June 18, 1940. E. I. ANDERSON ET AL 2,204,954

INTERFERENCE REJECTION CIRCUIT

Filed Jan. 4, 1939

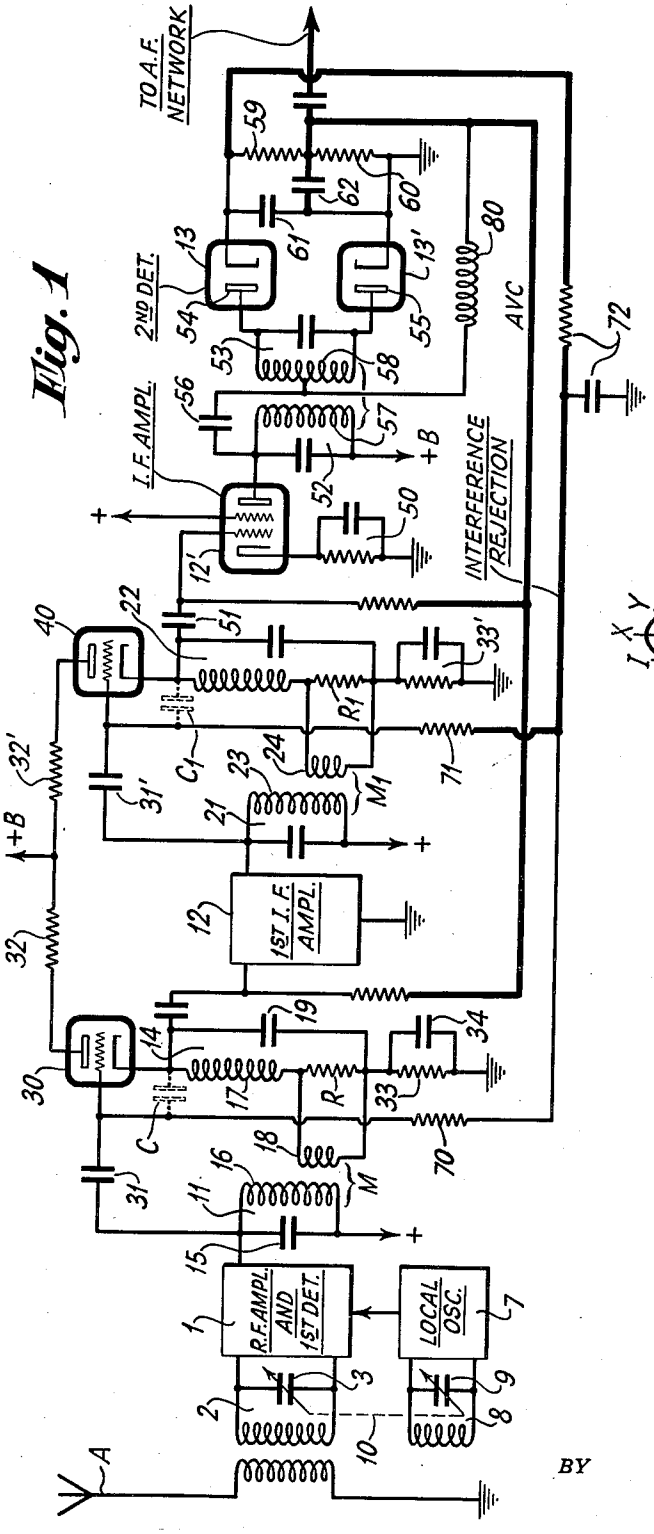


Fig. 1

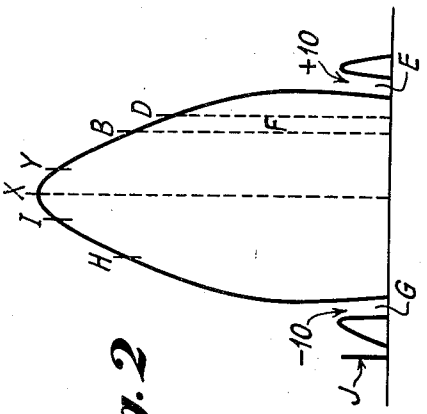


Fig. 2

INVENTORS
EARL I. ANDERSON AND
GARRARD MOUNTJOY

BY H. S. Brown

ATTORNEY.

