Oct. 22, 1935. J. F. WENTZ 2,018,477

COAXIAL CONDUCTOR SYSTEM

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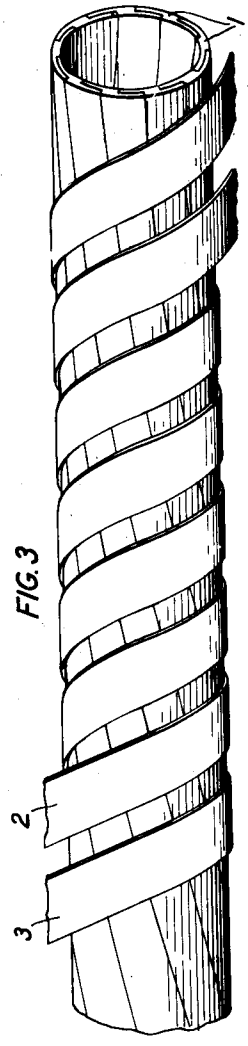

FIG. 3

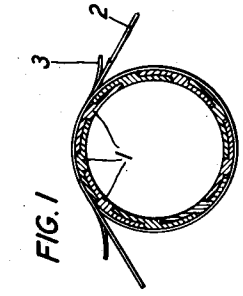

FIG. 1

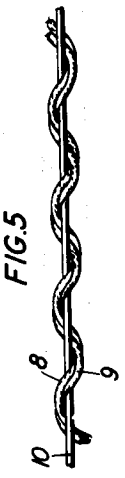

FIG. 5

FIG. 6

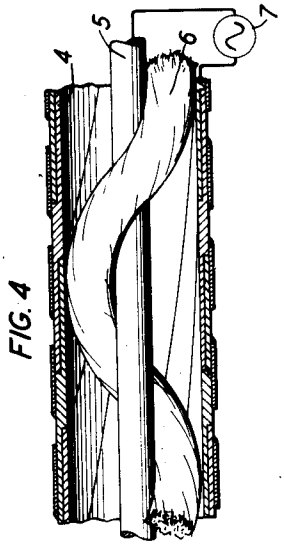

FIG. 4

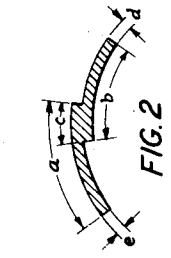

FIG. 2

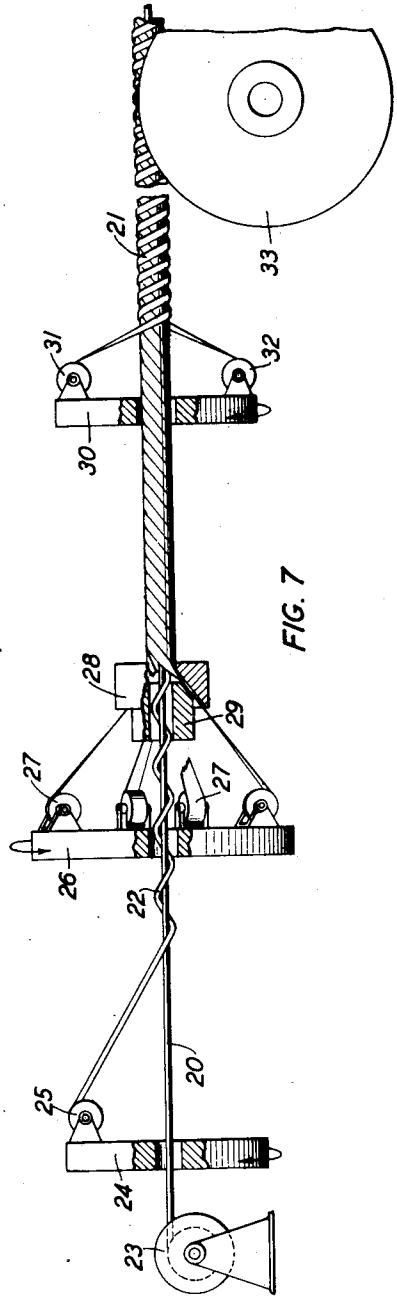

FIG. 7

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COAXIAL CONDUCTOR SYSTEM

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4 Claims. (Cl. 173—265)

This invention relates to hollow conductors and to the manufacture thereof, and more particularly to the design and manufacture of coaxial conductor cables.

