

DROP CABLE RF LEAKAGE THROUGHOUT 20 YEARS OF SERVICE

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ABSTRACT

A recent publication in the Multichannel News (1), "Signal Leakage Threatens to Cripple Cable Industry," emphasizes the importance of addressing CATV system signal leakage. Excessive egressive signal leakage could lead to fines by the FCC, ban of CATV use of aviation, navigation and communications frequencies. Excessive ingressive interferences signals lead to loss of customers due to poor reception. This paper evaluates drop cable "aging", an important characteristic which has not previously been evaluated on an experimental basis. Cables were removed from systems and evaluated to determine degradation. The cables measured had been in use for various periods of time, up to 23 years. The most significant "aging" observed was a decrease in shielding (increase in rf leakage). This information is correlated with laboratory "aging" tests to allow predictions of long term performance of relatively new drop cables. The test results show that the different drop cable types in use have varying degradation, a maximum of 18 dB compared to the best cable with only 7 dB degradation in 20 years of service. This quad shield cable, adhesive foil-60% braid-foil-40%-braid, which has the lowest degradation also has the lowest rf leakage at any point in time. (14 dB to 18 dB lower leakage than the second best).

INTRODUCTION

In the late 50's, two copper, 96% coverage braids were used for cable shields. This improved the shielding by 34 dB (a 99% reduction in rf leakage from the standard RG-59/U). However, this increased the cost by 70%. Cigarette-wrapped tapes and braids were introduced in the early 60's. Two basic types of aluminum-polypropylene-aluminum foil tape and aluminum braided shield cables are in use today, one with an adhesive tape and one without. The construction without adhesive adheres the foil tape to the dielectric, has approximately the same leakage as the two copper 96% braids and approximately 1/3 the cost. In the 70's, the adhesive foils were introduced to eliminate the connector installation problem and decrease the degradation of shielding resulting from cable flexure. A new shielding concept was also introduced in the 70's to achieve a significant improvement in shielding, i.e., "trapping" a tape between two braids, which further increases cost by approximately 50%. This cable, with an adhesive foil-braid-foil-braid shield, has a 99.96% reduction in rf leakage (55 dB improvement) over the original RG-59/U.

Usually improvements in cable shielding result in an increase in cost but this drop cable is less expensive than the original RG-59/U.

Many factors require a shielding performance which is much higher than has been acceptable in the past, such as possible interference with aeronautical transmissions, advent of citizen band transceivers (CB's) with illegal linear amps and advance in technology of CATV systems, i.e., CATV frequency spectrum has been expanded to 5 to 400 MHz due to the advent of 2-way and 54 channel systems.

Increasing the frequency spectrum to 400 MHz results in higher leakage since the shielding decreases as the frequency is increased above 300 MHz. The 2-way system uses the 5 to 50 MHz band, which also results in higher leakage since the shielding, of the common types of drop cable in use, degrades as the frequency decreases below 50 MHz. The optimum shielding for these cables typically occurs from 50 to 150 MHz.

Many experts have evaluated drop cable performance (4, 5, 6, 7) before installation. The purpose of this paper is to evaluate drop cable degradation on an experimental basis where drops were removed from systems and measured. This "field data" is correlated to the results obtained from laboratory "aging tests". The results show that one can predict the drop performance at any point in time using a special flexure test. The lab "aging" tests are needed since many drop cable types are relatively new and it is important to know their performance after 10 to 20 years in service.

Fifty drop cables were removed from cable systems and approximately 230 tests were performed on the samples. Cables were selected to confirm that the cable performance reported is typical for the same type manufactured in general by industry and to obtain performance for varying years in service. The attenuation of the drop was measured, then samples were taken for shielding measurements and a visual and mechanical analysis.

The shielding was measured using a Radiometer and the results plotted versus years in service to show drop cable degradation and performance at varying points in time.

The degradation in service, "aging", is thought to be predominantly a result of aeolian (wind) flexure; this deduc-

tion is based on a visual observation of cable. "Galloping" is commonly observed if the wind is preceded by wet snow build-up on the cable. Accordingly, laboratory flexure tests simulating the aeolian flexure are used to "age" the cable, allowing prediction of performance for varying years of service. The results of the "field data" are correlated with the lab flexure test results, showing that the laboratory evaluation of drop cable allows prediction of performance at any point in time after installation.

