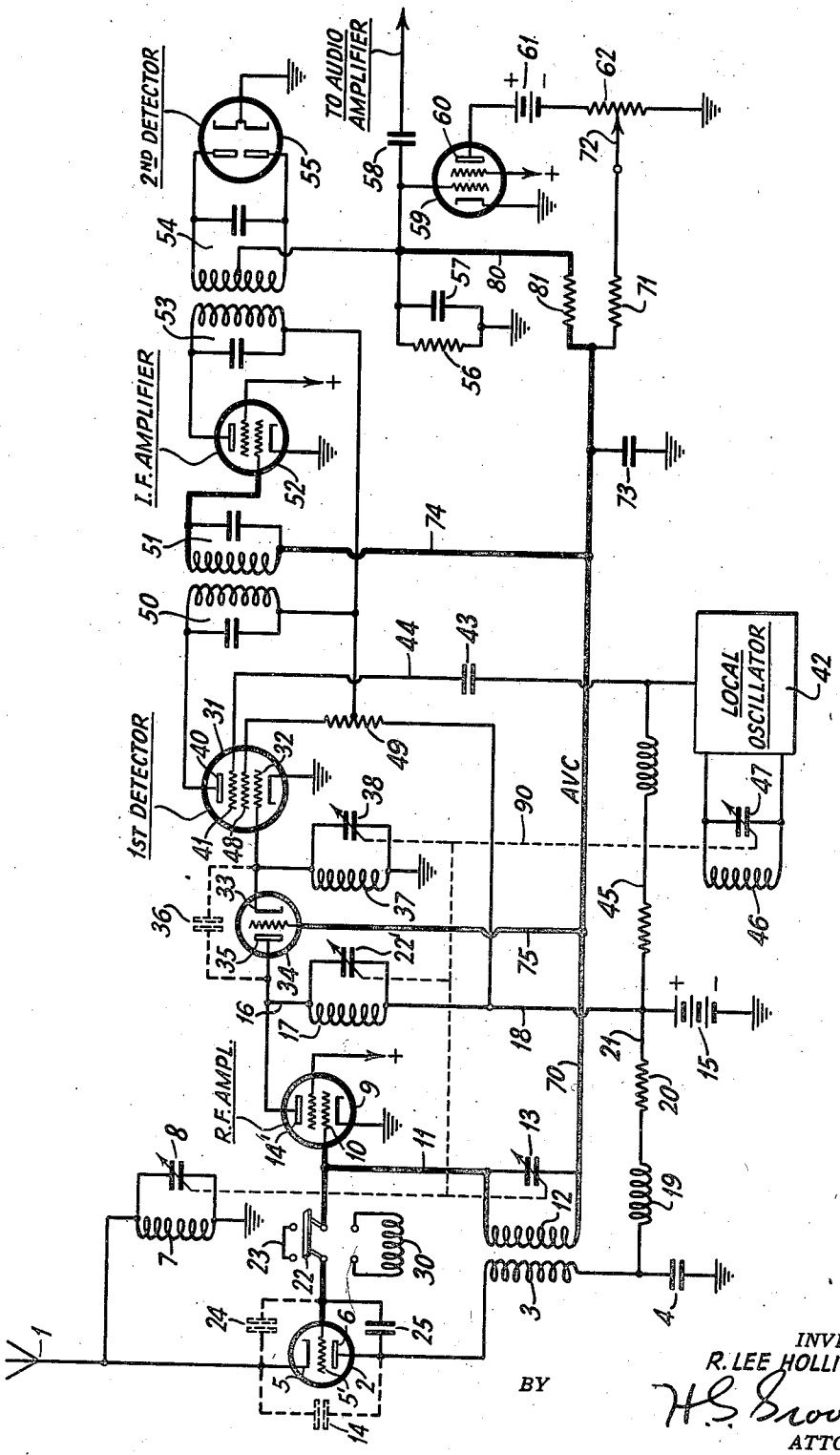
May 27, 1941. R L. HOLLINGSWORTH 2,243,423

AUTOMATIC VOLUME CONTROL CIRCUIT

Filed May 9, 1939



INVENTOR.
R. LEE HOLLINGSWORTH

BY H. S. Grover

ATTORNEY.

Patented May 27, 1941

2,243,423

UNITED STATES PATENT OFFICE

2,243,423

AUTOMATIC VOLUME CONTROL CIRCUIT

R Lee Hollingsworth, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application May 9, 1939, Serial No. 272,549

7 Claims. (Cl. 250—20)

My present invention relates to radio receivers provided with automatic volume control circuits, and more particularly to a radio receiver having an automatic gain control circuit functioning to vary the magnitude of signal coupling paths in the receiver.

