United States Patent

Roberts et al.

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[54] COAXIAL CABLE

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[52] **U.S. Cl.** .....**174/106,** 174/36, 174/107, 174/117 M, 174/126 CP

[51] **Int. Cl.** **H01b 7/18**

[58] **Field of Search** 174/36, 106, 105, 108, 107, 174/117, 117.1, 126, 36, 102

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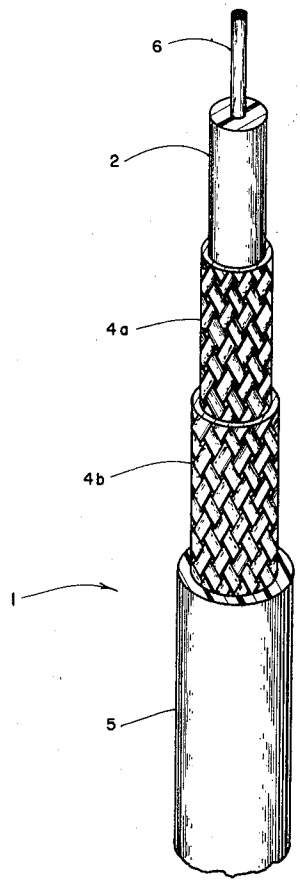
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[57] **ABSTRACT**

Disclosed herein is a coaxial cable structure having not only a center conductor nested axially in a tube of dielectric material and a second electrical conductor formed on the outer peripheral surface of the dielectric body, but an additional or third electrical conductor disposed around this second electrical conductor made of braided copper-clad steel. Surrounding the third conductor is a cylindrical sheath of dielectric material adhesively bonded to the third conductor by a resin copolymer. Both second and third conductors can be made of aluminum-coated polyethylene terepthalate. Where metal-coated plastic is used, the second electrical conductor tape generally is longitudinally wrapped around the dielectric body center conductor composite and the third conductor, made up of the same metallically coated polyethylene terepthalate, is helically wrapped around the second conductor.

13 Claims, 10 Drawing Figures



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SHEET 1 OF 6

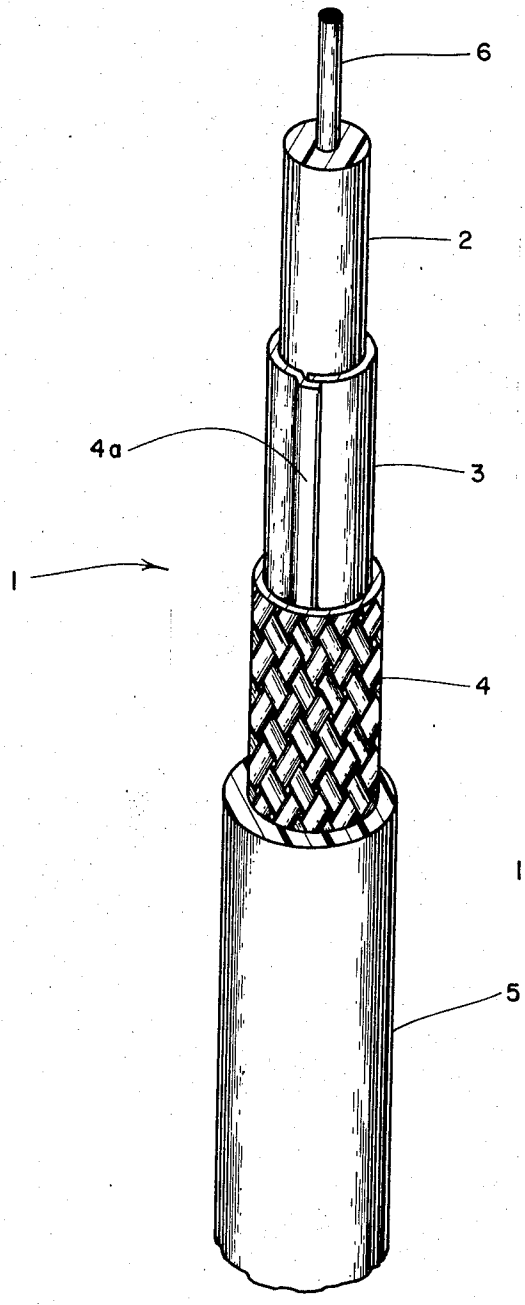


FIG. 1

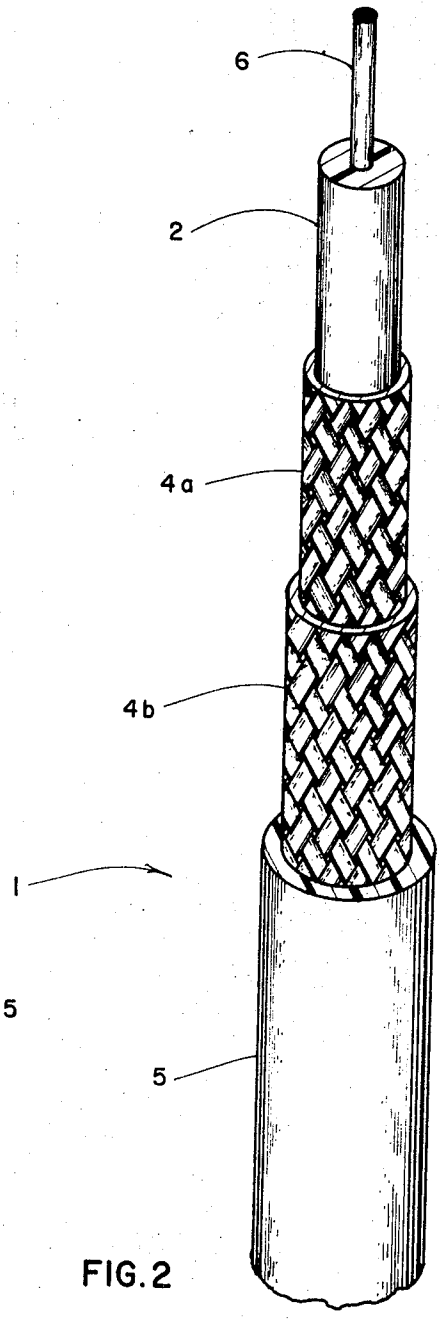


FIG. 2

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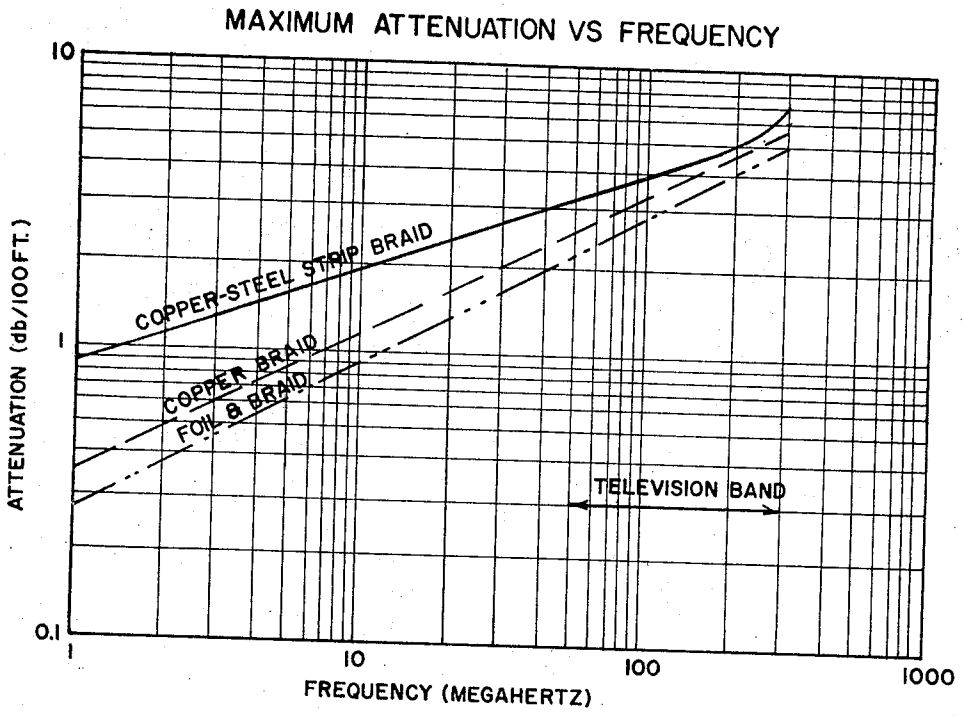


