Jan. 19, 1932. E. I. GREEN 1,841,473

ARRANGEMENT FOR CONNECTING OR TERMINATING COAXIAL CONDUCTORS

Filed Jan. 30, 1930

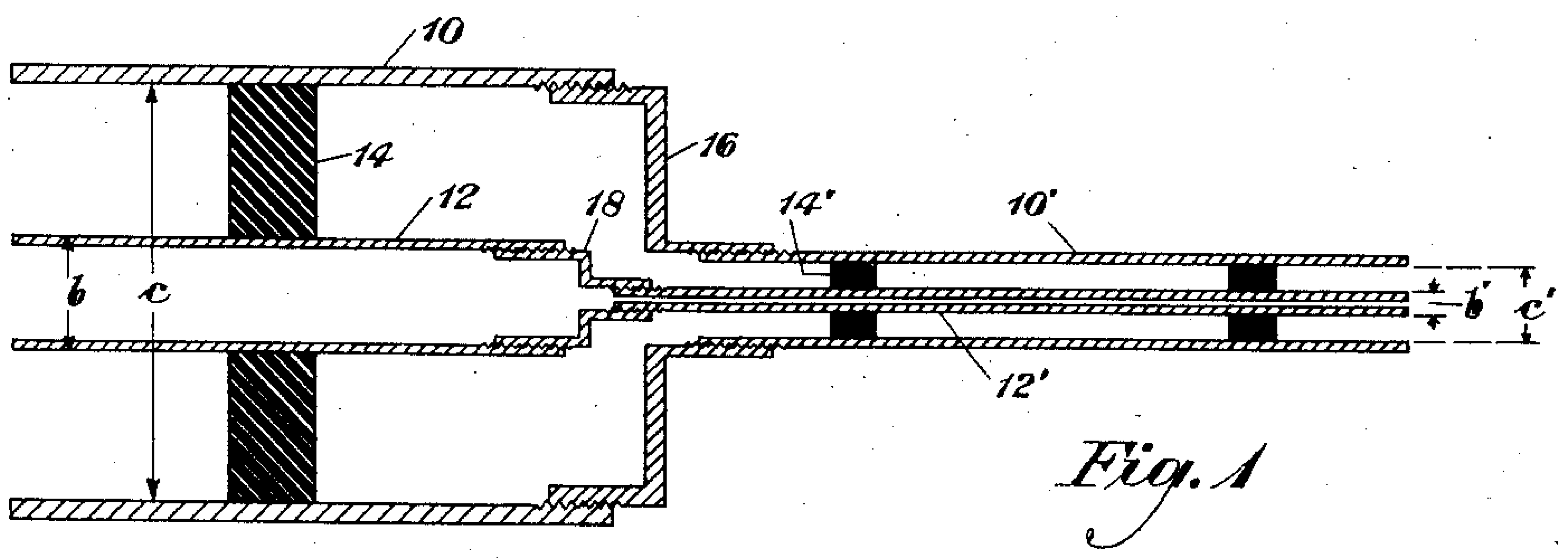

Fig. 1

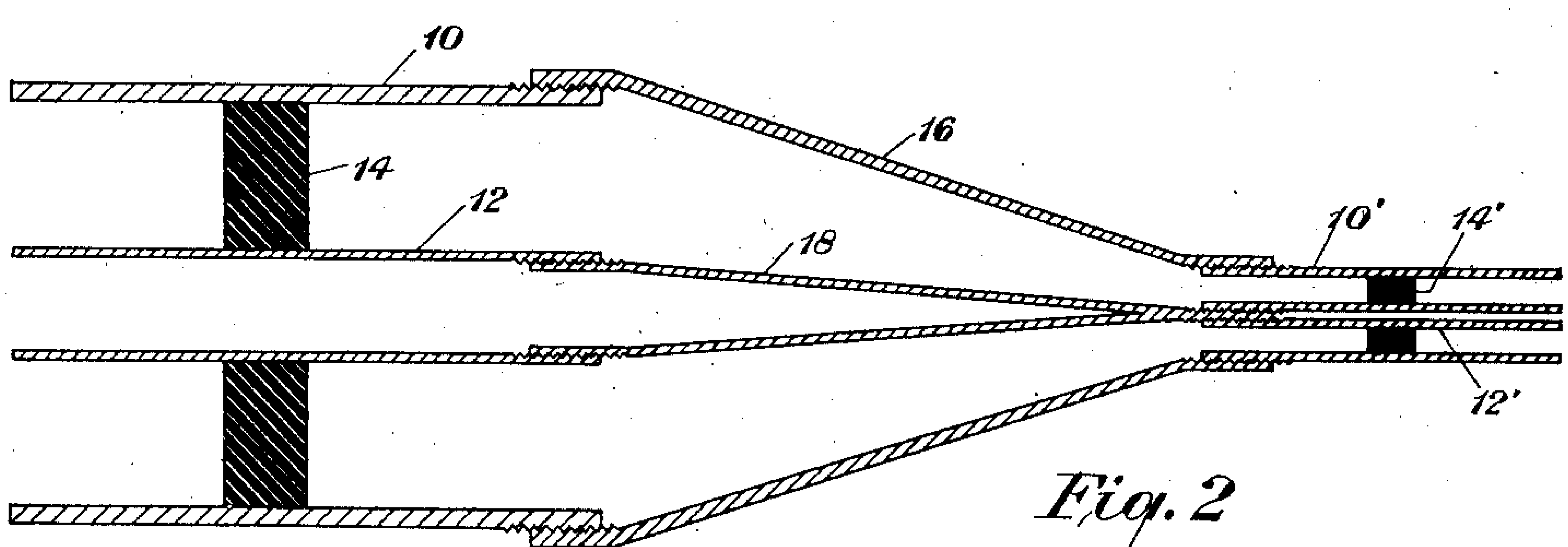

Fig. 2

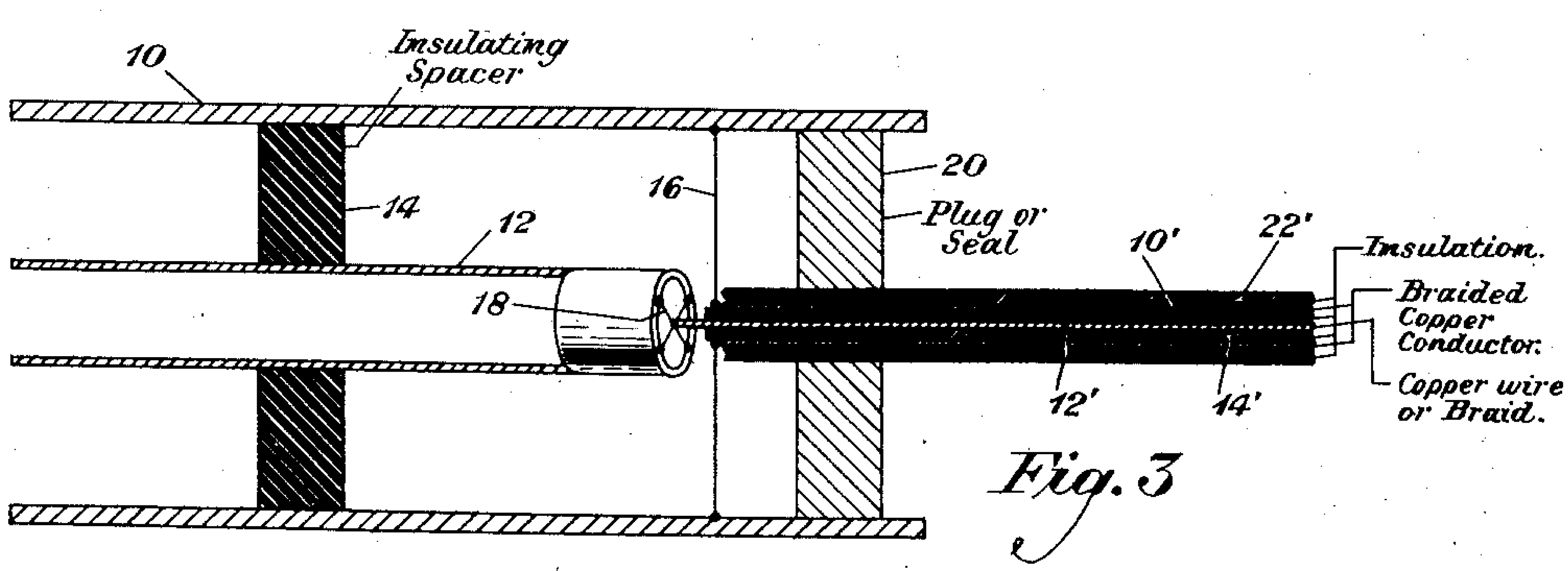

Fig. 3

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UNITED STATES PATENT OFFICE

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ARRANGEMENT FOR CONNECTING OR TERMINATING COAXIAL CONDUCTORS

Application filed January 30, 1930. Serial No. 424,677.

This invention relates to coaxial conductor systems, and more particularly to arrangements for connecting or terminating coaxial conductor systems of different sizes or dimensions without introducing impedance irregularities.

Where it is desired to transmit a wide range of frequencies as, for example, for television purposes or for providing a large number of carrier channels, it is advantageous to use a coaxial conductor system. Such a system may comprise an inner cylindrical conductor surrounded by a concentrically arranged hollow cylindrical conductor acting as a return for the inner conductor, the two conductors being separated preferably by a dielectric which is largely gaseous.

