Nov. 12, 1940. D. E. FOSTER 2,221,086

AUTOMATIC VOLUME CONTROL CIRCUIT

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Fig. 1

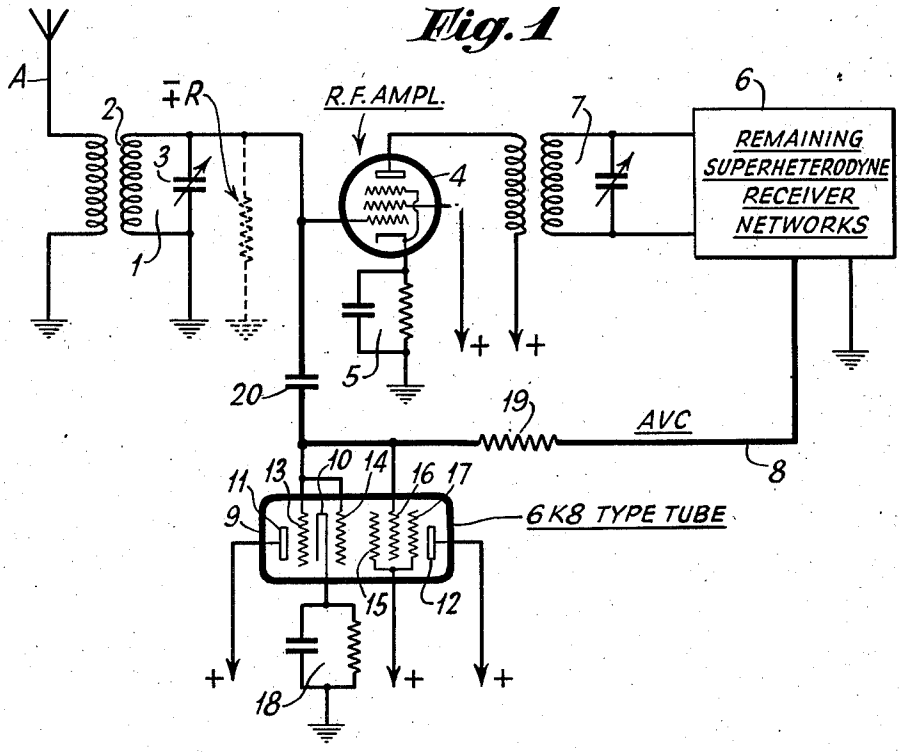
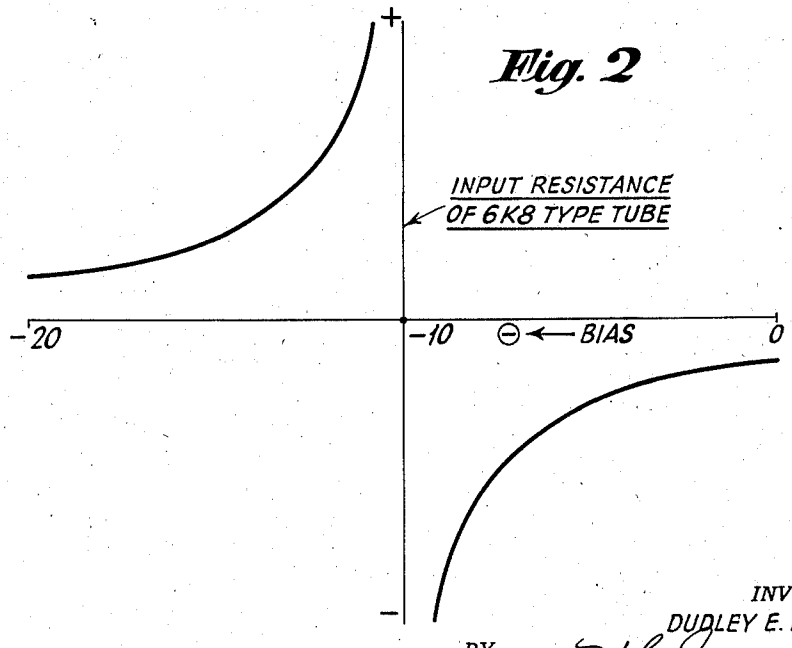


Fig. 2



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AUTOMATIC VOLUME CONTROL CIRCUIT

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12 Claims. (Cl. 250—20)

My present invention relates to automatic volume control circuits for radio receivers adapted to operate in the ultra high frequency ranges, and more particularly to an improved volume control circuit employed in a system for receiving signals of the order of 10 to 100 megacycles.

