Dec. 13, 1938. H. F. MAYER 2,140,391

AUTOMATIC SELECTIVITY CONTROL

Filed Oct. 22, 1936

Fig. 1.

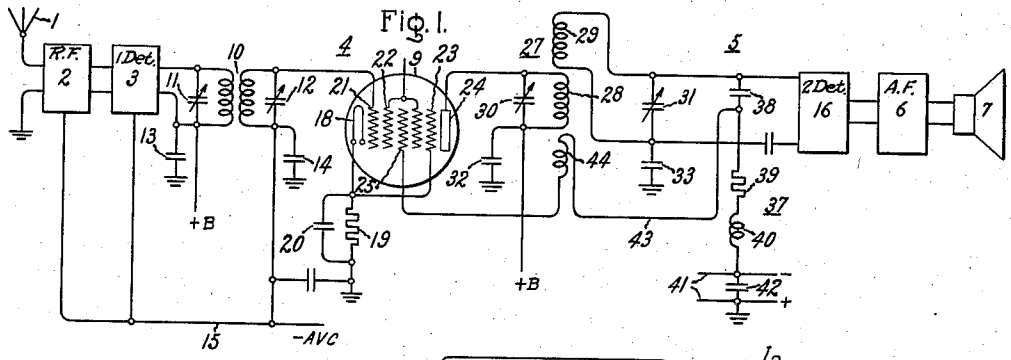


Fig. 2.

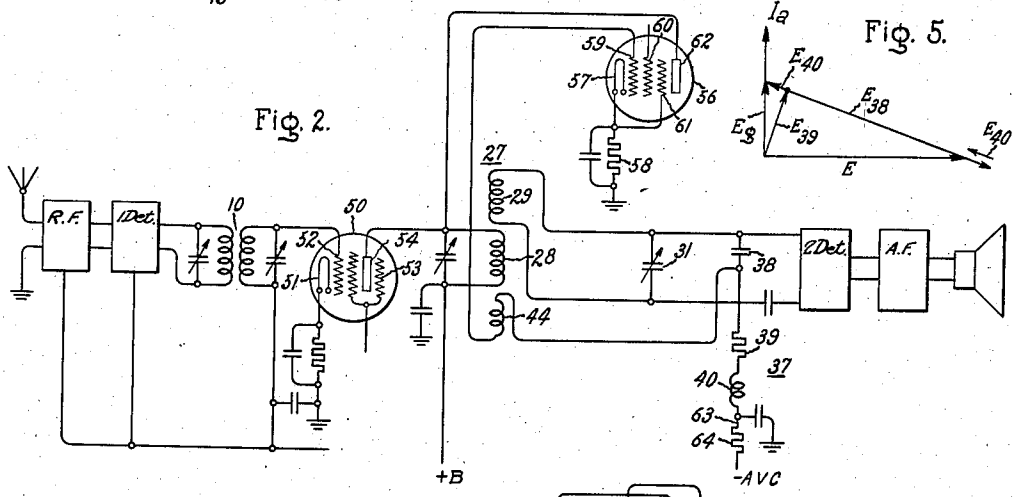


Fig. 5.

Fig. 3.

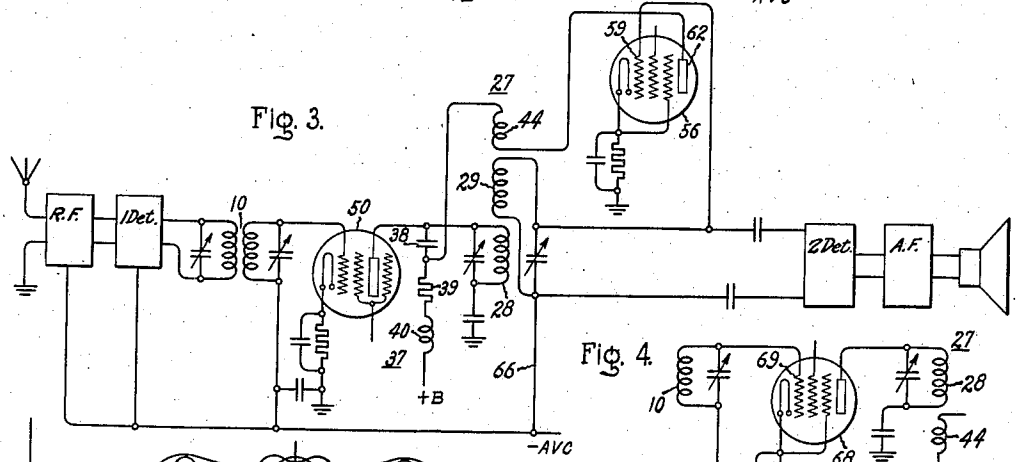


Fig. 4.

