July 27, 1937. R. A. BRADEN 2,088,229

AUTOMATIC FIDELITY CONTROL CIRCUIT

Filed July 29, 1933 3 Sheets-Sheet 1

Fig. 1

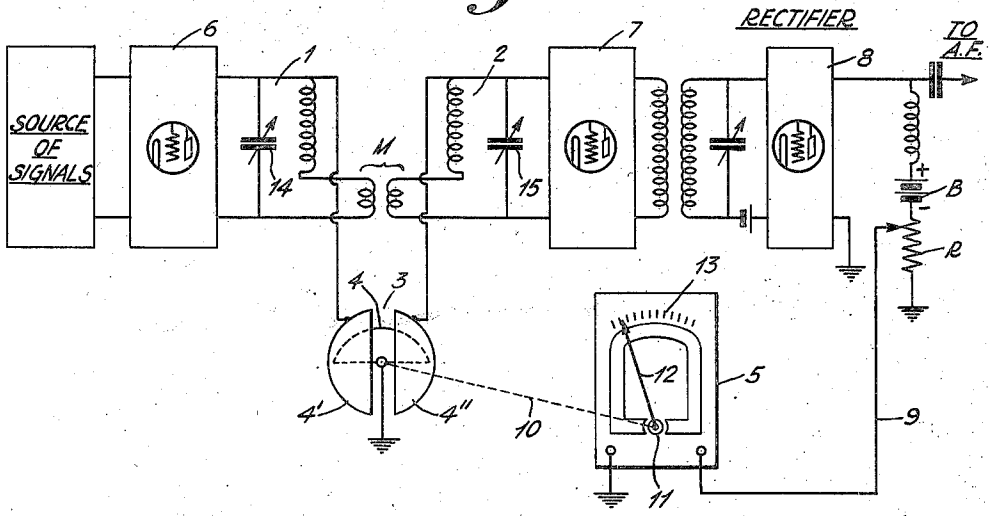


Fig. 2

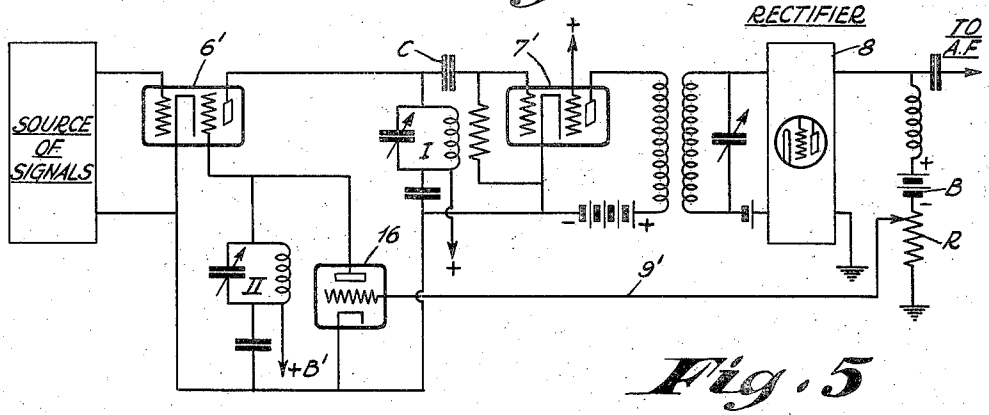


Fig. 3

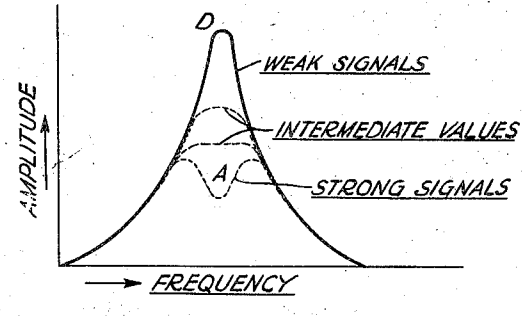
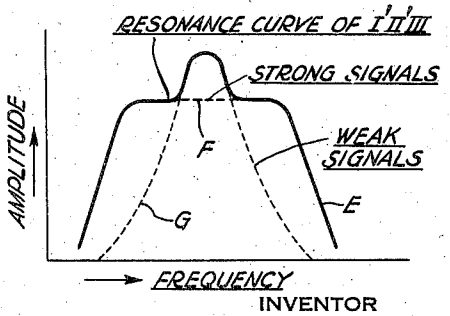