One of the main objects of my present invention is to provide a method of controlling the transmission of signals through a receiving system of the ultra high frequency type, the method including the utilization of an electronic device, across at least one tuned circuit of the system, which is capable of producing varying negative and positive resistance effects in response to signal carrier amplitude variation.

Another important object of the invention is to improve automatic volume control circuits for tunable ultra high frequency amplifiers; the control circuit comprising a tube having normally a negative input resistance which increases in value with control bias increase, finally assuming high positive resistance values which decrease with further increase of control bias.

Another object of my invention is to utilize, in an automatic volume control (A. V. C.) circuit, a tube so constructed that it has a negative input resistance; the input resistance being connected in shunt to a tuned circuit of a signal transmission system and being varied in magnitude by a control bias derived from the signals.

Still other objects of my invention are generally to improve automatic gain control circuits for ultra high frequency systems, and more especially to provide volume control circuits which are reliable, efficient and readily assembled in a receiving system.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 is a circuit diagram of a receiving system embodying the invention,

Fig. 2 graphically shows the operation of the control network.

Referring now to Fig. 1, there is illustrated in purely schematic manner a signal transmission system, such as a radio receiver which may be of the superheterodyne or tuned radio frequency types. Since the former type of receiver is commonly employed for signal reception, let it be assumed that the signal collector A feeds collected signals to the tunable input circuit 1 of the first radio frequency amplifier of a superheterodyne receiver. The input circuit comprises coil 2 and variable condenser 3 providing a parallel resonant network tunable over the desired modulated signal carrier frequency range. Since the present invention is of especial utility in the reception of signals of the order of 10 to 100 Mc., it will be assumed that the condenser 3 is adjustable to tune circuit 1 over a range of 20 to 50 Mc., for example. The receiver can be of the type used for television reception. The tube 4 can be an 1851 type amplifier; such a tube is a high mutual conductance pentode and functions well for ultra high frequency amplification.

The cathode circuit of tube 4 includes the usual condenser-resistor bias network; the input circuit 1 is connected between the input electrodes of tube 4. The plate and screen electrodes of the amplifier 4 may be maintained at positive potentials by the usual voltage supply source. The numeral 6 denotes the conventional networks following the R. F. amplifier of a superheterodyne receiver. Tunable circuit 7 may be the input circuit of the first detector, or it may be connected to a second R. F. amplifier. Those skilled in the art are fully aware that the networks in circuit 6 will comprise a converter of the combined, or separate, local oscillator-first detector type; one or more I. F. amplifiers; a second detector; one or more modulation amplifiers and a final reproducer. The A. V. C. bias may be secured in any well known manner. For example, the D. C. voltage component of the second detector output may be employed. Again, a separate diode rectifier, fed with amplified I. F. signals, can provide the necessary A. V. C. bias.

Regardless of the source of A. V. C. bias, numeral 8 designates the lead connected to tube 9 for performing the control function. Tube 9 is of the 6K8 type, and comprises a cathode 10, a plate 11, a second plate 12, a grid 13 disposed between plate 11 and the cathode, and grids 14, 15, 16 and 17 arranged in the same successive order between cathode 10 and plate 12. Grids 13 and 14 are connected together, within the tube, as are grids 15 and 17. Both plates 11 and 12 are maintained at a positive potential; the resistor-condenser bias network 18, in the grounded cathode lead, maintains the grids 13—14 at a normal negative bias. The A. V. C. lead 8, through a proper filter resistor 19, is connected to grids 13, 14 and 16. Grids 15 and 17 are positively biased, and hence surround grid 16 with a positive field.

Condenser 20 connects grid 16 to the high potential side of tuned circuit 1; the input resistance R of tube 9 is shown by the dotted line representation of a resistor in shunt to input circuit 1. The resistor R has been indicated as being capable of assuming negative or positive re-

sistance values; the polarity will depend on the magnitude of A. V. C. bias applied to grid 16. In explaining the action of the control circuit it will be understood that grids 13—14 may, if desired, be connected to the ground end of bias network 18. Further, the A. V. C. bias can be applied solely to the grids 13—14 if desired. In general, it can be stated that the sign and magnitude of the input resistance R of tube 9 will vary in response to the change in magnitude of the A. V. C. bias; the variation will follow along the lines graphically shown in Fig. 2. From the latter it will be seen that as the A. V. C bias increases from zero to —20 volts, by way of illustration, the negative input resistance R rises from a low value to infinity and then assumes a positive sign and decreases to a low value.

