

Sept. 21, 1937.

D. E. FOSTER

2,093,556

AUTOMATIC TRANSMISSION BAND CONTROL CIRCUIT

Filed June 27, 1936

2 Sheets-Sheet 1

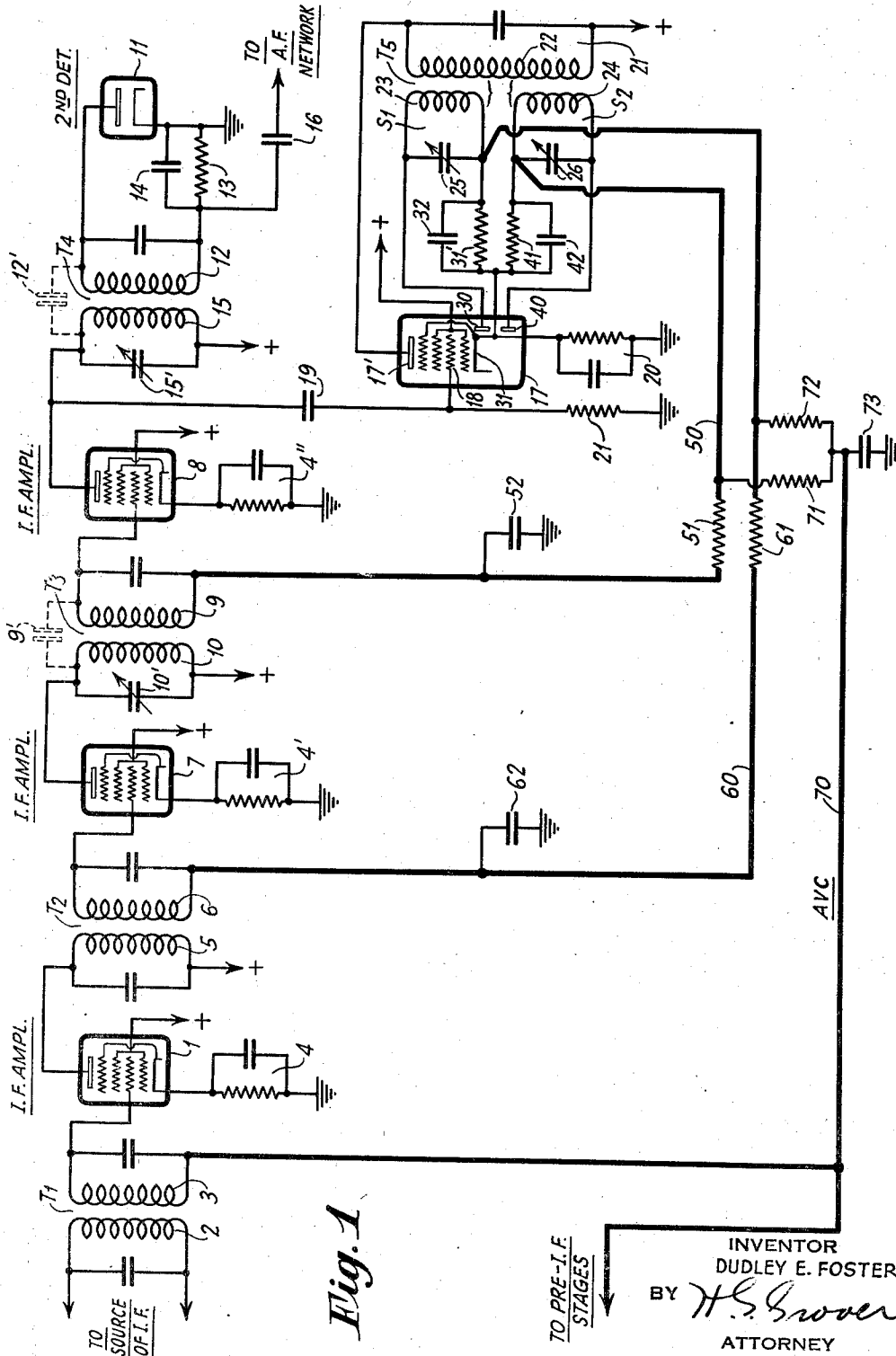


Fig. 1

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2 Sheets-Sheet 2

Fig. 2

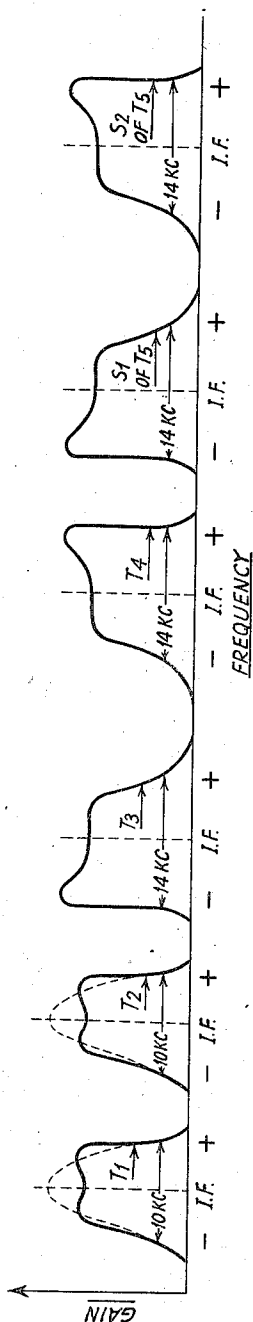


Fig. 4

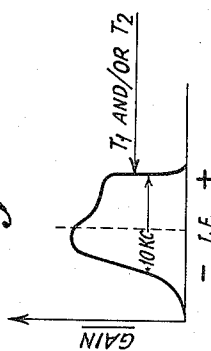
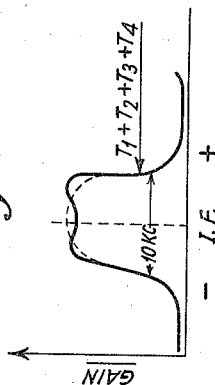


Fig. 3



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AUTOMATIC TRANSMISSION BAND CONTROL CIRCUIT

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7 Claims. (Cl. 250—20)

My present invention relates to control circuits for regulating the signal transmission band characteristics of a radio receiver, and more particularly to a signal-responsive arrangement for automatically modifying the signal transmission band characteristic of a receiver.

As is well known, dissymmetry of the transmission band characteristic of a radio receiver about the normal, or mean, frequency value produces a relative phase shift of the modulation side bands. For example, in a superheterodyne receiver the result of dissymmetry of the overall I. F. network transmission band characteristic is distortion caused by the relative phase shift of the modulation side bands of the I. F. energy. The lack of side band symmetry may be caused by any one of the following phenomena. There may be spurious couplings between the resonant networks of the cascaded transmission circuits; regenerative effects may give rise to dissymmetry of the transmission band. Again, overall mistuning of individual I. F. stages may also give rise to the dissymmetry referred to. Regardless of the cause, or causes, of the dissymmetry, this lack of symmetry of side bands is undesirable since it produces detector distortion.

Now I have found that such transmission band dissymmetry, when occurring, may be substantially eliminated by deliberately introducing into the signal transmission path a compensating effect which involves the introduction of a complementary dissymmetry; the overall effect of the two dissymmetries being such that the resultant signal transmission band characteristic is symmetrical with respect to a predetermined mean frequency value. In addition, I have found that the compensating dissymmetry can be introduced into the signal transmission path in response to the received signal energy, and that the compensating dissymmetry may be caused to appear on either side of the predetermined mean frequency value of the transmission band characteristic.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide a receiving system which includes a signal transmission path of at least three resonant circuits all tuned to a common operating signal frequency; the second and third of the resonant circuits being oppositely unsymmetrical on equal sides of the operating frequency, whereas the first resonant circuit has a resonance curve characteristic which is symmetrical with respect to the operating frequency; there being, additionally, provided a control arrangement which is con-

structed in such a manner that when the band characteristic of the first resonant circuit becomes unsymmetrical, the following resonant circuits have their signal transmission efficiencies relatively altered in a sense such that the dissymmetry in the first resonant circuit is substantially compensated for.

