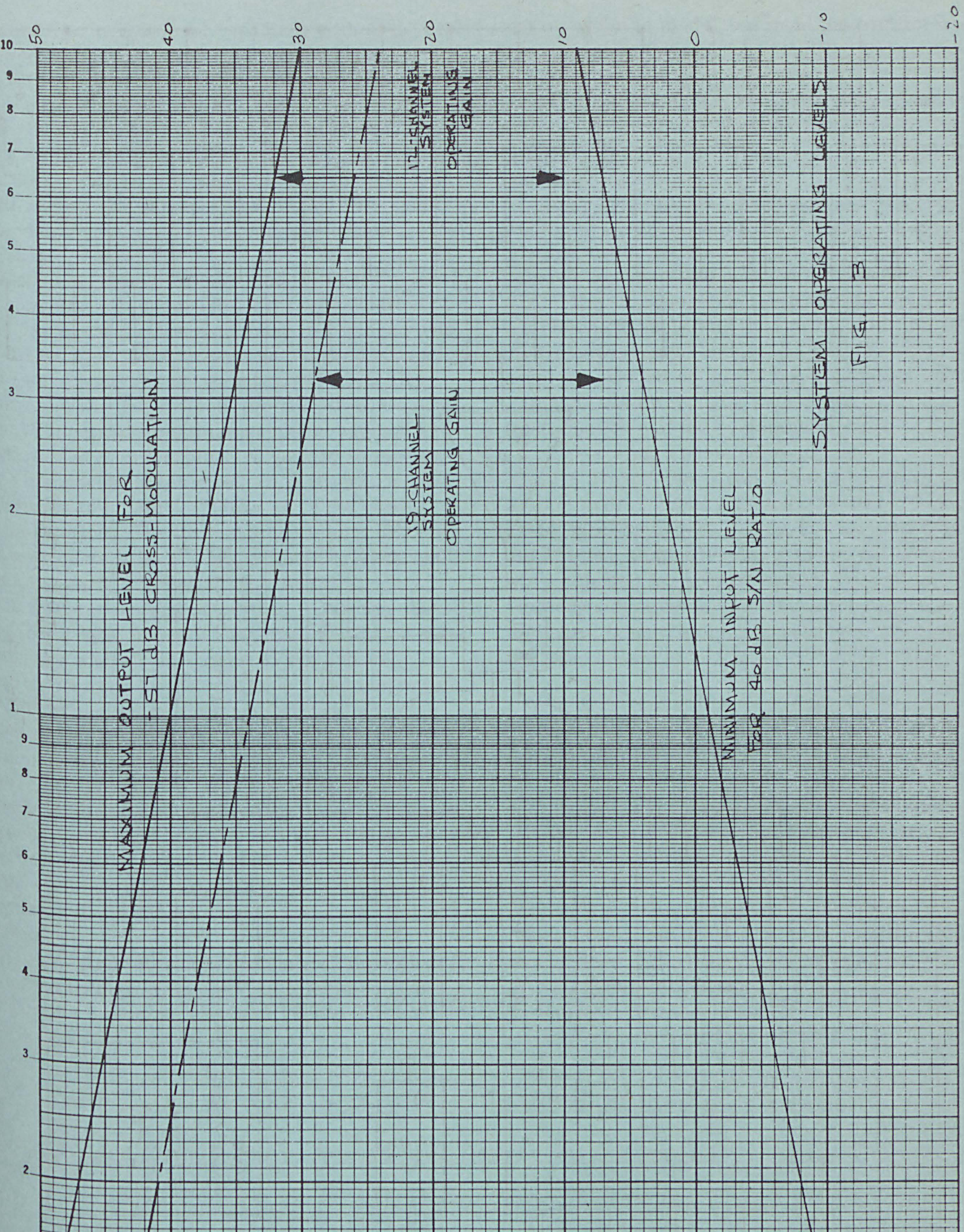
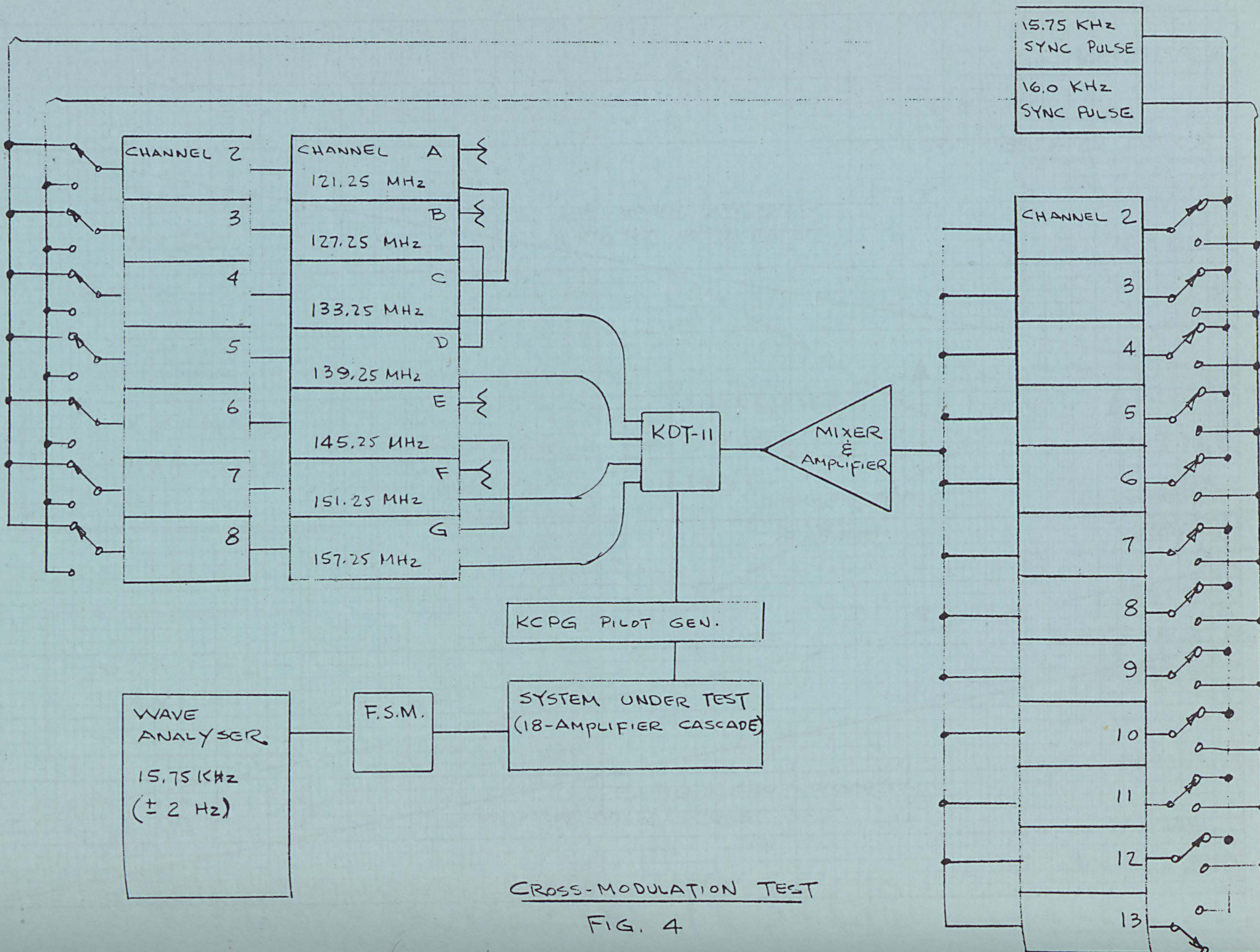


