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Iyengar et al.

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[54] **METHOD OF CONTROLLING THE CHARACTERISTICS IMPEDANCE OF COAXIAL CABLES**

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[52] **U.S. Cl.** ..... **29/624**, 29/203 C, 29/593, 174/28, 333/96

[51] **Int. Cl.** **H01b 13/20**

[58] **Field of Search** ..... 29/203 C, 193.5, 29/203 P, 200 D, 200 P, 624, 593; 156/47, 50, 55; 264/138, 157, 163, 145; 174/28; 333/96; 324/57 R

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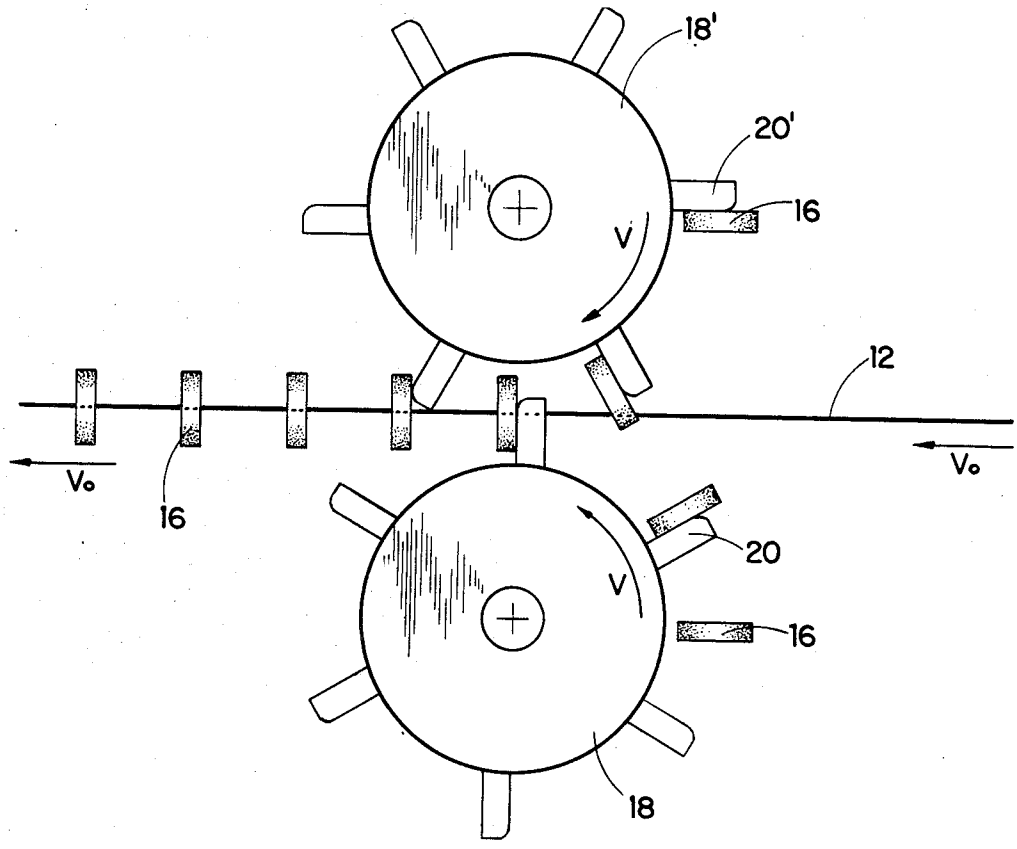
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Assistant Examiner—Joseph A. Walkowski, Jr.
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[57] **ABSTRACT**

A method is disclosed for adjusting the characteristic impedance of disc insulated coaxial cables. The method consists of varying the spacing between adjacent discs mounted on the center conductor during the manufacturing operation. An increase in impedance results from an increase in the spacing of the discs and, conversely, a decrease in impedance results from a decrease in spacing. The spacing between discs may be varied by changing the rate at which the discs are applied to the conductor which is moving at a constant linear speed.