FIG. 3

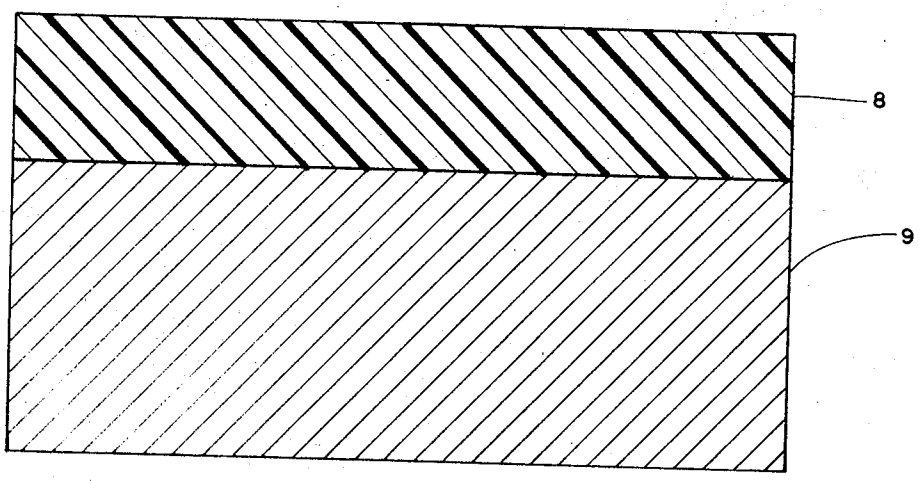


FIG. 4

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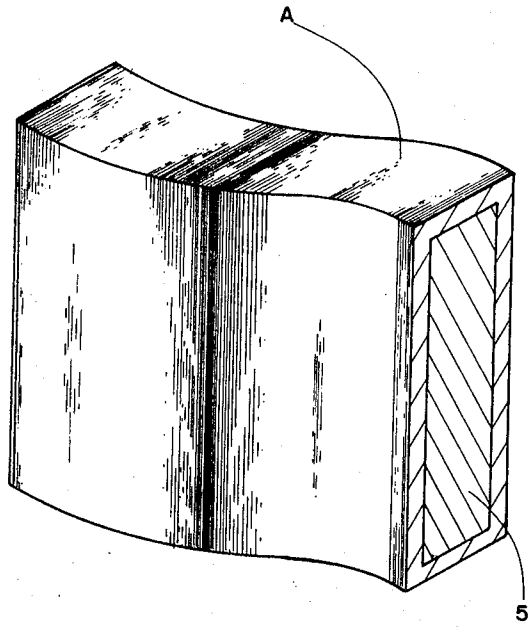


FIG. 5

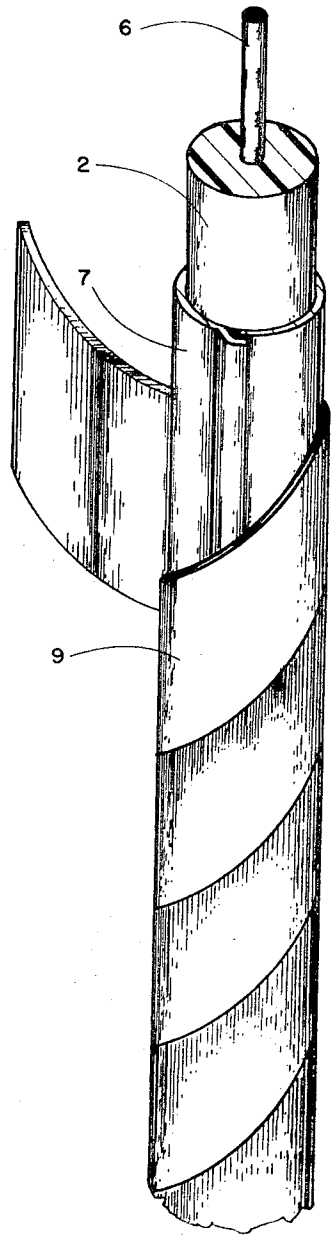


FIG. 6

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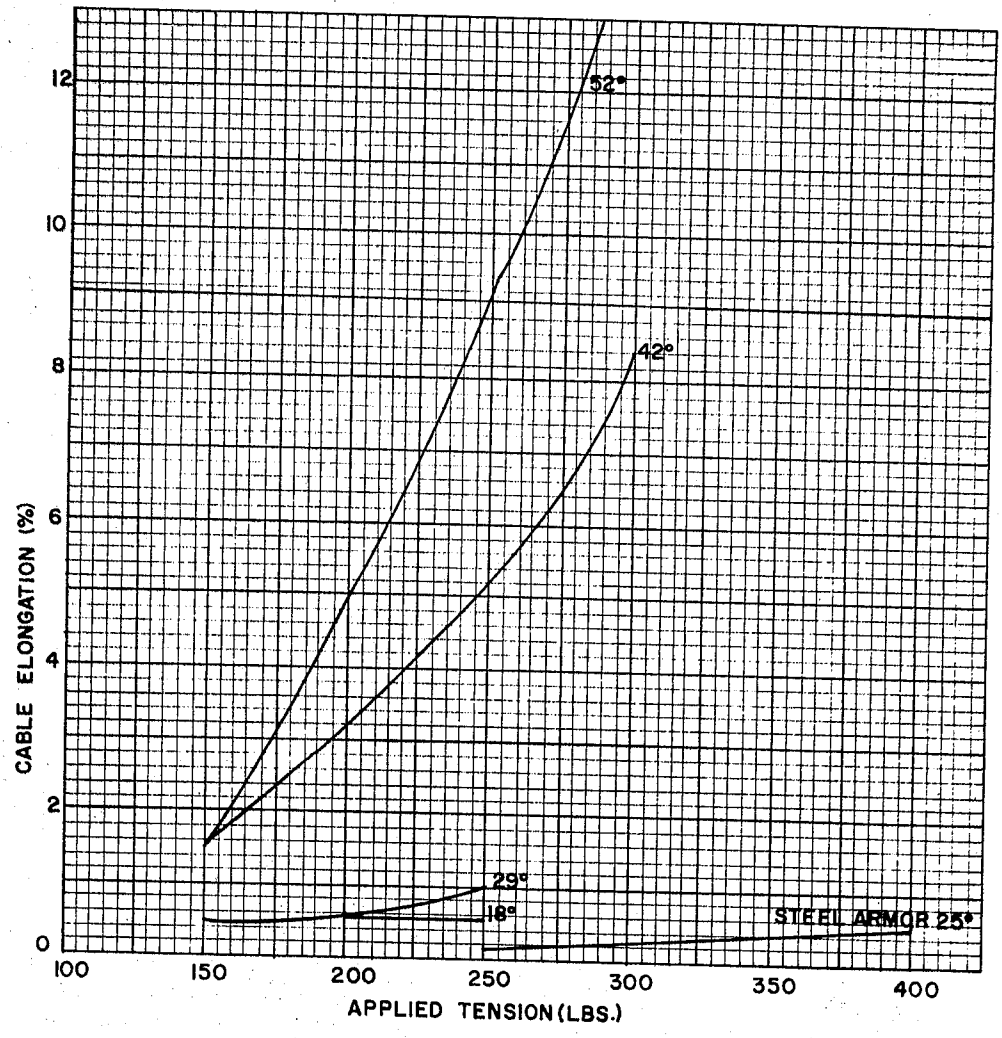