Fig. 5



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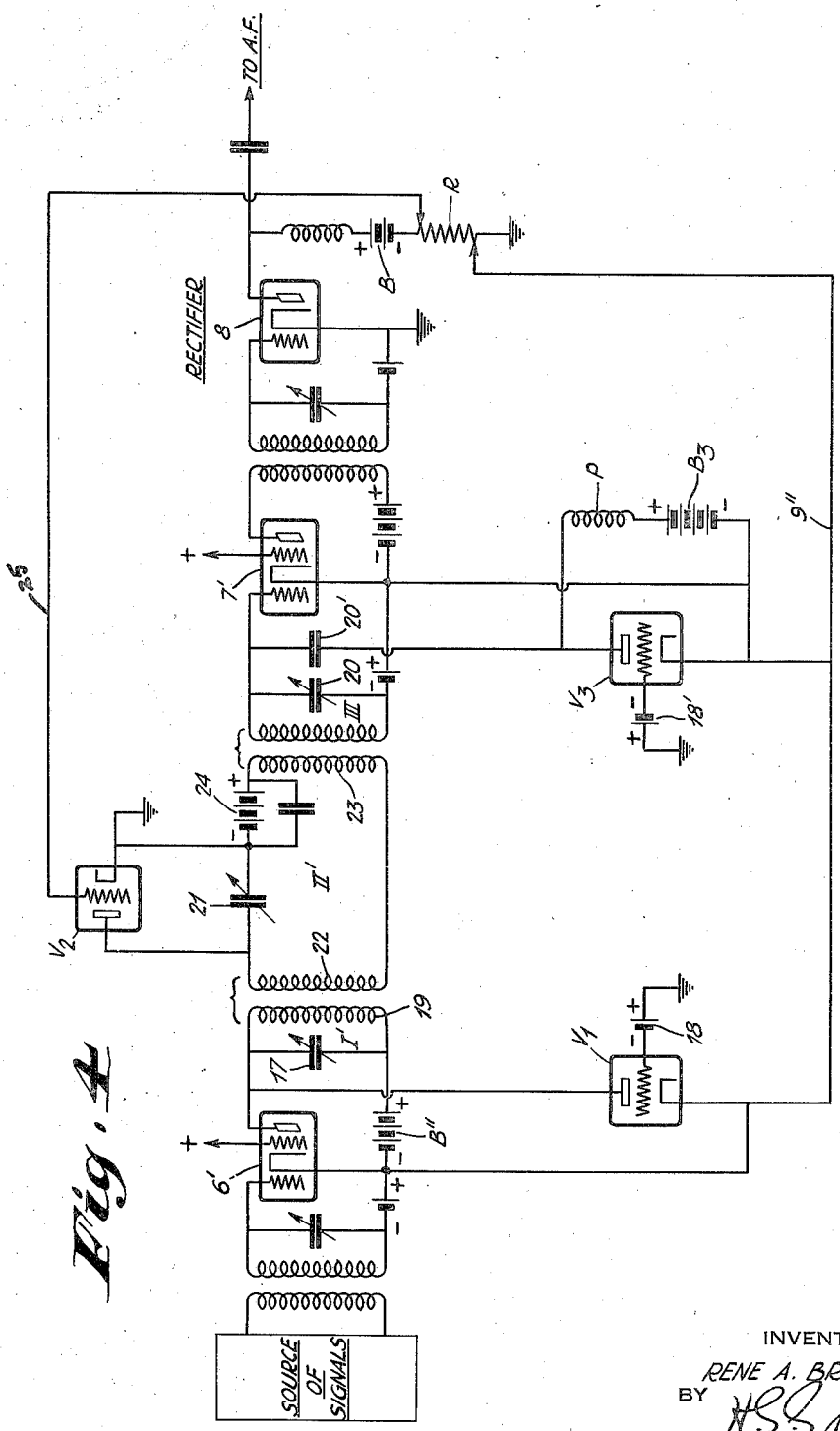