Another important object of the invention is to provide an I. F. network for a superheterodyne receiver, which network includes at least three cascaded circuits resonated to the operating I. F., the first of the I. F. circuits having a symmetrical resonance curve characteristic, whereas the second and third I. F. circuits have resonance curve characteristics which are opposite—unsymmetrical with respect to the operating I. F., and a pair of I. F. rectifier circuits being provided with tuned circuits whose resonance curve characteristics correspond respectively to the second and third I. F. circuits; gain control connections being provided between the rectifier circuits and corresponding I. F. circuits so that when the characteristic of the first I. F. circuit becomes unsymmetrical, the rectifier circuits will function to control the relative I. F. transmission efficiencies of the second and third I. F. circuits in a sense to compensate for the lack of symmetry in the characteristic of the first I. F. circuit.

Another object of the invention may be stated to reside in the provision in a transmission band modifying arrangement of the type described in the preceding paragraph, of an automatic volume control arrangement which functions to vary the transmission efficiency of the I. F. circuit whose characteristic is symmetrical, and wherein such volume control action depends upon the average value of the control bias produced by the pair of I. F. rectifier circuits.

Still other objects of the invention are to improve generally the efficiency of operation of radio receivers of the superheterodyne type, and more especially to provide an I. F. transmission band characteristic modifying arrangement, for a superheterodyne receiver, which will not only be reliable in operation, but be economically manufactured and assembled in a receiver.

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 a circuit organiza-

tion whereby my invention may be carried into effect.

In the drawings,

Fig. 1 shows a circuit diagram of a portion of the superheterodyne receiver embodying the present invention,

Fig. 2 illustrates graphically the various resonance curve characteristics of the networks forming a part of the invention,

Fig. 3 is the overall resonance curve characteristic of the I. F. transmission network of the receiving system,

Fig. 4 is an unsymmetrical resonance curve characteristic which the present invention is designed to correct.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar elements, there is shown in Fig. 1 the portion of a superheterodyne receiving system disposed between the output of the first detector and the input of the audio frequency amplifier network, the transmission band characteristic modifying arrangement, as well as the automatic volume control circuit, being embodied in this portion of the receiving circuit. In a superheterodyne receiver of the type shown in Fig. 1, the I. F. amplifier 1, shown as of the pentode type, usually has connected between its input electrodes a resonant network which is tuned to the operating I. F. Such a network is shown at T₁; it will be seen that it comprises a transformer whose primary and secondary windings 2 and 3 are respectively tuned to the said I. F. value. As is well known to those skilled in the art, each of these windings is tuned by a condenser, and the tuned primary 2 may be disposed in the output circuit of the first detector.

The circuit elements preceding the tuned primary 2 may comprise the usual signal collector; one, or more, stages of tunable radio frequency amplification; the amplified radio frequency signals being fed to the conventional type of first detector. Of course, a tunable local oscillator is provided; and a common tuning control device is provided, for varying the tuning of the radio frequency amplifiers, first detector and local oscillator in such a manner that the signal energy produced in the circuit 2 is constantly of the operating I. F. value. If desired, the first detector and local oscillator may utilize a 2A7 type tube connected to provide an electron coupled converter stage. Assuming that the receiving system is employed in the broadcast range of 500 to 1500 k. c., the operating I. F. may have a value of 460 k. c., although it may vary in value from 75 to 460 k. c. In addition, the receiver may be of the multi-range type.

The amplifier 1 has the usual signal grid biasing network 4 disposed in its grounded cathode lead, and in its plate circuit is disposed the tuned primary circuit 5 of the following I. F. coupling transformer T₂. The tuned secondary circuit 6 of transformer T₂ is connected between the input electrodes of the I. F. amplifier 7, and this amplifier includes in its cathode lead the signal grid biasing network 4'. A third I. F. amplifier 8, including the signal grid biasing network 4'' in its cathode lead, has its input electrodes connected to opposite sides of the tuned secondary circuit 9 of the I. F. coupling transformer T₃. The tuned primary circuit 10 of transformer T₃ is disposed in the plate circuit of I. F. amplifier 7. The second detector is shown as of the diode type and is denoted by the reference numeral 11, the anode of the diode 11 being connected to the high

alternating potential side of the tuned secondary circuit 12 of I. F. coupling transformer T₄. The cathode of diode 11 is grounded, and is connected to the low alternating potential side of tuned secondary circuit 12 through the diode load resistor 13, the latter being shunted by the I. F. bypass condenser 14. The tuned primary circuit 15 of transformer T₄ is disposed in the plate circuit of the I. F. amplifier 8.

