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Dec. 31, 1940. D. V. SINNINGER 2,226,836

INTERFERENCE-REDUCING SYSTEM

Filed Dec. 11, 1939

Fig. 1.

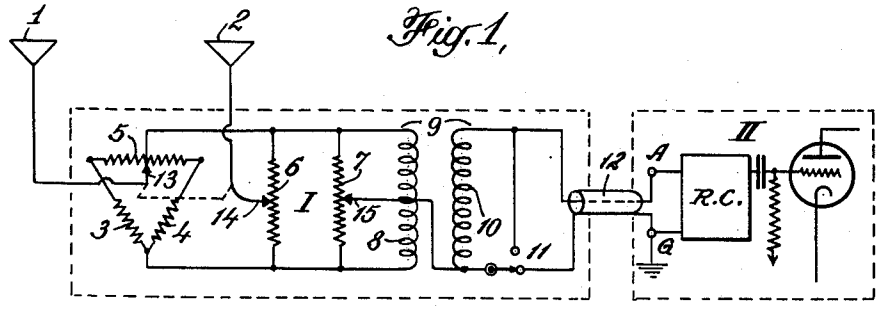


Fig. 2.

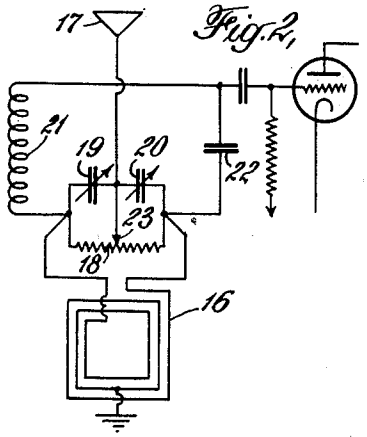


Fig. 3.

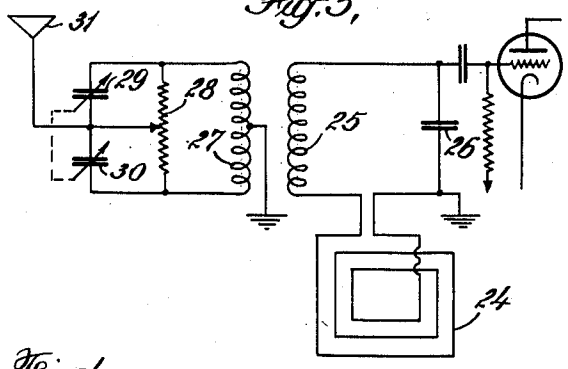


Fig. 4.

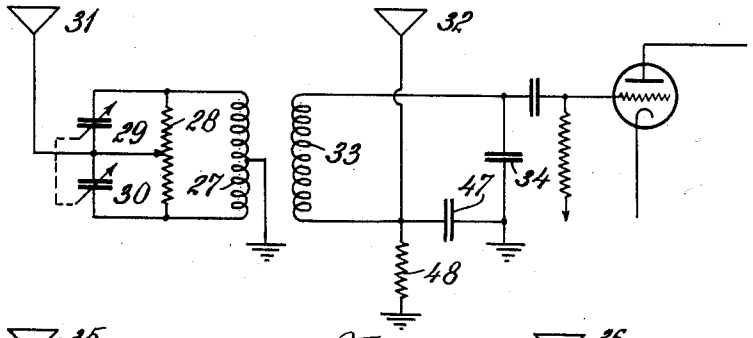
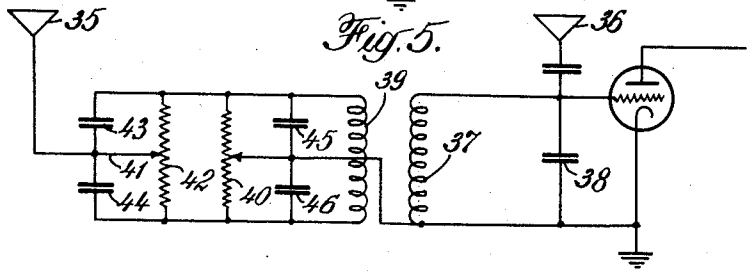


Fig. 5.



