Klixon is a very good unit.

QUESTION: You stated that DC line powering caused electrolysis. You have further stated that there is DC in the amplifier. Why doesn't this cause electrolysis in the fittings?

MR. SPRADLIN: Since the DC component is blocked by capacitors it does not go through the fittings.

MR. COOLEY: Any more questions, gentlemen: Well, I thank you very much, Mr. Spradlin. (Applause)

The next paper is entitled, "The Effects of Coaxial Jumpers". Our speaker is the director of Research and Quality Control for Superior Cable Corporation. He was educated at Lenore Ryan College in Hickory, North Carolina. He has a BS degree, major in chemistry, physics and mathematics. He has 3 years in the United States Army in classified work on the Security Agency. Two years in the Shepherd Enterprises, Inc. as a chemist. Ten years in the Superior Cable Corporation as a technician, research and laboratory development engineer. He is presently Director of Research and Quality Control. Gentlemen, Mr. Walter Roberts. (Applause).

MR. WALTER ROBERTS: Thank you. Does everyone have a copy of this paper? "Impedence Discontinuities and CATV Cables". The paper itself, which I hope you'll have time to read in more detail later and which I won't try to discuss in complete detail, begins with an introduction of why uniformity in CATV systems is important. And, I'm sure you folks can tell me more reasons it's important than I can tell you. In fact, I was in the transmission line of business quite a while before I found out broadbanded didn't have anything to do with an all-girl orchestra.

But, in this little paper some of the factors affecting uniformity and coaxial cable plan are discussed. There is no attempt made to at least directly describe the effects of non-uniformities in associated electronic equipment, except for some graphs which I hope to show you on combined effects.

Demands for improvements in signal transmission uniformity have probably been experienced in every CATV system operating today. The need for upgrading existing service through additional channels has oftern exposed system non-uniformities which were not at all obvious while carrying only a few channels. Similar problems have become evident only after initiation of color transmission. In recent years, new systems involving longer cable trunk runs have shown effects from irregularities which would probably have gone undetected in shorter runs.

Some of the factors affecting uniformity in coaxial cable plant are reviewed in this paper. Except for the effects on cable impedance characteristics, no attempt is made to describe nonuniformities in associated electronic equipment inserted into the cable system. Most of the descriptions are based on the effects the discontinuity produces on a transient pulse along the line. These are much easier to visualize than in the case of steady-state alternating currents and, anyway, the two modes are completely correlated mathematically.

the effect of impedance discontinuities on steady-state operation is best determined through input impedance measurements (and calculations). Input impedance of the line may be measured at a particular discontinuity or it may be at a point along the cable remote from the location of the nonuniformities. The performance of the line, or its deviation from normal, is determined by the impedance it exhibits at a frequency or band of frequencies.

Also presented are charts showing relationships between cable impedance uniformity and attenuation uniformity. These are shown both for the case of discrete discontinuities and for the case of periodic, distributed discontinuities along the cable. These two sources do not result in equivalent impedance deviation attenuation relationships.

One of the most common source of discrete discontinuities in trunk cable results from the use of jumper cables, usually at amplifier locations. Actual test data showing effects on return loss and transmission uniformity are given for some typical jumper - amplifier combinations. Also displated are curves showing effects of moisture in connectors at these junctions and, particularly, the frequency dependence of these effects.

Single and Double Impedance Discontinuities Consider a "long" coaxial cable whose impedance is uniform along the length but which abruptly increases to a larger value at a single point, then remains uniform over the remainder of the length. The cable is "long" in both directions from the discontinuity.

Assume a positive polarity pulse is traveling at the velocity of propagation of the cable and suppose it passes through the junction into the larger impedance portion of the cable. At the junction some of the energy is reflected back toward the origin. Encountering an impedance increase at the junction, the reflected pulse is also of positive polarity and its shape is a replica of the pulse just as it encountered the junction. (The pulse shape may be distorted from its original shape but this is a result of attenuation and phase distortion while traveling from the point of origin along the cable.) The magnitude of the pulse is proportional to the impedance change . . for small impedance differences. In the extreme case of an increase in impedance (i.e., an open circuit) all of the energy is reflected.