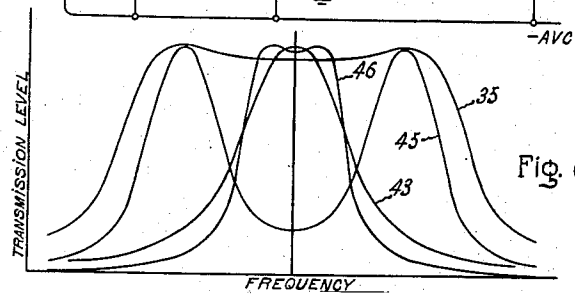


Fig. 6.

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AUTOMATIC SELECTIVITY CONTROL

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Application October 22, 1936, Serial No. 106,984

10 Claims. (Cl. 250—20)

My invention relates to resonant networks and particularly to such networks which are employed in radio receiving systems.

It is well known that when relatively weak signals are being received by such systems greater selectivity may be obtained by limiting the frequencies received to a narrow band and that when the signals are relatively strong the band of received frequencies may be broadened out thereby improving the fidelity of the reception although at some expense of selectivity. With systems as heretofore constructed when the signals are weak and when the band of frequencies received is narrowed to effect a higher degree of selectivity of a desired carrier there has been an objectionable loss in fidelity due to a partial cutting off of the side bands of the desired carrier and an objectionable amount of interference with signals in closely adjacent channels. One object of my invention, therefore, is to provide an improved system of this character by which those objections may be avoided. More specifically that object is to provide a system having coupled resonant circuits characterized by a resonance curve which at the higher signal strengths is more rectangular than that previously obtained. Another object of my invention is the provision of an improved system of this character wherein the band of radio frequencies passed by the system is relatively wide when the signal is strong but is automatically narrowed when the signal becomes weak to a band embraced by a resonance curve which is substantially flat topped and rectangular.

In accordance with my invention I have provided a resonant network having means automatically operative in response to a decrease in signal strength to decrease the effective resistance of one of the resonant circuits of the network and simultaneously to decrease the effective coupling between two coupled resonant circuits thereof and vice versa.

My invention will be better understood from the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 is a circuit diagram showing a preferred form of my invention; Figs. 2, 3 and 4 are circuit diagrams showing modifications thereof; Fig. 5 is a vector diagram; and Fig. 6 shows resonance curves obtainable under varying circuit conditions.

In Fig. 1 I have shown my invention as forming a part of a superheterodyne radio receiving system, wherein 1 is the antenna or pick-up device, 2 is the radio frequency amplifier stage, 3 is the detector and oscillator stage, 4 is the stage of intermediate frequency amplification, 5 is the second detector and automatic volume control stage, 6 is the audio amplifier and 7 is the loudspeaker.

The detector and oscillator stage 3 is shown coupled to the intermediate frequency amplifier 9 of stage 4 by the coupling transformer 10 whose primary and secondary windings are tuned to the intermediate frequency by the adjustable capacitors 11 and 12 respectively. Bypass capacitors 13 and 14 are shown connecting the lower ends of the windings with ground in the customary manner. Conductor 15 supplies negative automatic volume control voltage to the stages 2, 3, and 4 which voltage may be obtained in the customary manner from the second detector 16 forming a part of stage 5.

The intermediate frequency amplifier tube 9 has the cathode 18 which is self-biased by the resistor 19 through which it connects with ground, the resistor being bypassed by the capacitor 20. Amplifier 9 has the main control grid 21, which as shown connects with the upper end of the secondary of the transformer 10, the screen grid 22, the suppressor grid 23 and the anode 24. For reasons which will be explained later this amplifier is provided also with the auxiliary grid 25. The amplifier 9 is coupled with the detector 16 by the coupling transformer 27 which like the coupling transformer 10 has its primary and secondary windings 28 and 29 tuned to the intermediate frequency by the capacitors 30 and 31 respectively. Like transformer 10 also, the lower ends of the windings 28 and 29 are connected with ground by the bypass capacitors 32 and 33 respectively. The above-described apparatus with the exception of the auxiliary grid 25 in amplifier 9, is like that commonly employed in superheterodyne radio receiving systems and functions in a well known manner.

