Aug. 18, 1936. R. A. BRADEN 2,051,364

AUTOMATIC SENSITIVITY CONTROL CIRCUIT

Filed Oct. 16, 1933 3 Sheets-Sheet 1

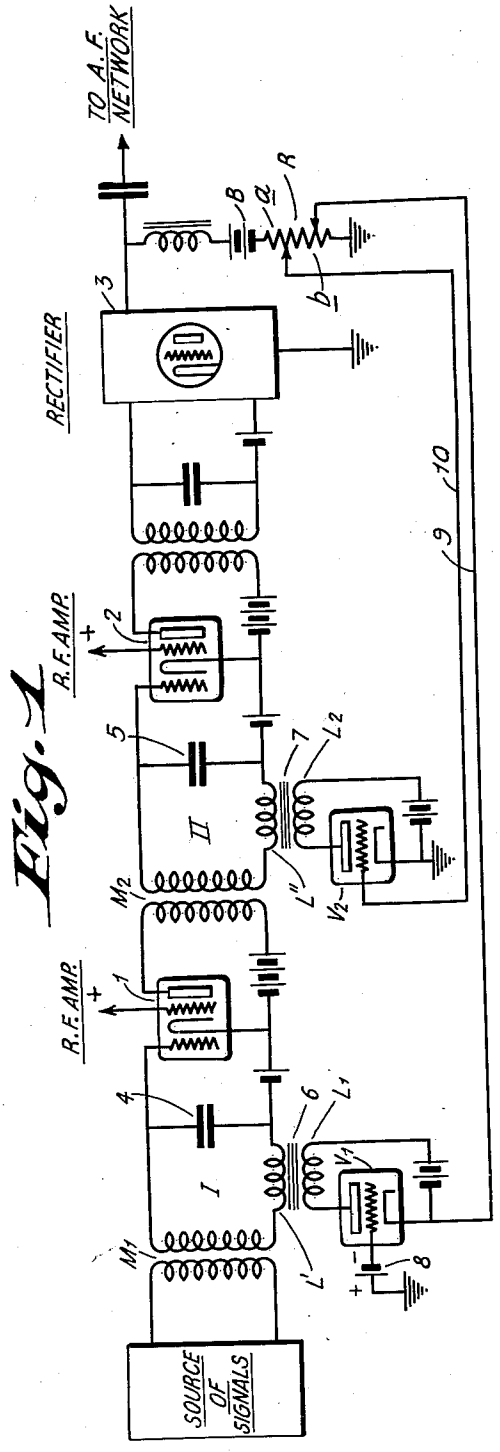


Fig. 1

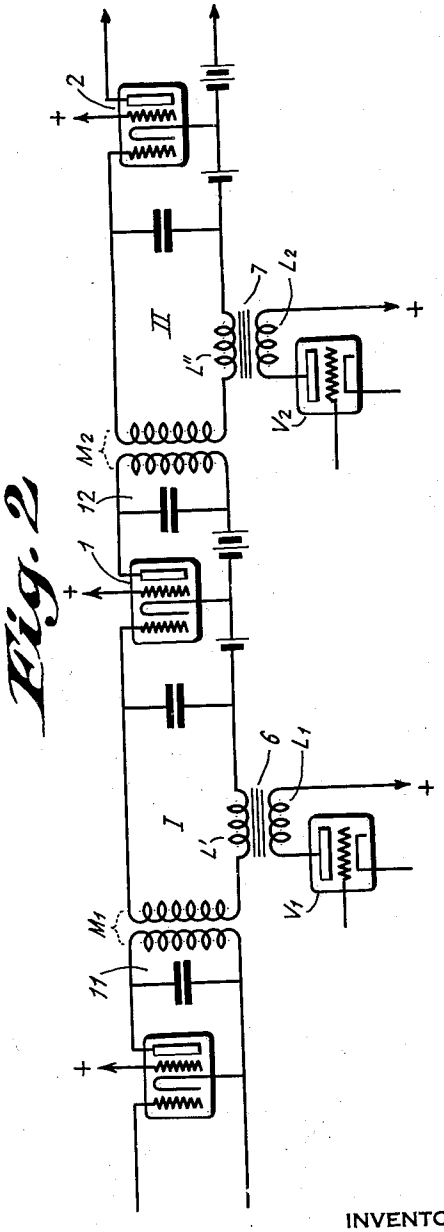


Fig. 2

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Filed Oct. 16, 1933 3 Sheets-Sheet 2