If the pulse were traveling from the opposite direction and thus encountered n an impedance decrease, the only difference from the above case would be that the polarity of the reflected pulse would become reversed. In the extreme case of a short circuit, again all of the energy would be reflected but the voltage amplitude at that point would be zero.

Instead of one, imagine two discrete impedance increases separated a short distance from each other but otherwise located a long distance from either cable end.

Again, assume a positive pulse traveling from the smaller toward the greater impedance section of cable. A portion of the energy is reflected from the first junction without polarity reversal and an additional portion is similarly reflected from the second junction. If the transit time of the pulse between the two junctions (round trip) is small compared to the time duration of the pulse, then the amplitudes of the two reflected pulses tend to add together. As the separation between junctions increases (or if the width of the pulse is decreased), the two reflections tend to resolve into distinct pulses.

If a signal of positive and negative pulses alternating at a fixed frequency is applied to this cable, a special case arises where the pulse transit time between discontinuities is comparable to the time between successive pulses. When the junction separation and pulse repetition rate are such that a pulse returns to the first junction just as the next pulse reflection occurs (a quarter-wave section) the two reflections tend to subtract by virtue of their opposite polarity. If the distance between junctions were doubled (producing a half wave section), a reflected pulse would return to the first junction at the instant a reflection of like polarity had occurred at the first junction. Thus the amplitudes add to each other and produce a very pronounced effect under this set of circumstances.

Another form of double discontinuity occurs when an impedance increase is followed by a second junction at which the impedance decreases. Here polarity reversal of a pulse occurs at one junction and the two reflected pulses tend to cancel when the transit time between junctions is small compared to the pulse duration. As the separation between junctions increases, the time delay becomes sufficient that separate reflected pulses are resolved.

For a repetitive set of alternating pulses as described previously, the results applied to this case must be interchanged because of the polarity reversal; i.e., reinforcement of the reflections occurs for a quarter-wave section, subtraction occurs for a half-wave section.

One other variation of the double (increase-decrease) discontinuity which is of practical importance can arise when two short (compared to the pulse width) double discontinuities occur separated by a distance comparable to the quarter or half-wave sections already discussed. Two double discontinuities representing impedance increases (or decreases) affect repetitive alternating pulses much as in the case of the stairstep type discontinuity just discussed. Pairs of double discontinuities changing in opposite directions are similar to the double (increase-decrease) discontinuity. In such cases as these, the resultant reflected pulses are not replicas of the incident pulse shape.

Many combinations of these discontinuities can be conceived but the preceding illustrate some of the more common forms encountered. A simple rule for visualizing results of various combinations of discontinuities is to remember that phase reversal accompanies reflection from a decreasing impedance junction -- no reversal from an increasing impedance junction.

Input Impedance Deviations The input impedance of a line containing discontinuities can vary radically over even a narrow band of applied frequencies. In fact, measurement of input impedance deviations of cables provides one of the most sensitive known means of detecting discontinuities. The most common technique employs swept-frequency equipment and results are usually reported as return loss in decibels or as VSWR (See Table I). In practical work only the modulus of the input impedance deviation is determined.

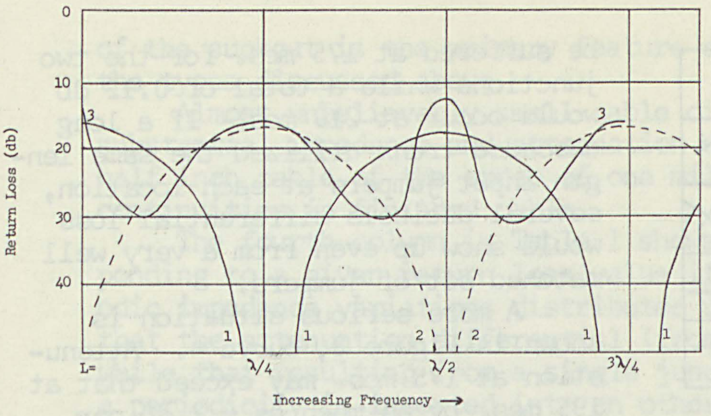
TABLE I

Return Loss (db)	VSWR	Reflection Coefficient	Attenuation Deviations Periodic (%)*	Attenuation Deviations Junction (db)
1	17.15	0.890	860	6.8
5	3.56	0.562	92	1.7
10	1.93	0.316	23	0.45
13	1.57	0.224	11	0.22
16	1.38	0.158	5.0	0.10
19	1.25	0.112	2.5	0.056
21	1.20	0.090	1.6	0.036
24	1.14	0.063	1.0	0.020
27	1.09	0.045	0.5	0.006
30	1.064	0.031	0.2	0.004
32	1.057	0.025	0.1	0.003

*At the "resonant" frequency of the cable periodicity.