The coupling transformer 27 is shown having its primary and secondary windings wound in opposite directions on the same axis, the windings being normally somewhat over-coupled adapting the transformer to pass a relatively broad band of frequencies, whereby the system has high fidelity at the expense of selectivity. The resonance curve of the transformer thus overcoupled is represented at 35 in Fig. 6, which curve is plotted between units of transmission level and frequency. With strong signals when selectivity is of minor importance one may thereby obtain maximum fidelity, as the width of the

curve is sufficient to include all the side bands of the desired carrier. With weak signals, however, selectivity becomes of the greater importance.

One manner of increasing the selectivity is to decrease the coupling between the primary and secondary windings of the transformer **27**. This may be done in various ways either actually or effectively. I prefer the latter and for that purpose have provided a feed-back circuit comprising the phase shifting network **37** and the amplifier **9**. The latter network comprises the capacitor **38** which, for example, may have a capacitance of 40 micro-micro-farads, the resistor **39** which, for example, may have a resistance of 2000 ohms, the impedance of the capacitor being high with respect to that of the resistor at the intermediate frequency employed, and the small reactor **40** whose inductance may, for example, be 250 micro-henries. The network **37** is connected as shown between the upper end of the secondary **29** and a suitable source **41** of negative bias voltage which, for example, may be —4 volts the source being shunted by the by-pass capacitor **42**. At a point intermediate the capacitor and the resistor the network is connected by means including the feed-back conductor **43** with the auxiliary grid **25** of the amplifier **9**.

The operation of the above-described phase shifting network may be better understood by reference to the vector diagram shown by Fig. 5 where E represents the voltage applied by the secondary **29**, E_{39} the voltage across the resistor due to the current advancing effect of the capacitor and E_{38} the resulting voltage across the capacitor **38** which is at right angles to E_{39}. The voltage E_{40} across the reactor, which voltage is 180° displaced in phase from E_{38}, is shown as an extension of E_{38} in the opposite direction. The vectorial sum of E_{39} and E_{40} is E_g, the voltage applied to the grid **25** by the network. With a reactor having the proper impedance at the frequency employed the angle between E and E_g and hence between E and the anode current I_a of the amplifier **9** may be made exactly 90°. Moreover, if desired, it may be made either greater or less than 90° by suitably changing the value of the reactor **40**. If should be understood that Fig. 5 does not truly represent the phase angles obtained with the impedance values mentioned above for the actual phase displacement obtained with the capacitor and resistor alone is closer to 90° than that shown. Under certain conditions, therefore, I may dispense with the compensating reactor **40** particularly if the losses resulting from a lack of a full 90° angle of displacement are not serious.

When the received signals are weak the effect of the feed-back voltage supplied by the above-described phase shifting network is a maximum since at that time the automatic volume control voltage being small, the gain in the amplifier is large. The form of the resonance curve will then change from that shown at **35** to that shown at **43** which change is the result of the effective decrease in the coupling between the windings of the transformer **27**. The feed-back which I have provided is spoken of as effectively decreasing the coupling only because it has the same effect upon the shape of the resonance curve as would be produced by an actual decrease in the coupling.

It is to be understood that the scale of ordinates of curve **43** is much smaller than that of the curve **35**, the change in scale being made for the purpose of making a comparison of the curves more convenient. The curve **43** while showing a high degree of selectivity also shows by its narrow top that there is a material loss in the side bands received of the desired carrier which results in lack of fidelity and because of its widely flaring lower portions shows that the frequencies of adjacent channels will be received to a considerable extent causing interference therewith.

To avoid these objectionable results I apply to the same auxiliary grid **25** of amplifier **9** another voltage whose effect is to decrease the effective resistance of the primary winding of the transformer **27**. For convenience and simplicity the letter "Q" is now commonly employed by those skilled in the art to indicate the reciprocal of the power factor of a winding in a resonant circuit. Since a decrease in the effective resistance of such a winding obviously is accompanied by a decrease in the power factor thereof, to say that the effective resistance of the winding is decreased is equivalent to saying that the Q of the winding is increased. For convenience this term Q will be used in the description to follow.

The manner which I prefer and have shown by the drawing of decreasing the effective resistance of the winding **28**, namely of increasing the Q of the winding, is by the use of the small coil or tertiary winding **44** comprising, for example, a few turns, which is wound in the same direction as and is coaxial and in close inductive relation with the primary winding **28**. The winding **44** is inserted in the conductor **43**, the lower end of the winding connecting with the auxiliary grid **25** whereby it applies to that grid a voltage which is 180° displaced from the voltage of the primary **28**; in other words when the voltage of the anode **24** is at a positive half cycle the voltage supplied by the winding **44** is at a negative half cycle.