Fig. 4

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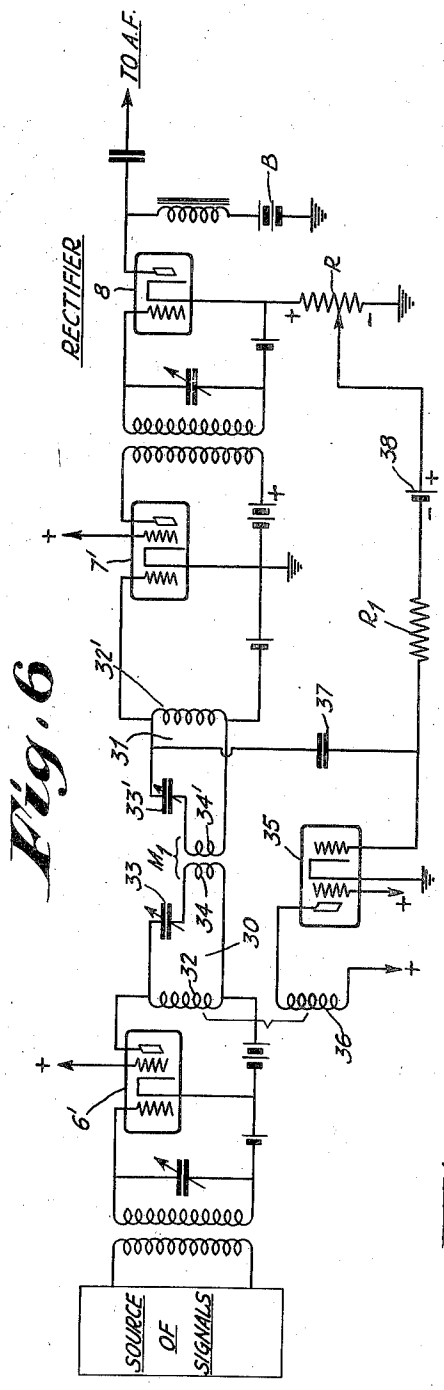


