

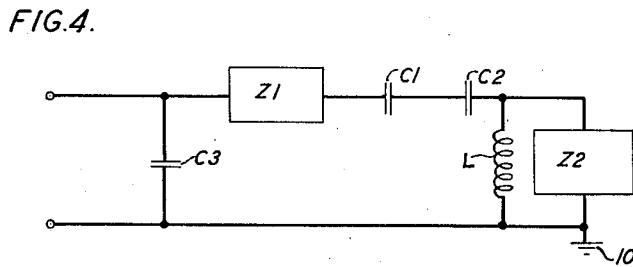
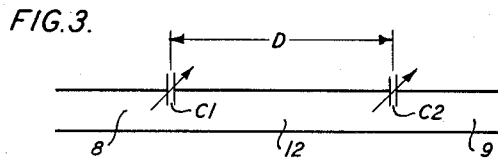
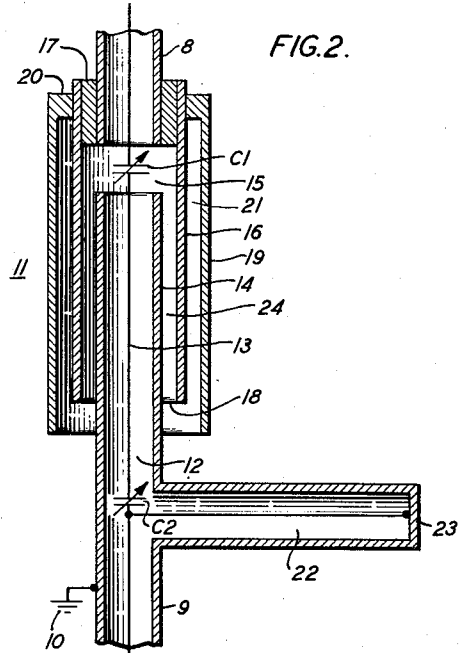
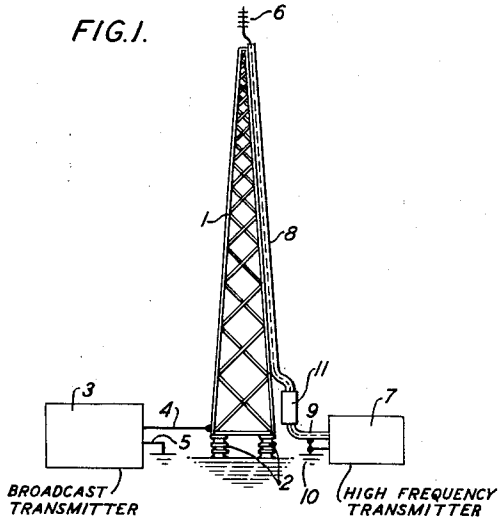
July 11, 1950

P. H. SMITH
RADIO FREQUENCY FILTER

2,515,061

Filed Dec. 27, 1946

2 Sheets-Sheet 1



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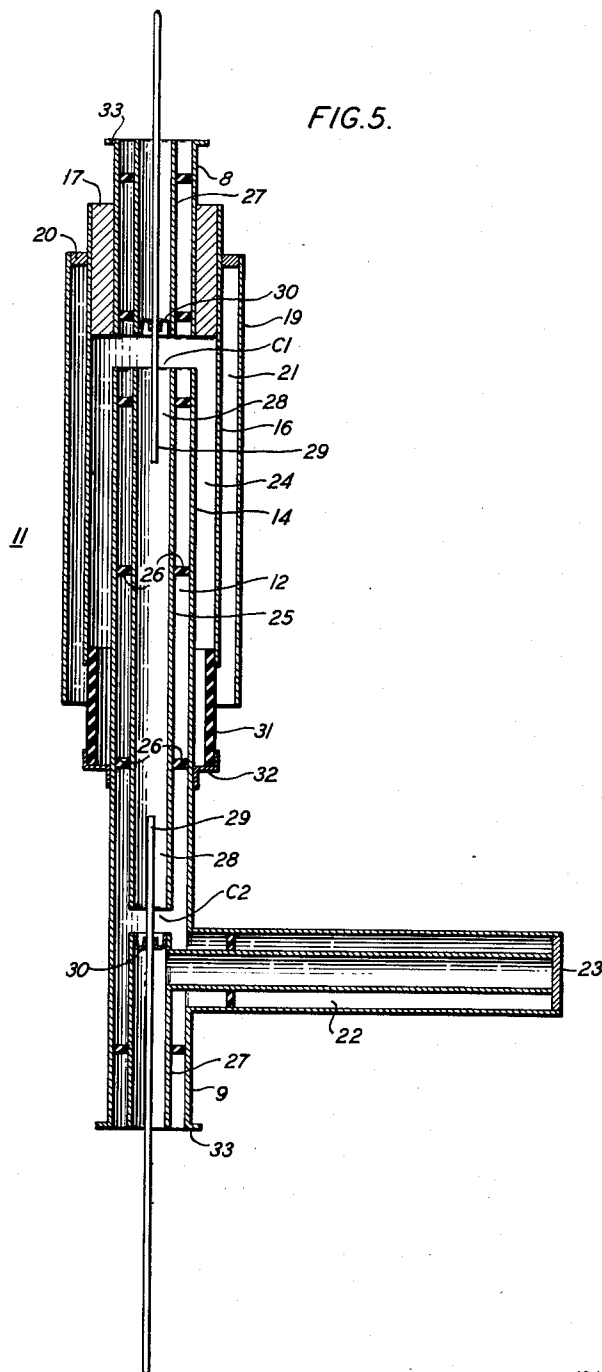
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RADIO FREQUENCY FILTER

