April 9, 1946. R. C. EMERSON 2,398,214

SUPERREGENERATIVE RECEIVER

Filed Feb. 14, 1944

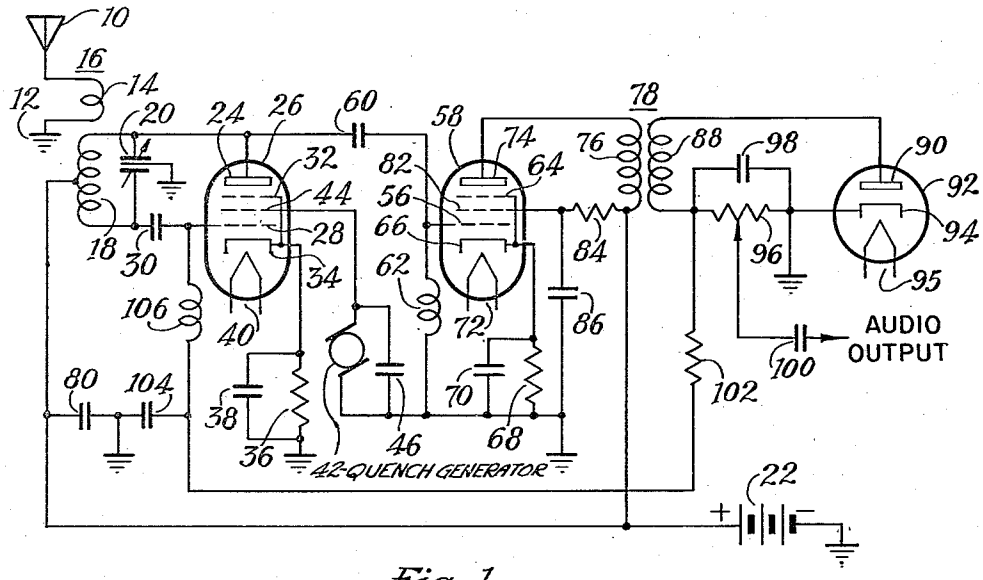


Fig. 1

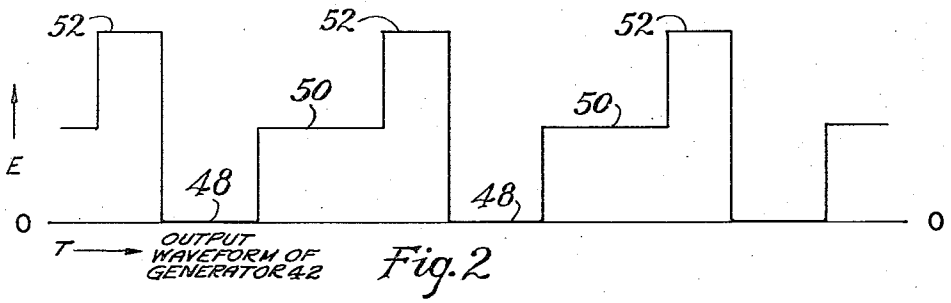


Fig. 2

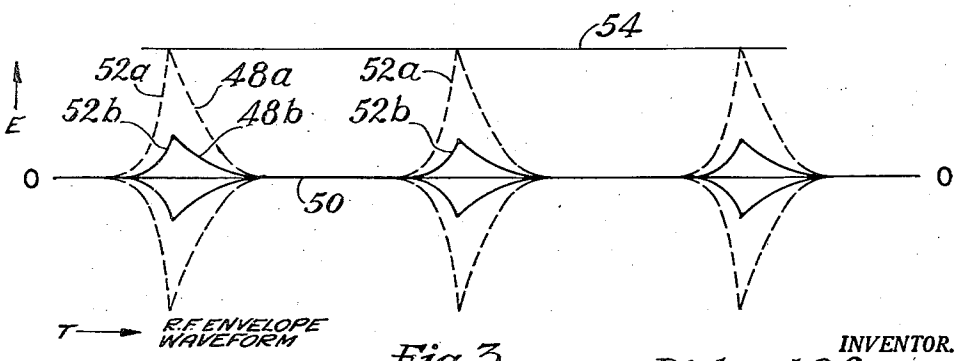


Fig. 3

INVENTOR.
Richard C. Emerson
BY
David J. Doody
ATTORNEY

Patented Apr. 9, 1946

2,398,214

UNITED STATES PATENT OFFICE

2,398,214

SUPERREGENERATIVE RECEIVER

Richard Carlisle Emerson, Glendale, Calif., assignor to Bendix Aviation Corporation, South Bend, Ind., a corporation of Delaware

Application February 14, 1944, Serial No. 522,295

6 Claims. (Cl. 250—20)

This invention relates to superregenerative receiving apparatus, and more particularly to receiving equipment of this class in which automatic volume control is secured without attendant loss in the fidelity of the demodulated output.

