give another noise wave form 3 db higher than each of them by itself. So when we make a measurement this way, all we have to do is subtract 3 db from the results and then we get the cable perfectly balanced against the best thing it could be balanced against, which is itself.

MR. TAYLOR: Did anybody have another question they would like to ask?

MR. SHIELD: Don Shield, Vancouver. Ken, I was wondering if you have come up with a practical limit to the length of cable for which your testing technique is useable? I know that 2000 feet is a typical length for a reel, but it seems to me that the length of the cable or the attenuation will have an effect on your results as well. Am I clear on that, or is that a confusing thing?

MR. SIMONS: The answer to that question is that the return loss method gives you a view into the first 500 to 1000 feet, depending on the loss of the cable. Of course, it doesn't matter how much longer than that it is, but you're not looking at the middle of the cable. You get a decidedly prejudiced view of each end of the cable and if the manufacturer, under the present circumstances, could make cable that was very good at both ends and bad in the middle and save money that way, I suppose you could get away with it. But it doesn't generally happen, if you have a cable that is good at both ends. All things being equal, it's apt to be good in the middle.

MR. TAYLOR: Thank you very much, again, Ken. We'll proceed onto the next paper by Mr. Allen Kushner of Times Wire and Cable, who is going to continue the discussion of cable by talking about, "Coaxial Cable Performance for CATV". This is a substitute for Dave Karrmann who was listed on the program. I introduce Mr. Kushner. [Applause]

MR. ALLEN M. KUSHNER (Times Wire & Cable, Division of The International Silver Company): Dave Karrmann was originally scheduled to write this paper. However, since the time we submitted his name he was taken off this particular project. I was assigned the job of writing the paper. I watched with great interest Ken's paper because since I came with the Company my primary responsibility has been really to watch over the testing of cable. So I have seen some 300,000,000 feet of test reports reflecting basically what Ken has had on the board and it was quite interesting.

PURPOSE

The purpose of this paper is to discuss the characteristics of coaxial cable which are of major importance in CATV system performance. We shall attempt to accomplish this by showing how the cable affects system design and customer pciture quality. We also shall attempt to show the substantial improvements which have been made in cable design and manufacture in the past 15 years, and to discuss what remains to achieve the optimum cable design of the future. As a result of this discussion we hope to have underlined those cable characteristics most critical to system performance.

ILLUSTRATIVE AMPLIFIER and CUSTOMER HOOKUP

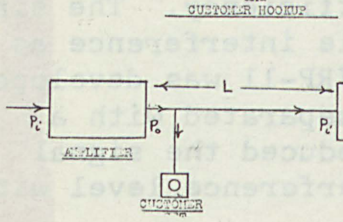


Figure 1

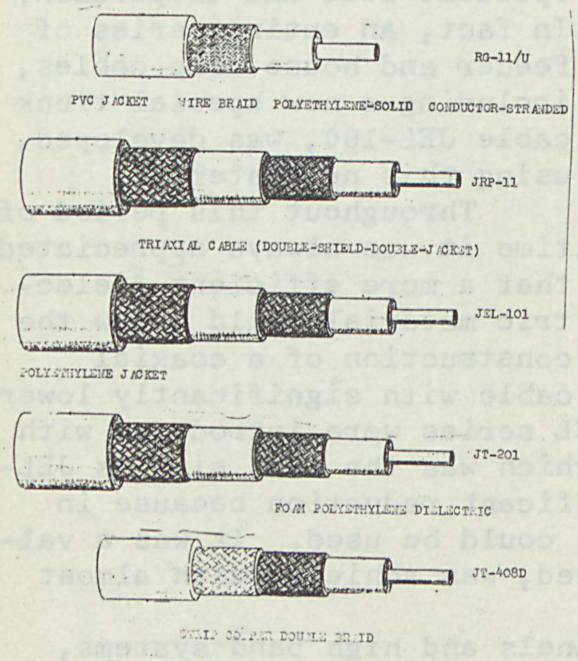
IMPORTANT CABLE CHARACTERISTICS

In Figure 1, a typical section of a feeder system is shown. The following important factors of this system should be noted:

1. For a minimum amplifier input signal, and a maximum amplifier output signal, the attenuation (loss) in the cable determines the distance between amplifiers. The lower the attenuation, the less the number of amplifiers to cover a specific distance.
2. Signals within the cable can escape. Such signals could exceed regulatory levels or disturb adjacent equipment. By the same means local interference due to ignition systems, ham operators, etc., could enter the cable and affect picture quality.
3. If there are reflections in the cable, these reflections will cause additional picture images to arrive at the customer's set after the main signal arrives, causing fading or ghosts.
4. It is not only necessary to have the cable meet specific performance requirements on installation, but it is also necessary to be certain that the cable meets these requirements throughout the system life.