A single impedance discontinuity along an otherwise uniform cable produces an input impedance deviation whose modulus is constant even though it contains non-constant real and imaginary components. Naturally the magnitude is a function of the size of the impedance step at the junction. But it is also a function of the distance between the junction and the point of measurement. If this distance is too great, the effect on input impedance is small even for large junction steps. The reflected energy is attenuated on the way back from the junction and therefore produces little effect at the point of measurement. This particular effect, incidentally, is responsible for one major limitation of the use of return loss measurements to determine cable uniformity -- the method is sensitive only to discontinuities located near the ends accessible for measurement.

Figure 1 (next page) shows impedance deviation (return loss) for several combinations of double discontinuities as measured from a point along the cable not too far away.



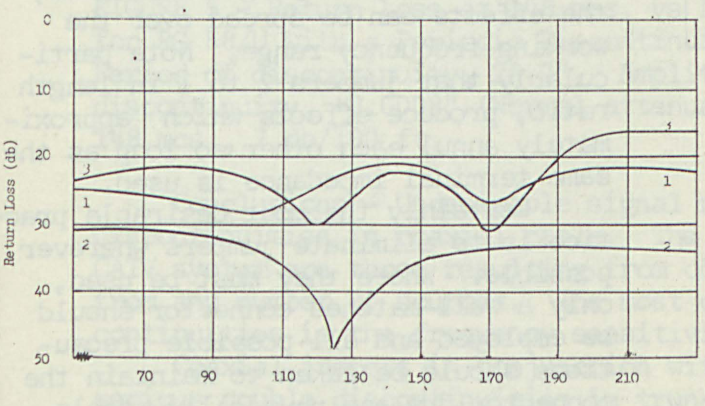
Increasing Frequency

FIGURE 1 - Calculated Return Loss vs Frequency of Various Double Discontinuity Cable Sections. (1) 90-ohm cable, 75-ohm section L, 60-ohm cable; (2) 90-ohm cable, 75-ohm section L, 90-ohm cable; (3) 125-ohm cable 75-ohm section L, 60-ohm cable.

Curve number 3 in Figure 1 is of special interest -- the magnitudes of the impedance steps are not equal. At no frequency does the impedance deviation become zero. Complex variants of such curves as this are the rule while idealistic curves such as numbers 1 and 2 are seldom encountered in system measurements. As in the cases described for alternating pulses, oppositely directed discontinuities result in interchanged input impedance deviations - compare curves 1 and 2.

Terminations at electronic devices may exhibit mismatches which act in conjunction with nearby discontinuities to produce double discontinuities generally showing characteristics of some of the pairs jus discussed. In the following section are presented details of just such effects.

Coaxial Jumper Cables - Though it is highly desirable to avoid the use of jumper cables in CATV systems, conditions arise where the practice cannot be avoided. However, the chances for creating a substantial double discontinuity are provided by the terminal equipment and conditions in the connector or splice. The use of an impedance matched connector avoids the more obvious source of mismatch at this junction but environmental conditions (such as the presence of water in the connector) can readily spoil the matched connection. Input and output terminals of typical amplifiers show substantial impedance deviations which also vary considerable over the working frequency range.



Frequency (mcs.)

FIGURE 2 - Return Loss vs Frequency - Amplifier Input with 18" Stub Cable. (1) Amplifier Input (SKL 222A), (2) Solid PE dielectric 75-ohm 18" jumper cable, (3) Ampl. Input incl. 18" jumper, with dry 75-ohm "N" connectors.

The combination of moist connectors and amplifier terminals can produce some startling effects. Figures 2 and 3 are drawn from data measured on actual jumper cable-amplifier combinations. The amplifier specifications indicate better than 20 db return loss, a fact which was substantiated by measurement. However results as poor as 17 db (Figure 2) were obtained with jumper cable-connector combinations which measured 32 db minimum before connecting to the amplifier input. As can be noted in Figure 3, extremely poor return loss values can result when the connector has been moistened.