The essential element of a superregenerative receiver is the combination of a vacuum tube and an oscillatory circuit connected together in positive feedback relationship. In the absence of amplifying action occurring within the tube, as may be attained by the application of a suitable potential to any desired element, oscillations existing by chance in the circuit die away. As this is indicative of a loss in power it may be said of this condition, that the circuit is characterized by positive resistance or loss. Upon the establishing of amplifying action, again by the application of suitable electrode potentials, chance oscillations in the circuit build up in amplitude. As this is indicative of an increase in power, it may be said of this condition that the circuit is characterized by negative resistance or loss. In superregenerative operation, the tube and circuit combination is caused to vary between these two states at a rate known as the quench frequency and the build-up in oscillation intensity occurring during the negative loss conditions is relied on to secure amplification greater than that of which the tube is capable without these expedients. It is well known that superregenerative receivers in which the reinforced signal frequency oscillations in the receiving circuit are permitted to build up to their final amplitude and to persist for some time at this level are possessed of a logarithmic response characteristic to variations in the strength of the incident signal. This type of operation is characteristic of most self-quenched superregenerative circuits and exists in circuits employing a separate source of quench voltage when the condition of negative loss in the tuned circuit is allowed to persist for a sufficient time to cause grid current to flow in the associated vacuum tube. Because of the logarithmic response characteristic, the incremental response in the presence of large signals is less than in the presence of small signals, affording a reasonably constant demodulated output despite changes in the magnitude of the received signal. For this reason, it is generally said that superregenerative receivers of this type have automatic volume control.

In the testing and employment of superregenerative receivers of the above type, it has been found that the demodulated output is not an accurate replica of the modulation originally impressed on the received carrier, a very large amount of distortion being present. In the communication service and many other classes of service, this harmonic distortion has prevented the widespread use of this type of receiver as it impaired the intelligibility of the communications and reduced the accuracy of indications secured in other services. This has been found due to the existence of the self-regulating action during the modulation cycle, with the result that the envelope of the modulation trough is detected with relatively little distortion, while the envelope of the modulation crest becomes quite flattened in the demodulation process, due to the non-uniform incremental sensitivity. In this respect contemporary superregenerative receivers differ in performance from conventional receivers employing automatic gain control. As in the latter, the gain, while regulated in accordance with variations in the strength of the received signal, remains constant throughout the entire modulation cycle, and the output of such receivers is therefore free from the above mentioned objectionable distortion. As a result, the larger, more complex and more costly conventional receivers have perforce been employed in many installations where otherwise the more compact, and less costly superregenerative receiver could have been used, were it not for the above mentioned difficulty.

Accordingly, it is an object of this invention to provide new and novel superregenerative receiving equipment incorporating automatic volume control and having substantially distortionless output.

Another object of the invention is to provide new and novel receiving equipment having high sensitivity, great selectivity, automatic volume control, and excellent fidelity while obtaining reduced size, weight and cost by comparison with the conventional straight tuned radio frequency and superheterodyne receivers providing equivalent performance.

The above objects and advantages of the invention are substantially accomplished by exciting a superregenerative amplifier connected to a resonant circuit with a quench wave preventing the attainment of saturation oscillation amplitudes, deriving a direct current potential proportional to the peak voltages appearing in said resonant circuit, and using said potential to regulate the mutual conductance of the superregenerative amplifier tube.

Other objects and advantages of the invention will in part be disclosed and in part be obvious

when the following specification is read in conjunction with the drawing in which:

Figure 1 is a schematic diagram of a receiver designed in accordance with the principles of the invention.

Figure 2 is a graph showing a possible wave form of quench supply potential.

Figure 3 is a graph showing the envelope of the radio frequency potentials in the resonant circuit corresponding to the quench wave of Figure 2.

In the accompanying schematic diagram, while the heaters associated with the emissive cathodes have been shown, the circuits for energizing said heaters have been omitted to simplify the presentation, it being understood that any of the well known arrangements may be employed to satisfy the heater requirements.

Referring now to Figure 1, an antenna 10 is connected to the ground 12 through the primary winding 14 of the antenna coupling transformer 16 having a secondary winding 18 tuned to the desired signal frequency by the split stator variable capacitor 20. The winding 18 may be tapped at or near the center, and the tap connected to the positive terminal of the direct current source 22, whose negative terminal is grounded. One extremity of the winding 20 is connected to the anode 24 of the superregenerative amplifier tube 26 and the other terminal of this winding is connected to the control grid 28 through the grid coupling capacitor 30. The tube 26 may be of the pentode type having a suppressor grid 32 internally connected to the cathode 34 which is connected to ground through the bias resistor 36 paralleled by the capacitor 38. The cathode 32 is brought to the operating temperature by the adjacent heater 40.

