

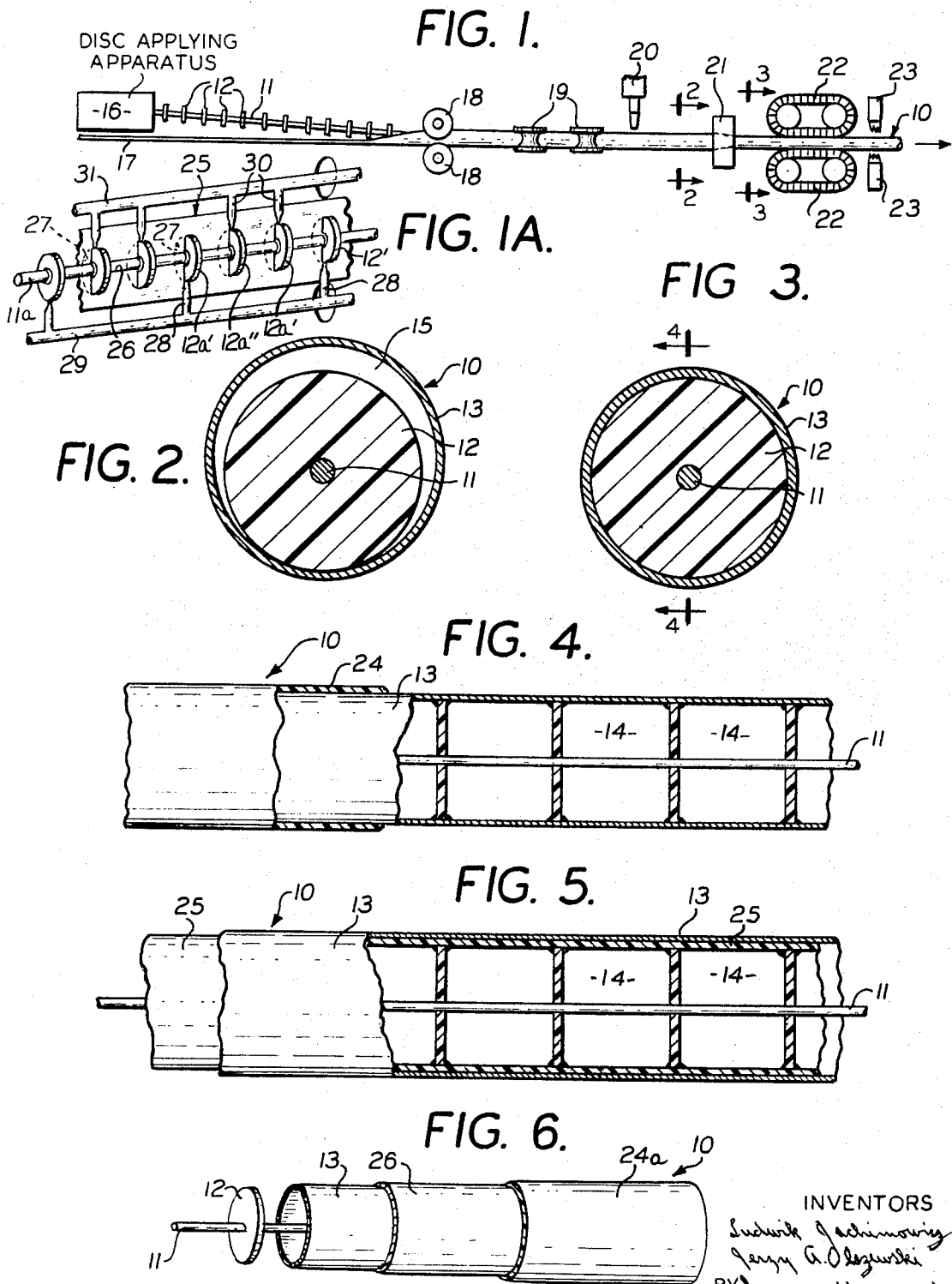
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WATERTIGHT DISC COAXIAL CABLE

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## WATERTIGHT DISC COAXIAL CABLE

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10 Claims

### ABSTRACT OF THE DISCLOSURE

A method of making a coaxial cable having a plurality of discs of a dielectric synthetic resin material that bonds to metal bonded to an elongated metal center conductor at spaced intervals therealong. A tubular metal outer conductor encloses the discs and is bonded thereto so that the discs define a plurality of separate watertight compartments. An inner tubular sheath of a synthetic resin may be between, and bonded respectively to, the inside of the outer conductor and the discs. Also, a layer of synthetic resin may be bonded around the exterior of the outer tubular conductor. Better electrical characteristics are obtained by having some discs of adhesive polyethylene and others of non-adhesive polyethylene.

