CROSSTALK AND ISOLATION REQUIREMENTS IN DUAL TRUNK SYSTEMS

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This paper examines the problems of crosstalk in dual cable single feeder two-way systems.

Common frequency crosstalk is examined and calculations are made of what amount of crosstalk is allowable without degradation of system performance.

The paper then describes briefly measurements made on a system meeting the calculated performance specifications for isolation.

Crosstalk due to amplifier distortion is then analysed and shown to be negligible in a system using high quality amplifiers presently available.

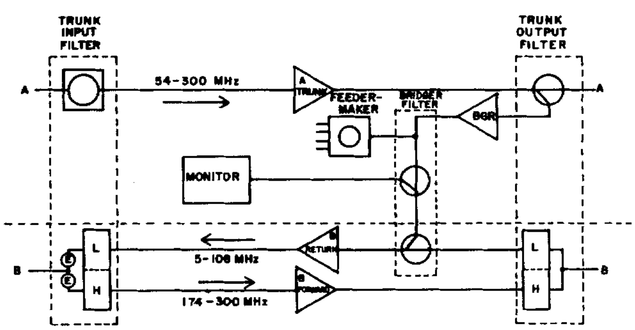


FIG. I

This paper will examine the problems of crosstalk and isolation in dual cable two-way systems. The major question this paper will attempt to answer is as follows:

"What kinds of crosstalk can occur in a dual cable two-way system, and what isolations are needed to ensure that such crosstalk causes no degradation to the quality of signals passing through the system?"

In this context, crosstalk is defined as any unwanted energy falling in either system from the other. There is a distinct difference between crosstalk from the outgoing system into the return system and crosstalk from the return system into the outgoing system, which I will examine in detail later on in the paper.

Figure (1) shows a dual cable system with one-way performance on the trunk of cable "A", two-way performance on the feeders of cable "A" with crossover for the return signals on those feeders to the two-way "B" cable electronics. The objective of the transmission system is to send signals down cable "A" to the home, and to return signals from the home subscriber back to the head end via two-way performance on the "A" cable feeders with crossover to the "B" cable at trunk locations. You will notice the extra bandwidth on the "B" cable return and the bandwidth available on the "B" cable outgoing. These bandwidths can be used for special kinds of subscriber.

Assume now that the electronics above the line across Figure (1) is in housing no. 1 and that below the line is in housing no. 2. The only form of crosstalk which can occur in this case is via the electronic connection from housing no. 1 to housing no. 2. The cable should have very good isolation so that signals from cable "A" should not be able to get into cable "B" via that path. The housings also should have good isolation which prevents signals from cable "A" getting into cable "B". The only path left is that connection from housing 1 to housing 2 and possibly power supplies, if they are used to feed both cables simultaneously.

Now, consider all the other products to be contained in one housing. There are economic advantages in this mode of operation. For example, a single power supply may be used instead of two. One housing instead of two. One connector chassis instead of two. The module and electronics count remains the same.

What crosstalks can occur in this single housing? You will notice that there are common frequency bands used on the different cables. For example, 174-300 MHz is used on both cable "A" and cable "B", shown going in the same direction in the diagram. The frequency band 54-108 MHz is common to the "A" cable downstream and the "B" cable upstream. Obviously, if energy from either system falls in the other in these common frequency bands, interference can be caused. This is obviously undesirable and must be guarded against. The question is, "What isolation is needed in order to give satisfactory performance?"

Another form of crosstalk which can occur in this system is crosstalk due to distortion products from either direction falling into the frequency band of the other direction and leaking into that other direction. It will be shown later that if the system uses high quality CATV amplifiers operated within the specified limits, this form of crosstalk is negligible. Incidentally, this form of crosstalk occurs in both single housing and dual housing dual cable system.

Let us now consider common frequency crosstalk.

(a) Outgoing to outgoing - that is, "A" cable outgoing crosstalking into "B" cable outgoing, or "B" cable outgoing crosstalking into "A" cable outgoing. The range of frequencies in which this can occur is from 174 MHz to 300. Consider a signal starting at the head end going down the "A" cable to the subscriber, and assume a cascade of 30 amplifiers. If energy from the "B" cable appears in the "A" cable at each station, it will occur on 30 different occasions. The question is, "How will the increments of energy from each station add?" If all stations are uniform in the phase and amplitude of the crosstalk, the power should add on a voltage basis. However, the transmission time is different on cable "A" and cable "B" due to the high/low split filters used on the "B" cable. This time difference will tend to disperse the voltage addition, but for the purposes of this paper, voltage addition will be assumed in order to define an isolation limit which should be achieved for good performance.