Fig. 6

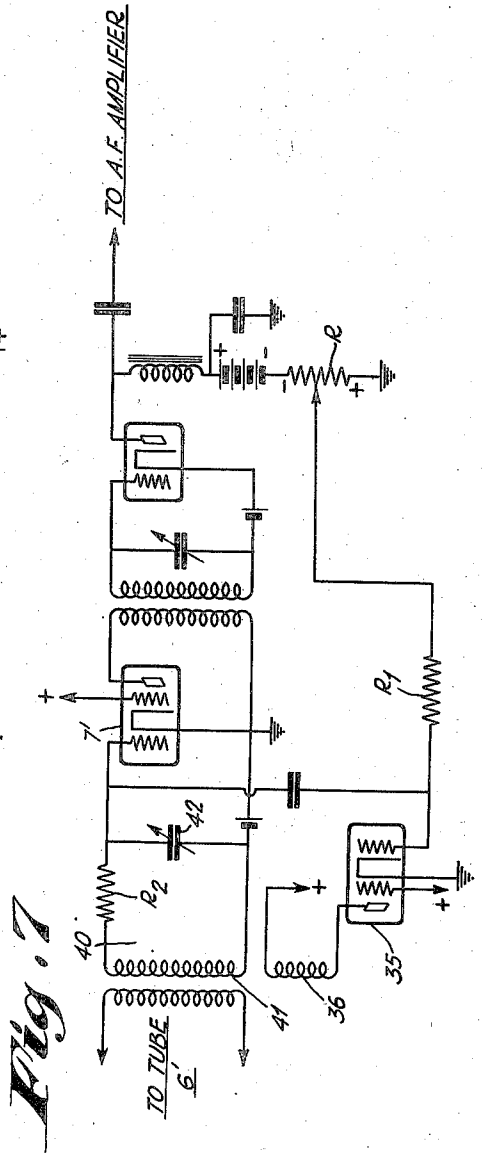


Fig. 7

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UNITED STATES PATENT OFFICE

2,088,229

AUTOMATIC FIDELITY CONTROL CIRCUIT

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Application July 29, 1933, Serial No. 682,743

4 Claims. (Cl. 250—20)

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

It is one of the primary objects of my present invention to provide a method of automatically controlling the selectivity of a radio frequency signalling system whereby the system is more selective on weak signals than on strong ones with the result that on strong local stations the selectivity is least, but on weak stations it is most.

Another important object of the present invention is to provide an automatic fidelity control for a radio receiver of the type wherein the resonance curve of a tunable network is automatically varied in response to the variation in amplitude of the received signal energy.

Another important 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.

Still another object of the present invention is to provide a fidelity control arrangement for a radio receiver, the latter operating on a band pass network preceding a rectifier in such a manner that the resonance curve of the network is automatically varied to have a single resonance peak when weak, or distant, station signals are received, and a double peak when strong, or local, stations are received.

Another object of the present invention is to provide an automatic selectivity control circuit for a receiver wherein a rectifier automatically regulates the amount of damping introduced into a preceding tuned circuit, the damping being increased when receiving strong signals, and being decreased when receiving weak signals.

Still other objects of the present invention are to improve generally the efficiency of radio receiving systems, and particularly to provide automatic fidelity control circuits for radio receivers which are not only efficient and reliable in operation, but economically constructed and assembled in radio 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 arrangements for carrying my invention into effect.

In the drawings,

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

Fig. 2 diagrammatically shows a modified form of the invention,

Fig. 3 is a graphic representation of the operation of the arrangement of Fig. 2,

Fig. 4 diagrammatically shows another modification of the present invention,

Fig. 5 is a graphic representation of the operation of the arrangement in Fig. 4.

Fig. 6 shows still another modification of the invention,

Fig. 7 shows another modification of the invention.

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 my invention. Broadly, it may be stated that the receiving circuit shown in Fig. 1 embodies means for varying the selectivity of a receiving set, which means can be operated by a signal actuated control tube. More specifically, two coupled tuned circuits 1 and 2 are connected to a three-plate variable condenser 3 which adds capacity to one of the tuned circuits when removing capacity from the other. Hence, by rotating the rotor 4 of the condenser 3 the tuned circuits can be detuned in opposite directions.

By detuning two circuits equal amounts in opposite directions, the mid-frequency of the resonance curve is held constant while the resonance curve is made broader, thus decreasing the selectivity and improving the fidelity. At the same time the signal output is decreased, as the amplification is decreased when the circuits are detuned. This produces some volume control action, and may assist the regular automatic volume control to extend the signal intensity range over which it can control the output, or if applied to several intermediate frequency and/or radio frequency stages, it may provide all the automatic volume control action needed, in addition to controlling the fidelity and selectivity.

The rotating plate, or rotor, 4 is mechanically coupled to the moving coil of a galvanometer 5, the latter carrying the direct current component of the plate current of a control tube, which tube may be the rectifier of the receiver, or signal demodulator, for example. Varying

the amplitude of the carrier impressed on the rectifier varies the I_p of the rectifier, swings the galvanometer coil, and changes the tuning of the coupled tuned circuits 1 and 2.

