

[54] IMPULSE NOISE REDUCTION CIRCUIT

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[58] Field of Search..... 250/20.54; 328/165; 325/474, 475, 476

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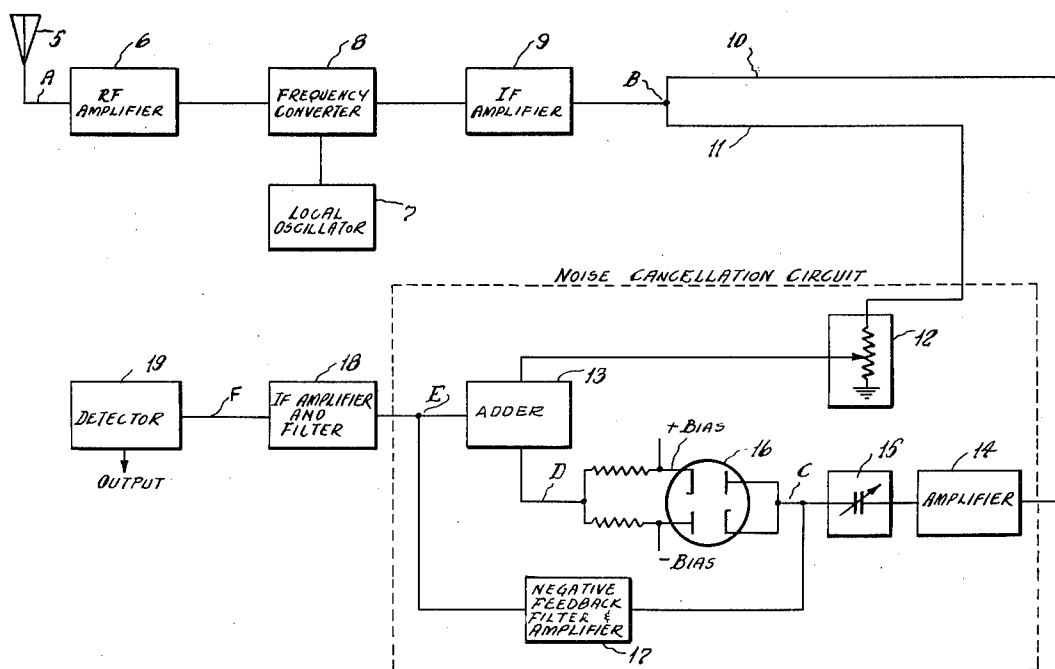
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EXEMPLARY CLAIM

1. In a radio receiver located at some distance from a transmitter emitting signal intelligence which is attenuated and may encounter and combine with atmospheric impulse noise along the transmission path between said receiver and transmitter so that both said signal intelligence and said impulse noise will be coincidentally received by said radio receiver as electromagnetic energy, an improved circuit for reducing the noise component of the received signal comprising separate electrically conductive paths, means for dividing said received electromagnetic energy and means for coupling said divided energy into two of said paths respectively, first of said paths having therein as part of said path phase inversion means for phase inversion of said signal passing along said path, amplitude dependent conduction means wherein said signal intelligence is removed from said electromagnetic energy in said first path, and having also in said first path amplitude adder means, a second path having as part thereof said amplitude adder means, whereby said signal passing along said first path which has been phase inverted and said impulse noise in said second path are combined in and the resultant output of said amplitude adder means is substantially signal intelligence, a third path having therein as a part thereof negative feedback means, said third path shunting said amplitude adder means and said amplitude dependent conduction means whereby the signal intelligence in said first path will be further reduced by the negative signal intelligence feedback.