The appearance of the interference we are discussing should be that of co-channel interference. Let us set a target of greater than 60 dB signal-to-interference ratio for the system. This measurement is made by terminating the input of cable "A" and observing the output of the station of cable "A". A signal is then injected at the correct level into the cable "B" input and the cable "B" output is terminated. The station, of course, is set to nominal gains such as would be used in a typical system. Cable "B" interference due to cable "A" is exactly the same as that just discussed, and requires the same isolation number.

(b) Cable "B" return crosstalking into Cable "A" outgoing in the band 54-108 MHz. The worst case for this kind of interference is where a signal is injected in cable "B" at a system extremity and flows back to the head end with crosstalk at each intervening station. In the 30 amplifier cascade system, the maximum number of stations which can be affected in this way is 30 in cascade. However, the addition of this kind of distortion is different from the previous example. There is significant time delay between stations in the system, and the signal which is causing the interference is flowing in the opposite direction to that which is being interfered with. Assume that channel 2 is injected at the system extremity on cable "B" and is observed at the same extremity on cable "A". Assume also that there is about 1 microsecond time of transmission between stations so that the "B" signal takes 30 microseconds to get to the head end and the "A" signal takes 30 microseconds to get to the extremity from the head end. Consider now the channel 2 signal leaving the head end. At station 1 it will pick up some crosstalk which originated 29 microseconds before at the system extremity. At station 2 it will pick up crosstalk which originated 28 microseconds before at the extremity, and so on down the system. If, now, channel 2 on the "B" system is, say, a video signal, with changing information, each of these increments of crosstalk will contain different information. They will, therefore, tend to add more like power than voltage. Furthermore, the visible effect of such interference will tend to be more like noise than co-channel interference. If, however, the signal injected into the "B" cable is a CW signal, the interference will tend to add more like voltage, and its effect will be that of a beat. Setting a desirable limit of better than 60 dB for signal-to-beat ratio, the isolation required between the "B" cable return and the "A" cable outgoing is set at 90 dB for a 30 amplifier cascade.

(c) "A" outgoing to "B" return. Assume a 30 amplifier cascaded system. In round figures, such a system would contain approximately 300 stations spread out in the tree fashion shown in Figure (2). Consider energy in the 54-108 MHz range flowing out from the head end on the "A" cable. Assume crosstalk occurs. It will occur in each and every one of the 300 stations in that system. This energy flowing in cable "B" will return to the head end. Assuming that the system is unity gained in both directions and that the crosstalk is uniform from station to station, at the head end there will appear, due to the "A" cable signals, 300 samples of crosstalk information.

These samples, we will assume, will be uniform in level but will have originated at different times in the system. What is the subjective effect of a distortion of this type, and what is the signal-to-interference ratio required for satisfactory performance?

It was theorized that there would be a difference in subjective effect depending on whether the "A" and "B" channel frequencies were exactly the same as in a phase lock situation, or were different by some few kc's as in the more normal type of situation. It was thought that, in the phase lock situation, the subjective appearance would be of a multiplicity of ghosts due to the time delays involved in the round trip for the "A" signal interfering with the "B". In the case of the non-phase lock situation, it was thought that the subjective effect would be more like a beat effect. In order to check out these two theories, a system was set up in which 52 separate echos could be superimposed upon a video picture and subjective judgments made. The results of the subjective testing were as follows:

In the phase lock case, the subjective effect was indeed one of multiple ghosts. Measurements were made of levels for barely perceptible interference. These measurements showed a much greater tolerance to the interference than in the non-phase lock case. In the non-phase lock case the interference effect was indeed a beat effect and was dependent on the difference in frequency between the two television carriers. Measurements were made of barely perceptible interference at that frequency which gave the worst case results. In round figures, the phase lock system was 20 dB more tolerant of crosstalk than the non-phase lock system. The isolation required for the non-phase lock case was 80 dB for 50 interfering sources. That is, at each station the interference was 80 dB below the desired signal. Furthermore, tests also showed that the addition was on a 3 dB per double basis; that is, when 25 of the interfering sources were removed, the ratio needed was now 77 dB below the desired signal so that for 300 stations, the ratio would be 80 dB + 10 log $\frac{300}{50}$, that is, 88 dB. This ratio can be measured by injecting a signal into the "A" cable input at such a level that the bridger is operating at system level and measuring the output in the 54-108 MHz band of the "B" cable return amplifier, and referencing this to the nominal output level of the desired signal at that station.