### RELATED APPLICATION

This is a continuation-in-part of patent application Ser. No. 861,792, filed Sept. 29, 1969, now U.S. Pat. No. 3,660,589.

### BACKGROUND OF THE INVENTION

The present invention is a method of making a coaxial cable which is watertight so as to be suitable for outdoor use and which has low attenuation for high-frequency currents.

It is possible to provide a moisture-tight coaxial cable wherein the center conductor is surrounded by foamed polyethylene insulation to form a core which is enclosed in an aluminum tube that serves as the outer conductor of the coaxial pair. The attenuation of this cable, however, is high due to the use of solid or semi-solid insulation, such as foamed polyethylene which has a dielectric constant of about 1.5.

Attenuation is reduced substantially if air is used as the dielectric, and at least two types of coaxial cables are known in which an air dielectric is provided by having the outer tubular conductor around spacing discs of dielectric material which are placed on the center conductor at regular intervals (about 1 inch apart, for example) along it.

### PRIOR ART

The discs in these known types have customarily been made of polyethylene, which is relatively inexpensive and easily moldable. In one known construction the outer tubular conductor is made of an elongated strip of copper having its edge portions bent up around the discs to form a tube over which one or two steel tapes are helically wound. In another similar type the outer conductor is formed of a corrugated laminate of steel and copper strips. The edge portions of the laminate are bent around the disc to form a tube, the adjacent edges being soldered together in a seam. These forms of air dielectric cables however are unsuitable for use outdoors or in other places where they would be subject to moist conditions, because moisture, which may enter through a cable connector or through a tear or break in the outer conductor, for example, can migrate around the discs and along through the interior of the cable.

### BRIEF SUMMARY OF THE INVENTION

A principal object of the present invention is to provide an improved method of making a coaxial cable having an air dielectric—and which thus has low attenuation—and in which any moisture which may get into the cable cannot migrate along it, so that the cable is adapted for use outdoors and in moist conditions.

A coaxial cable made in accordance with this invention consists of a plurality of discs of a dielectric material, which is moldable and which bonds to metal, spaced along the center conductor and bonded to the center conductor and to the tubular outer conductor. The discs thus form watertight compartments along the length of the cable.

One modification of the invention obtains attenuation improvement by making some of the discs of dielectric material which has good adhesion to metal and other intervening discs of dielectric material which has lower conductivity and, therefore, produces better attenuation characteristics for the cable, but which does not have as good adhesion to the metal. These intervening discs provide mechanical support for the outer conductor even though they may not always provide a waterproof filler. However, the discs with high adhesion are spaced closely enough to obtain compartments which prevent spreading of any water flooding along sufficient length of the cable to seriously impair the operation of the cable. In the preferred construction the adhesive discs are made of polar polyethylene and the intervening discs of ordinary non-polar polyethylene.

### DESCRIPTION OF THE DRAWINGS

The coaxial cable made by this invention and the method of making it will now be described in detail with reference to the accompanying drawings in which:

FIG. 1 is a schematic drawing showing the several steps of a method of forming the coaxial cable in accordance with the present invention;

FIG. 1a is a diagrammatic view showing one method of applying discs to the center conductor to improve attenuation characteristics of the coaxial cable;

FIG. 2 is a section along the line 2—2 of FIG. 1;

FIG. 3 is a section along the line 3—3 of FIG. 1;

FIG. 4 is a side view, partly in section and partly broken away, of a preferred form of a cable of this invention;

FIG. 5 is a side view, partly in section and partly broken away, of a modified form of cable embodying the invention; and

FIG. 6 is an isometric view, partly broken away, showing still another modification of a cable embodying this invention.

### DETAILED DESCRIPTION OF THE INVENTION

As best seen in FIGS. 3 and 4, a coaxial cable 10 in accordance with this invention comprises generally a center conductor wire 11 having spacer discs 12 of dielectric material on it at spaced intervals (of about 1 inch, for example), and a tubular outer conductor 13 around the circumferences of the discs 12.

The center conductor wire 11 is suitably copper, copper-clad aluminum or aluminum. The tubular outer conductor 13 is suitably aluminum or a steel and copper laminate. The spacer discs 12 are a moldable dielectric material which can be bonded permanently to metals, particularly to aluminum and copper, and to synthetic plastics, by the application of heat and pressure. Suitable materials for discs 12 are ionomers, such as the ionomer available from E. I. du Pont de Nemours and Co. under the trademark Surlyn, and copolymers of ethylene and a monomer containing acrylic acid, such as the copolymer identified

by the designation QX-2375 available from Dow Chemical Company.

