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WAVE TRANSMISSION NETWORK

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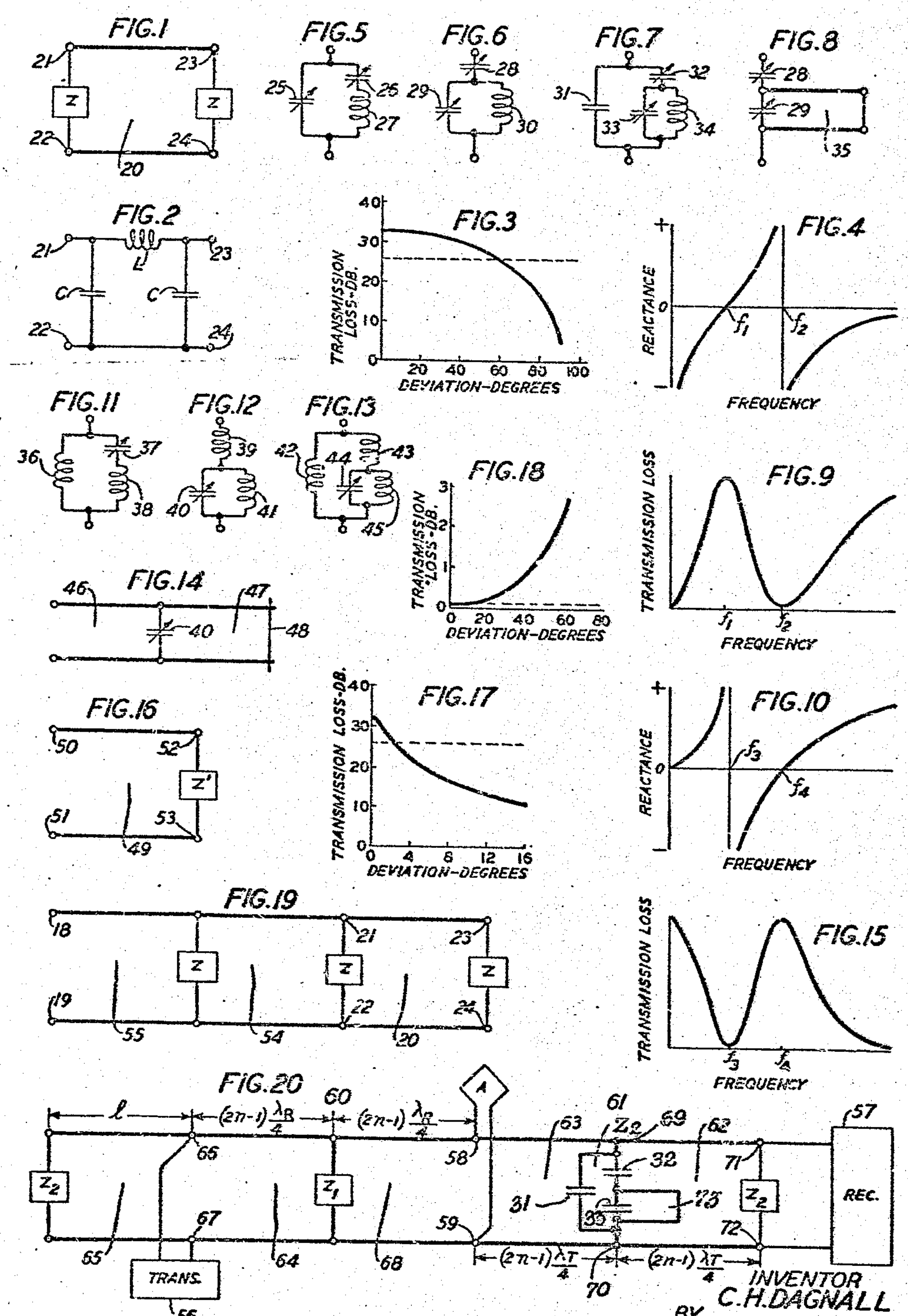

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WAVE TRANSMISSION NETWORK

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This invention relates to wave transmission and more particularly to frequency-selective transmission networks.