Fig. 3

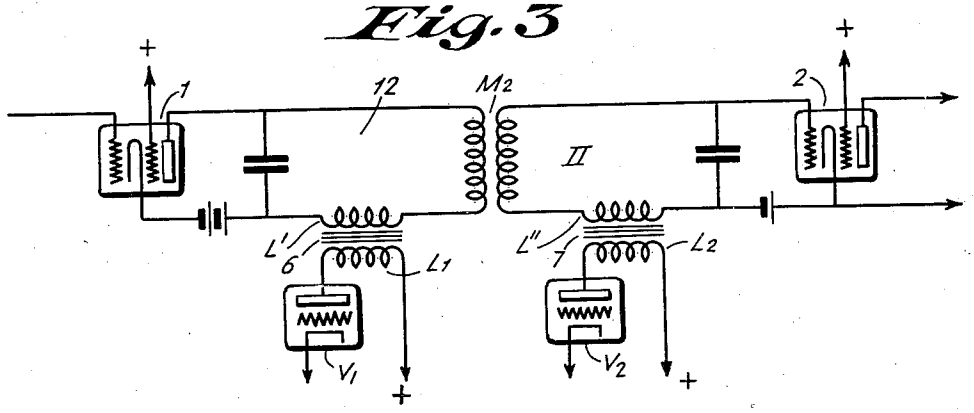


Fig. 4

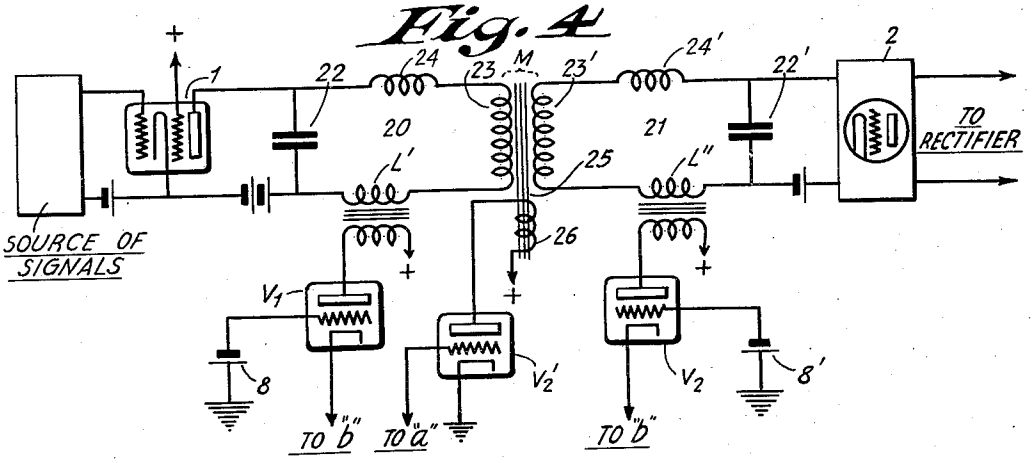
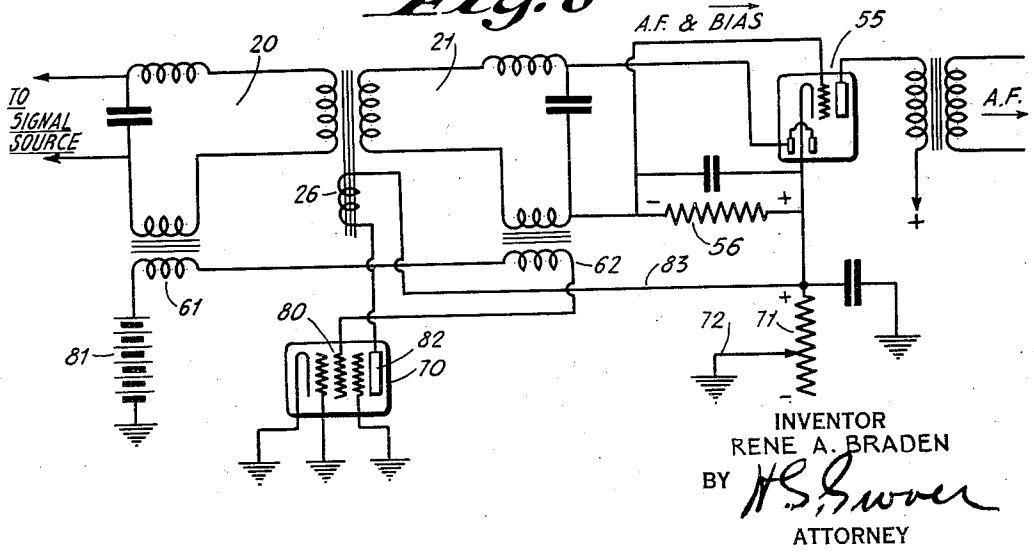