IMPROVEMENTS IN COAXIAL CABLE DESIGN

Figure 2



HISTORY OF CABLE DEVELOPMENT

It is important to study the improvement in cable characteristics over the years because these improvements were based on the changing system requirements and from feedback from field experience. In noting the trends in cable design and the reasons for the trends, we have an excellent foundation for selection of present day cable design as well as future cable development.

Let us trace first the changes in the cable constructions most commonly used and note the reasons for them. In Figure 2 we see the various cables and the approximate year in which they were first used. Prior to 1952, the cable first used as feeder cable was RG-11/U with stranded center conductor, solid polyethylene dielectric, a single braided outer conductor, and a polyvinyl chloride jacket. The most serious shortcoming of this design at that time was its shielding efficiency. The single braided outer conductor allowed significant cable interference as well as signal escape. To overcome this drawback, JRP-11 was developed, which was a triaxial cable having two outer braids separated with a layer of polyvinyl chloride. This triaxial cable reduced the signal escaping or entering to approximately 1% of the interference level with RG-11/U.

JRP-11/U, while an improvement over RG-11/U, still suffered from two major deficiencies. First, the polyvinyl chloride jacket material caused contamination of the polyethylene and an attenuation increase. In addition, the life expectancy of the PVC when exposed to sunlight was limited. In 1954, JEL-101 was introduced with Xelon, a long-life, non-contaminating polyethylene jacket and life expectancy of 20 to 30 years. This was a special high molecular weight polyethylene containing a predetermined percentage of carbon black of a specific size and dispersion. In fact, an entire series of feeder and house drop cables, including a new special trunk cable JEL-100, was developed, using this new material.