To summarize, then, the isolations required on a per station basis for the three cases are "A" cable to "B" cable outgoing, 90 dB; "B" cable outgoing to "A" cable outgoing, 90 dB; "A" cable to "B" cable return, 88 dB, for a maximum cascade of 30 amplifiers with a total of 300 amplifiers in the system. It is instructive to compare these isolations with the kind of isolation required in a one-way system. In Figure (3) the station is shown consisting of the trunk amplifier feeding a bridger with one feeder being driven. The levels are as shown on the diagram. The output level of the bridger is set at +45, the input level of the trunk amplifier is set at +10 dBmV. What isolation is required between the trunk input and bridger output in order to obtain satisfactory frequency response performance? If the isolation were 80 dB between trunk in and bridger out, the station would have a total loop gain of -45 dB. This could give a frequency response ripple of .05 decibels. This would add to .5 dB in ten stations, and would probably be very hard to spot in a single station measurement of gain vs. frequency. In contrast, the isolations required for dual cable operation in a single housing are at a ninety dB level except for the bridger filter which has to have isolation of 124 dB to allow for the effect of the high output level from the bridger vs. the low input of the return amplifer.

Figure (4) shows the levels in the two-way station and the required interference level in dBmV in order to meet the 88 dB ratio previously specified. It can be seen that the rejection of 54-108 MHz information which is accomplished in the bridger filter needs to be 124dB or greater.

Are these isolations feasible in a single housing? They are definitely realizable using good engineering practice. Figure (5) shows one realization of a dual trunk single feeder system contained in one housing. The module arrangement is outgoing trunk and bridger at the top of the housing with the return amplifiers in the bottom left hand corner. The input filter is vertically on the left, the output filter is vertically at the far right with the bridger filter next to it on the left. The housing has eight ports for dual cable operation and the ability to feed four feeders from the one housing.

In order to obtain the isolations discussed, the philosophy used was to make each module a very well shielded enclosure,to maintain coaxiality and integrity of ground throughout the housing, to use very careful routing of signal cables in the connector chassis keeping high level cables as far away as possible from low level cables.

One other aspect should be mentioned. Great care was taken in power supply decoupling to prevent any kind of crosstalk between modules via the power supply. All the precautions taken to ensure isolation were aimed at not only obtaining the correct isolation with comfortable margins, but also making the isolation obtained independent of whether the housing was open or closed. In fact, the isolations obtained are independent of whether the housing is closed or not, and the modules are so tight that signal ingress with the housing open is of extremely low level. There is a subtle bonus for this kind of construction which is this:

During the operation of a two-way system, whenever a housing is opened to perform maintenance or adjustment, there is a possibility of ingress. Where careful attention has been paid to module isolation, for example, in order to meet the specifications outlined previously, the ingress is greatly reduced to almost unmeasurable levels with the housing open. Measurements have been made on this type of station using the test equipment shown in Figure (6). The test equipment as shown is capable of a system floor better than 150 dB which makes measurements of 130 dB down quite accurate. Figure (7) shows the system gain flatness and system floor for the test equipment.

Figure (8) is a plot of the common frequency crosstalk, outgoing to outgoing, "A" cable into the "B" cable. The specification per station for this should be 90 dB, as discussed previously, and it will be seen in Figure (8) that this is met with margin up to and indeed above 300 MHz. The very noticeable fall-off below 150 MHz is due to the high/low mid-split filters in the station.

Figure (9) shows the isolation obtained for common frequency crosstalk, outgoing to outgoing, "B" cable to "A" cable. Again, you will notice, the 90 dB specification is comfortably met over the whole frequency range of interest.

Figure (10) shows the common frequency crosstalk "A" outgoing to "B" return. The band of interest is from 54 to 108 MHz and the specification set previously was 88 dB. This is comfortably met over the range 50 to 130 MHz, and then is exceeded. Again, this rapid drop above 130 MHz is due to the mid-split high/low filters.

The cable "B" return crosstalking into cable "A" outgoing in the band 54-108 is not shown, but is of the same order of magnitude, that is 110 dB or better across the band.

