Sept. 10, 1940. G. H. BROWN 2,214,041

ELECTRICAL NETWORK

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Fig. 1.

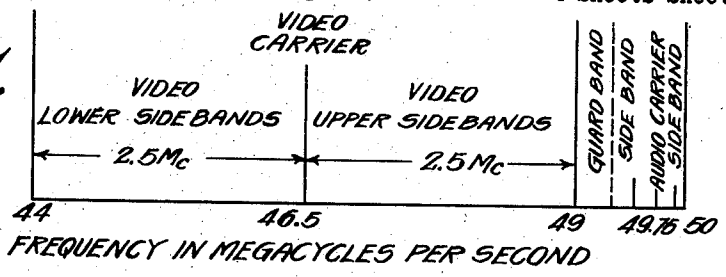


Fig. 2.

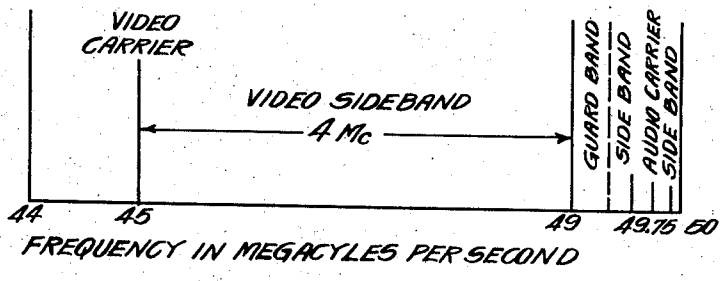
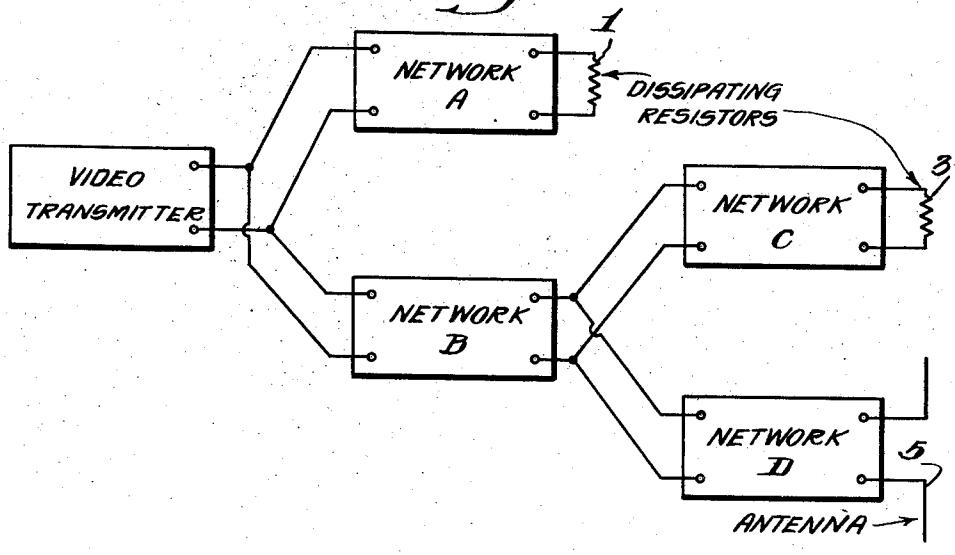


Fig. 3.



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Fig. 4.

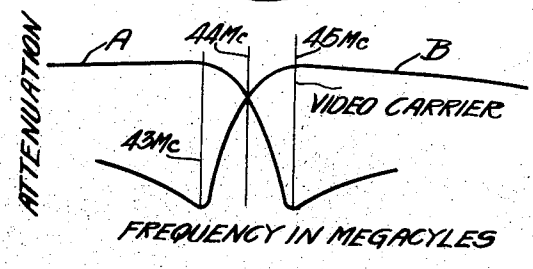


Fig. 5.