An object of the invention is to transmit freely waves falling in one band of frequencies while attenuating waves falling in another band or other bands of frequencies.

Other objects are to increase the discrimination between the transmitted band and the attenuated band in a frequency-selective transmission network and to reduce the cost and size of such networks, especially those designed for use at high frequencies.

Another object is to provide for the parallel operation at one end of two or more selective transmission networks each of which will freely transmit waves falling in a selected band of frequencies while attenuating waves of the frequencies transmitted by the other network or networks.

A further object of the invention is to permit the simultaneous operation on the same antenna of two or more translation devices, such as transmitters or receivers.

If a section of transmission line or other four-terminal transducer having a phase shift equal approximately to an odd multiple of 90 degrees at a certain frequency is shunted at one end by an impedance branch which has a low impedance at that frequency, the other end of the line section will present a high impedance at this frequency. Waves of this frequency impressed upon the line section at either end will be greatly attenuated in passing therethrough, since at the one end they encounter the high impedance of the terminated line and at the other end the low impedance of the shunt branch. However, waves of frequencies at which the impedance of the shunt branch is high compared to the characteristic impedance of the line section will pass along the line with small or negligible transmission loss. Greatest discrimination is secured when the shunt branch is resonant at the frequency to be excluded and anti-resonant at the frequency to be transmitted.

In accordance with the present invention, the discrimination in a frequency-selective wave transmission network of the type described is greatly increased by adding a second similar shunt impedance branch at the other end of the line section. As an example of the improvement obtainable, if a single shunt gives a discrimination of 26 decibels, the addition of the second shunt may be expected to increase the discrimination by as much as 32 decibels. The discrimination of the network may be further greatly increased by adding one or more sections of line similar to the first, each with a shunt impedance branch of the type described connected at its outer end. Each additional line section and associated shunt branch will increase the discrimination by as much as 32 decibels. If two or more networks of this type are to be operated in parallel at one end it is desirable to terminate each network at its paralleled end in an additional section of line having a phase shift equal approximately to an odd multiple of 90 degrees at the frequency to be attenuated.

The transducer may be a section of uniform transmission line of the coaxial type, of the balanced shielded type or, under some circumstances, an unshielded pair of wires. Alternatively, the transducer may be a four-terminal network comprising lumped reactance elements, the only requirements being that it has a phase shift equal approximately to an odd multiple of 90 degrees at the frequency to be excluded and has a low transmission loss at the frequency to be transmitted.

The shunt branch may be made up entirely of lumped reactance elements or it may include one or more sections of transmission line used as reactances. The branch may include a reactance element added to provide, in effect, an impedance transformation for the rest of the branch. Also, an impedance inverting network may be inserted between the shunt branch and its point of connection.

The networks of the invention are particularly useful in a radio system where two or more translation devices, such as transmitters or receivers, are associated with a common antenna. For example, a transmitter operating at one frequency and a receiver operating at a second frequency may be using the same antenna at the same time. It is necessary to keep the transmitter frequency, and noise of the receiver frequency generated in the transmitter, out of the receiver. It is also necessary to provide a transmission path from the transmitter to the antenna for the transmitter frequency, and from the antenna to the receiver for the receiver frequency.

All of these requirements can be satisfied by inserting selective networks of the type described in the transmission lines connecting the antenna with the transmitter and the receiver. The network in the line to the transmitter is designed to pass freely the transmitter frequency while attenuating the receiver frequency. The network in the line to the receiver passes freely the receiver frequency but attenuates the transmitter frequency.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, in which:

Fig. 1 is a schematic circuit showing one embodiment of the frequency-selective wave transmission network of the invention;

Fig. 2 is the circuit of a four-terminal transducer comprising lumped reactance elements which may be used in the network of Fig. 1;

Fig. 3 shows the effect on the transmission loss of the network of Fig. 1 of deviations from the optimum phase shift in the transducer;

Fig. 4 shows the reactance-frequency characteristic of the shunt impedance branches of Fig. 1 when the frequency to be attenuated is lower than the frequency to be transmitted;

Figs. 5 and 6 are alternative forms of an impedance branch having the reactance characteristic of Fig. 4;

