Sept. 3, 1946. W. F. FELL 2,406,945

INSULATOR FOR CONCENTRIC TRANSMISSION LINES

Filed Feb. 16, 1943

Fig. 1.

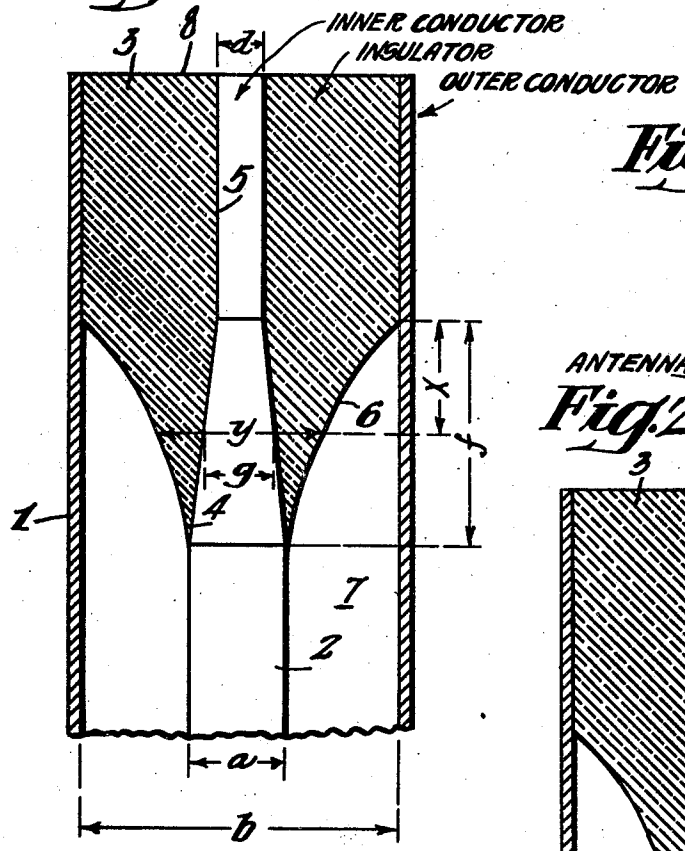


Fig. 5.

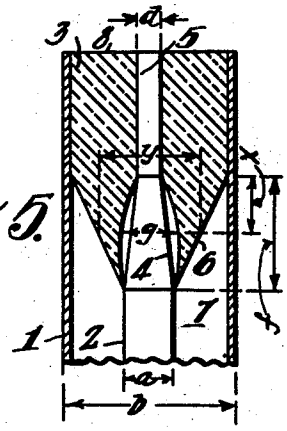


Fig. 2.

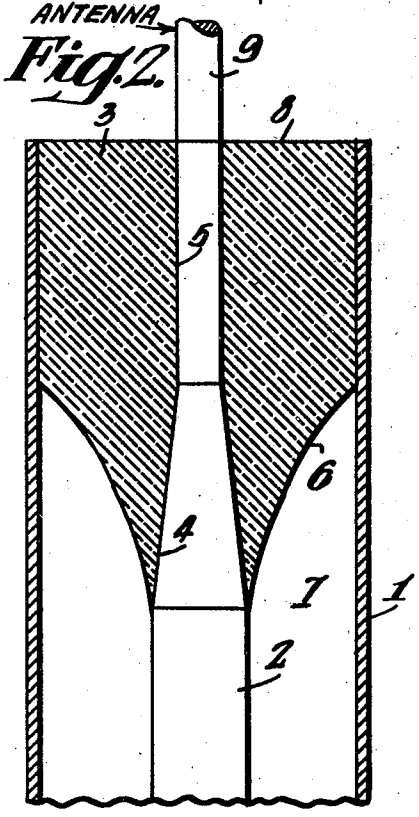


Fig. 4.

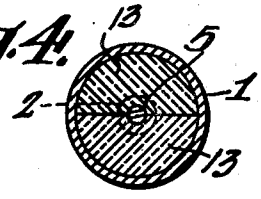
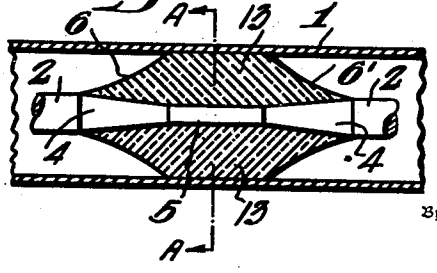


Fig. 3.



