

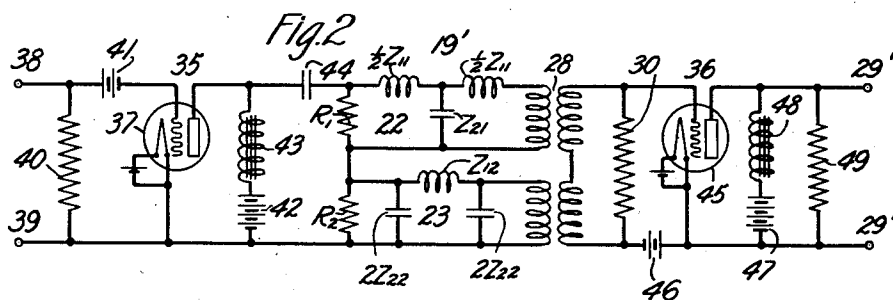
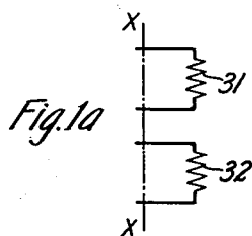
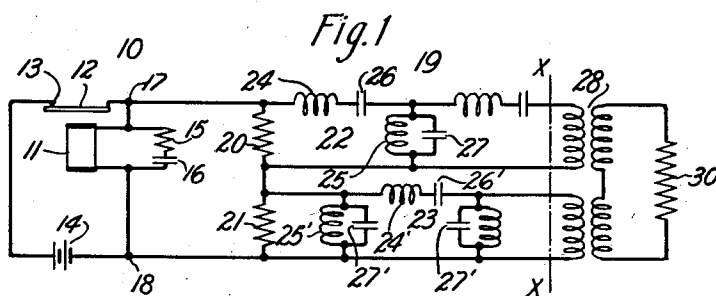
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ELECTRIC WAVE TRANSMISSION SYSTEM

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UNITED STATES PATENT OFFICE.

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ELECTRIC-WAVE TRANSMISSION SYSTEM.

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This invention relates to electric wave transmission systems and more particularly to means for generating and selectively transmitting electric waves.

5 An object of the invention is to generate electric waves and to selectively transmit the generated waves to a load device.

Another object is to selectively transmit complex waves and to prevent the production
10 of transient surges in the transmission path.

An additional object is to compensate for reactance in a path traversed by electric waves to render it substantially non-reactive.

15 A further object is to neutralize the reactance of a band transmission network by another reactive network to produce a non-reactive network of constant impedance for all frequencies both within and without the
20 transmission band.

An additional object is to prevent current or voltage surges of large amplitude when an electric current traversing reactive paths is varied.

25 A feature of the invention is a network included in an interrupter circuit which has a constant non-reactive impedance for all frequencies and a broad band filter transmission characteristic.

30 Another feature is an interrupter having its magnet winding included as an element of a non-reactive network.

A further feature is a means for coupling space discharge tubes, which means comprises a broad band filter having parallel
35 paths, one bearing a complementary relation to the other, whereby the two form a non-reactive, constant impedance path at all frequencies either within or without the
40 transmission band.

When an electric current is interrupted or the impedance of the path which it traverses is subjected to abrupt changes, waves or surges of current or voltage or
45 both, of large amplitude may be produced if the path includes reactive elements. A practical illustration of a case where such surges are likely to occur and where they are detrimental is in a circuit for generating
50 varying current by means of a circuit interrupter such as has been employed in telephone systems for generating low frequency currents for ringing purposes.

It is now known that waves of rectangular

form, such as are produced by interrupting a
55 direct current, contain an infinite series of components with different amplitudes. See an article by Ralph V. L. Hartley entitled "Relations of carrier and sidebands in radio transmission" published in the Bell System
60 Technical Journal for April, 1923, page 90.

When waves of this form are generated in or transmitted over a circuit including reactive paths, the resonance property of the reactive elements causes the components
65 of the wave corresponding to the resonant frequencies to develop currents or voltages of large amplitude which may be termed "surges" or "transients."

For example the winding of the inter-
70 rupter magnet in a ringing interrupter system of this kind will ordinarily provide a resonant path, since it has inductance and distributed capacity and hence will cause transient surges of detrimental character.
75 One disadvantage resulting from the presence of these surges in a telephone line, for example, is that inductive interference between adjacent lines may be produced. Another disadvantage is that the surges
80 may be of a frequency such as to cause undesired operation of bells or other signals in the system.