11 Claims, 4 Drawing Figures



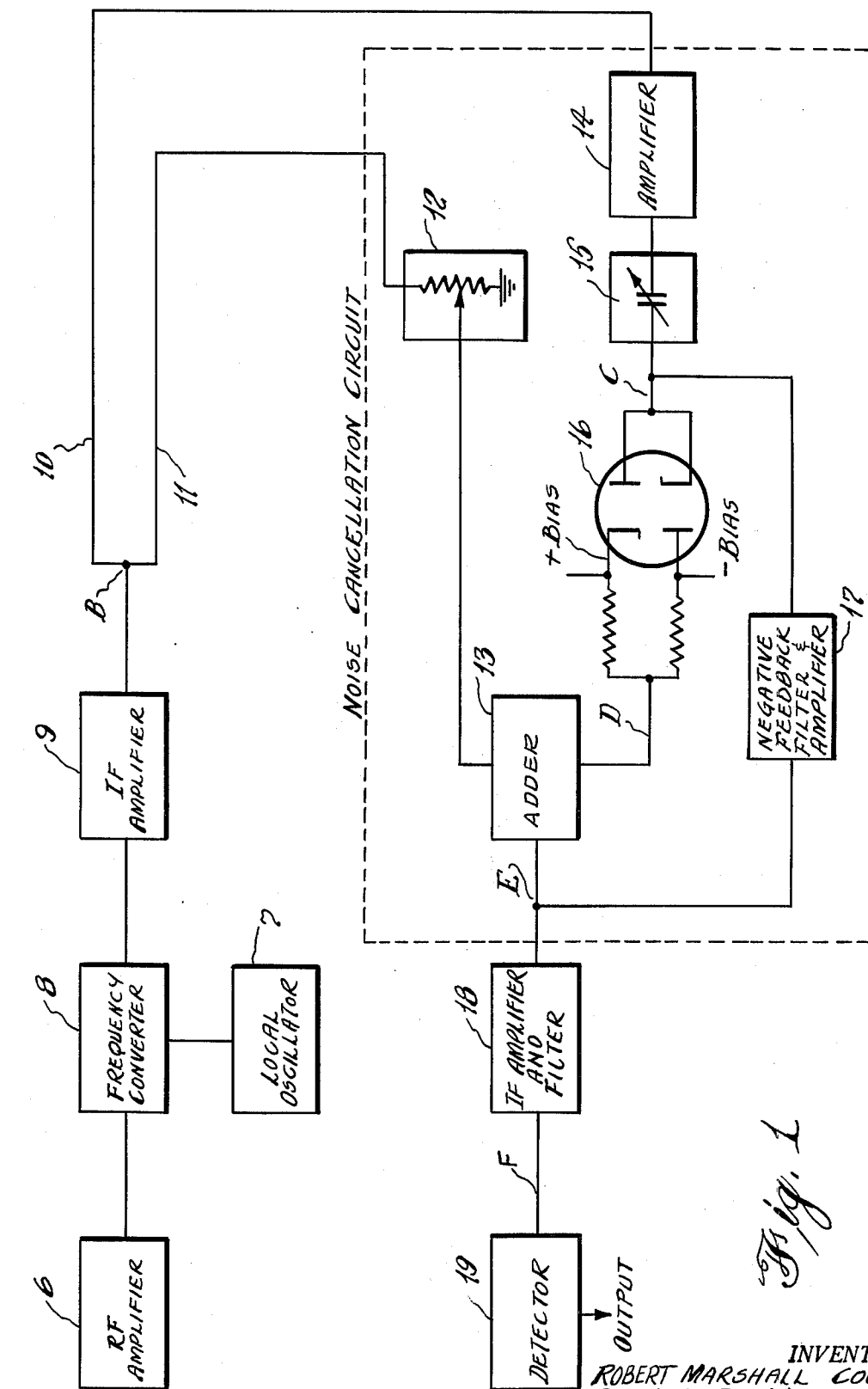