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INSULATOR FOR CONCENTRIC TRANSMISSION LINES

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10 Claims. (Cl. 178—44)

1

This invention relates generally to high frequency concentric transmission lines and more particularly to an improved transmission line insulator which provides substantially constant surge impedance throughout the length of the transmission line.

In the use of concentric transmission lines, it is desirable that necessary insulators introduce no discontinuity which would provide changes in the line surge impedance which would result in undesirable reflections on the line. It is well known that the introduction of a sharply discontinuous insulator, of relatively high dielectric constant material, in a line which otherwise employs an air dielectric between the concentric conductors, will provide such undesirable reflections due to the sudden change in surge impedance in the insulator. It is the purpose of the instant invention to provide an insulator which is so shaped that the surge impedance at any point in the insulator is the same as the surge impedance at any other point on the line which has an air dielectric. This condition may be accomplished by gradually reducing the diameter of the inner conductor of the transmission line where it passes through the insulator, thus increasing the inductance per unit length of line to compensate for the increase in capacitance provided by the relatively high dielectric constant of the insulator. It is important that the diameter of the inner conductor be gradually decreased in order to prevent sharp discontinuity therein which would also provide a sharp change in surge impedance. Therefore, the inner conductor is provided with a gradual linear taper which corresponds to a similarly tapered aperture in the insulator whereby the insulator structure snugly fits the inner transmission line conductor. The outer surface of the insulator is provided with a gradual non-linear concave taper to provide a gradual transition from the air dielectric to the insulating material. The precise method of calculating the non-linear taper will be described in detail hereinafter.

It should be understood that insulators designed according to the instant invention may be employed at regular intervals along a conventional coaxial transmission line for the purpose of separating the conductors thereof, or they may be employed as terminating insulators at the ends of such a transmission line. One highly useful application of such a terminating insulator would be for the purpose of supporting an antenna connected to one end of the transmission line inner conductor. Obviously, the particular methods of

2

inserting such an insulator into a transmission line may be accomplished in various ways. The particular forms to be described hereinafter are for the purpose of illustration only, and are not intended to limit the scope of the instant invention.

Among the objects of the invention are to provide a new and improved high frequency concentric transmission line which includes novel insulating separators which provide substantially constant surge impedance throughout the length of the line. Another object is to provide an improved insulator for a high frequency concentric transmission line. A further object is to provide an improved terminating insulator for a high frequency concentric transmission line which will introduce substantially no discontinuity therein and therefore provides substantially constant surge impedance on an otherwise uniform transmission line. Another object is to provide an improved terminating insulator for a high frequency concentric transmission line which will provide a support for an energy radiating conductor connected to the inner conductor of the concentric line. A still further object of the invention is to provide a split cylindraceous insulator for a high frequency concentric transmission line for the purpose of separating the inner and outer conductors thereof.

The information will be described in detail by reference to the accompanying drawing of which Figure 1 is a cross-sectional view of one embodiment of the invention; Figure 2 is a cross-sectional view of a second embodiment of the invention; Figure 3 is a cross-sectional view of a third embodiment of the invention; Figure 4 is a cross-sectional view at the section AA of Figure 3, and Figure 5 is a cross-sectional view of a modification of the invention. Similar reference numerals are applied to similar elements throughout the drawing.

Referring to Figure 1 a high frequency concentric transmission line, shown in cross-section, comprises an outer cylindrical conductor 1 having an inside diameter *b* and an inner conductor 2 having an outside diameter *a*. The outer and inner conductors 1 and 2, respectively, are disposed coaxially and supported in fixed relation to each other by an insulator 3. The inner conductor 2 is provided with a gradually linear tapered portion 4 which terminates in a second cylindrical portion 5 having a smaller diameter *d*. The insulator 3 is provided with an aperture which snugly fits the tapered and small diameter portions of the inner conductor 2. The outer

surface of the insulator **3** is of substantially the same diameter as the inside diameter b of the outer conductor **1** throughout the length of the small diameter portion **5** of the inner conductor **2**. The outer surface of the insulator **3** forms a non-linear concave tapered surface **6** in the region adjacent the linearly tapered portion **4** of the inner conductor **2**, thereby providing a gradual transition from the air dielectric **7** which normally separates the conductors **1** and **2**. In the particular embodiment disclosed, the other end of the insulator **3** presents a plane surface **8** which coincides with the extremities of the conductors **1** and **2**.