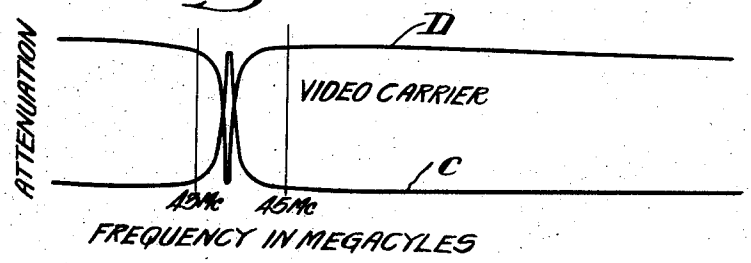
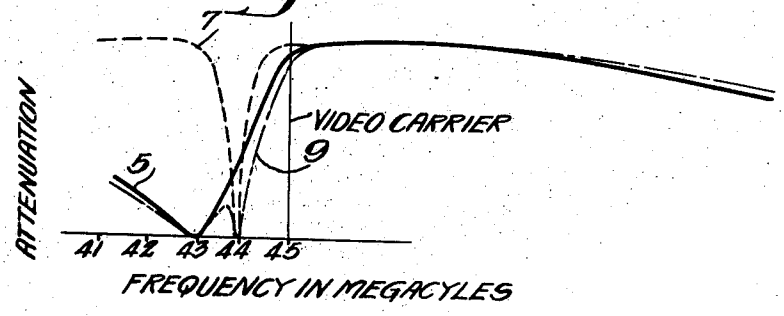


Fig. 6.



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Fig. 1.

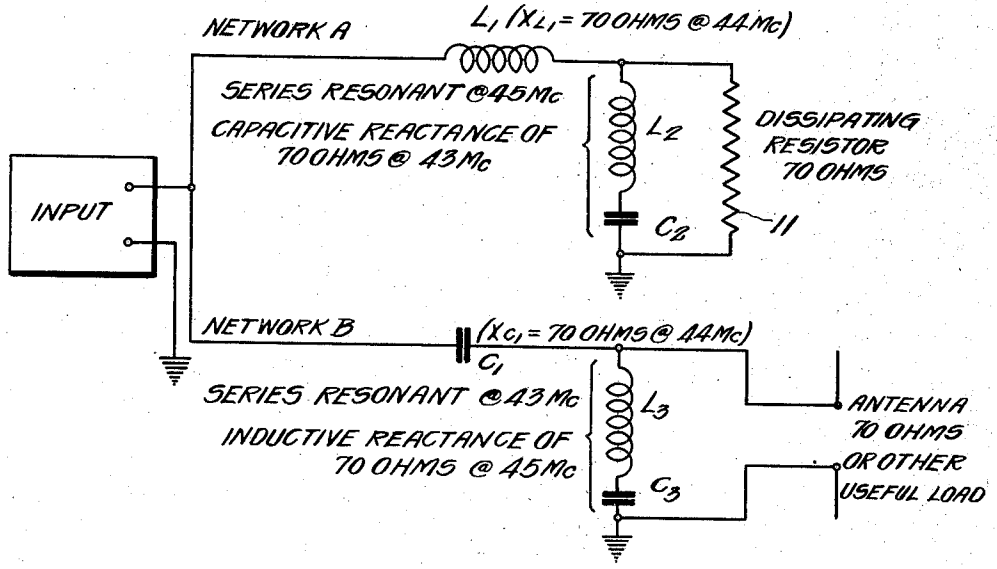
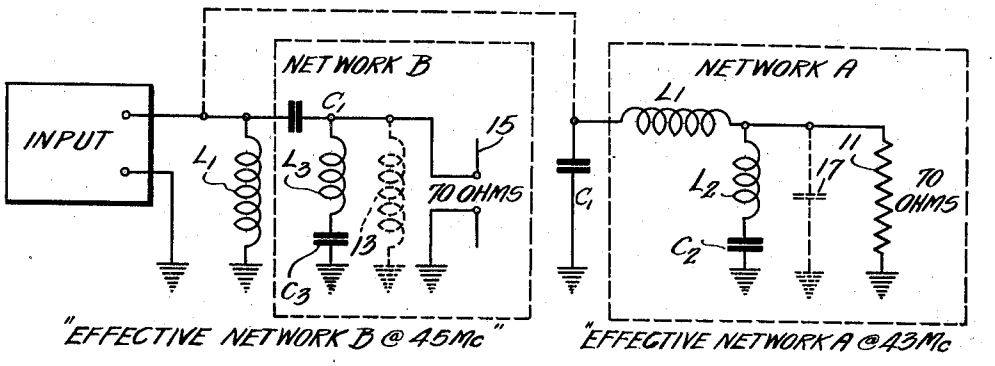


Fig. 8.



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Fig. 9.

