

June 18, 1957

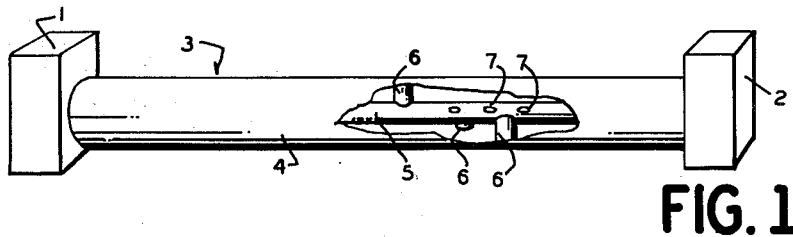
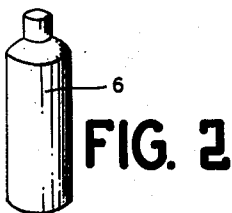
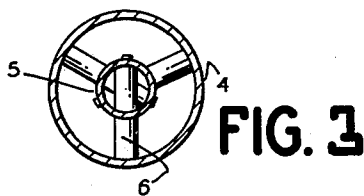
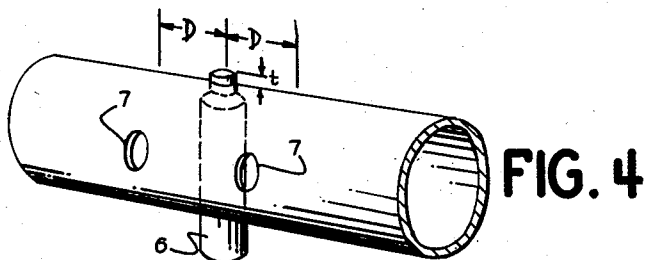
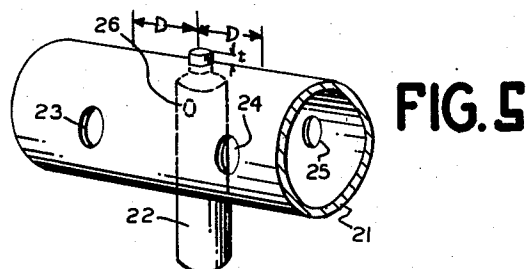
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2,796,589

COAXIAL TRANSMISSION LINE FOR SUPER HIGH FREQUENCIES

Filed Oct. 23, 1952

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

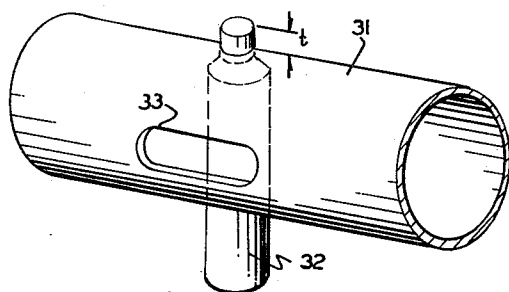


FIG. 6

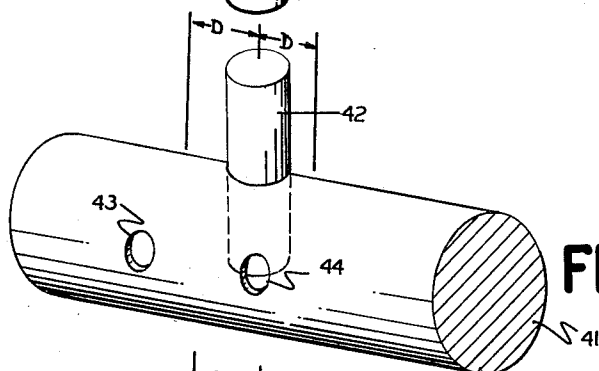


FIG. 7

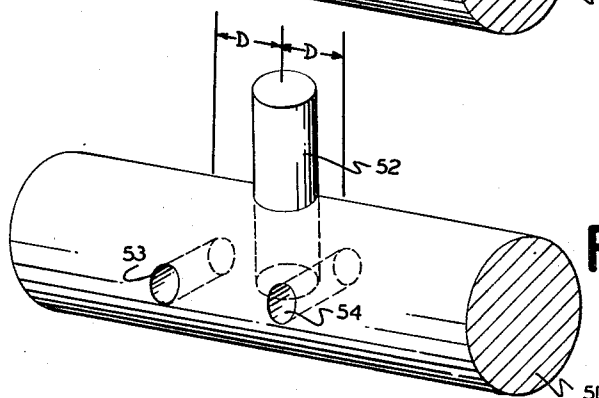


FIG. 8

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COAXIAL TRANSMISSION LINE FOR SUPER HIGH FREQUENCIES

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Application October 23, 1952, Serial No. 316,510

6 Claims. (Cl. 333—96)

This invention relates to transmission lines used to transmit electrical power at high frequencies and more particularly to coaxial transmission lines for use in transmitting microwaves.

An object of this invention is to provide a simple coaxial transmission line which will transmit microwaves substantially without reflection.

Another object of this invention is a coaxial transmission line substantially reflectionless not only at microwave frequencies, but also at lower frequencies.