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2,515,061

RADIO-FREQUENCY FILTER

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Application December 27, 1946, Serial No. 718,642

9 Claims. (Cl. 178-44)

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This invention relates to wave transmission and more particularly to wave filters.

An object of the invention is to couple a grounded coaxial transmission line to an ungrounded coaxial transmission line.

Another object is to transmit freely a desired band of frequencies from one to the other of such coupled lines while suppressing undesired frequencies.

A further object is to prevent the escape of energy when two such transmission lines are coupled together.

In high frequency transmission systems it is sometimes required to connect a grounded coaxial transmission line to an ungrounded transducer, which may be another coaxial line. For example, a coaxial line may be used to connect a high frequency transmitter to an antenna mounted on top of a series-fed, base-insulated standard broadcast tower radiator. As the outer conductor of this line is normally grounded a transmission network of special type must be inserted in the line at the point where it crosses the base insulator, to prevent grounding the tower and thereby disabling its use as a vertical antenna. Such a tower-base bridging filter must appear as practically an open circuit in the standard broadcast range but must freely transmit, without radiation, a sufficiently wide band of frequencies in the high frequency range.

In accordance with one embodiment of the invention a filter suitable for this purpose comprises a section of coaxial transmission line, two capacitors connected in series with the inner conductor and spaced preferably less than a half wavelength at a frequency to be passed, a circumferential gap in the outer conductor, and a quarter-wave coaxial skirt connected at one end to one side of and encircling the gap. At its inner end the skirt presents a very low impedance at the frequency to be passed. When the capacitors have the proper values the filter will pass a sufficiently wide high frequency band and substantially match the line impedances at each end. The capacitors are preferably made variable and each may comprise a coaxial rod inserted into the end of the hollow inner conductor of the coaxial section. To prevent the escape of energy at the open end of the skirt a second similar skirt may be connected to the connected end of the first skirt so as to encircle it. This second skirt may be made adjustable axially for precise tuning. However, the filter is substantially an open circuit at the standard broadcast frequencies which may be associated with the

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tower and the ungrounded portion of the line. To provide additional suppression for the energy in this latter range, a short-circuited quarter-wave stub line may be shunted across one end of the filter.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, in which like reference characters refer to similar or corresponding parts and in which:

Fig. 1 shows an antenna system employing a tower-base bridging filter in accordance with the invention;

Fig. 2 is a vertical sectional view, partly schematic, of one embodiment of the filter;

Fig. 3 shows the equivalent filter circuit at a transmitted frequency;

Fig. 4 is the equivalent circuit at a suppressed frequency; and

Fig. 5 is a vertical sectional view of the filter showing certain of the features in greater detail.

In Fig. 1 a tower 1 of conventional design mounted at its base on insulators 2 provides a vertical antenna insulated from ground. The tower 1 is series-fed from a broadcast transmitter 3 one output lead 4 of which is connected near the base and the other 5 of which is grounded.

On top of the tower 1 is mounted a high frequency antenna 6 which is fed from a high frequency transmitter 7 through a coaxial transmission line. The portion 8 of the transmission line which runs up the tower 1 must be insulated from ground so that the tower will function properly as a vertical radiator for the transmitter 3. However, the portion 9 of the coaxial line extending from the tower 1 to the transmitter 7 will ordinarily have its outer conductor grounded, as shown at 10. Therefore, in accordance with the invention, a tower-base bridging filter 11 of special design is inserted between the grounded portion 9 and the ungrounded portion 8 of the coaxial feed line.