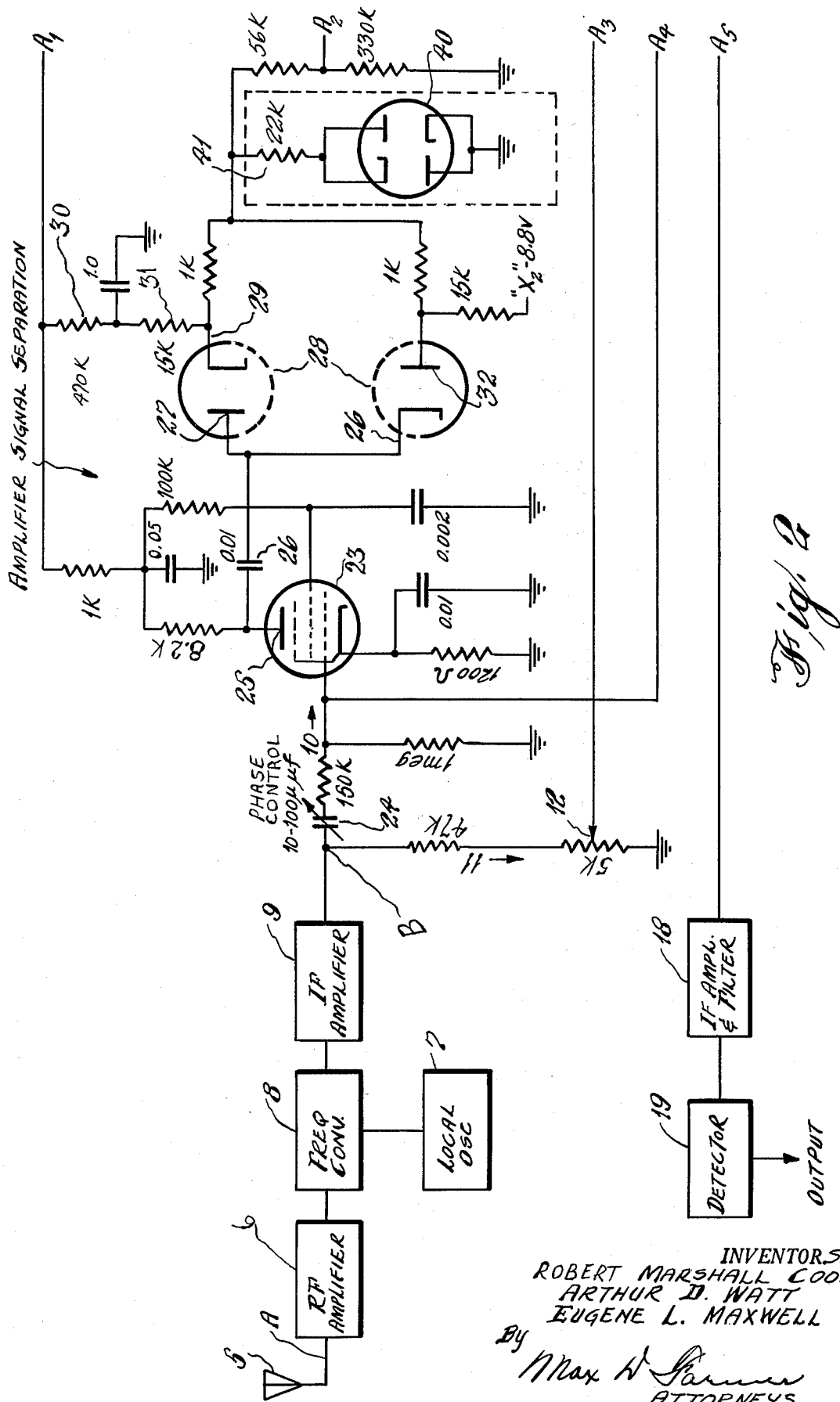