Fig. 6



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Aug. 18, 1936. R. A. BRADEN 2,051,364

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Filed Oct. 16, 1933 3 Sheets-Sheet 3

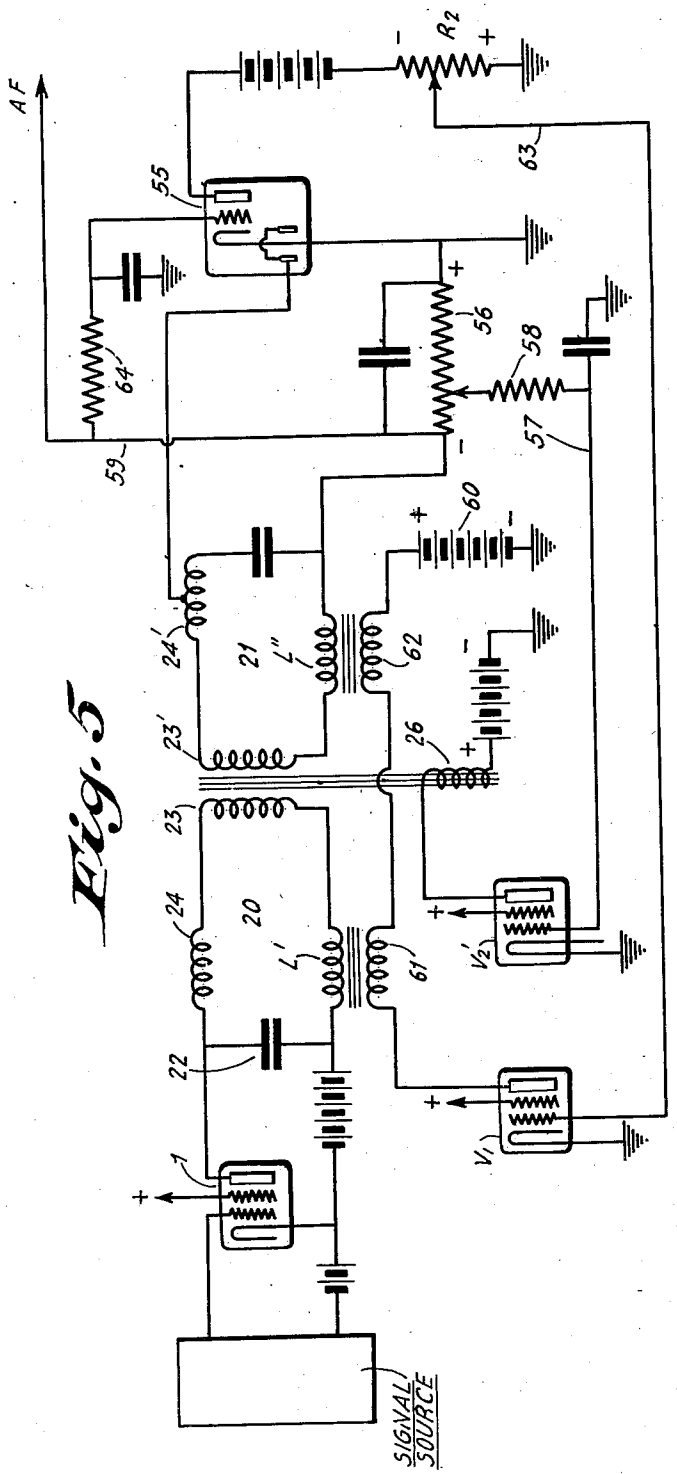


Fig. 5

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UNITED STATES PATENT OFFICE

2,051,364

AUTOMATIC SENSITIVITY CONTROL CIRCUIT

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Application October 16, 1933, Serial No. 693,715

14 Claims. (Cl. 250—20)

My present invention relates to fidelity control arrangements for radio frequency signalling systems, and more especially to automatic fidelity control circuits for radio receivers.