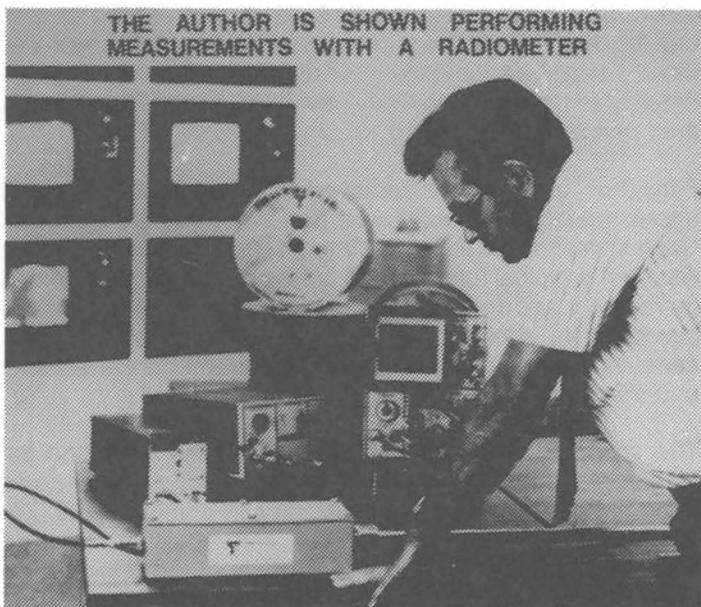
MEASUREMENTS

Drop cable was removed from systems in Wallingford, Danbury, New Milford, Meriden, Seymour and New Haven, Connecticut, South Yarmouth, Massachusetts, Kingston and Vestal, New York.

The attenuation of the drops was measured and was within +10% to -20% of the theoretical nominal for the cable except for a few exceptions which were unusually high. These exceptions were cables with corroded shields throughout a large portion of the length. Usually the corrosion, if it exists, is limited to a short length near the connector and does not have an appreciable effect. The maximum measured deviation was 75% above nominal for a copper braid which had been in service for 8 years. The attenuation of this 100-foot drop was only 3.2 dB above the nominal. The maximum measured deviation for aluminum shield constructions was 30% above nominal after 3 years in service. The unusually low attenuation values measured were probably caused by the measurement accuracy for short lengths of cable.

The shielding was evaluated using a Radiometer (See Fig. 1.) which measures the transfer impedance and capacitive coupling impedance of the coaxial shield (5).

FIGURE 1

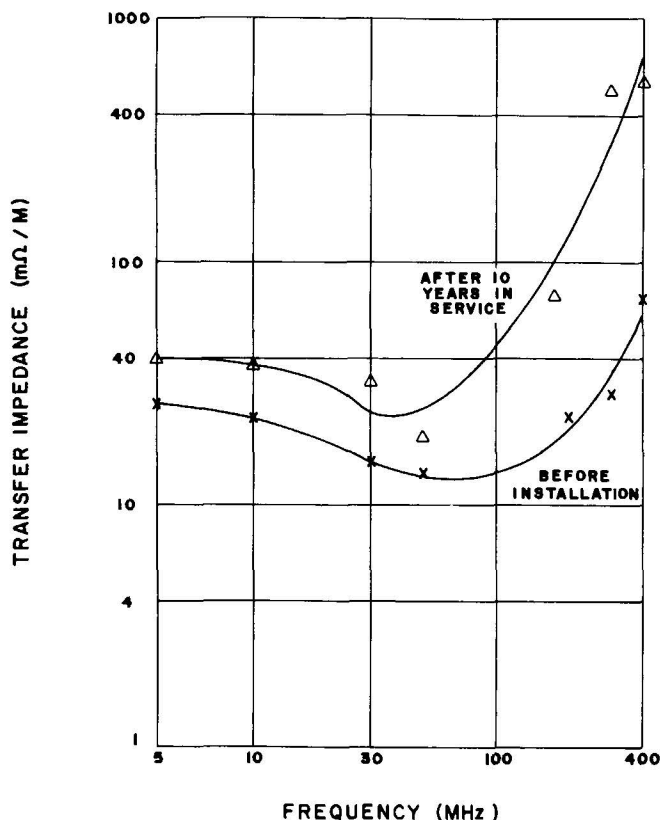


Transfer impedance is a measure of the voltage in the disturbed circuit caused by a current in an interfering circuit. It is a result of current diffusing through the metal in the shield (skin depth phenomena) and coupling of the magnetic field through openings in the shield. Capacitive coupling impedance is a measure of the voltage in the disturbed circuit as a result of electric field coupling through openings in the shield. Accordingly, these parameters control the shielding. The egressive leakage concern is excessive radiation causing violation of the FCC rules; these impedances control the external field strength caused by the CATV signal transmitted within the cable. The ingressive leakage concern is RFI; these impedances control the interference signal within the cable caused by a disturbing external field.

