July 29, 1947. I. W. CONRAD 2,424,925

NOISE REDUCTION DEVICE IN RADIO RECEIVERS

Filed Sept. 22, 1943 3 Sheets-Sheet 1

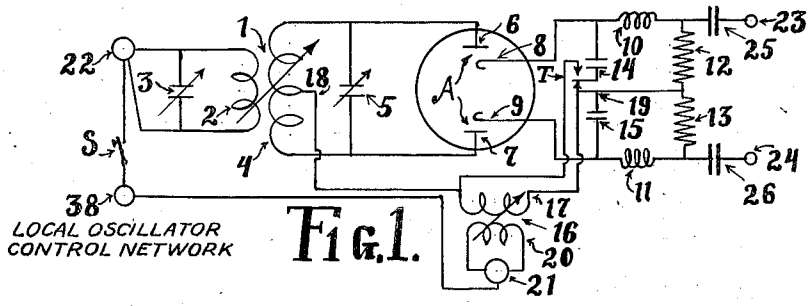


FIG. 1.

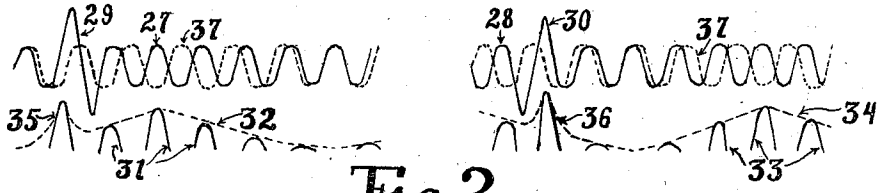


FIG. 2.

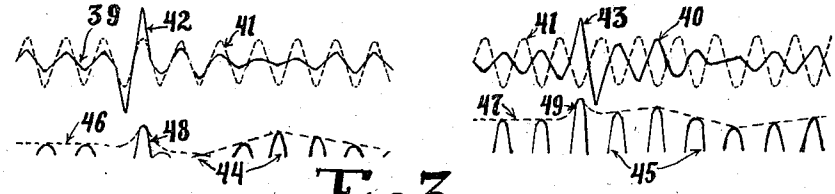


FIG. 3.

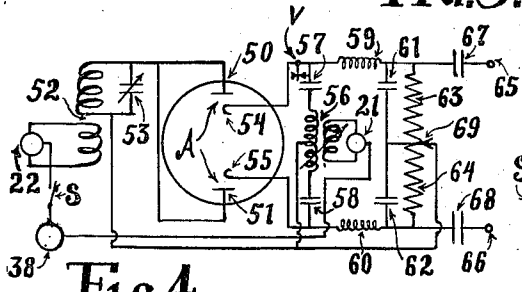


FIG. 4.

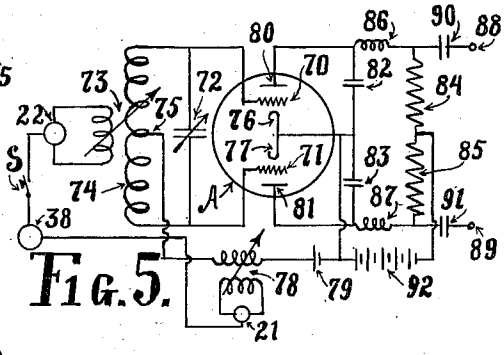


FIG. 5.

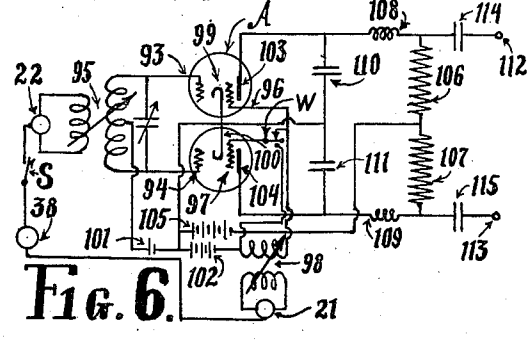


FIG. 6.