In my co-pending application Serial No. 682,743, filed July 29, 1933 there are disclosed, and claimed, various arrangements for automatically regulating the effective resonance curve of a tunable network in response to the variation in amplitude of received signal energy. The essential aim of these arrangements is to control the selectivity of a radio frequency signalling system in such a manner that the system is more selective on weak signals than on strong ones.

Now, in the present application there are disclosed further arrangements for automatically varying selectivity and improving fidelity when receiving strong signals. In each of the present arrangements the tuning of networks resonant to a desired carrier frequency is varied in response to variations in amplitude of the received signal energy.

Hence, it may be stated that it is one of the main objects of the present invention to provide further automatic fidelity control arrangements, the arrangements functioning to vary the tuning of resonant high frequency networks by regulating the effective inductances of certain inductors in the resonant network.

Another object of the present invention is to provide an automatic selectivity control circuit for a radio receiver wherein the rectified signal energy of the receiver is utilized to vary the high frequency response characteristic of a resonant circuit preceding the receiver rectifier by adjusting the self-inductance of a control inductor disposed in the said resonant circuit.

Another object of the present invention is to control the over-all resonance curve of a band pass network by adjusting the magnetic coupling between the circuits of the network, and simultaneously adjusting the tuning of each of the band pass circuits.

Still another object of the present invention is to provide a receiver with an automatic selectivity control arrangement of the type wherein the output of a control rectifier is utilized to regulate the tuning of a pair of cascaded resonant networks in a predetermined manner.

Still other objects of the invention are to improve generally automatic fidelity control circuits for radio receivers, and to provide such control circuits which are not only reliable in operation, but readily constructed and assembled in receivers.

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 drawings, in which I have indicated diagrammatically several organizations whereby my invention may be carried into effect.

In the drawings,

Fig. 1 diagrammatically shows an embodiment of the present invention,

Figs. 2 and 3 show two modifications of the arrangement shown in Fig. 1,

Fig. 4 shows another modification of the present invention,

Fig. 5 shows a modification of the arrangement in Fig. 4,

Fig. 6 shows a further modification of the circuit in Fig. 4.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 in highly conventional form a radio receiving system embodying one form of the invention. Broadly, it may be stated that the receiving system shown in Fig. 1 embodies a source of signal energy, conventionally represented, coupled, as at M_1, to the resonant input circuit I of a screen grid amplifier tube 1. The anode circuit of tube 1 is coupled, as at M_2, to the resonant input circuit II of a second screen grid amplifier tube 2. The output of the amplifier 2 is impressed upon a rectifier 3, the input circuit of the rectifier being tuned to the same frequency to which the circuits I and II are tuned.

The rectifier 3 may be the customary detector of the receiver, or it may be an auxiliary rectifier tube deriving its signal input energy from the network which feeds the conventional receiver detector. Furthermore, it is to be clearly understood that the stages including tubes 1 and 2 may be operating at intermediate frequency, as in a superheterodyne receiver, or they may be the cascaded amplifier stages of a tuned radio frequency amplifier receiver. In any case, the tuning condensers 4 and 5 are to be understood as resonating their respective circuits to a desired carrier wave frequency.

Where the rectifier 3 is the detector of the receiver, the reference numeral B designates the anode potential source for the anode of rectifier 3, the negative side of this source being connected to ground through a resistor R, the circuit be-

tween the anode of the rectifier and the positive side of the source B including a choke and condenser network to block the flow of alternating current energy through the source B. The audio frequency network (not shown) is connected to the anode circuit of rectifier 3 through the blocking condenser. To preserve simplicity of description, the energizing potential sources for the various stages including tubes 1 and 2 and rectifier 3, are conventionally represented by battery symbols, but it is to be clearly understood that the invention is not limited to such battery potential sources.

The detuning of circuits I and II for selectivity control is accomplished by iron core coils L' and L''. The inductances of these coils depend on the plate currents of control tubes V_1 and V_2 flowing through coils L_1 and L_2 respectively. These plate currents, in turn, depend on the control biases applied to tubes V_1 and V_2, and the control biases are derived from the rectifier anode circuit.