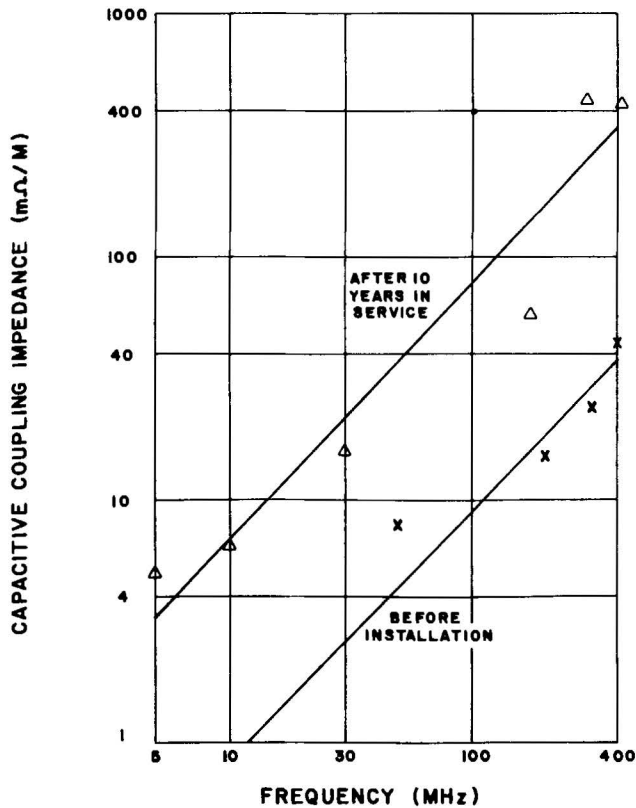
Radiometer test samples were taken from mid span, connection to the feeder line and connection to the house. The mid span tests were eliminated after evaluating the first 16 drops since this section had the lowest leakage in 81% of the cases. The street and house ends were essentially the same for 28% of all drops evaluated; the street end had the highest leakage in 44% of the samples.

The typical transfer impedance and capacitive coupling impedance of drop cable with an aluminum foil and braided shield is shown in Figures 2 and 3 respectively. Two curves are presented, before installation in a system and after 10

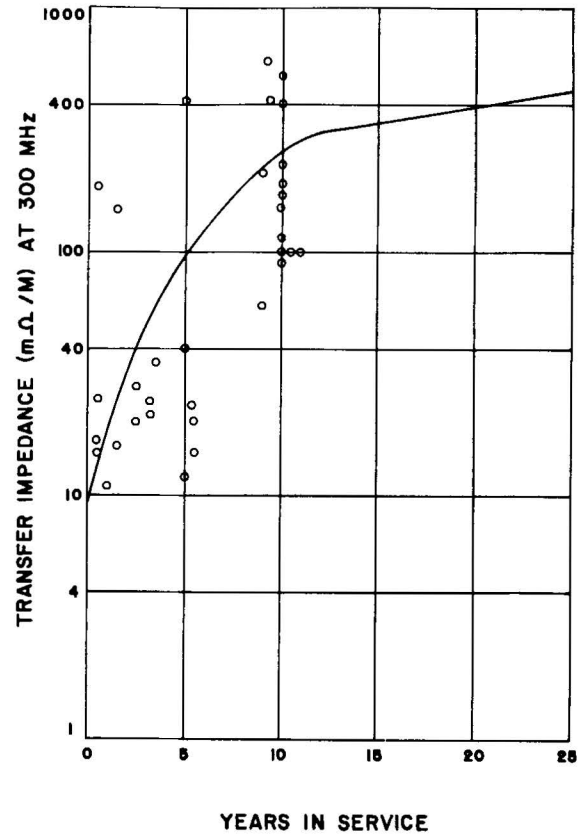
ALUMINUM FOIL-BRAID
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 2



