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AUTOMATIC VOLUME CONTROL CIRCUIT

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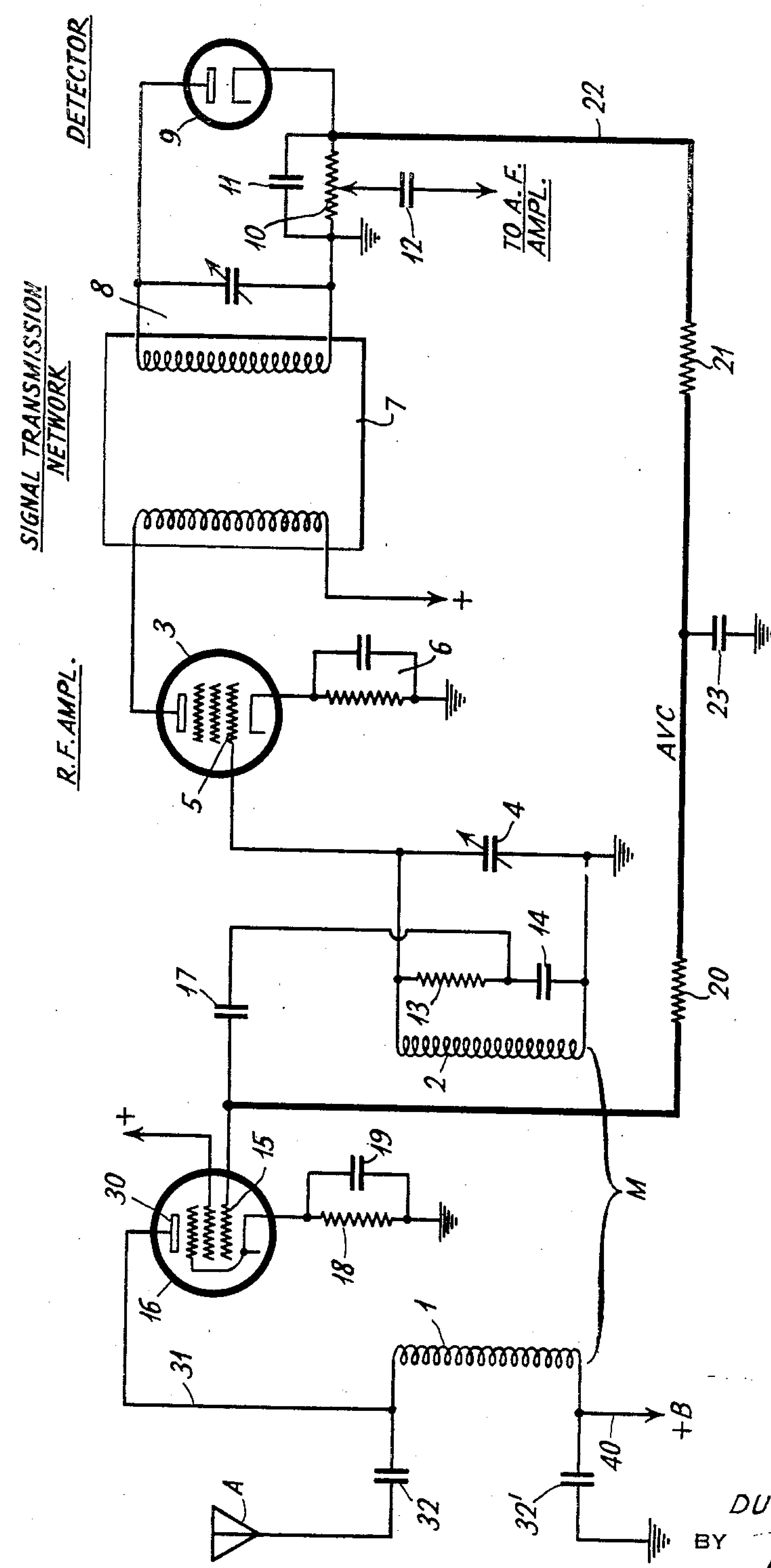

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AUTOMATIC VOLUME CONTROL CIRCUIT

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My present invention relates to automatic volume control circuits, and more particularly to an improved method of, and means for, automatically regulating the signal transmission to the demodulator of a radio receiving system.

In general, automatic volume control circuits have in the past utilized an automatic variation of mutual conductance of high frequency amplifier tubes; this has been accomplished by a variation in the bias of the signal grids of the high frequency amplifiers in response to a signal carrier amplitude variations. As is well known, such automatic volume control method has inherent disadvantages even when tubes of the exponential characteristic type are used for high frequency amplifiers under control. The signal voltage handling capabilities of such controlled tubes are a frequent handicap.