Fig. 1

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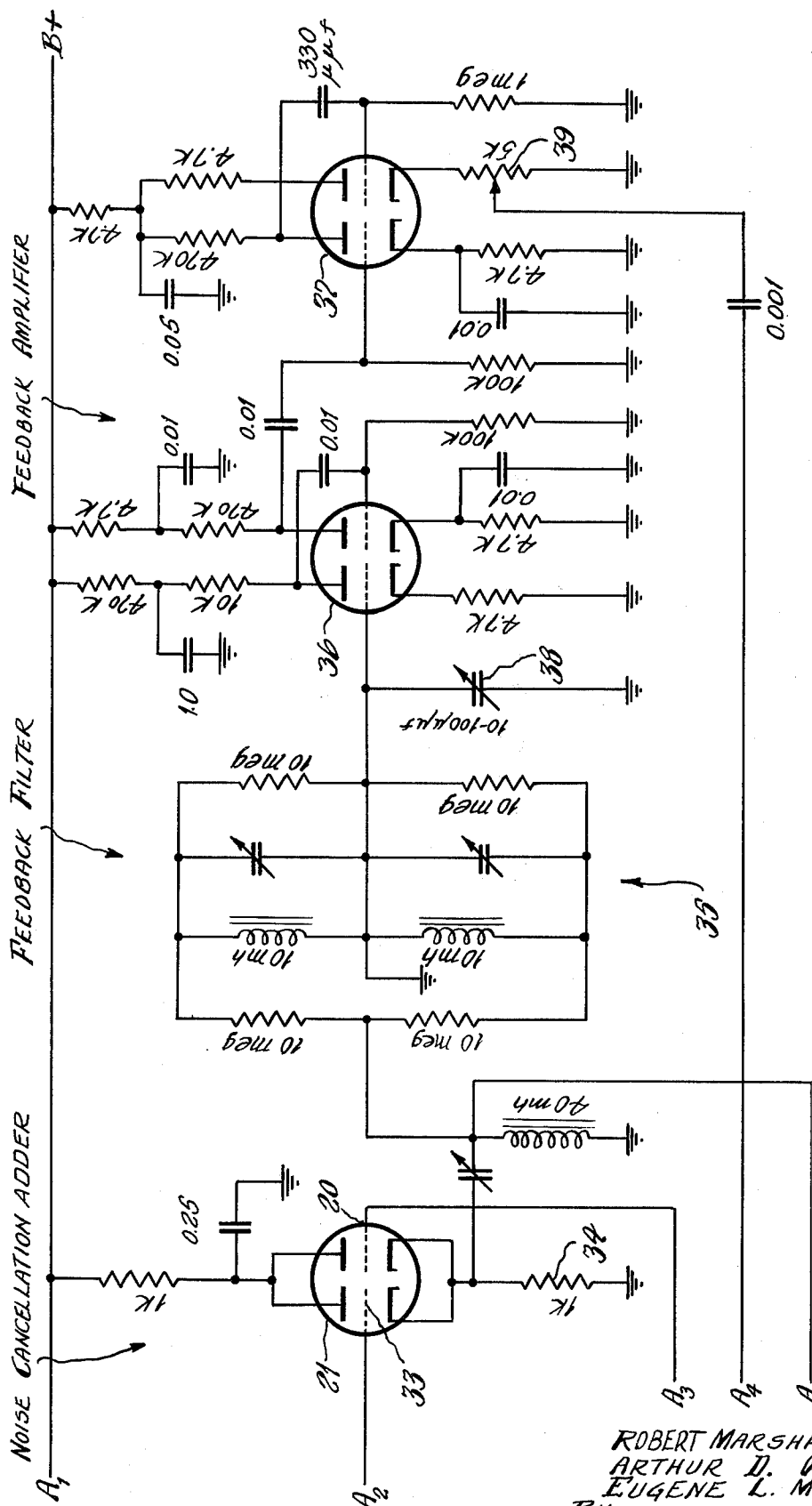