One of the main objects of my present invention is to provide a radio receiver of the type employing automatic gain control, wherein the gain control circuit is employed to vary the efficiency of transfer of signal energy between the signal collector and first tube of the receiver and between amplifying stages within the receiver.

Another important object of my invention is to provide a radio receiver which utilizes an electronic capacitive reactance to transfer signal energy from a signal collector to the first signal amplifier, and wherein a signal-derived voltage is utilized to vary the amplitude of the electronic reactance in the sense such as to provide a substantially uniform carrier amplitude at the receiver detector input circuit.

Another object of my invention may be stated to reside in the provision of electronic capacities between pairs of cascaded signal circuits of the receiver, and an automatic gain control circuit of the receiver being utilized to vary the magnitudes of said capacitances and simultaneously to vary the gain of at least one signal amplifier tube of the receiver.

Still another object of this invention is to provide, in a radio receiver, an automatic gain control circuit which functions to vary the gain of signal amplifier tubes, and in addition is used to vary the amplitude of a coupling capacity between the antenna circuit and the input tube of the receiver, the capacity being provided by the electrodes of an electron discharge tube.

Still further objects of my present invention are to improve generally the functioning of receivers employing automatic gain control, and more especially to provide a radio receiver, adapted to receive short waves, which has a highly reliable and efficient automatic gain control circuit embodied therein in an economical manner.

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.

Referring now to the accompanying drawing, wherein there is shown a circuit diagram of a superheterodyne receiver embodying my present invention, the receiving circuit is shown as comprising a signal collctor 1 which may be of any desired type. For example, the collector may be the usual antenna, or it may comprise a radio frequency distribution line, loop antenna, a dipole, or any other well known form of signal collector construction. The collector 1 is connected to ground through a path which includes an electron discharge tube 2, coil 3 and condenser 4. The cathode 5 of tube 2 is connected to the signal collector 1, while plate 6 is connected to one end of coil 3. A second path to ground includes the tunable signal circuit comprising coil 7 and variable condenser 8, the high potential side of circuit 7—8 being connected to the signal collector 1.

The numeral 9 denotes an electron discharge tube arranged in the tunable radio frequency amplifier stage, the signal grid 10 of the tube 9 being connected through lead 11 to the high potential side of the tunable signal input circuit comprising coil 12 and variable condenser 13. The antenna circuit coil 3 is magnetically coupled to the input circuit coil 12 to provide signal energy transfer from the collector 1 to the input circuit 12—13, it being understood that the signal energy is transferred in that case by virtue of the capacity existing between cathode 5 and plate 6. This cathode to plate capacity is designated by 14, and is shown in dotted lines. The cathode of tube 9 is established at ground potential, while the plate 14' thereof is connected to the common source of direct current potential 15 through a path which includes lead 16, coil 17 and lead 18. Lead 18 is connected to the positive terminal of source 15. The screen grid electrode of tube 9 may be connected to a desired positive potential point on source 15.

The plate 6 of coupling tube 2 is connected to the positive terminal of source 15 so as to provide space current flow in tube 2, and such connection is made through a path which includes coil 3, the radio frequency choke 19, resistor 20 and lead 21. The variable tuning condenser 22' is connected in shunt with coil 17, and circuit 17—22' functions as an additional tunable signal circuit. In order to augment the transfer of signal energy from the signal collector to the signal grid 10 of tube 9, there is provided a connection between the grid 5' of coupling tube 2 and the signal grid 10. This connection is provided when the switch 22 is adjusted in its uppermost posi-

tion, that is to say in position to provide the short lead 23 in the connecting path between grid 5' and grid 10. In such position of the switch the signal energy is transferred to grid 10 through the grid to cathode capacity of tube 2.

This grid to cathode capacity of tube 2 is designated by 24, and is denoted by the dotted line capacity on the drawing between cathode 5 and grid 5'. In order to augment the magnitude of capacity 24 there is provided a condenser 25 between the plate 6 and grid 5', and those skilled in the art are fully aware of the fact that such a plate to grid condenser augments the normal cathode to grid capacity value. Hence, it will be seen that when switch 22 is thrown into its uppermost position signal energy is impressed upon signal grid 10 through two paths. One of these paths comprises the capacity 14 and magnetic coupling between coils 3 and 12, whereas the other path comprises the capacity 24. It may be pointed out that the function of the tunable circuit 7—8 is to offer an infinite impedance to the desired signal energy, and provide a low resistance direct current return path for the tube 2. In other words, inserting the tuned circuit 7—8 in the antenna circuit provides an additional stage of selectivity ahead of the usual tunable input circuit 12—13 of amplifier 9.