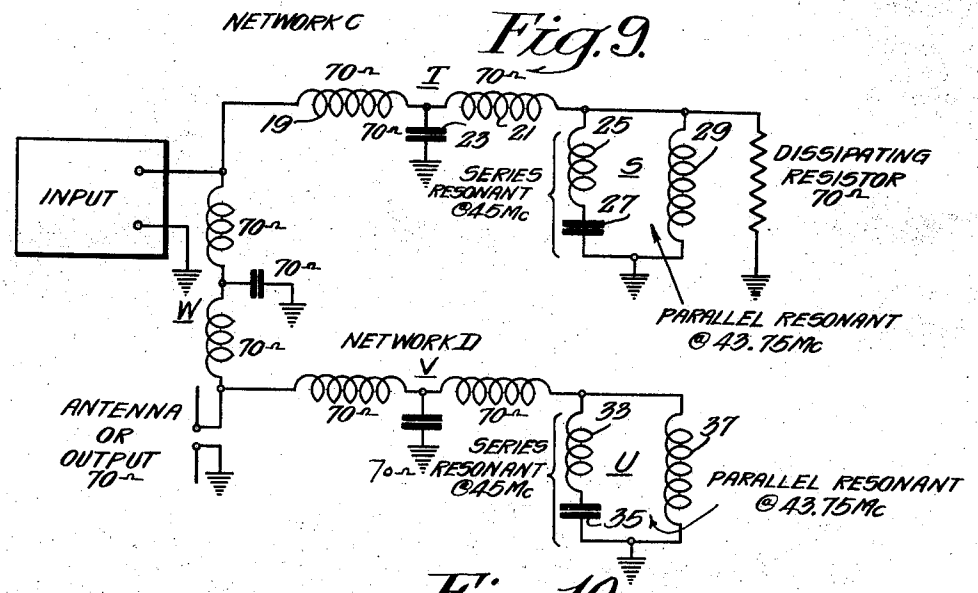
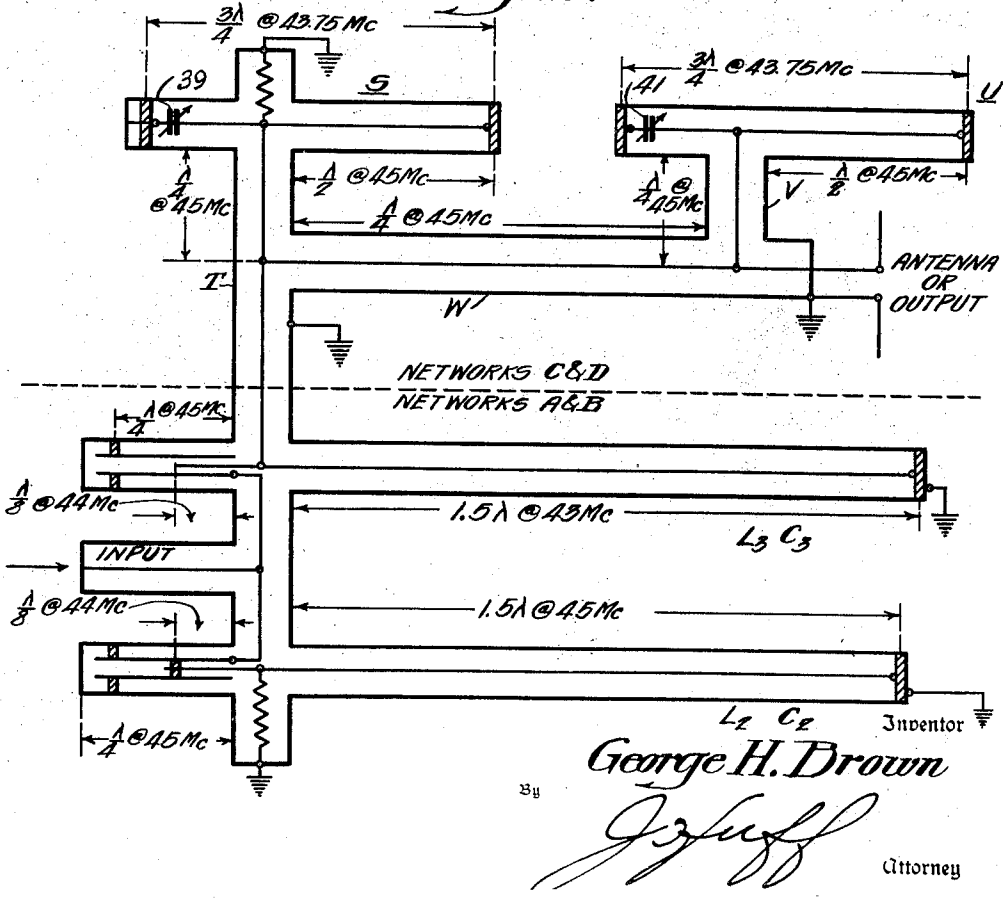


Fig. 10.