FIGURE 2
WHITE SCREEN TESTER



SYSTEM OPERATING LEVELS

FIG. 3



CROSS-MODULATION TEST

FIG. 4

single amplifier output level capability with a -57 dB cross-modulation indicated on all channels, minimum. The KAISER "White Screen Tester" (see Figure Nos. 1 & 2) is used in these tests.

The "White Screen" tester delivers signals that are very similar to standard television signals. These signals consist of the various video carrier frequencies with twelve (12) microsecond 15.750 KHz sync pulse modulation on a white screen level video modulation (85% ± 5% down from sync tip). The twelve (12) microsecond horizontal synch pulse is synchronous in all channels. For measuring cross-modulation on a particular channel, this sync pulse is replaced with a 16.000 KHz sync pulse on only the desired channel.

The wave analyzer is tuned to the 15.750 KHz frequency and will not indicate the 16.000 KHz modulation have identical rise time and pulse width characteristics, and it is therefore necessary to measure only one component of the modulation frequency spectrum in order to obtain an indication of the actual cross-modulation. The fundamental (15.750 KHz) is used inasmuch as it is of the greatest amplitude and provides the best-plus-noise to noise ratio.

It is well recognized in the CATV industry that the horizontal sync pulse of undesired television signals causes a significant portion of the cross-modulation detected by the viewer of a television receiver. This has led to the term "wiping" as a description of the effect produced by cross-modulation. To maximize the condition to the worst case, the "video signal" is made to go to the white screen video level between horizontal sync pulses. This produces the largest excursions of undesired signal level which may be experienced in actual CATV systems. Thus, it can be seen that use of the White Screen Tester in our investigation produces a more stringent trial of the system.

The mid-band television channels (A through G) are obtained by conversion of VHF television channels 2 through 8 from an identical "White Screen" tester, which is modulated from the oscillator used for channels 2 through 13. Modified Benavac head-end control units were furnished by BENCO TELEVISION CORPORATION for conversion of the standard VHF television channels 2 through 8 to the mid-band channels A through G. The following mid-band frequencies were used:

Mid-band channels A through G were mixed (see Figure No. 4) by nonadjacent channel looping and combined with the standard channels 2 through 13, using an eleven dB directional tap (KAISER Model KDT-11). The composite output of the nineteen (19) television channels was then mixed with the 166.5 MHz pilot carrier signal using the 10 dB directional coupler provided on the KAISER Model KCPG - Pilot Carrier Generator. The signals were fed into the first amplifier of the system under test.

The system consisted of eighteen (18) standard KAISER Phoenician Series trunk amplifiers with AGC at every second location. 22 dB of 75 ohm drop cable, similar to type RG-59/U, was used between amplifiers. Output levels, gain and tilt controls were adjusted for normal system operation. No "factory adjustments" for amplifier response were disturbed from the original setting as received from the stockroom.

LABORATORY TEST DATA AND THEORETICAL CALCULATIONS

Based upon single amplifier output capability for -57 dB cross modulation of +50 dBmV for 12 channel operation, the deration for 32 amplifiers would be 15 dB. This is based upon Figure No. 3 which illustrates a 10 dB per octave reduction in permissible output level. Theoretically, a 32 amplifier cascade would allow a +35 dBmV maximum output level for -57 dB cross-modulation. Using 5 dB block tilt, the following output levels apply.