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250. RADIANT ENERGY.
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INTERFERENCE-REDUCING SYSTEM

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8 Claims. (Cl. 250—20)

My present invention relates to radio receivers such, for example, as those used in the reception of broadcasting, and more particularly to arrangements for eliminating the effects of interfering signals in such receivers.

As is well known, whenever the interfering signal differs sufficiently in frequency, it is usually possible to sufficiently reduce the response to the interfering signal by means of resonant circuits. In some cases, however, such circuits do not suffice, whether they are tuned to the frequency of the desired signal or, as in the case of superheterodyne receivers, additional selective circuits, tuned to a lower frequency to which the signals are converted, are employed.

When the interfering signal has the same frequency as the desired signal or differs very slightly therefrom in frequency, it is impossible to successfully eliminate the interfering signal by means of resonant circuits. My present invention is particularly adapted for the elimination of interference of this character, but is effective in cases in which the interfering and desired signals differ in frequency.

The voltages generated in any two exposed circuits will, in general, reach their maxima at different times as the result of the finite velocity of the signal. If the two exposed circuits or systems are separated by a reasonable fraction of a wavelength, this will result in a difference in phase between the currents resulting from the two voltages if they are allowed to flow through a common circuit. As will be more readily understood from what is to follow, my invention takes advantage of this phase difference between the currents generated in two separate collector systems by any passing signal.

In practicing the invention, I provide a network to which any two convenient collector systems are connected, and in which means are provided for adjusting the currents resulting from voltages generated in the two collector systems by an interfering signal, so that they are equal in amplitude and opposed in phase. When the adjustment has been made for a particular interfering signal, the currents due to a desired signal on the same frequency will, in general, not be equal in amplitude and will be different in phase so that a residual voltage corresponding to the desired signal will be obtained. The voltage due to a desired signal of frequency differing from that of the interfering signal is only slightly reduced. I also provide a combining circuit in which the interfering signal is cancelled out and through which the desired signal is transmitted to the receiver.

It will be understood that in practicing my invention, I do not employ resonant circuits, but that devices in accordance with the invention, several embodiments of which I shall now describe, comprise aperiodic resistance networks some of the elements of which are variable and, in general, at least one winding utilized as a combining element.

The invention will be better understood and its method of operation more clearly apprehended by the following description of specific embodiments taken in connection with the drawing, in which:

Fig. 1 is a schematic diagram of a preferred embodiment of the invention; and

Figs. 2 to 5, inclusive, show various modifications of the basic arrangement of Fig. 1.

Referring to Fig. 1, my interference-reducing device, indicated generally by numeral I, is interposed between signal collectors 1 and 2, and the radio receiver, indicated generally by numeral II, which may be of any of the types now commonly employed. Signal collectors 1 and 2 may both be open-ended antennas, or alternatively, one may be a counterpoise or an earth return impedance, the only requirements being that each provide a voltage generated by any desired signal which is not less than the sensitivity of the receiver, and that the two collectors be so positioned or located that there will be an appreciable phase difference between the voltages generated in them by any one signal. This last requirement is met if the effective distance between the two collectors is a reasonable fraction of the wavelength of the signal.

Interference-reducing device I comprises an amplitude-adjusting and polarity-reversing network, a phase balancer, and a transformer in which the adjusted voltages are combined and from which the residual signal voltage is fed to the first vacuum tube in receiver II, preferably through a resonant circuit R. C as indicated. The amplitude-adjusting and polarity-reversing network comprises resistors 3 and 4, and potentiometers 5 and 6 which are preferably ganged together for simultaneous operation as shown. The phase balancer comprises potentiometer 7, which is connected across the primary 8 of tightly-coupled transformer 9, the secondary 10 of which is connected through cut-out switch 11 and concentric cable 12 to the antenna and ground terminals, A and G respectively, of receiver II.