ALUMINUM FOIL-BRAID CAPACITIVE COUPLING IMPEDANCE VERSUS FREQUENCY



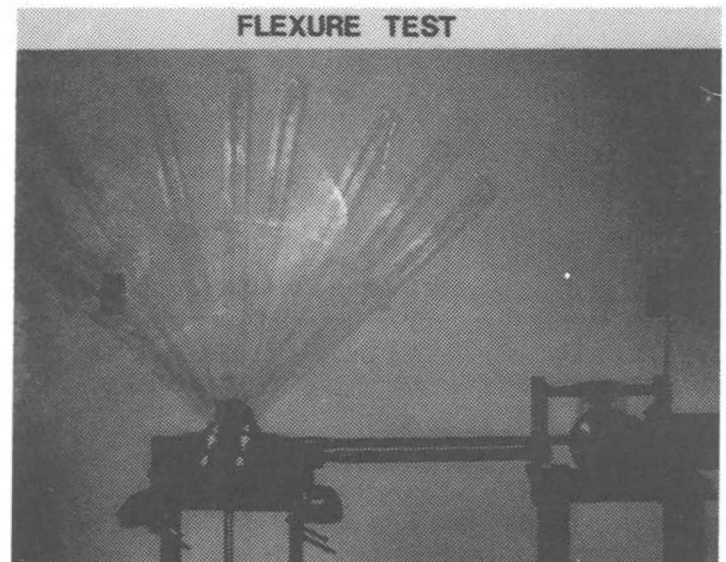
ALUMINUM FOIL-BRAID TRANSFER IMPEDANCE VERSUS YEARS IN SERVICE FIGURE 4



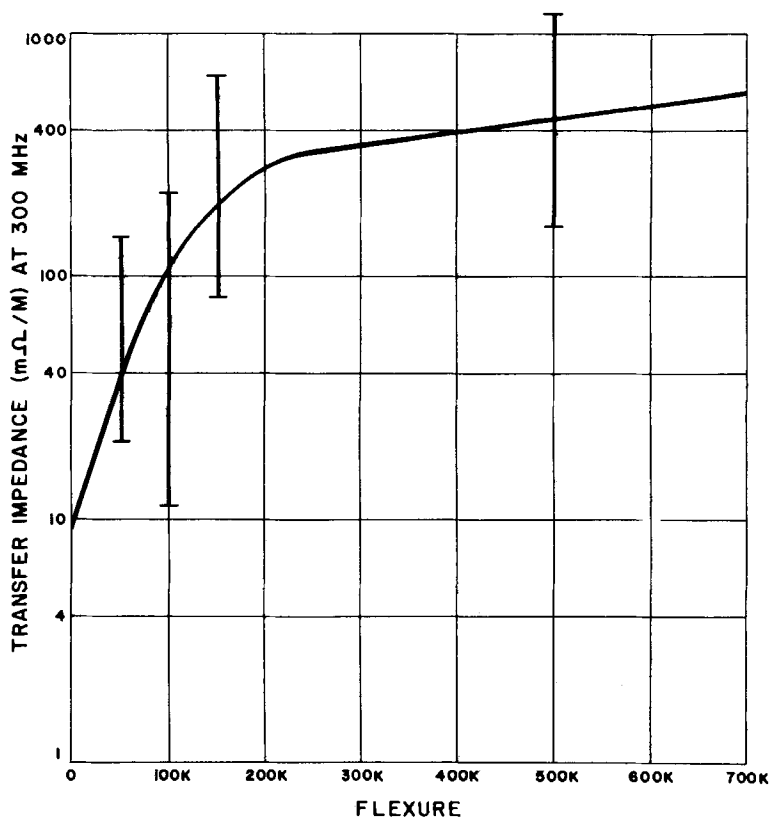
years in service. The maximum transfer impedance and maximum degradation occurs at the highest frequency. The degradation of the cable will be shown by plotting the 300 MHz transfer impedance versus years in service.

FIGURE 5

The degradation of drops whose shields are aluminum-poly-aluminum laminate foil tapes without an adhesive and an aluminum braid is shown in Figure 4. The points plotted are actual measured performance and the solid curve, which is a reasonable average of these data points, is the average performance obtained from laboratory flexure (aging) tests using a correlation of 15,000 flexure cycles per year in service. This correlation is used for all "aging" tests. The flexure test is shown in Figure 5. The cables are flexed at a rate of 40 cycles per minute. One flexure cycle is plus and minus 8 degrees travel. The results of the flexure test are shown in Figures 5 and 6. The vertical bars are the range of test results obtained on a number of samples from different cable manufacturers. This test simulates the drop cable flexure caused by the wind. The severity of flexure degradation could change with temperature; therefore, the degradation versus time could vary in geographical areas where the prevailing wind and/or temperature is substantially different from the areas evaluated.