FIGURE 5 - MID-BAND CHANNEL FREQUENCIES USED

Mid-Band Channel No.	Output Freq. (MHz)	Input Freq. (MHz)	Input Channel
A	121.25	55.25	2
B	127.25	61.25	3
C	133.25	67.25	4
D	139.25	77.25	5
E	145.25	83.25	6
F	151.25	175.25	7
G	157.25	181.25	8

FIGURE 6 - DESIGN OUTPUT LEVELS

Channel Number	12-Channel Operation dBmV	Millivolts	19-Channel Operation dBmV	Millivolts
2	+30	31.6	+24	15.9
3	+30	31.6	+24	15.9
4	+30	31.6	+24	15.9
5	+30	31.6	+24	15.9
6	+30	31.6	+24	15.9
A	---	----	+27	22.4
B	---	----	+27	22.4
C	---	----	+27	22.4
D	---	----	+27	22.4
E	---	----	+27	22.4
F	---	----	+27	22.4
G	---	----	+27	22.4
P.C.	+30	31.6	+30	31.6
7	+35	56.2	+29	28.2
8	+35	56.2	+29	28.2
9	+35	56.2	+29	28.2
10	+35	56.2	+29	28.2
11	+35	56.2	+29	28.2
12	+35	56.2	+29	28.2
13	+35	56.2	+29	28.2
Total	+55.3	583.0	+53.4	465.3

2 dB "Block Tilt" was used for the mid-band channels after consideration of the effect of the cable attenuation characteristics. It will be noticed that the total R. F. voltage existing across the output of each line amplifier is approximately the same for 19-channel operation (at the reduced output levels) as for the 12-channel operation (at maximum output levels).

The following cross-modulation measurements were recorded for the 19-channel operation through the 18-amplifier cascade.

On the basis of these test results, it was determined that thirty-two (32) amplifiers could be operated in normal cascade with nineteen (19) television channels and pilot carrier plus wide-band FM (at +14 dBmV maximum output level) provided the levels were adjusted in accordance with Test "A". The system was then connected through a bridging amplifier (KAISER Model KCBO-4) and two (2) line extenders (KAISER Model KCLE) operating at +35 dBmV (ch. 7-13), +33 dBmV (ch. A - G) and +30 dBmV (ch. 2 - 6). The output of this "feeder" system was connected to a television receiver converter furnished by INTERNATIONAL TELEMETER CORPORATION which was used to convert channels A through G to channel 2, and which permits channels 2 through 13 to pass directly to the television receiver.

No effect was measured upon the cross-modulation components of channels 2 through 13 due to the insertion of the television receiver converter. The following cross-modulation was recorded for the mid-band channels before and after conversion to channel 2.

No evidence of cross-modulation, spurious beats or harmonics were evident on the output of the INTERNATIONAL TELEMETER CORPORATION's converter when viewed on a television receiver. Off-the-air television signals were substituted for the corresponding channels furnished the "White Screen" tester, and the pictures did not exhibit perceptible degradation. Channels 3, 5, 10 & 12 were available with color on all four normal channels and channels B & D, which were converted from channels 3 & 5. This permitted a qualitative evaluation of the system degradation with channels 3, 5, 10, 12, B & D displaying off-the-air pictures, and all other channels were synchronously modulated by the 15.750 KHz sync pulse.

Operating System Test - Merced/Atwater, California

In order to further evaluate the feasibility of adding additional television channels in the mid-band,

FIGURE 7 - MEASURED CROSS-MODULATION/SYSTEM

	Test "A"		Test "B"		Test "C"		Test "D"	
Ch. No.	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)	Output Level (dBmV)	Cross Mod. (-dB)
2	+24	68	+23	67	+24	66	+22	74
3	+24	68	+23	67.5	+24	66	+22	74
4	+24	68	+23	68	+24	66	+22	75
5	+24	67	+23	66	+24	65	+22	72
6	+24	67	+23	67	+24	65	+22	69
A	+27	67.5	+28	68	+29	66	+27	69
B	+27	66	+28	67	+29	64.5	+27	67
C	+27	70	+28	71	+29	69	+27	71
D	+27	72	+28	72	+29	70	+27	71
E	+27	66	+28	67	+29	65	+27	68
F	+27	64	+28	64	+29	62	+27	66
G	+27	65	+28	65	+29	64	+27	69
7	+29	63.5	+28	64	+29	62	+27	70
8	+29	62	+28	61	+29	59.5	+27	66
9	+29	60	+28	60	+29	58.5	+27	65
10	+29	62	+28	62	+29	60	+27	66
11	+29	61	+28	61.5	+29	60	+27	66
12	+29	60	+28	60	+29	58	+27	64
13	+29	59.5	+28	60	+29	59	+27	64

the "White Screen" tester and mid-band Benavacs were transported to the Merced, California CATV system, operated by General Electric Cablevision Corporation.

This system presently has twelve (12) off-the-air television channels available at the head-end, and it is thirty-four (34) amplifiers "deep" from the head-end to the office with a total of forty-two (42) amplifiers in cascade from the head-end to the end of the system. General Electric constructed the system in accordance with KAISER's layout and specifications, using the Phoenician Series line amplifiers at 22 dB spacing. Although no summation sweep has been performed, the system response was "flat" within about 3 dB and has been in operation for about a year.

After sign-off of the normal television channels carried on the system, the "White Screen" tester was connected to the input of the trunk line at the head-end. The General Radio Wave Analyzer was connected to the service drop at the office and cross-modulation measurements made. As predicted from the laboratory tests, the cross-modulation was down -51 dB at the office; this being the result of a -57 dB cross-modulation level on the last trunk line amplifier and the normal degradation of a bridging amplifier and feeder system. Although the low and high band cross-modulation was only barely within the predicted level, the mid-band cross-modulation measured two to five dB better than expected (up to -55.5 dB down).

During the measurement of the cross-modulation, a television receiver was observed for indications of spurious beats and harmonics. No problems of this nature were indicated on the white screen displayed on the television receiver. The system levels were adjusted for +29 dBmV on channels 7 through 13, +27 dBmV on channels A through G, +24 dBmV on channels 2 through 6, and the pilot carrier was left at the normal +30 dBmV. The bridging amplifier and line extenders were set for a +35 dBmV on the high-band, +33 dBmV on the mid-band and +29 dBmV on the low-band.