Were the voltage of the tertiary winding **44** alone to be applied to the auxiliary grid when the gain is high the result of the consequent raising of the Q of the winding **28** would be to give a resonance curve like that shown at **45**. Such a curve it will be noticed has comparatively steep sides indicating a small amount of interference with adjacent channels. The curve has, however, a very objectionable dip in its central portion.

I have found that by combining the phase shifting effect of the voltage obtained from the phase shifting network by which the coupling is decreased with the Q raising effect of the voltage obtained from the tertiary winding I am able to obtain a highly selective resonance curve which is sufficiently broad at the top to include those side bands which are necessary for a desired degree of fidelity and whose sides are sufficiently steep to substantially avoid interference with adjacent channels. The curve obtained by this combined effect is that shown at **46**, it being understood that this curve as well as curves **43** and **45** are drawn with their ordinates at different scales from the ordinates of curve **35** thereby reducing the curves to a common height to facilitate their comparison. Since the resulting resonance curve **46** has substantially vertical sides and a substantially flat top, it may be said to have a substantially rectangular shape.

It will be understood that the resonance curve **46** is obtained when the received signal is weak at which time the automatic volume control voltage is small and the gain is large. When the received signal is strong, the automatic volume control voltage is large, the gain is small and the effect of the voltages impressed upon the auxil-

iary grid 25 accordingly is small. The coupling between the windings of the transformer 27 then increases to normal and the Q of the transformer decreases to normal. The resonance curve consequently returns to the form shown at 35.

The modified form of my invention illustrated by Fig. 2 is similar in construction and in the results obtained to that illustrated by Fig. 1 except that instead of employing a single amplifier to perform both functions of amplifying the intermediate frequency and amplifying the control voltages obtained from the network 37 and the tertiary winding 44, I employ in Fig. 2 separate amplifiers for performing those functions. The amplifier 50 has its cathode 51 connected to ground through a biasing resistor, its control grid 52 connected to the secondary of the coupling transformer 10, a screen grid 53 and the anode 54 connected to the primary of the coupling transformer 27 in the same manner as the amplifier 9 of Fig. 1. In this case the amplification of the control voltages obtained by the network 37 and the tertiary winding 44 is performed by an additional amplifier represented at 56, which may be a pentode. This amplifier has the cathode 57 which is connected with ground through the self-biasing resistor 58, the control grid 59 which connects with the lower end of the winding 44, the screen grid 60, the suppressor grid 61 and the anode 62 which connects with the upper end of the primary 28 of the transformer 27. The upper end of the winding 44 connects as before with a point on the phase shifting network 37 between the capacitor and the resistor thereof.

In Fig. 1 it will be remembered that the effect of the voltages from the network 37 and the winding 44 was controlled by the gain in the amplifier 9. In Fig. 2, however, the effect of the voltages from the network 37 and the winding 44 is controlled directly by the negative automatic volume control voltage which is supplied to the network 37 by the conductor 63 connecting through the resistor 64 with the source of automatic volume control voltage. As so constructed and connected this form of my invention operates in a regenerative manner like that represented by Fig. 1. This form may, however, be employed in a degenerative manner if desired. For this purpose the connections of the secondary of transformer 27 should be reversed, the connections of the tertiary winding 44 should be reversed and a source of positive biasing voltage such as an automatic signal control voltage should be applied to the network 37 instead of the negative automatic voltage control voltage.

The modification illustrated by Fig. 3 is similar to that represented by Fig. 2 except that the phase shifting network 37 is connected with the primary of the transformer 27, the tertiary winding 44 is wound in the same direction as and is in close inductive relation with the secondary of the transformer 27 and the amplifier 56 is arranged to amplify the voltage of the secondary winding before supplying it to the tertiary winding and the phase shifting network. The amplifier 56 is represented as a pentode and is similar to the corresponding pentode of Fig. 2 except that its control grid 59 in this case connects with the upper end of the secondary of transformer 27 and its anode 62 connects with the lower end of the tertiary winding 44, the upper end of that winding being connected with the phase shifting network 37. The degree of amplification of the amplifier 56 is controlled by the connection 66 with the source of negative automatic volume control voltage. The network 37 in this case connects between the upper end of the primary 28 and the source of anode voltage. This form of my invention is regenerative only and like that shown in Fig. 2 functions to modify the resonance curve by decreasing the coupling and increasing the Q in the same manner as has already been described above in connection with Fig. 1.