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NOISE REDUCTION DEVICE IN RADIO RECEIVERS

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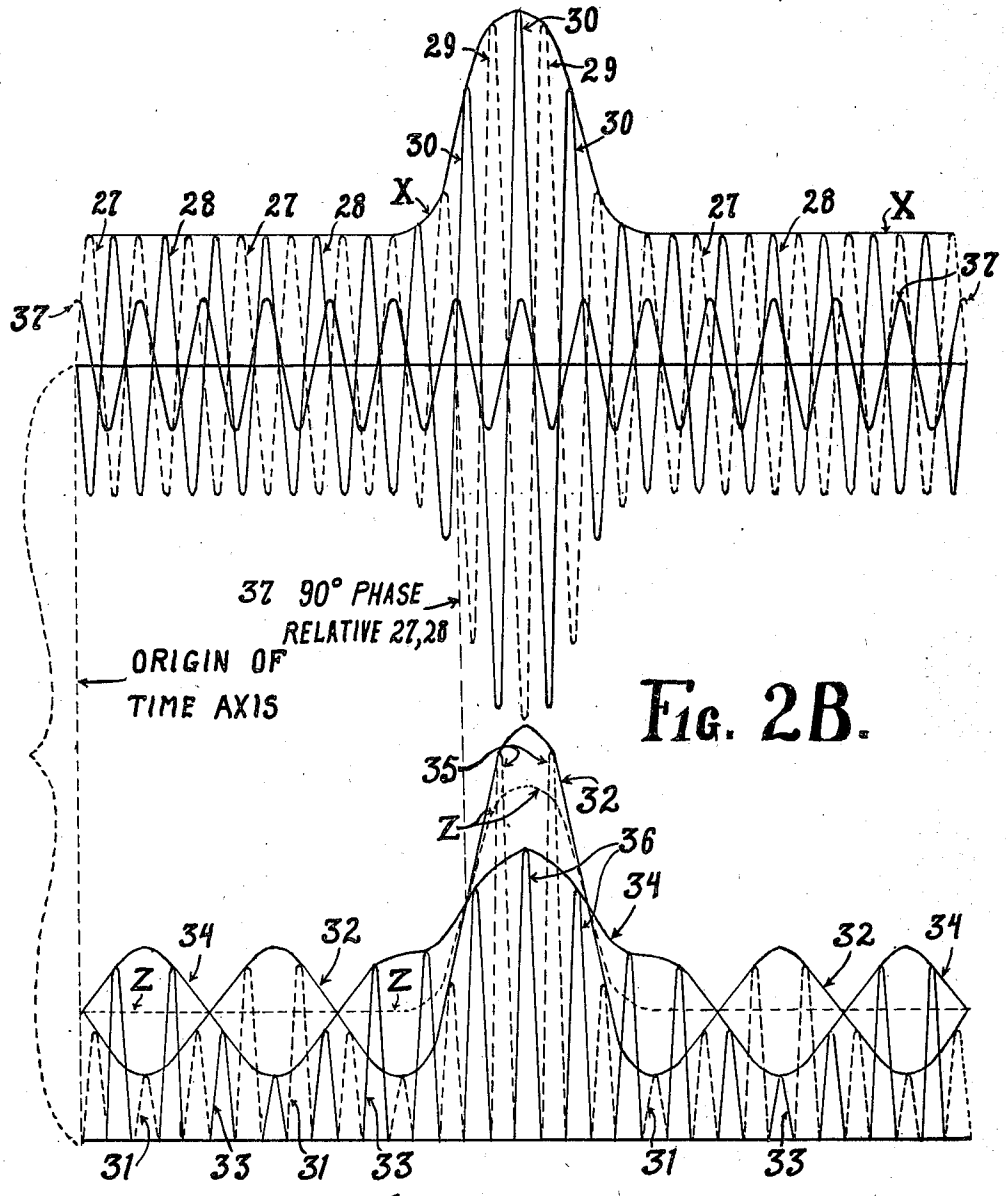


FIG. 2B.

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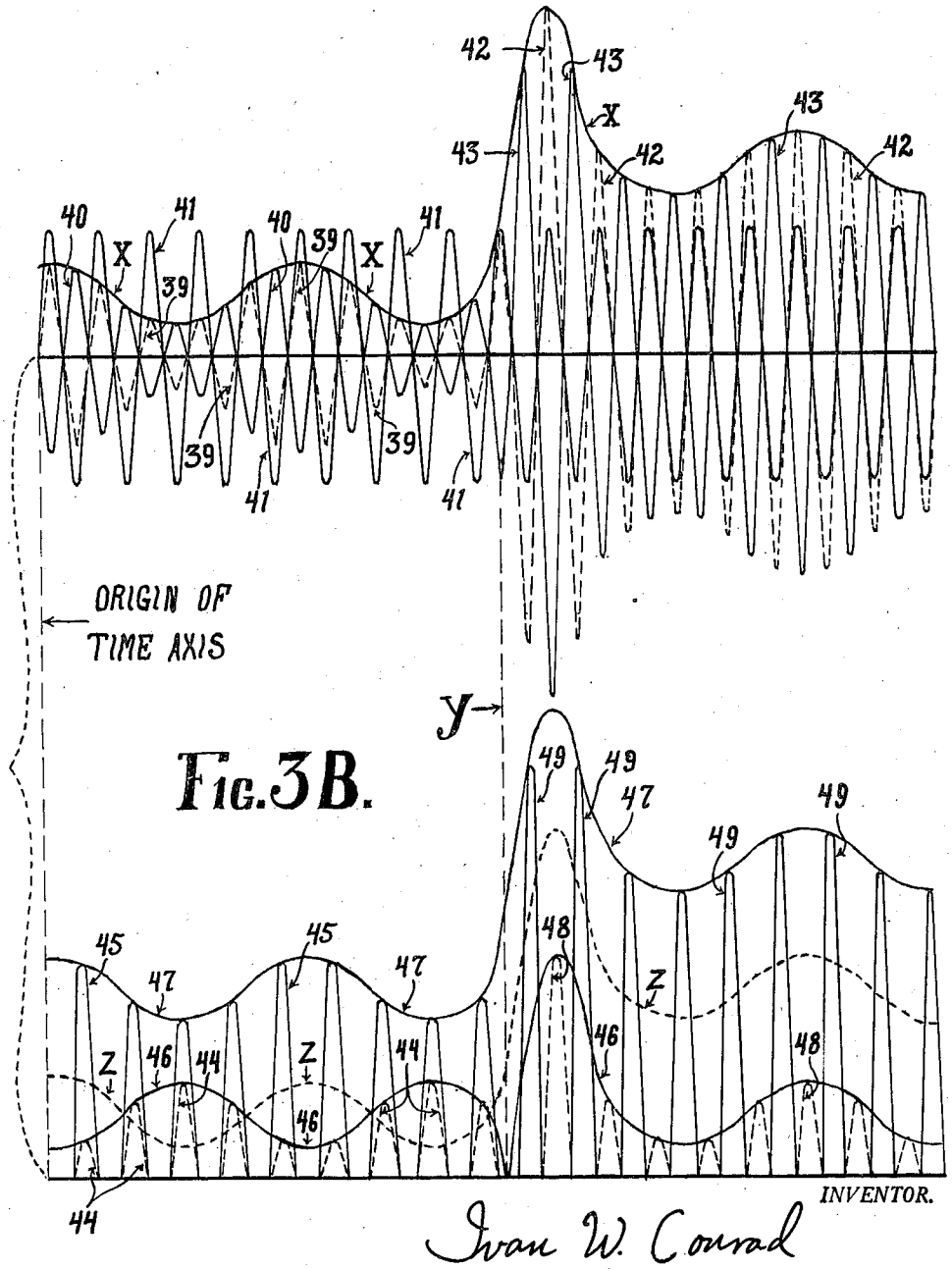


Fig. 3B.