FIG. 7

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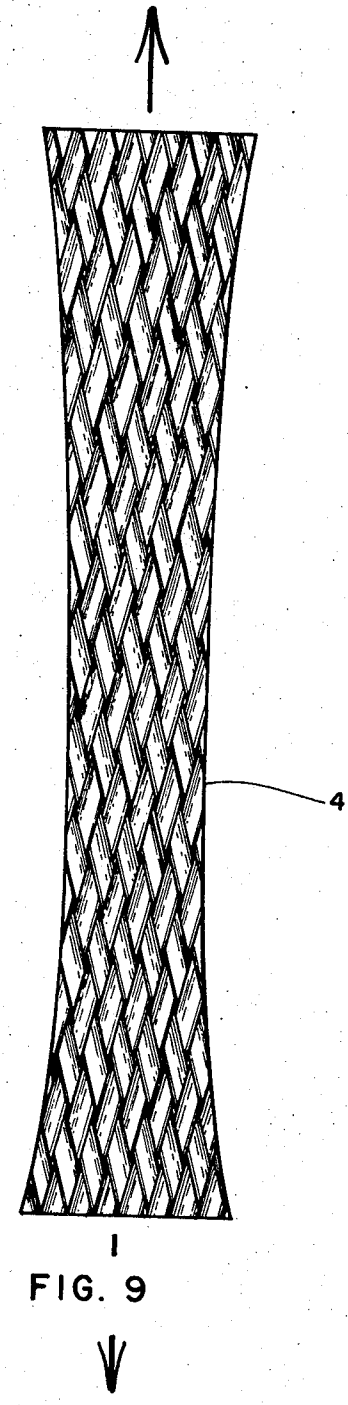


FIG. 9

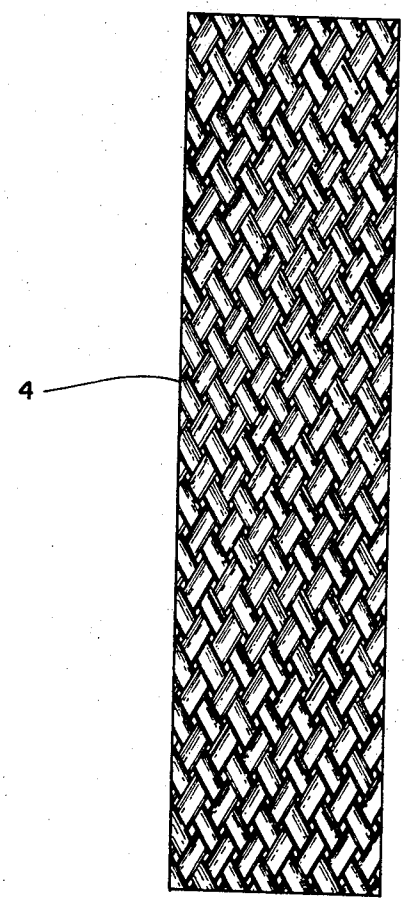


FIG. 8

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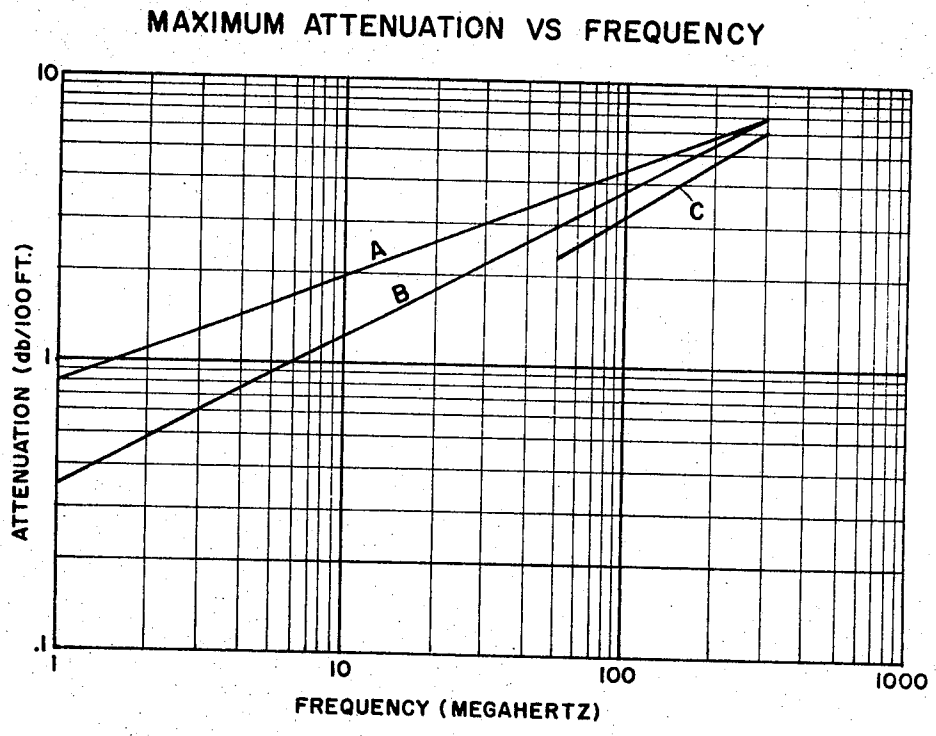


FIG. 10

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COAXIAL CABLE

The instant invention relates to electrical cables and more particularly to new and improved coaxial cables of such a construction or structure as to have reasonably low attenuation, improved flexibility properties, and surprisingly high tensile strengths. One of the most critical problems confronting designers of electrical cables has been the development of either small- or large-diameter cable that possesses a high tensile strength. This problem is solved by the instant invention. Specifically, the cable design of the instant invention is aimed primarily, but not exclusively, at the Community Antenna Television (CATV) coaxial cable drop application area. Drop coaxial cable is that cable forming the last link in a CATV cable distribution system which brings the television (TV) signals from a distribution line into a subscriber's premises. As is current practice, virtually all of these drop-type cables are of the aerial type. Consequently, it is imperative that in any design and subsequent manufacture of CATV aerial drop cables that a number of cable characteristics are required for this particular type of service. Among the most important are: (1) attenuation characteristics, (2) shielding efficiency in terms of confining the wanted signal to the cable and also exclusion of unwanted signals from the particular cable, (3) physical strength (self-supporting if at all possible), (4) ease of installation, both from a mechanical viewpoint and installation of electrical connections, (5) flexibility in that the cable must be able to withstand severe bending, repeated flexing and other potential and unanticipated physical abuses while in service, (6) initial costs, and, (7) durability in terms of attenuation stability and general mechanical stability.

Looking to the prior art and general practice in the CATV aerial coaxial cable drop application area, it is quite clear that prior cable designs have obvious drawbacks. These cables simply are an adaptation of an existing cable type to this particular service. While the cost of the presently used cable is reasonable, shielding characteristics are somewhat marginal and many times this shielding is completely inadequate. Customarily, strength characteristics of prior art CATV aerial drop cable will rely almost entirely on the inherent strength of the center conductor. Tensile stresses in a cable are transferred from a clamp to the cable outer jacket, from this outer jacket thence to the shield or outer conductor, from this outer conductor to the dielectric, and finally to the center conductor. Attenuation characteristics of the presently used CATV coaxial aerial cables are reasonable but are somewhat greater than would be realized with an ideal outer conductor.