Patented June 18, 1940

2,204,954

UNITED STATES PATENT OFFICE

2,204,954

INTERFERENCE REJECTION CIRCUIT

Earl I. Anderson, Bayside, and Garrard Mountjoy, Manhasset, N. Y., assignors to Radio Corporation of America, a corporation of Delaware

Application January 4, 1939, Serial No. 249,200

6 Claims. (Cl. 250—20)

Our present invention relates to signal selector circuits, and more particularly to tuned selector circuits having substantially infinite attenuation for undesired adjacent channel signals. In U. S. Patent No. 2,137,475, granted Nov. 22, 1938, G. Mountjoy has disclosed and claimed an intermediate frequency (I. F.) transmission network, for a superheterodyne receiver, which includes two cascaded I. F. resonant circuits. The first of the circuits is designed to reject substantially completely one adjacent undesired signal channel, and the following circuit is constructed to reject the adjacent channel on the opposite side of resonance. As disclosed in said patent there exists some mechanical complexity in the manipulating elements; as a result a certain degree of operating skill is required to effect the ejection of adjacent channel signals.

One of the main objects of our present invention is to provide an automatically operating network of the aforesaid infinite attenuator type; the system employed eliminating the need for especial skill on the part of the receiver operator and taking advantage of the natural tendency to attempt to retune the receiver when interference occurs.

Another important object of our invention is to replace the coupling capacities of the infinite attenuator network by tubes acting as electronic capacities; a frequency discriminator responsive to detuning of the receiver, with respect to a desired carrier frequency, being used to control the magnitude of either of the electronic capacities to an extent such as to provide practically complete rejection of an undesired adjacent channel signal.

Still other objects of this invention are to improve generally the selectivity and transmission efficiency of coupled signal selector circuits, and more especially to provide selector circuits of substantially complete rejectivity against adjacent channel interference and which selector circuits are not only automatic and simple in operation, but are also readily assembled in radio receivers.

The novel features which we believe to be characteristic of our 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 we have indicated diagrammatically a circuit organization whereby our invention may be carried into effect.

In the drawing:

Fig. 1 diagrammatically shows a receiving system embodying the invention,

Fig. 2 graphically illustrates the functioning of the invention.

Referring now to the accompanying drawing, there is shown in Fig. 1 a superheterodyne rereceiver of a type generally known. The receiver may comprise a signal collector A; and the latter may be the usual grounded antenna circuit, a radio frequency distribution line, or even the usual signal collector employed on an automobile receiver. The numeral 1 denotes a network comprising a radio frequency amplifier whose output is fed to a first detector. The input circuit 2 includes the usual type of tuning condenser 3. It will be understood that the first detector will also include a tunable input circuit, and that the latter will be provided with a variable tuning condenser. There is impressed upon the first detector locally produced oscillations from the local oscillator 7. The oscillator tank circuit 8 includes a variable tuning condenser 9, and the dotted line 10 designates the usual mechanical uni-control device which functions to vary the positions of the rotors of the three variable condensers employed in the tunable circuits of network 1 and the tank circuit 8.

Those skilled in the art are fully acquainted with the manner of constructing the aforesaid portions of a superheterodyne receiver; they are, also, aware of the fact that the three tunable circuits are so related that the signal energy appearing in the output circuit 11 of the first detector has a frequency value equal to that of the operating intermediate frequency (I. F.). The I. F. value may be chosen from a range of 75 to 460 k. c., and the frequency of the oscillator tank circuit 8 must constantly differ from the frequency of the tunable signal circuits by a value equal to the I. F. It is to be clearly understood that instead of using separate tubes for the first detector and oscillator, a tube of the pentagrid converter type (2A7) may be used to provide a combined local oscillator-first detector network. The I. F. output circuit 11 is followed by an I. F. amplifier 12, which may be of any well known type. A second I. F. amplifier 12' follows amplifier 12, and the subsequent second detector network comprises diodes 13 and 13' arranged in an electrical relation to be described at a later point.

Between the I. F. output circuit 11 and the input electrodes of amplifier 12 there is connected the tuned circuit 14, and the latter is resonated to the operating I. F. Input circuit 11 comprises

coil 16 and the shunt tuning condenser 15; tuned circuit 14 comprises coil 17 and the link coupling coil 18, coils 17 and 13 having connected in shunt therewith the resonating condenser 19. The capacity C connects the high alternating potential sides of the circuits 11 and 14, and provides a capacity coupling path between the cascaded tuned circuits. Inductive coupling is provided between circuits 11 and 14 by the coupling between coils 16 and 18, and this inductive coupling is denoted by the symbol M. The circuit details of amplifier 12 are not shown, but it will be understood that the cathode circuit thereof, as shown in connection with amplifier 12', includes the usual signal grid biasing network. The I. F. output circuit 21 is connected to the plate of the amplifier 12.