I_p of the demodulator (diode or triode) is more or less proportional to the strength of the carrier impressed on the demodulator, so that the position of the movable condenser plate varies with the strength of this carrier. The output of the rectifier, or demodulator, may be amplified by a direct current amplifier, and the output of the direct current amplifier can be used to operate the galvanometer and condenser. In that case, of course, the bias of the control tube is varied.

It is believed sufficient to show and describe in purely conventional manner the circuit elements of the receiving system in Fig. 1 which are not essential to a proper understanding of the present invention. For this reason the source of signal energy is conventionally represented as feeding into a stage of amplification 6, the coupled tunable circuits 1 and 2 being connected between the amplifier 6 and the succeeding amplifier 7. The rectifier 8 may be the customary detector of the receiver, or it may be an auxiliary rectifier deriving its signal input energy from the network which feeds the receiver detector. The galvanometer may be operated by an automatic volume control tube, when a separate tube for this purpose is provided. Furthermore, it is to be clearly understood that stages 6 and 7 may be operating at intermediate frequency as in a superheterodyne receiver, or they may be cascaded amplifier stages of a tuned radio frequency amplifier receiver.

The reference numeral B designates the anode potential source for the anode of rectifier 8, the negative side of this source being connected to ground through a resistor R, the circuit between the anode of the rectifier and the positive side of the source B including a choke and condenser network to block the flow of high frequency energy through the source B. The galvanometer 5 may be a milliammeter, one terminal of which may be grounded, and the other terminal of which adjustably connected, as by a lead 9, to the negative side of resistor R.

The dotted line 10 represents a mechanical coupling, such as a shaft, between the grounded metallic rotor 4 and the moving coil 11 of the milliammeter 5. An indicator needle 12 is shown affixed to the moving coil 11, this needle cooperating with the index marks 13 to indicate the degree of selectivity adjustment. The tuned circuits 1 and 2 are resonated to the desired carrier frequency by the tuning condensers 14 and 15, and the circuits 1 and 2 are magnetically coupled, as at M, the coupling being less than critical.

One of the stator plates 4' of the control condenser 3 is connected to the high potential side of tuned circuit 1, while the other stator 4'' is connected to the high potential side of the other tuned circuit 2. The tuned circuits 1 and 2 are tuned to the desired carrier frequency when the rotor plate 4 is at its center position as shown in Fig. 1.

Starting with the rotor plate 4 in its center position, as described, only a 90° rotation can be used. However, the galvanometer can operate through only 90°, so this is good enough. The condenser can be made with quarter-circle plates instead of half-circle plates. That is, the stators 4' and 4'' may be made of quarter plates, and the rotor 4 may be a quarter plate. This saves space and provides only as much condenser plate as is actually used. With no signal, the galvanometer is undeflected, and the rotor is in one extreme position. With increasing signal strength, the rotor turns a maximum of 90°, which gives the full range of variation provided the signal strength at which action begins may be set at any desired level by adjusting the spring bias of the galvanometer. For example, the springs which oppose the action of the current in the galvanometer coil may be tightened so that the galvanometer does not begin to turn until, say, a current of 5 milliammeters is flowing. In this way the system can be made to operate only on signals which are well above the noise level, in which case an improvement in fidelity is desirable.

Since the rectifier plate current is proportional to the signal strength, an increase in the signal strength results in the rotation of rotor plate 4, with the result that the circuits 1 and 2 are detuned in opposite directions to broaden the tuning and reduce the gain. Of course, this is what is desired because when receiving strong signals, as from local stations, it is desired to have the fidelity of the receiver at its best, hence the selectivity of the receiver need not be at a maximum. When receiving weak signals, as from distant stations, the rectifier plate current affecting the control meter 5 is at a minimum with the result that the rotor plate 4 is at its center position, thereby making the selectivity characteristic of the coupled tuned circuits sharp, the fidelity at that point of course being poorest.