The audio frequency component of rectified I. F. current flowing through the load resistor 13 is transmitted to the audio frequency network through the audio condenser 16, and it will be understood that the audio network may comprise one, or more, stages of audio frequency amplification, followed by a reproducer of any desired type. It will be understood that each of circuits 2, 3, 5, 6, 10, 9, 15 and 12 are tuned to the operating I. F. of 460 k. c. However, the resonance curve characteristics of the stages including coupling transformers T₁, T₂, T₃, and T₄ are different. In Fig. 2 there are shown the various resonance curve characteristics of the individual I. F. coupling transformers, it being understood that each of the characteristics is that of a coupling transformer in conjunction with its immediately preceding tube. Thus, the resonance curve characteristic of the transformer T₁ and the tube immediately preceding it, that is the first detector tube, is shown as the first curve of the series of curves.

The full line curve is a double peaked curve of the band pass type, and is secured, as is well known, by employing coupling between windings 2 and 3 which is greater than critical. The dotted line curve is of the single peak type, and may be the characteristic of the transformer T₁ when it is desired to have this transformer provided with a single peak characteristic. Such a single peak characteristic is secured by coupling windings 2 and 3 with critical coupling. The next coupling transformer T₂ has a resonance curve characteristic similar to that of transformer T₁. Hence the full line curve is exactly the same as the full line curve of transformer T₁, and there is also shown, in dotted line, the single peak characteristic for the transformer T₂. Here, again, it is to be understood the characteristic shown is that of the transformer T₂ considered in conjunction with amplifier 1. The coupling transformer T₃, considered in conjunction with amplifier 7, has the resonance curve characteristic shown by the third full line curve in Fig. 2. It will be seen that this curve is unsymmetrical with respect to the I. F. value, and that it is prominently peaked on the minus, or lower, modulation side band.

On the other hand, the transformer T₄, considered in conjunction with amplifier 8, has a resonance curve characteristic illustrated by the fourth full line curve in Fig. 2; it will be observed that this characteristic is unsymmetrical with respect to the I. F. value in the opposite sense of the characteristic of transformer T₃. In other words, the coupling transformers T₃ and T₄ have transmission band characteristics such that they favor the lower and upper modulation side bands of the I. F. carrier respectively. These last two characteristics may be secured in any well known manner. For example, the condenser 10' of tuned circuit 10 may be made adjustable so as to detune circuit 10 a sufficient frequency distance from the operating I. F. value so as to produce the dissymmetry shown in Fig. 2. In the same way the condenser 15' may be made adjustable to

secure the dissymmetry shown in the fourth characteristic curve of Fig. 2. Additionally, and in place of the detuning method of securing dissymmetry, the distributed capacity, shown in dotted lines and denoted by the numeral 9', between coils 9 and 10 may be used to secure the dissymmetry in the characteristic curve of transformer T₃. Similarly, the distributed capacity 12' between coils 12 and 15 may be used to secure the dissymmetry in the characteristic curve of transformer T₄.

In Fig. 3 there is shown the overall resonance curve characteristic of the signal transmission path between the first detector and the second detector. The full line curve in Fig. 3 is obtained by combining the first four full line characteristics in Fig. 2. The dotted line portion of the curve in Fig. 3 illustrates the nature of the overall I. F. transmission band characteristic when transformers T₁ and T₂ have the dotted line single peak characteristics. It will be observed that the overall characteristic in Fig. 3 is symmetrical, and when this is the nature of the characteristic the I. F. energy delivered to the second detector will not cause detector distortion. When this overall characteristic becomes unsymmetrical, detector distortion results.

It is pointed out that the band widths of the curves T₃ and T₄ are approximately 14 k. c., whereas the band width of the characteristic curves of transformers T₁ and T₂ are shown as 10 k. c. For this reason the overall characteristic in Fig. 3 has a width of 10 k. c. Of course, these values are subject to change depending upon the other design considerations, but they are given to illustrate that the band width of the compensating transformers need not necessarily be the same as that of the normal transformers of the circuit. In Fig. 4 there is shown the characteristic curve of the coupling transformer T₁ and/or T₂ when dissymmetry occurs. Let it be assumed that for any of the reasons given heretofore at least one of the characteristic curves of the stages including transformers T₁ and T₂ becomes unsymmetrical with respect to the operating I. F. This, without any corrective or modifying action, produces a dissymmetry of side band transmission in the overall I. F. band transmission characteristic. In other words, the curve in Fig. 4 illustrates the resultant characteristics of the stages including transformers T₁ and T₂ when dissymmetry in at least one of these two characteristics takes place. When this happens more energy will reside in frequencies lower than the center frequency and, therefore, more lower side band energy will be delivered to the detector thus resulting in detector distortion. The control circuit shown in Fig. 1 is constructed and arranged to correct for, and eliminate, the dissymmetry shown in Fig. 4. At the same time that this is accomplished, normal AVC action to correct for signal fading is secured.