As soon as the normally-carried channels resumed their transmission (about 8:00 A.M.), the system was returned to normal operation (+32 dBmV at channel 13 and +26 dBmV at channel 2 half-tilt output levels on trunk line amplifiers, and +40 dBmV at channel 13 on bridgers and line extenders tilted for about 15 dB of feeder cable).

Based upon the satisfactory quantitative evaluation, actual television channels in the mid-band (A through G) were added to the 12-channel head-end output with the system operating at the normally 3 dB higher trunk output levels and 5 dB higher feeder levels. The mid-band channels were added one at a time in order to check the system for any resulting degradation due to the expected over-load condition. A slight "beat" was observed on channel 5 (estimated to be 35 to 40 dB down) on the television monitor in the office. It

FIGURE 8 - MEASURED CROSS-MODULATION/CONVERTER

Channel Number	Cross-Modulation Direct	Cross-Modulation Converted
A	-63.5 dB	-60 dB
B	-62 dB	-59 dB
C	-63 dB	-61 dB
D	-64 dB	-61 dB
E	-62 dB	-59 dB
F	-60 dB	-58.5 dB
G	-61 dB	-60 dB

is believed this beat was a result of the simplified mixing method employed at the head-end for adding the mid-band channels. A KAISER Model KDT-11 directional tap was inserted into the head-end output with no additional traps, filters or other devices for isolation.

However, no noise, over-load or other types of picture degradation were observed. Therefore, in order to further evaluate the cable distribution of the nineteen channels, the pictures were observed under these abnormal conditions at the end of forty-two (42) amplifiers. Although it was anticipated that some cross-modulation or other indication of over-load would be apparent on the system at this extreme cascade, there was no indication of degradation of any kind. It was also noted that the "beat" on channel 5 was no worse than previously observed at the office.

Conclusion

Although it was successfully demonstrated that seven mid-band channels (A through G) could be added to the Merced, California CATV system without operating at lower levels -- and without noticeable degradation -- it is not implied that this proves that the 19 channels can be carried on all 42-amplifier cascades without system level deration.

The limitation existing on the insertion of additional mid-band television channels is a function of the individual amplifier output capability, primarily. It is, of course, necessary that the head-end conversion and mixing be free of all spurious frequencies and distortion and that the line amplifiers, as well, exhibit no appreciable harmonic distortion or intermodulation characteristics.

Amplifier noise figure determines the minimum amplifier input signal level, and to operate a system of 32 amplifiers in cascade at the levels used in this test will require a 17 dB MINIMUM Low-Band Noise Figure for a 40 dB signal-to-noise ratio.

A +35 dBmV maximum feeder level appeared to provide adequate distribution signal without noticeable distortion or cross-modulation. The television receiver conversion unit furnished by INTERNATIONAL TELEMETER CORPORATION did not appreciably contribute to the signal degradation when operating with normal (0 dBmV) input levels. The low noise figure and gain of the converter actually improved the picture definition. There was no sign of color degradation at any time.

In considering the addition of mid-band television channels to existing twelve-channel systems, the following factors should be carefully evaluated:

(1) Amplifier output capability must be sufficiently high as to permit the indicated deration. In addition, the amplifier must have linear output level vs. cross-modulation characteristics, i.e., a two-for-one reduction in cross-modulation should occur with incremental output level reduction over the maximum-to-minimum useable output level range.

Cross-modulation products increase by 6 dB each time the number of cascaded amplifiers is doubled, based upon the voltage addition factor, 20 log M. However, for each dB reduction in output level, the cross-modulation decreases by two (2) dB. Therefore, with a simultaneous system output level reduction of 10 dB per octave with increasing number of amplifiers in cascade, we accomplish the required 20 dB per octave reduction in cross-modulation to result in no over-all increase in the cross-modulation with cascade.

If, for example, you can operate one amplifier at +50 dBmV and maintain cross-modulation down 57 dB, then the cross-modulation would be down 63 dB, if that amplifier were operated at a +47 dBmV output level -- and two of these identical amplifiers in cascade would result in 6 dB worse cross-modulation, or at the +47 dBmV output level the cross-modulation would be down 57 dB on the output of the second amplifier.

(2) Deration for additional television channels is assumed to be on a voltage basis (20 log N). This is in accordance with accepted theory and may be mathematically proven. The test generally demonstrated the validity of this assumption.

(3) Conversion and mixing methods must result in clean head-end output with all spurious frequencies down at least 50 dB. The tests indicated there was no appreciable "build-up" of these beats, but no extensive investigation was conducted.

(4) Pilot carrier signals must be protected for adjacent channel interference on the system by adequate "guard band" separation.

(5) If normal amplifier spacing is retained, the amplifier noise figure must be sufficiently low as to permit the use of lower input levels without noise degradation.

(6) The television channel converter must be designed so as to provide adequate adjacent channel rejection, switching isolation, and add insignificant noise and cross-modulation products. It also helps if it is easily tuned and simple to operate, of course.

(7) No second order harmonic distortion problems were observed. However, it is logical to assume there are certain "forbidden" mid-band conversions. These conversions, where necessary, can be worked out I am sure by double conversation or other well known techniques.

In summary, we have demonstrated the practicability of adding seven (7) mid-band television channels on an existing twelve (12) channel CATV system with no modification of the Phoenician Series line amplifiers. Additional mid-band channels may be added with appropriate consideration of the seven (7) factors mentioned above.

The author would like to express his appreciation for the complete cooperation of BENCO TELEVISION CORPORATION and INTERNATIONAL TELEMETER CORPORATION in supplying the end equipment on short notice to permit the testing of the complete system. In addition, GENERAL ELECTRIC CABLEVISION CORPORATION encouraged the tests and made available the operating system at Merced, California, used to verify the laboratory results. Interested observers at Merced, who also participated in the field testing included Mr. M. Ferguson, Vice President and Chief Engineer of the Philadelphia Community Antenna TV Company, Mr. George Henderson of the Matador Construction Company, and Messrs, G. Dail, C. Nichols, J. Gannon and technicians of the Merced CATV system.