If a filter network of the ordinary kind be provided to discriminate between desired
85 and undesired frequencies, the reactances of the filter elements will likewise provide resonant paths for producing other transients in the manner explained above.

In the present invention, a broad band filter network is included in a circuit with a
90 variable impedance device and a source of current, representative of any source of complex waves, and a load circuit, representing any desired form of wave receiving arrangement or device. The filter network, as a
95 whole, comprises two parallel paths or complementary filters so designed that their resultant impedance measured at the input terminals is a constant resistance at all
100 frequencies. Each filter has a broad band transmission characteristic and the two combined have a similar characteristic.

The two paths of the filter are rendered complementary by providing series impedances in one corresponding to shunt admittances in the other, series coils corresponding to shunt condensers, series condens-

ers corresponding to shunt coils and series resistances in the one corresponding to shunt conductances in the other.

The load circuit, per se, preferably presents a non-reactive impedance, otherwise its reactance might be reflected into the interrupter circuit even though the latter alone were non-reactive. This does not mean that the load circuit must not contain reactive elements but rather that the non-reactive components of its impedance should be very large as compared to its reactive component. This requirement is ordinarily met in efficient signal receiving arrangements.

The invention is illustrated in the drawings wherein:

Fig. 1 represents an interrupter circuit including a filter having a non-reactive impedance;

Fig. 1^a represents a modified terminal element for the filter of Fig. 1; and

Fig. 2 represents a wave translating circuit including space discharge tubes coupled by means of a non-reactive band pass filter.

In the several figures of the drawings like reference characters have been used to indicate like parts.

The circuit shown in Fig. 1 comprises a variable impedance device, namely an interrupter 10, including a magnet 11 having an armature 12 and a contact 13. The winding of magnet 11 is included in a circuit with a battery 14 in series with contact 13 and armature 12. The winding of magnet 11 is shunted by a path including a resistance 15 in series with a capacity 16. The terminals 17 and 18 of the interrupter connect to the input terminals of a band filter 19 including terminal impedance elements 20 and 21 preferably resistances.

The band filter 19 includes parallel transmission paths or component broad band filters 22 and 23. Path 22 has series inductance elements 24, shunt inductance elements 25, series capacity elements 26 and shunt capacity elements 27. Path 23 contains similar elements 24', 25', 26' and 27'. The two paths of filter 19 have their output terminals connected to independent primary windings of a three-winding transformer 28, the secondary winding of which is connected to a resistance in path 30 representing any efficient load circuit or device the impedance of which is chiefly resistance.

The transformer 28 may be omitted and resistance 30 replaced by the elements shown in Fig. 1^a which include separate resistances 31 and 32 representing separate load devices or elements arranged to be connected to the respective output terminals of the paths 22 and 23.

The winding of magnet 11 is energized by means of current from battery 14 whereby its armature is caused to alternately open and close contact 13. Interrupter 10 and

battery 14 represent any desired source of complex waves. The current supplied from source 14 to filter 19 is thus substantially in the form of rectangular waves. It has been explained that when a direct current is interrupted or when waves of rectangular form are supplied to a path including reactance elements that surges or transient voltages or currents will ordinarily be produced. In the present invention, however, the path including the elements 15 and 16 is provided to compensate for the reactance of the winding of magnet 11 to render the whole path non-reactive. In order for the one path to compensate for the other their respective time constants must be the same and their resistances must be equal. Again, the paths 22 and 23 of filter 19 are designed to be of a complementary nature, so far as the reactance of these paths is concerned, so that the filter, as a whole, is substantially non-reactive at all frequencies. By virtue of this fact, when waves of rectangular or other complex form or interrupted direct current are supplied to the filter 19, transient surges are prevented from being produced in the input circuit. Moreover, the filter functions to transmit a desired band of frequencies from the interrupter 10 to the load and to exclude any undesired frequencies which may be present as components of the rectangular waves produced by the source. In addition, the impedance of filter 19 is constant for all frequencies.

The resistances 30, 31 and 32 may be replaced by any load circuit or device, such, for example, as a telephone line including telephone ringers and the like.