Fig. 2a

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WAVEFORMS AT THE INDICATED POINTS IN THE CIRCUIT
OF FIG. 1 UNDER THREE CONDITIONS.

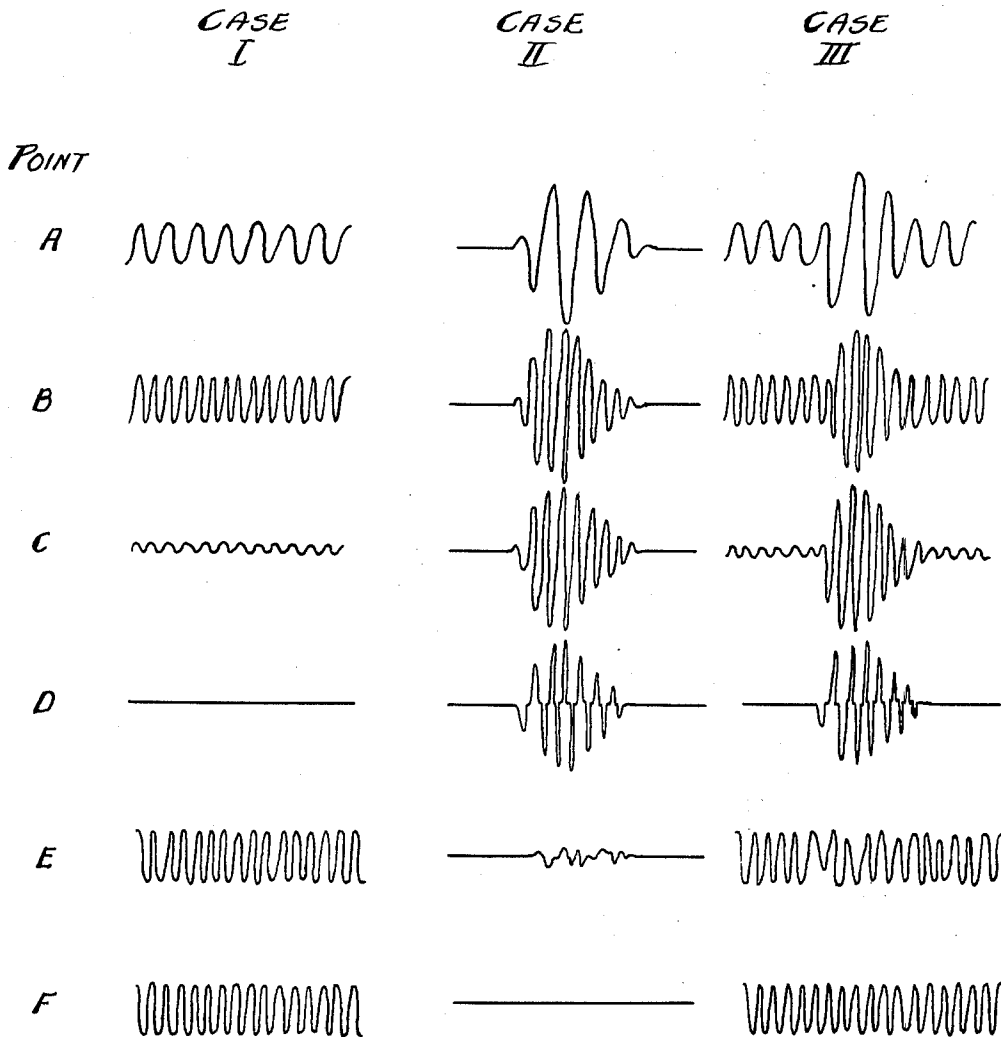


Fig. 3

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IMPULSE NOISE REDUCTION CIRCUIT

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to noise reducing circuits for use with radio receivers and in particular with impulse reducing circuits.

Radio signals which are transmitted over great distances require high power and are themselves subject to atmospheric and man-made interference or radio noise. Radio signals in the VLF (very low frequency) range have many desirable characteristics for long range communication not found at other frequencies; however, the problems of impulse atmospheric noise interference exists most in the VLF range which fact counteracts the advantages of VLF communication to a great extent. The inventors have made studies of some of the fundamentals of VLF atmospheric noise which studies were found to be useful in determining what factors are necessary in a receiver to permit successful discrimination against large and rapidly recurring noise impulses. The elimination of the effects of atmospheric interference increases the effective range because when these disturbing effects are eliminated, the signal received by a distant receiver will not be obliterated.

Prior methods and proposals for the elimination of interference have included systems whereby the receiver was made inoperative during the time interference was received, using two antennas, one receiving the signal and interference and the other turned off the signal so as to receive only interference and then, by balancing the two inputs, the interference would be cancelled. In actual practice, an adjacent channel noise signal cannot be employed to cancel atmospheric noise in the desired signal channel since it does not have the proper amplitude and phase characteristics. In addition, the time varying nature of relative amplitude and phase across the frequency spectrum would prevent the satisfactory use of any amplitude and phase correcting network.

An object of this invention is to provide a radio receiver exhibiting a relatively high degree of impulse interference reduction.

Another object of this invention is to provide a simple, efficient, practical and inexpensive circuit for use with a radio receiver for the reduction of impulse interference.

A further object of this invention is to provide a radio receiver capable of receiving and detecting intelligence, in the presence of atmospheric interference, from a distant transmitter.

Other objects and advantages will be apparent from the following description of an embodiment of the invention and the novel features thereof will be particularly pointed out hereinafter in connection with the appended claims.

In the accompanying drawings:

FIG. 1 is a block diagram of a receiver circuit employing the noise reduction principle of this invention;

FIGS. 2 and 2A together are block diagrams partly is schematic detail of the receiver circuit of FIG. 1; and

FIG. 3 illustrates the waveforms of an input signal at various circuit points of the block diagram of FIG. 1.

In the embodiment of the invention illustrated in FIG. 1, a received amplitude modulated or frequency modulated signal and impulse interference is impressed on the antenna 5 and then fed into a broad band R.F. amplifier 6. The output of the R.F. amplifier 6 is combined with the output of the local oscillator 7 in the frequency converter 8 so as to produce an intermediate frequency which is then fed into a broad band intermediate frequency amplifier 9. The R.F. amplifier 6, the frequency converter 8, the local oscillator 7 and the intermediate frequency amplifier 9 are conventional circuits and are well known in the art as to both design and operation. The broadband features of the above-mentioned circuits are necessary in order to preserve the impulse nature of the noise against which this invention is designed to discriminate and not to allow the impulse noise to take on the characteristics of random noise. Following the intermediate frequency amplifier, the input signal is divided into two paths 10 and 11. Path 11 includes an amplitude control potentiometer 12 and a conventional adder or mixer 13 where the resulting signals of the two paths are recombined. Path 10 includes therein a single stage amplifier 14, a phase control variable capacitor 15, a biased duodiode 16 or an amplitude dependent conduction device, the adder 13 and a negative feed-back amplifier, and a filter combination 17 of conventional design in shunt across the input of diode 16 and the output of adder 13. The circuit path from the output of the mixer 13 includes a conventional intermediate frequency amplifier and filter 18 and a detector circuit 19.