If the current in the galvanometer exceeds the amount required to give maximum broadening of the circuits, the galvanometer strikes a stop, and for all values of signal above this, the fidelity and selectivity remain constant. When tuning in a strong signal, the action of the condenser 3 makes the receiver appear to be very broad by means of its automatic volume control action, if the tuning is done slowly enough to allow the galvanometer to follow the signal strength variation. In this case the pointer on the galvanometer can be used as a tuning indicator. If the signal is much stronger than just enough to deflect the galvanometer to its extreme position, the variable tuning system is, in effect, locked in a fixed position, and there is no automatic volume control effect to make tuning difficult. In this case the pointer does not operate as a tuning indicator, as it is held against the stop, and does not respond to signal variations.

It is not necessary to employ a mechanical selectivity control arrangement, since an electrical one may be utilized. In Fig. 2 is shown such an electrical selectivity control arrangement. In this figure the source of signal energy is coupled to the input electrodes of the screen grid tube 6', and the input circuit of the rectifier 8 is coupled to the anode circuit of the screen grid 7'. The anode circuit of screen grid tube 6' is coupled to the input electrodes of tube 7' through a tuned circuit I, the anode of tube 6' being connected to the control grid of tube 7' through a condenser C. A second tuned circuit II is connected to the screen grid electrode of tube 6', as well as to the anode of a control tube 16. The screen grid of tube 6' and the anode of tube 16 have positive potentials applied thereto from a source B' (not shown) through the coil of the resonant circuit II.

The cathode of control tube 16 is connected to

the common lead connecting the cathodes of tubes 6' and 7', while the control grid of tube 16 is adjustably connected, as by a lead 9', to the negative side of resistor R. It is to be clearly understood that the rectifier 8 may again be the usual detector of the receiver, or an auxiliary rectifier deriving its signal energy input from the input to the said usual detector.

The resonant circuit II and the circuit I are both tuned to the desired carrier frequency, the circuit II reacting so as to cause the over-all resonance curve of the network between tubes 6' and 7' to be like the curve A in Fig. 3. If the bias on the grid of tube 16 is reduced so as to reduce the R_p of the tube, the effect of circuit II is reduced, and the resonance curve becomes sharper, and the gain is increased, as shown by the curve D in Fig. 3. By controlling the negative bias on the grid of tube 16 in accordance with the intensity of the rectifier plate current, the selectivity of the receiving system shown in Fig. 2 can be made to increase with decreasing signal strength. The curves between curves A and D show intermediate signal values.

Where, for example, the network 6'—I—7' is a stage of intermediate frequency amplification, the circuit I is given a sharp resonance curve. The circuit II, which is tuned to the carrier, pushes down the peak of this resonance curve, making a broad or double-peaked curve, and reducing the gain. With low bias on the control tube 16 the tuned circuit II is almost short-circuited, and the effect of this circuit is very small. With high bias on tube 16, the circuit II has its maximum effect, and hence provides a network of optimum fidelity when it is receiving strong signals.

The action in this case of Fig. 2 is similar to that described in my application Serial No. 517,154, filed February 20, 1931, patented February 13, 1934 as U. S. Patent 1,947,184 in connection with Figs. 3 and 4 of that patent. In that patent the output circuit had no frequency characteristics, and so the over-all curve had an intermediate valley. In the present case, the output circuit has a resonance curve, and the tuned circuit in the screen operates to reduce the gain a large amount at resonance, and smaller amounts off resonance. In this way the gain curve D of the amplifier is operated on to produce the curves below it corresponding to various shunt resistances across the tuned circuit II. Curve A provides compensation for loss of high modulation frequencies in other radio frequency and intermediate frequency stages not provided with fidelity control.