In order that path 22 of filter 19 may be the proper counterpart of path 23, the series coils 24 in one correspond to shunt condensers 27' in the other and the series condensers 26 in one path correspond to bridged or shunt coils 25' in the other path.

In the article entitled "Theory and design of uniform and composite electric wave filters" by Otto J. Zobel, published in "The Bell System Technical Journal" Vol. II, January, 1923, page 1, it is shown that, to any non-dissipative reactance network there corresponds an inverse reactance network which is so related that the product of their impedance is a constant, independent of frequency. The rules by which inverse networks may be designed are developed under the heading Theorem 2 on page 36 of the above journal.

It may further be shown that in the network of filters 19 of Fig. 1 and 19' of Fig. 2, the product of the corresponding impedances of the component networks is a constant and moreover that the resultant impedance is a pure resistance.

Let Z represent the impedance of either filter 19 or 19' measured at the input ter-

minals, i. e., the outer terminals of resistances 20 and 21; assume resistance 20 equals resistance 21 and designate these resistances by R . Let Z_1 represent the impedance of the network 22 at the terminals connected to resistance 20 and Z_2 the corresponding impedance of network 23 at the terminals connected to resistance 21. These latter impedances include the effect of the load element 30.

It is readily shown that the total impedance Z of the filter has the value

$$Z = \frac{RZ_1}{R+Z_1} + \frac{RZ_2}{R+Z_2} = R,$$

when $Z_1 Z_2 = R^2$.

This expression sets forth the relation which impedances Z_1 and Z_2 must bear to each other in order that the total impedance Z shall be a constant resistance; in other words, in order that the filters 19 or 19', as the case may be, shall be of non-reactive and constant impedance. If one impedance Z_1 be given, the impedance Z_2 may be determined from these relationships as set forth by Zobel in the above mentioned article.

If now in a practical case one branch of the filter 19, such as branch 22, be designed to be a broad band filter of a particular type, then in accordance with the present invention an inverse network 23 may be designed and this inverse network will be a broad band filter having transmission characteristics similar to the network 22.

In the present instance filters 19 and 19' comprise each a filter 22 of the constant k type. The distinguishing characteristic of a constant k filter is that the product of its series and shunt impedances is a constant real quantity dimensionally of the type (resistance)². The inverse filter network 23 in each case is also a constant k filter. It is not to be understood, however, that these filters are necessarily of this type for they may be of any general type whether constant k or not, this particular type of filter having been used as an illustration merely from considerations of convenience.

In order that the construction of an inverse filter network may be better understood, a practical case will now be illustrated. For this purpose, in Fig. 2 the various shunt and series elements of the component filters are designated as Z_{11} , Z_{21} , Z_{12} and Z_{22} , respectively. It is to be noted that filter 22 is terminated in mid-series at both ends, whereas filter 23 is terminated in mid-shunt at both ends.

If it be assumed that the filter 22 is the given impedance Z_1 , then applying the rules laid down by Zobel, the reciprocal network 23 may be constructed, in which series elements correspond to shunt elements of the filter 22 and vice versa; and series combinations of elements in one correspond to shunt

combinations of elements in the other. The relationships which must exist between various impedances are as follows:

$$R_1 R_2 = Z_{11} Z_{22} = Z_{21} Z_{12} = R^2$$

The fulfillment of these conditions gives also:

$$\frac{Z_{11}}{Z_{21}} = \frac{Z_{12}}{Z_{22}}$$

This equation shows that the propagation constants of the component filters are alike, since by well-known filter theory

$$\cosh P_1 = 1 + \frac{1}{2} \frac{Z_{11}}{Z_{21}}$$

$$\cosh P_2 = 1 + \frac{1}{2} \frac{Z_{12}}{Z_{22}}$$

where P_1 and P_2 are the respective propagation constants of a single complete section of each filter respectively.