Numerous modifications of presently used cable have been attempted with varying degrees of success. Most commonly, the modifications attempted by others employ a thin metal foil in the form of longitudinal tape in order to reduce cable loss and improve shielding efficiency. These foils suffer from obvious difficulties due to their lack of inherent strength. The present invention, although employing foils in some embodiments as one component of the overall cable structure, uses other means to overcome the obvious difficulties of foil used. Combinations that have been tried by previous investigators to overcome some of these difficulties are as follows: foil plus a drain wire, foil plus overall braid made of a single metal, and foil plus a bonded plastic jacket. Difficulties arose from foil cracking and separation in the case of those constructions, which exhibited a reasonable flexibility in prior art cables. On the other hand, stiffness of the cable and difficulties in handling were exhibited with those constructions which were structured of higher strength foils and are bonded to avoid difficulties previously mentioned.

Related to the cable structure hereinafter to be described is a braid (or outer conductor) design, which per se was employed a number of years ago by several manufactures in an attempt to produce a low-cost, yet high electrical efficiency cable. This outer conductor employed a braid composed of flat strips of copper in lieu of the multiwire ends normally employed in a wire braid. Such a design did not prove feasible because of inherent mechanical difficulties experienced with the thin strips of copper used as braid strands. These strips

were hard as a result of the flattening process to which the copper had to be subjected to obtain the flat strips and as a result of this hardness, these strips would break with very little mechanical flexing. Attenuation stability problems were also reported in this previously used cable, most of these problems resulting from poor mechanical design and reportedly poor control of chemical characteristics of oil used in the flattening process to obtain the flat strips of copper. In contradistinction to prior practice using flat strips of copper, it was envisioned as an initial part of the instant invention to use in place of these flat copper strips copper-clad steel strips. The copper-covered steel strip braid coaxial cable, when initially conceived, was composed of a conventional core made up of a center conductor plus a dielectric sheath. This sheath was covered by an outer conductor braid composed of flat members, each member being a strip of copper-covered steel. An outer cable jacket covering the copper-clad strip braided conductor composed of either polyvinyl chloride, polypropylene, or polyethylene was extruded in the conventional manner over the braid. This construction was considerably more economical in cost than the standard cable of the prior art. Additionally, it was further conceived that the braid angle in combination with the copper-clad steel braid should be adjusted to as low an angle (with respect to cable axis) as possible without hampering cable flexibility. This low angle concept provided the most efficient construction from a structural strength viewpoint because then the copper-covered steel could be relied upon as a strength member per se. Consequently, a desirable result was reached in that the copper-clad steel braid was used to minimize direct tension imposed on the dielectric and center conductor. Use of a small braid angle allows a greater proportion of applied axial tension to be imposed on the braid members directly rather than to load the core. Additionally, and quite importantly, the compression or squeezing of the core as a result of the tendency of a braided tube to constrict upon the application of tensile forces is reduced for a given axial load. These relationships are not only quite obvious on their face, once the information is presented, but can be demonstrated in a mathematical sense.

A coaxial cable design employing copper-clad steel strips braided into a tubular outer conductor and disposed on the outermost surface of a conventional dielectric in which a center conductor is nested evidenced unique electrical shield efficiency. Tests proved that shielding efficiency was more than that of conventional all copper round wire braid design, which has been used in prior art cable structures. The attenuation characteristics of such a composite copper-clad steel braid used as an outer conductor (particularly containing a low-conductivity material such as steel), would be expected to differ from one employing pure copper conductors at frequencies below which the well-known skin effect was dominant. However, such a copper-clad steel braid at some frequencies, most surprisingly, exhibited a resistance approximately equal to that of pure copper. Since individual braid members weave in and out of the immediate vicinity of the electrical field, some of the current carried by this braid is carried deeper into the conductor than would be predicted in the case of an ideal composite nonbraided tube. Perhaps this is the reason for the unexpected results observed.

The particular copper-steel thickness ratio employed in the instant invention produces a resistance versus frequency characteristics such that the attenuation loss is somewhat identical to that if pure copper were used instead, beginning at the highest normally anticipated working frequency (channel 13) in the television assignments. At frequencies less than this value, the attenuation loss is greater than would be normally experienced using conventional copper. Nevertheless, this attenuation loss is less than the value at channel 13. This deviation from normal (all copper construction) is actually desirable since less discrimination between the high-frequency and low-frequency signals is evident at the subscriber's television set. This is to say when pure copper round wire braid is used, the slope of a curve plotting maximum attenuation versus

frequency within the television band range is less than that curve plotted when copper-clad steel is substituted for the copper braid. Thus, inasmuch as it is desirable that such a curve have no slope at all, the desirability of the copper-clad steel is clear.

The cable design as epitomized by the instant invention has a plastic jacket made of either polyvinyl chloride, polyethylene, polypropylene, or polystyrene extruded over the copper-clad steel braid to a diameter equivalent to that of conventional cables. Using individual braid strip members, whose exemplary dimensions run in the order of 0.002 in. as a thickness by 0.042 in. as a width, an overall breaking strength of about 250 pounds was observed. This was approximately 1½ times that achieved when the braid was made of pure copper as in the conventional structure, notwithstanding the fact that any load less physical strain was imposed on the coaxial cable core itself.

Further embodiments of the original invention concept envisions cable structures employing a double flat strip braid, the second braid being applied directly over the first. Shielding efficiency of this particular construction was observed to be approximately 100 times as great as that when a single copper braid was used and the maximum attenuation versus frequency curve was essentially the same for that when a single copper-clad steel braid was used. The breaking strength of this double cooper-clad steel braid was increased to something in excess of 400 pounds, while the cost of the double copper-clad steel braid was just slightly more than that of a conventional single round wire copper braided coaxial cable. Additionally, it was found to be most advantageous to apply an adhesive or primer, e.g., a resin copolymer, to the surface of the outer copper-clad steel braid and, subsequently, achieving adhesive bonding between the braid and outer extruded plastic jacket. This last-mentioned combination further enhanced the working strength characteristics of the double braided cable construction.

Because the copper-clad steel braid has high strength and low elongation characteristics, it was found desirable in a double braided copper-clad steel coaxial cable to replace the innermost copper-clad steel braid with a thin metallic foil such as copper. This was done to reduce high-frequency resistance without risking the likelihood of cracking the foil under load as has been noted and experienced with prior cable designs. The combination of a braid on the outside of a foil gave unexpected and surprising results not anticipated when the cable structure was first assembled. When tension was applied to the cable there was some constricting of the inner diameter of the outer braid member. This constriction acted on the foil member lying just beneath the braid and caused indentations of a mirror image, like unto that of the braid surface configuration itself. As a result, the foil was pleated in a manner such that subsequent flexing of the foil caused it to act like an accordion and resist any cracking. It is to be understood, however, that the primary use of the foil was thought by prior investigators to be primarily used to reduce high-frequency resistance. Nonetheless, perfectly satisfactory shielding characteristics can be obtained without the use of the foil notwithstanding the preconception by previous researchers.

An economic advantage, which resulted from the use of an adhesively bonded outer jacket to a braid member, was realized because a low-cost clamp, such as the well-known P-clamp, used on commonplace telephone drop wire could be employed with this particular type of copper-clad steel coaxial cable construction. Use of such a common clamp would be enhanced if the clamp were slightly modified by use of a split cylinder insert to partially match the cable contour. Such an insert could be molded from anyone of a number of high modulous thermoplastic materials such as high-density polyethylene, polycarbonate an so forth.

The coaxial cable design of the instant invention employs most or all of the following elements:

1. Center conductor of solid copper, stranded copper, copper-covered steel, or copper-covered aluminum.
2. Dielectric core of solid polyethylene, foam polyethylene, styrofoam, polypropylene or other suitable materials.
3. Outer conductor composed of either conventional round wire braid or flat strip copper-covered steel braid as described above.
4. A second braid composed of flat strip copper-covered steel braid (this second braid may not be used in some cases).
5. An adhesive coating of a resin copolymer intended to improve adhesion between the outer conductor and overall plastic jacket.
6. An outer jacket of polyvinyl chloride, polyethylene, rubber or other suitable materials.

