CAN COAXIAL CABLE COPE WITH THE CATV SYSTEMS OF THE 70'S?

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Introduction

At a time when the cable television industry is absorbing such sophisticated new technologies as laser link and microwave transmission, it may seem unusual to suggest taking another look at a tool as familiar and comfortable as the coaxial cable. Unusual, that is, until you consider the demands likely to be made of this cable during the remainder of the 1970's.

Most observers predict that penetration of cable television into the top 100 cities during this decade will stimulate dramatic changes in both your services and systems. There is talk of 24, 48, 64, or more channels. You will be called upon to transmit not only video signals, but also data and facsmile reproductions. Two-way communications is likely. Average system size will jump from approximately 100 miles of cable per city to as much as 4,000 miles per city.

Such growth places heavy demands on the technical resources available to you. Utilization of laser link and microwave technology is crucial to providing economical service to large metropolitan areas. Yet even such advanced equipment will not eliminate the need to wire with coaxial cable in any system of the foreseeable future. In fact, it is the basic system you know today which will be called upon to provide the many new services upon which your industry will grow. There is little doubt that more sophisticated electronics hardware will become available as your industry requires it. The question is, can your cable keep pace?

The nature of a cable television system makes this a crucial question because noise-to-signal limitations are principally a function of the cable. The most effective way to improve system efficiency is to use cable with lower signal loss rather than to depend on high gain amplifiers which unavoidably are limited by attenuation characteristics of the system's cable. Thus, as the state of the art in active equipment improves, the electrical properties of the coaxial cable become even more significant to the system owner. This paper examines factors which must be considered in producing cable with low signal loss characteristics.

Attenuation

The coaxial cable is itself a system, a combination of materials fabricated together to transmit RF signals efficiently. Basically it is made of two metal conductors separated by an insulating (dielectric) material. (Figure 1) Attenuation, the loss of signal strength from one end of a cable to the other, is unavoidable and a function of eight variables: frequency, impedance, RF resistivity of the outer conductor, diameter of the outer conductor, RF resistivity of the center conductor, diameter of the center conductor, the dielectric constant and the power factor of the dielectric. (Figure 2) Only a few of these variables, however, can be altered in CATV cable to reduce attenuation.

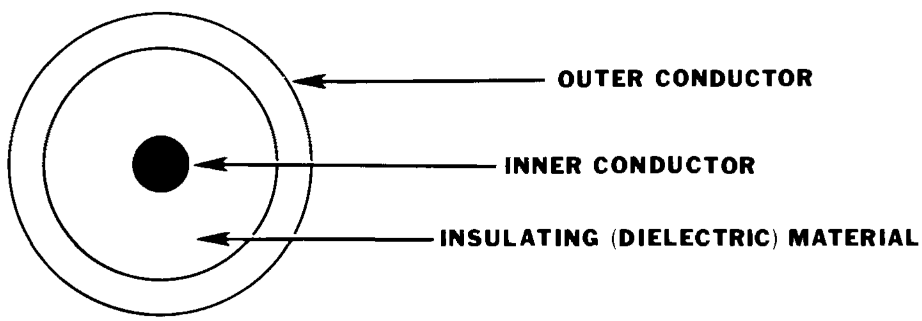

FIGURE 1

The basic attenuation formula:

$$\alpha = \underbrace{0.660 \times 10^{-3} \frac{\sqrt{\varepsilon f}}{Z_o} \left(\frac{\sqrt{R_1}}{d} + \frac{\sqrt{R_2}}{D} \right)}_{\text{Conductor Loss}} + \underbrace{2.77 \times 10^{-6} \, f \sqrt{\varepsilon} \, \tan \delta \, \frac{\text{dB}}{100 \text{ ft}}}_{\text{Dielectric Loss}}$$

FIGURE 2

Frequency (f)

Frequency currently is restricted to the 54 to 212 mhz band by the capability of the television receiver. However, plans are being made to employ the 5 to 300 mhz band to provide other capabilities such as 2-way communications.

Impedance (Zo)

There are two widely accepted cable impedances in use today, 75 ohm and 50 ohm. The two were developed to fulfill distinct needs: transmission with minimum attenuation and transmission of maximum voltage.