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Patented July 29, 1947 2,424,925

UNITED STATES PATENT OFFICE

2,424,925

NOISE REDUCTION DEVICE IN RADIO RECEIVERS

Ivan W. Conrad, Alexandria, Va.

Application September 22, 1943, Serial No. 503,423

21 Claims. (Cl. 250—20)

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The present invention relates to radio reception and has for its principal object to provide relatively simple, practical means for reducing interfering electrical noise of either natural or man made origin, normally encountered in the reception of radio telegraph and radio telephone signals. Another object is to accomplish this result with equipment which can readily be added to existing radio equipment.

Essentially the invention contemplates the use for mixer or detector functions in a radio receiver, of a balanced modulator circuit in which essentially all amplitude modulation on the incoming radio signal is balanced out, except insofar as this cancellation may be made intentionally incomplete to permit desired modulation to be received. When adjusted for complete cancellation, no output signal voltage is derived from the circuit from either an incoming signal or from undesired electrical noise; if, however, the cancellation be made only partially complete, essentially all amplitude modulation components above an arbitrary, variable level may be made to balance out, while those components below this same level are passed to the output. In this manner the received signal may be freed of noise and interference components above the selected signal or modulation level.

With the foregoing general object in view the invention consists in the novel combinations and arrangements of features as will be hereinafter more fully described, illustrated in the accompanying drawings and defined in the appended claims.

In the accompanying drawings, wherein are illustrated different practical embodiments of the invention and wherein like characters of reference denote corresponding parts in related views:

Figure 1 is a diagrammatic view illustrating one practical embodiment of the invention utilizing a balanced diode rectifier.

Figures 2 and 2B are diagrammatic views illustrating the action of the circuit of Fig. 1 upon an incident mixture of noise and desired signal, when adjusted for the reception of CW or radio telegraph signals.

Figures 3 and 3B are diagrammatic views illustrating the action of the circuit of Fig. 1 upon an incident mixture of noise and a desired modulated signal, when adjusted for the reception of amplitude modulated radio telephone signals.

Figure 4 reflects diagrammatically another practical embodiment of the invention wherein the balancing voltages are derived from the same envelope of the incoming signal and noise, resulting in independence of incoming signal symmetry for the desired cancellation.

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Figure 5 is a diagrammatic view illustrating another practical embodiment of the invention utilizing triode modulator elements.

Figure 6 is a diagrammatic view reflecting still another practical embodiment wherein multi-grid modulator elements are used.

In the drawings, modulator elements are represented generally by A. Referring in detail to Fig. 1, there is shown at 1 an input radio frequency transformer, the primary 2 of which is tuned by variable condenser 3 and the secondary 4 of which is tuned by variable condenser 5 to any desired frequency. The end terminals of secondary 4 are connected respectively to diode plates 6 and 7; and the corresponding diode cathodes 8 and 9 are connected through radio frequency chokes 10 and 11 respectively to equal load impedances 12 and 13. In addition, cathodes 8 and 9 are connected respectively to the junction 19 of loads 12 and 13 by equal radio frequency by-pass condensers 14 and 15. A second radio frequency transformer is shown at 16, the secondary 17 of which is connected between center tap 18 of input transformer secondary 4 and junction 19. The primary 20 of transformer 16 is excited by radio frequency source 21, and the primary 2 of transformer 1 is excited by signal source 22. Source 22 ordinarily will be the radio frequency or intermediate frequency sections of a conventional radio receiver, but may be some other source, as for example, an antenna. Source 21 ordinarily will be a self excited local oscillator and associated phase shifting network, but may be connected as shown to source 22 through switch S and a heterodyne oscillator-limiter amplifier 38, whereby the frequency of 21 may be controlled by source 22 in a manner well known to the art, either to lock in on the identical frequency of 22, or to become operative on a slightly different frequency from 22 only when 22 is operative. With respect to center tap 18, the diode plates 6 and 7 will be excited 180° out of phase by signal source 22, whereas cathodes 8 and 9 will be excited in phase with each other by source 21. Relative excitation of plates 6 and 7 may be varied by varying the coupling between primary 2 and the corresponding halves of center tapped secondary 4 to secure the desired degree of balance. Excitation of cathodes 8 and 9 may be varied by varying the coupling between primary 20 and secondary 17. Output voltage is taken between terminals 23 and 24 connected to loads 12 and 13 respectively through equal coupling condensers 25 and 26. At

T is shown a single-pole double-throw switch which, when thrown to the other position, removes the excitation by source 21 from one of the cathodes 8.