Now, I have found that such disadvantages of the prior automatic volume control (AVC hereinafter) method are avoided if the tuned impedance of a circuit, or circuits, to which a high frequency amplifier tube is connected, is varied in proportion to the carrier amplitude change. By such method of AVC the control action is secured without undue signal swing.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide an AVC arrangement for a radio receiver, and wherein the arrangement functions by automatically regulating the input impedance of the tuned input circuit coupled to the signal collector of the receiving system.

Another important object of the present invention is to provide a method of, and means for, providing AVC in a radio receiver, wherein there is employed a negative feedback circuit between the first tuned input circuit and the signal collector, and the magnitude of negative feedback is varied in response to the carrier amplitude variation of received signals.

Another object of my present invention is to provide in association with the signal collector and first tunable input circuit of a radio receiver, a negative feedback amplifier circuit which utilizes signal voltage developed at the first tunable input circuit and which feeds it back to the signal collector circuit in degenerative phase; and the magnitude of degenerative feedback being regulated in response to carrier amplitude variation in such a manner that the signal transmission to the demodulator is reduced with carrier amplitude increase and at a rate such that the carrier amplitude at the demodulator input circuit is substantially uniform.

Still other objects of my present invention are to improve generally the simplicity and efficiency of AVC circuits, and more especially to provide an AVC circuit which is not only reliable and effective in operation, but is economically manufactured and assembled in radio receivers of all types.

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 in schematic form a radio receiving system, it will be observed that the signal collector A is of the grounded antenna type. Of course, the collector A may be a radio frequency line, a loop collector, or even the usual type of collector employed on mobile structures, such as an automobile. The antenna circuit A includes the primary winding **1** of the radio frequency coupling transformer M; the secondary winding **2** of the latter being included in the tunable input circuit of the first radio frequency amplifier tube **3**. The winding **2** has connected thereacross a variable tuning condenser **4**. The reference letter M denotes the mutual inductance coupling the signal collector circuit and the tunable input circuit **2—4**; and it is to be understood that the magnitude of the mutual inductance M is such that weak signals are efficiently transmitted between the signal collector and the input circuit **2—4**.

One side of input circuit **2—4** is at ground potential, whereas the opposite side is connected to the signal input grid **5** of amplifier tube **3**. The cathode of the amplifier **3** is connected to ground through the usual self-biasing resistor-condenser network **6**, and the bias developed by this network will be of the order of −3 volts. The amplified signal output of amplifier **3** may be transmitted through a signal transmission network **7**, and it will be noted that the network **7** is schematically represented. Regardless of the construction of network **7**, it will be understood that the output energy thereof will be impressed on the tuned input circuit **8** of the demodulator, or detector, **9**.

The numeral **9** denotes a diode type of demodulator, and the anode is connected to the cathode thereof through a series path which includes input circuit 8 and the load resistor 10; the load resistor being shunted by the carrier by-pass condenser 11. The anode terminal of load resistor 10 is established at ground potential; while the audio voltage component of the rectified voltage, developed across load resistor 10, is taken off by a connection 12 for utilization in the subsequent audio frequency amplifier network. The latter network may comprise one or more stages of audio frequency amplification, and a reproducer will terminate the amplifier network.

The receiving system described up to this point is of a general character, and, of course, specifically the receiver may be of the tuned radio frequency type or of the superheterodyne type. Where the receiver is of the tuned radio frequency amplifier type, the network 7 will include one or more additional stages of tunable radio frequency amplification similar to the stage including tube 3. The variable tuning condenser of the circuit 8 will be uni-controlled in adjustment with the variable tuning condensers in the preceding networks. The tuning range of the receiver may be in the broadcast band of 500 to 1500 k. c.; the receiver may be of the multi-range type. If the receiver is of the superheterodyne type, then the network 7 may include the first detector circuit whose resonant input circuit is tunable over the same range as the input circuit 2—4 and a local oscillator network will be used to supply oscillations to the first detector, whose oscillations differ in frequency from the signal frequencies by the operating I. F. value. The I. F. energy will be amplified in one or more stages of I. F. amplification, and the input circuit 8 of the diode 9 will be fixedly tuned to the operating I. F. value. It is not believed necessary to show these circuit details, for the reason that those skilled in the art are fully aware of these two general types of circuits.

The AVC circuit functions, as is well known, to compensate for signal carrier amplitude variations which occur over a wide range at the collector A. Such variation may be due to fading, or other causes. The AVC circuit is employed to maintain the signal carrier amplitude at the detector input circuit 8 substantially constant regardless of the relatively wide variation in carrier amplitude at the collector A. In the present circuit this is accomplished, unlike in the prior art, by providing a negative feedback path between the input circuit 2—4 and the signal collector circuit. More specifically, there is connected across the secondary winding 2 a path which includes the resistor 13 and the condenser 14. The junction of resistor 13 and condenser 14 is connected to the grid 15 of tube 16 through a path which includes condenser 17. The tube 16 may be an electron discharge tube of the pentode type, and the cathode thereof is connected to ground through a resistor 18 which is shunted by a signal carrier by-pass condenser 19. The voltage developed across resistor 18 is employed to provide the normal operating bias for the grid 15.