For the purpose of high frequency electrical signaling there have been proposed signaling cables comprising one or more coaxial pairs. A cable of this type is disclosed, for example, in U. S. Patents 1,978,418 and 1,978,419, issued on October 30, 1934 to H. W. Dudley. The hollow outer conductors of the coaxial pairs are self-supporting. Not only must they possess sufficient mechanical strength to resist crushing, but also it is necessary that they be flexible enough to withstand the bending to which they are subjected in the processes of manufacture and installation.

In accordance with the present invention there is provided a flexible hollow conductor comprising a plurality of profiled strips which are arranged to engage one another and which are held to a tubular shape by means of an external binding member.

The electrical and mechanical characteristics which a tubular conductor must have to make it suitable for use in a coaxial conductor system of the type referred to, are not readily obtainable by the use of profiled strips. In the first place, the space between the central conductor and tubular conductor is essentially gaseous, only so much solid material being interposed as is necessary to maintain the central conductor in position. The use of internal supporting elements for a collapsible composite structure therefore is necessarily restricted. The thinness of the tubular conductor introduces another difficulty. Flexibility, as well as economy, dictates that the wall thickness be of the order of only twenty or thirty thousandths of an inch. Diameters may be as small as a quarter of an inch. With these dimensions it is difficult, if not impossible, to produce a rugged, self-supporting conductor by the use of ordinary interlocking profiled strips. A third restriction is imposed on the length of lay of the strips. Where the strips are interlocked against relative radial movement, as in a tongue-and-groove construction, added strength may be obtained by spiralling the strips with a short lay. A short lay, although it improves the mechanical characteristics, increases the effective resistance of the tubular conductor and introduces an undesirable circular component of current. For this reason it is almost essential in some cases that the length of lay be at least ten times the internal diameter of the conductor. The detailed description of a construction in accordance with the present invention whereby the foregoing requirements can be met, will appear hereinafter.

A feature of the invention is in the method of fabricating the hollow conductor, and more especially in the method of manufacturing and assembling an insulated coaxial pair. In accordance with this feature the outer conductor of the coaxial pair and the central conductor, together with the insulated structure associated with the latter, are brought together during the fabrication of the hollow conductor, whereby the coaxial assemblage is created by a continuous process.

Another feature of the invention is the machine by which the foregoing method is practised.

Other features of the invention will appear in the following detailed description of a specific embodiment of the invention. Reference will be made to the accompanying drawing, in which:

Figs. 1 and 2 represent, respectively, a cross-sectional view of a hollow conductor in accordance with the invention, and a profile of one of the strips;

Fig. 3 shows an assembled conductor;

Fig. 4 is a longitudinal cross-sectional view of a coaxial conductor assemblage;

Figs. 5 and 6 show alternative means for positioning the central conductor; and

Fig. 7 illustrates a method of fabricating the hollow conductor and a continuous process of assembling a coaxial pair.

Referring now to Fig. 1, there is shown in cross-section a preferred form of conductor in accordance with the present invention which may be used to meet the requirements outlined above. The invention, however, it will be understood, is capable of embodiment in a variety of other and equivalent forms within the scope of the claims appended hereto. The conductor shown comprises a plurality of arcuate strips 1, roughly Z-shaped in profile, arranged in overlapping fashion to form a tube. For purposes of analysis the hollow conductor may be considered as comprising two coaxial tubular layers each made up of a plurality of strips arranged with their edges abutting, each strip being integral with and uniformly overlapping a corresponding strip in the other layer. Binding members 2, 3, wrapped around the assemblage render it self-supporting. It is realized that heretofore hollow conductors comprising non-interlocking strips have been proposed. In these, however, the thickness of the strips was such that the strips, under the influence of external pressure, cooperated as members of an arch to maintain their relative positions. Considering the thinness of the abut-

ting edges of the strips used in the present structure it will be realized that the conductor derives its ruggedness only to a slight degree from such arch action. The strips are so shaped, it will be noted, that a smooth cylindrical surface is presented on the interior of the conductor, a feature that is desirable from an electrical transmission standpoint.