MR. KLEYKAMP: Mr. Chairman, I should like to add that I agree with Mr. Palmer that we have not exhaustively tested and investigated this use of mid-band channels, or any other channels other than the normal ones. So, although it was successfully demonstrated that seven mid-band channels, A through G, could be added to the Merced/Atwater, California, system without operating at lower levels and noticeable degradation, it is not, and I underscore "not", implied that the 19 channels can be carried on all 42 amplifier cascade systems without degradation.

Again, thank you. (Applause)

CHAIRMAN CLEMENTS: Does anyone have any questions of Mr. Kleykamp on the subject of the mid-band use?

Copies of his paper are available.

MR. KLEYKAMP: I would like to mention, also, that I have a couple of hundred more copies available in the exhibit area, and I will be there for the remainder of the day. I will not be leaving until tomorrow. If you do want to save your questions and see me personally I will be most happy to talk with you.

MR. JEFFERSON (Jerrold Electronics Corporation): I have a question. I appreciate that you recognize there are some signal distortion characteristics in the band you mentioned, but apparently they were not too offensive. I have made a few calculations on just a few of them, and I would like to bring this out as being of interest -- if you take the standard difference between the Channel 13 video and Channel 6 video, you get a beat at 128 megacycles, which is about a three-quarters megacycle beat on your Channel 8.

If you do Channel 12, you have another three-quarters of a megacycle beat above your Channel A.

As you add at the specific channel, such as your Channel A, that will cause a stone beat, which is three-quarters of a megacycle above Channel 7.

In addition, if you do the same thing on a different base with, let us say, Channel 11, you get a beat about three-quarters of a megacycle above Channel 5.

These beats, if you did the total spectrum, as I am sure we have all done, would be of a second order beat product, all over the mid-band; and in addition now, and more importantly as you add carriers into that band, you will then generate second-order beats all over the existing low and high bands.

And for measurement from our own figures, on particular amplifiers, as well as those of competitors, we find that typically for a system at the end of a normal operating system, where we, Jerrold, and others typically rate in the 57 and 51 bracket, that those second-order beat products at the end of the system are approximately 40 db down; maybe 42, or something similar.

We get into the subjective problem of what can you tolerate in second-order beat?

In our opinion, and in that of others, with whom we have talked, second-order beat, or triple beat, or any of the distortions should be in the neighborhood of 65 down; otherwise, they very definitely show up.

I am just curious to know what sort of a figure you put on your second-order beat products? Do you consider a beat range approximately 40 to 45 as an acceptable one?

MR. KLEYKAMP: My answer to that is, I was not attempting to evaluate the data. I was attempting to obtain and report data on an actual test.

This will have to come later. We have to do this sort of thing, the subjective evaluation as well as the objective evaluation.

I am merely saying that we have investigated this phenomena, and we saw no picture degradation. That is what the thing is all about. Let's get the pictures there.

Now, what numerical limitations we could place on any type of interference is, I feel, not fully defined at this time.

I merely wanted to report that the system worked; that it can be done. I am not saying that this is something that we can presently adequately and fully describe, all of the phenomena that contribute to obtaining pictures such as were displayed here.

MR. JEFFERSON: I would like to bring one other thing out, if I may, and I think most of you are aware and have been for many years that Jerrold has promoted full amplifiers in the low sub-region, and, indeed, we are faced with the same particular problems down there, and we felt a very definite need to go to those great lengths to have satisfactory pictures.

In a very similar fashion we attempt to operate outside of an octave and a single amplifier in the lower sub-region for transportation purposes, and we have many, many customers, and many on our own systems that use low subs in a transportation load.

We have very definitely discovered that we do have to go to a very expensive and elaborate method of minimizing second-order distortions that fall in the band because, indeed, the figures we get on single-line amplifiers are such that we did not consider them tolerable.

Thank you.

CHAIRMAN CLEMENTS: Thank you.

Are there any further questions or comments?

If not, we are going to move to our next speaker, who will be Mr. Donald C. Stewart, Director of Corporate Development, Superior Cable Corporation, and he is going to address us on the matter of PERT/CPM - USES IN CATV.

Mr. Stewart. (Applause)

MR. DONALD STEWART (Superior Cable Corporation): Mr. Chairman, Ladies and Gentlemen: First I had better explain what the PERT/CPM means. I have been asked several times what I am talking about when I refer to this.

Basically, PERT and CPM are tools or techniques to manage projects -- big ones; small ones -- all kinds of projects, either in CATV operation or in equipment manufacture and development, or in anything else.

So, I just want to run through what these techniques are, and make a few suggestions.

I want to challenge you to decide how you can use PERT and CPM in your business to get your work done.

Let's define PERT and CPM, first of all, and I shall begin by saying PERT, the four letters -- P-E-R-T -- is an acronym for the words "Program Evaluation Review Technique".

And the closely-related CPM just stands for "Critical Path Method".

Those are the magic words here.

Basically, these are techniques or tools to manage products; to plan; schedule; and control projects.

And, of course, the project we think of as something that has a definite beginning; a definite end; composed of a lot of component jobs or activities; and completion time and cost, are important. If you do not care when you get it done, you are not going to use this technique.

The visual representation of the project which you may have seen is the network -- just a bunch of lines hooked together.

This CPM example happens to be concerned with the rebuilding of a steelmaking furnace that U. S. Steel utilized. It is just an example of what it looks like, and incidentally, I would like to ask a show of hands of how many of you are generally familiar with PERT and CPM? I will assume that you have no knowledge at all so that we may lay the groundwork.

there will be a better understanding of the use of this technique.