In accordance with the invention, the discs 12 are bonded both to the center conductor 11 and to the tubular outer conductor 13, so that the air dielectric of the cable is provided by a plurality of separate watertight compartments 14 along the length of the cable. Thus, water or moisture getting into the cable at any point—through a connector or through a break or tear through the outer conductor 13, for example—will be confined to the compartment 14 it enters. By thus limiting the length of the portion of the cable affected by any water or moisture getting into it, the reliability of the cable is greatly increased. For example, entry of moisture into the cable—assuming the amount is not enough to cause a short circuit—produces an impedance discontinuity which affects transmission in proportion to the physical length of the discontinuity expressed in terms of wavelength. At 300 mc. the wavelength is about 1 meter. With the spacer discs 12 one inch apart, if moisture gets into one of the compartments 14, the length of the cable affected by the moisture is  $2.5 \text{ cm.}/100 = \frac{1}{40}$  of the wavelength, which is not enough to produce significant deterioration of transmission. A discontinuity of  $\frac{1}{4}$  wavelength would have a more significant effect, but to produce a discontinuity of this magnitude ten of the one-inch compartments 14 would each have to be punctured.

In accordance with the method of forming a coaxial cable 10 of this invention, the spacing discs 12 are pressure-molded onto the center conductor 11, while the center conductor 11 is heated sufficiently for the heat and pressure of the molding to bond the discs to the conductor. The conductor may be preheated if necessary, but the heat of the pressure-molding operation will normally heat the center conductor to the extent required.

The center conductor 11 with the discs 12 thereon is then enclosed by the tubular conductor 13. This may be done either by drawing the center conductor and discs into a preformed tubular outer conductor 13 or by blending the edge portions of an elongated strip of outer conductor material around the circumferences of the discs and welding or soldering the adjacent edges of the strip together. In either case, as initially formed or provided, the inside diameter of the outer conductor 13 is larger than the outside diameters of the discs, so that there is a space 15 between, as illustrated in FIG. 2. Thereafter, the diameter of the outer tubular conductor 13 is reduced by die-sinking, or by any other suitable method, to shrink it down into intimate pressure contact with the circumferences of the discs 12. The outer conductor 13 is then heated to complete the bond between the discs 12 and the inside of the tubular outer conductor 13.

FIG. 1 illustrates schematically apparatus for making the above-described coaxial cable in accordance with a method of this invention. The discs 12 are pressure-molded onto the center conductor 11 by disc-applying apparatus indicated at 16. The conductor 11, with discs 12 thereon, and a continuous strip 17 of aluminum, or other suitable metal, for the outer tubular conductor 13 are brought together and fed through a pair of forming rolls 18, which start the bending of the edge portions of the strip 17 up around the circumferences of the discs 12. From the rolls 18, the partially formed cable is drawn through tube-forming dies 19, which bring the opposite edges of the strip 17 together to be welded into a seam at a successive welding station 20. At this point the tubular outer conductor 13 is a larger diameter than the disc 12, as indicated in FIG. 2, and is then die-sunk down into intimate pressure contact with the discs 12, as illustrated in FIG. 3, by being drawn through sinking dies 21. Movement of the cable 10 through the rolls 18, dies 19, welding station 20 and dies 21 is provided by conventional forwarding means, such as caterpillar forwarding device 22 engaging the tubular outer conductor 13 of the cable.

After the outer conductor 13 is sunk into pressure contact with the discs 12, it is heated at a heating station 23, for example, to complete the bond between the circumferences of the discs 12 and the outer conductor 13. In a preferred form of the cable, however, the exterior of the tubular outer conductor 13 is provided with an outer protective jacket 24 of polyethylene, illustrated in FIG. 4, and it has been found that the heat provided by extruding the polyethylene jacket onto the tubular outer conductor 13 is enough to cause satisfactory bonding of the discs 12 to the tubular outer conductor 13.

FIG. 1a shows one way in which discs can be applied to the center conductor. An injection mold 25 has a passage 26 through which an inner conductor 11a can be advanced with intermittent motion. There are mold cavities 27 at spaced locations in the mold 25 corresponding to the desired spacing of discs 12a' and 12a'' along the conductor 11a.