The modification illustrated in part by Fig. 4 is similar to that represented by Fig. 2 except that I employ a single amplifier, shown as the pentode 68, instead of the two amplifiers 50 and 56 and I connect the tertiary winding 44 with the control grid 69 of that amplifier through the secondary of the transformer 10. The automatic volume control voltage is thus applied to the control grid 69 through the phase shifting network 37 and the tertiary winding 44. It will, of course, be understood that those portions of the circuit from the antenna to and including the transformer 10 and those portions including the transformer 27 to the loudspeaker, while not shown in this figure, are the same as shown in Fig. 2. In this form of my invention the phase shifted voltage from the network 37 and the voltage from the tertiary winding 44 both are applied to the control grid 69 in addition to the signal voltage. With an increase in the signal strength, therefore, the coupling of the transformer 27 is decreased and the Q is increased whereby the form of the resonance curve is modified in the same manner as has already been described in connection with the other forms of my invention.

I have chosen the particular embodiments described above as illustrative of my invention and it will be apparent that various other modifications may be made without departing from the spirit and scope of my invention which modifications I aim to cover by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, means for obtaining from one of said circuits a voltage substantially in quadrature with the voltage thereof, means for obtaining from another of said circuits a voltage substantially in phase opposition with the voltage in said other circuit and means for applying said voltages to said other circuit in accordance with the strength of the received signal.

2. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, means for obtaining from one of said circuits a voltage substantially in quadrature with the voltage thereof, means for obtaining from another of said circuits a voltage substantially in phase opposition with the voltage of said other circuit and amplifying means for applying said voltages to said other circuit with greater amplification when the received signals are weak than when they are strong.

3. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, means responsive to the current in one of said circuits for decreasing the effective resistance of said circuit and means responsive to the voltage of another of said circuits for supplying to said one circuit a voltage whose phase is substantially in quadrature with that of said other circuit.

4. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, means including a coil in-

ductively related to one of said circuits for decreasing the effective resistance thereof and means for supplying to said one circuit a voltage whose phase is substantially in quadrature with that of another of said circuits.

5. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, means including a reactive circuit connected to one of said coupled circuits for supplying to the other of said coupled circuits a voltage whose phase is substantially in quadrature with that of said one coupled circuit, and means for simultaneously supplying to said other coupled circuit a voltage in accordance with the current therein.

6. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, a grid controlled electron discharge device having its anode circuit connected with one of said coupled circuits, means for supplying to said grid a voltage which is substantially 180° displaced from the voltage of said one circuit and means for supplying also to said grid a voltage which is substantially 90° displaced from that of another of said circuits.

7. In combination, a plurality of coupled circuits tuned to the same frequency and arranged to transmit a signal, a grid controlled electron discharge device having its anode circuit connected with one of said coupled circuits, means connected with another of said circuits for supplying to said grid a voltage substantially in quadrature with that of said other circuit and a coil in series therewith in inductive relation with said one circuit.

8. In a radio receiving system having means for producing a desired frequency, a pair of coupled oscillatory circuits tuned to said frequency, a grid controlled electron discharge device having its anode circuit connected with one of said circuits, a winding inductively associated with said one circuit, apparatus including a reactance connected with the other of said circuits for obtaining a voltage substantially in quadrature with the voltage thereof and means connecting said grid, winding and apparatus in a series circuit.

9. In a radio receiving system of the superheterodyne type, an electron discharge amplifier having a main control grid and an auxiliary control grid, a coupling transformer having its primary and secondary windings tuned to the intermediate frequency of said system and having its primary in the anode circuit of said amplifier, and a feed back circuit including means for supplying a voltage to said auxiliary grid to change the Q of said primary and means for simultaneously supplying a voltage to said auxiliary grid to change the effective coupling between said windings, the effect of said voltages being controlled by the amplification of said amplifier.

10. In a radio receiving system of the superheterodyne type, an electron discharge amplifier having a main control grid and an auxiliary control grid, a coupling transformer having its primary and secondary windings tuned to the intermediate frequency of said system and having its primary in the anode circuit of said amplifier, a tertiary winding adjacent said primary winding to produce a voltage for raising the Q of said primary winding, a circuit including a capacitor and a resistor connected in series across said secondary winding to produce a voltage for decreasing the coupling between said primary and secondary windings, means connecting said tertiary winding and said resistor in series to said auxiliary grid and a source of supply of automatic volume control voltage connected with said main control grid.

HARRY F. MAYER.