Collectors 1 and 2 are connected to the movable contacts 13, 14 of potentiometers 5 and 6 respectively. The movable contact 15 of potentiometer 7 is connected to a midtap on primary 8 and to the low-potential terminal of secondary 10 of transformer 9, and also to the arm of switch 11.

The center of potentiometer 5, and the high-potential terminals of potentiometers 6 and 7 are connected to the high-potential terminal of primary 8. Resistors 3 and 4 are connected in series across potentiometer 5. The junction of resistors 3 and 4 and the low-potential terminals of potentiometers 6 and 7, are connected to the low-potential terminal of primary 8. The resistance of potentiometer 5 is equal to the sum of the resistances of resistors 3 and 4 which are made equal.

In one position switch 11 short-circuits secondary 10 of transformer 9, and under these conditions the midtap of primary 8 is connected directly to the antenna terminal A of receiver II, so that any signal voltage existing across either half of primary 8 will be applied across receiver II. This permits tuning adjustments of receiver II to be made before interference reducing device I is interposed by throwing switch 11 to the other position, i. e., to the position shown.

Transformer 9 is of the type in which equal currents in the two halves of primary 8 will produce zero residual voltage in secondary 10. When interference reducing device I is in use, the midtap on primary 8 is connected directly to ground. A signal intercepted by collector 1 causes a current to flow through primary 8, and this current is a maximum when contact 13 is at the center of potentiometer 5, and decreases to zero as contact 13 is moved to either end thereof. It will be noted that this current flows in the same direction for all positions of contact 13.

A signal intercepted by collector 2 also causes a current to flow through primary 8, and this current is a maximum when contact 14 is at either end of potentiometer 6, but falls to zero as contact 14 is moved to the center thereof. It will be noted that the direction of this current reverses as contact 14 is moved from one side of the center of potentiometer 6 to the other side thereof.

As already explained, contacts 13 and 14 are mechanically connected so that they may be moved in unison by a single control, and are so positioned that they pass the centers of their respective resistance elements simultaneously. Movement of this tandem control from one extreme position to the other, therefore, provides at the start maximum current from signals in collector 2 and zero current from signals in collector 1, then decreasing current from collector 2 and increasing current from collector 1, then, at the center position, zero current from collector 2 and maximum current from collector 1, then reversed and increasing current from collector 2 and decreasing current, not reversed, from collector 1, and finally, at the other extreme position, maximum reversed current from collector 2 and zero current from collector 1.

Whatever the relative efficiences of collectors 1 and 2 may be, therefore, a position of the tandem contacts 13 and 14 can readily be found at which the currents in primary 8 due to any one signal intercepted by both collectors will be equal in amplitude and opposed in direction. Since, however, collectors 1 and 2 are separated by an appreciable fraction of a wavelength, there will, in general be a phase displacement between them, so that they will not completely cancel each other without further adjustment.

Adjustment of phase difference so as to bring about substantially exact phase opposition and complete cancellation of the currents due to any one signal is accomplished in the well-known manner by adjustment of contact 15 on phase balancer potentiometer 7.

It is apparent, therefore, that by means of my improved interference-reducing device any signal intercepted by collectors 1 and 2 can be so balanced with respect to the currents in primary 8 that no appreciable voltage corresponding to that signal is applied across receiver terminals A and G. It is equally apparent that this adjustment will be effective only against the specific signal for which it is made, and that as to the desired signal which it is sought to receive without interference there will in general be a residual voltage adequate to produce normal output from the receiver. This will be true except in the rare and fortuitous circumstance that the desired and interfering signals not only have precisely the same frequency but additionally are approaching the collectors 1 and 2 in the same direction, i. e., with parallel wave fronts.

Still referring to Fig. 1, it will be understood that signal collectors 1 and 2 are not adjustable as to their orientation and that, in general, they are preferably of non-directional types, since in carrying out my invention I do not rely in any way upon changing the orientation of either of the signal collectors. However, in the case of a point to point radio service in which continuous operation and high reliability were essential, it is apparent that directional signal collectors having their maximum efficiency in the direction of arrival of the desired signal, and so positioned as to secure a maximum phase difference for the desired signal and a minimum phase difference for the interfering signal would increase the ability of the system to discriminate against the interfering signal.