In designing coaxial cable for minimum attenuation, the optimum ratio of conductor diameters is determined from the attenuation equation as derived in detail by Dummer and Blackland . (Figure 3)

The conductor loss:

$$\alpha_c = 0.660 \times 10^{-3} \frac{\sqrt{\varepsilon_f}}{Z_0} \left(\frac{\sqrt{R_1}}{d} + \frac{\sqrt{R_2}}{D} \right)$$

For minimun α_c with air dielectric:

$Z_0 = 75$ ohm with $\frac{D}{d} = 3.5$

FIGURE 3

In designing coaxial cable for maximum voltage rating (required, for instance, in microwave radar applications) the equation is as shown in Figure 4.

The peak voltage:

$$V = \tfrac{1}{2} E \, d \log_e \frac{D}{d}$$

where E is the voltage gradient with a cable spacing.

To achieve maximum V:

$\frac{D}{d} = 2.72$ thus $Z_0 = 50$ ohm

FIGURE 4

Since for cable television transmission the principal concern is low attenuation, 75 ohm has been selected as the industry standard.

Outer conductor resistivity (R_2)

In CATV, aluminum is used almost exclusively for outer conductors since it provides the most suitable technical/economic selection of materials available. Outer conductor resistivity, therefore, can be considered a constant.

Outer conductor diameter (D)

The size of outer conductors has been fixed at various standard diameters to allow flexibility and interchangeability for connections and equipment hook up. This, too, may be considered a constant.

Dielectric (ε and tan δ)

Efficiency of the coaxial cable dielectric can, and does, change since the dielectric effect can be reduced by lowering the density of the insulating foam to approach an electrically optimum air dielectric. Foamed polyethylene, and more recently foamed polystyrene are the most common dielectric materials.

Center conductor diameter (d)

When lower loss dielectrics are used and the outer conductor size is not changed, as in the case of CATV coaxial cable, then the diameter of the center conductor must increase to improve performance.

Center conductor resistivity (R_1)

Copper clad aluminum and copper are the standard materials in use today. Due to the inherent characteristics of RF signals which are transmitted only on a conductor's surface, the RF resistivity of copper clad aluminum and solid copper are identical.

Cable Engineering

With the need for larger systems, improved cascadability and reduced system cost, cable designers are turning to dielectric materials having lower loss and lower density. Inherent in these changes however, is a reduction in the supporting capability of the dielectric. This creates a problem because there is a simultaneous need for larger--and therefore heavier--center conductors.

The solution to the dichotomy is found in copper clad aluminum wire--a material already used widely by your industry in current cable designs. Two inherent physical properties of copper clad aluminum provide the basis for this solution.

Weight

Because copper clad aluminum is 40% lighter than copper it effectively reduces the tendency of a center conductor to "drift" in the dielectric during its service life, thus preventing impedence discontinuities and shorts.