To cause the tube 26 to act as a superregenerative amplifier, the net losses in the combined arrangement of the tube 26 and the resonant circuit 18, 20 must be periodically varied positively and negatively of zero. The net loss is determined by the operating mutual conductance of the tube 26 and in the circuit shown is caused to vary by the connection of a quench energy generator 42 between the space charge grid 44 and ground. Grid 44 is maintained at ground potential for signal currents by the connection of bypass capacitor 46 in parallel with the generator 42.

A suitable form of quench wave to be supplied by the generator 42 is shown in Figure 2, this particular form being chosen because of the ease with which the resulting diagrams may be understood. The wave includes an initial portion 48 during which the potential of grid 44 is substantially zero. During this period the losses in the circuit 18, 20, 26 are positive and any stored energy in the circuit is dissipated. The next portion 50 of the wave elevates the grid potential to a point at which the net losses of the circuit 18, 20, 26 are substantially zero and the alternating potentials in the circuit rise under the control of the received signal energy. Then the section 52 of the wave raises the grid 44 to a voltage increasing the mutual conductance of the tube 26 to a point where the losses in the combined circuit of inductance 18, capacitor 20 and tube 26 are negative and the voltage across the circuit 18, 20 builds up exponentially until the voltage on grid 44 drops once more to zero at the next voltage minimum 48, shifting the circuit losses into the positive region to permit the built up voltages to die away.

Figure 3 shows the envelopes of the radio frequency voltage appearing across the resonant circuit 18, 20 during the above operation, the dashed lines illustrating the envelope when a modulation crest is being received and the solid lines illustrating the envelope when a modulation trough is impressed. With the voltage minimum 48 on the grid 44, the envelope at peak positive modulation is as shown at 48*a*, that for peak negative modulation being shown at 48*b*. Each of these curves is a negative exponential, corresponding to the positive losses in the circuits. When the intermediate voltage plateau 50 is reached, all original voltages in the resonant circuit have been damped out, and new potentials gradually build up in the circuit 18, 20 under the control of the signal energy. However, these potentials are normally so small that on the scale with which this figure has been constructed they are quite invisible. Upon the arrival of the peak positive plateau 52 the circuit losses become negative and the envelope rises steeply as shown at 52*a* for a positive modulation peak and at 52*b* for a negative modulation peak. The form of the envelope during this interval may be expressed as a positive exponential equation of the form Ae^{bt}. Before the oscillations in the circuit 18, 20, 26 can build up to the saturation point, which is that point at which the grid 28 begins to draw appreciable current, the next potential minimum 48 arrives permitting the stored energy in the resonant circuit to dissipate itself and restore the apparatus to a state ready for the next cycle of operation. As the change in sign of exponent takes place at a fixed time interval after the passage of the circuit into the negative loss region, the peak potential attained is directly proportional to the signal amplitude, thus making the envelope 54 of these peaks a perfect replica of any modulation existing on the signal.

Returning now to Figure 1, the radio frequency potentials existing at anode 24 may be impressed on the control grid 56 of a radio frequency amplifier tube 58 through the coupling capacitor 60 having the grid end thereof connected to ground by the choke 62 offering high impedance to currents at the signal frequency, but negligible impedance to currents of the quench frequency. The tube 58 may be of the pentode type having a suppressor grid 64 connected internally to the cathode 66 grounded by the resistor 68 shunted by capacitor 70. A heater 72 is provided for the cathode 66. The anode 74 of tube 58 is connected through the primary winding 76 of the aperiodic transformer 78 to the positive terminal of the source 22, short circuited for signal frequency currents by the parallel capacitor 80. The screen grid 82 is energized from the positive terminal of source 22 through the dropping resistor 84 whose grid end is connected to ground through the bypass capacitor 86.

The secondary winding 88 of transformer 78 may be connected at one terminal to the anode 90 of the diode vacuum tube 92 and at the other terminal to the cathode 94 of the tube 92 through the load resistance 96. A heater 95 is provided for the cathode 94. The resistor 96 is shunted by the capacitor 98 selected in conjunction therewith to provide a time constant large with respect to the period of the quench frequency, but small with respect to the period of the highest modulation frequency to be received. The resistor 96 is provided with an adjustable tap, and the modulation frequency energy is fed from this tap through capacitor 100 to any desired additional apparatus, such as headphones or an additional

amplifier. Resistor 96 is connected at the cathode end to ground, causing the other end thereof to appear negative with respect to ground by an amount depending on the signal strength in transformer 78. A resistor 102 is connected between the ungrounded terminal of resistor 96 and one terminal of the choke 106 which has a high impedance at the signal frequencies. The other terminal of choke 106 is connected to the grid 28 of the amplifier 26, and the junction between resistor 102 and choke 106 is connected to ground through the capacitor 104, selected in conjunction with resistor 102 to provide a time constant large with respect to the lowest modulation frequency to be received. Where the lowest modulation frequency is 100 cycles per second, a time constant of 0.1 to 0.25 second will prove satisfactory.