To give a little of the historical development of PERT/CPM, it is not quite 10 years old. In 1958, PERT was developed on the Navy Polaris Submarine Missile Program. Booz Allen and Hamilton, Lockheed, and the Navy, working together, developed this technique in order to get the Polaris Missile Program operational. It is credited with a great portion of the success in getting the Program operational, approximately a year and a half sooner than the initial estimate.

This was a state of the art breakthrough. While they were not even certain they could make the system work, using PERT they were able to ramrod the Program to completion.

Since then, PERT has been successfully applied to many of the major Department of Defense and NASA projects. So, if you are in the area of defense production, you are probably having to use it whether you want to, or not. The government is really sold on it.

The other "grandfather" of the family of techniques, CPM, was first used in 1957 on a Du Pont chemical plant construction project. Here they knew exactly what they had to do, but they wanted to do it as fast and as economically as possible. They believe they saved up to a million dollars by getting the chemical plant built and getting it built more rapidly under this system.

Since then many different companies, many different people, have developed their tailormade systems. Someone has counted about 40 different acronyms, where people have put together tailor or custom-made plans to handle their problems.

We have names like RAMPS, PRIME, PERT/COST, et cetera; but it is all the same basic concept -- project management.

I think the best way to describe this system is to take a look at a small example in the CATV area. I call it the "bare bone demonstration project", because we have taken away all of the glamour and all of the elaboration, and we are just getting down to the essentials which are straight-forward. We have some exhibits here to show the way, and if we may have the first slide (slide) -- we are going to start with a list of the steps that one goes through in any PERT/CPM project.

What do we have to do to use this technique or tool?

I hope you can all read that, but I will try to read it, too.

First of all, we have to define the project. What are we trying to do?

This seems intuitively obvious, but I think in a number of cases people do not define their project, and that is the reason they never get it done.

Number two -- we have to identify the activities, the components, that together make up the project.

Number three -- following that, we draw the network, which is the visual portrayal that I held up a short time ago. It indicates how these activities tie together to get the project completed.

Number four -- following that we get time estimates for each activity in the project.

Number five -- next we go through the calculation, which is basically a matter of adding up the elapsed times from start to end through the various tasks in the network.

Number six indicates the critical path and slack, which is the key concept in this whole technique.

Number seven -- generally, the first time we run through a project we do not like the answer. We are not going to get enough done, so we go back and try to speed it up and expedite it.

After that, we have to update, and as time goes by, as we make progress, as changes occur, we want to take another look, perhaps every two weeks or every month, to see how the project is going. This is step number eight.

Number nine -- probably the most important of all, we have to follow up with action to get the job "on the road"; to get the project done.

Now let us go to Exhibit 2 (slide), and we will start with a small project in the CATV industry. We have chosen building a CATV system and getting it operating. We could just as easily have chosen the development of a new 20-channel amplifier. The project in this case is to build a CATV system.

Number two -- what are the project activities?

We have really "sweated the thing down" as you can see. Normally you would have hundreds of activities. In our example we will consider only these activities: We say we have to obtain the franchise. We have to make a signal survey. We have to obtain financing. We have to employ the staff, the people to operate the system.

We have to choose the turnkey contractor (assumed), by bidding or negotiation.

Then we have to actually build the system physically. Naturally, we have to sign up some subscribers to have a viable economic system.

So, those are the activities we have to get done in this small project.

(Slide) We have taken the list of activities, and we have put them into the network. Each of these lines (indicating), with the arrow, is an activity. That is a job; a component activity.

Each of the circles that are numbered, incidentally for identification, the circles are events which you can consider as points in time.

So, an activity is an arrow or a line which runs from a beginning event to an end event, and it consumes time, elapsed time.

Most people find in drawing networks they do better by starting at the end and working backwards. So in this case we would say we have a system operating; what has to be done just before we can have an operating system.

Obviously, we have to build it; and that is the activity at the top there, on the right, which is numbered "Five to Six" -- build the system.

We also have to get some customers, and that is the bottom activity on the right, Activity four to six -- sign up subscribers.

Staying with the subscriber signup at the bottom, before we sign up subscribers we have to have some people to go out and call on them. We are saying we have to employ the staff, which is Activity two to four.

Back on the construction side, at the top, before we build a system we have to have the money. That is Activity two to five. That is the predecessor activity before we can build the system.

We also have to have somebody to build it. So, we put in Activity three to five at the top, which is, choose your turnkey contractor, so you can build the system.

Then we work our way back toward the beginning, which is Activity one to two on the left, to get the franchise, from which everything else flows.

So now we have the network constructed. This is the way we see the activities fitting together.

The necessary predecessors to our activities before we can go on to the next step and get on to our goal, the operating of a CATV system, are indicated.

(Slide) The next step, once we have our network constructed, the interactions are pinned down, we want to estimate how long it will take to do each of these activities. Again we want to get realistic time estimates. We do not want any "pie in the sky". We do not want any wishful thinking. We want the best guess for each of these activities.

So, we try to go to the person who knows the most about each activity; and, of course, we are getting somewhat of an implied commitment here, too, for example we are saying in this case we think we can get the franchise in 20 weeks.

The signal survey -- let's say three weeks.

We think obtaining financing will take about two months, let's say eight weeks.

Employing the staff -- four weeks should take care of that.

Choosing the contractor, perhaps three weeks.

Actually building the system, 16 weeks, or roughly speaking four months.

Then the campaign, the promotional campaign to sign up the subscribers, we are saying will take six weeks.

Just as an aside here, the basic PERT system which was used on the Polaris Missile and in most of the government programs involves a very high degree of uncertainty in the research environment. The engineers will say, "We can't give you a good estimate."

To combat this they replied, "Give us three estimates -- an optimistic one if everything goes right; a most-likely, your-best-guess; and then, a pessimistic estimate."