There is provided a direct current voltage connection between the control grid 15 and ground through a path which includes the filter resistor 20, the resistor 21 and the lead 22. The condenser 23, connected between resistor 21 and ground, functions to provide with resistor 21 a filter network having a time constant such that the AVC circuit will be responsive solely to carrier amplitude variations. The resistor 20, as well as network 21—23, functions to suppress pulsations in the AVC bias transmitted to grid 15. The lead 21 is connected to the cathode side of load resistor 10, and an increase in current flow through resistor 10 results in an increase in the potential of control grid 15 in a positive polarity sense.

The plate 30 of tube 16 is connected by lead 31 to the high alternating potential side of winding 1. A direct current blocking condenser 32 is disposed between the collector A and the high potential side of winding 1. Similarly a direct current blocking condenser 32′ is connected between ground and the low alternating potential side of winding 1; it being noted that a lead 40 connects the positive potential terminal of a direct current voltage source (not shown) to the junction of condenser 32′ and winding 1. Hence, it will be seen that the plate 30 of tube 16 is connected to a point of proper positive potential through a path which includes lead 31, winding 1 and lead 40. It will be understood that the various energizing potentials for the electrodes of tubes 16, 3, as well as any tubes in network 7, may all be derived from a common direct voltage source.

In explaining the operation of the present invention, it is first pointed out that there has been provided between an antenna A and the first high frequency amplifier tube 3 a pair of coupling paths. One of these paths feeds signal energy towards the amplifier 3 and is reactive in nature; the other path feeds signal voltage back from the input circuit of the amplifier towards the signal collector circuit, and it may be said that this coupling is electronic in nature. The relation between these two couplings is such that they are in opposition, and the magnitude of electronic coupling is varied by the direct current voltage developed across resistor 10 in a sense such that the signal voltage fed back to the signal collector circuit increases in its opposition effect as the signal carrier amplitude increases. This biasing effect is at a rate such that the signal carrier amplitude at the input circuit 8 is maintained substantially constant. By having, the signal voltage fed through coupling M a maximum during weak signal reception and the signal voltage fed through tube 16 a minimum at such reception, it will be seen that carrier amplitude increase will cause the biasing signal voltage fed to amplifier 16 to decrease the transmission of signal voltage through coupling M.

The specific mechanism of the negative feedback arrangement through tube 16 will now be considered. By virtue of the series path including resistor 13 and condenser 14, and the tube 16, there is impressed across coil 1 signal voltage which is in degenerative phase with the signal voltage impressed upon collector A. The tube 16 may have a cut-off bias applied to the grid 15 thereof in the absence of signals above a predetermined amplitude. This is done by choosing the magnitude of resistor 18 so that in the absence of voltage developed across resistor 10, the grid 15 will be biased to cut-off at the voltage across the resistor 18. As the signal carrier amplitude increases above this cut-off bias value the cathode side of resistor 10 will become increasingly positive, and the grid 15 will be varied in a positive polarity sense in potential. This will increase the mutual conductance of tube 16, and, therefore, increase the magnitude of the signal voltage fed to the winding 1 in degenerative phase.

When a signal from the collector A traverses path 32—1—32′ to ground the current in coil 1 lags the voltage thereacross by substantially 90 degrees; this current induces a voltage in coil 2 by virtue of the mutual inductance M, and which voltage again undergoes a 90 degree phase rotation. This phase rotation may be in either positive or negative direction depending upon the relative polarity of coil 1 and 2; that is, they may be connected in series aiding phase, or series opposition. The induced voltage in circuit 2—4 produces an in-phase current since the circuit will be tuned to resonance with the impressed frequency; this in-phase current producing a voltage across coil 2 in quadrature with the induced voltage. The voltage across coil 2, also, flows through the path 13—14, and, if the absolute magnitude of resistance 13 be high in comparison with impedance of capacity 14, the current will be substantially in phase with the voltage. This in-phase current produces a leading voltage across capacity 14 which is then applied to the grid of tube 16.