Crosstalk due to distortion. Figure (11) is a block diagram of a dual cable two-way system with crosstalk. The output levels of all trunk amps are set at +32 dBmV. The input level to the return trunk is set at +15 dBmV and the output of the bridger amplifier is set at +50 dBmV per channel. The performance of the bridger amplifier gives second and third order products down 75 dB at +50 dBmV per channel output level. Let us assume that the trunk amplifiers perform in the same manner, whether they be "A" or "B" cable trunks. The worst case distortion producer is, of course, the bridger since this has by far the highest level. The number below the output level in the bridger's case is -25 dBmV and represents second or third order distortion products level at that point. The ones of interest as far as the return direction are concerned lie in the range 5-30 MHz and 54-108. In the 5-30 MHz direction, the high/low split filter has 90 dB floors so that a signal input of -25 dBmV to that high/low split filter will come out of the low port 90 dB down, at a level of -115 dBmV. The 3 dB coupler places the signal at -118 dBmV at the input to the return amplifier. With a specified input level of +15 dBmV at that point, the ratio of desired signals to undesired is 133 dB for either second or third order products due to the bridger. The signals in the "B" cable outgoing also produce distortion and the arithmetic there is shown in Figure (11). Second order products are down -61 dBmV at the output of the "B" cable outgoing amplifier, and after passing through the high/low split filter at the output of the station are reduced a further 60 dB by the filtration action to arrive at the input of the return amplifier at -121 dBmV which is a ratio of 136 dB desired-to-undesired signal.

The distortions falling in the return direction caused by the "B" outgoing system will add on a total number of amplifier basis, that is, if there are 300 outgoing "B" amplifiers in the 300 stations there will be power addition of 300 sources of distortion. Why power addition? Consider the distortion arriving at the head end at some instance in time T0. In our system model there will be 300 separate signals arriving at that time. These signals have been caused by the outgoing signal and show a distribution in time proportionate to the round trip time for each single source. This time delay of the order of 2 microseconds per station out from the head end will destroy any coherence of distortion. The distortion, therefore, will add on a power basis. The summation factor for 300 amplifiers on a power basis is 25 dB so the figure shown on the diagram should be raised by 25 dB to give the total power observed at the head end to obtain a signal-to-interference ratio of 111 dB for distortion caused by the "B" outgoing amplifier falling in the "B" return and 108 dB for distortion caused by the "A" system bridgers falling in the return system. Distortions falling in the 54-108 MHz region caused by the "A" cable bridger will be -25 dBmV at the output of the bridger. These signals will undergo an attenuation of 130 dB through the high/low split filter to arrive at -158 dBmV at the input to the return amplifier. These are 40 dB below those distortions in the 5-30 MHz region and can be neglected for all practical purposes. The same thing applies to distortions in the 174-300 MHz region caused by the "A" cable bridger. These distortions at the same -25 dBmV at the bridger output before they are injected into the "B" cable outgoing amplifier suffer an attenuation of 170 dB minimum and would therefore appear at a level of -195 dBmV at the input to the "B" cable amplifier. Again, they can be disregarded for all practical purposes.

There remains one more distortion to be considered which is, distortion products produced by the "B" return amplifier falling in the "B" outgoing amplifier. At an output level of 32 dBmV per channel on the return amplifier, distortion products would be at that point -61 dBmV for second, -76 dBmV for third order products. These would undergo 40 dB of attenuation due to the high/low split filter and appear at the input of the "B" outgoing amplifier at -101 dBmV and -116 dBmV respectively. That is a ratio of signal-to-interference then would be 81 dB and 96 dB for second and third order products.

From the foregoing it can be seen that the crosstalk due to distortion in all amplifiers in this system is very low and can be disregarded.

To summarize, then, in this paper common frequency crosstalk in dual cable two-way systems has been examined, and certain specifications have been set to give good system performance. Measurements have been described which show that these specifications can be met using good engineering practice. Crosstalk due to distortion has been examined and shown, with high quality CATV amplifiers, to be negligible in its effect on the system.