Fig. 7 shows how impedance transformation may be introduced in the branch of Fig. 6 by the introduction of an added reactance element;

Fig. 8 shows an impedance branch equivalent to the one of Fig. 6 in which the inductance is furnished by a section of transmission line;

Fig. 9 gives a typical transmission loss characteristic for the network of Fig. 1 when shunt branches of the type shown in Figs. 5, 6, 7 or 8 are used;

Fig. 10 represents the reactance-frequency characteristic of the shunt branches of Fig. 1 when the frequency to be attenuated is higher than the frequency to be transmitted;

Figs. 11 and 12 are alternative circuits of impedance branches having the reactance characteristic of Fig. 10;

Fig. 13 shows the introduction of impedance transformation in the branch of Fig. 12 by the addition of an inductance;

Fig. 14 shows an equivalent circuit for the branch of Fig. 12 in which the inductances are furnished by sections of transmission line;

Fig. 15 gives a typical transmission loss characteristic obtainable with the network of Fig. 1 when it has shunt impedance branches of the type shown in Figs. 11, 12, 13 or 14;

Fig. 16 shows an impedance ranch associated with a section of line used as an impedance inverter;

Figs. 17 and 18 show the effect that deviations in the phase shift of the impedance inverter have upon the transmission loss at the attenuated and at the transmitted frequencies, respectively;

Fig. 19 shows the network of Fig. 1 modified by the addition of a second section of line with its associated shunt branch to improve the discrimination, and the addition of a terminal section of line to provide for parallel operation with a second network; and

Fig. 20 shows two networks in accordance with the invention associated with a radio system in which two translation devices use a common antenna.

Fig. 1 is a schematic circuit of a selective wave transmission network in accordance with the invention adapted to attenuate waves of one frequency while freely transmitting waves of another frequency. The network comprises a four-terminal transducer in the form of a section of transmission line 20 and two shunt impedance branches Z connected at its ends. At one end the network has a pair of terminals 21, 22 to which a wave source of electromotive force may be connected, and at the other end a second pair of terminals 23, 24 to which a load or utilization circuit may be connected. For the best results it is desirable that the impedances of the terminal loads match the characteristic impedance of the line section.

The only requirements on the transducer 20 are that it have a phase shift equal approximately to an odd multiple of 90 degrees at the frequency f_1 to be suppressed and a low attenuation at the frequency f_2 to be transmitted. These requirements are met by a section of uniform transmission line, preferably of the coaxial or balanced shielded type, the length of which is approximately equal to an odd multiple of one-quarter of the length of the waves to be attenuated. Alternatively, the transducer may be made up of lumped reactance elements. When the section of line is found to be unduly long the substitution of lumped elements will generally reduce the cost and size of the network. A suitable transducer using lumped elements is shown in Fig. 2. The network is of the ladder type and comprises a series inductance L with two shunt capacitances C, C connected at its ends. The values of the elements may be so proportioned that the network will have a phase shift of approximately 90 degrees, or an odd multiple thereof, at the frequency f_1.

The effect on the transmission loss of the network of deviations, either plus or minus, from the optimum phase shift in the transducer 20 is shown by the curves of Fig. 3. The ordinates represent transmission loss in decibels and the abscissas represent the deviation in degrees from a phase shift equal to an odd multiple of 90 degrees at the frequency of the waves to be attenuated. It is assumed that the attenuation in the transducer 20 is negligible and that each shunt branch Z has an impedance equal to one-fortieth of the characteristic impedance of the transducer at the frequency to be attenuated. The dotted-line curve gives the transmission loss introduced by a single shunt branch Z. This loss has a constant value of about 26 decibels regardless of the deviation in phase shift. The solid-line curve gives the added transmission loss attributable to the introduction of a second shunt branch Z. This loss is 32 decibels for zero deviation and falls to six decibels for a deviation of 90 degrees. However, the loss is greater than that introduced by the first branch for deviations up to about 58 degrees. It is seen that if the second branch is connected at the same point as the first, or at a point separated from the first by an interval in which the phase shift is an even multiple of 90 degrees, the second branch will add a loss of only six decibels, but if the phase shift has the optimum value this loss may be increased to 32 decibels. However, as the curve shows, considerable deviation from the optimum phase shift is permissible and the second branch will still provide a large added loss. The effect of deviations of the phase shift upon the loss to the waves transmitted through the network is negligible.