The coupling capacity C is denoted in dotted lines, because it is provided by the capacity between the grid and cathode of tube 30. The control grid of tube 30 is connected to the high alternating potential side of circuit 11 by a direct current blocking condenser 31, whereas the cathode of tube 30 is connected to the high potential side of circuit 14. The plate of tube 30 is connected to a source of positive potential through a resistor 32. The magnitude of capacity C is controlled by varying the bias of the grid of tube 30.

The inductive coupling M is so poled that the voltage induced through M is opposite in sign to the voltage induced through the capacity coupling C. Furthermore, these voltages are made to cancel at an adjacent channel frequency which is spaced from the I. F. value by a predetermined frequency magnitude. In Fig. 2 there is shown the type of selectivity characteristic secured with the circuit disposed between the network 1 and amplifier 12'. It will be understood that the curve in Fig. 2 to one side of the vertical, dotted center line represents the rejection characteristic of the coupling network between 1 and 12. The resistor R, connected across the link coupling coil 18, functions to correct for all factors in the circuit. In other words, the function of the resistor R is to provide accurate cancellation of the opposed voltages due to C and M; correct values of M, C and R provide infinite rejection of the undesired adjacent channel frequency.

The resistor 33, connected between resistor R and ground, is shunted by by-pass condenser 34 and functions as the grid biasing network for the grid of tube 30. An examination of Fig. 2, and particularly one-half the curve on either side of the central vertical line, shows the infinite rejection characteristic secured. This type of rejection characteristic is secured when the capacity C is adjusted to reject an adjacent channel frequency which is 10 k. c. off resonance. It may be pointed out that while the capacity coupling C increases with frequency, impressed voltages transmitted through the coupling M are subjected to a decreasing coupling with frequency increase.

Accordingly, while no coupling exists between circuits 11 and 14 at the channel 10 k. c. off resonance, coupling does exist at the I. F. The network between amplifier 12 and amplifier 12', on the other hand, is constructed to produce a rejection characteristic as shown in the opposite half of the curve in Fig. 2. In other words, the coupling circuit between networks 1 and 12 has the characteristic shown to one side of the vertical dotted line in Fig. 2, while the coupling circuit between amplifiers 12 and 12' has the characteristic curve shown in the opposite half of the curve in Fig. 2. It will be seen that the coupling network between amplifiers 12 and 12' rejects the adjacent channel frequency on the opposite side of the I. F.

The coupling network between amplifier 12 and amplifier 12' comprises the output circuit 21 and the input circuit 22 of amplifier 12'. The circuit 21 is tuned to the I. F., and the coil 23 thereof is magnetically coupled, as at M_1, to the link coupling coil 24 of the I. F. input circuit 22. The capacity C_1, shown in dotted lines, provides the coupling capacity between the high alternating potential points of circuits 21 and 22, and is provided by the capacity existing between the grid and cathode of tube 40. It will be noted that the construction of the selector network between amplifiers 12 and 12' is substantially similar to that preceding amplifier 12.

The control grid of tube 40 is connected to the high potential end of coil 23 by a direct current blocking condenser 31', and the plate of the tube 40 is connected to the positive potential source of tube 30 through a resistor 32'. The cathode of tube 40 is connected to the high potential side of circuit 22. The resistor R_1 is connected in shunt with coupling coil 24, and functions in the same manner as described in connection with resistor of tube 40. Circuits 21 and 22 are each resonated to the operating I. F. value. The I. F. amplifier 12' includes in its grounded cathode circuit a signal grid biasing network 50, and its control grid is connected by the direct current blocking condenser 51 to the high potential side of input circuit 22. The plate circuit of tube 12' includes an output circuit 52 which is resonated to the operating I. F. value.

The second detector network is of the type which is disclosed and claimed by S. W. Seeley in U. S. P. 2,120,103 granted June 21, 1938. Since this type of frequency discriminating network is well known, it is not believed necessary to describe the circuit in great detail. The common input circuit 53 has one end thereof connected to the anode 54 of diode 13, while the opposite end of the input circuit is connected to the anode 55 of diode 13'. The midpoint of the coil of circuit 53 is connected through the large condenser 56 to the high potential side of circuit 52. The primary coil 57 is magnetically coupled to the secondary coil 58, and the cathodes of diodes 13 and 13' are connected by series resistors 59 and 60. The cathode end of resistor 60 is at ground potential. The resistors 59 and 60 are shunted by a by-pass condenser 61, and the junction of resistors 59 and 60 is connected through condenser 62 to one side of condenser 61.