Considerable departure from conventional and well-known noise reduction circuits is evident in the noise separation circuit of this invention. It should be noted that the circuit does not include any "ringing circuit" and that the noise is not regenerated but is actually separated from the signal (intelligence plus noise) to be used for cancellation of itself.

The operation of the circuit may best be described by first considering the three possible types of input signal that might be received, namely, (I) only signal intelligence, (II) only impulse noise, and (III) intelligence and noise simultaneously. Referring now to FIGS. 1 and 3, we will consider case I.

Case (I). When noise free intelligence is received in the form of a modulated RF carrier (point A), it is first amplified (RF amplifier 6) and then converted to the IF (converter 8) without change in modulation waveform since the bandwidths involved are sufficiently broad so as to prevent distortion. The output of the IF amplifier is divided into two outputs, at point B paths 10 and 11, and we shall first follow path 11 where we observe that the signal (intelligence) is transmitted through the amplitude control 12, and hence to the adder 13 in the usual manner. The signal travelling along path 10 which is in phase opposition to the signal in path 11, first passes through amplifier 14 which inverts the phase so that the signal travelling in this path is in phase opposition to the signal on path 11, then through phase control 15 and thence to a biased duodiode 16. The automatic gain control (not shown) which is well known in the art, the voltage level of the signal appearing at the duo-diode 16 is held just under the voltage required for conduction through the biased duo-diode and so the signal (intelligence) cannot pass to the point D.

The signal which has reached the mixer via path 11 passes through the mixer to point E and thence through the output. Also from point E the signal is fed to a negative feedback filter and amplifier 17 whose frequency bandwidth is only broad enough to pass the inverted signal back to point C so as to obtain effective cancellation of the signal voltage arriving at point C via path 11. This negative feedback loop reduces the signal (intelligence) voltage level much below that required for conduction through the duo-diode 16 so that the output of the receiver will be solely intelligence which arrived at the adder 13 via path 11. Signal waveforms present at the various circuit points mentioned above are illustrated on FIG. 3.

Case (II). When only impulse noise is being received, it is transmitted through the RF Section 6 of the receiver and converted into impulses of the intermediate frequency voltage as in a conventional superhetrodyne receiver. The frequency bandwidth of the RF and and IF(9) sections is from 5 to 10 times the bandwidth required to pass the modulated carrier. The broad bandwidth is essential to permit the impulse noise to retain its impulse characteristics. After passing through point B, the impulses of intermediate frequency are conducted in phase opposition along paths 10 and 11. The impulse on path 11 travels through the amplitude control 12 and then to the adder 13. The impulses on path 10 are directed through the amplifier 14 where phase inversion occurs then to phase control 15, thence to the biased duo-diodes 16 and, if the voltage of the impulses is higher than that required for conduction through the diodes, the impulses are conducted to the mixer and are cancelled with those impulses arriving via path 11. Although the amplifier 14 inverts the instantaneous voltages of the impulses on path 10 with respect to those on path 11, the amplitude 12 and phase 15 controls are necessary to permit a high degree of noise cancellation at point E. Once these controls have been adjusted, no further adjustment is required. Since the filter in the feedback amplifier 17 offers high attenuation to frequency components of the noise lying outside of its narrow pass band and the only noise present at point E is the residual noise due to any imperfect cancellation at the mixer 13, very little noise is fed back to point C by the feedback amplifier. Waveforms for Case (II) are indicated in FIG. 3.

Case (III). When the received signal comprises a modulated R.F. carrier (intelligence) and impulse interference which are received simultaneously, path 11 transmits the IF intelligence and impulse noise through the amplitude control 12 and then to the adder 13. Path 10 transmits the IF intelligence and impulse noise which have been inverted at amplifier 14 through the phase control 15 and thence to the biased duo-diode 16. As in Case (I), the IF intelligence voltage is held by AGC (automatic gain control) action to a level just below the voltage required for conduction through the duo-diode 16. However, as in case (II), the impulse noise or noise impulses which exceed the necessary voltage for conduction, pass through the duo-diode and are conducted to the mixer 13 where they are combined in phase opposition with the impulses arriving at the mixer 13 via path 11. The signal-to-noise ratio at the mixer output (point E) is considerably higher than the ratio at point B. The negative feedback filter-amplifier 17 which is connected in shunt across the mixer output and the duo-diode input, feeds nearly

noise-free IF intelligence back to the duo-diode input (point C) where it cancels the intelligence arriving at this point via path 10 to an extremely low voltage level. This is done so that during the instants when noise pulses are being conducted through the duo-diode 16, there will be very little intelligence voltage present to be conducted through the duo-diode to cause undesirable cancellation of intelligence within the adder.