The effects on an operating system can be better compared if the actual attenuation component resulting from a particular value of return loss is selected from Table I. For example, in Figure 2, a total of 0.026 db would

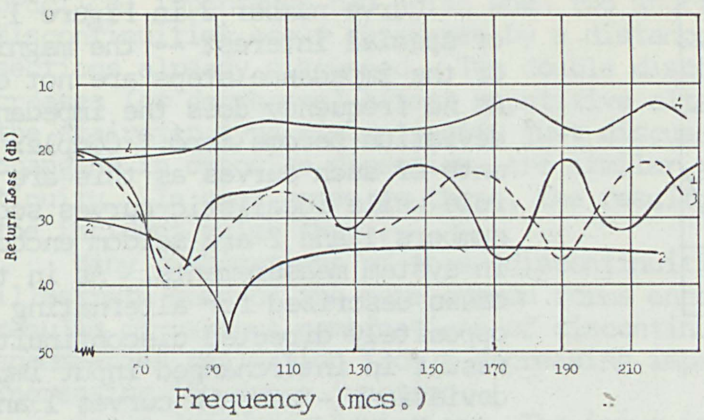


FIGURE 3 - Return Loss vs Frequency - Amplifier Output with 24" Jumper Cable. (1) Amplifier Output (SKL 222A), (2) Solid PE dielectric 75-ohm 24" jumper, (3) Ampl. Output incl. 24" jumper, with dry 75-ohm "N" connectors, (4) Same as (3) except connector moistened with water.

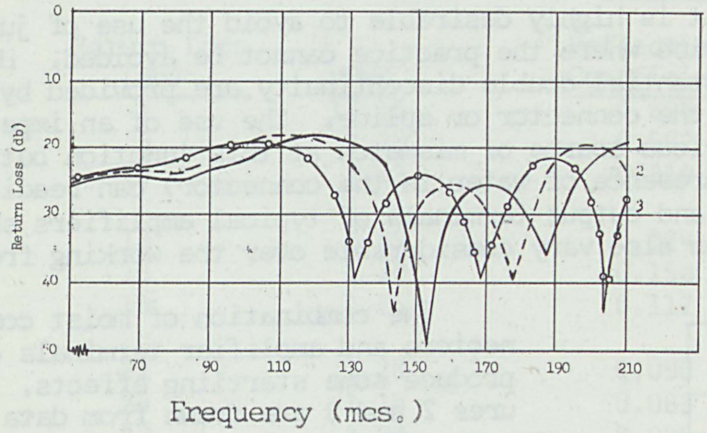


FIGURE 4 - Return Loss vs Frequency for Various Length Jumper Cables Connected Through Half-Step Equalizer (SKL 499) to Amplifier Input (SKL 222A) (1) 12" solid PE dielectric jumper cable, (2) 18" solid PE cable, (3) 24" solid PE cable.

be suffered at 175 mcs. for the two junctions while a total of 0.12 db would occur at 210 mcs. If a long cascaded trunk utilized the same length input jumpers at each location, several decibels differential loss would show up even from a very well matched set of jumpers.

A more serious situation is shown in Figure 3, curve 4. Attenuation at 175 mcs. may exceed that at 195 mcs. by as much as 0.2 db per output location. Six or eight decibels of differential attenuation could accue in a long run. Furthermore, transient dry and moist conditions can cause unpredictable and quickly changing differentials. Obviously this would represent an intolerable situation and most certainly the moisture must be eliminated.

If jumper cable lengths are to be limited to less than a quarter wave length, their utility is lost. A solid polyethylene dielectric jumper would be limited to less than about 8 inches at 210 mcs. Figure 4 illustrates one means of reducing the frequency sensitive results which would accrue with a large number of equal length jumpers. By deliberately varying the lengths, the effects can be spread over the working frequency range. Note particularly that jumpers 2 to 1 in length ratio, produce effects which approximately annul each other so long as the same terminal impedance is used.