The potential drop across resistor 59—60 will depend in magnitude and polarity upon the amount and sense respectively of the frequency shift of the intermediate frequency energy from the operating I. F. value of circuits 52 and 53. In the type of discriminator network shown the primary and secondary circuits 52 and 53 are so connected that two vector sum potentials of the primary and secondary voltages may be realized. At I. F. resonance the intermediate frequency voltages impressed on the diode rectifiers 13 and 13' are equal in magnitude, but opposite in phase; this relation exists by virtue of the connection shown, and is clearly described in the aforesaid Seeley patent. Since the rectifiers are in series opposition, the direct current potential developed across resistors 59 and 60 is zero at I. F. resonance. If, now, the intermediate fre-

quency energy developed at circuit 52 departs from the I. F. resonance, a phase shift of 90 degrees occurs. The intermediate frequency voltages induced, in that case, in the two halves of coil 58 are still equal in magnitude and opposite in phase with respect to the midpoint of coil 38. However, the voltage drop across the primary circuit 52 is now added vectorially to the induced voltages. Thus, the potential at one side of the secondary 58 will be the sum of the voltage induced across one half the coil 58 and the voltage developed across circuit 52.

The potential of the other side of the coil 58 will be the difference between the voltage drop in the primary circuit 52 and the voltage induced in the opposite half of secondary coil 58. In the last case, then, the input voltage to one of the diode rectifiers is much greater than that to the second one. Hence, the voltage drop across one of the output resistors will be greater than that across the other one. For example, when the voltage drop across resistor 59 exceeds that across resistor 60, then the cathode end of resistor 59 will be positive with respect to the grounded end of resistor 60. When the intermediate frequency energy impressed on primary circuit 52 is off resonance in the positive direction, then the cathode end of resistor 59 becomes negative with respect to ground. The sense of detuning of the receiving system thus determines the polarity of the cathode end of resistor 59; and the amount of detuning determines the magnitude of the bias at the cathode end of resistor 59.

The gain of each of tubes 30 and 40 is controlled in response to the potential variation at the cathode end of resistor 59. The grids of tubes 30 and 40, are, therefore, connected through filter resistors 70, 71, as well as through the filter network 72, to the cathode end of resistor 59. It will now be observed that the signal grid circuits of tubes 30 and 40 are completed to ground through the series resistors 59 and 60. The audio modulation on the I. F. carrier is derived from the junction of resistors 59 and 60; AVC. bias is also derived from this junction point. Each of the signal grids of amplifiers 12 and 12' is connected by the AVC. lead, through proper filter resistors, to the junction of resistors 59 and 60. It will be noted that a radio frequency choke coil 80 is connected between the midpoint of coil 58 and the junction of resistors 59 and 60.

To explain the operation of the receiving system shown in Fig. 1, let it be assumed that the selectivity curve shown in Fig. 2 is that of the receiving system with an incoming signal properly tuned to; in that case no direct current voltage is developed across resistors 59—60. The desired signal carrier may then be represented as being located at the point X which is at the central dotted line of the curve. Assuming further now that an interfering signal occurs at a point B, the natural tendency of the operator would be to adjust the tuning device 10 so as to retune the receiver to attempt to reduce the magnitude of the interfering signal. If the desired carrier were shifted to a point corresponding to point Y, the undesired signal would be shifted a corresponding amount to point D. However, upon adjusting the tuning mechanism 10 so as to shift the desired signal carrier frequency to point Y, there would be developed sufficient discriminator voltage across 59—60 to move the rejection notch E to the position F located between the vertical dotted lines B and D. The effect of this shift of the rejection notch E to the position F would be entirely to remove the interfering carrier.

In the same way if an interfering signal should appear at point H, it could be removed by adjusting the tuning mechanism 10 until the desired carrier were shifted to the point I. In other words, upon adjusting the tuning mechanism 10 in a sense to tune out the interfering carrier H, the rejection notch G is shifted towards the position of the interfering carrier H, as was described in connection with the rejection notch E. While shifting of either of the rejection notches, say E, towards the center line X results in a simultaneous shift of the rejection notch G to the point J, the proper operation of the system will not be affected. The essential advantage of the present arrangement is that the discriminator functions automatically to adjust the magnitude of either of the capacities C or C_1 when the tuning device 10 is adjusted to detune the receiver on either side of a desired carrier frequency.