This variation of sign and value of R is in the correct sense for A. V. C. action. For example, when the signal carrier amplitude is small, as during weak or distant signal reception, it is desired to have the tuned circuit 1 as free of damping as possible. To secure this result the shunt resistance R should be of maximum value, since the equivalent series value of R will then be a minimum and its loading effect will be small. From Fig. 2 it will be observed that for small A. V. C. bias values, the magnitude of —R is low; hence there will be, in effect, a high value of —R in series in circuit thereby causing the circuit to be free of damping.

As the carrier amplitude increases however, the shunt-R value increases with a concurrent increase of the damping of circuit 1. When the A. V. C. bias passes into the region where R assumes a positive value, the damping effect of the shunt positive R will still be below maximum. The latter is secured upon the A. V. C. bias assuming a value of —20 volts, when the shunt R is small, and, therefore, the equivalent series resistance in circuit 1 is a maximum. Accordingly, it will be seen that as the carrier amplitude increases, the A. V. C. bias increases in value and causes a gradual increasing loading of the circuit 1. The variation will be such as to maintain the carrier amplitude at the second detector input circuit uniform over a wide range of carrier amplitude variation at collector A.

There will now be explained the nature of the electronic reactions in tube 9 which permit the input resistance thereof to vary in the manner depicted in Fig. 2. The tube 9 acts in the manner of a triode-hexode; cathode 10, grid 13 and plate 11 provide a triode, whereas cathode 10, grids 14, 15, 16, 17 and plate 12 provide a hexode. It can be stated that negative input resistance in the tube results from a deficiency of electrons in the space between grid 16 and screen grids 15—17.

The space current between grids 14 and 15 is relatively independent of the bias on grid 16 due to the interposed screen 15. That is to say, the sum of the currents in plate 12 and the screens 15 and 17 is relatively constant. The electrons passing through grid 15 will be subject to the influence of grid 16 and at some high negative bias on grid 16 will be completely prevented from passing through this grid thereby resulting in current cut-off of plate 12 as in the ordinary triode. However, as the negative bias on grid 16 is decreased from some high value, plate 12 current will not decrease linearly because the supply of electrons passing through grid 15 is limited. This limitation is brought about as follows: The potential of grid 14 exerts the primary influence in determining how many electrons shall be available for the remainder of the hexode section. The grid 15, by virtue of its potential and its position, will draw some value of current, which current will be relatively independent of the potential of grid 16; the remainder of the hexode section current passing to plate 12.

Therefore, by a proper choice of potentials for grids 14 and 15 there will be a scarcity of electrons on the grid 16 side of grid 15 for some range of low values of negative bias on grid 16. Decrease in charge in the 15—16 space will cause electrons to flow into the grid 16, or current to flow out. Thus, an increase in potential of grid 16 is accompanied by a change of opposite sense in the current of that electrode, which condition is the criterion for negative input resistance. The net input resistance of the tube will depend in sign and in magnitude upon the relative importance of the two effects operating simultaneously within the space between grids 15 and 16. The frequency also affects the input resistance, because the proportionate magnitude of the in-phase, or resistance, component depends upon the finite electron transit time, and it is for that reason that this negative resistance effect occurs only at relatively high frequencies.

The average potential of grid 16 will effect the distribution of electrons within the space 15—16, and the average potential of grid 14 will determine the number of electrons passing through screen 15. Therefore, the bias on grids 14 and 16 will both affect the magnitude of input resistance R. When the tube is operated with a high value of negative bias on grid 16, the current of plate 12 will decrease and the screen grid current will rise. These effects will be accompanied by the building up of a space charge in the space between grids 15 and 16. Under these conditions the tube will simulate a triode whose plate current is space charge limited insofar as consideration of the input resistance is concerned. For high values of negative bias on grid 16 the tube 9 behaves as a triode; that is to say, the input resistance is positive. The input resistance R, as it goes from negative to positive, passes through infinity, and so as bias is increased the positive resistance must decrease from infinity, as long as the tube is operating under "electron deficiency" condition. When the bias becomes sufficiently negative this condition is departed from and the tube acts like ordinary tubes where input resistance increases with more negative bias; however, that effect is small compared to the variation from low negative resistance through infinity and thence to decreasing positive resistance values. Of course, in place of tube 9 any other tube can be used that has an input resistance which is capable of varying in the manner illustrated in Fig. 2. Again, the control action may be applied to any other tuned circuit of the system. It can be shown that the sign and magnitude of R vary much the same as shown in Fig. 2, when the bias on grids 13—14 is varied.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set for in the appended claims.