The transmitter 3 may, for example, be of the amplitude modulation type having a frequency f_1 falling within the standard broadcast range of 550 to 1600 kilocycles while the transmitter 7 employs frequency modulation at a frequency f_2 within the range from 88 to 108 megacycles.

As shown somewhat schematically in Fig. 2, one embodiment of the filter 11 comprises a section of coaxial transmission line 12 having two capacitors C1 and C2, preferably variable, connected in series with its inner conductor 13. The capacitors C1 and C2 are spaced apart a dis-

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tance D preferably less than half a wavelength at the frequency f_2 to be transmitted. The outer conductor 14 of the coaxial section 12 has a circumferential gap 15, preferably opposite the capacitor C_1 . A conductive coaxial skirt 16 having a length approximately equal to a quarter wavelength at the frequency f_2 encircles the gap 15 and is connected at one end to a side thereof through the conductive annular member 17, but is left open at the opposite end 18. A second similar coaxial skirt 19 of approximately the same length but of larger diameter is connected to the connected end of the first skirt 16, as shown at 20, so as to encircle the first skirt. The outer skirt 19 is preferably made so that it can be moved axially along the skirt 16 for adjustment of the effective length of the coaxial line section 21 formed therebetween. A section of coaxial line 22 short-circuited at its outer end 23 and having a length approximately equal to a quarter wavelength at the frequency f_2 is connected in shunt at one end of the line section 12, preferably near the capacitor C_2 at the end connected to the grounded portion 9 of the feed line.

The operation of the filter 11 will now be explained in connection with the circuits of Figs. 3 and 4. As shown in Fig. 3 the equivalent electrical circuit at the transmitted frequency f_2 consists only of the section of line 12 of length D with the series capacitors C_1 and C_2 at its ends. The outer conductor 14 and the sleeve 16 constitute an open quarter-wave line section 24 the impedance of which viewed at the gap 15 is substantially zero. The short-circuited quarter-wave line section 21 is adjusted to provide a substantially infinite series impedance at the open end of the line section 24 and thus prevent the escape of any energy of the frequency f_2 flowing in the section 12. As viewed at the point of connection the stub section 22 has a substantially infinite impedance at the frequency f_2 but a low impedance at the frequency f_1 , and therefore effectively prevents the passage of energy from the broadcast transmitter 3 through the filter 11 to the high frequency transmitter 7.

The proper adjustment of the capacitors C_1 and C_2 will now be considered. A series reactance, such as C_1 , at one point in a uniform, dissipationless transmission line may be adjusted to a value such that the impedance looking into the line at a second point, located a fixed distance D from the first point, is conjugate to the impedance at the first point. Connecting at the second point a second series reactance, such as C_2 , of the same character and magnitude as the first will make the impedance of the combination just equal to the characteristic impedance of the line. That is, the reflection caused by the first reactance is completely cancelled out by the second reactance. The distance D may be any length within wide limits, but to minimize the overall length of the filter, it is preferably made less than a half wave-length at the frequency f_2 to be passed.

When the capacitors C_1 and C_2 are adjusted in the manner explained above, the circuit of Fig. 3 will be effectively equivalent to a smooth section of transmission line, that is, a low-loss one to one transformer having an image impedance at each end equal to the characteristic impedance of the line section 12. The filter will, therefore, transmit a wide band of frequencies including f_2 and will match in impedance the coaxial lines 8 and 9 connected to the ends thereof.

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Fig. 4 shows the equivalent circuit for the filter 11 at the frequency f_1 as viewed at the open end 13 of the line section 24, which is the only point at which energy of this frequency may enter. There is one path from the skirt 16 to the ground 10 through the capacitance C_3 , which represents the capacitance between the skirt 16 and the outer conductor 14. Since this capacitance is comparatively small its reactance will be high. A second path to ground comprises the impedances Z_1 , C_1 , C_2 and Z_2 in series. Z_1 is the impedance looking from the filter 11 into the line section 8 and Z_2 is the impedance looking into the line section 9. The capacitors C_1 and C_2 also have high reactances at the frequency f_1 . It is seen, therefore, that the filter offers a high impedance to ground for energy of the frequency f_1 which is being radiated by the tower 1. In practice this impedance can be made from 10 to 100 times the impedance to ground across the insulators 2. The inductance L in shunt with Z_2 represents the stub line 22. It may have a reactance of an ohm or less at f_1 and thus assists greatly in preventing energy of this frequency from reaching the transmitter 7.