The present invention is not limited to the disposition of a single tuned circuit between the amplifier tubes 6' and 7', as shown in Fig. 2, but there may be employed coupled tuned circuits between these amplifier tubes. Thus, in Fig. 4 there is shown disposed between screen grid amplifier tubes 6' and 7' a network consisting of three coupled tuned circuits I', II' and III. Each of these tuned circuits is resonant to the desired carrier frequency, and are coupled closely enough to give a curve of the type designated by the full line curve E in Fig. 5. In the arrangement shown in Fig. 4 the rectifier 8 has its anode circuit resistor R adjustably connected, as by lead 9'', to the cathodes of control tubes V_1 and V_3.

The amplifier tube 6' includes the tuned circuit I' in its anode circuit, the control tube V_1 having its anode and cathode connected across the tuning condenser 17. The control grid of tube V_1 is maintained negative with respect to ground by a potential source 18, and the potential source B'' provides positive potential for the anodes of tubes 6' and V_1 through the coil 19 of the tuned circuit I'. The control tube V_3 has its anode and cathode connected across the tuning condenser 20 of the tuned circuit III, while the control grid of tube V_3 is maintained negative with respect to ground by the potential source 18'. Plate voltage is supplied tube V_3 by insulating the plate of V_3 from the grid of tube 7' through condenser 20', and connecting the plate to the positive side of B_3 through a choke coil P having a high impedance at signal frequency.

The tuned circuit II' includes a tuning condenser 21, the condenser being connected in series with the coils 22 and 23 and the potential source 24. A control tube V_2 has its anode and cathode connected across the tuning condenser 21, while the control grid of the tube is connected, as by a lead 25, to a point on resistor R which is negative with respect to the point to which lead 9'' is connected. The cathode of V_2 is grounded so that grid bias can be applied from R. The plate battery 24 in circuit II' is not in the high radio frequency potential part of the network.

If the R_p of tubes V_1 and V_3 is low, then the center peak of the resonance curve E in Fig. 5 is lowered, and a curve is obtained which is of a flat top, designated by the curve F in Fig. 5. The curve F is used for strong signals; that is to say, for local stations where the fidelity should be optimum. If the tubes V_1 and V_3 have a high R_p, while the tube V_2 has a low R_p, the resonance curve E in Fig. 5 is changed to the curve G which gives a high degree of selectivity. The resonance curve G is utilized for weak signals; that is for distant stations where selectivity is most important.

The biases on the control tubes V_1, V_2 and V_3 are controlled by the rectifier anode current. As the signal strength increases, the biases of V_1 and V_3 decrease and that of V_2 increases. It is also pointed out that the operation of the arrangement in Fig. 4 can be considered from the point of view of each of the tuned circuits between tubes 6' and 7' having a damping tube connected across it. For strong signals, and broad tuning, the center circuit II' only is damped. As the signal strength decreases, the damping on the middle circuit decreases and the damping on the end circuits increases. In this way the selectivity of the network between amplifiers 6' and 7' is automatically controlled in response to variations in received signal strength.

A damping action on one of the tuned circuits between amplifiers 6' and 7' can also be secured by the utilization of a feed-back arrangement. Such an arrangement is shown in Fig. 6 wherein between the screen grid amplifiers 6' and 7' is connected a pair of coupled tuned circuits 30 and 31. The tuned circuit 30 includes in a series arrangement a coil 32, the tuning condenser 33, and the coupling coil 34. The tuned circuit 31 includes in a similar series arrangement the coil 32', the tuning condenser 33', and the coupling coil 34'. The magnetic coupling between coils 34 and 34' is less than critical.

A control tube 35 has its anode connected to a source of positive potential (not shown) through a coil 36, coils 36 and 32 being inductively coupled, while the cathode tube 35 is grounded. The control grid of tube 35 is connected to the high potential side of tuned circuit 31 through a condenser 37, the control grid also being connected

to an intermediate point of the rectifier anode circuit resistor R through a path which includes the resistor R_1 and the negative biasing source **38**.