What I claim is:

1. A method of operating a wave transmission system of the type comprising at least one tuned circuit feeding a wave transmission tube, which includes producing a minimum negative resistance effect across the tuned circuit for waves of minimum amplitude, deriving a control voltage from the waves which varies directly in magnitude in response to wave amplitude increase, increasing the magnitude of said effect in response to control voltage magnitude increase, and converting said effect into a positive resistance effect of decreasing magnitude in response to further increase of the control voltage magnitude beyond a predetermined value.

2. A method of operating a wave transmission system of the type comprising at least one tuned circuit feeding a wave transmission tube, which includes producing a negative resistance effect across the tuned circuit, deriving a control voltage from the waves which varies in magnitude in response to wave amplitude changes, varying the magnitude of said effect in response to control voltage magnitude variation, and converting said effect into a positive resistance effect of opposite magnitude variation in response to variation of the control voltage magnitude beyond a predetermined point.

3. A method of operating a wave transmission system of the type comprising at least one tuned circuit feeding a wave transmission tube, which includes producing a negative resistance effect across the tuned circuit, deriving a control voltage from the waves which varies in magnitude in response to wave amplitude changes in a sense such that the control voltage is increasingly negative as the wave amplitude increases, varying the magnitude of said effect in response to control voltage magnitude variation, and converting said effect to one of opposite sign in response to an increase in the control voltage magnitude beyond a predetermined point.

4. In a receiver including at least one tuned signal circuit, the method which includes producing a resistive effect across the circuit, and varying the sign and magnitude of the effect across said one circuit in a predetermined order in response to signal amplitude variation.

5. In combination with a receiver having at least one tuned signal circuit, an electronic device providing a resistance across the circuit, said device being constructed to impart to said resistance a variable sign which depends on the gain of the device, and means, responsive to signal amplitude variations, for adjusting said device gain thereby to vary the sign of the resistance across said one signal circuit.

6. In an amplifier having a tuned input circuit, an electron discharge tube having input and output electrodes arranged to provide a negative input resistance between the input electrodes at low negative bias values, means connecting said input electrodes across the input circuit thereby to connect said resistance across the latter, means responsive to signal amplitude increase for increasing the bias on said tube thereby to increase the magnitude of said resistance up to a predetermined value of bias and thereafter to convert the sign of the resistance to be positive.

7. In an amplifier having a tuned input circuit, an electron discharge tube having input and output electrodes arranged to provide a negative input resistance between the input electrodes at low negative bias values, means connecting said input electrodes across the input circuit thereby to connect said resistance across the latter, means responsive to signal amplitude increase for increasing the bias on said tube thereby to increase the magnitude of said resistance up to a predetermined bias value and thereafter to convert the sign of the resistance to be positive, said tube comprising a cathode, a positive plate, a negative grid, a positive field surrounding the grid, and a second negative grid between the cathode and positive field, said resistance being provided between the cathode and first negative grid.

8. In combination with a receiver having a transmission tube whose input circuit is tuned to a frequency of the order of 10 to 100 megacycles, a tube having its input resistance connected across said input circuit to control the gain of said receiver, said control tube being constructed to provide an electron deficiency between a pair of electrodes thereof whereby said input resistance may be controlled in sign, and means responsive to signal amplitude variation for controlling said resistance sign.

9. In a signal reception system including at least one tuned signal circuit, the method of regulating signal transmission therethrough which includes producing a resistive effect across the circuit, and varying the sign of the effect across said circuit from negative to positive in response to signal amplitude increase.

10. In a signal reception system including at least one tuned signal circuit, the method of regulating signal transmission therethrough which includes producing a resistive effect across the circuit, varying the sign of the effect across said circuit from negative to positive in response to signal amplitude increase, and varying the magnitudes of said negative and positive effects in opposite senses.

11. In a signal reception system including at least one tuned signal circuit, a method of adjusting the damping of the signal circuit which includes introducing resistance of a desired sign into said signal circuit in response to the reception of signals of a predetermined amplitude, varying the value of said resistance in response to variation of said signal amplitude, and introducing resistance of opposite sign into said signal circuit in response to a substantial shift of the signal amplitude from said predetermined amplitude.

12. In a signal reception system including at least one tuned signal circuit, a method of adjusting the damping of the signal circuit which includes introducing resistance of a desired sign into said signal circuit in response to the reception of signals of a predetermined amplitude, varying the value of said resistance in response to variation of said signal amplitude, introducing resistance of opposite sign into said signal circuit in response to a substantial shift of the signal amplitude from said predetermined amplitude, and varying the value of the opposite sign resistance in a sense opposed to said first variation in response to further change in said signal amplitude.

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