4 Claims, 2 Drawing Figures



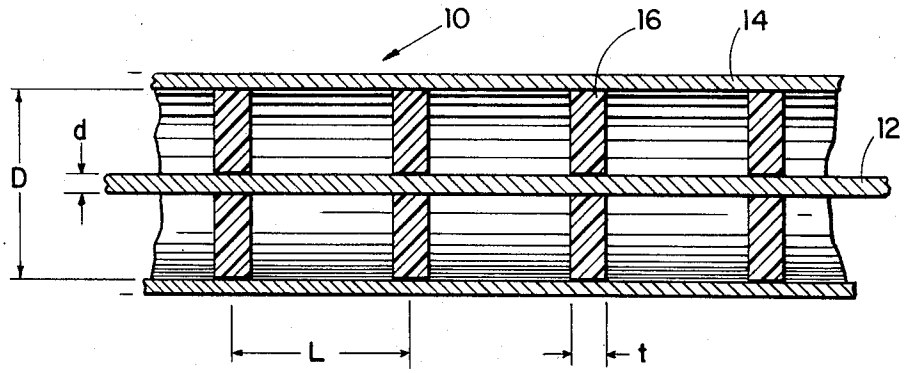


FIG. 1

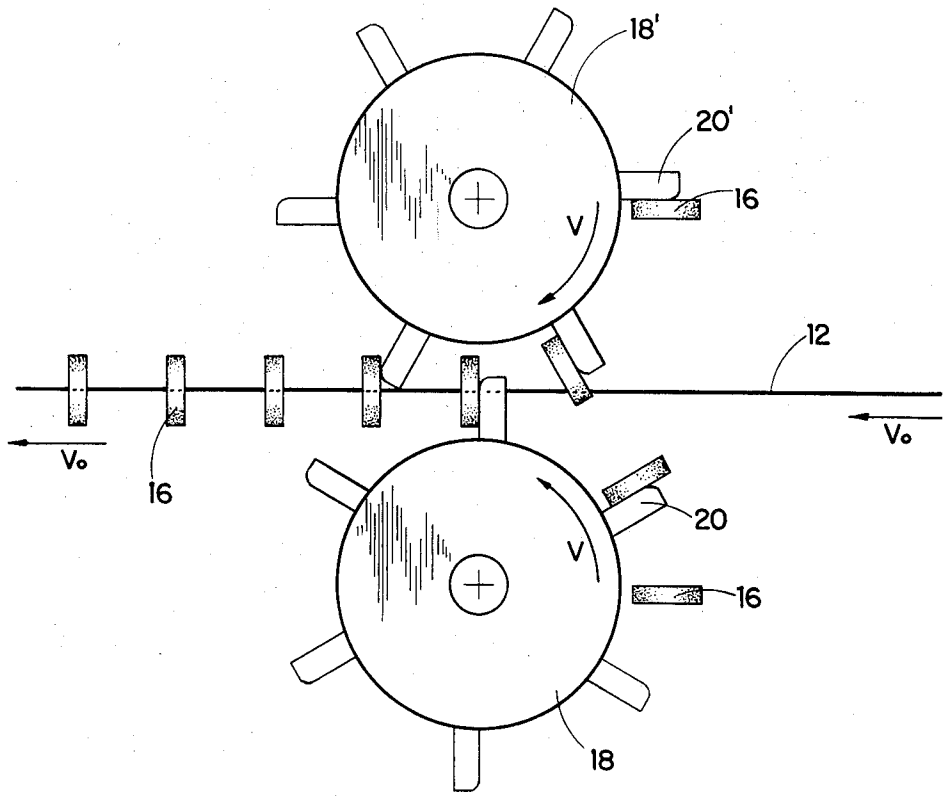


FIG. 2

METHOD OF CONTROLLING THE CHARACTERISTICS IMPEDANCE OF COAXIAL CABLES

This invention relates to a method of adjusting the characteristic impedance of coaxial cables and more particularly to a method of adjusting the characteristic impedance of disc insulated coaxial cables during the manufacturing process.

The variation in the characteristic impedance Z_o of a coaxial cable between minimum and maximum values is generally limited to approximately 1 percent. For example, the design tolerance for a coaxial cable having a nominal impedance of 75 ohms is ± 0.5 ohms. While these remain as absolute limits for the impedance of the cable, present requirements are to control the actual tolerances of cables to even narrower limits for optimum impedance matching between spliced cables to minimize reflection which could be troublesome if not kept to extremely low energy levels. Thus, it is preferred that the tolerance of a nominal 75 ohm cable not vary more than approximately $\pm$ 0.2 ohms while remaining completely within the design tolerance of 75$\pm$ 0.5 ohms.

Prior manufacturing processes have been incapable of providing the required degree of control on the variation of impedance in a practical manner.