The instant invention uses as one of its basic principals the concept of a coaxial cable having a double outer conductor. That is to say, a composite made up of a tube of electric material in which a center conductor is axially nested is surrounded by at least two outer conductors. As was previously discussed above, these two outer conductors take the form of either a double copper-clad steel braid or a metal foil plus a copper-clad steel braid. A further derivative embodiment of the instant invention, employing the same concept of a double outer conductor, departs from the braided concept and uses in its place a tape, such as polyethylene terepthalate coated only on one side with a conductor such as aluminum. This particular embodiment envisions a composite (dielectric and center conductor) being surrounded by at least two layers of aluminum-coated polyethylene terepthalate. Adjacent to the outermost surface of the dielectric core is a longitudinally folded aluminum-coated polyethylene terepthalate tape as a first outer conductor. A second outer conductor, which is a corrugated polyethylene terepthalate, is helically wrapped around the longitudinally wrapped first outer conductor. The helical wrap is used as a second conductor rather than the first so as to avoid any electromagnetic effect resulting from the helical configuration.

A second basic principal of the instant invention is the use of copper-clad steel strips woven into a braid and used as either a single or double outer electrical conductor. In this particular embodiment, there is envisioned a core composite—a center conductor axially nested in and surrounded by a dielectric—covered or surrounded on its peripheral surface by a single or double tube composed of a braid made from copper-clad steel.

It is one of the objects of the present invention to provide a coaxial cable design that has improved attenuation characteristics, shielding efficiency, physical strength, ease of installing, flexibility, initial costs and durability.

It is a more specific object of the instant invention to reduce the dependency of the cable industry on copper and to replace some of the copper used in cable construction with high-strength steel, without any deleterious loss of electrical properties when the cable is in service.

A further object of the instant invention is to provide a coaxial cable having at least one outer conductor made of braided copper-clad steel.

A more specific object of the instant invention is to provide a coaxial cable having more than one outer conductors made of copper-clad steel braid.

Another object of the instant invention is to provide a coaxial cable with two outer conductors, the first outer conductor being a metallic foil, the second outer conductor being a copper-clad steel braided tubelike member.

An additional object of the instant invention is to provide a coaxial cable with two outer conductors, the first outer conductor being a longitudinally wrapped plastic tape coated on one side with a metal, and the second and outermost conductor being a helically wrapped corrugated plastic tape also coated only on one side with a metal.

A further object of the instant invention is to provide a coaxial cable having two outer conductors, both constructed of copper-clad steel braid which has a maximum attenuation versus frequency curve that is less in slope than that of a braid made from copper alone.

Other objects, advantages and features of the present invention will become apparent from the following detailed description, one embodiment which is present in conjunction with the drawings in which

FIG. 1 shows a coaxial cable possessing two outer conductors, one of which is a braid and the other being a foil member;

FIG. 2 shows a coaxial cable having two outer conductors, both of which are made from woven strips of copper-clad steel to form a braid;

FIG. 3 depicts in graphic form a plot of the maximum attenuation versus frequency of various types of coaxial cable;

FIG. 4 shows in cross section the metal-coated plastic tape used in the coaxial cable of FIG. 6;

FIG. 5 shows in cross section the copper-clad steel strip used to form the outer conductor braid as shown in FIG. 1 and 2;

FIG. 6 shows a coaxial cable having two outer conductors, both outer conductors being a tape composed of a metal plated onto only one surface of a plastic substrate;

FIG. 7 shows in graphic form a plot of applied tension (pounds) versus cable elongation (percent) for various types of coaxial cable;

FIG. 8 shows in plan view a section of copper-clad steel braid under no axial tension;

FIG. 9 shows in plan view how the copper-clad steel braided tube of FIG. 8 constricts the diameter of the tube when axial tension is applied to the terminal portions of a braided tubelike member; and,

FIG. 10 shows a plot of values for maximum attenuation versus frequency for flat strip copper-clad steel braid plus copper foil, round wire braid (copper) plus copper foil, flat strip braid (copper-clad steel), and round-wire (copper) braid.

Turning now to FIG. 1, the coaxial cable drop wire of the instant invention is shown overall by the numeral 1. The center conductor of the coaxial drop wire cable is shown at 6 and the dielectric core in which the center conductor 6 is axially nested is shown at 2. Disposed on the outer surface of the dielectric 2 there is a first outer conductor 3. As shown in FIG. 1, this first outer conductor is a metal foil wrapped in a longitudinal fashion so that the terminal edges of the foil overlap one another as shown by 3*a*. For the purposes of this disclosure, a foil is defined the same as found on page 18 of the METALS HANDBOOK, Volume 1, 8th Edition, published by the American Society for Metals, to wit: A foil is a metal in sheet form possessing a thickness of less than 0.006 in. Disposed on the outer surface of the longitudinally wrapped foil 3, there is a tubelike member made up of woven strips of copper-clad steel braid shown at 4 in FIG. 1. This braid is made in the conventional manner, i.e., by waving individual strands possessing a rectilinear cross section made of copper-clad steel braid into the tubular configuration as shown by item 4 in FIG. 1. The combination of elements 6, 2, 3, and 4 follow the basic dictates of a coaxial cable in that there is an outer conductor, elements 3 and 4 separated by dielectric core 2 from the center conductor 6. Disposed on the outer surface of the tubelike member, made up of copper-clad steel as shown by item 4, is the conventional coaxial cable outer sheath member shown at 5. This sheath 5 is formed in the conventional manner by means of extruding the sheath 5 on the composite made up of the combination of elements 4, 3, 2, and 6. It is within the scope of the instant invention to coat the outer surface of braid member 4 with a resin copolymer so as to create an adhesive bond between the outermost surface of braid member 4 and the innermost surface of sheath 5.

Examples of resin copolymers used to create an adhesive bond between a metal member, such as braid member 4, and a plastic outer sheath member 5 are maleic anhydride modified polyethylene and acrylic acid polyethylene copolymer. Both of the above-mentioned materials are copolymers and a modification of a polyethylene molecular chain. Such a modification results in a two-component composite molecule, one component having a polyethylene chainlike configuration in combination with a maleic or acrylic acid complex, not the polyethylene, that has the affinity and bonding characteristics to metal or another substrate of unlike material. On the other hand, it is clear that the polyethylene chainlike portion of the composite molecule is so adapted that it becomes an integral part of any subsequently added polyethylene. Thus, viewing FIG. 1, it is immediately obvious that it is the polyethylene portion of the copolymer chain that has the affinity for the subsequently extruded polyethylene sheath 5, and it is the modified portion of the chain, i.e., either the maleic anhydride or acrylic acid portion that has the affinity for the metal in the braid 4.

When tension is applied to braid member 4, this tubular like member has the tendency to seek an internal diameter less than that which it exhibits when no tension at all is applied to this member. Such a well-known phenomena is exhibited by FIGS. 8 and 9 wherein braid member 4 of FIG. 8 represents a tubular braid to which no axial tension has been applied. On the other hand, FIG. 9 shows the braid member 4 of FIG. 8 under applied tension and further showing the characteristic (necking down) or the reduction of diameter as a result of the applied tension. Focusing attention to FIG. 1, it can be readily appreciated that when the necking-down phenomena, as exhibited by FIGS. 8 and 9, is brought about by applying tension forces to the axis of braid member 4, this braid member will obviously affect foil member 3 as well as dielectric core member 2. Because first outer conductor 3 is made up of foil and this foil by definition has a thickness of less than 0.006 in., the undulating surface configuration of braid member 4 is impressed into the malleable and flexible first conductor 3 to the extent that the foil, which makes up first outer conductor 3, is deformed in a permanent fashion. That is to say, foil 3 is molded to the extent that the outer conductor 3 takes on a mirror image of the undulations and surface configuration of braid member 4. In short, the foil 3 is pleated in a surface configuration that is complementary to the surface of braid 4. Obviously, the compression needed to bring about this pleating is the compression resulting when tensile forces are applied to braid member 4 causing the necking-down of the braid member as exhibited in FIGS. 8 and 9. Once the foil is pleated in this manner, the pleats act as a hinge giving the foil an accordianlike action when the cable as a whole is flexed. Consequently, contrary to what prior art experience has been with the use of foil in coaxial cable when the cable was flexed, there is no tendency to crack or break the foil in the invention combination disclosed in FIG. 1. Prior art cables employing metal foils did not have metal foils that were pleated, i.e., possessing a plurality of small hingelike pleats of indentations, that contribute greatly to the flexibility of the foil as the cable itself was flexed in various and sundry directions.