The control circuit comprises a tube 17 of the duplex-diode-pentode type, commercially known as a 2B7 type tube. The signal grid 18 of this tube is connected through the I. F. bypass condenser 19 to the plate side of the tuned primary circuit 15. The grounded cathode lead of tube 17 includes the usual biasing network 20 for the input grid 18, and the latter is connected to ground through the resistor 21. The plate 17' of tube 17 is connected to a source of positive potential through the resonant circuit 21, the latter being fixedly tuned to the operating I. F. value. The coil 22 of circuit 21 is the primary

coil of the coupling transformer T₅, and there are provided two secondaries 23 and 24. The secondary winding 23 has connected across it the condenser 25, and the secondary winding 24 has connected across it condenser 26. The coil 22 is magnetically coupled to coil 23, and the coil 22 is also magnetically coupled to the coil 24. However, coils 23 and 24 have zero coupling between them, and it is to be understood that there is to be no coupling from coil 23 to coil 24 through the coil 22. To accomplish this any means well known to those skilled in the art may be provided in the primary circuit 21 in order to maintain zero coupling between coils 23 and 24.

Each of condensers 25 and 26 is made adjustable so that it can be adjusted to detune the input circuits of the diode rectifiers on either side of the operating I. F. The tube 17 includes a pair of diode sections. Those skilled in the art are fully aware of the construction of a tube of the 2B7 type, and know that the tube includes a pair of diode anodes disposed adjacent the common cathode out of the main electron stream flowing to the plate 17'. The diode anode 30 is connected to the cathode 31 through a series path which includes the secondary coil 23 and the diode load resistor 31', the load resistor 31' being shunted by the I. F. bypass condenser 32. The diode anode 40 is connected to the cathode 31 through a series path which comprises secondary coil 24 and the diode load resistor 41, the resistor 41 being shunted by the I. F. bypass condenser 42.

The anode side of resistor 41 is conductively connected to the low alternating potential side of the tuned secondary circuit 9 through a path which includes the lead 50. This lead includes in series therewith a resistor 51, and a condenser 52 is connected to ground from the lead 50. The function of resistor 51 and condenser 52 is to filter out the pulsating component from the direct current voltage which is transmitted through lead 50 to the signal input grid of amplifier 8. In the same manner the lead 60 is connected between the anode side of the load resistor 31' and the low alternating potential side of the tuned secondary circuit 6. The numerals 61 and 62 denote the pulsating component filter element for this gain control connection. The normal AVC connection for the receiver circuit is designated by the letters "AVC", and this comprises the lead 70 which is connected to lead 50 through resistor 71, and to lead 60 through resistor 72, the junction of resistors 71 and 72 being connected to ground through the condenser 73.

The resistors 71 and 72, as well as condenser 73, function to suppress the pulsating component of the direct current voltage transmitted through lead 70 to the signal grid circuit of amplifier 1. The lead 70 may, also, be connected to any of the tubes preceding the I. F. amplifier 1, and, for example, this AVC connection may be made to the tunable radio frequency amplifiers and the first detector signal grid, if desired. It will be appreciated that the direct current voltage which is transmitted through lead 70 is the average of the direct current voltages derived from across the resistors 31' and 41. Whereas amplifier 1 has its gain varied in dependence upon the average direct current voltage output of both diode rectifiers, the gain of each of amplifiers 7 and 8 depends directly upon the direct

current voltage developed across resistors 31' and 41 respectively.