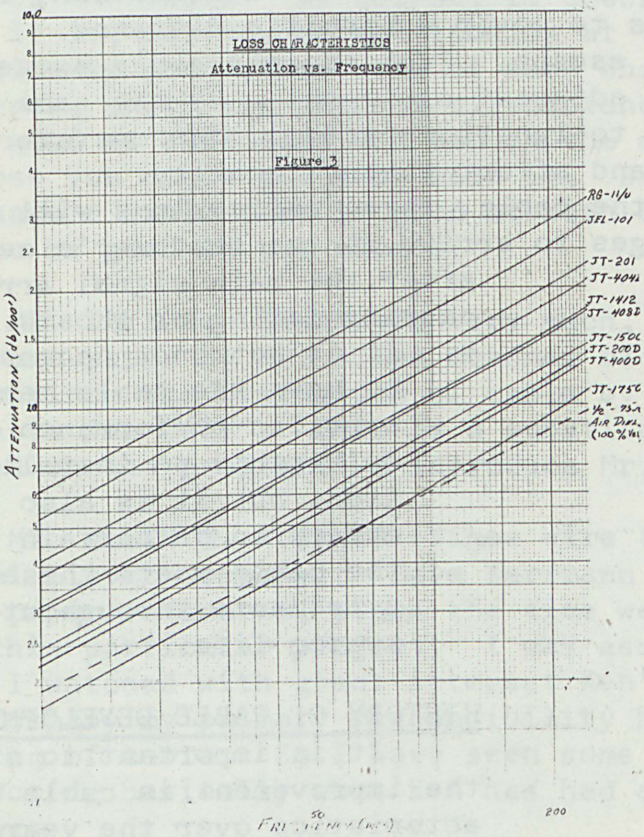
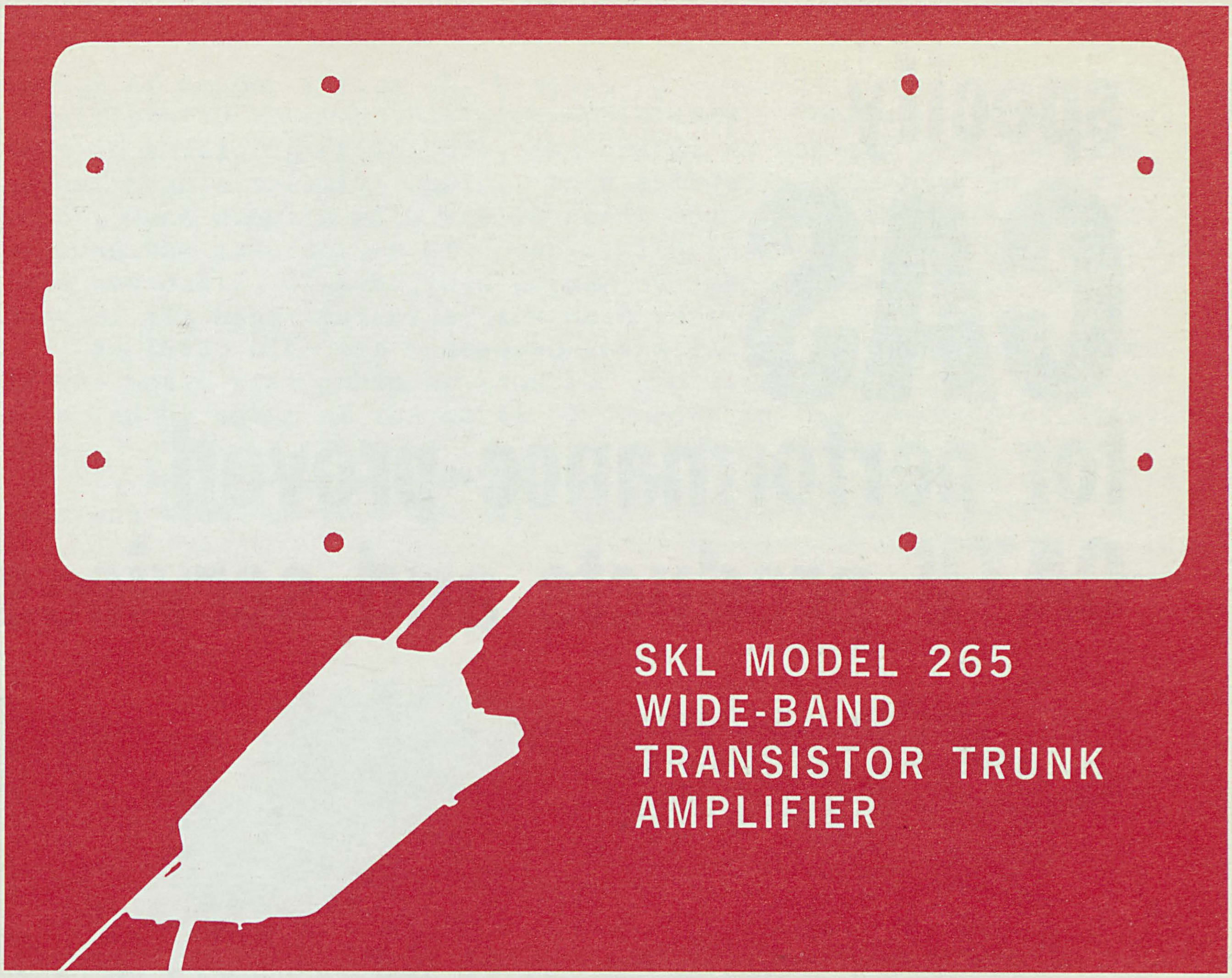


Figure 3

Throughout this period of time it was always appreciated that a more efficient dielectric material could allow the construction of a coaxial cable with significantly lower losses. In 1955 cables similar to the JEL series were introduced with foam polyethylene dielectrics. JT-201, which was the same size as JEL-101, had 25% less loss. This was a significant reduction because in the same installation 25% less amplifiers could be used. It was a valuable improvement which, it should be noted, was achieved with almost no cost increase.

In 1960, with a demand for more channels and high band systems, there developed a need for a cable with lower losses at basically the same cable cost. This was achieved through the development of flexible


SKL MODEL 265
WIDE-BAND
TRANSISTOR TRUNK
AMPLIFIER

braids of copper strips which achieved somewhat lower losses, but significantly greater shielding efficiency. Because of the improvement in shielding efficiency, two braids in contact could be used rather than a triaxial cable. This allowed a reduction in cost which, when coupled with the inherent economy in the strip itself, allowed the manufacture of a cable with larger dielectric than JT-201. This new cable, JT-408D, was primarily responsible for the development of all band systems at low band costs.