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UNITED STATES PATENT OFFICE

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ELECTRICAL NETWORK

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Application August 31, 1938, Serial No. 227,865

5 Claims. (Cl. 178—44)

My invention relates to electrical networks. More specifically, the invention is an electrical network which has a substantially constant resistive and low reactance input circuit over a wide band of frequencies, which attenuates a wide band, and which passes an adjacent wide band.

Although the invention is not to be limited to any particular use, I shall describe its use in conjunction with a television transmitter. A television transmitter which is to provide detail in the transmitted picture must cover a very wide band of frequencies. For example, in a 441-line system, it has been proposed to use 5 megacycles for the video transmission and 1 megacycle for a guard band and an audio band. With a transmitter using both upper and lower side bands, the sideband frequency range of 2.5 megacycles is sufficient to transmit pictures with 441 lines. If more detail (i. e., more lines) is to be transmitted, a wider band of frequencies (e. g., 4 megacycles) must be transmitted. But a frequency band of 4 megacycles on either side of the video carrier would interfere on one hand with the audio channel and on the other with the next assigned communication channel.

One solution would be to increase the band but this is undesirable because it limits the available channels. Another solution would be to filter out one side band and use the entire video channel for the required single side band. The second solution is not without difficulty because electrical filters usually have reactive effects which cause transients. Often the transients account for double images and shadows which mar the picture.

The problem of suppressing one side band of a television transmitter requires that such suppression be effected without establishing transient effects, without substantial attenuation of the transmission band, and without interference with the adjacent channels. Furthermore, in a transmitter of several kilowatts output, the energy in one sideband is of the order of one kilowatt and, therefore, such power must be dissipated. In terms of the electrical network, it should have a resistive input over the operating frequency band, its input reactance should be substantially zero, the cut-off must be sharply defined, and its attenuation low and substantially unity within the transmission band.

It is one of the objects of the invention to provide means for suppressing a wide band of frequencies and transmitting a wide band without causing transient effects within the transmitted band. Another object is to provide means for establishing an electrical network in which the branches are characterized by complementary attenuation characteristics. A further object is to provide an electrical network which may be connected to a television transmitter to suppress one sideband of the video transmission without affecting the picture transmitted by the other sideband. A still further object is to provide means in an electrical network which will have a constant resistive and substantially non-reactive input characteristic over a wide band of frequencies.

The invention will be described by referring to the accompanying drawings in which

Figures 1 and 2 are, respectively, graphic illustrations of a double and single sideband television and audio transmission system;

Figure 3 is a schematic diagram of one embodiment of the system;

Figures 4, 5 and 6 are graphs illustrating the attenuation characteristics of the network;

Figure 7 is a circuit diagram of two portions of the network;

Figure 8 is a circuit diagram for purposes of illustrating the principle of operation;

Figure 9 is a circuit diagram of additional portions of the network; and

Figure 10 is a figure showing a practical embodiment of the network in a concentric line system.

Referring to Fig. 1, a conventional distribution of the video and audio channels of the television system is shown. In the conventional system, the carrier is transmitted, for example, at 46.5 Mc. The abbreviation "Mc," as used herein, stands for "megacycles per second." The lower video side band extends from 46.5 to 44 Mc; the upper video side band extends from 46.5 to 49 Mc. A guard band is included between the upper limit of the upper side band and the lower audio side band. The audio carrier is transmitted at 49.75 Mc and 50 Mc represents the upper limit of the band. It should be understood that other communication channels are assigned above 50 and below 44 Mc. If a wider video band is desired, and the frequency kept within the limits of 44 to 50 Mc, it will be necessary to transmit a single video side band as shown in Fig. 2. In this arrangement of frequencies, the video carrier is transmitted at 45 Mc and extends upwardly 4 Mc. In view of other communication channels below 44 Mc, it is necessary to completely suppress the side band at frequencies below 44 Mc.