The radio frequency energy having the envelopes shown in Figure 3 appears in the transformer 78 with enhanced energy due to the action of amplifier tube 26. As earlier mentioned, the peak value of voltage attained during the build-up period is determined by the signal strength, and an aperiodic transformer is employed at 78 to avoid the distortion of this peak such as would occur were the circuit tuned. The voltages appearing in the secondary 88 are of substantailly the same form as shown in Figure 3, the ordinates merely being expanded due to the presence of amplifier 58. As earlier mentioned, the time constant of the resistor-capacitor combination 96, 98 is chosen large with respect to the period of the quench frequency and as a result the voltage developed across resistor 96 has the form of the envelope 54 in Figure 3, the voltage across the capacitor 98 not decreasing appreciably between successive radio frequency peaks. As this envelope executes the same variations as the envelope of the modulated wave, the voltage appearing across resistor 96 and that available at the output terminal of capacitor 100 are faithful reproductions of the original signal modulation. The average value of the envelope 54 is negative and appears at capacitor 104 and grid 28 after the removal of the modulation components by the filter action of resistor 102 and capacitor 104. This potential thus applied to the control grid varies the factor "*b*" in the envelope expression Ae^{bt}, reducing the factor in the presence of large signals. As a result, the total build up ratio is reduced for large signals and the demodulated output appearing across the load resistor 96 is maintained approximately constant without appreciable distortion.

In this respect, the apparatus described differs distinctly from past superregenerative receivers in which distortion was inevitably associated with the existence of automatic volume control, rendering available the desirable economy of parts, space and weight possible in superregenerative apparatus without the sacrifice of performance as compared with more conventional receivers. Where extreme simplicity of design is wished, the amplifier 58 may be omitted and the secondary 88 coupled directly to the winding 18 of antenna coupling transformer 16.

It will be obvious that many changes and modifications may be made in the invention without departing from the spirit thereof as expressed in the foregoing description and in the appended claims.

I claim:

1. In radio apparatus, a resonant circuit, an electric discharge device having a cathode, control grid and an anode, means connecting said cathode, control grid and said anode to said resonant circuit in feed back relationship, means for periodically varying the net loss of said circuit and discharge device combination positively and negatively of zero, means for deriving a potential proportional to the peak potential appearing across said resonant circuit, and means for impressing said derived potential on said control grid.

2. In radio apparatus, a resonant circuit, an electric discharge device having a cathode, control grid and an anode, means connecting said cathode, control grid and said anode to said resonant circuit in feed back relationship, means for periodically varying the net loss of said circuit and discharge device combination positively and negatively of zero, a resistor connected in parallel with a capacitor, a unilateral conductor, means responsive to potentials across said resonant circuit for impressing electrical energy on said parallel connected resistor and capacitor in series with said unilateral conductor, and means for impressing potentials appearing across said resistor between said cathode and said control grid.

3. In radio apparatus, a resonant circuit, an electric discharge device having a cathode, control grid and an anode, means connecting said cathode, control grid and said anode to said resonant circuit in feed back relationship, means for periodically varying the net loss of said circuit and discharge device combination positively and negatively of zero, the duration of said negative loss state being a value preventing the flow of grid current, means for deriving a potential proportional to the peak potential appearing across said resonant circuit, and means for impressing said derived potential on said control grid.

4. In radio apparatus, a resonant circuit, means for impressing signal potentials on said resonant circuit, an amplifying device having its input and output circuits coupled to said resonant circuit, means for periodically varying the net loss of the combination including said amplifying device and said resonant circuit positively and negatively of zero, rectifying means responsive to the potentials of said resonant circuit, a load impedance connected to the output of said rectifying means, and means responsive to variations in the output of said rectifying means for controlling said amplifying means.

5. In radio apparatus, a resonant circuit, an amplifying device having its input and output circuits coupled to said resonant circuit, means for periodically varying the net loss of the combination including said amplifying device and said resonant circuit positively and negatively of zero, and means responsive to the envelope of the potentials in said resonant circuit modifying the operation of said amplifying means.

6. In radio apparatus, a resonant circuit, an amplifying device having its input and output circuits coupled to said resonant circuit, means for periodically varying the net loss of the combination including said amplifying device and said resonant circuit positively and negatively of zero, a resistor connected in parallel with a capacitor, a unilateral conductor, means for impressing potentials from said resonant circuit on said parallel connected resistor and capacitor through said unilateral conducting means, and means connecting said amplifying device to said parallel connected resistor and capacitor.

RICHARD CARLISLE EMERSON.