By 1963, with the increased installation of high band systems, it was noted that cable attenuation and useful cable life could be affected by aging of the cable components in the presence of moisture vapor.

It was determined that the metallic-type barrier achieved with a seamless aluminum tube was sufficient to prevent vapor entry. However, it was also noted that the dielectric must be compressed sufficiently to prevent longitudinal vapor entry through taps and fittings. In 1963 an economical technique was developed for producing 1000-foot lengths of cable with a seamless aluminum outer conductor properly applied.

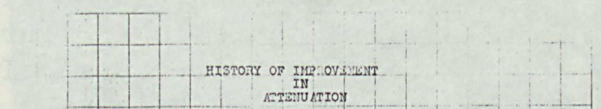


Figure 4

The limitation of 1000-foot lengths did require the splicing of lengths, causing additional costs, reflections and maintenance problems. In 1965 the manufacturing techniques for producing up to one-half mile, continuous splice-free lengths was developed to reduce costs and improve performance.

This, then, is the history of the development of the coaxial cable. Please note that the key factors are: Shielding efficiency, jacketing materials, low loss, cable life (moisture resistance) and cable lengths.

IMPROVEMENT IN CABLE ATTENUATION

The attenuation versus frequency response of all the cables are shown in Figure 3. It is interesting to note how the attenuation of the feeder and trunk cables was improved over the years. Figure 4 shows the attenuation of the trunk, feeder-trunk and feeder cables most commonly used and the year in which they appeared.

Though the purpose of this paper is to present the technical aspects of cable development, it is pertinent to this discussion to talk of the improvements which have been made in light of the cost for the various cables. To make this meaningful it is helpful to create an Amplifier Spacing/Cable Cost Figure of Merit. This figure of merit is created by determing the number of feet of each type cable which we would have between amplifiers with 20 db spacing at Channel 13:

$$F \text{ of } M = \frac{20/\alpha \text{ per foot}}{\text{cable cost per 1000 ft.}}$$

The higher the Figure of Merit, the more efficient is the cable construction. Figure 5 shows the improvement in amplifier spacing/cable cost Figure Of Merit over the years. It should be noted that this is a comparison on cable characteristics only, which is justified in the case of feeder cable, and does not take into account any costs due to amplifier requirements.

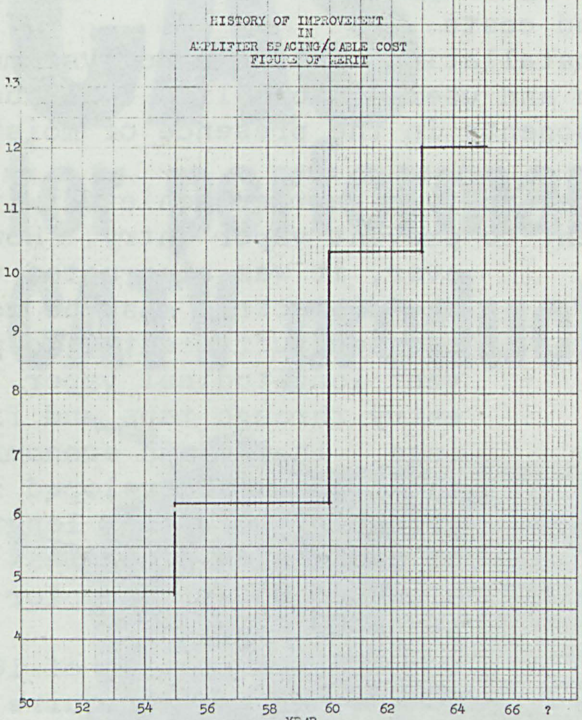


Figure 5

In the case of trunk cable, we must take into account the effect of amplifiers. In this case it is helpful to talk of an effective cable cost per 1000 ft. The cost of trunk cable and amplifiers is approximated by this relationship: Cable and amplifier cost =

