REDUCING ATTENUATION OF TRUNK AND FEEDER CABLE

Richard Thayer
Vice President Engineering

Times Fiber Communications, Inc.
358 Hall Avenue
Wallingford, CT 06492

ABSTRACT

The availability of 550 MHz systems may require reduced cable attenuation to maintain economical amplifier spacings. Coax attenuation can be reduced by using thinner aluminum walls, decreased dielectric constants or larger cable sizes. Since each approach can compromise reliability if done in excess, an optimum combination of each factor is necessary. The design and development of such a cable is described.

INTRODUCTION

The advent of 550 MHz systems has focused attention on the need to reduce trunk and feeder cable attenuations. Several approaches have been attempted with mixed results. This paper reviews various alternatives available to reduce coax attenuation and offers a solution to minimize the need to compromise established performance standards.

KEY FACTORS CONTROLLING ATTENUATION

Coax cable attenuation is determined by several variables:

1. Dielectric size (center conductor size has little affect on attenuation if the dielectric constant is not changed). (Figure 1),

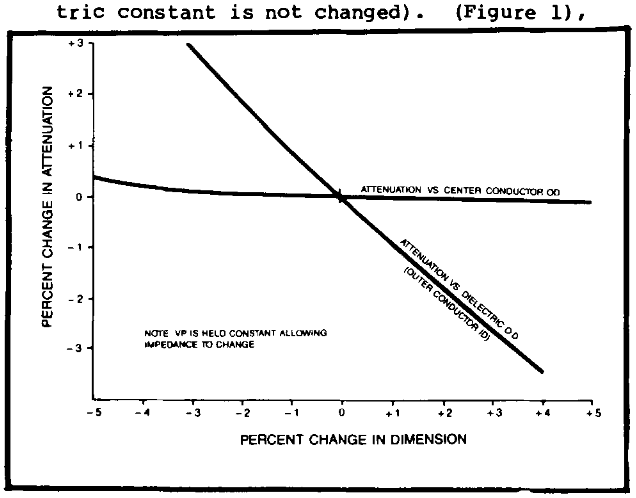

FIGURE 1. PERCENT ATTENUATION CHANGE VS. PERCENT DIMENSIONAL CHANGE

2. Impedance,
3. Center conductor and outer conductor conductivities,
4. Dissipation factor and percent velocity of propagation (VP) of the conductor coat and the foamed dielectric,
5. Structural return loss (SRL), and
6. Operating frequency.

With the exception of item 4, these factors have essentially been standardized in the cable TV industry: 1) Six standard attenuation levels plus a supertrunk; 2) Impedance of 75 ohms; 3) Copper clad aluminum center conductor with aluminum outer conductor; 4) SRLs specified in the 26-30 dB range, depending on system needs; 5) System frequency of 5-550 MHz.

However, even with these basic factors standardized, there are two remaining factors which can still be varied to reduce coax attenuation:

1. Reduction of the aluminum-sheath wall thickness, allowing a larger dielectric for the same cable outside diameter (OD) (Figure 2), and

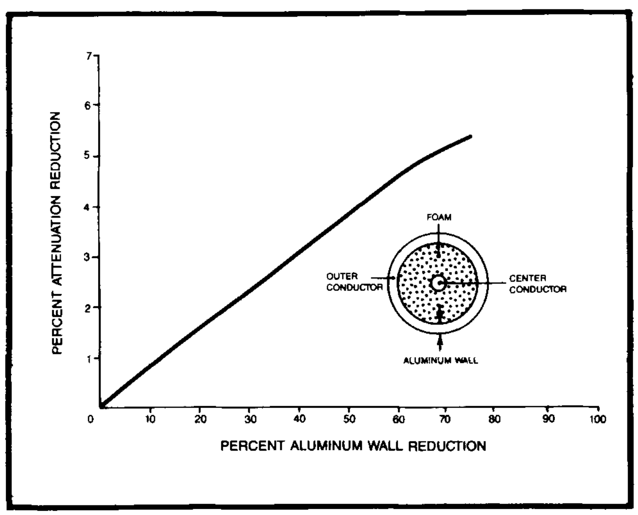

FIGURE 2. PERCENT ATTENUATION REDUCTION VS. PERCENT ALUMINUM WALL REDUCTION

2. Increased VP and reduced loss factor for the dielectric system (foam and center conductor coat) (Figure 3).

REDUCED ALUMINUM-SHEATH WALL THICKNESS

Reducing the thickness of the aluminum-sheath wall accomplishes two goals: a modest improvement in attenuation and a reduction in product cost if the sheath is thinned sufficiently. Figure 2 indicates the substantial aluminum wall reduction necessary for a given attenuation improvement.