In the calculations they worked out a weighted average time estimate, and they were also able to make a probability estimate on completion time.

On the other hand, in the CPM version they pretty much know what they have to do in construction, but they are very interested in cost, and also in how much additional cost if they go to a crash basis with a lot of overtime. So, for each activity in CPM you get a time and a cost on a normal scheduled 40-hour week.

You also get a time and a cost on a crash basis, with lots of overtime, with paying premium prices for quick delivery, and then you make a trade-off between time and cost.

In our "bare bones" example here, we are just going out and getting one time estimate for each of these activities.

We are now ready to go into the calculation routine.

(Slide) Now we are back to our network as we had it the first time, but we have added the estimates on each of those legs, each of those activities; the number of weeks we think it is going to take to do each of those activities, assuming that the necessary predecessor-activities have been completed.

You can see the first one on the left, concerning the obtaining of the franchise, one to two, is being quoted at 20 weeks. The calculation is just a matter of arithmetic. We just go through and add up the elapsed time for each of these tasks, through every possible path in the network. Only three are possible here, one across the top, one through the middle, and one down at the bottom. We add the elapsed time for each of these paths.

If you have a very large project you might want to go to the computer. I think all of the computer people have "canned" programs available in which you can plug in these time estimates and it will crank through the arithmetic. We have calculated networks with as many as six or eight hundred activities within half a day manually. So I would say, don't worry about the computer yet.

We add each of the possible paths. We find on the top we have 20 weeks plus 3 weeks plus 3 weeks plus 6 weeks or 32 weeks total.

In the middle we have 20 plus 8 plus 6. At the bottom we have 20 plus 4 plus 6 or 30 weeks.

The Middle path is the critical one. It requires 44 weeks. That is what we have to focus on; that is the heart of this technique, if we want to cut the time for this project, if we want to make sure it gets finished on time, we want to make doubly certain that these critical path activities are taken care of in good time.

To emphasize the critical path we make a heavier line along it so we have a visual picture of where our problems probably rest. On a typical "real world" problem, no more than, say 15 per cent of all the activities will be on the critical path. So, everyone can focus their attention on the critical path.

In this particular example we are saying that the project time estimate, which is the length of the critical path is 44 weeks, running through events one, two, five and six.

In this case our management, let's assume, is demanding 40 weeks. They want the system operating in 40 weeks, and no more. This is usually the case, of course, with an important project.

So, we say the project slack or spare time is negative four weeks. We are four weeks behind before we even get started!

Now we ask what changes can we make? How can we speed up the project? Of course, another thing to stress in PERT/CPM is we do not do it by pounding the table; by wishful thinking; by unrealistic promises. We try to go back as hardheadedly as possible and see what we can do to speed up this project to meet the 40-week demand by our superiors.

There are really only three ways we can speed up the project.

Number one -- we can add resources, such as going on overtime. We might have to pay more to the turnkey contractor. If he puts on another crew, works on Saturdays and Sundays and 12 hours a day, or something of that nature, this is one approach.

Another alternative is to just eliminate certain activities on the critical path. I do not think there are any obvious eliminations here, but in the Polaris Program they took a calculated risk and eliminated certain testing and prototype activities. They knew they were taking a chance, but they felt it was worth it; and it did pay off. They did save the time.

The third thing we can do is parallel activities. We do Activity A and Activity B at the same time rather than waiting for one to be complete before the next one is done. I think we could probably do something of that nature in this instance by starting our financing program; our campaign to get our financing, before we get the franchise. We should be able to do some paralleling there and compress the elapsed time in the length of the critical path.

You can see in this example we have done all of this analysis before the project starts. This is prior planning. Most people think that in a typical project you get, 50 to 75 per cent of all the benefits just going through these steps -- just laying out your project; getting a picture of it that everybody can look at; and planning how to do it best and quickest.

You also, however, should update. Time goes by and things happen. It is important to go back and refigure your network as the project proceeds toward completion and take action.

Let's recap the advantages that most people feel this PERT/CPM technique provides.

Number one -- it gets the project done -- very basic; very important.

Number two -- PERT/CPM saves time; it gets the project done faster; most people report a 15 per cent saving in time.

We also, want to save costs wherever possible; and again many people say they have realized savings up to 15 or 20 per cent of the total project cost through doing it more efficiently; eliminating those 100 per cent crash programs which are typical in the construction industry, where every activity goes on overtime whether or not it is a critical path activity.

PERT/CPM fixes responsibility, because each activity is related to a person, and you know whom to go to when a job does not get done on time. I think that increases the responsibility people feel for getting the job done. It also forces human beings to plan. I think most of us do not like to plan if we can avoid it. This forces us to get in there and make some estimates, and give the problem some organized throught.

It stresses management by exception. We can key in on this 15 per cent of the job that is really critical, the critical path. The visual aspect of the project network is extremely valuable in communicating status. We can lay out the job on a big piece of paper, and everyone can look at it and see what has to be done.

I was involved in the development of an electronic product several years ago using PERT. We had the draftsman draw large project network charts. We put them up in a conference room and brought in top management. It was really an eye-opener to them to see what had to be done to get this product on the market. They were much more amenable to giving us more resources-people; and also changing their time demands. The original schedule was impossible, and the chart was the only device that convinced them it was impossible.

This all sounds very good; but what is the trick here? There must be some limitations or some shortcomings to PERT/CPM.

Of course there are; and I think the most important is that it is a tool -- it is not a substitute for management action, and this cannot be stressed enough.

It also must be updated over a period of time. You cannot do it once, put it into the drawer, and expect the project to get done smoothly and on time These two factors, in my experience, have been most important in limiting results from PERT. If you want to call them "drawbacks", that is your privilege, but I submit they are not inherent limitations of the technique but rather misapplication.