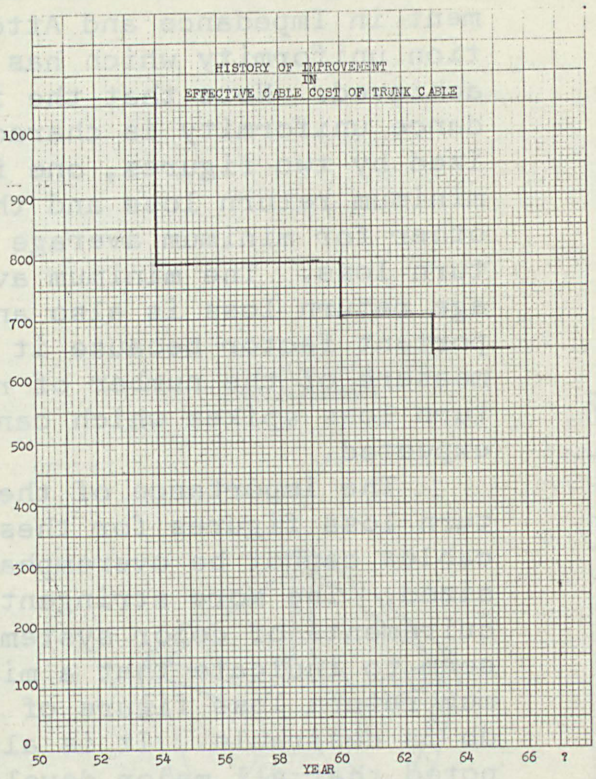
$$\text{Length of Cable X Cable Cost} + \frac{\text{Lgt. of cable x atten. x ampl. cost}}{20 \text{ db}}$$

The amplifier cost consists of initial cost, plus installation cost, plus pole rental, power and maintenance cost. If we consider the life of the system to be five years, a conservative cost of $760. is used. Since the length of cable is common to both factors, we can rewrite this expression as follows:

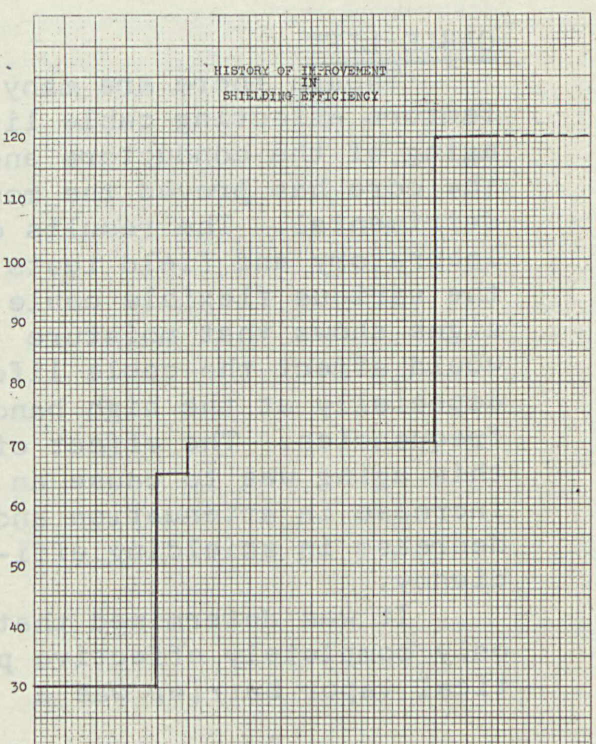
$$\text{Cable and Amplifier Cost} = \text{Length of Cable}\left[\text{Cable Cost} + \frac{\text{Atten.} \times 760}{20}\right]$$

$$= L\ (\text{Cost/1000 ft.} + 38 \text{ attenuation/1000 ft.})$$

$$= L\ (\text{Effective Cable Cost})$$



YEAR
Figure 6



YEAR
Figure 7

Figure 6 shows the reduction which has been achieved in Effective Cable Cost for trunk cable.

IMPROVEMENT IN SHIELDING EFFICIENCY

It was determined in 1952 that a triaxial version of RG-11/U was necessary to meet the limits of system interference requirements. This requirement has not truly changed to the present time. However, the shielding efficiency of present day constructions are vastly improved so that it is interesting to chart the change in shielding efficiency. Figure 7 shows the shielding chamber. It should be noted that the limitation of present day cable is in the connectors used. In fact, our present test equipment is not sensitive enough to measure radiation from the aluminum sheathed cable.