Shown in FIG. 2 is another embodiment of the instant invention employing two outer conductors shown as 4*a* and 4*b*. A center conductor is shown at 6 being disposed and separated from the two outer conductors 4*a* and 4*b* by dielectric core 2. The composite formed by elements 6, 2, 4*a* and 4*b* have extruded over the outer peripheral surface of outer conductor 4*b* a plastic sheath shown at 5. The embodiment as shown in FIG. 2 is essentially the same as that as shown in FIG. 1 except that the foil member 3 is replaced by an additional braid member 4*a*. As with the embodiment shown in FIG. 1, the braid in FIG. 2, elements 4*a* and 4*b*, is made from copper-clad steel. It is to be understood that in the embodiment shown in FIG. 2 the outer surface of the outer conductor braid 4*b* can be coated with a resin copolymer, as was the case with the outer braid member 4 of FIG. 1, and subsequent to this coating there can be extruded plastic sheath member 5 so as to form an adhesive bond between the braid member 4*b* and plastic sheath 5. However, it is to be understood, that as it was with the embodiment shown in FIG. 1, it is not mandatory that such adhesive be used to achieve a viable and strong coaxial cable.

The braid angle employed in the copper-clad steel braid shown in FIGS. 1 and 2 elements 4, 4*a* and 4*b*, can be quite important to overall coaxial cable design. Generally speaking,

disregarding for the moment any flexibility requirements of the cable, the smaller the angle between the individual strands that make up the composite braid, the more strength the cable exhibits in service under an applied tensile load. When tension is applied to a braided cable armor, i.e., as in the case of a coaxial cable the outer conductor or conductors, the tension or force applied along the axis of any given strand member making up the braid is the product of the specific tension applied to the overall cable times the cosine of the angle between the braid member and the axis of the cable itself. Thus, (F_b) the tension component along an individual braid member, equals to F (cosineα) where F equals applied axial tension and α equals braid angle (angle between cable axis and tangent to braid member). The tension component applied directly to the cable core **2** is called F_r, where F_r is equal to F sine$^2\alpha$. The pressure (P) exerted on cable core **2** equals to 2F sine 2α divided by NWD where W equals braid member width, D equals core diameter, and N equals number of carriers.

An additional relationship determination is necessary when one is calculating equilibrium core outer conductor brakes member strain values. This additional relationship refers to the change (increase) in braid length for a given change (decrease) in core diameter. As shown by FIGS. **8** and **9**, the braid member has a tendency, when tensional forces are applied thereto, to neck down and decrease the diameter which it otherwise exhibits when no tensional forces are applied. For small diameter changes, the following is pertinent: C_d = (tangent$^2\alpha$)dD/D. Assuming a Poisson's ratio of 0.5 then the aforementioned expression resolves itself to C_d=½ tangent$^2\alpha$. Letting C equal to the cable axial strain, the net braid member strain C_b is then calculated as: C_b=C−C_d=(1−½ **tan**$^2\alpha$).

From the above, it is then apparent that small braid angles are much to be preferred if strain and pressure on the cable core are to be minimized. If the yield strength of the cable core is not negligible compared to that of the armor or outer conductors as in the case of coaxial cable, there exists an optimum angle for minimum total strain. Where the armor or outer conductor is required to supply most of the strength contained in the cable, this optimum braid angle generally occurs at an angle so small that overall flexibility of the coaxial cable becomes a limiting factor.

The graph shown by FIG. 7 sets forth strain measurements performed on a coaxial cable having an inner conductor composed of 7 strands of AWG size 21 silver-covered copper wire with a cable core being of the solid type and overall diameter of approximately 0.280 in. An inner braid outer conductor member was used employing 24 carriers, six ends, and 16.6±10% picks/inch. An outer conductor braid member was used that had 24 carriers, seven ends, and 15.4±10% picks/inch. The outer jacket material disposed around the outer conductor braid member had an overall diameter of 0.420 in. The specific specifications of the coaxial cable used in this particular test meets Military Specification C-17/4B. It is referred to as RG-9B/U cable, radiofrequency, coaxial, and has individual strands made up of a plurality of round wire silver-covered copper wire. The individual braid strands of the instant invention are integral (solid) and are not made up of a plurality of strandlike members. However, the characteristics of the coaxial cable employing inner and outer conductors as in the case of cable conforming to Military Specification C-17/4B is analogous to that cable made up of braided strands of copper-clad steel for purposes of showing the relationship of braid angle to applied tensile load. Such a relationship is shown in FIG. **7** where various braid angles (52°, 42°, 29°, 18°, and 25°) are shown plotted showing the relationship of applied tension (lb.) versus cable elongation (percent). Braid angles of 18°, 29°, 42° and 52° were angles employed in the overall design of a coaxial cable meeting the specification of MIL-C-17/4B. Viewing this family of lines, it can be immediately grasped that the lower the braid angle the less the cable elongation under a given applied tension. When the silver-coated copper round wire was replaced with steel wire and a braid angle of 25° was employed, the curve so identical as 25° and shown on the graph of FIG. 7 was obtained. Thus, even though steel has more tensile strength than that of copper, one can see immediately from comparing the steel armor 25° angle versus the copper armor 18° angle that the braid angle plays a most important function in contributing to the percent of cable elongation under a given applied tension assuming that at an extrapolation of the 18° curve would exhibit no extreme slope deviation from that which is shown in the FIG. 7.

As a general rule, fewer picks/inch in a braid identifies a lower brain angle than a higher number of picks/inch. The following table is compatible with the information derived from the plots shown in FIG. 7 when one compares the picks/inch versus breaking strength and elongation:

TABLE I

	7 picks/inch	6 picks/inch	5 picks/inch
Breaking strength (lb.)	207	215	228
Percent elongation	18%	18%	18%

The breaking strength exhibited by the data in Table I versus the braid angle (picks/inch) appears to be more sensitive than the percent elongation as noted and actually plotted in FIG. 7. Thus, the combined teaching of the plots in FIG. 7 along with the data exhibited in Table I strengthen the proposition that the lower the braid angle the more desirable the resulting mechanical properties of the coaxial cable. Correspondingly, a low braid angle results in a large magnitude of any applied tensile forces to be applied along the axes of the individual strands of braid itself. A lesser component of the overall applied load manifests itself in a tangential manner to the axes of the cable. Thus, there is a correspondingly lesser amount of force, when a small braid angle is used, available to create compressive forces on the dielectric core and the center conductor. Hence, the center conductor is thus relieved of some of the load it would have to carry if the braid angle were otherwise.