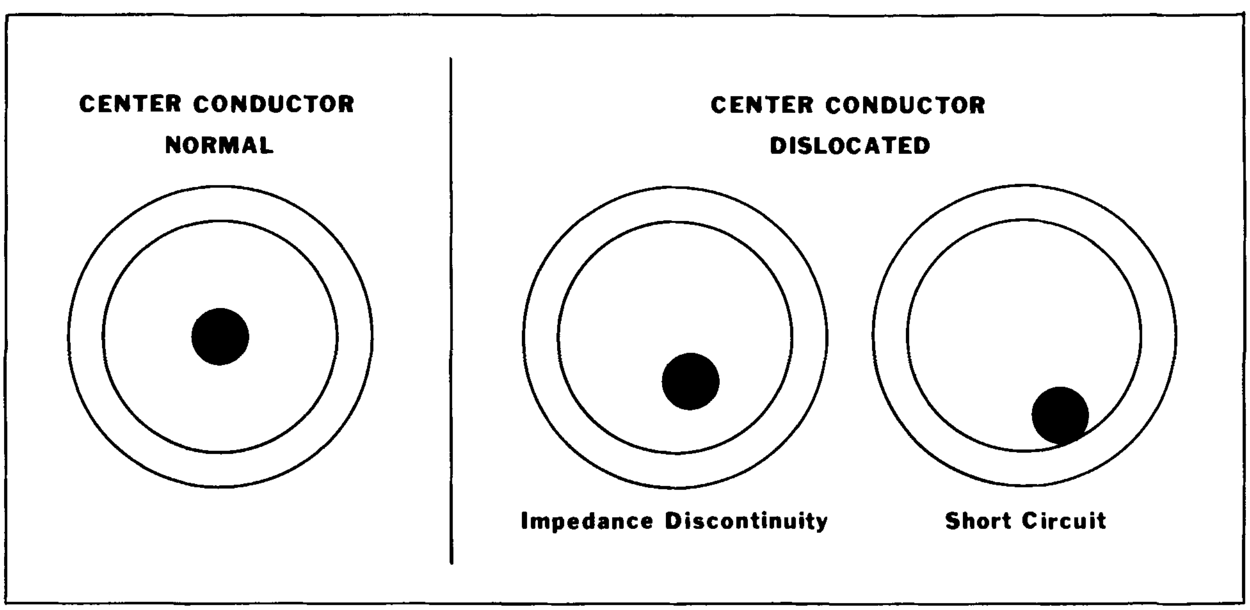

FIGURE 5

Bendability

In the installation of a CATV system, coaxial cable has to be formed into many bends. The bend may cause some impedance distortion if the center conductor is dislocated in an eccentric position within the cable. This can be caused by the resistance of the conductor to the bending forces.

Results of bending force tests verify that copper clad aluminum requires less force to bend or form into different shapes. It therefore reduces the chance of impedance discontinuity due to migration of the center conductor into the dielectric at the bend. The tests were performed with the bending fixture (Figure 6) mounted directly on a tensile testing machine to measure bending forces accurately. The comparison of the annealed copper conductor to annealed copper clad aluminum conductor is shown in Figure 7.