The usual method of controlling the Z_o was on a trial and error basis, that is, a length of cable was manufactured and immediately tested for impedance. Corrective action consisted in varying the dimensions of either the center or outer conductors on the next length to be manufactured. Obviously, this method was both time consuming and very costly since the production of the next length had to be delayed while adjustments were made, such as changing the sizing die for the center conductor. Furthermore, it was usually necessary to make additional adjustments for several successive cable lengths before the permissible level of impedance tolerance was achieved.

The present invention is predicated upon our discovery that the impedance of a disc insulated coaxial cable can be controlled by varying the distance between adjacent discs mounted on the center conductor. Thus, the present invention provides a practical method for continuously controlling the impedance of a coaxial cable during the manufacturing operation by varying the spacing between the insulating discs on the inner conductor. This is achieved either by changing the rate at which discs are applied to a center conductor advancing at a constant speed past a disc applying station or by changing the speed of the advancing conductor while applying the discs at a constant rate.

A complete understanding of the invention may be had from the following description of a method of spacing the discs, with reference to the accompanying drawing in which:

FIG. 1 is a cross sectional view of a typical disc insulated coaxial cable; and

FIG. 2 is a schematic view of a portion of an apparatus for applying insulating discs upon a center conductor.

FIG. 1 illustrates a typical disc insulated coaxial cable **10** which comprises a center conductor **12** coaxially spaced within a tubular outer conductor **14** by means of thin insulating discs **16** mounted at spaced intervals along the center conductor **12.** Normally both the inner and outer conductors are copper, however, the outer conductor **14** may comprise a combination of copper and steel. The preferred material for the insulating discs **16** is polyethylene.

The impedance Z_o of the cable in FIG. 1 is a function of the inner diameter (D) of the outer conductor **14,** the outer diameter (d) of the center conductor **12** and the effective dielectric constant (ϵ_e) of the insulation. We discovered that the effective dielectric constant of the insulation was affected by the spacing of the discs **16** on center conductor **12,** and subsequently this affected the characteristic impedance Z_o of the cable. The correlation of the characteristic impedance Z_o with respect to the spacing of the discs that we have discovered may be realized from the following mathematical derivation with reference to FIG. **1.**

The variation of the impedance Z_o with respect to the spacing L of the discs can be expressed as dZ_o/dL from which it follows that

$$dZ_o/dL = (dZ_o/d\epsilon_e) \cdot (d\epsilon_e/dL) \tag{1}$$

where $d\epsilon_e$ = effective dielectric constant of the polyethylene-air dielectric of a disc insulated coaxial cable.

The relationship between the effective dielectric constant ϵ_e for a disc insulated cable and the dielectric constant ϵ for the polyethylene disc alone is:

$$\epsilon_e = 1 + (t/L)\,(\epsilon - 1) \tag{2}$$

where t = the thickness of a disc.

It follows from equation (2) that:

$$d\epsilon_e/dL = (d/dL)\,[1 + (t/L)\,(\epsilon - 1)\,]$$

and differentiating the above equation yields the following result:

$$d\epsilon_e/dL = -(\epsilon - 1)tL^{-2} \tag{3}$$

The standard equation for the characteristic impedance Z_o is:

$$Z_o = (138/\sqrt{\epsilon_e}) \cdot \log_{10}(D/d) \tag{4}$$

where D = inner diameter of outer conductor and

d = outer diameter of center conductor.

Therefore it follows that:

$$dZ_o/d\epsilon_e = (d/d\epsilon_e)\,[(138/\sqrt{\epsilon_e}) \cdot \log_{10}(D/d)\,] \tag{5}$$

and differentiating equation (5) yields

$$dZ_o/d\epsilon_e = 138 \log_{10}(D/d)\,[-1\epsilon_e^{-3/2}/2] \tag{6}$$

Substituting equations (3) and (6) in equation (1) gives:

$$dZ_o/dL = 69 \log_{10}(D/d) \cdot \epsilon_3^{-3/2}\,(\epsilon - 1)tL^{-2} \tag{7}$$

From equation (7) one can express the impedance in ohms per unit spacing length in terms of the known parameters of the cable.