Shown in FIG. 3 are a family of curves plotting maximum attenuation versus frequency. For purposes of comparison, a coaxial cable attenuation value versus specific frequencies was plotted for a cable that had an outer conductor braid made entirely out of copper. The plot thus obtained is represented by the middle line and identified as copper braid. The plot just above this copper braid line is a line representing the maximum attenuation versus frequency plot of a copper-clad steel braid member used as the outer conductor in a coaxial cable. These values for this last-mentioned plot are nominally applicable for both double or single copper-clad steel outer conductors. Just below the "standard" or comparative copper braid plot are the plotted values for maximum attenuation versus frequency for a double outer conductor coaxial cable having the inner conductor made of foil and the outer conductor made of copper-clad steel braid, identified as (foil and braid). Both the top and bottom copper-clad steel braid lines are braids made of strip rather than of round wire. Stated in an alternate manner, the top line or plot in FIG. 3 represent values observed for the cable as shown in FIG. 1 whereas the bottom line or plot represent values observed for that cable construction as shown in FIG. 2. Nominal values for the television band are shown for purposes of comparison and study. As it has been previously discussed, the particular copper-steel thickness ratio employed in the coaxial cable produces a resistance (attenuation) versus frequency characteristics such that the loss is somewhat identical to that when pure copper is used, beginning at the highest normally anticipated working frequency (channel 13) in the television assignments. Such a phenomena can be easily seen by the family

of plots shown in FIG. 3 by comparing these plots to the indicated television band in the uppermost reaches of this area of frequencies. Here, the foil plus copper-clad steel strip braid coaxial cable structure has essentially the same loss as the copper-clad braid coaxial cable in the indicated television channel 13 range. Where the copper-clad strip braid (either single or double) is compared with the copper braid, one can see from FIG. 3 that at frequencies less than channel 13 the attenuation is greater than that which would be normally experienced using conventional copper. This deviation from normal, contrary from what would be anticipated or expected, is actually desirable since less discrimination between high-frequency and lower frequency signals is evident at the subscriber's TV set. Furthermore, it would be desirable that the plots of maximum attenuation versus frequency be horizontal and have no slope at all. This would mean that the attenuation (loss) would be constant for a wide range of frequencies. When either double or single copper-clad steel strip braid was used in the coaxial cable structure, the plot of the maximum attenuation versus frequency had a lower slope for this particular cable structure than that when pure copper braid was used. Constructions employing a double flat-strip braid (the second braid being applied on the first) exhibited a shielding efficiency that is approximately 100 times as great as that of the single braid. Furthermore, the braking strength was increased to something in excess of 400 pounds while the cost was very little more than that of conventional single round wire braided coaxial cable.

Also shown in FIG. 3 is a plot representing values of maximum attenuation versus frequency for a cable structure of that of FIG. 1 (foil and braid). The particular values, as expressed for this plot, are quite significant because it will be immediately noticed that the plot in question expresses a lower maximum attenuation versus frequency values than those plots obtained when the copper braid cable structure or the copper-clad steel strip braid was employed. Since it was observed first that the copper-clad strip braid cable had maximum attenuation versus frequency characteristics greater than that of the copper braid per se, it would be anticipated that a coaxial cable made up of the combination of copper-clad strip braid and copper foil—the copper foil being somewhat analogous to the copper braid—that the attenuation versus frequency characteristics of this particular structure would lie between that curve for the copper braid and the curve for the copper-clad strip braid. However, this was not the case. Surprisingly, the maximum attenuation versus frequency was less than that which would be expected and even less than those values observed when employing the copper braid alone.

Shown in FIG. 6 is a coaxial cable also incorporating the concept of having two outer conductors in combination with a dielectric core and center conductor disposed axially inside of the dielectric core. Disposed on the outside peripheral surface of the dielectric core member is a longitudinally wrapped piece of tape 7, this tape being composed of a plastic substrate 8 of a given thickness with a coating of metal 9 two times the thickness of a plastic on top of the plastic substrate as shown in FIG. 4. The plastic substrate 8 is usually Mylar (polyethylene terepthalate). Helically wrapped around the first longitudinally wrapped outer conductor 7 is an additional piece of tape 9 somewhat identical to the longitudinally wrapped tape. This tape also is composed of a plastic substrate of a given thickness with a double thickness of metal deposited on one surface only. In both tapes, the substrate can be a polyolefin (polypropylene or polyethylene) or Mylar (polyethylene terepthalate). Generally speaking, the helically wound outer or second conductor is corrugated, the corrugations running parallel to the long axis of the tape itself. A longitudinal wrap is employed as the first outer conductor so as to avoid any electromagnetical effects created by a helical configuration. Thus, a helical wrap is used only on the outside surface of the longitudinally wrapped first inner conductor. Inasmuch as the first and second conductors are composed of a plastic coated on one side only with a metal, that metal generally being aluminum or copper, one embodiment of the invention envisions that the metal surface of the longitudinally wrapped tape be in contact with the outer peripheral surface of the dielectric core member. Furthermore, and in like manner the metallized surface of the helically wound plastic tape member is in contact with the outer peripheral surface of the longitudinally wound tape, i.e., its nonconductive (plastic) surface.

In FIG. 6 it is to be noted that the composite made up by the center conductor 6, dielectric core 2, and outer conductors 7 and 9 normally is covered by an outer sheath member not shown. This outer sheath member, as in the case of the cables shown by element 1 in FIGS. 1 and and 2, may be of polyvinyl chloride, polyethylene, polyolefin, or of butyl rubber. Furthermore, an adhesive coating maybe employed by spreading such a coating over the outer peripheral surface of the helically wound coated tape member 9. This adhesive compound may take the same form as that used in coating the braid members 4 of the cables 1 shown in FIGS. 1 and 2. That is to say, a resin copolymer having a molecular chain, one end of which possesses an affinity for plastic materials such as polyethylene and the other end of which possesses an affinity for a metal. After the outer peripheral surface of the helically wound conductor has been coated with a resin copolymer, the thus coated composite is traversed through an extruder where an outer sheath member is molded on to the composite. As a result of the use of this adhesive resin copolymer and the thinness of the resin substrate used with the metal-coated plastic, the heat from the extrusion process affects the resin plastic substrate to the point that the metal foil is exposed thus permitting that portion of the resin copolymer molecular chain having an affinity for metal to carry out its intended function. In this matter, a most desirable bond between the outer sheath member and the outermost conductor is achieved.

A further embodiment of the concept using two outer conductors made up of a plastic strip coated on one side only with a metal foil 7 and 9 employs the combination wherein the longitudinally wrapped strip is so disposed that the plastic substrate is in contact with the dielectric core 2. Thus, the longitudinally wrapped tape would have its metal coated side disposed in an outward fashion. Helically wrapped on top of this first longitudinally wrapped tape is a second metal-coated plastic tape where the metal surface of the helically wrapped tape is in contact with and adjacent to the peripheral metal surface of the longitudinally wrapped tape. Thus, there results an outer conductor made up of two metal-coated layers, one lying on top of one another with the outermost peripheral surface of the helically wound tape being the plastic substrate. The purpose of this particular embodiment is to place two metal coatings in side-by-side contacting relationship and in contact with each other, this particular structural configuration concentrating the amount of metal in the outer conductor. Yet, there is maintained still a high magnetic shielding efficiency within the concept of using two distinct outer conductor preforms disposed around a dielectric core.

As previously mentioned, the helically wound tape is normally corrugated along the metal coated plastic tape longer axes. However, this corrugation is not obligatory but such corrugations do enhance the flexibility of the tape per se as well as the anchoring of any subsequently extruded outer jacket. As was the case in the previous embodiment employing alternating layers of plastic substrate and metal coating, it is to be understood that prior to the extrusion of outer jacket or sheath on to the two outer conductors, the outermost conductor, i.e., the helically wound tape, may be coated with a resin copolymer adhesive possessing a molecular chain as previously discussed.

Shown in FIG. 5 is a cross section of the copper-clad steel strip used in the braid 4 of FIGS. 1 and 2. It will be noted that the copper A completely surrounds the steel core 5. Shown in FIG. 4 is a cross section of the metal-coated plastic tape used in the coaxial cable embodiment of FIG. 6. The plastic or non-

conductive substrate is shown at **8** with the metal coating on one side only of that metal tape shown at **9**. As previously stated, the nonconductive plastic tape **8** can be anyone of the polyolefins or polyethylene terepthalate whereas on the other hand, its coating **9** is generally aluminum, silver, copper, or alloys thereof.