The action of the circuit of Fig. 1 is best visualized by plotting voltages and currents at various critical points, and in Figs. 2 and 2B this has been done diagrammatically for the conditions under which the circuit of Fig. 1 is suited for the detection and reception of radio telegraph signals. Referring to Figs. 2 and 2B, which are related to Fig. 1, there is represented by line 27 the signal voltage from source 22 on diode plate 6 (Fig. 1) and by solid line 28 the signal voltage on diode plate 7 (Fig. 1). In general these lines represent a uniform sine wave signal; however, at 29 and 30 are shown the effects of a modulation peak of interference or static. The envelope of the signal from 22 is shown as X in Fig. 2B. Line 37 represents the voltage on cathodes 8 and 9 (Fig. 1) resulting from source 21, operating on a frequency slightly different from the signal frequency of 22. Lines 31 represent the resulting pulses of current through cathode 8, and the effective envelope of these pulses appears as a potential at terminal 23 by virtue of the action of load 12. This envelope is shown in Figs. 2 and 2B diagrammatically as line 32. Similarly, lines 33 represent the resultant pulses of current through cathode 9 and the effective envelope 34 of these pulses appears as a potential at terminal 24. Since these envelopes are 180° out of phase, it is thus apparent that an alternating electromotive force appears between points 23 and 24, the frequency of which is the familiar "beat" or difference frequency between the frequencies of sources 22 and 21. However, it is equally apparent that as a result of signal peaks 29 and 30 respectively, at 35 and 36 peaks occur, the envelopes of which are in phase with each other, and which therefore, tend to cancel when measured between points 23 and 24. Cancellation will be most nearly complete during the periods when a 90° phase difference exists between excitation from sources 21 and 22 as may be seen by reference to Fig. 2B, where it will be noted that envelopes 32 and 34 cross each other (i. e., have equal values and therefore cancel completely) at those points where such a 90° phase difference exists between cathode excitation 37 and diode plate excitation curves 27, 28. This is further shown in the mathematical discussion hereinafter set forth.

The net effect of the circuit shown in Fig. 1, then, under the conditions imposed, is to produce a heterodyne frequency between terminals 23 and 24, while effectively cancelling all incoming signal modulation effects from source 22 that exceed an arbitrary level. That this arbitrary level is determined by the amplitude of the excitation from source 21, may be seen by letting the amplitude of 37 in Figs. 2 and 2B diminish, approaching zero. The amplitudes of envelopes 32 and 34 vary accordingly, approaching each other as adjacent pulses 31 and 33 become more and more nearly equal and as adjacent peaks 35 and 36 become more and more nearly identical in amplitude (height), with essentially complete cancellation occurring. Under the conditions described, therefore, the circuit of Fig. 1 is suitable for the reception of radio telegraph signals, with a high degree of noise rejection.

A still higher degree of readability of radio telegraph signals is obtained by deriving source 21 from the radio telegraph signal source 22 through heterodyne of source 22 with an auxiliary limiter-oscillator 38 in such a manner that the frequency of source 21 again is slightly different from that of source 22. Thus source 21 will operate to unbalance the modulator circuit, only when 22 is producing a signal. For the intervals between marking signals of the telegraph code characters, the modulator circuit will be completely balanced, and the resultant noise in these intervals is less than when the cathodes 8 and 9 are excited continuously. The result is a more clear cut distinction between marking and spacing intervals, and is correspondingly easier to read.

From examination of Figs. 2 and 2B, it will be further apparent that the excitation from source 21 may be applied to cathode 8 or cathode 9 singly, rather than to both, with essentially the same result, with the exception that only one envelope 32 or 34 will be effective in producing the desired beat note. The other envelope degenerates into a steady potential, except as it is affected by modulation peaks on the incoming signal from source 22, i. e., it becomes the envelope of the original signal from source 22 as shown at Z in Fig. 2B. Cancellation of excessive modulation effects, therefore, occurs as before. For example, if switch T in Fig. 1 be thrown to the other position, excitation by source 21 will be removed from cathode 8 and thus only cathode 9 will be excited. In this event, diode 6, 8 acts as an ordinary detector, and the potential across load resistor 12 will then follow the envelope X of the original signal from 22, as shown at Z; i. e., envelope 32 becomes envelope Z. Since excitation is still on cathode 9, envelope 34 remains unchanged. Thus the potential difference between points 23 and 24 now reflects the difference between envelope Z and envelope 34, which, as shown in Fig. 2B, still reproduces the "beat" note, and still substantially cancels modulation peaks of noise and interference.

In Figs. 3 and 3B which are also related to Fig. 1, there is represented diagrammatically the action of the circuit shown in Fig. 1, upon an incoming amplitude modulated radio signal from source 22 when the frequency of source 21 is locked in synchronism with source 22 and is either 0° or 180° out of phase with 22. The line 39 reflects the modulated signal potential on diode plate 6 (Fig. 1); the solid line 40 reflects the modulated signal potential on diode plate 7 (Fig. 1) and the line 41 reflects the potential on cathodes 8 and 9 (Fig. 1) produced by source 21. At 42 and 43 are shown the potentials produced on plates 6 and 7 respectively by an interference noise pulse. The envelope of the original signal from 22 is represented by line X in Fig. 3B. At 44 and 45 are shown the resulting pulses of cathode current from cathodes 8 and 9 respectively. The effective envelopes of these pulses shown as 46 and 47 appear at terminals 23 and 24 (Fig. 1), respectively, as potentials through the action of loads 12 and 13. From inspection of the envelopes 46 and 47, it is evident that they follow the original signal modulation envelope X and are 180° out of phase with each other, so long as the signal modulation peaks do not exceed in amplitude the amplitude of cathode potential 41. However, it is further apparent as shown by peaks 48 and 49, that when the signal modulation peaks 42 and 43 exceed the amplitude of cathode potential 41, the envelopes 46 and 47 of resulting cathode pulses 48 and 49 respectively are in phase with each other and therefore tend to cancel each other when measured as a potential difference

between terminals 23 and 24. Therefore, the effect of the circuit shown in Fig. 1 upon an amplitude modulated signal from source 22 under the conditions stated is to produce between output terminals 23 and 24 a potential difference which accurately follows the original signal modulation envelope up to the point where the modulation peaks equal in amplitude the cathode excitation potential derived from source 21; and to effectively cancel all modulation above that point. Phase reversal of envelope 46 may be seen to occur at point Y where the amplitude of the signal X from 22 becomes equal to that, 41, from source 21.