In a system of this type, if the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor is fixed, the attenuation of the conducting system varies inversely with the diameter. It is, therefore, desirable in using such a system to make the main line circuit of as large a diameter as is economically and physically practicable in order that a low attenuation may be obtained. Occasions will frequently arise, however, in which it is desirable to use a part of the system a conductor arrangement of smaller diameter than that employed for the normal line construction. Under these conditions it is extremely advantageous to be able to match the impedance of the two coaxial circuits, thereby eliminating reflection effects. It is one of the purposes of the present invention to provide arrangements whereby this result may be attained.

The invention will now be more fully understood from the following description, when read in connection with the accompanying drawings, Figures 1, 2 and 3 of which illustrate different arrangements for interconnecting coaxial conductor systems of different types and dimensions.

Let us consider concentric conductor arrangements comprising an inner cylindrical conductor having an outer diameter b surrounded by a coaxial outer cylindrical conductor having an inner diameter c, the two conductors being maintained in proper concentric relation and out of electrical contact with each other by means of spaced dielectric washers or the like, preferably of small loss angle and low dielectric constant, so that the dielectric between the two conductors will be principally of air. Ordinarily in the design of such a system the diameter of the outer conductor will be determined by physical conditions and may be treated as fixed. The attenuation of the system for a given inner diameter of the outer conductor will then vary with different outer diameters of the inner conductor. By analogy to formula (55), page 109, of "Calculation of alternating current problems", by L. Cohen, the capacity of the structure herein considered will have the value.

$$C=\frac{0.0894}{\log \frac{c}{b}} K\times 10^{-6} \text{ farads per mile} \quad (1)$$

in which K is the dielectric constant of the insulation between the conductors. Likewise from formula (56) on page 72 of the Cohen publication the high frequency inductance in abhenries per centimeter has the value

$$L=2\log\frac{c}{b} \quad (2)$$

Reducing this to henries per mile we have

$$L=\frac{2\times 1.60935\times 10^{5}}{10^{9}}\log\frac{c}{b}= .32187\times 10^{-3}\log\frac{c}{b} \quad (3)$$

The high frequency impedance of the coaxial circuit is

$$Z_o=\sqrt{\frac{L}{C}} \quad (4)$$

Substituting the values given by Equations (1) and (3) in Equation (4) we have

$$Z_o=\sqrt{\frac{L}{C}}=\sqrt{\frac{.32187\times 10^{-3}}{.0894\times K\times 10^{-6}}}\times \log\frac{c}{b} \quad (5)$$

which reduces to

$$Z_o=60\times\frac{1}{\sqrt{K}}\times\log_e\frac{c}{b} \quad (6)$$

From Equation (6) it is evident that the impedance at high frequencies is determined by the ratios of the diameters of the conductors for any given insulating material.

Now in an application of E. I. Green, Serial No. 365,518, filed May 23, 1929, entitled "Concentric conductor transmission system", it is shown that when the size of the outer conductor is fixed the attenuation will be a minimum when the ratio

$$\frac{c}{b}$$

is equal to about 3.6. Using this ratio and assuming that air insulation is used between the conductors so that K becomes unity, the impedance Z_0 will be equal to about 77 ohms regardless of the size of the conductors. This condition will not be materially changed by the fact that thin and widely spaced washers of dielectric material of low dielectric constant are employed in the system.

In accordance with the present invention advantage is taken of this discovery that the impedance of the system is fixed by the ratio

$$\frac{c}{b}$$

for interconnecting concentric conductor sections of different dimensions without introducing impedance irregularities. This is done by so designing the two sections which are to be joined that regardless of their actual diameters the ratio

$$\frac{c}{b}$$

is the same for both where the same dielectric material is employed.

There are various conditions under which a change in diameter in a coaxial system may be necessary or desirable. For ordinary construction the diameter of the outer conductor may be determined by the fact that it must enter the opening of a conduit or pass through the bridle ring of an overhead cable system. When entering an office, however, a concentric conductor system of smaller diameter may be very useful. In fact a flexible coaxial construction, perhaps provided with solid insulation between conductors, might be desirable. Also, for long spans over rivers a conductor of large diameter might be disadvantageous and a concentric conductor section of smaller diameter could be employed. For short submarine stretches under rivers, a form of construction somewhat different from that normally employed would be necessary. Smaller conductors, probably stranded, and separated by solid insulation would doubtless be required in this instance. For certain types of duct constructions in cities or towns it might be necessary to introduce a concentric conductor section of smaller diameter. And finally, for emergency construction where a portion of the regular conductor system is out of order, a flexible form of construction would be desirable for use in bridging around the line sections under repair.