The profile of one of the strips is shown in amplified form in Fig. 2. In a particular instance where the inner diameter of the conductor was 0.318 inch, and the thickness 0.020 inch, ten such strips were used to form the conductor. The total width of each strip was approximately 0.165 inch. The dimension *a* across the face of one of the two stepped segmental portions comprising the strip was 0.100 inch, and the corresponding dimension *b* of the other face was the same. The dimension *c*, indicating the width of the body of the strip, was 0.035 inch. Both portions were of equal thickness, in this particular case dimensions *d* and *e* being both 0.010 inch. It is desirable generally for mechanical strength that the ratio of the width of each segmental portion to its thickness not exceed ten to one. The ratio of conductor circumference to the width of the segmental portion likewise generally need not exceed ten to one.

It will be apparent from the proportions of the profile just described, and specifically from the fact that dimensions *a* and *b* are equal, that while the edges of the inner portions will be forced into abutting relation by the external binding member, the outer portions will be separated from each other by several thousandths of an inch.

Fig. 3 shows an external view of the assembled conductor. The strips 1 are bound tightly by a double wrapping of thin tape 2, 3, which is preferably of metal. Brass and iron, for example, are suitable materials for this purpose. The dimensions of the tape are not critical; brass tape 0.125 inch wide and 0.004 inch thick applied with a lay of 0.50 inch was found satisfactory in one case.

A coaxial conductor system utilizing the conductor shown in Fig. 3 is represented in Fig. 4. The system comprises a hollow outer conductor 4, a central conductor 5, an insulating or separating member 6 and generator 7. The latter may represent a carrier wave telephone system adapted to utilize frequencies of the order of a megacycle per second, as disclosed, for example, in H. W. Dudley Patent 1,978,419, supra. The means used for separating the two conductors may take a variety of forms. The separating member 6 shown in Fig. 4 consists of a tube of insulating material wrapped in a helix about the central conductor. Partially acetylated cotton, washed cotton and crinkled paper have been found to be satisfactory materials. Preferably the helical direction of the insulation is opposite to that of the conducting tape. In one particular case where the inside diameter of the outer conductor was 0.275 inch, a ¾ inch partially acetylated cotton tape was rolled into a tube, twisted and wrapped with a ¾ inch lay about the central conductor.

Other separating means are represented in Figs. 5 and 6. The separator shown in Fig. 5 comprises two threads or strings 8, 9 of suitable material twisted together and applied helically to the central conductor 10. The direction of the twist is opposite to that of the spiral, and the pitch of the latter is slightly less than twice the twisting pitch. The construction is such that the area of contact between separator and the central conductor is small. An analogous principle of construction is employed in the embodiment represented in Fig. 6. Separator 11 shown here comprises a strip or narrow tape of a solid insulating material such as cellulose acetate or other material having great flexibility and toughness. The strip is first twisted, preferably with a lay of approximately five times the diameter of the central conductor 12, and it is then served on the central conductor with an opposite lay of approximately twice the twisting pitch. Only distinct points on the narrow edge of the strip come in contact with the central conductor. Losses due to shunt conductance as a result are unusually low. With all of the separators herein disclosed the softness of the material used and the slight contact made with the outer conductor are such that the separator does not contribute materially in resisting deformation of the conductor, restoring the conductor to its tubular shape, or preventing the component profiled strips from twisting.