Each shunt branch Z in Fig. 1 has a low impedance at the frequency f_1 which is to be blocked and a high impedance at the frequency f_2 which is to be transmitted. The branch is preferably resonant at f_1 and anti-resonant at f_2. There may, of course, be additional critical frequencies, either resonances or anti-resonances. In some cases extra critical frequencies may be used to advantage to control the values of the component reactance elements in the branch, or to regulate the sharpness of resonance.

If f_1 is lower than f_2 the simplest form of the reactance characteristic for the branch Z will be of the type shown in Fig. 4, with a zero at f_1 and a pole at f_2. Such a reactance may be provided, for example, by the two-thermal impedance branch shown in Fig. 5 which comprises a capacitance 25 shunted by an arm consisting of a second capacitance 26 in series with an inductance 27. The capacitance 26 and the inductance 27 are proportioned to resonate at the frequency f_1, and the capacitance 25 is so chosen that the entire branch is anti-resonant at the frequency f_2. The capacitances 25 and 26 may be made variable, as indicated by the arrows, to facilitate the adjustment of the frequencies of resonance and anti-resonance. Alternatively, the reactance characteristic of Fig. 4 may be provided by an impedance branch of the type shown in Fig. 6 comprising a variable capacitance 28 in series with an anti-resonant loop consisting of a second variable capacitance 29 in parallel with an inductance 30. In converting from the configuration shown in Fig. 5 to the equivalent one of Fig. 6 the capacitance 25 may be divided into two portions, one of which is associated with the capacitance 26 and the inductance 27 and converted into a circuit of the type shown in Fig. 6. The resulting structure will be as shown in Fig. 7 comprising a capacitance 31, shunted by an arm consisting of a second capacitance 32 in series with an anti-resonant loop made up of a third capacitance 33 and an inductance 34 in parallel. By varying the value of the capacitance 31 the values of the remaining reactance elements may be changed and in this way there is provided a choice of values for these elements. The addition of the capacitance 31 in effect provides an impedance transformation for the remaining elements in the branch. The value of the capacitance 31 may be so chosen that the most desirable values are obtained for the remaining elements.

The inductance in the shunt branch Z may, under certain circumstances, be furnished by a section of transmission line. For example, the inductance 30 in Fig. 6 may be provided by a section of line 35 short-circuited at its distant end, as shown in Fig. 8. Some of the distributed capacitance of the line 35 will be effective across its input terminals and the value of the shunting capacitance 29 is reduced to allow therefor. Of course, an additional capacitance may be connected in shunt with the branch shown in Fig. 8 in order to provide impedance transformation, as explained above in connection with Fig. 7.

If the shunt impedance branches Z in Fig. 1 take any one of the forms shown in Figs. 5, 6, 7 and 8, or an equivalent form, the network will have a transmission loss characteristic of the type shown diagrammatically in Fig. 9 with a maximum loss at the frequency f_1 and a transmission region including the frequency f_2 and extending to either side thereof. The width of the effective transmission band can be increased by lowering the impedance level of the branch Z, that is, by making the reactances less stiff. A change in this direction will at the same time raise and broaden the attenuation peak. On the other hand, if the branch Z is raised in impedance level the transmission band is narrowed and the attenuation in the region of the frequency f_1 is lowered and made more peaked. In practice the impedance level of the branch is so chosen that the resultant transmission loss characteristic most nearly meets the requirements encountered in any particular case.