The resonance curve characteristic of the secondary circuit S₁, the input to the diode rectifier 31—30, has a resonance curve characteristic which is illustrated by the fifth full line curve of Fig. 2. It will be noted that this characteristic corresponds to the characteristic of coupling transformer T₃. On the other hand the resonance curve characteristic of the secondary circuit S₂, the input circuit of diode rectifier 31—40, is illustrated by the last full line curve of Fig. 2. This characteristic of secondary circuit S₂ corresponds to the resonance curve characteristic of transformer T₄. The resonance curve characteristic of circuit S₁ may be produced by adjusting condenser 25 to detune the circuit S₁ sufficiently to secure a dissymmetry such that the lower modulation side band is favored; the condenser 26 of circuit S₂ is adjusted to secure the characteristic wherein the upper modulation side band is favored. It is pointed out, in addition, that in each of the last four characteristic curves of Fig. 2 the spacing between the pronounced peak in its particular side band from the I. F. value is approximately 5 k. c.

In considering the operation of the system shown in Fig. 1, let it be assumed that for one reason or another dissymmetry of the type shown in Fig. 4 occurs. Then more signal energy will reside in frequencies on the side of the minus, or lower, modulation side band, and hence more signal energy will exist in the input circuit S₁, since its characteristic in Fig. 2 shows that it favors the lower modulation side band. Accordingly, more direct current voltage will be developed across resistor 31' than across resistor 41. This means that more negative bias will be transmitted through lead 50 to the signal grid of amplifier 7, and therefore reduce the gain of the amplifier. By the same token the bias transmitted through lead 50 to the signal grid of amplifier 8 will decrease, and the gain of amplifier 8 will increase with respect to that of amplifier 7. In other words, the amplifier feeding coupling transformer T₃, whose characteristic favors the lower modulation side band, decreases in gain, whereas the amplifier 8 feeding transformer T₄, whose characteristic favors the upper modulation side band, increases in gain. This results in a compensation of the dissymmetry shown in Fig. 4.

It will now be seen that the corrective action of the automatic control bias derived from the two diode rectifier circuits will vary the differential gain of T₃ and T₄ so that a symmetrical transmission characteristic is produced. If the uncorrected transmission characteristic were such that the upper, or positive, modulation side band were accentuated in the overall transmission curve, relatively more gain control bias would be developed in the diode circuit connected to circuit S₂. This bias would be applied to amplifier 8 to decrease the energy transmission of the upper modulation side band, and concurrently increase the lower side band amplitude.

The normal AVC connection is derived, as stated above, from both diode rectifiers, and is applied to amplifier 1 which feeds the transformer T₂, as well as the tube feeding the transformer T₁. The bias voltage transmitted over lead 70 is the average, or mean, value of the direct current voltages derived from resistors 31' and 41. As the received signal amplifier increases, the amplitude of the signal energy increases thereby increasing the voltage drops across resistors 31'

and 41. This results in an increase in the mean value of both voltages, and a resultant decrease in gain of amplifier 1 as well as any of the preceding tubes of the receiving system.

The control circuit is shown separate from the audio detector, and this arrangement is employed since it permits a symmetrical transmission characteristic, with resultant freedom from distortion, to be applied to the audio detector. The audio frequency current may also be obtained from the same pair of diodes which supply the AVC voltage. In this case one of the diode rectifiers will introduce audio frequency distortion of one phase, and the other diode will produce audio frequency of equal magnitude, but opposite phase. In this way the two audio frequencies will tend to cancel. Hence, if a separate audio detector 11 is not desired for design reasons, the audio output of the two diodes may be employed to supply the audio currents for the audio amplification network.

It will now be seen that there has been provided a signal rectifier system which functions to maintain the overall I. F. characteristic shown in Fig. 3, in spite of dissymmetries of the type shown in Fig. 4. As soon as a dissymmetry of the latter type occurs, the signal rectifier network acts to change the relative transmissions through the networks T₃ and T₄ so as to restore the symmetrical characteristic shown in Fig. 3. At the same time, the normal AVC action is secured from the same control circuit by utilizing the average value of current voltages produced by the two signal rectifiers.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular circuit organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What is claimed is:

1. In combination in a signal transmission system comprising at least two resonant circuits, each of the circuits being tuned to an operating side band modulated carrier wave frequency, the resonance curve characteristic of one of said resonant circuits being symmetrical with respect to the mean frequency value of the characteristic, the resonance curve characteristic of the other resonant circuit being unsymmetrical with respect to the mean frequency value of the characteristic, a signal rectifier having an input circuit tuned to said operating frequency and having a resonance curve characteristic which is unsymmetrical with respect to the mean frequency value, and means, responsive to the uni-directional current output of the signal rectifier, for varying the signal transmission through said first unsymmetrical resonant circuit in a sense such as to compensate for an undesired dissymmetry in the resonance curve characteristic of the said symmetrical resonant circuit.