In Fig. 3, a video transmitter is connected to a network A which is terminated in a dissipating

resistor 1. The video transmitter is also connected to a second network B which may terminate in an antenna but is preferably connected to a second network C and a third network D. The former, C, is terminated in a dissipating resistor 3 and the latter, D, in a suitable antenna 5. The function of networks C and D will hereinafter be described. If the network B has an attenuation characteristic such as shown in Fig. 4, it will be apparent that the energy at its output will be largely suppressed below 45 Mc and transmitted above 45 Mc. At the same time, the attenuation characteristic of the network A is such as will absorb currents of frequencies below 45 Mc and substantially pass the frequencies above the carrier. In other words the networks A and B have complementary attenuation characteristics. In some installations, this may offer sufficient attenuation to avoid interference with the assigned adjacent lower frequency channel. In other cases, the attenuation will be insufficient and may be made greater by using several similar networks serially arranged.

It is preferable to reduce the possibility of adjacent channel interference by further dissipating currents of the lower side band by using networks C and D. The attenuation characteristic of the networks C and D is shown in Fig. 5. From inspection, it appears that currents of a frequency of 43.75 Mc are substantially attenuated in the network D and, at the same time, are substantially dissipated in the network C. In other words, the networks C and D have complementary attenuation characteristics. The attuation characteristics of the transmission band are indicated in Fig. 6 in which the solid line curve 5 is the characteristic of the output of the network B and the dash line curve 7 is the characteristic of the network D. The resultant characteristic is indicated by the dash-dot line 9. It will be observed that frequencies below 44 Mc are substantially attenuated, while frequencies above the carrier are transmitted with very little attenuation. If further attenuation is desired, two or more of the networks A, B, C, D are suitably connected in series.

The elements of the networks A and B will now be described by reference to Fig. 7. The input to the network A is connected through an inductor L_1 which has a reactance of 70 ohms at 44 Mc. The inductor is connected to ground through a dissipating resistor 11 which has a resistance of 70 ohms. A series circuit, resonant at 45 Mc and comprising inductor L_2 and capacitor C_2, is connected across the dissipating resistor. This series resonant circuit is so designed that it will have a capacitive reactance of 70 ohms at 43 Mc. The network B includes a capacitor C_1 which has a capacity reactance of 70 ohms at 44 Mc. The capacitor C_1 is connected to an antenna which is grounded and which has an input resistance of 70 ohms. In place of the antenna any 70-ohm circuit may be connected, as will hereinafter be described. Across the antenna is connected a series circuit L_3C_3 which is resonant at 43 Mc. The series circuit is so chosen that its inductive reactance at 45 Mc will be 70 ohms.

The operation of the networks A and B will be described by referring to the illustrative diagram of Fig. 8. At 45 Mc, the "Effective network B" may be redrawn to represent a filter which is comprised of the parallel inductor L_1, series capacitor C_1, and shunt circuit L_3C_3, which is an inductive reactance at 45 Mc. The series circuit L_3C_3, may be represented as inductor 13 at this frequency. While the inductor L_1 is ordinarily in the network A, at 45 Mc the series resonant circuit L_2, C_2 is substantially a short circuit and, in effect, connects the inductor L_1 across the network B to thereby form what is termed the "Effective network B at 45 Mc." Likewise L_2, C_2 short circuits the dissipating resistor 11 at 45 Mc. The antenna or output circuit 15 is connected across the filter. It follows that the antenna is matched to the filter and that currents of 45 Mc will be transmitted without attenuation.

At 43 Mc, the "Effective network A" may be represented as a filter having a parallel capacitor C_1, a series inductor L_1 and a parallel circuit L_2C_2. Since the circuit L_2C_2 is in series and is resonant at 45 Mc, it will have a capacitive reactance at 43 Mc and, therefore, may be represented as a capacitor 17. While the capacitor C_1 is ordinarily in the network B, at 43 Mc the series resonant circuit L_3, C_3 is substantially a short circuit and, in effect, connects the capacitor C_1 across the network A to thereby form what is termed the "Effective network A at 43 Mc." Likewise, L_3, C_3 short circuits the antenna or output circuit. The 70 ohm dissipating resistor 11 is connected across the filter. The network A will represent a high impedance input at 45 Mc which will have substantially no effect on the network B at the frequency of 45 Mc. On the other hand, the network B will have a high impedance input for currents of 43 Mc and will, therefore, have substantially no effect on currents of 43 Mc which are dissipated by the resistor 11 in the network A at this frequency. It may be shown that, at all frequencies higher than 45 Mc, the network B will transmit substantially without attenuation and that, at all frequencies below 43 Mc, the network A will dissipate substantially all of the power. At frequencies intermediate 43 and 45 Mc, intermediate results in the way of transmission and attenuation will be obtained, as shown in the curves of Fig. 4.