As a specific example, consideration of the well known 0.375 disc insulated coaxial cable yields the following, where:

$D/d = 3.75$

$t = 0.085$ inch

$L = 1.0$ inch

$\epsilon_e = 1.095$

$\epsilon = 2.28$

The solution of equation (7) gives:

$dZ_o/dL = 3.73$ ohms/inch

or expressed in a different way,

$$dZ_o = 3.73 \times dL \text{ ohms} \tag{8}$$

i.e., the change in impedance (dZ_o) equals 3.73 times the change in spacing (dL) between adjacent discs.

For example, if the spacing of the discs is changed by 5 percent;

then $dL = 0.05$ inch

and $dZ_o = 3.73 \times 0.05$

therefore $dZ_o = 0.1865$ ohms

It can be seen from equation (8) that if the characteristic impedance of a length of cable is high, a reduction in the spacing between the discs will reduce the impedance and alternately, if the impedance is low, an increase in the spacing of the discs will result in an increase in the impedance.

Referring now to FIG. **2**, there is shown a portion of an apparatus for applying discs to a conductor, the complete description of which is given in U. S. Pat. No. 3,634,606 issued Jan. 11, 1972 entitled "Method of and Apparatus for Applying Insulating Discs to Conductors." There, the disc applying apparatus is synchronized with the linear speed of the advancing conductor to apply the discs at a uniform and predetermined spacing. The spacing of the discs with such an apparatus may be altered either by increasing or decreasing the speed of the advancing conductor while keeping the speed at which the discs are applied to the conductor constant or, alternately, by increasing or decreasing the note of application of the discs while keeping the linear speed of the conductor constant. While both methods are feasible, we prefer the latter method to maintain constant productive speeds.

As illustrated in FIG. **2**, a pair of disc applicator wheels **18–18'** are mounted on either side of a conductor **12** advancing at a constant velocity V_o. Each of the applicator wheels is provided with a series of retaining teeth **20–20'** mounted in equally spaced relation around the periphery of each wheel which advance slotted discs **16** toward center conductor **12.** Slotted discs **16** may be fed from a suitable feeding device such as is described in the previously referred to in U. S. Pat. No. 3,634,606. The applicator wheels rotate at the same peripheral speed V and are synchronized to place the discs **16** on the conductor **12** alternately from one wheel and then the other.

The apparatus is designed to operate at a nominal speed at which the peripheral speed of the applicator wheels equals the linear speed of conductor **12.** This together with the diameter of the wheels determines the number of retaining teeth **20–20'** to apply discs to conductor **12** at a nominal spacing. For the purpose of the present invention, such apparatus may be provided with a variable speed drive mechanism whereby the speed of the applicator wheels may be varied to alter the spacing of the discs on conductor **12.**

Such an arrangement provides a simple system for adjusting the characteristic impedance of disc insulated coaxial cable and avoids the excessive down-time of the cable making apparatus that was previously required to change components thereof. A first length of cable can be manufactured and tested for its characteristic impedance. In the meantime, production can commence on another length of cable. Once any change in impedance is determined from the first length of cable, a corresponding alteration in disc spacing can be made while the second length is being fabricated simply by adjusting the peripheral speed of the disc applicator wheels.

What is claimed is:

1. A method of controlling the characteristic impedance of a disc insulated coaxial cable comprising the steps of:

a. advancing an elongated conductor past a disc applying station;

b. applying discs to the conductor at said station; and

c. changing the rate of application of discs relative to the speed of the conductor in response to a variation in cable impedance while the conductor is being advanced past said station to change the spacing between successive discs on the conductor from one uniform spacing to a different uniform spacing.

2. A method as defined in claim **1** further including the steps of:

detecting a change in impedance from a predetermined value on a completed length of cable;

determining the change in uniform spacing between successive discs required to restore the impedance to said predetermined value; and

changing the rate of applying the discs to the conductor of a successive cable length to achieve said required uniform spacing while said conductor is being advanced past said station.

3. A method as defined in claim **2** wherein the relationship between the impedance and disc spacing is determined from the formula:

$$dZ_o/dL = 69 \log_{10} (D/d) \cdot \epsilon_e^{-3/2} (\epsilon - 1) t L^{-2}$$

where dZ_o = change in impedance

and dL = change in spacing between discs

and where D, d, ϵ_e, ϵ, t and L are known parameters of a given cable.

4. A method as defined in claim **3** wherein the uniform spacing between successive discs is changed by altering the rate at which the discs are applied to the conductor advancing at a constant linear speed.

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