For many years coaxial transmission lines have been used to transmit high frequency power from a translating device to antenna or vice versa. Such lines usually consist of an outer conductor with a tubular inner conductor supported by disc-like insulating beads in the tubular outer conductor. When the frequency of the power which is transmitted through the coaxial line is relatively low so that there are ten or more beads per wavelength, there is little reflection. When the frequency is increased until there are, say, two or fewer beads per wavelength, the reflection due to beads substantially increases and in some applications become intolerable. This is particularly true when the frequency is above 1000 megacycles for example, 3000 megacycles.

Such reflections of beads can be reduced by undercutting the inner conductor under each bead or by using dielectric pins in place of beads, but none of these methods result in a really reflectionless line. Even when an uninterrupted solid dielectric sleeve is used to fill the space between inner and outer conductors, a reflectionless line is usually not achieved because it is very difficult to make a long, really uniform, dielectric cylinder.

In accordance with the present invention, the inner conductor is supported by dielectric pins but contrary to practice of the prior art, the disturbing effect of each pin is compensated by simply drilling one or more holes or by making depressions of proper size through or in the inner conductor in the immediate neighborhood of each pin.

The invention applies to symmetric coaxial conductors and to eccentric and unsymmetric coaxial conductors whether fully closed or only partially closed.

The above described, and further objects and advantages of this invention and the manner of attaining them, will be more fully explained in the following description taken in conjunction with the accompanying drawings in which:

Figure 1 shows a perspective view of the invention with parts broken away to show the interior.

Figure 2 shows a perspective view of a detail.

Figure 3 shows a section through the coaxial line.

Figure 4 shows a perspective view partly broken away of the inner conductor and a pin.

Figure 5 shows a modification of Figure 4 and Figures 6 and 7 and 8 show further modifications of the arrangement shown in Figure 4.

Referring more particularly to Figure 1, 1 is a source of high frequency power, connected to load 2 through

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coaxial transmission line 3. Coaxial line 3 comprises metal tubular outer conductor 4, metal tubular inner conductor 5 supported by dielectric pins such as pin 6. The waves traveling along the transmission line are partially reflected by dielectric pins such as 6. While each pin causes a relatively small reflection the cumulative effect of a large number of such pins, however, can be so large as to cause improper operation of the source of microwave power; for example, frequency jumping of a magnetron. My measurements show that the reflection of a dielectric pin can be reduced to a negligible value by drilling two holes such as 7 through one wall of the tubular inner conductor. The distance D between the center of hole 7 and the plane perpendicular to the inner conductor and passing through the center of pin 6 should be less than a quarter wave of the highest frequency to be transmitted and preferably small in comparison with this quarter wavelength. The size of the holes is also important. When holes are too small they do not completely compensate for the reflection of the pins. On the contrary, holes which are too large over-compensate for the effect of the pins. The correct size of the holes depends on the thickness of the pins, the dielectric constant of the material of which the pins are made, and on the sizes of the inner and outer conductors.

The following method was used to determine the proper sizes of the compensating holes. Forty pins were installed in a test inner conductor at equal intervals. The spacing was so chosen that it would become a half wavelength at a convenient frequency around 3000 megacycles. The line was terminated into a load which was very accurately matched to the characteristic impedance of the line. This was verified by observing the absence of standing waves along the portion of the line adjacent to the load. The latter portion of the line was deliberately left free of pins. The standing waves observed near the generator end of the line was then due to the effect of the pins. As the frequency was varied, it was found that there is a frequency, F, at which the reflection is a maximum. The frequency is quite critical and is near the frequency at which the pins are spaced just a half wavelength apart. At frequency F the effects of the individual pins add up and the total effect is much easier to measure than the relatively very small effect of one pin.

Then small holes such as 7 were added on each side of each pin. When this was done, the reflection as frequency F decreased, but the critical frequency F at which maximum effect was observed did not change appreciably. The holes were then enlarged in steps and the measurement repeated. With a certain hole size the reflection became so small that it was difficult to measure. Frequency was then varied over a wide range but the reflections remained very small and no peaks of reflection were observed. The holes were then made still larger. The reflection reappeared and near the critical frequency F.

The actual dimensions of the conductors, pins and the compensating holes resulting in least reflection in these tests are given in Table 1 below:

Table 1

Inner diameter of outer conductor.....inches..	1.026
Outer diameter of inner conductor.....do.....	.437
Inner diameter of inner conductor.....do.....	.375
Diameter, <i>a</i> , of dielectric pins.....do.....	.187
Small diameter, <i>b</i> , of pins.....do.....	.125
Dielectric constant of pins.....do.....	2.30
Diameter of compensating holes.....do.....	.156
Longitudinal distance, D, between center of pin and center of compensating hole.....inches..	.125
Distance, <i>t</i> , in Figure 4.....do.....	.03
General arrangement as in Figure 1.	
Characteristic impedance of the line.....ohms...	.51

The material for the pins in the above example was a Polychlorotrifluoroethylene sold under the trade-name "Kel-F" by the M. W. Kellogg Company of Jersey City, New Jersey, but pins of other materials such as "Teflon" (polytetrafluoroethylene) which has a slightly lower dielectric value may be used. Where pins of lower dielectric values are used the holes may be a little smaller or the area of the holes a little less.