IMPROVEMENT IN RETURN LOSS FIGURE

Any variation of dimensions or velocity of the dielectric will cause reflections within the cable. If there are enough of these reflections, and if they are evenly spaced, we will find that the reflections will add at specific frequencies to give attenuation increases and impedance variations. We determine the attenuation variation by sweeping the cable and looking for attenuation "suckouts". We determine the impedance variation by using a bridge and measuring the db difference

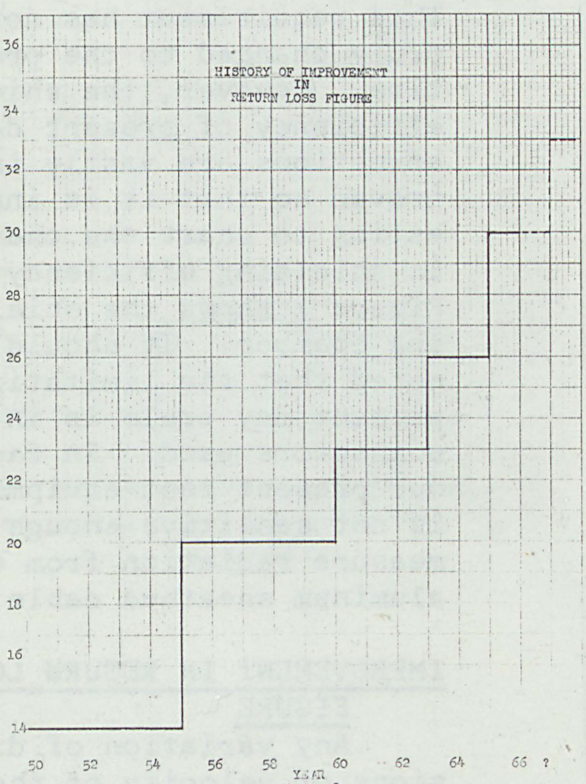


Figure 8

between the signal in and the signal reflected, and by looking for return loss spikes.

Figure 8 shows the improvement in Impedance and Attenuation uniformity which has been achieved. Note that the impedance uniformity is characterized by two figures, one for minimum return loss and the other for minimum average return loss. The minimum average return loss is also an important factor because it is a measure of the number of return loss spikes which can be expected.

The importance of the return loss figures for these cables cannot be overemphasized. The more stringent requirements of color systems seem to indicate that a minimum return loss figure of 30 db is desirable. It is also noted that all major developmental work being performed today is being done with 30 db as the minimum acceptable return loss figure.

<u>CABLE LIFE</u>

Though there are many factors affecting cable life, aging of the conductors and the core has proved the most detrimental. The results of laboratory and field tests on the various flexible cable designs shows that moisture would affect the cable life especially at the high band frequencies. The effect of this aging was to cause an increase in attenuation and a decrease in shielding efficiency.

It was determined that the only completely effective practical vapor barrier was a metallic barrier such as that formed by a tubular outer conductor of copper or aluminum. It was further determined that this barrier has to be continuous all the way around, with no opening. Though this did take care of radial leakage, there was the additional problem that leakage at the connectors or taps would allow moisture to enter. This vapor would propagate the length of the cable if there were longitudinal paths.

To prevent longitudinal paths, new aluminum sheathed coaxial cable must be manufactured with adhesion to the center conductor and with compression of the dielectric under the outer conductor.

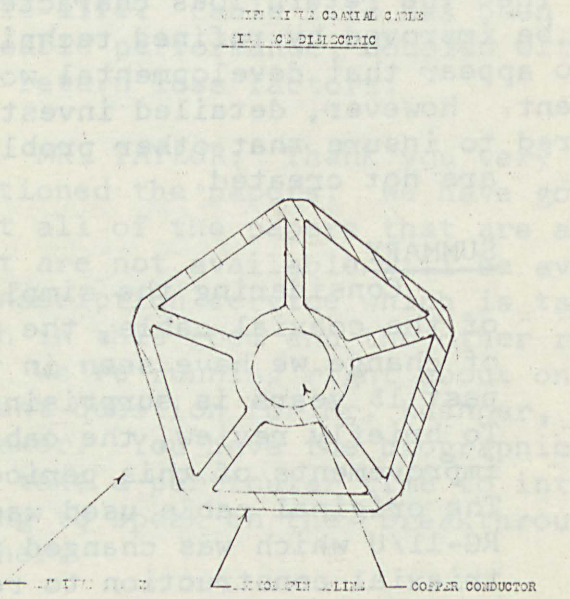


Figure 9

ATTENUATION REDUCTION

It would appear that future development will be in the area of improved dielectric material. Figure 4 shows the attenuation which could be achieved if improved foam polyethylenes were available. The attenuation which could be achieved with air dielectric cables is also shown in Figure 4. While the development of improved foam dielectrics appears feasible, it is questionable whether the use of air dielectric cable is practical.