The aluminum-sheath wall thicknesses currently in use for seamless products, as opposed to welded, have been standardized for all suppliers and have stood the test of time in both aerial and underground applications. The standard wall thicknesses (Table 1) are approximately 5 percent of the aluminum OD. Some of the welded reduced wall cables offer ratios as low as 2 percent of the aluminum OD.

Reducing aluminum-sheath walls must be approached with caution to avoid the following potential problems:

1. Increased sheath resistance (Figure 4) associated with grounding and powering problems,

2. Mechanical integrity as compared to full wall seamless,

3. Reduced corrosion life caused by a significant reduction in aluminum thickness and mass, and

4. Problems with coring and connector installation, including aluminum splitting near the

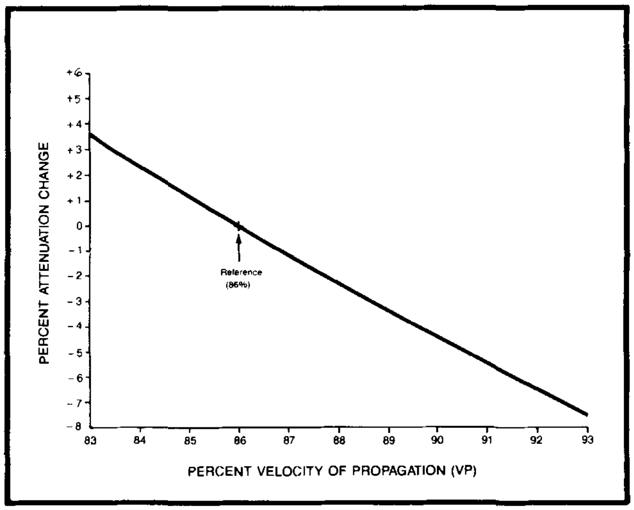

FIGURE 3. PERCENT ATTENUATION CHANGE VS. PERCENT VP

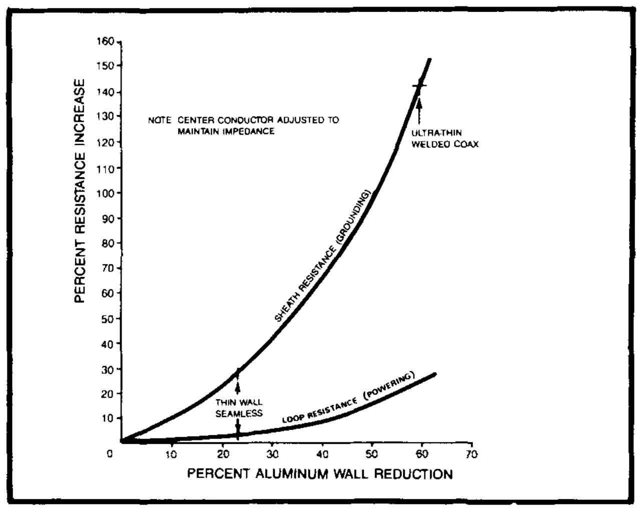

FIGURE 4. PERCENT RESISTANCE INCREASE VS. PERCENT ALUMINUM WALL REDUCTION

TABLE 1. WALL THICKNESS FOR STANDARD, THIN, AND ULTRA THIN CABLES

Standard Size	Standard Seamless Wall	Fused Disc Size	Thin Welded Wall	QR Size	Ultra Thin Welded Wall	New 90% VP Low Loss Size	Reduced Seamless Wall
0.412	0.025	0.440	0.020	---	---	---	---
0.500	0.025	0.500	0.020	0.500	0.012	0.480	0.021
0.625	0.031	0.650	0.022	---	---	0.565	0.023
0.750	0.036	0.750	0.025	---	---	0.710	0.027
0.875	0.039	---	---	0.860	0.016	0.840	0.030
1.000	0.055	1.000	0.033	1.125	0.021	1.160	0.040

connector after fatigue aging, field, abuse, temperature induced expansion/contraction, and servicing of amplifiers.

When attempting to reduce aluminum walls more than 15 to 25 percent, the unavailability of the required seamless aluminum dictates that the manufacturer resort to welded aluminum. Since the aluminum tape is substantially more expensive per pound than seamless aluminum, far thinner walls (as much as 60 percent thinner) are required to achieve an economic construction.

Most cable users prefer extruded seamless aluminum to welded aluminum tape. The full wall seamless product is felt to be inherently superior in terms of freedom from micro-pinholes and splits, and long-term corrosion resistance.

If the aluminum wall reduction from the standard thickness is kept to a modest 15 to 25 percent, economic and reliable seamless tubing can be used without having to resort to welded aluminum or excessively thinned aluminum walls.