The theory of operation of the noise reduction circuit of this invention, which is shown in a schematic detail in FIGS. 2 and 2A, may appear to be quite complex; it actually is rather straightforward, however, since only a minimum of components are required in addition to those normally employed in a complete receiver. The circuit operates nominally as follows: The loop antenna 5, RF amplifier section 6 and the local oscillator 7 are conventional and operate in the usual manner. The frequency converter 8 may be of the balanced type since such converters may be easily designed to possess very low inherent noise which is a desirable feature. The IF amplifier 9 output in the illustrated embodiment was chosen to be 35kc though other frequencies may be employed and would work equally well. The following IF section 9 is of the wide band type whose 6 db bandwidth is approximately 1,200 cycles. Following the wide band IF section 9 are the signal separation and noise cancellation sections and these sections are shown schematically. The output of the IF section 9 is divided into two channels or paths 10 and 11 with both noise and intelligence present at the IF output or point of division B. The lower channel, path 11, passes both intelligence and noise amplitude through the variable portion of a potentiometer 12 which controls the signal to one grid, as for example, grid 20, of the adder or noise cancellation tube 21, which is a duo-triode. The intelligence and noise are also fed along the upper channel, path 10, to grid 22 of the amplifier tube 23 through a variable capacitor 24 which acts as a phase control in that it adjusts the phase of the signal (noise and intelligence) fed to the amplifier tube 23 with respect to the signal appearing at grid 20 of the noise cancellation tube 21. The output of the amplifier tube 23 is fed from the tube plate 25 through a coupling capacitor 26 to a plate 27 and cathode 26 of a duo-diode tube 28. The cathode 29 of the upper diode section is biased slightly positive for B+ through resistors 30 and 31 so that only that portion of the signal fed into this upper diode section whose signal level exceeds the intelligence voltage will pass through. In other words, the intelligence is blocked and the noise passes through the upper biased diode section. Likewise, the plate 32 of the lower diode section is biased slightly negative and only the noise portion of the signal passes through so that there is full wave blocking when the entire upper and lower duodiode sections are considered. Troublesome noise bursts easily exceed the bias on the duo-diode and pass through to the other grid 33 of the noise cancellation tube 21. By careful adjustment of amplitude and phase relationships, the noise passed to grid 20 can be made to cancel out the effect of the noise passed to grid 33 of the noise cancellation tube 21 bearing in mind that the signal passed along the upper channel was fed through amplifier tube 23 while the lower channel signal did not. The output of the noise cancellation tube 21 which is taken across the cathode resistor 34 is essentially intelligence since the noise was cancelled out therein. This output is divided, a portion

feeding the conventional stages of a receiver and another portion is fed to a negative feedback amplifier which includes a conventional filter circuit 35 and two conventional stages of amplification, tubes 36 and 37. The feedback amplifier circuit is tuned so that, for frequency modulated signals, it introduces a minimum of phase shift between the limits of the frequency shifted intelligence. The output of the feedback amplifier is adjusted in phase by variable capacitor 38 and in amplitude by potentiometer 39 to reduce the signal (intelligence) component originally passed to grid 22 of the amplifier tube 23 by approximately 12 db. Since the input signal intelligence to the amplifier tube 23 has been reduced, the biases on the duo-diode 28 may be operated at approximately the carrier level without causing appreciable carrier reduction while providing easy passage of even the very low level noise bursts. High impedance between the feedback amplifier and the output of the IF amplifier 9 prevents noise cancellation at the IF amplifier output.

Since biased duo-diode 28 does not possess linear plate characteristics, its output is somewhat nonlinear and though not essential to the operation of the noise cancellation or reduction circuit, it is preferable to add a linearizing network to the noise cancellation circuit in order to improve the efficiency and operation of the system. Many well-known circuit configurations may be employed to linearize the duo-diode output, as for example, a duo-diode tube 40 may be employed as a compensating nonlinear load for the biased duo-diode 28 when connected through a resistor 41 across the biased duo-diode 28 output and ground. It has been found that this scheme quite effectively linearizes the circuit for noise passage.

It should be understood that the invention herein described is not necessarily limited to receivers of the superheterodyne type and may be applied to other receiver types, as for example, a fixed-tuned single-channel receiver.