**ALUMINUM FOIL-BRAID
TRANSFER IMPEDANCE
VERSUS FLEXURE
FIGURE 6**



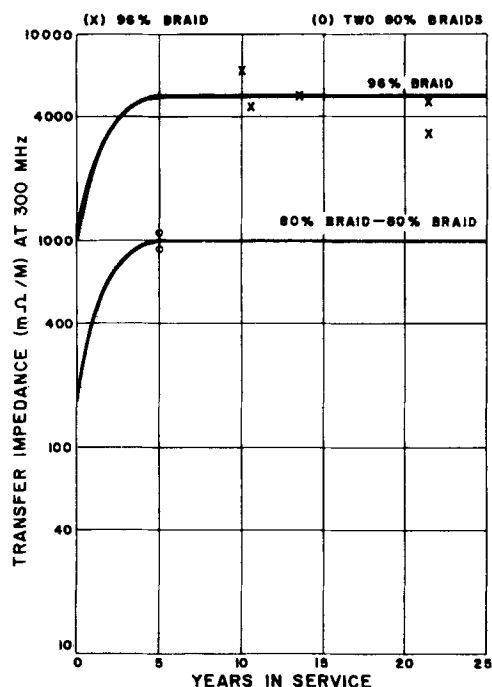
The degradation of copper braid drop cable shields is shown in Figure 7. The points plotted are actual measured performance. There is an initial increase, probably due to corrosion, that does not appear in an "aging" test performed at room temperature. The solid curves are the average flexure performance, no degradation, with an initial increase allowing for corrosion.

Limited evaluation is obtainable for the other constructions, since they have only been in service for a relatively short period of time. The two types evaluated suggest that the flexure test is a valid "aging" test allowing laboratory evaluation of cable performance after any given length of time in service.

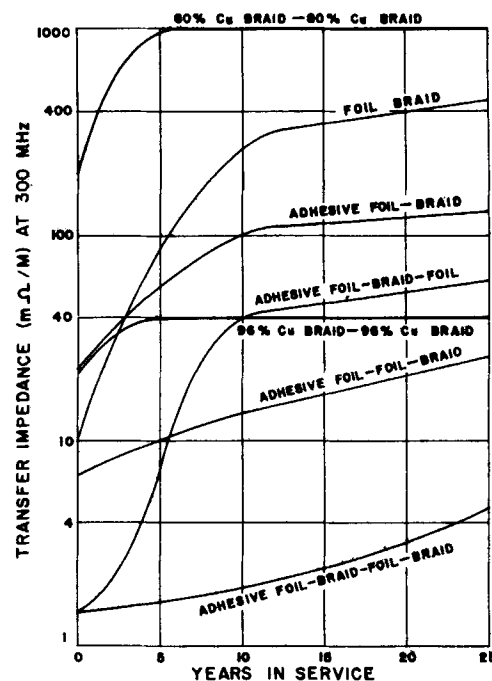
The typical 300 MHz performance of the different types of drop cable which are in use is shown in Figure 8. The curves are based on the average of a number of flexure test samples obtained from a number of cable manufacturers and the results of the "field data".

The typical transfer impedance from 5 to 400 MHz, before installation and after 10 years in service, is shown in Figures 2, 9, 11, 13, and 15. The capacitive coupling impedance for the different drop cables versus frequency for these cables is shown in Figures 3, 10, 12, 14, and 16.