From the foregoing discussion and reference to Figs. 1 thru 3, it will be apparent to those skilled in the art that the excitation from source 21 may be applied to cathode 8 alone rather than to both 8 and 9, as for example by a switch arrangement similar to that shown at T in Fig. 1, but connected to cathode 9 instead of 8, with essentially the same result under the phase relations shown. In this case, potential 41 vanishes for cathode 9; i. e., diode 7, 9 then acts as an ordinary detector, the output of which follows the impressed modulation envelope as shown at Z in Fig. 3B, the phase relation of which in regard to envelope 46 is identical to that of 47. However, it is not possible to excite cathode 9 only under the phase relation shown, because to do so would result in the inversion of envelope 46, that is, envelope 46 would then become envelope Z, so that both envelopes 46 and 47 would be completely in phase and would cancel each other for all modulation values.

In the embodiment reflected by Figs. 1, 2, 2B, 3, and 3B, rectification or "detection" of opposite half cycles of the incoming signal has been utilized to furnish opposing potentials which are so added as to cancel modulation effects above an arbitrary, variable value. Obviously, the completeness of cancellation is partially dependent on the symmetry of such opposite half cycles for equivalent opposing potentials, and any non symmetrical excursions of the incoming signal will result in an uncancelled potential between output terminals 23 and 24.

This dependence upon the symmetry of the incoming signal is avoided in the embodiment shown in Fig. 4 where the input signal from source 22 is impressed on diode plates 50 and 51 in the same phase thru the agency of a radio frequency transformer 52, and associated tuning condenser 53. Cathodes 54 and 55 are excited 180° out of phase from source 21 through the agency of transformer 56 and coupling condensers 57 and 58. Cathodes 54 and 55 are also coupled through radio frequency chokes 59 and 60 to equal radio frequency bypass condensers 61 and 62 respectively and to essentially equal load impedances 63 and 64 respectively. Output is taken from terminals 65 and 66 through coupling condensers 67 and 68.

With the circuit of Fig. 4, therefore, since both plates 50 and 51 are driven positive by identical half cycles of the signal from source 22, exactly the same modulation and noise components will affect each, and under conditions of no excitation from source 21, complete cancellation of all modulation effects may be obtained by balancing variable adjustment 69 to produce equal voltage drops across loads 63 and 64. If, now, cathodes 54 and 55 are excited by source 21 at a frequency slightly different from that of signal source 22, the modulation products or beat frequencies will appear as potential differences between 65 and 66, with complete cancellation of all signal modulation peaks above an arbitrary level, determined by the amplitude of the excitation from source 21, in a manner very similar to that described above for the operation of the circuit of Fig. 1. Under the conditions indicated, therefore, the circuit of Fig. 4 is suited for the reception of radio telegraph signals, and as in the case of the circuit of Fig. 1, the effectiveness may be increased to some extent by making source 21 operative only when actuated by source 22 through the agency of a heterodyne oscillator 38, as described under the operation of the circuit of Fig. 1.

Likewise, in a manner analogous to that explained for the circuit of Fig. 1 and graphically represented in Figs. 3 and 3B, the circuit of Fig. 4 may also be adapted to the reception of radio telephone signals by synchronizing local source 21 with signal source 22, and applying the excitation from source 21 to cathodes 54 and 55 in either 0° or 180° phase difference with the excitation on plates 50 and 51 from signal source 22. Under these conditions the amplitude modulation envelope of the signal from source 22 will be recovered as a potential difference between terminals 65 and 66, up to the point where the modulation peaks exceed the amplitude of the excitation of cathodes 54 and 55 from source 21. Above this point, the amplitude modulation envelope of the signal from source 22 will be essentially balanced out.

Again, as in the case of the circuit of Fig. 1, the desired effect may also be obtained by applying the excitation from source 21 to a single cathode rather than to both 54 and 55 as for example by opening switch V in Fig. 4. For radio telephone operation, the excited cathode must be in phase with its corresponding diode plate.

Application of the principle of the invention is not limited to diode detection or rectification, and, accordingly, in Fig. 5 is illustrated diagrammatically a practical embodiment of the invention wherein the excitation from signal source 22 is applied through a radio frequency transformer 73 to the control grids 70 and 71 of a balanced dual triode circuit. With respect to the center tap 75 of transformer secondary 74, grids 70 and 71 are driven 180° out of phase by source 22, and cathodes 76 and 77 are driven in phase with each other by local frequency source 21 through the agency of transformer 78. Variable condenser 72 serves to tune secondary 74 to the desired signal frequency of source 22. Grids 70 and 71 normally are biased essentially to cut off by potential source 79. Plates 80 and 81 are by-passed to cathodes 76 and 77 by equal condensers 82 and 83 respectively, and are coupled to essentially equal load impedances 84 and 85 through radio frequency chokes 86 and 87 respectively. Output is derived as potential difference between terminals 88 and 89 through coupling condensers 90 and 91. Plates 80 and 81 are made positive with respect to cathodes 76 and 77 by potential source 92. Under conditions of no excitation from source 21, and equal excitation on grids 70 and 71 from source 22, it will be apparent that no symmetrical modulation products will appear between points 88 and 89. Plate current will flow through both loads 84 and 85, but under the conditions stated, they will be opposed in voltage effect and thereby cancel between points 88 and 89. Upon adding excitation from source 21, when 21 is slightly different in frequency from that of source 22, modulation prod-

ucts between the frequencies of source 21 and source 22 will appear between the output terminals 88 and 89; however, all signal modulation peak envelopes existing on the signal from source 22 and exceeding the level determined by the the amplitude of the excitation from source 21, again will remain cancelled, since they necessarily will be in phase with each other, and are added in opposition. Under the conditions described, therefore the circuit of Fig. 5, is suitable for the reception of radio telegraph signals, with a high degree of incoming noise rejection, and as before, the effectiveness of the signal reception may be improved by making source 21 operative only when actuated by source 22 through the agency of a heterodyne oscillator 38.