The effect of the detuning is to develop discriminator voltage; the latter is utilized for automatically adjusting the appropriate one of the rejection networks in a sense to eliminate the interfering carrier. Minimum interference occurs when rejection notch E and the interfering carrier coincide in frequency. This would occur when the desired carrier is tuned to Y. The interfering carrier has been moved to point D. By detuning the desired signal to Y a positive voltage is developed by the discriminator circuit; this increases the electronic capacities of tubes 30 and 40. In turn, this moves notch E to D which eliminates the interfering carrier. At the same time notch G would have moved to J but this effect in this case is unimportant. If, however, the interfering carrier had appeared at H the desired signal would have been tuned to I; and the discriminator output would have been negative and notch G would have moved in to take out the interference. As a practical matter the receiver operator, upon tuning to a desired carrier frequency and hearing an interfering carrier, will adjust the tuning device 10 until the interfering carrier response is a minimum. This means that he has detuned the receiver sufficiently to one side of the desired carrier frequency to develop enough discriminator voltage thereby to shift a rejection notch to the position occupied by the interfering carrier frequency.

While we have indicated and described a system for carrying our invention into effect, it will be apparent to one skilled in the art that our 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 our invention, as set forth in the appended claims.

What we claim is:

1. In combination with at least two resonant signal circuits each tuned to a common operating frequency, at least two reactive coupling paths between said circuits which are poled in phase opposition, said circuits being characterized by the ability substantially completely to reject a frequency spaced from said operating frequency, and means, responsive to a frequency shift of the signal energy from said operating frequency to a frequency intermediate said spaced frequency and operating frequency, for automatically shifting said spaced frequency towards said intermediate frequency.

2. In combination, in a signal transmission

network, a first pair of resonant circuits, at least two reactive paths coupling said pair of circuits in phase opposition relation so that complete rejection is effected of a frequency spaced from the common operating frequency of said pair of circuits by a predetermined frequency value, a second pair of resonant circuits in cascade with said first pair, at least two reactive paths coupling said second pair of circuits in phase opposition to reject the frequency on the other side of said operating frequency which is spaced from the latter by said frequency value, and means, responsive to a frequency shift of the signal energy from said operating frequency value, for automatically shifting one of said spaced frequencies towards said operating frequencies.

3. In a superheterodyne receiver of the type comprising at least two cascaded intermediate frequency energy transmission networks; the method comprising transmitting the energy through the first of said networks with substantially complete rejection of energy of a frequency spaced by a predetermined frequency value from said intermediate frequency, transmitting the energy through the second of said transmission networks with substantially complete rejection of energy of a frequency value spaced by an amount equal to said first frequency separation but on the other side of said intermediate frequency, and automatically decreasing the frequency separation between the intermediate frequency and a rejection frequency upon a frequency departure of the intermediate frequency energy from said intermediate frequency.

4. In a superheterodyne receiver of the type provided with an intermediate frequency transmission network; the method which includes transmitting intermediate frequency energy through said network with substantially complete rejection of signals of a frequency spaced by a predetermined amount from the intermediate frequency value, and automatically decreasing the frequency spacing magnitude between the rejection frequency and the intermediate frequency value upon a frequency shift of the intermediate frequency energy towards said rejection frequency value.

5. In combination with a source of signal waves and a load circuit, a wave transmission network coupling the source and load circuit, said network comprising a plurality of resonant circuits arranged in cascade, and said cascaded circuits including at least two in number, at least two reactances coupling said resonant circuits, said reactances being of opposite sign and in phase opposition at a frequency spaced from the transmitted wave frequency by a predetermined frequency value thereby to secure substantially complete rejection of wave energy at said spaced frequency, and means, responsive to a frequency shift of the wave energy from the operating wave frequency, for automatically decreasing said predetermined frequency value.

6. In a superheterodyne receiver of the type including at least a first detector, an intermediate frequency amplifier and a second detector, an intermediate frequency transmission network between the first detector and intermediate frequency amplifier, said network comprising at least two resonant circuits each tuned to an operating intermediate frequency, means for coupling said tuned circuits in such a manner that substantially infinite rejection is produced of one side of the intermediate frequency by a distance of approximately 10 kilocycles, a second intermediate frequency transmission network between the amplifier and second detector, said second network comprising at least two resonant circuits each tuned to said operating frequency, and means for coupling the latter in such a manner that substantially infinite rejection is produced on the other side of the operating frequency by said frequency distance, and said second detector being constructed and arranged to produce a direct current voltage whose magnitude and polarity depends upon the amount and sense of the frequency departure of the intermediate frequency energy from said operating frequency, and means for utilizing said direct current voltage for decreasing at will the frequency distance between either one of said rejection frequencies and said operating frequency.

EARL I. ANDERSON.
GARRARD MOUNTJOY.