Since the attenuation at 44 Mc is not very great, I have found it desirable to further attenuate the transmission between the frequencies of 43 and 45 Mc. This is accomplished by using networks of the type illustrated in Fig. 9. In this circuit, the network C includes a filter T which has series inductors 19, 21 and a parallel capacitor 23. The output of the filter T is connected to a series circuit including an inductor 25 and a capacitor 27. The series circuit is resonant at 45 Mc and is shunted by an inductor 29 which, together with the series circuit 25, 27, makes a parallel circuit resonant at 43.75 Mc. The parallel resonant circuit is designated by the reference letter S. The network C is terminated in a dissipating resistor of 70 ohms. The network C is connected to the network D by a filter W, which corresponds to the filter T previously described. The filter W is terminated in the antenna or output circuit 31, which preferably represents an input resistance of 70 ohms. The filter W is connected through a filter V, which is also similar to the filter T previously described. The filter V is terminated in a circuit U which is comprised of a series circuit which includes an inductor and a capacitor 33, 35. The series circuit is resonant at 45 Mc and is shunted by an inductor 37, which makes the circuit U parallel resonant at 43.75 Mc.

The principle of operation of the networks C

and D is as follows: At a frequency of 43.75 Mc, The circuit S is parallel resonant and, therefore, offers a high impedance but, since the circuit is shunted by the 70 ohm dissipating resistor, the output of the filter T will be terminated by 70 ohms resistance. Its input will also represent 70 ohms. The circuit U in the network D at 43.75 Mc will be parallel resonant and will, therefore, represent a high impedance for the termination of the filter V but, since the output of the filter V is terminated in a high impedance at this frequency, its input will represent a very low impedance, and, therefore, this impedance will shunt the antenna circuit and thereby attenuate currents in the antenna. The shunting effect in the antenna circuit will also provide filter W with a low impedance output, which will be reflected as a high impedance at the input terminals of the filter W, and, therefore, the network D will have no deleterious effect on the network C.

At a frequency of 45 Mc, the series circuit **25**, **27** of circuit S will be resonant and therefore will be effectively a short circuit. The short circuit condition in the output of the filter T will appear as a high impedance in the input and therefore currents of 45 Mc will not pass through the filter to the dissipating resistor. Considering the output of the filter V, the series resonant circuit **33**, **35** will be substantially a short circuit at 45 Mc. Such short circuit at the output of the filter V will appear as a high impedance at its input. The high impedance at the input of the filter V will have no effect on the antenna or output circuit **31**, and therefore the antenna or carrier currents will not be attenuated at 45 Mc. Since the filter W is interposed between the antenna **31** which has an input resistance of 70 ohms, the load on the transmitter will likewise appear as 70 ohms.

In the practical application of my invention to a television system having a video carrier operating at 45 Mc, I have found that circuits utilizing lumped elements are difficult to adjust and that concentric-line elements are better adapted at the frequency in question. By way of example, I have found that a concentric line whose outer conductor has an inside diameter of 4½ inches and whose inner conductor has an outside diameter of 1¼" is particularly adapted because it represents an impedance of 70 ohms, which is suitable.

One embodiment of the invention, in a concentric line system, is represented in Fig. 10. The networks A and B are represented in the lower portion of the figure and the networks C and D are represented in the upper portion. Inasmuch as the corresponding elements of the concentric line are identified by the same reference numerals or letters as are used in Figs. 7 and 9, no detailed description is required. It should be understood that the drawing does not represent the actual lengths of the concentric lines. The effective lengths of the lines are indicated in terms of wave lengths. In the actual adjustment of the concentric lines, I find it desirable to have short-circuiting plug which may be adjusted within the line. One suitable form of such short-circuiting device is described in the copending application Serial No. 227,795, filed August 31, 1938, in the name of Lester John Wolf. The adjustable short-circuiting members are indicated in Fig. 10 by cross-section lines.