From the above discussion of the principle of the invention, it is believed that it will now be apparent to those skilled in the art that by synchronizing the frequency of local source 21 with signal source 22, and by applying the excitation from source 21 to cathodes 76 and 77, 180° out of phase with the signal source 22 excitation of grids 70 or 71, all amplitude modulation on the signal from 22 which lies below an arbitrary level determined by the amplitude of the excitation from source 21 will be recovered between terminals 88 and 89; and that essentially all signal modulation above this same arbitrary level will be balanced out in a manner analogous to that explained for the circuit of Fig. 1 and graphically represented in Figs. 3 and 3B. Under these conditions, the circuit of Fig. 5 is suitable for the reception of radio telephone signals.

Alternatively, it is to be noted that grids 70 and 71 of Fig. 5, rather than being excited 180° out of phase with each other by source 22 as shown, may be excited in phase, and that upon exciting cathodes 76 and 77 180° out of phase with each other from source 21, the action resulting will be essentially the same as for the circuit shown in Fig. 5, except that the balancing potentials across the output terminals are then derived from identical half cycles of the signal from source 22 and therefore do not depend upon the symmetry of the modulation existing on this signal from 22 for equivalence and perfection of cancellation.

Since the principle of the invention involved in the circuit of Fig. 5 is inherently similar to that of Fig. 1 and Fig. 2, it will be observed that again, one of the cathodes 76 or 77 may be excited alone by source 21 to produce the desired result, and it is not necessary that both cathodes be excited.

In Fig. 6 there is illustrated diagrammatically still another embodiment of the invention wherein multi-element tubes are employed as modulating units. As before, 22 again denotes a signal source and 21 a local source capable of control by means of heterodyne oscillator 38. The signal from source 22 is applied in push-pull, (180° out of phase) to grids 93 and 94 through radio frequency transformer 95. The signal from source 21 is applied to another set of grids 96 and 97 in phase through radio frequency transformer 98. With respect to cathodes 99 and 100, grids 93 and 94 are normally biased essentially to negative cut-off by means of potential source 101, and grids 96 and 97 are maintained positive by means of potential source 102. Plates 103 and 104 are maintained positive with respect to cathodes 99 and 100 by means of potential source 105 acting through equal load impedances 106 and 107 and then radio frequency chokes 108 and 109 respectively. Plates 103 and 104 are also bypassed to cathodes 99 and 100 by radio frequency bypass condensers 110 and 111. Output is taken between terminals 112 and 113 through coupling condensers 114 and 115 respectively. Under conditions of no excitation from source 21, equal and opposite voltages will be produced across loads 106 and 107, corresponding to the amplitude modulation envelopes recovered from the positive excursions of grids 93 and 94 respectively under excitation from source 22. Therefore, essentially no modulation products will be produced between points 112 and 113 except those which result from non symmetrical excursions of grids 93 and 94. If now, grids 96 and 97 are excited by source 21 at a frequency slightly different from that of source 22, the heterodyne or beat frequency will appear as a modulation product between points 112 and 113. And in a manner analogous to that discussed above for Figs. 1, 4, and 5, amplitude modulation peaks on the signal from source 22, if they exceed in their effect on the plate current through loads 106 and 107, the excursions of grids 96 and 97 on such plate current, the resulting plate currents will be in phase and since added in opposition, will balance out. Thus, under the conditions named, the circuit of Fig. 6 will automatically reject noise peaks above an arbitrary level, while passing the heterodyne or beat note required for radio telegraph signal reception.

Alternatively, by synchronizing source 21 with source 22 and exciting grids 96 and 97 in phase (0° phase difference) with either grid 93 or 94, through action analogous to that illustrated in Figs. 3 and 3B, all amplitude modulation existing on the signal from source 22, which does not exceed in effective amplitude an arbitrary level determined by the excitation from source 21, will appear as a potential difference between points 112 and 113; whereas, all amplitude modulation on the signal from 22 which exceeds this level will cancel out between points 112 and 113. Under these latter conditions, then, the circuit of Fig. 6 is suitable for the reception of amplitude modulated signals from source 22, and provides cancellation of noise peaks or pulses which are in excess of any desired level.

Again, it is to be noted that as in the preceding embodiments, grids 93 and 94 may be excited in phase from source 22, and upon exciting grids 96 and 97 180° out of phase with each other from source 21, similar results will be obtained to those indicated for Fig. 6 circuit. However, the effect of exciting grids 93 and 94 in phase is to derive the opposing modulation envelopes appearing across loads 106 and 107 from the same positive excursions of grids 93 and 94, and thereby to render the noise cancellation independent of the symmetry of signal modulation from source 22.

It is further to be observed that in Fig. 6, if the excitation from source 21 is applied to either grid 96 or 97 singly rather than to both, as for example by throwing switch W to the other position, essentially the same result will be obtained between terminals 112 and 113, provided that for radio telephone reception, source 21 be properly phased relative to source 22; i. e., the grid driven by source 21 must be 180° out of phase with the corresponding grid driven by source 22.

Application of the principle of the invention is not restricted to the use of electronic tubes as balanced modulator elements, indicated in the drawings generally by A. Any modulating device capable of combining the signals from sources 21

and 22 to form a modulation product in its output may be used, as for example, any of the various mineral "detectors," well known in the art.