In any of the foregoing cases a perfect impedance match at high frequencies can be obtained by using a proper diameter ratio for the two circuits which are to be joined. If air insulation is employed between conductors in both circuits or if the same solid insulation is employed in both circuits, the diameter ratios will be the same for both. The use of solid insulation between the conductors of one circuit and air insulation for the connecting circuit would necessitate different diameter ratios for the two circuits. The correct diameter ratio when using solid insulation of dielectric constant K for one circuit and air insulation for the other would be

$$\frac{c'}{b'}=\left[\frac{c}{b}\right]^{\sqrt{K}} \quad (7)$$

where

$$\frac{c'}{b'}$$

is the diameter ratio for the circuit employing the solid insulation, and

$$\frac{c}{b} \quad (6)$$

is the diameter ratio for the circuit with air insulation. When the insulating medium is not uniform, the value of K should be the weighted average dielectric constant for the different insulating materials employed. When different types of solid insulation are employed for the two circuits the correct diameter ratios are given by the expression:

$$\left(\frac{c_1}{b_1}\right)^{\sqrt{K_2}}=\left(\frac{c_2}{b_2}\right)^{\sqrt{K_1}} \quad (8)$$

where

$$\frac{c_1}{b_1}$$

is the diameter ratio for the circuit employing insulation of the dielectric constant K_1, and

$$\frac{c_2}{b_2}$$

is the diameter ratio for the circuit with insulation of dielectric constant K_2.

Various mechanical arrangements may be employed for interconnecting the two sections of concentric conductor of different diameters, the essential feature being that the diameter ratios are determined in accordance with Equation (7). One such arrangement is shown in Fig. 1. Here a large inner conductor 12 is surrounded by a large concentric outer conductor 10, the two conductors being separated by spaced dielectric washers 14. The concentric system thus formed is to be connected to a similar concentric system of smaller conductors comprising an inner conductor 12′ surrounded by an outer conductor 10′, these two conductors being separated by spaced insulating washers 14′. Assuming that the diameter ratios are properly determined in accordance with Equation (7), the physical connections between the two sections may be made by employing unions 16 and 18 of shouldered construction, each union having its flanges secured to the corresponding conductors as shown.

Instead of employing shouldered flanges as in Fig. 1, the flanges may be tapered as illustrated in Fig. 2.

Fig. 3 shows an arrangement which may be employed where a concentric conductor system employing substantially air dielectric is connected to a conducting system in which the insulation between the conductors is of solid material. For example, the latter conductor system is shown as comprising an inner conductor 12′ surrounded by a braided copper conductor 10′ which is insulated from the inner conductor by a solid mass of insulation 14′. Also the outer conductor may be covered by some solid insulating material such as 22′. The outer dielectric does not affect the impedance of the conducting system, however, as the current, due to the skin-effect, flows in the inner surface of the outer conductor and the outer surface of the inner conductor and there is substantially no electric or magnetic field extending into the space surrounding the outer conductor. To effect the junction the system comprising conductors 10 and 12 may have the end of the smaller cable 10′—12′ inserted in the opening of the conductor 10 and sealed thereto by means of a terminal plug or seal 20. The inner conductor 12′ is then tied to the inner conductor 12 by means of wires 18, and the outer conductor 10′ is connected to the outer conductor 10 by means of wires 16. Here again the design of the conductor system 10′—12′—14′ may be readily determined from formula (7), assuming that K is the dielectric constant of the insulating material of the smaller conductor system while the dielectric constant of the space between the conductors 10 and 12 is not materially different from that of air.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a transmission system, two concentric conductor sections each comprising inner and outer cylindrical conductors coaxially arranged, the outer conductors of the sections being of different diameters but said sections being so designed as to have substantially the same characteristic impedance, and means for interconnecting said sections.

2. In a transmission system, two concentric conductor sections each comprising inner and outer cylindrical conductors coaxially arranged, the outer conductors of the sections being of different diameters but the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor of the one section being so related to the corresponding ratio for the other section that each section has substantially the same characteristic impedance, and means for interconnecting said sections.

3. In a transmission system, two concentric conductor sections each comprising inner and outer cylindrical conductors coaxially arranged, the outer conductors of the sections being of different diameters but the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor being substantially the same for both sections, and means for interconnecting said sections.

4. In a transmission system, two concentric conductor sections each comprising inner and outer cylindrical conductors coaxially arranged, the outer conductors of the sections being of different diameters, the conductors of one section being separated by a substantially gaseous dielectric and the conductors of the other section being separated by insulation having a dielectric constant different from that of air, the diameters of the conductors of the two sections being related by the formula

$$\frac{c'}{b'}=\left[\frac{c}{b}\right]^{\sqrt{K}}$$

when c is the inner diameter of the outer conductor and b the outer diameter of the inner conductor of one section, c' and b' are the corresponding dimensions of the other section, and K is the dielectric constant of the insulation of the second section.

In testimony whereof, I have signed my name to this specification this 29th day of January, 1930.

ESTILL I. GREEN.