Every third one of the cavities 27 is supplied with moldable material through injection nozzles 28 which connect with an injection channel 29. Adhesive dielectric material such as the polar-polyethylene QX-2375 of Dow Chemical Co., previously referred to, is supplied from injection molding equipment to the mold cavities which communicate with the nozzles 28. The disc molded in these cavities are indicated by the reference character 12a'.

Intervening discs are molded in other cavities 27 supplied with moldable material through nozzles 30 communicating with an injection channel 31. Extending apparatus supplies dielectric material, preferably non-polar polyethylene, to the channel 31 and the discs 12a'' which are formed in the cavities supplied by the nozzles 30 are, therefore, non-polar polyethylene. Such ordinary polyethylene gives the cable better attenuation characteristics than does the polar-polyethylene.

When a metal tube such as the outer conductor 13 is brought into contact with the discs as shown in FIG. 4, the circumferences of the polar-polyethylene discs are bonded chemically to the metal of the conductor 13 whereas the discs made of ordinary non-polar polyethylene may be bonded mechanically by fusion bonds, such bonds do not have the strength of the polar-polyethylene and may be broken in service so that the watertight compartments of the coaxial cable have a length equal to the distance between successive polar-polyethylene discs. In such a case, with every third disc made of polar-polyethylene, as shown in FIG. 1a, and one inch spacing of the discs along the inner conductor, the compartment which can be affected by moisture is three times as long as when all discs are made of polar-polyethylene. This affected length is not sufficient to impair substantially the operation of the cable.

Whether the construction is made with all of the discs of the same composition, or made with different discs of different composition as shown in FIG. 1a, the construction of the coaxial cable is the same as shown in FIG. 4.

FIG. 5 illustrates another embodiment of a cable of this invention wherein, after the discs 12 are pressure-molded onto the center conductor 11 and prior to putting on the tubular outer conductor 13, a thin-walled tube 35 of material, which is the same as or similar to the material of the discs 12, namely, moldable material which will bond to metal and synthetic plastics under heat and pressure, is extruded over the circumferences of the discs 12 so as to become bonded thereto. The wall of this tube 25 is suitably 10 to 20 mils thick, for example.

The tubular outer conductor 13 is then applied over the tube 35, die-sunk into intimate pressure contact therewith, and bonded to it by applying heat, as described above. The inner tube 35 being thus bonded to both the circumferences of the discs 12 and to the inside of the tubular outer conductors 13 bonds the tubular outer conductor to the discs. The inclusion of this tube 35, of course, increases the expense due to the extra material and the additional extruding step. It also increases slight-

ly the attenuation due to the presence of the additional quantity of dielectric in the space between the outer conductor 13 and the center conductor 11. But the addition of this tube 35 provides a higher degree of protection against moisture and thus increases the reliability of the cable.

As mentioned above, an outer protective jacket of polyethylene, illustrated by the jacket 24 in FIG. 4, may be applied over the tubular outer conductor 13 for adding reinforcement. FIG. 6 illustrates another modification in which an outer protective jacket 24a of polyethylene is bonded to the tubular outer conductor 13 by means of an intermediate layer 26 of the aforementioned type of moldable material which will bond to metal and plastic under heat and pressure. In this embodiment the layer 26 of the moldable material is extruded over the tubular outer conductor 13, the heat of the extrusion process normally being sufficient for the layer 26 to bond to the tubular outer conductor 13. Then the outer jacket 24a of polyethylene is extruded over the layer 26, the heat of the extrusion process also normally being sufficient to bond the layer 26 to the jacket 24a.

As an alternative, the surfaces of the inner and outer conductor coming in contact with the discs can be treated or coated to produce regular non-polar polyethylene at the region of contact with the discs.

This invention provides a coaxial cable in which the dielectric between the center conductor 11 and the tubular outer conductor 13 is approximately ninety percent air with the discs 12 spaced about 1 inch apart along the center conductor 11, and thus provides a cable which has low attenuation for high frequency currents (on the order of from about 3 to 300 MHz., for example). Moreover, this cable is particularly adapted for use outdoors or in moist conditions, since the numerous small watertight compartments 14 along the length of the cable severely limit the possibility of water or moisture getting in. But, if water or moisture should get in, it is confined to a small section and is prevented by the sealed discs 12 from migrating along inside the cable.

Table 1 shows the comparative attenuation results at different frequencies between coaxial cable with continuous foam between the inner and outer conductors and coaxial cable of equivalent size that has dielectric discs of this invention use in place of foam. Column 3 of the table shows results with all of the polar-polyethylene (QX-2375) and the 4th column shows results with every third disc made of polar-polyethylene and two intervening discs made of ordinary non-polar polyethylene.