In practice, a vacuum tube voltmeter is capacitively coupled to the inner conductor through apertures in the outer conductor and the several sections of line are then separately adjusted until the required characteristic is obtained. It should be understood that the approximate adjustment is first obtained by actual linear measurement of the line. In the case of the filters S and U, I have found it desirable to include small variable capacitors **39**, **41** which are used in getting the exact resonance required. In the case of the elements C_1 and L_1 in the networks A and B, I have found it practical to use a concentric line within a concentric line, as shown. With respect to the series resonant circuits L_2C_2 and L_3C_3 of the networks A and B, respectively, I have found it desirable to use an effective length of 1½ wave lengths and instead of using a 70-ohm line I use a line of approximately twice the 70-ohm impedance by employing an inner conductor of $\frac{11}{32}$nds of an inch with the inside diameter of the outer conductor of 4½ inches. Where a concentric line is arranged within a concentric line, the outside diameter of the innermost conductor may be ¼" in diameter.

Thus, I have described a novel electrical network. The network sharply attenuates currents below a predetermined frequency and passes currents above this frequency with very little attenuation. A very desirable characteristic of the network is its freedom from reactive defects which would cause transient currents within the useful range. I have described the characteristics as applied to a single side band television transmitter and have shown the effective dimensions of a concentric-line network which is used to transmit frequencies from 44 to 49 Mc and to suppress currents of frequencies lower than 43 Mc. Those skilled in the art will realize that a different range of operating frequency will require a different design. The utility of the device is not to be limited to television, as the network may be used in numerous other electrical systems.

I claim as my invention:

1. An electrical network having a pair of input terminals offering substantially constant resistance and substantially zero reactance over the operating frequency band, a first pair of complementary networks, a second pair of complementary networks, said networks having input and output terminals, means connecting together the input terminals of said first pair of networks to form said first-named input, said first pair of networks including respectively series-resonant circuits tuned to different frequencies and reactive elements offering substantially the same reactance at the same frequency, a dissipating load, means connecting said load to the output terminals of one of said first pair of networks, means connecting the output terminals of the other of said first pair of networks to the input terminals of said second pair of networks, each of said second networks including circuits parallel-resonant to the same frequency and series-resonant to the same frequency, impedance inverting networks connected between the last-mentioned resonant circuits and the input terminals of said second pair of networks, means for connecting the output terminals of one of said second networks to a dissipating load, and means for connecting the other of said second networks to a useful load.

2. An electrical network having an input offering substantially constant resistance and substantially constant reactance over the operating frequency range, a first pair of complementary networks, a second pair of complementary net-

works, each of said networks having input and output terminals, means connecting together the input terminals of said first pair of networks to form said first-named input, said first pair of networks including reactive elements having complementary reactive characteristics, a dissipating resistor, means connecting said resistor to the output terminals of one of said first pair of networks, means connecting the output terminals of the other of said first pair of networks to the inputs terminals of each network of said second pair of networks, said second pair of networks including respectively one and two impedance inverters, said two impedance inverters being serially connected to form a common junction, a resonant circuit connected to the network including one impedance inverter, a dissipating resistor effectively connected in shunt to said last-mentioned resonant circuit, a second resonant circuit connected to terminate one of the two impedance inverters connected in the other of said second networks, and a useful load connected to said junction of said two impedance inverters.

3. A network of the character of claim 2 in which the last-mentioned resonant circuits include series-resonant circuits responsive to the same frequency, and parallel-resonant circuits responsive to another frequency.

4. An electrical network including complementary branches, one of said branches including one impedance inverter, the other of said branches including two impedance inverters, each of said branches including input and output terminals, the input terminals of one branch being connected to an impedance inverter and the input terminals of the other branch being connected to the first of said two impedance inverters, said two impedance inverters being connected in series, a resonant circuit connected across the output terminals of said first branch, a dissipating resistor connected to the output terminals of said first branch, a resonant circuit connected to the output terminals of said second branch and a useful load circuit connected to the junction of the two impedance inverters in said second branch.

5. An electrical network including two branches, one of said branches including an impedance inverting filter and a circuit parallel-resonant to one frequency and series-resonant to a different frequency, said branch being terminated in a dissipating resistor, said second branch including two serially-connected impedance inverting filters, the junction of the filters terminating in a useful load circuit and the second of said filters terminating in a circuit parallel-resonant to the first-mentioned frequency and series-resonant to said different frequency.

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