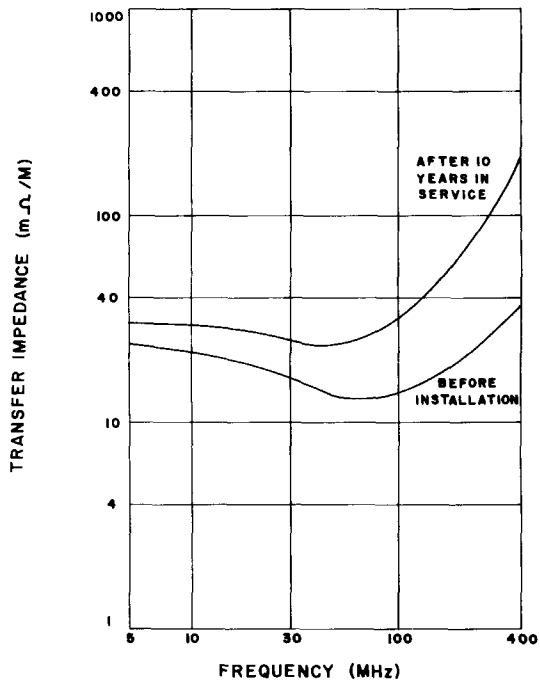
**COPPER BRAID
TRANSFER IMPEDANCE
VERSUS YEARS IN SERVICE
FIGURE 7**



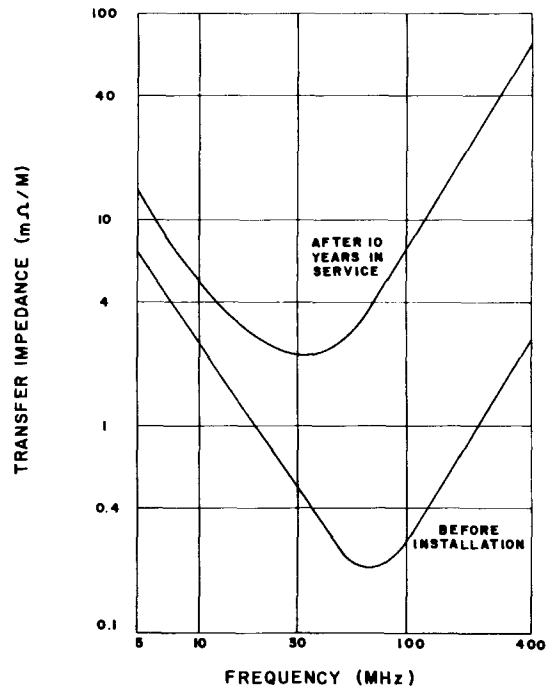
**DROP CABLE PREDICTED
TRANSFER IMPEDANCE
VERSUS YEARS IN SERVICE
FIGURE 8**



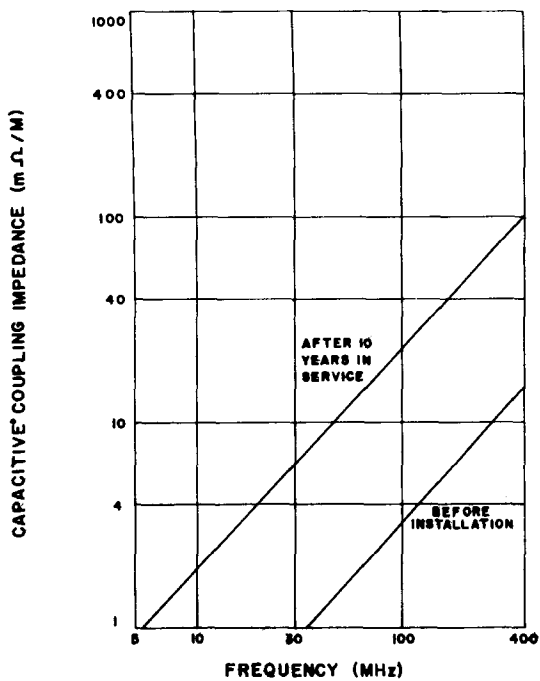
**ADHESIVE FOIL-BRAID
TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 9**



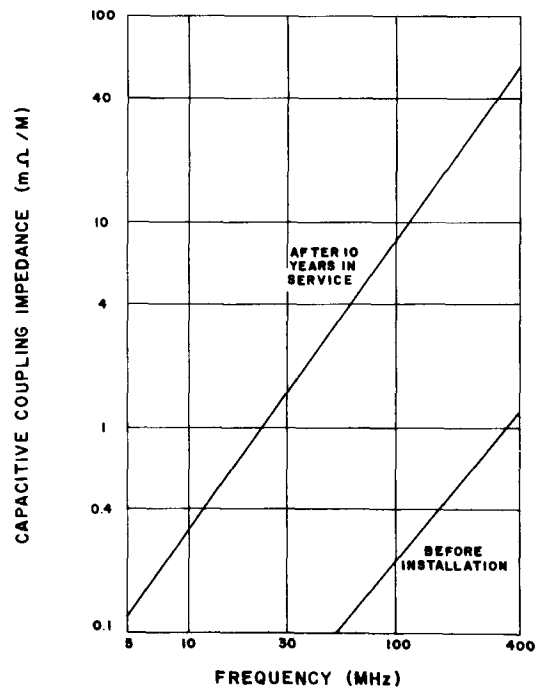
**ADHESIVE FOIL-BRAID-FOIL
PREDICTED TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 11**