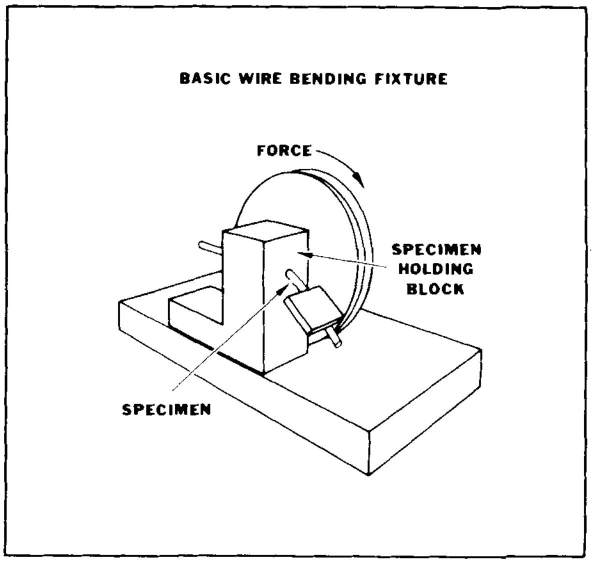

FIGURE 6

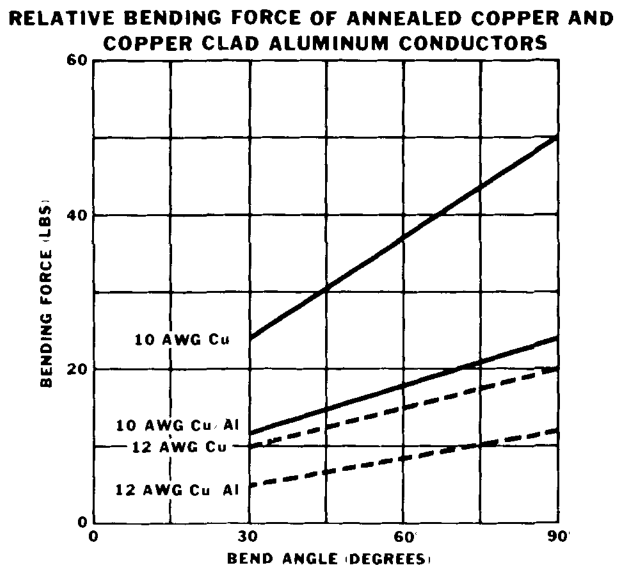

FIGURE 7

Frequency

With the predictable expansion of the usable frequency range to 5 to 300 megahertz in use in the '70's, the question comes to mind as to whether or not there will be any change in the attenuation properties of copper clad aluminum, especially in the lower frequency range. With the help of cable manufacturers, data was accumulated measuring the attenuation of copper versus copper clad aluminum cables using a foamed polyethylene dielectric. The results are shown in figures 8, 9, and 10. Note that copper clad aluminum in the 750 cable is equal to copper at the 500 khz frequency and shows only a loss of 10% attenuation as low as 50 khz. In the 500 and 412 cable with copper clad aluminum the attenuation is equal at 1 mhz and shows a 10% loss at 100 khz compared to copper. With the application of lower density, lower loss dielectrics, then, copper clad aluminum center conductors can be utilized for lower frequencies as the industry requires it. Copper offers no attenuation advantages over copper clad aluminum based on either current or expected demands in frequency range.