The radio frequency plate current of tube 16 flowing through lead 31 to coil 1 is responsive to variations of mutual conductance of tube 16 produced by change in the direct current bias of that tube. The radio frequency current flowing in the lead 31, by proper polarity of mutual inductance M, will be in opposition to the signal current, and, therefore, be made to decrease the current of signal frequency in coil 1. The effect of the connection of tube 16 across coil 1 is similar to the addition of a resistor thereacross, the magnitude of the resistance being varied by the direct current bias on tube 16; that is by the AVC voltage. Since coil 1 is coupled to coil 2 any resistance connected across coil 1 will affect circuit 2—4. The tuned impedance of circuit 2—4 is equal to the square of the reactance divided by the circuit resistance. The variations of virtual resistance across coil 1, due to tube 16, will therefore vary the effective resistance, and consequently the tuned impedance of circuit 2—4. With resistor 13 and capacity 14 connected as shown, the polarity of mutual inductance M which causes a reduction of voltage across coil 1 with increasing mutual conductance of tube 16 produces an effective positive resistance across coil 1 independent of frequency. The opposite polarity of M will produce a negative resistance, and an effective increase in coupling between the circuits with increase of mutual conductance of tube 16.

If the positions of 13 and 14 be reversed so that the grid voltage of tube 16 is taken across resistor 13, the polarity of M, which produced an effective positive resistance independent of frequency across coil 1 with 13 and 14 connected as in the drawing, will produce a negative impedance across coil 1 varying inversely as the square of the frequency. In general the connection of 13 and 14 as shown is to be preferred. With tube 16 biased to cut-off in the no-signal condition, the magnitude of M should be such that optimum transfer occurs. The polarity of M should be such that increased signal causes radio frequency currents to flow in plate of tube 16 in a direction to oppose the signal voltage across coil 1, and, therefore, to act so that the effective coupling between 1 and 2 is reduced with strong signals.

It will be seen that the use of the AVC arrangement disclosed does not vary the bias of the signal grid 5 of the high frequency amplifier; the present arrangement is free from cross-modulation effects. Further, the signal voltage handling capabilities of the high frequency signal amplifier need not be considered. For example, it is not necessary to use tubes of the exponential type. The tube 16 which has the variable signal-derived bias applied thereto, does not feed signal energy towards the demodulator, and a tube can be chosen for its purpose without considering its effects on signal reproduction.

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 is claimed is:

1. In a radio receiver of the type including an antenna circuit, a radio frequency amplifier having a tunable input circuit, a coil in said antenna circuit reactively coupled to said input circuit, a rectifier having an input circuit coupled to the said amplifier, means common to the amplifier input circuit and said antenna circuit for impressing upon said antenna circuit signal voltage derived from said amplifier input circuit but in degenerative phase with respect to the signal voltage at the antenna circuit, means, responsive to the variation in magnitude of the direct current voltage at said rectifier, for varying the magnitude of said degenerative voltage, said last means including the load resistor in circuit with said rectifier, and a connection between a point on the resistor, which assumes an increasingly positive potential as the carrier amplitude increases, and said common means, said common means comprising a tube which includes said antenna coil in its space current path.

2. In combination with an antenna circuit, a high frequency amplifier having a resonant signal circuit associated therewith, a coil in said antenna circuit reactively coupling the antenna circuit and said resonant circuit, means in said resonant circuit for deriving a voltage from signals impressed by the antenna circuit upon said resonant circuit through the reactive coupling, means, consisting of a tube having said coil in its space current path, for impressing the derived voltage upon the antenna circuit in substantially degenerative phase with respect to the signal voltage transmitted through said reactive coupling, and means, responsive to an increase in signal carrier amplitude, for increasing the magnitude of the degenerative voltage and thereby reducing the effective magnitude of said reactive coupling.

3. In combination with an antenna circuit, a high frequency amplifier having a resonant signal circuit associated therewith, a coil in said antenna circuit reactively coupling the antenna circuit and said resonant circuit, a reactive impedance in shunt across said resonant circuit for deriving a voltage from signals impressed by the antenna circuit upon said resonant circuit through the reactive coupling, means impressing the derived voltage upon the antenna circuit in substantially degenerative phase with respect to the signal voltage transmitted through said reactive coupling, means, responsive to an increase in signal carrier amplitude, for increasing the magnitude of the degenerative voltage thereby to vary the value of said reactive coupling, and said impressing means including an electron discharge tube having said coil in its space current path and having an input electrode connected to said voltage deriving means, and an output electrode of

said last tube being connected to said antenna circuit.

4. In combination with the tuned input circuit of a signal transmission tube of a signal receiving system, a coil reactively coupled to said input circuit, a source of signals coupled to said coil, an automatic volume control circuit comprising a tube having at least an input electrode, a cathode and an anode, a reactive impedance in shunt across said input circuit for developing signal voltage in degenerative phase to the signal voltage at the coil, means for impressing the degenerative voltage between said cathode and input electrode, said coil being in the space current path of said tube and having a direct current connection to said anode, and means responsive to signal amplitude increase for varying said tube gain in an increasing sense.

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