The coil L', as well as the coil L'', is a small iron core coil which is disposed in its associated resonant circuit in series between the tuning condenser of the circuit and the coupling transformer secondary inductor of the circuit. The coils L_1 and L_2, which carry the plate currents of tubes V_1 and V_2, are constructed so that they magnetize the cores 6 and 7 without being coupled to the coils L' and L''. When the plate currents of tubes V_1 and V_2 vary, the magnetic flux in each of the cores 6 and 7 respectively varies, and consequently the self-inductances of coils L' and L'' respectively vary in proportion. As current through L_1 increases, flux through core 6 increases, as explained. As flux increases, incremental permeability decreases, due to approach to the condition of magnetic saturation. The inductance of coil L' is proportional to the incremental permeability, and hence it decreases as current through L_1 increases. This provides a means of varying the tuning of circuits I and II a small amount.

The plate currents of tubes V_1 and V_2 are regulated by connecting the control grid of the tube V_1 to the negative side of a grounded bias source 8, and the cathode being connected by a lead 9 to a point on the resistor R. The cathode of tube V_2 is grounded, while its control grid is connected by a lead 10 to a point on resistor R. As the signal strength impressed on rectifier 3 varies, the direct current through R varies, and the voltage drop across R varies. The drop across R, or fractions of it, is included in the grid circuits of V_1 and V_2, and thus variations in this drop across R cause variations in the grid biases of V_1 and V_2, and consequent variations in plate current of V_1 and V_2. Circuits are so arranged that increase in signal strength causes one plate current to increase and the other to decrease. In Fig. 1, I_p of V_1 increases and I_p of V_2 decreases, when signal becomes stronger.

Taking circuit I as an example, when current flows in L then the inductance of coil L' is decreased. With increasing signal strength I_p of V_1 increases, and hence the inductance of L' decreases, and the resonant frequency of circuit I becomes higher.

In circuit II, increasing signal strength causes the resonant frequency to become lower. When no signal is impressed on the rectifier 3, bias source 8 in the grid circuit of V_1 is to be adjusted so that the I_p of V_1 will be zero, or very small. At the same time, the bias on grid of V_2 will have the smallest value that it can have at any time, and I_p will have its maximum value. Under this condition, circuit I will be resonant at the low frequency end of its range of variation, and circuit II at the high frequency end of its range of variation. However, circuits I and II must be adjusted to the same frequency by means of the condensers 4 and 5, or by altering the other inductances in the amplifier circuits; that is, the lower end of the range of variation of I must coincide with the upper end of the range of variation of II.

Then, when a sufficient signal strength is impressed, circuit I is tuned by the action of V_1, L_1 and L' to a higher frequency, and circuit II by the action of V_2, L_2 and L'' to a lower frequency, and if the circuits are constructed properly, each will shift the same number of kilocycles from the initial, common frequency, and the mid-frequency of the overall response characteristic will not be altered while the response characteristic itself is made broader in proportion to the strength of the signal.

Summing up, circuit I may be tuned to resonance with the carrier, when receiving weak signals, with a small current in tube V_1. In this case it is necessary that circuit II be in resonance with the carrier with a high current in tube V_2. Then, for weak signals tube V_1 has a high grid bias, and tube V_2 has a low grid bias. As the signal strength increases, the bias on tube V_1 decreases and that on tube V_2 increases. Thus, it will be seen that an increase in signal strength causes the self-inductance of coil L' to decrease and that of coil L'' to increase. This means that circuits I and II are detuned in opposite directions from the carrier frequency, thus reducing the selectivity. It will thus be seen that when the receiving system of Fig. 1 is used to receive strong local station signals that the resonance characteristic of the network including tubes 1 and 2 is broadened and fidelity increased, while when receiving weak signals as from distant stations, the over-all resonance curve of the network is sharpened, thereby decreasing the fidelity but increasing the selectivity.

Fig. 2 shows a modification of the arrangement shown in Fig. 1 wherein both primary and secondary windings of inter-stage transformers are tuned, and the coupling M_1 between the resonant circuit I and the preceding tuned circuit 11 is less than critical, the coupling M_2 between the circuit II and its preceding resonant circuit 12 also being less than critical. Otherwise, the circuit elements in the arrangement of Fig. 2 are the same as in Fig. 1, and for this reason the rectifier and its connections to tubes V_1 and V_2 are not shown.

The arrangement in Fig. 2 operates in the following manner; the couplings M_1 and M_2 being less than critical so that, with a weak signal impressed on the system, and circuits 11, 12, I and II tuned to the desired signal frequency, the tuned amplifier will be highly selective. Then, as the signal strength is made to increase, circuits I and II are detuned equal amounts in opposite directions from the signal frequency, and thus the over-all response curve is made broader, in proportion to the strength of the signal, while the mid-band frequency, or the frequency at the center of the response curve, remains fixed. Of course, the detuning of the network including tubes 1 and 2 may be effected on the primary cir-

cuits 11 and 12 if desired, instead of on circuits I and II.