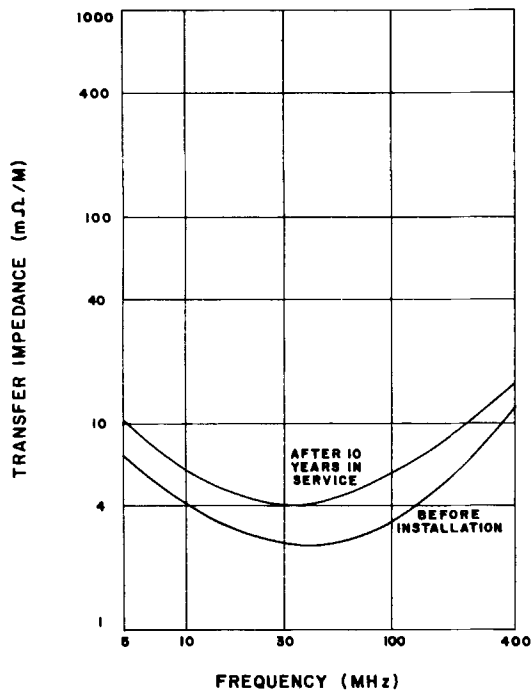
**ADHESIVE FOIL-BRAID
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 10**



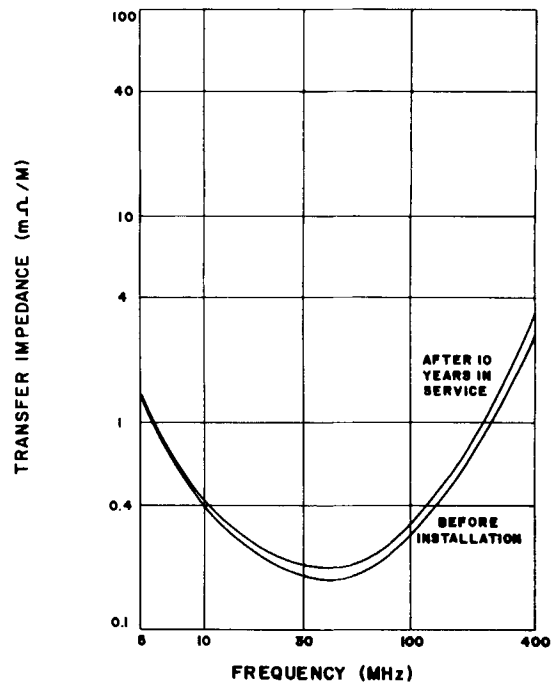
**ADHESIVE FOIL-BRAID-FOIL
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 12**



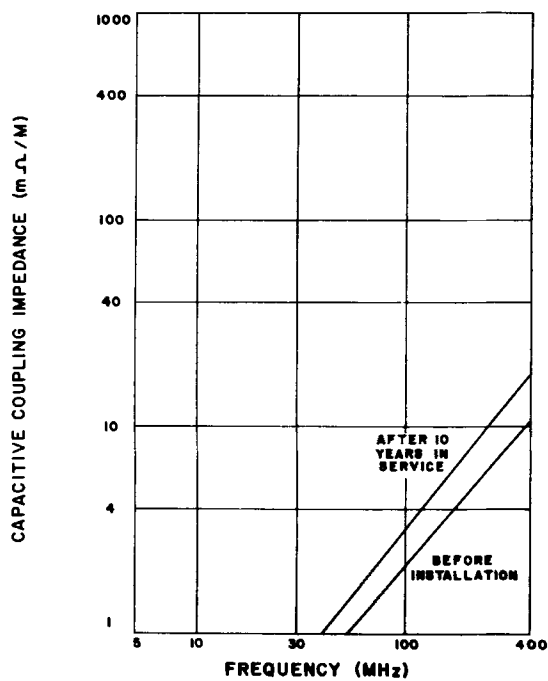
**ADHESIVE FOIL-FOIL-BRAID
PREDICTED TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 13**