"TREE" TYPE DISTRIBUTION SYSTEM

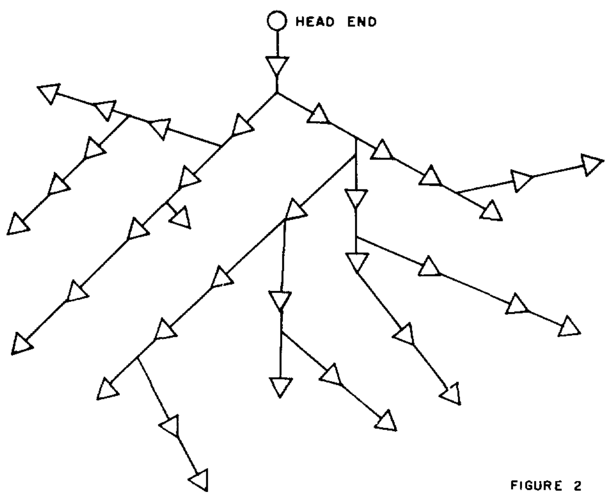


FIGURE 2

ONE WAY TRUNK STATION

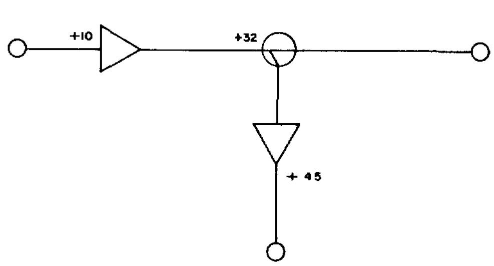


FIG. 3

LEVEL DIAGRAM

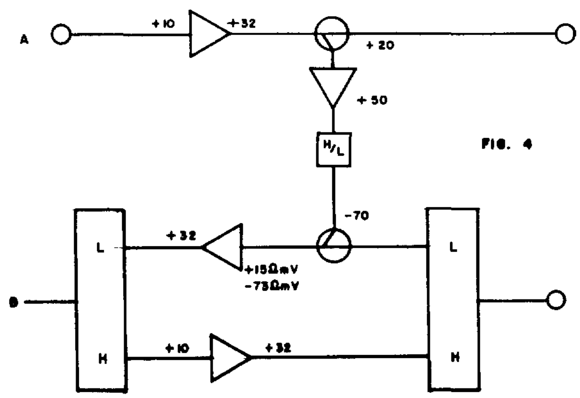


FIG. 4

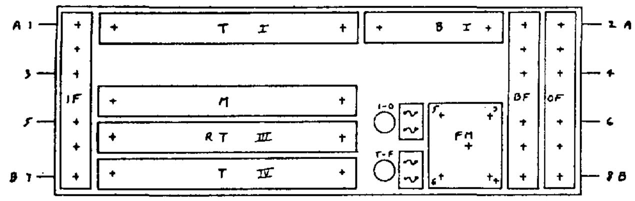
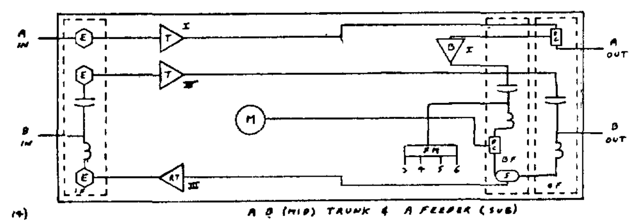