A third limitation -- the concept is very simple as we demonstrated it. The application can be complex. You can get 500, 1,000, or 5,000 activities in a large project with much time and effort necessary to construct the network and get all of the estimates. Also PERT/CPM does have limitations in handling multi-project situations where the same resources -- people and equipment are needed on several of projects at the same time.

Despite all these apparent disadvantages, I think the advantages far outweigh them; and as most people who have used it will tell you, it has done a remarkable job in getting projects accomplished more quickly and economically.

Let us comment on some of the applications, and there have been thousands of them. A few examples will indicate the variety.

The defense and military area is dominant starting with the Polaris Submarine Missile Program, with which everyone is familiar.

They have gone to PERT with most of the major defense and space programs, and the government is extremely enthusiastic about the technique.

I think it has been proven that PERT/CPM has accelerated our weapons system progress.

Secondly -- the construction industry has really taken CPM to heart. Naturally the example of a project that first comes to mind is in construction, and the construction industry has made extremely wide use of CPM. Most of the major chemical and steel companies have handled plant construction and maintenance using the CPM technique. These include Du Pont; Olin Mathieson; U. S. Steel; Union Carbide; Wheeling Steel, PPG just to name a few.

Expo-67 was planned on PERT. I was up there a week ago, and I was extremely impressed with the job they have done in about three and a half years. They have built 200 buildings; a subway; a bridge; a new island in the river, and all of this was planned on PERT networks.

Actually I think they had 150 networks altogether, and they were dealing with approximately $750 million in cost. This application was so successful that the 1970 Japanese World's Fair is going to consider using PERT also.

The Atlanta Stadium was also PERTed. In Atlanta they were very anxious to get a major league baseball team, so they paid extra to compress the construction time. The stadium ready for a baseball team a year earlier than otherwise.

Sun maid Raisin, in California, put up a new plant using CPM, and they have indicated that they saved a million dollars because they had the plant ready for the growing season. In effect, they saved a year by getting the plant ready for the pack.

A number of the contracting firms have used CPM as part of their promotional effort. Rust Engineering and Catyltic Construction are two good examples. They use it in their advertising. They say they will build your plant more efficiently by using CPM.

A third major application area is in R and D and new products, where there are many opportunities to reduce the time to get a new product on the market.

Xerox, monitored their new "2400" copier development program on PERT, and they estimated that they saved about a year and a half. They originally planned the "2400" program on a six to seven year cycle. Management was not satisfied, so they went back and ultimately arrived at a five-year cycle. The speedup involves a great deal of overtime. This was a case where the president of Xerox insisted on seeing the PERT analysis. It was a $40 million investment, and he was very much interested in the program.

Winchester Arms used PERT to lay out the program for the M-14 army rifle and get themselves competitive in a government bidding situation.

The major auto companies have used PERT in the new model changeover, getting all of the component parts of the new car and the assembly line changes ready so they can start the new models sooner.

There are many other examples, such as the one I commented on about the electronic product. General Electric and other companies have used this technique in getting new products through the research and pilot plant stages to the market.

Still another large area for application has been accounting and data processing. People have speeded up their accounting closings by just flow-charting all of the things they have to do. Anaconda Aluminum and Collins Radio are two examples here.

People have installed new budget and cost systems using PERT/CPM, and I believe all of the major computer manufacturers use it in installing new computer systems. They try to get all of the programming taken care of; all of the makeready at the site, and all of the staff hiring controlled through a PERT network, so the customer has his computer turned on as rapidly as possible.

There is an entire range of miscellaneous applications. I just selected a few here for you: Kidney transplant operation in a hospital was PERTed; a Broadway play by the name of MORGANA was laid out on a PERT network to get the play to opening night. One of my friends moved his new family to a new house and used a CPM network, involving such things as "stop the milk"; "get the telephone hooked up", et cetera.

Management consultants quite often use PERT/CPM in planning their engagements. In fact, in one job in which I was involved, the client insisted on a PERT network as part of the proposal.

So, you can see there is no end to the number of applications. I think the only limit is your own ingenuity.

In CATV, I will just suggest quickly some applications. Building a CATV system is an obvious project, or expanding or rebuilding a system.

Turnkey contractors could also use PERT/CPM for their work in controlling the construction of systems.

Promotional campaigns come to mind, with advertising, house-to-house solicitation, and related publicity.

The program to get the franchise is another that lends itself to this technique with the various political and public relations aspects. Financing is still another possible project.

Of course the equipment and new product area is one of the best potential applications. We used CPM to plan a new cable plant for CATV-TV.

You can readily understand there are a great many potential applications. I do not think there are too many actual applications in CATV. I would like to hear about them.

This is all very good, but the next question, is how do I get started? What do I do next?

The first thing you can do is read. Many of the professional journals and business magazines have had articles; and we have here a short bibliography on the subject which you are welcome to take.

You can also go to PERT/CPM seminars. AMA conducts them, as do various other organizations. I do not think it is particularly necessary, but a great many people attend these seminars. I think the most important step and what I suggest is just to try a project; just select a project that is important to you and plan it out; and then you can decide for yourself whether this is going to help you in your work.

Thanks very much, and good luck. (Applause)

CHAIRMAN CLEMENTS: Thank you, Don.

This is most interesting. I would make just one remark on it, and that is with our highly-complex system in Manhattan Cable Television, this is used to a great degree. I imagine they will use 15 to 20 very large sheets a day with the PERT method, and I know we can adopt it to our use.

I wish to thank all of the panelists for being very prompt and for a selection of most informative material.

We have approximately a half-hour break, with the lunch at 12:30, and the business session at two o'clock.

Thank you, gentlemen, for your most appropriate remarks; and thank you, our audience, for your very fine attention.

We are adjourned.

(Technical Session 1 adjourned at twelve o'clock.)