It will be understood that various changes in the details, materials, and arrangement of parts, which have been herein described and illustrated in order to explain the nature of this invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims. We claim:

1. In a radio receiver located at some distance from a transmitter emitting signal intelligence which is attenuated and may encounter and combine with atmospheric impulse noise along the transmission path between said receiver and transmitter so that both said signal intelligence and said impulse noise will be coincidentally received by said radio receiver as electromagnetic energy, an improved circuit for reducing the noise component of the received signal comprising separate electrically conductive paths, means for dividing said received electromagnetic energy and means for coupling said divided energy into two of said paths respectively, first of said paths having therein as part of said path phase inversion means for phase inversion of said signal passing along said path, amplitude dependent conduction means wherein said signal intelligence is removed from said electromagnetic energy in said first path, and having also in said first path amplitude adder means, a second path having as part thereof said amplitude adder means, whereby said signal passing along said first path which has been phase inverted and said

impulse noise in said second path are combined in and the resultant output of said amplitude adder means is substantially signal intelligence, a third path having therein as a part thereof negative feedback means, said third path shunting said amplitude adder means and said amplitude dependent conduction means whereby the signal intelligence in said first path will be further reduced by the negative signal intelligence feedback.

2. The improved circuit according to claim 1, wherein said phase inversion means is a phase inversion amplifier and also includes a selectively adjustable phase shift means.

3. The improved circuit according to claim 2, wherein said amplitude dependent conduction means is a biased diode whereby only signals exceeding the intelligence voltage level will pass through said diode.

4. The improved circuit according to claim 3, wherein said negative feedback means is a negative feedback amplifier and also includes a narrow band filter tuned to said signal intelligence.

5. The improved circuit according to claim 4, wherein said second path also includes selectively adjustable amplitude gain control means.

6. The improved circuit according to claim 5, wherein said phase shift means is a variable capacitor.

7. The improved circuit according to claim 6, wherein said amplitude gain control is a potentiometer.

8. The improved circuit according to claim 1, wherein said amplitude dependent conduction means is a biased duo-diode having two diode sections with the cathode of one section and the plate of the other section biased, whereby only signal voltage levels exceeding the intelligence voltage level will pass through said duo-diode.

9. The improved circuit according to claim 8, wherein said amplitude adder means is an adder circuit.

10. In a radio receiver located at some distance from a transmitter emitting signal intelligence which is attenuated and may encounter and combine with atmospheric impulse noise along the transmission path between said receiver and transmitter so that both said signal intelligence and said impulse noise will be coincidentally received by said radio receiver as electromagnetic energy, an improved circuit for reducing the noise component of the received signal comprising separate electrically conductive paths, means for dividing said received electromagnetic energy and means for coupling said divided energy into two of said paths respectively, first of said paths having therein as part of said path amplitude dependent conduction means wherein said signal intelligence is removed from said electromagnetic energy in said first path, and also having in said first path amplitude adder means, a second path having as part of said second path phase inversion means for phase inversion of said signal passing along said second path and also in said second path said amplitude adder means, whereby said signal passing along said second path which has been phase inverted and said impulse noise on said first path are combined in said amplitude adder means whose resultant output is substantially signal intelligence, a third path having therein as a part thereof negative feedback means, said third path shunting said amplitude adder means and said amplitude dependent conduction means whereby the signal intelligence in said first path will be further reduced by the negative signal intelligence feedback.

11. In a radio receiver located at a substantial distance from a transmitter that emits intelligence signals that during transmission are attenuated and may encounter and combine with atmospheric impulse noise signals, that improvement at such receiver which comprises means for receiving the transmitted, modified signals, and amplifying them, detector means, means connecting said receiving and amplifying means to said detecting means for passing the amplified signals to the detector means, and having, in series therein, first means to change the phase of such transmitted signals by 180°, then biased means to pass the phase inverted signals solely when they exceed in voltage that of such amplified intelligence signals, and then means to add signals, a negative feedback amplifier connecting the output side of the adding means to the input side of said

bias means, for returning output adding means intelligence signals to combine with the incoming signal to said bias means in phase opposition means connecting said signal receiving and amplifying means to said adding means, said adding means being operable to combine the two inverted and uninverted signals delivered thereto and passing the resultant combination signal to said detector, whereby when the phase inverted signals are combined in the adding means with the uninverted mixed signal, the noise signals which only passed through the biased means, will materially destroy the noise signals in the uninverted signals and the remaining signal including the intelligence signals will be delivered to said detector.

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