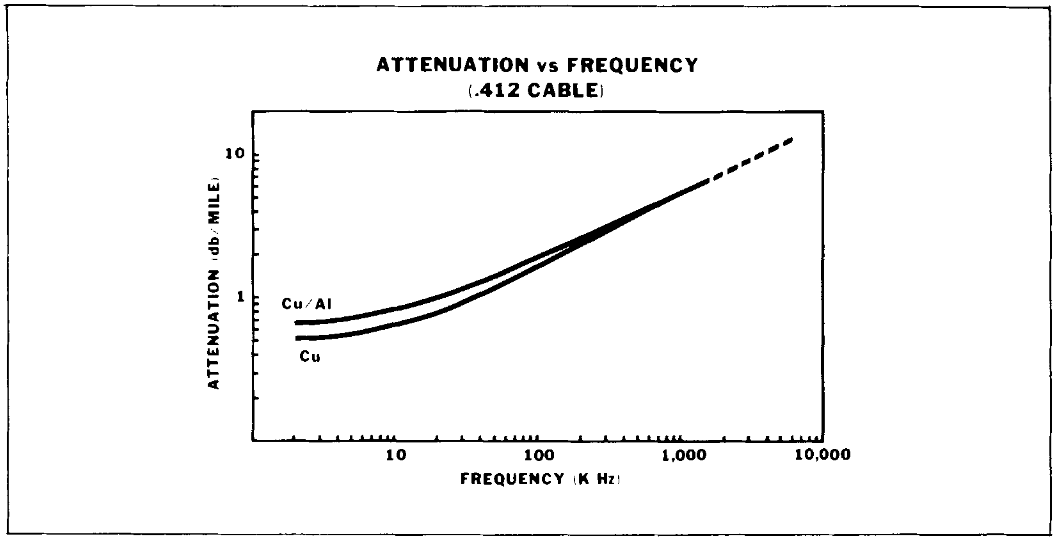

FIGURE 8

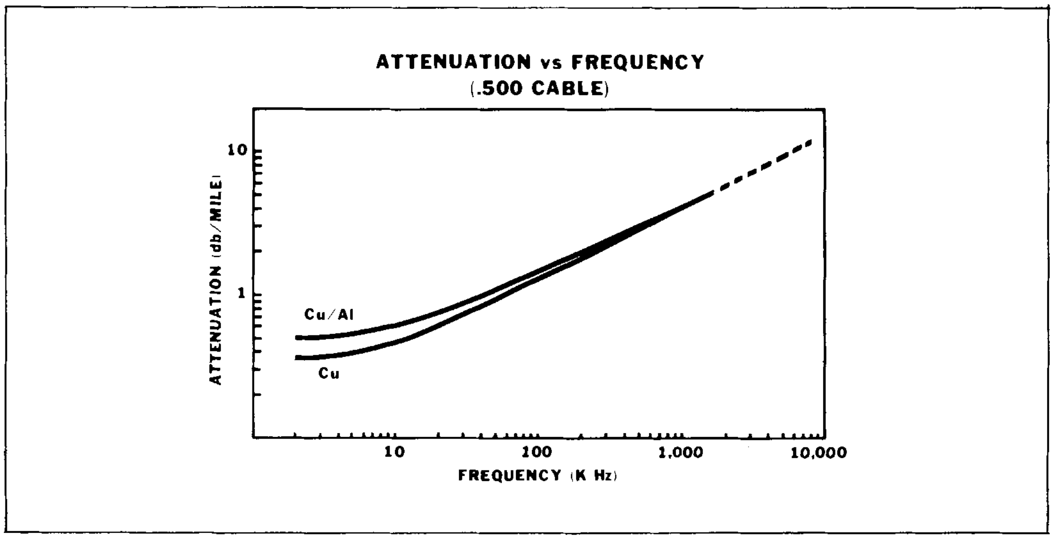

FIGURE 9

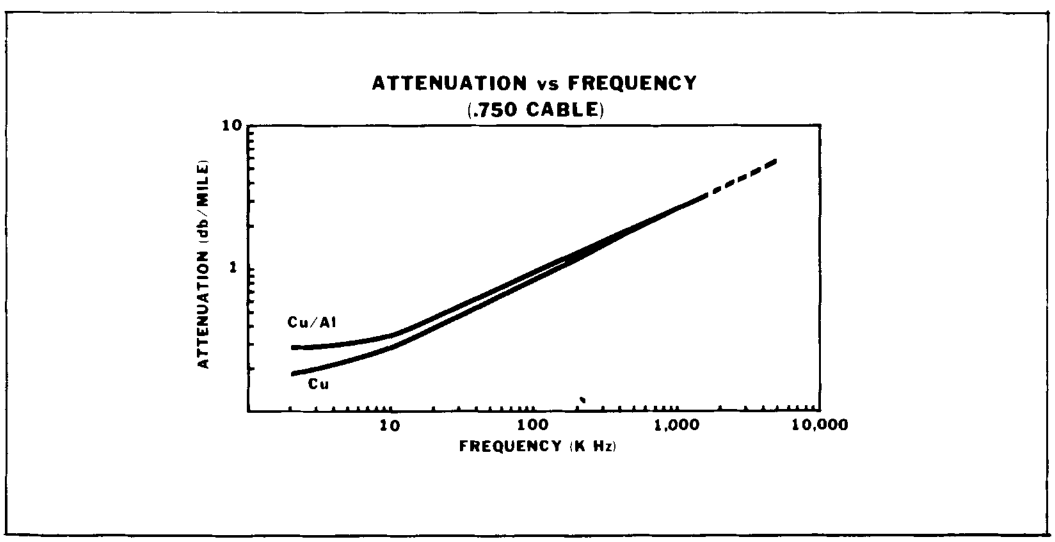

FIGURE 10

Power

It is a popular assumption that the 40% increase in loop resistance due to the use of copper aluminum center conductor requires a 20% increase in power supply. This is a misleading assumption and has caused some misunderstanding regarding the use of copper clad aluminum. Actually, experience indicates that over 80% of existing CATV systems using solid copper conductor cables could make direct substitution of copper clad aluminum center conductor cable without any additional power supplies. This is because:

1. The main consideration in the design of a system is the quality of the RF signal. This dictates that the layout be made of the amplifiers and the cable to the most suitable RF situation.

2. Cable powering is normally considered after this basic layout stage. The location of a power supply, therefore, is extremely flexible.

3. The use of marginal voltage is seldom seen in actual CATV systems. There appears to be sufficient voltage remaining for adding copper clad aluminum without adding power supplies.

4. Parallel powering is the common method used instead of series powering.

5. Geography seldom permits optimum power supply locations. The system must accommodate itself to existing streets and buildings.

In addition, many systems now under design, and most systems of the future, will use at least a 60 volt powering method. This virtually eliminates the question of loop resistance or marginal voltage. The economics in the system hardware, including copper clad aluminum coaxial cables, together with more efficient power usage, should be most attractive to the CATV system today and in the future.

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