The arrangements shown in Figs. 1 and 2 are not the only ways of accomplishing the mode of operation represented by these figures, and in Fig. 3 is shown an arrangement wherein the network, including circuits 12 and II, between screen grid tubes 1 and 2 in Fig. 2 is controlled. In this arrangement of Fig. 3, as in Figs. 1 and 2, the control tubes V_1 and V_2 have their plate currents regulated in accordance with the flow of plate current in the anode circuit of rectifier 3, the control on circuits 12 and II being in opposite directions. It is believed that the diagrammatic showing in Fig. 3 will be sufficient to illustrate this modification, since it is substantially the same as in Fig. 2, with the exception that the control tube V_1 operates on the circuit 12 instead of the circuit I, thus eliminating the need for operating on two separate stages.

Another means for varying the selectivity of coupled tuned circuits is shown in Fig. 4, wherein the screen grid tube 1 is shown as having its input electrodes connected to a source of signals, as in Fig. 1, while the anode circuit of tube 1 is coupled to the input electrodes of the amplifier tube 2, the latter tube being conventionally shown. The output of tube 2 is to be understood as being connected to rectifier 3 as in Fig. 1. The coupling network between tubes 1 and 2 includes the tuned circuits 20 and 21, the circuit 20 comprising in series the tuning condenser 22, the coupling inductor 23, the iron core coil L' and the tuning inductor 24. The circuit 21 includes in series the tuning condenser 22', the coupling inductor 23', the iron core coil L'' and the tuning inductor 24'.

The magnetic coupling M between circuits 20 and 21 is provided by the coils 23 and 23' which are wound on an iron core 25. There is also wound on the core 25 a saturating winding 26, one terminal of the winding being connected to a source of positive potential, not shown, and the other terminal of the winding being connected to the anode of control tube V'_2. It is to be understood that the structure comprising 23, 23', 25 and 26 is similar to the structures 6—L_1—L' and 7—L_2—L'' in Fig. 1, with respect to the shape of the core and the relative positions of the D. C. coil and the A. C. coils. This means that there is not intended to be any coupling between coils 23 and 26, or between 23' and 26. This provision is made because if such coupling did exist, the plate impedance of V'_2 would be reflected into circuits 20 or 21, or both, appearing there as a damping resistance. The saturating winding 26 reduces the inductances of coupling coils 23 and 23', and, therefore, reduces the coupling M and sharpens the tuning.

Simultaneously, the circuits 20 and 21 are detuned. To correct the tuning, the iron core coils L' and L'' are provided, these coils and their control tubes V_1 and V_2 being similar to the corresponding elements shown in Fig. 1. When M is reduced by increasing direct current flow through coil 26, the self-inductances of 23 and 23' are reduced also. Reduction in self-inductance of 23 must be balanced by an equal increase in the self-inductance of L'. This applies as well to 23' and L''.

The control grid of tube V_1 is connected to the negative terminal of the grounded potential source 8, while its cathode is connected to point *b* on the resistor R of Fig. 1. The control grid of tube V_2 is connected to ground through a negative biasing source 8', while its cathode is connected to point *b* on the resistor R of Fig. 1. The cathode of tube V'_2 is grounded, while its control grid is connected to point *a* of the resistor shown in Fig. 1. If circuits 20 and 21 have same L and C, equal control voltages, as pointed above, should be applied to tubes V_1 and V_2, and the two cathodes can go to the same point on resistor R (of V_1 can be connected to coils associated with L' and L'', in series, eliminating V_2). Grid of V_2 should go to a separate adjustable tap on R, so that amount of inductance change due to operation of V'_2 can be made equal (though opposite) to the inductance change produced by the operation of V_1 and V_2. Of course, either "*a*" or "*b*" connection may be made at any suitable point along the resistor R.