The length f of the linear tapered portion of the insulator **3** should preferably be at least five times the normal diameter a of the inner conductor **2**. The diameter d of the reduced portion of the inner conductor **2** will depend upon the dielectric constant of the insulator **3**. For the purpose of determining the precise curvature of the non-linear tapered surface **6** of the insulator **3**, we may consider a given point on the surface **6** to have an outside diameter y at a distance x along the transmission line axis from the end of the tapered surface. At this point the inner diameter of the insulator may be represented by g.

If we assume that the taper length f is relatively large in comparison to the normal diameter of the inner conductor **2** such as, for example, five times the diameter of the inner conductor, then

$$Z_0=\sqrt{L/C} \tag{1}$$

where Z_0 is the surge impedance of the transmission line and C is the capacitance per unit length of line, and L is the inductance per unit length of line. Then

$$L=\left[2\log_e\frac{b}{a}\times 10^{-9}\right)\text{ henrys/cm.} \tag{2}$$

where a is the outer diameter of the inner conductor and b is the inner diameter of the outer conductor of the line, and

$$C=\frac{K}{\left(18\log_e\frac{b}{a}\right)\times(10^{11})}\text{ farads/cm.} \tag{3}$$

where K is the dielectric constant of the insulator material.

In the region where the insulator fills only part of the transmission line, the capacity can be considered to be composed of two capacitors in series, one with air dielectric, and the other with the insulating material as a dielectric. Therefore, the total capacitance will be

$$C=\frac{\left[\frac{1}{(18\log_e b/y)10^{11}}\right]\left[\frac{K}{(18\log_e y/g)10^{11}}\right]}{\frac{1}{(18\log_e b/y)10^{11}}+\frac{K}{(18\log_e y/g)10^{11}}} \tag{4}$$

and

$$Z_0=\sqrt{\frac{(2\log_e b/g)(10^{-9})}{\left[\frac{1}{(18\log_e b/y)10^{11}}\right]\left[\frac{K}{(18\log_e y/g)10^{11}}\right]}{\frac{1}{(18\log_e b/y)10^{11}}+\frac{K}{(18\log_e y/g)10^{11}}}} \tag{5}$$

From the above equation,

$$y=\sqrt[K-1]{\frac{b^K}{g(e)^{\frac{Z_0^2K}{3600\log_e b/g}}}} \tag{6}$$

In the section of the line containing only insulation

$$Z_0=\sqrt{\frac{(2\log_e b/d)(10^{-9})}{\frac{K}{(18\log_e b/d)(10^{11})}}} \tag{7}$$

where

$$d=\frac{b}{e^{\frac{Z_0\sqrt{K}}{60}}} \tag{8}$$

which will be a constant for any given line and insulating material. From the geometry of the device

$$g=d+\frac{x(a-d)}{f} \tag{9}$$

Therefore g may be substituted in Formula 6 to determine the corresponding values of y with respect to x.

Referring to Figure 2, a similar transmission line including an outer cylindrical conductor **1** and inner conductor **2**, which is shaped in the same manner as that described in Figure 1, includes an insulator **3** which also is of the same shape as described in Figure 1. The small diameter portion **5** of the inner conductor **2** terminates in a coaxial conductor **9** such as an antenna. The insulator **3** is therefore utilized for the dual purpose of separating the inner and outer conductors **2** and **1**, respectively, and supporting the antenna **9**.

Figures 3 and 4 are separate views of a transmission line comprising a cylindrical conductor **1** and an inner conductor **2** which has a portion **5** of reduced diameter and two tapered portions **4**, **4'** connecting the cylindrical portions thereof. An insulator **13** includes two inside linearly tapered portions adapted to fit the linear tapered portions **4**, **4'** of the inner conductor, and two outside non-linear concave tapered portions **6** and **6'** which each have a conformation of the type described in detail in Figure 1. The insulator **13** may be directly molded upon the inner conductor **2** and thence inserted in the outer conductor **1**. Another method of assembling the line is to form the insulator **13** in two hemi-cylindraceous portions as indicated in Figure 4. The hemi-cylindraceous portions are then applied to the inner conductor **2** and inserted within the outer conductor **1**.