If the frequency to be transmitted is lower than the frequency to be blocked, in its simplest form the reactance characteristic of the shunt impedance branches Z of Fig. 1 will be of the type shown in Fig. 10, with a pole at the frequency f_3 to be transmitted and a zero at the frequency f_4 to be suppressed. In this case the branch Z may, for example, take the form shown in Fig. 11 comprising an inductance 36 shunted by an arm consisting of a capacitance 37 in series with a second inductance 38. Alternatively, the branch Z may take the equivalent form shown in Fig. 12 comprising an inductance 39 in series with an anti-resonant loop consisting of a capacitance 40 in parallel with a second inductance 41. In the same way as already explained in connection with Fig. 7, impedance transformation may be provided by adding the shunt inductance 42 as shown in Fig. 13. By properly choosing the value of the inductance 42 the remaining reactance elements 43, 44 and 45 may be given the most desirable values, within certain limits.

In this type of shunt also the inductance elements may be replaced by sections of transmission line if desired. For example, the two inductances 39 and 41 of Fig. 12 may be replaced, respectively, by the sections of line 46 and 47 as shown in Fig. 14. The line section 47 may be short-circuited at its remote end by a low-impedance strap 48 as shown, and the value of the inductance 41 may be adjusted by changing the location of this strap. Part of the distributed capacitance of the two lines will appear in shunt at their junction, and the value of the capacitance 40 is reduced to allow for this. A portion of the distributed capacitance of the line 46 will also appear shunted across its input terminals, but the effect of this will only be to introduce another anti-resonance at a frequency above f_4. The introduction of this additional pole will ordinarily not be detrimental to the performance of the network. In some cases it may be desirable to shunt additional capacitance across the input terminals of the line section 46 in order to bring this added anti-resonance nearer to the resonance at f_4, thereby giving additional control of the transmission loss characteristic and providing an additional range of selection for the values of the component impedance elements in the branch.

Fig. 15 shows the type of transmission loss characteristic obtainable with the network of Fig. 1 when the shunt branches Z take any one of the forms shown in Figs. 11, 12, 13 and 14. The network will pass a band of frequencies in the neighborhood of f_3 and will have a maximum loss at or near the frequency f_4.

In accordance with the invention a four-terminal transducer may be used as an impedance inverter in connection with the shunt impedance branches Z. A new impedance Z′ having a reactance characteristic which is the inverse of that of the branch Z is connected at one end of the transducer and the other end is connected at the point where the branch Z is ordinarily found. The only requirements on the transducer are that its phase shift is approximately an odd multiple of 90 degrees at all frequencies at which the impedance of Z′ is to be inverted and that the transmission loss is low at these frequencies. The transducer may, for example, be a section of transmission line having a length which is approximately equal to an odd multiple of a quarter wave-length at each frequency at which the impedance is to be inverted. Alternatively, the transducer may be made up of lumped reactance elements, as shown in Fig. 2 for example, proportioned to provide the required phase shift.

Fig. 16 shows an impedance inverter in the form of a section of transmission line 49 having input terminals 50, 51 and output terminals 52, 53, with the impedance Z′ connected across the output terminals. If Z′ is resonant at the frequency f_r and anti-resonant at the frequency f_a and at the terminals 50, 51 it is desired to see a high impedance at f_r and a low impedance at f_a, then the length of the line section 49 must be so chosen that it is approximately equal to an odd multiple of a quarter wave-length at both of these frequencies. Under these conditions the impedance at each of these frequencies seen at the terminals 50, 51 is equal to the characteristic impedance of the line section 49 squared and divided by the impedance Z′. If the frequencies f_a and f_r are close enough together the line may be a quarter wave-length, or an odd multiple thereof, at either of them, or at some intermediate frequency, and the conditions will be satisfied. However, for other spacings of the frequencies it may be necessary to make the line section 49 an odd number of quarter wave-lengths at one of the frequencies and a different odd number of quarter wave-lengths at the other frequency. For example, the length of the section of line might be five-quarters of a wave-length at f_a and seven-quarters of a wave-length at f_r.

By the addition of an impedance inverter a reactance characteristic of the type shown in Fig. 10, for example, which ordinarily requires two inductors and one capacitor may be provided by an impedance branch Z′ consisting of two capacitors and one inductor. The designer is thus given his choice of two electrically equivalent types of branches and he will ordinarily select the one which is the less expensive to build.