With the connections made as described when the saturation of coil 26 increases, that of coils L' and L'' decreases, thus keeping the total inductance constant in both tuned circuits 20 and 21. It will, therefore, be seen that in Fig. 4 there is shown a variable coupling circuit for a band pass network wherein additional means is provided for preventing detuning of the coupled tuned circuits of the band pass network. The effect of the variable coupling is to sharpen or broaden the resonance curve of the coupled circuits, and this is accomplished by control of the saturating winding 26. In effect there is shown in Fig. 4 a pair of tuned circuits coupled by a small iron core transformer with an extra winding 26 carrying direct current for saturation. The saturating current flowing through the coil 26 is the plate current of control tube V'_2. The grid bias of this control tube is varied in accordance with the rectified direct current potential variations. To correct for detuning of the coupled circuits, other saturating iron core elements are inserted in the coupled circuits, and these other iron core coils are controlled by control tubes to prevent the detuning.

Figure 5 is a modification of the arrangement shown in Fig. 4, wherein an improved arrangement is shown for feeding the control potentials to the tubes V_1 and V'_2. Since the circuits associated with the networks 20 and 21 are substantially the same as those shown in Fig. 4, such networks will not be further described, but it will be understood that similar reference numerals designate similar circuit elements. A duplex diode triode tube 55, whose construction is well known to those skilled in the art at the present time, is shown as a source of control potentials for tubes V_1 and V'_2. The two diode anodes of the tube 55 are connected to an intermediate point on coil 24', in order to make a good impedance match. There is arranged a resistor 56 in series between the grounded cathode of tube 55 and the coil L'' of the network 21. The direct current potential component of the rectified voltage developed across resistor 56 is utilized for biasing the control grid of tube V'_2 by connecting the grid to a point on resistor 56 through a lead 57 which includes the filter resistor 58. The lead 57 is adjustably connected to the resistor 56. The audio frequency potential component of the rectified voltage developed across resistor 56 is impressed upon a succeeding audio frequency amplifier (not shown) through a lead 59.

The plate of tube V_1 is connected to the positive terminal of the voltage source 60 through the coils 61 and 62, while the control grid of tube V_1 is connected by a lead 63 having an adjustable tap to a desired point on the resistor R_2 arranged

in the plate circuit of tube 55. The entire direct current potential developed across resistor 56 is impressed on the control grid of tube 55 through a path which includes lead 59 and the filter resistor 64. The operation of the arrangement shown in Fig. 5, with respect to the operation of tubes V_1 and V'_2 is substantially the same as in the case of Fig. 4. It is to be noted that the tube V_2 has been eliminated. Briefly, the operation of this modification is as follows:—

When signal strength increases, the negative bias applied to the grid of tube V'_2 is increased. At the same time, the voltage drop across resistor 56 is applied to the grid of the triode section of tube 55, the audio frequency component being filtered out by the filter resistor 64 and the filter capacity. With increasing signal strength this bias increases and, hence, the plate current through resistor R_2 decreases. A portion of the voltage drop across R_2 is applied as a bias to the grid of tube V_1. Thus, as signal strength increases, the grid of V'_2 becomes more negative, while that of V_1 becomes less negative.

Of course, modifications in the arrangement of Fig. 5 are possible. For example, the triode section of tube 55 may be used to amplify the audio signal component, while the control function performed by this tube in Fig. 5 may be accomplished with a separate triode. This might be done to avoid connecting the B battery, which is shown in Fig. 5, between resistor R_2 and the plate of tube 55.

The arrangement shown in Fig. 6 is a modification of the arrangement in Fig. 5, insofar as a single tube 70 is employed to perform the functions of tubes V_1 and V'_2 of Fig. 5. The tube 55, shown in Fig. 5, accomplishes half wave rectification, as in the case of Fig. 5, and the grid of the triode section has both the audio and direct current potential components of the voltage developed across 56 impressed thereon. A resistor 71 is arranged in the cathode circuit of tube 55, and an adjustable tap 72 is connected between ground and a negative point on the resistor 71. The coils 61 and 62 are connected in series with the screen grid electrode 80 of tube 70, and positive potential is supplied to this screen grid through a source 81. The plate electrode 82 of tube 70 is connected to the positive terminal of resistor 71 through coil 26 and lead 83. The operation of the arrangement shown in Fig. 6 is as follows:—

The plate current of the triode section of tube 55, which is controlled in accordance with signal strength by the bias developed across resistor 56, flows through resistor 71 and produces a voltage drop which is applied to the plate of tube 70. With increasing signal strength the plate voltage of tube 70 decreases and the plate current also decreases. Simultaneously, screen current increases with increasing signal strength. Thus, the current through coil 26 decreases and the current through coils 61 and 62 increases with increasing signal strength.