LOWER LOSS DIELECTRICS

The two basic dielectrics being used in the cable TV industry are gas injected foamed polyethylene and spaced-disc air dielectric.

Spaced-disc air dielectric cable offers the highest VP at 93 percent compared to VP values of 85 to 88 percent which are typical of foamed dielectrics. Cable users have preferred the foamed dielectric cables because of their historical advantages in handling, moisture resistance and the availability of these cables with seamless aluminum.

In order to increase the VP and reduce the loss incurred by foamed dielectrics, the foam density must be reduced below current levels. At a typical foam density of 0.28 g/cc with an 86 percentVP, the dielectric is 70 percent air as compared to solid polyethylene at a density of 0.93 g/cc. In order to increase the VP to 90 percent, foam densities will have to be reduced down to approximately 0.18 g/cc (81 percent air) which is 36 percent lower than the already enhanced foams currently available.

Most manufacturers have experimented with these lower foam densities and abandoned their efforts because of several inherent problems:

1. Foam Softness - As the foam density is reduced, the effective hardness is also reduced, degrading cable handling characteristics.

2. Foam Integrity - Reducing foam density means increasing the volume of injected gas. Beyond a certain point, the foam density may remain essentially the same with the excess gas forming continuous pockets, voids, and open cells. These undesirable internal voids may lead to erroneous low flotation density measurements, even though the basic closed cell foam may actually be at higher densities. The objective is to achieve reduced foam densities without compromising the integrity of the foam structure.

Currently available foams are much harder than those that were introduced in the 1980 to 1982 period as manufacturers have developed the ability to utilize higher proportions of High Density Polyethylene (HDPE) as opposed to Low Density Polyethylene (LDPE). To complicate the situation even further for foam development engineers, design engineers require that even more HDPE must be used for the lower density foams to offset the inherent reduction in hardness that occurs.

CENTER CONDUCTOR COATING

One of the obstacles to achieving increased dielectric VP is the existence of a solid 66 percent VP polyethylene layer directly over the conductor. The proximity of this layer next to the conductor increases its influence on the overall dielectric VP. Typical coatings (Figure 5), from 0.004 to 0.010 thick, may degrade the overall VP by as much as 1.3 to 2.8 percent.

Although the center conductor coating should be as thin as possible to minimize attenuation, it cannot be eliminated entirely because it performs several key functions:

1. Provides corrosion and moisture ingress protection for the conductor,

2. Acts as an interface to uniformly bond the foamed dielectric to the conductor, preventing moisture leakage into the foam at this critical point,

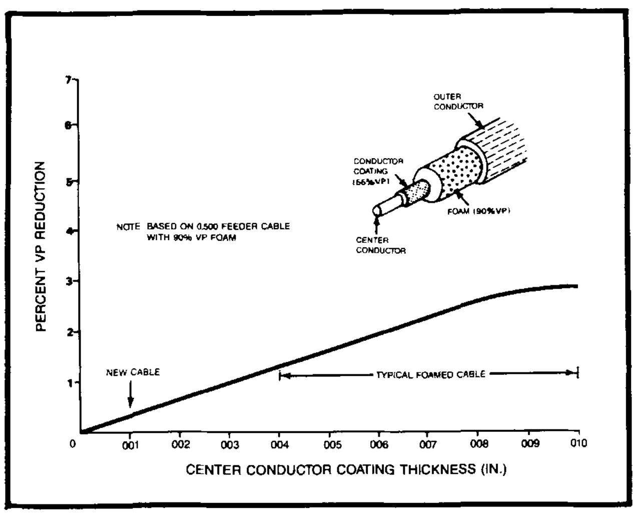

FIGURE 5. REDUCTION IN NET VP VS. CONDUCTOR COATING

3. Provides a controlled adhesion level to allow removal of the layer during connector installation, and

4. Helps in overall foam cell formation by anchoring the dielectric during the expansion process.

The coating can be applied by a variety of processes including dip coating, extrusion, electrostatic powder deposition, and chemical dip coating. Whichever is used, minimizing the coating thickness without compromising its basic function is needed to effectively reduce attenuation.

CAN THE FOAM DENSITY BE RELIABLY REDUCED?

In order to achieve 90 percent VP foam densities, an in-depth analysis must be made of all foaming parameters. Experimentation has shown that substantial improvements in the foaming process can be made if each of the basic components is optimized.

The key elements of foaming and their characteristics include:

1. POLYETHYLENE RESIN FORMULA - Compatibility of resins used (LDPE, LLDPE, MDPE, and HDPE), densities, molecular weight distributions, melt points, melt index, purity, and consistency.

2. EXTRUSION SCREW DESIGN - Shear rates, residence time, outputs, rpm, flow uniformity, temperature uniformity, mixing capabilities, and required temperature profiles.