When the switch 22 is adjusted to its lowermost position, that is when in contact with the ends of radio frequency choke coil 30, the grids 5' and 10 are decoupled. In that case no signal transfer occurs through the capacity 24, and signal transfer is effective solely through capacity 14 and the magnetic coupling between coils 3 and 12. The radio frequency amplifier tube 9 is coupled to the input electrodes of the first detector tube 31. The cathode of the latter is established at ground potential, while the signal input grid 32 thereof is connected to the cathode 33 of a coupling tube 34. The plate 35 of coupling tube 34 is connected to the lead 16 so that the plate 35 is established at a positive potential with respect to cathode 33. The capacity 36 existing between plate 35 and cathode 32 provides the signal energy transfer path between the tunable signal circuit 17—22' and the succeeding tunable signal circuit comprising coil 37 and variable tuning condenser 38.

The high potential side of circuit 37—38 is connected to the junction of cathode 33 and grid 32, while the low potential side thereof is grounded. The tube 31 includes a plate electrode 40 and an oscillation electrode 41. There is impressed upon electrode 41 locally produced oscillations from any well known type of local oscillator 42, the local oscillations being transmitted to electrode 41 through a path which includes condenser 43 and lead 44. The lead 45 is provided between the oscillator network 42 and the positive terminal of source 15 to provide a path through which the required positive potential can be applied to the oscillator tube of network 42. Numeral 46 denotes the oscillator tank circuit coil, while the variable tuning condenser of the tank circuit is denoted by 47. Numeral 48 denotes the positive screen grid electrode of tube 31, and this screen electrode is positioned between signal grid 32 and oscillation grid 41. The electrode 48 may be connected through a voltage reducing resistor 49 to the positive potential lead 18.

It is not believed necessary to describe in detail the manner in which the intermediate frequency energy is produced in the plate circuit of tube 31. Those skilled in the art are fully acquainted with the fact that the signal and oscillator voltages modulate the electron stream flowing to plate 40. There is produced across the intermediate frequency output circuit 50 voltage of a predetermined operating intermediate frequency. The high potential side of the output circuit 50 is connected to plate 40, whereas the low potential end of the circuit is connected to an intermediate point on resistor 49 so that the plate 40 may be established at a desired positive potential. The intermediate frequency voltage produced across circuit 50 is impressed upon the resonant input circuit 51 of the succeeding intermediate frequency amplifier tube 52. Circuit 51 is tuned to the operating intermediate frequency, and is magnetically coupled to circuit 50. The cathode of tube 52 may be grounded while the signal input grid thereof is connected to the high potential end of input circuit 51.

The resonant output circuit 53, tuned to the operating intermediate frequency, is connected between the plate of amplifier 52 and the positive potential lead to resistor 49. The amplified intermediate frequency voltage developed across circuit 53 is impressed upon the second detector resonant input circuit 54, the latter being tuned to the operating intermediate frequency. The second detector is shown as embodying a tube of the double diode type, and this may be a tube of the 6H6 type if desired. The common cathode lead of the second detector tube 55 is grounded, while the diode anodes are connected to the opposite ends of the input circuit 54. The midpoint of the coil of circuit 54 is connected to ground through a path which includes the load resistor 56, and it will thus be seen that there is developed across resistor 56 a direct current voltage component, and an audio frequency voltage component assuming the received carrier is modulated by an audio signal. The tube 55 is embodied in a full wave rectifier circuit, and an intermediate frequency carrier by-pass condenser 57 is shunted across the load resistor 56.

The audio frequency voltage component developed across resistor 56 is impressed upon the succeeding audio frequency amplifier through an audiofrequency transmission condenser 58, whereas the direct current voltage component is impressed between the input electrodes of direct current amplifier tube 59. The cathode of tube 59 is established at ground potential, whereas the input grid thereof is connected to the anode end of lead resistor 56. The plate 60 of tube 59 is connected to the positive terminal of a direct current source 61, and the negative terminal of source 61 is connected to ground through a resistor 62.