I may substitute for either of the signal collectors 1 and 2 in Fig. 1, a loop antenna. Such an arrangement is advantageous, for example, in broadcast receivers in which it is desired to include one signal collector in the receiver itself. In such an arrangement, a counterpoise or an earth return impedance may be employed as the second signal collector. Modifications of my circuit arrangement suitable for employment with a loop are illustrated in Figs. 2 and 3.

Referrring to Fig. 2, 16 is a loop and 17 is an antenna, counterpoise or earth return impedance, each of which impresses a voltage across potentiometer 18 for each signal to which they are exposed. Differential variable capacitors 19 and 20 have a single control and are so constructed that the capacitance of portion 19 increases as the capacitance of portion 20 decreases, and vice versa.

The collector system comprising loop 16, signal collector 17, potentiometer 18 and differential variable capacitors 19 and 20 is inserted in the low-potential side of the first resonant circuit of the receiver, shown as comprising inductor 21 and capacitor 22, either of which may be made variable for adjusting the circuit to resonance with the desired signal.

It will be apparent that the mode of operation of the arrangement of Fig. 2 is essentially the same as that described in connection with Fig. 1, and that by adjustment of differential variable

capacitors 19 and 20 and adjustment of potentiometer contact 23, the amplitude and phase of the signal currents developed by loop 16 and signal collector 17 for any particular interfering signal may be adjusted to be equal and opposite respectively.

Fig. 3 shows an arrangement similar to that of Fig. 2, except that a transformer is employed. In this arrangement, the first resonant circuit of the receiver comprises loop 24, secondary 25 and capacitor 26, it being understood that the circuit may be tuned to resonance by adjusting either the inductance of secondary 25 or the capacitance of capacitor 26.

In the arrangement of Fig. 3, any signal voltage generated in loop 24 produces a current in resonant circuit 24, 25 and 26, which will be a maxima when the circuit is adjusted to resonance with the frequency of the current. Coupled to secondary 25, however, there is primary 27 across which is connected potentiometer 28 in parallel with differential capacitors 29 and 30, signal collector 31 which may be an antenna, counterpoise or earth return impedance, being connected to the junction of differential variable capacitors 29 and 30.

Still referring to Fig. 3, it will be apparent that by proper adjustment of differential variable capacitors 29 and 30, and of potentiometer 28, it will be possible to cause a current to flow in primary 27, corresponding to any interfering signal which it is desired to eliminate, which will generate in secondary 25, a voltage of proper amplitude and phase to cancel the interfering-signal voltage impressed across the resonant circuit by the loop 24.

Fig. 4 shows an arrangement essentially similar to that of Fig. 3 both in its arrangement and operation, except that in Fig. 4, loop 24 of Fig. 3 is replaced by an antenna, counterpoise or earth return impedance 32, inductor 33 and capacitor 34 being appropriately chosen with respect to the characteristics of signal collector 32.

The arrangement shown in Fig. 5 employs two open signal collectors 35 and 36, collector 35 being connected to the interference-reducing network and collector 36 being connected to the first resonant circuit in the radio receiver, comprising inductor 37 and capacitor 38, in the conventional manner.

Still referring to Fig. 5, it will be apparent that primary 39 and potentiometer 40 are arranged similarly to primary 8 and potentiometer 7 in Fig. 1, and that they will operate in the same manner. Signal collector 35 is connected to the moving contact 41 of potentiometer 42, which operates to adjust the amplitude of the current in primary 39 due to a signal intercepted by collector 35 and to reverse its direction in a manner similar to that described with respect to potentiometer 6 and signal collector 2 in Fig. 1. Capacitors 43, 44, 45 and 46 are optional swamping capacitors.