The method of manufacturing a tubular conductor in accordance with the present invention will be explained with reference to Fig. 7. This figure shows not only means for fabricating the outer conductor of a coaxial pair, but also means for simultaneously applying the separating member to the central conductor and for assembling the complete structure. Heretofore, in the manufacture of coaxial conductor systems, it was necessary to prepare the outer conductor in relatively short sections, and to draw through each a correspondingly short length of the central conductor-separator assembly. The assembled sections were then united and wound on reels. By the present invention the physical limitations of the prior methods are overcome and it is now possible to manufacture by a continuous process assembled coaxial conductor pairs of any desired length.

The segmental strips comprising the hollow conductor may be given the required profile by drawing, rolling or other suitable process. They are then wound on a plurality of spools 27 carried on the face of the rotatable member 26. From spools 27 the strips pass through a tapering guide 28 and by the cooperation of a corresponding guide member 29 they are brought into the overlapping relation shown in Fig. 1. Any desired amount of lay can be introduced by continuously rotating member 26. The axial tension required for the operation is provided by capstan 33 about which the assembled conductor 21 is passed before it is reeled. The binding tapes are applied under tension to conductor 21 from spools 31 and 32 carried on rotatable member 30 through the center of which the conductor passes.

Simultaneously with the formation of the tubular conductor the central conductor 20 with the separating member 22 wound thereon is fed continuously through the center of rotating member 26 and through the center of guide member 29, the outer conductor in effect being formed about the central assemblage. Preferably the separating member 22 is applied helically to the central conductor 20 as a part of the same process. For this purpose conductor 20 may be fed under tension from drum 23 through the center of a rotatable member 24 on which is carried a spool 25 of the separating material. By adjusting the speed of rotation of member 24 any desired spac-

ing of the turns of the separator may be obtained.

Although the present invention has been described with reference to specific illustrative embodiments of it, it is to be understood that other and widely different embodiments may occur to those skilled in the art within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A radio frequency transmission system comprising a pair of coaxial conductors connected one as the return for the other, the outer of said conductors being a hollow tube made up of a plurality of laterally elongated profiled strips disposed in overlapping relation, each of said strips comprising two integral strip-like portions in different tubular layers laterally offset from each other several times the thickness of one of said portions, the inner of said portions being arranged with their edges abutting to form a smooth, substantially cylindrical inner conducting skin, and an external restricting member adapted to force said abutting portions together to render said conductor self-supporting, the relative angular positions of adjacent strips being maintained principally by radial forces exerted on the outer of said strip portions.

2. A combination in accordance with the claim next preceding in which said integral strip-like portions are offset from each other approximately three times the thickness of said outer conductor.

3. A radio frequency transmission system comprising a pair of coaxial conductors separated by a substantially gaseous dielectric and connected one as the return for the other, the outer of said conductors being a hollow tube made up of a plurality of overlapping, laterally elongated strips each comprising a pair of integral strip-like portions laterally offset from each other in different planes so that one of said strip-like portions enters into the formation of the outer surface of the conductor and the other enters into the formation of the inner surface, said strips being disposed with the edges of the inner portions of adjacent strips abutting to provide a smooth, substantially cylindrical interior surface and with adjacent strips overlapping a distance several times the thickness and about two-thirds the width, respectively, of one of said portions, the internal diameter of said outer conductor being of the order of fifteen times its thickness and roughly three times the width of one of said portions, and an encircling member around said conductor holding said abutting edges in contact with each other.

4. A high frequency transmission system comprising a pair of coaxial conductors connected one as the return for the other, the outer of said conductors being less than thirty mils in thickness and a fraction of an inch in internal diameter, said outer conductor being made up of a plurality of non-interlocking profiled strips each comprising integral, laterally elongated offset portions in different tubular layers, adjacent strips being disposed with respective portions in different layers overlapping a distance of about two-thirds the width of one of said portions and with the edges of the inner portions in abutting relation so as to form a smooth interior surface, and a thin tape of ferromagnetic material wound helically around said outer conductor maintaining said strips in abutting relation and shielding said pair of conductors from electrical interference.

JESSE F. WENTZ.