While I have indicated and described several systems 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 circuits 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. A method of regulating the selectivity of a network including at least two coupled circuits tuned to a desired carrier frequency, which includes the steps of impressing signal energy of said frequency upon the network, rectifying the impressed energy, and regulating the high frequency response characteristic of said network with the direct current component of the rectified energy by adjusting the inductances of said circuits in a sense to charge the tuning of the coupled circuits in opposite directions.

2. A method of regulating the selectivity of a network including at least two coupled circuits tuned to a desired carrier frequency, which includes the steps of impressing signal modulated carrier energy of said frequency upon the network, rectifying the impressed energy, and regulating the high frequency response characteristic of said network with the direct current component of the rectified energy by varying the effective magnetic coupling between the coupled circuits in a sense inverse to carrier amplitude variation.

3. In a receiving system, a pair of amplifier tubes, at least two tuned circuits cascaded between said tubes, said tuned circuits being resonant to a desired signal frequency, a rectifier, and a selectivity control means electrically associated with each of said tuned circuits, said means being responsive to variations in potential of the direct current component of the rectified output of said rectifier, said means being conductively connected to the rectifier output circuit and including devices operatively associated with the tuned circuits for adjusting the tuning of said tuned circuits in opposite directions with respect to said desired signal frequency.

4. In a receiving system as defined in claim 3, said devices comprising iron core coils disposed in said tuned circuits.

5. In a receiving system as defined in claim 3, said devices comprising iron core coils disposed in said tuned circuits, and each selectivity control means comprising a control tube electrically associated with each of said coils to vary the magnetic flux of the coil associated with it.

6. In a receiving system including a band pass network consisting of a pair of magnetically coupled tuned circuits resonant to a common signal frequency, means, responsive to direct current potential variations derived from signal currents, for varying the intensity of said magnetic coupling in a sense opposed to signal amplitude variation and in a manner to vary the signal response characteristic of the network.

7. In a receiving system including a band pass network consisting of a pair of magnetically coupled tuned circuits resonant to a common signal frequency, means, responsive to direct current potential variations derived from signal currents, for varying the intensity of said magnetic coupling in a sense opposed to signal amplitude variation and in a manner to vary the signal response characteristic of the network, said coupling varying means including a control tube, and means associated with the coupled tuned circuits for compensating for detuning produced by said coupling variation.

8. In combination with a pair of resonant circuits, an iron core transformer coupling said circuits, an auxiliary winding associated with the core of said transformer and means for varying the coupling between said circuits including a device for regulating a flow of direct current through said auxiliary winding thereby varying the saturation of said transformer core.

9. In combination with at least two cascaded

resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means.

10. In combination with at least two cascaded resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means, said additional means comprising a rectifier network having an input circuit coupled to the second of said resonant circuits, and a control connection between a point in said rectifier network and said regulating means.

11. In combination with at least two cascaded resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means, said additional means including a diode rectifier network coupled to the second of said resonant circuits, and said regulating means including at least one electrode discharge tube having a cold electrode thereto connected to said diode circuit.

12. In combination with at least two cascaded resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means, said regulating means consisting of a pair of electron discharge tubes, each of said tubes being connected to one of said cores, a rectifier network having an input circuit coupled to the second of said resonant circuits, and said rectifier network including an impedance in its space current path, and an electrode on each of said tubes and a predetermined point on said impedance.

13. In combination with at least two cascaded resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means, means for magnetically coupling said resonant circuits, and a control connection between said additional means and said magnetic coupling means for varying the magnetic coupling between said resonant circuits.

14. In combination with at least two cascaded resonant circuits tuned to a common carrier frequency, an iron core choke connected in each of said circuits, means associated with each of said chokes for regulating the magnetization of the choke cores, and additional means for varying the effectiveness of the last named means, said additional means including an electron discharge tube provided with independent diode and triode sections, means for coupling the diode section to the second of said resonant circuits to provide a diode rectifier circuit, a connection between a grid of said triode section and a point in said diode circuit, an impedance in the space current path of said triode section, and a control connection between said impedance and said regulating means.

RENE A. BRADEN.

Certificate of Correction

Patent No. 2,051,364. August 18, 1936.

RENE A. BRADEN

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 66, for "L", read L_1; page 4, second column, line 7, claim 1, for "charge" read *change*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of March, A. D. 1937.

[SEAL]

HENRY VAN ARSDALE,
Acting Commissioner of Patents.