Fig. 5 shows in greater detail the mechanical structure of an embodiment of the filter 11. The skirts 16 and 19 and the stub line 22 are substantially the same as those shown in Fig. 2. The coaxial line section 12, however, has a hollow inner conductor 25 spaced from the outer conductor 14 by the insulating rings 26. Each of the coaxial lines 8 and 9 connected to the ends of the filter 11 also has a hollow inner conductor 27.

Each of the variable capacitors C_1 and C_2 comprises a section of open-circuited coaxial line 28 constituted by the hollow inner conductor 25 and a conductive rod 29 which extends into an end thereof. The other end of the rod 29 extends into the hollow inner conductor 27 and is slidably mounted in a conductive chuck 30. The effective length of the line section 28, and therefore the capacitance, is adjusted by inserting the end of the rod 29 a greater or less distance into the conductor 25. The proper values for the capacitors C_1 and C_2 are most easily found by trial, but they ordinarily will be approximately equal.

A cylinder 31 of insulating material attached at one end to the conductor 14 by means of the annular flanged member 32 and at the other end to the sleeve 16 serves to hold the parts of the filter 11 together and also protects the interior of the filter from the weather. The flanges 33 facilitate the connection of other portions of the coaxial feed line.

The section of line 24 may be of fixed length and is preferably made a quarter wavelength long at the high frequency end of the range over which the filter 11 is to be tunable. Then, at lower frequencies within the range the impedance of the line 24, at the gap 15, will always be capacitive and its reactance will be small in magnitude. This capacitance is in series with C_1 and may be considered to be a part thereof when the gap 15 is opposite the capacitance C_1 , as shown. Therefore, at the lower frequencies C_1 may be slightly increased in value to compensate for the capacitance of the line 24.

The stub line 22 may also be of fixed length and is preferably made a quarter wavelength long at the center of the tunable range of frequencies. Its reactance will change over the range but is almost exactly equivalent to a small series reactance at the same position along

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the line. The effect of this equivalent series reactance may be exactly compensated by an adjustment of C2 provided the stub 22 is connected near the capacitor C2, as shown. This compensation will require the value of C2 to be reduced at the upper end of the range and increased at the lower end.

It is evident that the filter 11 is a weather-proof, gas-tight, non-radiating structure which is relatively low in cost, small in size, light in weight and easy to install, having a sufficiently high impedance at the frequency f_1 but low loss over a wide band centered at the frequency f_2 . Furthermore, for optimum performance at any specified frequency f_2 within a wide range only three elements, the rods 29 and the sleeve 19, require adjustment, which is easily made with the aid of a calibration curve and an ordinary ruler.

What is claimed is:

1. A wave filter for connecting a grounded coaxial transmission line to an ungrounded coaxial transmission line comprising a section of coaxial transmission line, two capacitors connected in series with the inner conductor of said section with a spacing therebetween of less than a half wavelength at a frequency to be passed by said filter, a circumferential gap in the outer conductor of said section approximately opposite one of said capacitors, a conductive coaxial skirt connected at one end to one side of and encircling said gap, and a second similar skirt connected to the connected end of and encircling said first skirt, each of said skirts having a length approximately equal to a quarter wavelength at said frequency and said capacitors being adjusted to provide for said filter image impedances which are substantially equal and each of which is substantially equal to the characteristic impedance of said section of line.

2. A filter in accordance with claim 1 in which said capacitors are variable.

3. A filter in accordance with claim 1 in which

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the inner conductor of said section is hollow and one of said capacitors comprises a conductive rod extending for an adjustable distance into the end of said inner conductor.

4. A filter in accordance with claim 1 which includes a short-circuited section of coaxial transmission line connected in shunt at one end of said filter and having a length approximately equal to a quarter wavelength at said frequency.

5. A filter in accordance with claim 1 which includes a short-circuited section of coaxial transmission line connected in shunt at one end of said filter near the other of said capacitors and having a length approximately equal to a quarter wavelength at said frequency.

6. A filter in accordance with claim 1 in which the inner conductor of said section is hollow and each of said capacitors comprises a conductive rod extending for an adjustable distance into an end of said inner conductor.

7. A filter in accordance with claim 1 in which said capacitors are approximately equal in capacitance.

8. A filter in accordance with claim 1 in which said second skirt is adjustable axially with respect to said first skirt.

9. A filter in accordance with claim 8 in which said capacitors are variable.

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