In the absence of received signal energy the rectified voltage developed across resistor 56 does not appear. Accordingly the space current flow through tube 59 is maximum, and the voltage drop across resistor 62 is also a maximum. A predetermined portion of the direct current voltage developed across resistor 52 is impressed upon the control grid of each of tubes 2, 9, 34 and 52. The predetermined portion of voltage is chosen to have a magnitude, in the absence in received signals, such that the transmission efficiency of these controlled tubes is a minimum. As a matter of fact, the minimum transmission efficiency is chosen so low that reproduction of noises, due to the low signal to noise ratio, is substantially prevented. This is accomplished by providing a

lead 70 which is connected to the desired point on resistor 62 through a path including resistor 71 and the adjustable tap 72.

The signal input grid of amplifier 52 is connected to lead 70 through a lead 74. The control grid of coupling tube 34 is connected to lead 70 by a lead 75, and the signal grid 10 of amplifier 9 is connected to lead 70 by virtue of its connection to lead 11 and coil 12. It is pointed out that lead 70 is connected to the low potential end of input coil 12. It will now be seen that regardless of whether the switch 22 is in its upper or lower positions, grid 5' will be connected to lead 11 and, therefore, to the biasing lead 70.

It will now be appreciated that in the absence of signal energy above a predetermined intensity magnitude, the control grids of each of tubes 2, 9, 34, 52 will have a bias which is determined by the position of tap 72 on resistor 62. This bias will be sufficiently negative to prevent efficient transmission of electrical impulses through these tubes. In the case of coupling tubes 2 and 34 the consequence of such high negative biasing will be to diminish the magnitudes of capacities 14, or 24, and 36 to minimum values. It will, therefore, be seen that there is provided a noise "squelch" circuit which functions electrically to prevent reproduction of undesirable noises when the received signal carrier amplitude is less than predetermined intensity.

Since the control grid of tube 59 is connected to the anode end of load resistor 56, it follows that as soon as the received signal energy increases in intensity the space current flow of tube 59 will be reduced and the resulting direct current voltage drop across resistor 62 will also be reduced. Hence, as the received carrier amplitude increases, the noise reduction bias of the controlled tubes will be reduced, and maximum gain of these controlled tubes will be restored. To provide automatic gain control of the controlled tubes for received signals whose carrier amplitude exceeds a predetermined amplitude, there is provided a lead 80 between the junction of lead 70 and resistor 71 and the anode end of load resistor 56. The lead 80 includes the resistor 81. The volume control network comprises resistors 81 and 71 and the condenser 73 which function as the usual time constant network. The resistors 81 and 71 also suppress pulsating components in the voltages applied to the control grids of the controlled tubes, and which voltages are derived from across resistors 56 and 62.

It will now be seen that when the anode end of resistor 56 becomes sufficiently negative to cause the control grid of tube 59 to cut off the space current flow through the latter, then the direct current voltage across resistor 62 will be zero. The control grids of each of tubes 2, 9, 34 and 52 will now be electrically biased by virtue of the AVC path including leads 70 and 80. As the received carrier amplitude increases, the direct current voltage developed across resistor 56 increases. As a result, the control grids of the controlled tubes will be biased in an increasingly negative manner to decrease the gain of each of the controlled tubes. Such gain decrease will occur to an extent sufficient to maintain the carrier amplitude at the detector input circuit 54 substantially uniform over a wide range of signal carrier amplitude variation at the collector 1.

The rotors of the variable tuning condensers 13, 8, 22' and 38 may be uni-controlled with the rotors of the tank circuit tuning condenser 47, and the dotted line representation 90 denotes such common tuning mechanism. As those skilled in the art fully know, the frequency range of the tank circuit 46—47 will differ at all times from the signal frequency range by the chosen intermediate frequency. While the present arrangement of automatic gain control may be utilized in the broadcast range of 500 to 1500 kilocycles, it has particular value in the short wave frequency ranges because of the greater degree of automatic signal amplitude control provided by this system. It will be realized that in the present arrangement, and assuming that the tuning mechanism has been adjusted to receive a signal of relatively small amplitude as when receiving a distant station, the automatic volume control (designated as AVC in the drawing) is at its minimum operation because a minimum direct current voltage is produced across resistor 56. In this case each of tubes 9 and 52 is operating at maximum gain, and each of coupling tubes 2 and 34 is operating with maximum gain.