FIG. 5



ISOLATION TEST SYSTEM

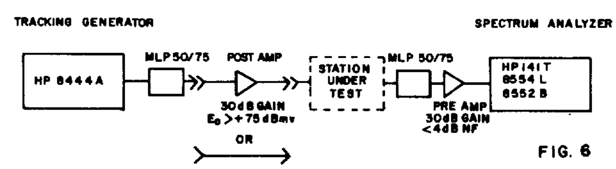


FIG. 6

TEST SYSTEM RESPONSE AND ISOLATION

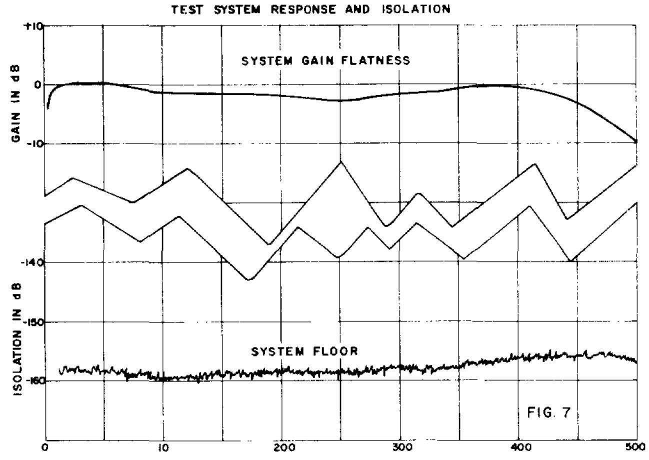


FIG. 7

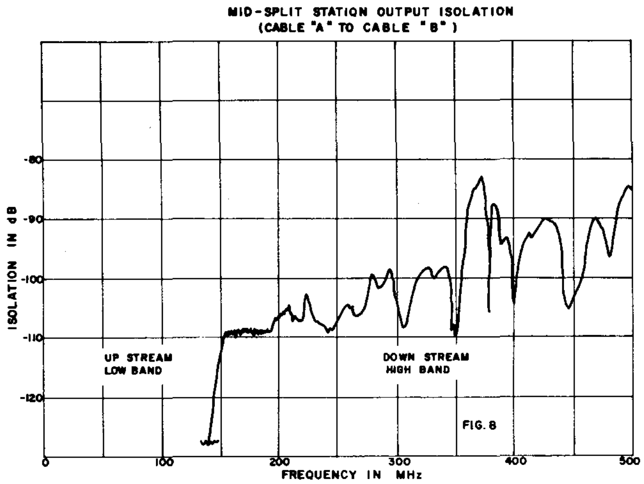


FIG. 8

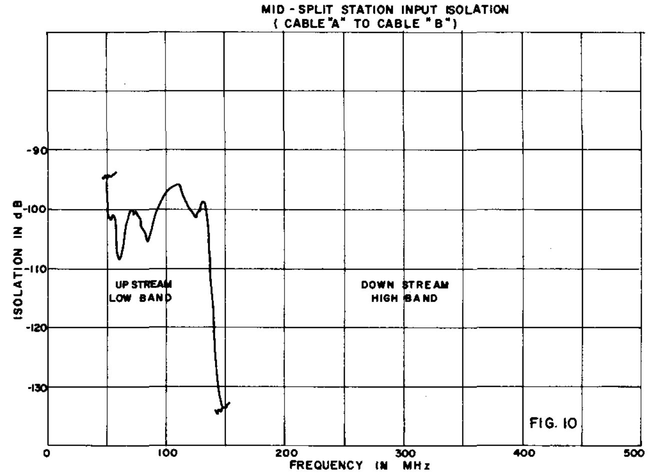


FIG. 10

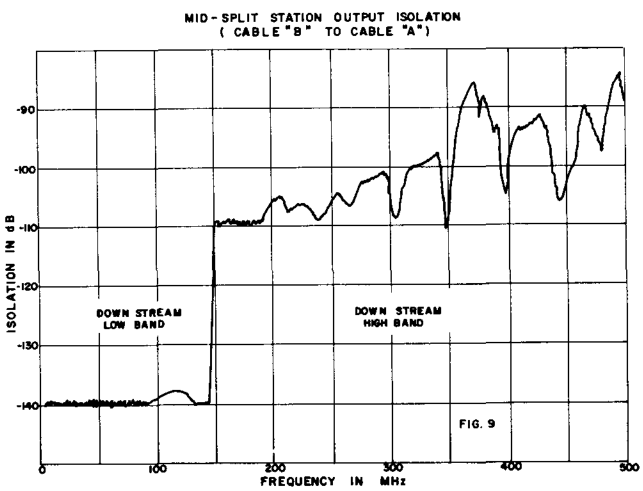
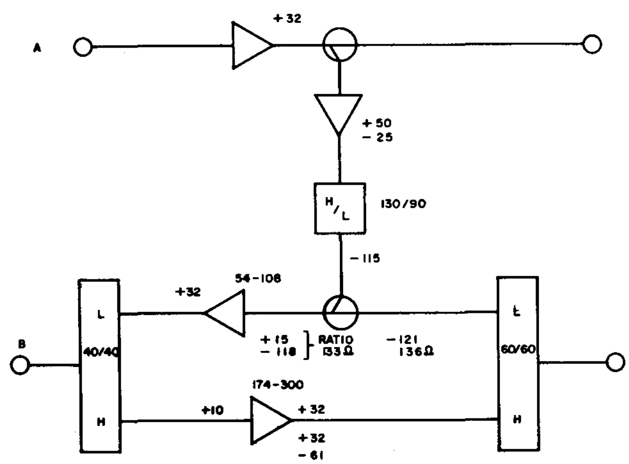


FIG. 9

LEVEL AND DISTORTION DIAGRAM



ALL LEVELS IN dBMV

FIG. 11