Turning briefly to the data shown by the plot in FIG. **10**, unexpected results are shown here by a coaxial cable made from copper-clad flat strip in combination with copper foil (plot C). In this particular Figure, which is a plot of maximum continuation versus frequency, the electrical characteristics of three different types of coaxial cables are shown. Curve A represents the maximum attenuation versus frequency plot for a known coaxial cable that employs a copper-clad steel braid for a single outer conductor. Curve B represents the maximum attenuation versus frequency plot for a coaxial cable using round wire braid as an outer conductor made entirely of copper. On the other hand, curve C is a plot of the maximum attenuation versus frequency for a coaxial cable employing as a first outer conductor a longitudinally wrapped copper foil and a a second outer conductor a braid made up from either copper-clad steel flat strips or copper-clad steel round wire. Only a brief study of the plots shown in FIG. **10** is required to come to the conclusion that the slope of the curve C is essentially the same as that for A and B. Furthermore, the attenuation loss of a coaxial cable employing the structure of the instant invention (FIG. **1**) has a lower attenuation loss at a given frequency when compared to coaxial cables of other constructions. In addition to the above noted low attenuation loss at a given frequency, the use of the combination foil plus copper-clad flat steel strip accomplishes essentially 100 percent shielding effect as opposed to an approximately 90 percent shielding effect in the case of the cables exhibiting maximum attenuation versus frequency characteristics like unto that plotted and shown as curves A and B. Thus, in summary, it can be readily appreciated that the novel cable structure of the instant invention (FIG. **2**) achieves increased shielding efficiency as well as lower attenuation loss at given frequencies.

A series of laboratory tests were performed to determine the tensile breaking strength of the several coaxial cable drop wires disclosed by the instant invention. All testing was done on a Mark B Universal Testing machine at a crosshead separation rate of 2.0 in. per minute, the initial separation of clamps being 20 in. All failures were recorded to be between 1 and 3 minutes.

TABLE I

Tensile-breaking Loads of Coaxial Cable Drop Wires

Sample	Breaking Load (lb.)
No. 34 AWG copper braid	Average—176
Flat strip copper/steel braid	Average—284

TABLE II

Tensile-Breaking Loads of Copper-Clad Steel Braids

Sample	Breaking Load (lb.)
One layer No. 34 copper braid plus one layer flat strip braid	Average—343
Two layers flat strip braid	Average—450

Viewing the data shown in Tables I and II, it can be seen that the short-time breaking strength of the copper-clad steel braid is about 100 pounds higher than that of the No. 34 AWG Copper Braid coaxial cable. Data shown in Table II indicates that the coaxial cable employing one layer of No. 34 copper braid plus one layer of flat strip braid (copper-clad steel) has an average breaking load of about three times that of the breaking load of No. 34 AWG Copper braid alone. Furthermore, in the case where two layers of flat strip copper-clad steel braid were employed, i.e., the structure as shown in FIG. **2**, the breaking strength was approximately 2½ times that of the coaxial cable employing No. 34 AWG Copper braid alone.

From the foregoing, it can be observed that employing the basic concept of a double outer conductor disposed over the peripheral surface of a dielectric core in which a center conductor is axially disposed brings about a unique construction in the CATV coaxial cable drop wire application. By using a double outer conductor, improved shielding efficiency is achieved. Furthermore, by employing as either one or both of the outer conductors a copper-clad steel flat braid, improved strengths and attenuation versus frequency characteristics are achieved. A foil member used in combination with a copper-clad steel braid coacts with the braid, when it is under tensile forces, and the copper foil beneath it configurates the copper foil in a manner that renders the copper foil crack resistant. Coupled with this desirable mechanical characteristic is the electrical property of a double electrical magnetic shield creased by the foil.

The same double outer conductor coaxial cable construction concept was carried over into the embodiment employing an outer conductor made up of two wrapped tapes, both tapes being composed of a nonconductive (plastic) strip member coated on one side only with a metal. Various modes of wrapping these particular first and second outer conductor tapes on the dielectric core have been disclosed, one of which achieves a more viable and thicker outer conductor. Additionally, it has been shown that by applying a modified resin copolymer to the outer peripheral surface of the second outer conductor a desirable bond between the second outer conductor and the subsequently molded outer sheath can be achieved.

From the foregoing, it is believed that the invention may be readily understood by those skilled in the art without further description, it being borne in mind that numerous changes may be made in the details disclosed without departing from the spirit of the invention as set forth in the following claims.

We claim:

1. A multiconductor electrical cable comprising:
a. an elongated cylindrical body of dielectric material;
b. a first electrical conductor embedded and nested axially within said dielectric body;
c. a second electrical conductor formed on the other peripheral surface of said dielectric body and disposed concentrically about said first conductor; and,
d. a braided third electrical conductor formed concentrically about said second conductor and made of steel braided strands that are each completely covered by a layer of copper.

2. An electrical cable as defined by claim **1** further comprising a cylindrical jacket concentrically disposed about said third conductor.

3. An electrical cable as defined in claim **1** wherein said second conductor is a copper foil.

4. An electrical cable as defined in claim **3** wherein said center conductor is composed of materials selected from the group consisting of copper, copper-covered steel and copper-covered aluminum.

5. An electrical cable as defined in claim **3** wherein said dielectric material is composed of solid and foamed polyolefin.

6. An electrical cable as defined in claim **3** wherein the outermost surface of said third conductor is coated with an adhesive film composed of a resin copolymer.

7. An electrical cable as defined in claim **1** wherein individual strands woven together to form said braided flexible conductor, form an angle with the cable axis that is less than 25°.

8. The electrical cable defined in claim 1 wherein said second conductor is made of steel braided strands that are completely covered by a layer of copper.

9. The electrical cable defined in claim 8 wherein each of the strands of said second and third conductors has a rectilinear cross section that possesses a width which is greater than its thickness.

10. The electrical cable defined in claim 1 wherein each of the strands of said third conductor has a rectilinear cross section that possess a width which is greater than its thickness.

11. An electrical cable having only inner and outer electrical conductor means and comprising an elongated cylindrical body of dielectric material, said inner electrical conductor means being embedded and nested axially within said dielectric body, said outer electrical conductor means being of flexible, braided, tubular configuration and being formed on the outer peripheral surface of said dielectric body in peripheral surrounding relation thereto, and a sheath of dielectric made covering and peripherally surrounding said outer conductor means, said outer electrical conductor means being made only of steel braided strands that are each completely covered by a layer of copper.

12. The electrical cable defined in claim 11 wherein said outer electrical conductor comprises first and second electrical conductors nested one within the other, and each of said first and second conductors being made of steel braided strands that are completely covered by copper.

13. The electrical cable defined in claim 11 wherein angulated pairs of said strands, which are woven together to form said outer conductor means, form an angle with the longitudinal cable axis that is less than 25°.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,643,007 Dated February 15, 1972

Inventor(s) Walter Roberts, Jimmie D. Sherrill, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 54, change "used" to --use--.

Column 4, line 16, change "electric" to --dielectric--.

Column 5, line 74, after "complex" insert --chemically bonded thereto. It is this maleic or acrylic-acid complex--.

Column 6, line 42, change "cordianlike" to --cordian-like--.

Column 6, line 48, change "hingelike" to --hinge-like--.

Column 7, line 55, change "has" to --had--.

Column 7, line 66, change "(lb)" to --(lbs)--.

Column 7, line 73, change "identical" to --identified--.

Column 8, in the chart,"(lb)" should be --(lbs)--.

Column 11, line 21, change "aa" to --as--.

Column 12, line 47, (line 5 of claim 1) change "other" to --outer--.

Column 14, line 8, (line 2 of claim 12) after "conductor" insert --means--.

Signed and sealed this 26th day of December 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
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ROBERT GOTTSCHALK
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FORM PO-1050 (10-69)

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