Fig. 17 shows the change in the transmission loss of the network at the frequency to be attenuated caused by deviations in either direction from the optimum phase shift in the impedance inverter 49. The transmission loss in decibels introduced by a shunt branch is plotted against the deviation in degrees from a phase shift equal to an odd multiple of 90 degrees at the frequency of the waves to be attenuated. It is assumed that the attenuation in the impedance inverter 49 is negligible and that the impedance of Z′ is equal to one-fortieth of the characteristic impedance of the inverter at the frequency to be attenuated. For comparison, the dotted-line curve represents the transmission loss introduced by a single shunt branch Z. The solid-line curve gives the added transmission loss attributable to a second shunt branch, consisting of an impedance inverter 49 terminated at its outer end in an impedance Z′, connected at the optimum distance from the branch Z. This loss is 32 decibels for zero deviation and falls off to about 11 decibels for a deviation of 15 degrees. It is apparent, therefore, that for a high loss the deviation in phase shift in the impedance inverter from the optimum value should be kept small.

Fig. 18 shows the variation in the transmission loss for the waves to be transmitted due to deviations from the optimum value in the phase shift in the impedance inverter. It is assumed that the impedance of Z′ is equal to forty times the characteristic impedance of the inverter at the frequency to be transmitted. For comparison, the dotted-line curve gives the loss introduced by a single shunt branch Z. This loss remains constant at about 0.1 decibel. The solid-line curve gives the added loss due to a second shunt branch consisting of an impedance inverter 49 terminated in an impedance Z′. This loss starts at 0.1 decibel for zero deviation and rises to a value of less than three decibels for a deviation of 60 degrees. It is apparent, therefore, that so far as the loss to the transmitted waves is concerned the value of the phase shift in the impedance inverter is not very critical. In practice, therefore, it is advisable to have the phase shift in the inverter as near the optimum value as possible for the frequency to be attenuated, but a considerable deviation from the optimum value for the frequency to be transmitted is permissible.

The discrimination between the frequency to be passed and the frequency to be blocked can be increased by the addition of one or more sections of line similar to the first, each with its associated shunt impedance branch. Fig. 19 shows the network of Fig. 1 modified by the addition of a second section of line 54, similar to the section 20, with a third shunt branch Z connected at its outer end. If the network is to operate in parallel at one end with another similar network it is desirable that each network be terminated at the paralleled end in a section of line which is a quarter wave-length, or an odd multiple thereof, at the frequency to be excluded. In Fig. 19 such a line section 55, similar to the line sections 54 and 20, is connected between the terminals 18, 19 and the remainder of the network.

A useful application of the invention is in a radio system where two or more translation devices operating at different frequencies are associated with a common antenna. For example, as shown in Fig. 20, a transmitter 56 operating at the frequency f_T and a receiver 57 operating at some other frequency f_R may be simultaneously using the same antenna A. Two transmission lines, jointed in parallel at the terminals 58, 59, connect the antenna with the transmitter and the receiver, respectively. It is apparent that the path between the transmitter and the antenna must pass freely waves of the transmitter frequency and that the path from the antenna to the receiver must pass freely waves of the receiver frequency. In addition, the path between the transmitter and the receiver must offer a high loss to the transmitter frequency to keep these high level waves out of the receiver, and also a high loss to any waves of the receiver frequency which may originate as noise in the transmitter.

The requirements mentioned may be met by using two selective wave transmission networks designed in accordance with the principles of the invention, one included in the transmitter branch and the other in the receiver branch. The network 60 in the transmitter branch has a low transmission loss at the frequency f_T and a high loss at f_R, and the network 61 in the receiver branch has a low loss at f_R and a high loss at f_T. As shown in Fig. 20 the network 61 includes a section of transmission line 62 which is approximately an odd multiple of a quarter wave-length at the transmitter frequency. The length of this line section is therefore equal to

$$(2n-1)\frac{\lambda_T}{4}$$

where λ_T is the wave-length of the transmitter frequency f_T and n is any integer. In practice n is usually chosen as unity and the line section 62 is a quarter wave-length.