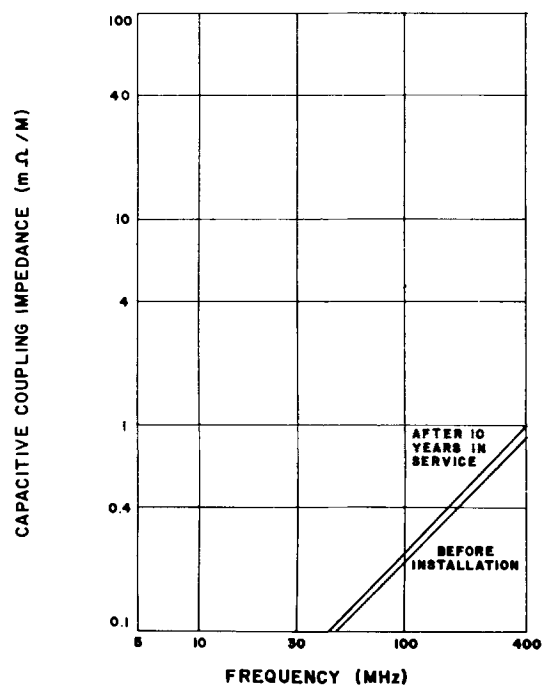
**ADHESIVE FOIL-BRAID-FOIL-BRAID
PREDICTED TRANSFER IMPEDANCE
VERSUS FREQUENCY
FIGURE 15**



**ADHESIVE FOIL-FOIL-BRAID
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 14**



**ADHESIVE FOIL-BRAID-FOIL-BRAID
PREDICTED CAPACITIVE COUPLING
IMPEDANCE VERSUS FREQUENCY
FIGURE 16**



DISCUSSION OF RESULTS

Considerable effort has gone into the solutions of the theoretical transfer impedances, capacitive coupling impedance, in-grressive and egressive leakage signals but they will not be discussed in this paper. This discussion will be limited to a brief review of the test results.

There are essentially three types of drop cable shields in use, i.e., (1) braids, (2) laminate foil tapes with a braid adjacent to one side of the tape and in metallic contact and (3) a laminate foil tape with a metallic sheath adjacent to both sides of the tape and in metallic contact.

The 96% optical coverage copper braid cable was replaced with a cable which had two 96% copper braids to significantly improve the shielding. These braided shields have less degradation than the constructions using foil-braid shields. The excessive cost of two 96% copper braids resulted in the advent of laminate foil tape-braid shields. The constructions with one foil and one braid have significantly lower cost with low braid coverage and initial performance similar to two 96% copper braids, but they have higher degradation in service resulting in poorer shielding. The use of adhesive foil decreases the degradation. Similar foil constructions using up to 95% braid coverages are used, but the slight improvement in performance does not warrant the increased cost. Adding a second laminate foil tape over the braid significantly improves the performance before installation in a system; however, this cable has very high degradation in service. Therefore, the net result is a small improvement.

The third drop cable type was introduced to significantly improve the shielding without a substantial increase in cost. The concept employed to improve the shielding and minimize the degradation in service is "trapping" a laminate foil tape between two braids. The two round wire braids electrically short circuit any openings in the tape, thereby eliminating or minimizing the electromagnetic coupling through the opening. This significantly decreases the transfer impedance, improving the shielding (a significant decrease in rf leakage). The drop cable which has two laminate foil tapes under a braid falls into this category, i.e., "trapping" a tape between two metallic sheaths. However, the metallic tape does not short circuit the openings as well as the round wire braid. This cable is considered the second best drop evaluated.

The relative performance of the drop cable types can be expressed in decibels (dB) by the following equation:

$$\text{Relative performance} = 8.686 \ln \frac{Z_{ta}}{Z_{tb}} \text{ dB}$$

where

\ln = natural or Napierian Logarithm

Z_{ta} = Transfer impedance of one cable type

Z_{tb} = transfer impedance of a second cable type

Example: The second best drop has a transfer impedance of 10 mΩ/m after ten years in service and the best drop has 1.7 mΩ/m.

$$\text{Relative performance} = 8.68 \ln \frac{10}{1.7} = 15\text{dB}$$

The best cable has 15 dB lower RF leakage than the second best after ten years of service.

CONCLUSIONS

Severe corrosion throughout a large portion of the drop cable length causes an appreciable increase in attenuation and seems to affect copper shields more than aluminum.

Drop cable shielding degrades in service as a result of corrosion and aeolian flexure. The drop cable with maximum degradation had 20x increase in leakage (poorer shielding) after 10 years in service, whereas the increase for the best cable is less than 2x. The various types of drop cable in use results in a large variation in shielding, rf leakage, at any point in time. The best drop available, adhesive foil-braid-foil-braid, has a 99.96% reduction in rf leakage over the original RG-59/U and is less expensive. This cable offers a substantial improvement (14 dB to 18 dB) over the second best at any point in time. Considering the importance of rf leakage, can the second best be afforded?

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James Strevey, Empire/Pioneer Cablevision
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John Trotter, Cape Cod Cablevision
John Wigglesworth, TWC

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