In Figure 9 is an air dielectric cable which Times manufactures. Even though the center conductor is tightly covered with a layer of polyoelfin, and can in no way corrode, the attenuation of the cable is affected by moisture entry. To properly and dependably use this construction would require pressurizing the cable. While this is possible, the cost of pressurizing equipment, cost of special fittings and the increased maintenance problems, make the economic feasibility doubtful. Should the use of airspace cable be considered, it is worthwhile to note that corrosion of the center conductor is an irreversible process and that the center conductor should be protected.

IMPROVED RETURN LOSS RESPONSE

Our present evaluations indicate that the return loss characteristics of our present constructions can be improved by refined techniques and improved equipment. It would also appear that developmental work in new materials may lead to improvement. However, detailed investigation of such materials would be required to insure that other problems are not created.

SUMMARY

Considering the simplicity of the coaxial cable, the amount of change we have seen in the past 15 years is surprising. To briefly review, the cable improvements of this period: The original cable used was RG-11/U which was changed to a triaxial construction to reduce interference; the jacketing material was changed to eliminate contamination and increase cable life; this was followed by changing the dielectric to reduce attenuation, and next the outer conductor braid material to reduce cost. The most recent changes were to substitute a seamless aluminum outer conductor to prevent cable aging and to manufacture longer lengths to reduce installation costs.

We note that there have been significant reductions in attenuation coupled with reduction in cable costs which are indicated by the amplifier-spacing/cable cost Figure of Merit for Feeder Cable. We note also that there have been significant reductions in the Effective Cable Cost. Though materials are not presently available, it would appear that in the future a decrease in cable attenuation of approximately 10% will be realizable without significant cost increase. If an airspaced dielectric cable considered only 3% additional reduction in attenuation would be achieved.

It is questionable whether this additional increase in performance would be justified in light of additional equipment and maintenance costs.

It also appears feasible that return loss figures of 36 and 40 db may eventually be feasible. Present system requirements as established by major development groups in this field, have set a minimum return loss figure of 30 db for feeder and trunk cable, at the present time.

Because of the development of the aluminum sheathed coaxial cable with prevention of longitudinal vapor paths, it would appear that we have also approached optimum shielding efficiency and cable life. Cable life has been shown to be a very important factor in cable performance, coupled with the attenuation, cost, shielding and return loss factors.

MR. TAYLOR: Thank you very much, Mr. Kushner. Mr. Kushner mentioned the papers. We have gotten papers out of the boxes so that all of the papers that are available are here. Those papers that are not available will be available, however, through the transcription service which is taking down all of the presentations both in this room and the other room.

We're running right about on schedule. Unless somebody has an urgent question for Mr. Kushner, I would like to move on to the next speaker. You have the biographical sketch on your chairs so I will not take a particular time to introduce Dr. Theodore Hafner, who is going to speak on the "Breakthrough With Microwave by Wire". Dr. Hafner.

DR. THEODORE HAFNER (President, Surface Conduction, Inc.): I am somewhat embarrassed. I have to talk about something which is entirely different from what you have just seen. It is, in a way, fundamentally new. This has a certain advantage, but it also has a certain disadvantage. The disadvantage is in the difficulties of an explanation.

Now, if I may, I hope my predecessor here in speaking will forgive me if I use some of his figures. He's talking about improvements from 50 db per mile to 40 db per mile. And, I am going to speak about improvements from 40db per mile to 10 db per mile.

HISTORY AND THEORY

Wire or wireless. The surface wave, a third medium combining privacy of wire with the low loss of radiation. The surface wave, a fundamentally novel wave mode. Simple (though only theoretical) derivation of existence of surface wave; its low loss and wide applicability.

What is the G-Line? Where does it come from? Where does it go?

I am reminded of the famous Austrian General Radetzky. At one of the war games of the Austrian army, one of the participating army groups was commanded by an Archduke who was not too well known for his intelligence. After the battle, Radetzky surveyed the happenings