Assuming, now, that switch 22 is in its upper position, this means that signal energy is being transferred to the signal input circuit 12—13 through capacities 14 and 24, and that capacity 36 is operating with maximum signal energy transfer between circuits 17—22 and 37—38. However, should the tuning mechanism be now adjusted to receive a strong local station, then the direct current voltage developed across resistor 56 increases, and as a result the control grids of each of tubes 2 and 34 are biased to an extent such as greatly to decrease the magnitude of each of capacities 14, 24 and 36. At the same time, the gain of each of tubes 9 and 52 is decreased. The result of this reduction of the gain of each of the controlled tubes is greatly to decrease the overall signal transmission efficiency to the detector input circuit 54, and thus providing a much greater degree of control over the volume of the receiver. It will be understood that the reverse of the gain control sequence takes place should a strong carrier amplitude begin to fade so as to require greater amplification prior to the detector input circuit. The type of automatic volume control circuit shown herein, except for the action of the coupling tubes 2 and 34, is similar to that described in my U. S. Patent No. 2,144,221 granted Jan. 7, 1939.

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 forth in the appended claims.

What I claim is:

1. In combination with a signal amplifier having a tunable signal input circuit, a signal collector, a coupling network between the collector and input circuit, said network comprising a tube having at least a cathode, grid and plate, said tube having its cathode to plate capacity connected between the collector and input circuit to provide a first signal coupling path, and means for varying the potential of the grid thereby to adjust the magnitude of said capacity, said tube additionally having a cathode to grid capacity, and means connecting said last capacity between the collector and input circuit for providing a second coupling path between said collector and said input circuit.

2. In a receiver comprising a plurality of cas-

caded signal transmission tubes, a signal collector, an electron discharge tube having its plate to cathode capacity connected between the collector and the input electrodes of the first of said tubes to provide a signal coupling path between the collector and the first transmission tube, said coupling tube having a control grid between the cathode and plate, and means for connecting the cathode to grid capacity thereof as a second coupling path between the collector and first transmission tube, means responsive to variations in the signal carrier amplitude for providing a variable unidirectional voltage, and means for controlling the space current flow between the said plate and cathode to adjust the magnitude of the said capacity.

3. In a radio receiving system, a signal collector, a tunable signal amplifier, a coupling tube having a cathode, grid and plate, means connecting the tube between the collector and amplifier to provide the cathode to plate capacity as a signal coupling path therebetween, a second signal amplifier, a second coupling tube provided with a cathode, grid and plate, means connecting the second coupling tube between said amplifiers to provide the cathode to plate capacity of the second coupling tube as a signal coupling path between the amplifiers, an automatic gain control circuit connected between the second amplifier output circuit and at least said first amplifier, means for connecting the grid to cathode capacity of the first coupling tube as an auxiliary signal coupling path between the collector and the first amplifier.

4. In combination, in a radio receiving system, a source of signal oscillations, a tuned oscillatory circuit, a signal transmission path comprising a tube provided with at least a cathode, grid and plate, the plate to cathode capacity of the tube providing the said transmission path between the source and circuit, and means responsive to signal amplitude variation for automatically varying the grid potential thereby to adjust the magnitude of said capacity, means for connecting the grid to cathode capacity of said tube between the source and oscillatory circuit to provide an additional signal coupling path, and said varying means functioning to adjust the magnitude of the grid to cathode capacity.

5. In a signal receiver, a pair of cascaded similarly tuned circuits, a tube provided with at least a cathode, grid and plate, means for connecting the tube between said circuits to provide the cathode to plate reactance of the tube as a signal transmission path between the circuits, and means responsive to an increase in the signal amplitude for increasing the negative potential of said grid to an extent sufficient substantially to reduce the reactance value, and additional means for connecting the grid to cathode reactance of the tube between said circuits to provide an additional signal transmission path.

6. In a radio receiving system, a signal collector, a signal amplifier having a tuned signal input circuit, a tube provided with a cathode, grid and plate, means connecting the tube to said collector and input circuit to provide the grid to cathode capacity as a first signal transfer path, means including the cathode to plate capacity of said tube as a second signal transfer path, and signal-responsive automatic gain control means for adjusting the grid potential thereby to vary the value of said two capacities.

7. In combination with a signal responsive circuit followed by a signal utilization tube having at least a cathode, a control electrode and an output electrode, a signal voltage transmission path connected between said signal responsive circuit and a control electrode of said utilization tube, an electron discharge tube included in said path, and the capacity existing within said tube between the plate and cathode thereof providing a signal coupling element of said transmission path, a control grid located between said last plate and cathode and providing capacity between the cathode and grid, said last capacity providing a second signal coupling element to said path, and means responsive to received signal energy above a predetermined amplitude for reducing the magnitude of said capacities.

R LEE HOLLINGSWORTH.