3. SELECTION OF INJECTION GAS - Expansion pressure vs. temperature, plastic permeability, thermal flow, and injection characteristics.

4. FOAM NUCLEATING AGENTS - Particle sizes, decomposition products, inert vs. active, temperature activation profile, dispersive properties, and effect on dielectric loss.

5. EXTRUSION ADDITIVES - Lubricants, antioxidants, cell formation promoters, and property enhancers.

6. EXTRUSION TIP AND DIE TOOLING - Expansion ratios, pressures, and flow properties.

RESULTS OF FOAMING STUDY

Selection of the optimum combination of all these related variables is obviously a very complex and time-consuming process, especially considering the additional variables of extruder size and equipment variations. Such a program was implemented at Times Fiber Communications with successful results. A specific combination of the above parameters was determined which yielded a 90 percent VP foam with a high HDPE content, along with the required cell formation integrity to provide moisture resistance.

ENHANCING CABLE HANDLING CHARACTERISTICS

Even though the 90 percent VP dielectric exhibited surprising hardness in view of its significant reduction in foam density, it was not as hard as a standard density foam. As a result, further design enhancements to provide the exceptional handling characteristics that are required in the field were added:

1. BONDED DIELECTRIC - The dielectric was bonded to the aluminum to provide enhanced handling in addition to core pull-out protection during temperature extremes. A modified adhesive formula has been used to facilitate coring in preparation for connector installation.

2. BONDED JACKET - The jacket is bonded to the aluminum to further enhance handling and increase corrosion protection. The bonding agent is controlled so that no adhesive residue can be left on the aluminum surface and excessive removal forces are inherently avoided.

To improve cable handling characteristics, the cable must be made more resistant to the formation of wrinkles, ripples, and kinks. Typical tests to confirm improved performance include minimum bend radius, reverse bend testing, and expansion loop cycling.

Close study of an aluminum wrinkle usually reveals a section where the aluminum has been indented into the dielectric and an adjoining section where the aluminum has pulled away from the dielectric. In order to improve resistance to wrinkling, both of these tendencies must be resisted. The actual cable mechanics which explains how handling is improved from a hard dielectric, tough jacket, and bonding of both, is as follows:

1. Inward Wrinkling - The dielectric hardness must provide basic indent resistance. A bonded jacket assists further by inhibiting the indent portion of the wrinkle by attempting to "hold it back."

2. Outward Wrinkle - The dielectric bond is more critical than the hardness here, holding the aluminum in a cylindrical form and preventing it from "moving away." The jacket assists by acting as a tough barrier to the outward movement of the wrinkle. In addition, it also helps to distribute the stress of the bend, further protecting against wrinkling.

By using a reasonably hard dielectric which is bonded to the aluminum and a tough jacket which is also bonded to the aluminum, the 90 percent VP foam dielectric is able to exhibit the required handling characteristics.

ATTENUATION REDUCTION REDUCES CABLE OD

Described above is an increase in VP from 86 percent to 90 percent and a reduction in seamless aluminum wall by about 25 percent. The net affect of these changes is a 6.4 percent attenuation reduction with 4.5 percent provided by the dielectric and 1.9 percent provided by the slight thinning of the aluminum. Such a product would exhibit attenuations which were different from anything currently available. Thus, it could not be considered for a standard system design. In order to allow a cable user to benefit fully from the reduced attenuation capabilities, the cable must be reduced in size until the attenuation increases to a standard level (Table 2). In this way, the attenuation improvement is translated to a smaller cable with reduced cost and a standard attenuation level. Improved economies and cable interchangeability can thus be maintained.

Specific sizes and attenuation values are shown in Table 2. As is the case with other low loss coaxes, special connectors, coring tools, and jacket stripping tools (if used) must be specified. Such tools are now available as the cable development was coordinated with tooling suppliers.

SUMMARY

Previous attempts to reduce cable attenuation have been based on standard foam dielectrics with ultra thin wall welded aluminum or air dielectrics with thin wall welded aluminum. Optimization of the foaming process has produced an increased VP, low loss, economical coax with the following characteristics:

1. 90 percent VP low loss foam with good overall cable handling properties,

2. Closed cell, moisture protected high integrity foam,

3. Seamless aluminum with a moderately reduced wall, and

4 Bonded construction for enhanced handling and reliable operation during temperature extremes.

TABLE 2. NEW 90% VP FOAM
CABLE SIZES AND ATTENUATIONS
dB/100'

New Cable Size	300 MHz	450 MHz	550 MHz
0.480	1.32	1.64	1.82
0.565	1.13	1.40	1.56
0.710	0.91	1.13	1.26
0.840	0.78	0.98	1.09
1.160	0.59	0.75	0.84