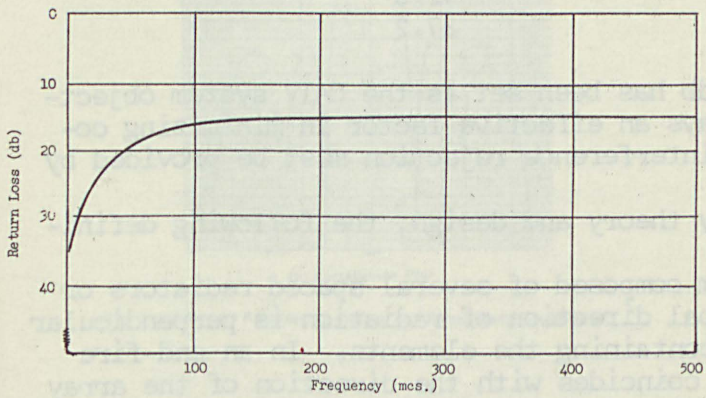
Certainly the most desirable practice is to eliminate jumpers wherever possible. Where they must be used, only a well-matched connector should be employed and all possible precautions should be taken to maintain the connector dry and physically stable.

Cable Periodicities - An impedance change does not have to occur abruptly to produce a discontinuity and accompanying reflections. Smoothly changing cyclic variations in local impedance along cable lengths have plagued cable manufacturers at almost every stage of cable fabrication. The resulting effects on input impedance and transmission properties are, in principle, much as has already been described for discrete discontinuities. At a frequency for which the impedance variation period equals a half-wave section, the input impedance increases and a significant increase in attenuation occurs for extreme cases.

At the frequencies encountered in CATV systems, these discontinuities (or suckouts as commonly termed) occur over very narrow frequency ranges - in the order of a couple megacycles. The impedance variations, cycling every few feet, can repeat several hundred or thousand times throughout a cable length. In practice, the narrow band width of the suckout is the primary feature distinguishing this type of discontinuity from the types discussed above.

Almost unbelievably small cable diameter variations, if periodic, can cause a substantial impedance and attenuation discontinuity. Cable diameter variations in a half inch cable of the order of one mil (0.001") can cause intolerable impedance discontinuities in finished cable.

The fourth column in Table I shows the percent variation in attenuation corresponding to a given return loss value if the impedance deviation resulted from periodic impedance variations distributed uniformly along the length of the cable. Noticee that the attenuation differential (from normal) is proportional to the cable length while that resulting from a single junction is a fixed quantity. If a cable containing a periodicity is inserted into an otherwise uniform system, the distributed attenuation excess would occur and, in addition, junction reflections would occur at the terminal ends of the cable because of the mismatch in input impedance at that band of frequencies.



Length (feet)

FIGURE 5 - Return Loss at 148 mcs. vs Length for RG 58/U with a Periodic Discontinuity. Period of discontinuity, 26.7". Amplitude of discontinuity, +0.0008" (Normal attenuation at 148 mcs., 7 db/100 ft.

Figure 5 shows another trait exhibited by a cable with a periodic impedance discontinuity. The effective value of the return loss increases with cable length only over a limited length. This is natural because the attenuation of the reflected energy farther down the length prevents a substantial contribution to the energy reflected from points nearby. A single discontinuity located a reasonably short distance from a cable end can produce the same apparent return loss as would a set of small but periodic discontinuities. Yet, if these should persist, the small variations can accumulate a large attenuation discontinuity while the effect of the single discontinuity would have been negligible by comparison.

Conclusions - Undesirable signal reflections occur from all sources of impedance discontinuities in coaxial cable. The most serious sources of reflections for the CATV system are those resulting from double discontinuities which, in turn, arise from any number of sources. The most objectionable problem created by double discontinuities is the frequency sensitivity of the input impedance.

Coaxial jumpers in conjunction with equipment terminal impedances can result in serious double discontinuities in trunk runs, particularly if all jumpers are of equal length. Staggered jumper lengths and well matched and protected connectors will alleviate problems of this source.

For a given input impedance deviation, periodic impedance variations in a cable can produce far more serious attenuation variations than would a single or double discontinuity.

Thank you. (Applause)

MR. COOLEY: Thank you, Mr. Roberts. The next subject on the agenda is "A New Antenna for CATV" and our speaker is a graduate of Mississippi State University with a BSEE. He did graduate work at Southern Methodist and worked for Ling Temco, All Products Company and Scientific Atlanta. He has published papers on a high gain space telemetering array and engineering report on a high frequency rotable log periodic