At each end of the line section 62 is a shunt impedance branch Z_2. If the transmitter frequency is lower than the receiver frequency each branch Z_2 may take any one of the forms shown in Figs. 5, 6, 7 and 8, or any equivalent form. The branch connected between terminals 69 and 70 is represented as being of the type shown in Fig. 7 except that the inductance 34 and a portion of the capacitance 33 are furnished by a section of transmission line 73 short-circuited at its distant end as explained above in connection with Fig. 8. The capacitance 31 is added to provide an impedance transformation for the other reactance elements in the branch and thus permit the use of more easily obtainable values. If, on the other hand, the transmitter frequency is higher than the receiver frequency the shunt should take the form shown in Figs. 11, 12, 13 or 14, or an equivalent form. In either case the branch Z_2 is resonant at the frequency f_T and anti-resonant at f_R. The network is terminated at its paralleled end in a second section of line 63 of the same length as the section 62. This terminating line section is included so that the network 61 will operate satisfactorily in parallel with the network 60.

The network 60 in the transmitter branch includes a section of line 64 which is approximately an odd multiple of a quarter wave-length at the receiver frequency. The length of this line section is equal to

$$(2n-1)\frac{\lambda_R}{4}$$

where λ_R is the wave-length of the receiver frequency f_R and n is any integer. At one end the line section 64 is shunted by an impedance branch Z_1 which is resonant at the receiver frequency f_R and anti-resonant at the transmitter frequency f_T.

At its other end the line section 64 is shunted by an impedance-inverting line section 65 at the distant end of which there is connected an impedance branch Z_2. This branch has an impedance characteristic inverse to that of the branch Z_1, that is, Z_2 is resonant at the frequency f_T and anti-resonant at f_R. As explained above in connection with Fig. 16 the length l of the line section 65 is so chosen that it is approximately an odd multiple of a quarter wave-length at both of the frequencies f_T and f_R. Due to the impedance-inverting properties of the line section 65 the impedance seen at its terminals 66, 67 is the same as the impedance of the branch Z_1. It is apparent, therefore, that the line section 65 and its terminal impedance branch Z_2 may be substituted for the impedance branch Z_1, and vice versa. If the former is done all of the impedances will be of the Z_2 type. In some cases this may lead to a less expensive pair of networks, as only one type of impedance need be developed. It is clear also that an impedance-inverting line section terminated by an impedance Z_1 may be substituted for each of the branches Z_2 in the network 61 in the receiver branch. The network 60 is terminated at its paralleled end in a section of line 68 of the same length as the line section 64.

In the system of Fig. 20 it is preferable that all of the line sections 62, 63, 64 and 68 have matching characteristic impedances, and it is also desirable that the transmitter 56, the receiver 57 and the antenna A have impedances which match the characteristic impedance of the lines. As explained above in connection with Fig. 19, additional line sections with their associated shunt branches may be added to the network 60 or the network 61, or to both, in order to increase the discrimination between the frequency to be transmitted and the frequency to be attenuated.

The operation of the system shown in Fig. 20 may be summarized as follows. At the transmitter frequency f_T the impedance of each branch Z_2 is nearly zero and these branches provide, in effect, short circuits across the line at the points of connection. Because of the impedance-inverting properties of the line section 65 a low impedance connected at its outer end will appear at the terminals 66, 67 as a high impedance. Waves of the frequency f_T from the transmitter 56 impressed upon the network 60 at the terminals 66, 67 will therefore flow along the line section 64 and not into the line section 65. Since the shunt branch Z_1 has a high impedance at the frequency f_T the waves will flow past this branch and along the line section 68 to the terminals 58, 59. At this point the impedance looking into the network 61 will be high for these waves because the line section 63 is terminated at the terminals 69, 70 in a substantially zero impedance. However, since the antenna A matches the line 68 in impedance, the transmitter signal will pass freely to the antenna. A small amount of energy of the frequency f_T will enter the network 61 at the terminals 58, 59 but at the terminals 69, 70 it encounters the high impedance of the line section 62 which is shunted at its terminals 71, 72 by a low impedance at this frequency. Most of this energy is therefore drained off by the low-impedance shunt Z_2 connected across the terminals 69, 70. The small amount of energy that remains will be largely drained off by the low-impedance shunt Z_2 connected across the terminals 71, 72.