With regard to the spacing D, the shorter this distance the better for higher frequencies. Reflections commence at the pins and may be compensated immediately adjacent the pins. I have found that the spacing D should be less than

$$\frac{\lambda}{8}$$

in most cases and preferably less than

$$\frac{\lambda}{16}$$

where λ corresponds to the wave length of the highest frequency in the band. Angles of 10° to 20° have been successfully used.

The end of the pin projecting through the inner conductor, that is the distance t (Figure 4) should be small and in fact the end may be flush with the outer surface of the inner conductor.

Compensation of the extra capacitance of the supporting dielectric pins may be accomplished by drilling four holes instead of two holes in the vicinity of the pin, as shown in Figure 5. In this figure 21 is the tubular inner conductor, 22 is the dielectric pin, and 23, 24, 25 and 26 are four compensating holes. The four holes need not be of the same size, for the only requirement is that the additive effects of the four holes be just sufficient to offset the extra capacitance of the dielectric pin.

It is also possible to achieve satisfactory compensation by using only two holes on opposite sides of the inner conductor, for example holes 23 and 25. It is preferable that the holes drilled on the generator side of the pin be equal in size and be similarly arranged to the holes on the load side of the pin, but the two groups of holes need not be on the same side of the inner conductor.

The effect of the dielectric pin can also be compensated by the means of a single hole. It is found, however, that such a single hole turns out to be rather large and if round tends to substantially weaken the inner conductor. A single slot rather than a single round hole results in a somewhat stronger inner conductor. Such a slot arrangement is shown in Figure 6 in which 31 is tubular inner conductor, 32 is the dielectric pin, and 33 is the compensating slot.

In Figure 7 is shown another embodiment of this invention. In this figure 41 is the inner conductor which is a solid bar. The dielectric pin 42 is inserted into a hole in bar 41. The compensating holes 43 and 44 are drilled part way through the inner conductor.

In Figure 8 is shown still another arrangement in which 51 is a solid inner conductor, 52 is the dielectric pin, and 53, 54 are compensating depressions in the inner conductor.

While round compensating holes or round depressions are usually easier to make, oblong, rectangular holes or depressions may be employed instead. Also, in place of depressions, one may use notches part way around or all the way around the inner conductor.

It is to be noted that there are a number of modifications by which the present invention may be carried out. In essence the inner conductor is supported from the outer conductor by a series of spaced pins producing wave reflections which are particularly objectionable. These wave reflections are reduced to a minimum and made substantially zero by making depressions or holes on either side of the pins which are sufficiently large

to cancel out or make these reflections a minimum. Not only may the shape, size, number and position of the holes vary with the size of the pin, dielectric constant and other elements but the depth of the holes may also vary, so that it is not possible to assign special shapes, dimensions and distances to these depressions on either sides of the pins other than as set forth above. However, for a particular line at its operating frequency, the best compensation is readily determined as explained above.

Having now described my invention I claim:

1. A coaxial transmission line for high frequency waves comprising an outer conductor, a hollow inner conductor means supporting the inner conductor within the outer conductor including spaced dielectric pins of a diameter substantially less than

$$\frac{\lambda}{4}$$

20 wave length of the transmitted wave frequency and including means for reducing wave reflections comprising means forming holes through the inner conductor on either side of the position of the pins providing corrective reactance opposing that introduced by the pins in the transmission line whereby reflection of waves travelling along the line is substantially reduced.

2. A coaxial transmission line as in claim 1 in which a hole is formed through the inner conductor on each side of a pin, said holes being spaced from said pin a distance not more than

$$\frac{\lambda}{8}$$

35 as measured from the center of the hole to a plane passing through the axis of the pin normal to the axis of the inner conductor, λ corresponding to the highest frequency in the transmission band.

3. A coaxial transmission line as in claim 1 in which the inner conductor has holes on opposite sides of the conductor, length-wise on the conductor on either side of the pin.

4. A coaxial transmission line as in claim 1 in which said holes in said inner conductor are on both sides of the pins, one set on one side of the conductor and another set on the opposite side of the conductor.

5. A coaxial transmission line for high frequency waves comprising an outer conductor, a hollow inner conductor means supporting the inner conductor within the outer conductor including spaced dielectric pins of a diameter substantially less than

$$\frac{\lambda}{4}$$

55 wave length of the transmitted wave frequency and including means for reducing wave reflections comprising means forming elongated slots in said inner conductor extending on both sides of the pins a distance measured on the surface of said inner conductor from a plane normal to said inner conductor passing through the axis of the pins not greater than

$$\frac{\lambda}{8}$$

70 where λ corresponds to the highest frequency in the operating band thereby providing corrective reactance opposing that introduced by the pins in the transmission line whereby reflection of waves travelling along the line is substantially reduced.

6. A coaxial transmission line as in claim 1 wherein the holes in said inner conductor are no more than 10° to 20° away from the adjacent pin as measured on the basis of $\lambda=360$ where λ is a wave length corresponding to the highest frequency in the operating band.

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