Figure 5 is a cross-sectional view of a transmission line similar to the devices described in Figs. 1 and 2 with the exception that the insulator surface g has a non-linear taper while the insulator surface y has a linear taper. In this modification Equation 6 would be solved for g instead of y, and the following equation would be substituted for Equation 9:

$$y=b-\frac{(b-a)x}{f} \tag{10}$$

Thus the invention described comprises a new and improved insulator for separating the conductors of a high frequency concentric transmission line wherein the conformation of the insulator provides substantially uniform surge impedance throughout the length of the transmission line.

I claim as my invention:

1. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor having regions of varying diameters coaxial therewith, insulating means interposed between pre-

determined varying diameter regions of said conductors, said insulating means and said inner conductor having complementary conformations to provide substantially constant surge impedance along said line.

2. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor coaxial therewith, said inner conductor having a cylindrical region of reduced diameter and a linearly tapered region connecting said cylindrical regions, cylindraceous insulating means interposed between said conductors adjacent said tapered region and said region of reduced diameter of said inner conductor, said insulating means having a non-linear concave tapered portion extending from the junction of said inner cylindrical conductor and said linearly tapered region to said outer conductor in the region of said linearly tapered region of said inner conductor.

3. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor coaxial therewith, said inner conductor having a cylindrical region of reduced diameter and a linearly tapered region connecting said cylindrical regions, cylindraceous insulating means interposed between said conductors in contact with said tapered region and said region of reduced diameter of said inner conductor, said insulating means having a non-linear concave tapered portion extending from the junction of said inner cylindrical conductor and said linearly tapered region to said outer conductor in the region of said linearly tapered region of said inner conductor.

4. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor coaxial therewith, said inner conductor having a cylindrical region of reduced diameter and linearly tapered regions connecting said cylindrical regions, cylindraceous insulating means interposed between said conductors adjacent said tapered regions and said region of reduced diameter of said inner conductor, said insulating means having non-linear concave tapered portions extending from the junction of said inner cylindrical conductor and said linearly tapered region to said outer conductor in the regions of said linearly tapered regions of said inner conductor.

5. Apparatus of the type described in claim 2 including conductive means extending said inner conductor beyond the extremities of said outer conductor to form energy radiating means.

6. Apparatus of the type described in claim 2 including conductive means extending said inner conductor beyond the extremities of said outer conductor and said insulating means to form energy radiating means.

7. Apparatus of the type described in claim 1 characterized in that one extremity of said insulating means coincides with one extremity of said outer conductor to provide a terminating insulating member therefor.

8. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor coaxial therewith, said inner conductor having a cylindrical region of reduced diameter and linearly tapered regions connecting said cylindrical regions, a pair of hemi-cylindraceous insulating means interposed between said conductors adjacent said tapered regions and said region of reduced diameter of said inner conductor, said insulating means having non-linear concave tapered portions extending from the junction of said inner cylindrical conductor and said linearly tapered region to said outer conductor in the regions of said linearly tapered regions of said inner conductor.

9. Apparatus of the type described in claim 2 characterized in that the conformation of said non-linearly tapered portion of said insulating means bears to the inner and outer conductors the relation

$$y=\sqrt[K-1]{\frac{b^K}{g(e)^{\frac{Z_0^2 K}{3600 \log_e b/g}}}}$$

where y is the outside diameter, and g is the inside diameter of said insulator, b is the inside diameter of said outer conductor, K is the dielectric constant of said insulator, e is the natural logarithmic base, and Z_0 is the line surge impedance.

10. In a concentric high frequency transmission line comprising an outer cylindrical conductor and an inner cylindrical conductor coaxial therewith, said inner conductor having a cylindrical region of reduced diameter and a linearly tapered region connecting said cylindrical regions, cylindraceous insulating means interposed between said conductors in contact with both of said conductors in said region of reduced diameter of said inner conductor, said insulating means having a linearly tapered portion extending from said inner to said outer conductor and a non-linear concave tapered surface adjacent said linearly tapered region of said inner conductor.

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