TABLE I

Megahertz	.412" standard foam	All discs (QX-2375)	Every 3rd disc of QX-2375
54.....	.7608	.6322	.6077
100.....	1.0612	.8825	.8370
216.....	1.6274	1.3542	1.2564
250.....	1.7680	1.4716	1.3584
300.....	1.9623	1.6338	1.4979

NOTE.—The above figures for comparative attenuation are for decibels per hundred feet of cable.

The above for aluminum outer conductor, copper inner conductor and discs occupying 8.7% of the free space between conductors.

From the above table it will be evident that changing from continuous foam insulation to the discs of QX-2375 effects a reduction in attenuation of approximately 16.8%. Using the polar-polyethylene for every third disc and ordinary polyethylene for the intervening discs effects a reduction in attenuation, as compared to the continuous foam, of from 20.1 to 23.7% depending upon the frequency.

The preferred embodiment of the invention has been illustrated and described but changes and modifications can be made and some features can be used in different

combinations without departing from the invention as defined in the claims.

What is claimed is:

1. A method of making a coaxial cable having a plurality of separate watertight compartments therealong comprising: molding discs of dielectric material, comprising polyethylene or the like, that bonds to metal under heat and pressure onto an inner elongated metal center conductor with the discs of substantially the final desired diameter and at spaced intervals along the center conductor, the molding operation having sufficient heat and pressure to bond the discs to the inner conductor, applying an outer conductor around the discs as a metal tube with the inside diameter of the tube greater than the diameter of the discs, reducing the diameter of the outer conductor to bear against the circumferences of the discs, and heating the outer conductor to bond the discs to the outer shell.

2. The method described in claim 1 characterized by reducing the diameter of the metal tube into contact with the circumferences of the spacer discs by pulling it through a sinking die.

3. A method of making a coaxial cable having a plurality of separate watertight compartments therealong comprising: molding discs of dielectric material, comprising polyethylene or the like, that bonds to metal under heat and pressure onto an elongated metal center conductor with the discs of substantially the final desired diameter and at spaced intervals along the center conductor, the molding operation having sufficient heat and pressure to bond the discs to the inner conductor, applying a tubular outer shell around the discs with the discs in contact with the inside surface of the outer shell, at least a part of the shell being metal and providing the outer conductor of the coaxial cable, characterized by the outer shell including a tubular metal outer conductor of aluminum, said outer conductor being of a diameter substantially greater than the diameter of the discs, reducing the inside diameter of the outer conductor to bear against said tube and to press said tube against the circumferences of the discs under pressure, and thereafter heating the outer conductor to bond the outer conductor to the tube to complete the shell.

4. The method of claim 1 in which said outer conductor is heated to bond the discs to the outer conductor by extruding a coating of synthetic resin material over the exterior of the outer conductor.

5. The method described in claim 1 characterized by applying to the center conductor dielectric plastic discs that have chemical adhesion to metal of the outer conductor and bringing the metal of the outer conductor into direct contact with the circumferences of the discs, applying to the center conductor other dielectric plastic discs of lower electrical conductivity than the first discs but that have poorer adhesion to the metal, said other discs being located on the center conductor in spaces between successive discs of the first discs.

6. The method in claim 5 characterized by there being a plurality of said other discs between every two of the discs that have the chemical adhesion to the metal.

7. The method described in claim 6 characterized by the discs that have the chemical adhesion being made of polar polyethylene and being chemically bonded to both the inner and outer conductors, and the other discs being non-polar polyethylene and mechanically bonded to the inner and outer conductors.

8. The method described in claim 1 characterized by at least some of the discs being made of non-polar dielectric material and others of the discs being bonded to the metal of the outer conductor by polar dielectric material on the circumferences of the discs.

9. The method described in claim 3 characterized by enclosing the center conductor and the discs in a shell that has a plastic inside lining and an outer metal portion,

bonding the outside of the lining to the metal portion and bonding the inside of the lining to the circumferences of the discs.

10. The method of making coaxial cable having a plurality of separate watertight compartments therealong 5 compartments therealong comprising molding discs of dielectric material comprising polyethylene or the like, that bonds to metal under heat and pressure, onto an elongated metal center conductor at spaced intervals along the center conductor with sufficient heat and pressure to bond the 10 discs to the center conductor, enclosing the discs in a tubular outer conductor and bonding the discs to the outer conductor to form watertight compartments, and providing mechanical support for the outer conductor by locating on the center conductor other discs between and 15 spaced from the first discs and of material having a lower electrical conductivity than the first discs.

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