Since the impedance Z_1 is low at the receiver frequency f_R the impedance looking into the line section 68 at the terminals 58, 59 is high at this frequency. Also, at f_R the impedance of the branches Z_2 is high and the branches may be considered to be open-circuited. Waves of the frequency f_R picked up by the antenna and impressed upon the terminals 58, 59 of the network 61 will therefore be blocked from entering the network 60 but will pass freely along the line sections 63 and 62 to the receiver 57, which matches the line in impedance.

Noise energy of the frequency f_R generated in the transmitter 56 when it reaches the terminals 66, 67 of the network 60 will encounter a high impedance looking into the line section 64 and a low impedance looking into the line section 65. Much of this energy will therefore be drained off through the shunt branch at this point. The small amount which passes along the line section 64 will be largely drained off by the shunt branch Z_1 which has a low impedance at this frequency. Thus noise of the frequency f_R originating in the transmitter will not enter the network 61 and cannot interfere with the operation of the receiver 57.

In Fig. 20 the two translation devices are shown as a transmitter 56 and a receiver 57. It is to be understood, however, that both of these devices may be transmitters or they may both be receivers. Furthermore, the number of translation devices associated with a common antenna is not limited to two, but may be extended to three or more, all operating at different frequencies. In each transmission line connecting the antenna with a translation device there will be included a network, designed in accordance with the principles of the invention, which will pass the frequency of that device but exclude all of the other frequencies.

What is claimed is:

1. A frequency-selective wave transmission network for attenuating waves of one frequency f_1 while transmitting waves of a different frequency f_2 comprising an impedance branch which includes two reactors connected in series, a third reactor connected in shunt with said two reactors, and a fourth reactor connected in shunt with one of said two reactors, said fourth reactor having a reactance at the frequencies f_1 and f_2 which is of opposite sign to the reactance of said other three reactors at said frequencies and one of said reactors being a section of transmission line.

2. A network in accordance with claim 1 in which said fourth reactor has a positive reactance at the frequencies f_1 and f_2.

3. A network in accordance with claim 1 in which said fourth reactor is a section of transmission line.

4. A network in accordance with claim 1 in which said fourth reactor is a section of transmission line short-circuited at its distant end.

5. A network in accordance with claim 1 in which said first three reactors have a positive reactance at the frequencies f_1 and f_2.

6. A network in accordance with claim 1 in which said first three reactors have a positive reactance at the frequencies f_1 and f_2 and one of said three reactors is said section of transmission line.

7. A network in accordance with claim 1 in which said first three reactors have a positive reactance at the frequencies f_1 and f_2 and one of said two series-connected reactors is said section of transmission line.

8. A network in accordance with claim 1 in which said fourth reactor has a negative reactance at the frequencies f_1 and f_2 and the reactor connected in shunt therewith is said section of transmission line.

9. A network in accordance with claim 1 in which said fourth reactor has a negative reactance at the frequencies f_1 and f_2 and the reactor connected in shunt therewith is a section of transmission line short-circuited at its distant end.

10. A network in accordance with claim 1 in which said impedance branch is connected in shunt.

11. A network in accordance with claim 1 in which said impedance branch is resonant at the frequency f_1 and anti-resonant at the frequency f_2.

12. A frequency-selective wave transmission network comprising an impedance branch which includes two capacitors connected in series, a third capacitor connected in shunt with said two capacitors and a section of transmission line connected at one end across one of said two series-connected capacitors, said third capacitor having a capacitance value so chosen that said section of transmission line may be made of convenient physical length.

13. A network in accordance with claim 12 in which said impedance branch is connected in shunt.

14. A network in accordance with claim 12 in which said section of transmission line is short-circuited at its distant end.

15. A frequency-selective wave transmission network comprising an impedance branch which includes two sections of transmission line connected in tandem, a shunt capacitor connected at the junction of said sections of line and an inductor connected in shunt at the outer end of one of said sections of line.

16. A network in accordance with claim 15 in which the other of said sections of line is short-circuited at its outer end.

17. A network in accordance with claim 15 in which said capacitor is variable.

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