In Fig. 2, a filter 19' in general similar to the filter 19 shown in Fig. 1, is arranged to couple the output circuit of a space discharge repeater 35 to the input circuit of a second space discharge repeater 36. Repeater 35 includes a space discharge tube 37 having a grid cathode and anode. Input terminals 38 and 39 are connected to the grid and cathode respectively and are shunted by a resistance 40 which provides a leak path for currents between the grid and cathode. A battery 41 of suitable electromotive force is provided to supply the proper average potential to the grid of tube 37. The output circuit of tube 37, which is connected to its anode and cathode, includes a source of space current represented by battery 42 connected in series with a choke coil 43. The output circuit is coupled to the filter 19' by means of a condenser 44. The output terminals of transformer 28 are connected to the input electrodes of a space discharge tube 45 and include in shunt thereto, the resistance 30. In series in the input circuit of space discharge tube 45 is included a battery 46 for supplying a suitable average potential to the control electrode. The output circuit of this tube also includes a space current source 47 in series with choke coil 48 and is connected to output terminals 29' and shunted by a high impedance represented by resistance 49. Electric waves of any desired form may be supplied to the input circuit of tube 37 to produce fluctuations of the potential upon the control electrode thereof and to cause corresponding fluctuations in the current traversing the space path in the tube. By providing batteries 41 and 42 having suitable voltages, the fluctuations produced in the output circuit of tube 37 may be caused to be of greater amplitude than the corresponding waves supplied to its input circuit. Filter 19' serves

to selectively transmit the waves supplied to its input terminals, that is, the waves present in the output circuit of tube 37, through transformer 28, to the input circuit of repeater 36. This repeater includes the space discharge tube 45 which may be adjusted in the manner described in connection with tube 37 to cause amplification of the waves translated thereby in a manner now well understood. These waves increased in amplitude are then supplied to terminals 29', which may supply any suitable load circuit, or device, as already mentioned in connection with Fig. 1. Filter 19' may be designed to pass any desired band of frequencies and to exclude frequencies outside of the selected band. Moreover, this filter which includes the two paths 22 and 23, similar to corresponding paths of filter 19, is preferably rendered non-reactive by making one path thereof the counterpart of the other. That is, series coils in one correspond to bridged condensers in the other, and series impedances in one correspond to bridged impedances in the other.

An important advantage of the filter 19' as a coupling between the space discharge tubes 37 and 45 is that, being substantially non-reactive, the tendency for the amplifiers to establish parasitic oscillations or singing in the system is greatly reduced.

It is to be understood that the invention herein described is capable of general application and is not to be limited to the specific embodiments disclosed but only as indicated by the scope of the appended claims.

What is claimed is:

1. In a wave transmitting system, a wave source, a load circuit, and a filter network connected between said source and said circuit, said filter network comprising two separate filters for transmitting waves independently between said source and said circuit, said separate filters being complementary as regards their reactance.

2. In a wave transmitting system a source of complex waves, a wave filter connected thereto and including reactive impedance elements, and a load circuit connected to the output terminals of said wave filter, said filter comprising two portions included in separate wave channels, said portions being complementary with respect to their impedances and including resistance elements

whereby the impedance of the system to waves from said source is made a constant resistance at all frequencies.

3. In an interrupter circuit, a source of waves, including an interrupter, a load circuit, a plurality of filters arranged to transmit in parallel between said source and said load circuit, said filters being complementary, whereby their combined impedance to waves of all frequencies is substantially constant and non-reactive.

4. In an electric wave transmission system, a source of waves, a load device, a resistance connected to said source, and a filter terminated by said resistance, said filter comprising a plurality of component filter networks, each terminated by independent portions of said resistance, said filter as a whole being substantially non-reactive.

5. An electric wave transmission system in accordance with claim 4, characterized in this that said independent portions of said resistance are equal.

6. In an electric wave transmission system, a source of waves, a load device, a resistance in two equal parts R_1 and R_2 connected to said source and a broad band filter terminated by said resistance, said filter comprising two component filter networks terminated respectively in the parts R_1 and R_2 of said resistance, the first component filter having series elements of impedance Z_{11} and shunt elements of impedance Z_{21} and the other component filter having series impedance elements Z_{12} and shunt impedance elements Z_{22} said filters being so designed that

$$R_1 R_2 = Z_{11} Z_{22} = Z_{21} Z_{12}$$

7. A wave transmission network comprising a pair of input terminals and a pair of output terminals, a pair of wave channels between said input terminals and said output terminals, frequency selective networks included in said channels, said selective networks having impedances reciprocally related to each other with respect to a constant value denoted by R and resistance elements of resistance R included in each of said channels whereby the reactances of the two channels are made to mutually compensate each other.

In witness whereof, I hereunto subscribe my name this 1 day of May A. D., 1925.

GEORGE H. STEVENSON.