2. In a superheterodyne receiver provided with an I. F. transmission network comprising at least three resonant circuits arranged in cascade, each of said circuits being tuned to an operating I. F. value, the resonance curve characteristic of the first tuned circuit being symmetrical with respect to its characteristic mean frequency value, the resonance curve characteristic of the second tuned circuit being unsymmetrical in one of the modulation side bands with respect to the characteristic mean frequency value, the resonance curve characteristic of the third tuned circuit

being unsymmetrical in the opposite sense from the dissymmetry of the second circuit, a pair of signal rectifiers arranged to receive I. F. energy from the said I. F. transmission network, one of said rectifiers having an input circuit provided with a characteristic corresponding to the characteristic of the second I. F. tuned circuit, and the other rectifier circuit having a tuned input circuit whose characteristic corresponds to the characteristic of the third I. F. tuned circuit, and means for utilizing the direct current voltage output of the signal rectifiers to vary the relative transmission efficiencies through the second and third I. F. tuned circuits.

3. In a superheterodyne receiver provided with an I. F. transmission network between the output of the first detector and the input of the second detector, at least three resonant circuits arranged in cascade, each of said circuits being tuned to an operating I. F. value, the resonance curve characteristic of the first tuned circuit being symmetrical with respect to its characteristic mean frequency value, the resonance curve characteristic of the second tuned circuit being unsymmetrical in one of the modulation side bands with respect to the characteristic mean frequency value, the resonance curve characteristic of the third tuned circuit being unsymmetrical in the opposite sense from the dissymmetry of the second circuit, a pair of signal rectifiers arranged to receive I. F. energy from the said I. F. transmission network, one of said rectifiers having an input circuit provided with a characteristic corresponding to the characteristic of the second I. F. tuned circuit, and the other rectifier circuit having a tuned input circuit whose characteristic corresponds to the characteristic of the third I. F. tuned circuit, means for utilizing the direct current voltage output of the signal rectifiers to vary the relative transmission efficiencies through the second and third I. F. tuned circuits, and means for utilizing the mean direct current voltage output of the two rectifiers for varying the signal transmission efficiency through the first I. F. tuned circuit.

4. In a superheterodyne receiver provided with an I. F. transmission network, at least two amplifying stages in cascade, one of said stages being

dissymmetrical about the operating I. F. so that one modulation sideband is increased relative to the other modulation sideband, the second of said stages being dissymmetrical in the opposite sense so that the two in cascade produce a symmetrical transmission characteristic, a pair of signal rectifiers with their associated input circuits so arranged that if the applied frequency is higher than the operating I. F. more energy is supplied to the one rectifier than the other, whereas if the applied frequency is lower than the operating I. F. more energy is supplied to the second rectifier, means for applying the direct current voltage output of each rectifier to one of said amplifying stages, whereby the gain of the amplifying stage having dissymmetry in one sense, with respect to the operating frequency, is reduced when additional energy on that same side of the operating frequency is applied to the signal rectifier associated therewith.

5. In a system as defined in claim 1, and additional means, responsive to the direct current voltage output of the rectifier, for decreasing the signal transmission through the symmetrical resonant circuit as the carrier wave amplitude increases.

6. In a system as defined in claim 2, means independent of the signal rectifiers coupled to the last of the cascaded resonant circuits for demodulating the I. F. energy.

7. In a superheterodyne receiver provided with an I. F. transmission channel having at least two amplifier networks in cascade, the resonance curve characteristics of the networks being oppositely unsymmetrical about the operating I. F. whereby the networks in cascade produce a symmetrical resultant transmission characteristic, at least two rectifiers, means for applying I. F. energy from the channel output to the rectifiers, the input circuits of the rectifiers having resonance curve characteristics which correspond to said two unsymmetrical characteristics, and a gain control connection between each rectifier and the amplifier network having a corresponding characteristic for reducing the gain thereof when the I. F. energy applied to the rectifier favors the dissymmetry of the latter.

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