The tube **35** feeds back signal voltage to the tuned circuit **30**, and the feed-back polarity is opposite to that required for oscillation. Hence, there is a tendency to reduce the output of the receiving system. The reduction of output is greatest at resonance, and therefore the over-all selectivity curve of the system is flattened into a band pass curve. By regulating the bias of tube **35** the sharpness of the selectivity curve can be altered. This is accomplished automatically by the signal so that the selectivity is inversely proportional to the signal strength. In other words, the auxiliary control tube **35** connected to the network between tubes **6'** and **7'**, which network may be operating at intermediate frequency or at a much higher frequency, produces reversed feed-back, which in turn reduces the gain and pushes down the center of the resonance curve so as to make it broad and flat, or double-peaked. The bias on the control grid of tube **35** controls the reversed feed-back; accordingly, if the bias is high there is no feed-back and the coupling network tunes sharply and has a normal gain.

When signals of weak amplitude, as from distant stations, are received, the bias on the grid of tube **35** will be high; this following from the fact that the negative bias source **38** overcomes the effect of the voltage developed in resistor R between ground and the grid tap. As the signal amplitude increases, this voltage across the portion of resistor R between ground and the grid tap from tube **35** increases; thus overcoming the effect of the negative bias from source **38** and increasing the gain of tube **35** as well as the reversed feedback effect.

A modification of the arrangement shown in Fig. 6 is represented in Fig. 7. The amplifier tube **7'** is connected across the tuned circuit **40**, the latter including the coil **41**, the resistor R_2 and the tuning condenser **42**. The function of the resistor R_2 is to broaden the tuning of the circuit **40**. The control tube **35** provides regeneration which sharpens the resonance curve and increases the gain. The amount of regeneration is controlled by the control grid bias, or screen voltage if desired, of tube **35**, the latter in turn depending on the signal strength.

With increasing signal strength the bias of tube **35** must be increased to reduce the regeneration. Several stages of this kind can be used in cascade. The function, then, of tube **35** of Fig. 7, is to regenerate in the tuned circuit **40**, which may be a radio frequency or intermediate frequency stage, which has high damping so as to reduce the effective damping, and, thus sharpen tuning and increase gain when weak signals are being received. When strong signals are being received the regenerative feed-back to the circuit **40** is reduced, and hence the effective resonance curve of circuit **40** is flattened thereby increasing the fidelity of reception.

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. In a radio broadcast receiver of the type which includes a source of modulated signal carrier energy, a utilization circuit provided with a signal transmission tube and a network coupling the source and input of said tube, the improvement which comprises three reactively coupled resonant circuits arranged in cascade in said coupling network without the interposition of electron discharge tubes, each circuit being tuned to the operating carrier frequency, a separate resonance curve characteristic control device connected to each of said resonant circuits, and carrier energy rectifying means connected to each control device for adjusting the damping of the second resonant circuit inversely with respect to the damping of the other two resonant circuits and in a sense to provide a wide over-all resonance curve characteristic for said coupling network while maintaining the resonant circuits tuned to said operating frequency when strong signals are received.

2. In a receiver as defined in claim 1, each control device consisting of an electron discharge tube having its internal impedance connected to its associated resonant circuit in a predetermined manner.

3. In a receiver as defined in claim 1, said rectifying means being the signal demodulator of the receiver, and each resonance control device consisting of a tube having a gain control electrode connected to a point of predetermined direct current voltage in the space current path of the demodulator.

4. In combination with a source of signal waves and a load circuit, a wave transmission network comprising at least three resonant circuits in cascade between the source and load circuit, each resonant circuit being tuned to the same wave frequency, said resonant circuits being reactively coupled to produce for normal signal reception a wide over-all resonance curve characteristic with a peak at substantially the mid-curve frequency, each resonant circuit having electrically connected thereto a separate resonance curve control tube, means, responsive to changes in wave amplitude, connected to said control tubes to vary the internal impedance of the second circuit control tube inversely with respect to the internal impedances of the other two control tubes and in a sense to eliminate said peak when the amplitude is relatively high and to narrow said over-all curve when the amplitude is low.

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