Referring now to any of the figures, the operation of my interference-reducing device may include as a first step, short-circuiting the device so that the receiver may be adjusted for resonance with and maximum response to the desired signal. With the interference-reducing device in circuit the operation consists in first adjusting tandem control 13 and 14 in Fig. 1 or its equivalent in the other figures to secure as much reduction in the interfering signal as possible and, second, adjusting phase balancer in Fig. 1 or its equivalent in the other figures to produce substantially precise phase opposition with respect to the interfering signal.

It will be apparent that my improved interference-reducing device is substantially aperiodic, although as in Fig. 2 it may be inserted into the first resonant circuit of the receiver. It will also be understood that my interference-reducing device may be arranged with only one of the signal collectors connected directly to the device, the other signal collector being connected directly to the receiver as, for example, in Figs. 4 and 5.

In a specific embodiment in accordance with Fig. 1, potentiometers 5 and 6 are preferably of the linear carbon-strip type and may each have a resistance of 2,000 ohms tapped at the center and, as already noted, arranged to tandem control by a single knob. Potentiometer 7 is also preferably of the linear carbon-strip type and may have a resistance of 1,000 ohms. Resistors 3 and 4 are preferably of the fixed carbon type and may have a resistance of 1,000 ohms. Primary 8, in such an embodiment, is preferably a center-tapped universal coil and may have an inductance of 270 μh and secondary 10 is preferably also a universal coil, tightly coupled to primary 8 and may have an inductance of 340 μh. The constants just recited are for operation in the broadcast band of frequencies and represent a satisfactory compromise for substantially all of the receivers now currently available, giving a satisfactory impedance match for these receivers.

In a practical embodiment in accordance with Fig. 3, differential variable capacitors 29 and 30 may each have a minimum capacitance of 10 $\mu\mu$f and a maximum capacitance of 100 $\mu\mu$f. If the resonant circuit is to be tuned by inductance variation, the inductance of loop 24 may be 50 μh and the minimum inductance of secondary 25 may be 150 μh. Potentiometer 28 may have a resistance of 5,000 ohms. Primary 27 may have an inductance of 30 μh and is preferably tightly coupled to secondary 25.

Referring to the modification shown in Fig. 4, if the resonant circuit is to be tuned by inductance variation, secondary 33 may have an inductance of 200 μh and capacitor 47 may have a capacitance of 500 $\mu\mu$f, resistor 48 having a resistance of approximately 15,000 ohms.

Still referring to Fig. 4, it will be understood that signal collector 32 may alternatively be coupled to resonant circuit 33—34 in any of the well-known ways.

It will be understood that the constants given above for practical embodiments of the invention, in accordance with three of the figures, are intended merely to enable those skilled in the art to readily practice the invention and are not to be taken as in any way limiting the scope thereof, which is defined in the appended claims.

Having thus described my invention, what I claim is:

1. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding aranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal, including a variable resistance network for adjusting the amplitude and for de-

termining the direction of flow of said first-mentioned current.

2. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including an amplitude-adjusting potentiometer and a phase-balancing potentiometer for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

3. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including tandem-controlled amplitude-adjusting and current-reversing elements for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

4. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including tandem-controlled amplitude-adjusting and current-reversing elements and an independently-controlled phase-balancing potentiometer, for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

5. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including tandem-controlled amplitude-adjusting and current-reversing potentiometers for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

6. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including tandem-controlled amplitude-adjusting and current-reversing potentiometers and an independently-controlled phase-balancing potentiometer, for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

7. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including two tandem-controlled potentiometers with their movable contacts connected respectively to said collectors, for causing a current to flow in said winding due to a voltage generated in one of said collectors and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

8. A system for use with radio receivers having a first vacuum tube, to prevent appreciable response to an interfering signal, including a winding arranged to supply signal voltages to said first vacuum tube, two signal collectors, and aperiodic means including two tandem-controlled potentiometers with their movable contacts connected respectively to said collectors and an independently-controlled phase-balancing potentiometer for causing a current to flow in said winding due to a voltage generated in one of said collectors by said interfering signal which is equal in amplitude and opposite in phase to the current in said winding due to the voltage generated in the other of said collectors by said interfering signal.

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