In general mathematical form, if the signal from source 22 is represented by:

$$c \sin 2\pi Nt$$

where

c is the amplitude of this signal
N is the frequency of this signal
t is time parameter

and if the excitation from source 21 is represented by:

$$b \sin 2\pi nt$$

where

b is the amplitude of excitation
n is the frequency of excitation
t is time parameter

then the necessary and sufficient conditions of the invention will be met if, first, the respective currents I_x and I_y through the two load impedances (e. g. 12, 13; 63, 64; 84, 85; 106, 107) of a balanced modulator system in a radio receiver can be represented (neglecting harmonic and high order terms) by functional expressions of the type:

$$I_x = F(2\pi Nt, 2\pi nt) - c \sin 2\pi Nt \sin 2\pi nt$$
$$I_y = F(2\pi Nt, 2\pi nt) - c \sin 2\pi Nt \sin 2\pi nt$$

when b is greater than c and

$$I_x = f(2\pi Nt, 2\pi nt) - b \sin 2\pi Nt \sin 2\pi nt$$
$$I_y = f(2\pi Nt, 2\pi nt) - b \sin 2\pi Nt \sin 2\pi nt$$

when c is greater than b and if, second, the output voltage E_0 be derived from these currents in opposition so that:

$$E_0 = k(I_y - I_x) = 2ck \sin 2\pi Nt \sin 2\pi nt$$
$$= ck \cos [2\pi(N-n)t] - ck \cos [2\pi(N-n)t]$$

when b is greater than c, and where k is a proportionality constant and

$$E_0 = k(I_y - I_x) = 2kb \sin 2\pi Nt \sin 2\pi nt$$
$$= kb \cos [2\pi(N-n)t] - kb \cos [2\pi(N-n)t]$$

when c is greater than b, and where k is a proportionality constant and if, third, b is maintained at a value to limit the output modulation product to a non-reception disruptive value of amplitude, whereby undesired modulation product peaks in excess of such limiting value are substantially eliminated.

In the event an initial phase difference of value θ exists between the signals from source 21 and source 22, the expressions for E_0 shown above become:

$$E_0 = ck \cos [2\pi(N-n)t + \theta] - ck \cos [2\pi(N+n)t + \theta]$$

and

$$E_0 = kb \cos [2\pi(N-n)t + \theta] - kb \cos [2\pi(N+n)t + \theta]$$

respectively.

From these equations, it is seen that when the amplitude c of the incoming signal from source 22 is less than the amplitude b of excitation from source 21, a beat frequency of amplitude ck will be present in the output; it is also apparent that if a peak of noise causes amplitude c to exceed amplitude b, the output voltage is limited by the magnitude of b and is independent of c. This is the condition for reception of radio telegraph signals. It is further apparent from the above

equations that at the beginning of each train of incoming waves $t=0$, and if the frequency $N+n$ is filtered out, as for example by condensers 14 and 15 in Fig. 1, then the expressions for E_0 become:

$$E_0 = ck \cos \theta$$

and

$$E_0 = kb \cos \theta$$

respectively. If then, in addition, the initial phase difference θ be made equal to 90°, the expressions for E_0 vanish. That is, if an initial phase difference of 90° be present between the signals from source 21 and source 22, the output is substantially zero regardless of the values of amplitudes b and c, until such time as the expression $2\pi(N-n)t$ has reached a value substantially greater than zero.

For the reception of radio telephone signals, frequencies N and n become identical; $N-n=0$; and the frequency $N+n$ is filtered out by radio frequency by-pass condensers (for example, by condensers 14 and 15 in Fig. 1). Therefore when the initial phase difference θ is equal to 0° or 180°, $E_0=ck$ when b is greater than c, and now since amplitude c is fluctuating because of the amplitude modulation impressed on it in radio telephone transmission, it is apparent that this same modulation will appear in E_0 and the signal will be "detected" or received. As soon, however, as the amplitude c of source 22 exceeds the amplitude b of excitation from source 21, then $E_0=bk$; that is, the output voltage is limited by the amplitude b of source 21 and the modulation of amplitude c disappears above this level. It is also noted that under the conditions where $N=n$, if the initial phase difference θ is equal to 90°, E_0 becomes zero for all values of amplitudes b and c; i. e., all modulation is cancelled out. For values of θ intermediate between 0° and 90°, the modulation of c will be recovered, but will be more reduced in amplitude as θ approaches 90°.

The mathematical steps in the above description are familiar to those skilled in the art; however, it is noted that a mathematical statement of the fundamental relations involved in amplitude modulation may be found in "Frequency Modulation," pages 1 thru 9, by August Hund; and further, the derivation of the sum and difference frequencies from a product of the two parent frequencies may be found in any standard trigonometry book, as for example on page 57 of "Elements of Plane and Spherical Trigonometry" by Dr. D. A. Rothrock.

While only certain specific embodiments of the invention have been illustrated and described to convey the general concept of the invention, it is to be understood that the same is readily capable of various other embodiments within its spirit and scope as defined in the appended claims. It is further to be understood that although intended primarily for radio wave reception, the present invention is equally applicable to the reception of any electrical wave disturbances, as, for example, any of the various carrier systems now in communications use.

I claim:

1. In an electrical wave receiving system, means for receiving signal and noise waves, means for generating local electrical waves, balanced modulator means interconnected with and responsive to excitation from both of said first-named means to produce combinational waves, means constantly limiting the amplitude of the local waves applied to said balanced modulator means to a value lower than that of reception-disruptive

components of said signal and noise waves, thereby constantly to limit the amplitude of said combinational waves to a value proportional to the value of the local waves applied to the modulator means, and selective means acting on said combinational waves to segregate the desired ones thereof.

2. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises two or more balanced modulator elements for the production of said combinational waves.

3. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises balanced rectifier-modulator elements for the production of said combinational waves.

4. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises balanced diode electronic rectifier elements for the production of said combinational waves.

5. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises balanced multi-element electronic tubes as modulator elements for the production of said combinational waves.

6. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises at least two balanced modulator elements; and in which the received signal and noise waves are applied to said modulator elements in the same phase for the production of said combinational waves.

7. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises at least two balanced modulator elements; and in which excitation from the local electrical wave source acts on only one of said modulator elements for the production of said combinational waves.

8. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises at least two balanced modulator elements; and in which the local electrical wave source acting on said modulator elements is interconnected with the said signal wave receiving means and is actuated only by the presence of said received signal waves.

9. An electrical wave receiving system as set forth in claim 1 in which the balanced modulator means comprises at least two balanced modulator elements; and in which the local electrical wave source acting on said modulator elements is interconnected with the said signal and noise wave receiving means to produce an initial phase difference of 90° between said received waves and the excitation from said local source upon the beginning of each new received wave train.

10. An electrical wave receiving system as set forth in claim 1 in which the local source of electrical wave energy is operated at the same frequency as one component of said received signal waves to produce the said combinational waves.

11. In an electrical wave receiving system, means for generating a local electrical wave substantially of the form $b \sin 2\pi nt$, where b is the amplitude of the local wave, n is the frequency of the local wave, and t is time parameter; means for receiving signal and noise waves, said signal and noise waves being generally represented by one or more expressions of the type $c \sin 2\pi Nt$, where c is the instantaneous amplitude of said waves, N is frequency of said waves, and t is time parameter; balanced modulator means interconnected with and responsive to excitation from both of said first-named means to produce modulation-product waves of the general form

$$2b \sin 2\pi nt \sin 2\pi Nt$$

when c is greater than b, and of the general form $2c \sin 2\pi nt \sin 2\pi Nt$ when b is greater than c; means constantly limiting the amplitude b to a value lower than reception disruptive values of c, thereby substantially to eliminate reception disruptive components of said modulation product waves, and selective means acting on said modulation product waves to segregate the desired ones thereof.

12. An electrical wave receiving system as set forth in claim 11 in which the balanced modulator means comprises balanced rectifier elements for the production of said modulation product waves.

13. An electrical wave receiving system as set forth in claim 11 in which the balanced modulator means comprises balanced diode electronic rectifier tubes for the production of said modulation product waves.

14. An electrical wave receiving system as set forth in claim 11 in which the balanced modulator means comprises balanced multi-element electronic tubes for the production of said modulation product waves.

15. An electrical wave receiving system as set forth in claim 11 in which the balanced modulator means comprises at least two balanced modulator elements; and in which the said received signal and noise waves are applied to said modulator elements in the same phase for the production of said modulation product waves.

16. An electrical wave receiving system as set forth in claim 11 in which the balanced modulator means comprises at least two balanced modulator elements; and in which excitation from the local electrical wave source acts on only one of said modulator elements for the production of said modulation product waves.

17. An electrical wave receiving system as set forth in claim 11 in which the local electrical wave source is inter-connected with the said signal and noise wave receiving means and is actuated only during presence of said received waves to produce said modulation product waves.

18. An electrical wave receiving system as set forth in claim 11 in which the local electrical wave source is inter-connected with the said signal and noise wave receiving means, whereby said received waves actuate the local source only during the presence of said received waves, and whereby an initial phase difference of 90° is produced between said received waves and the excitation from said local source by the beginning of each new received electrical wave train.

19. An electrical wave receiving system as set forth in claim 11 in which the frequency n of the local source of electrical wave energy is made equal to the frequency N of the said received signal and noise waves for the production of modulation product waves which may be represented by expressions of the general type $c(1-\cos 4\pi Nt)$ when c is less than b; and $b(1-\cos 4\pi Nt)$ when c is greater than b.

20. In a radio signal receiving system, means for receiving radio signal and noise waves; means for generating local radio waves; balanced modulator means interconnected with and responsive to excitation from both of said first named means to produce combinational waves; means constantly limiting the amplitude of the local waves applied to said balanced modulator means to a

value lower than that of reception-disruptive components of said signal and noise waves, thereby constantly and substantially to eliminate reception-disruptive components in said combinational waves; and selective means acting on said combinational waves to segregate the lower frequency ones thereof.

21. In an electrical wave-receiving system, a tuned receiving circuit for receiving signal and noise waves, balanced modulator means comprising two modulator elements each having input and output circuits, connections between said tuned receiving circuit and the input circuit of each of said modulator elements, a source of locally generated electrical waves, means for applying said locally generated waves to each of said modulator elements, means constantly limiting the amplitude of said local waves applied to said balanced modulator means to a value lower than that of reception-disruptive components of said signal and noise waves, and an output system differentially connected to the output circuits of said modulator elements.

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Certificate of Correction

Patent No. 2,424,925. July 29, 1947.

IVAN W. CONRAD

It is hereby certified that error appears in the above numbered patent requiring correction as follows: In the drawing, Figure 4 should appear as shown below instead of as shown in the patent—

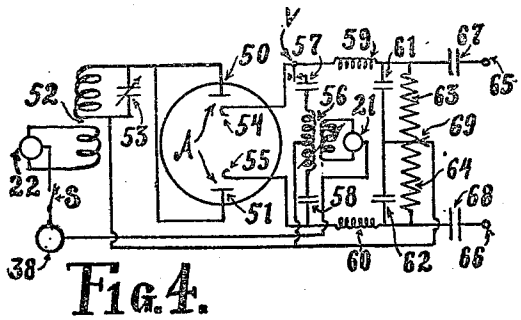


Fig. 4.

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of November, A. D. 1947.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.