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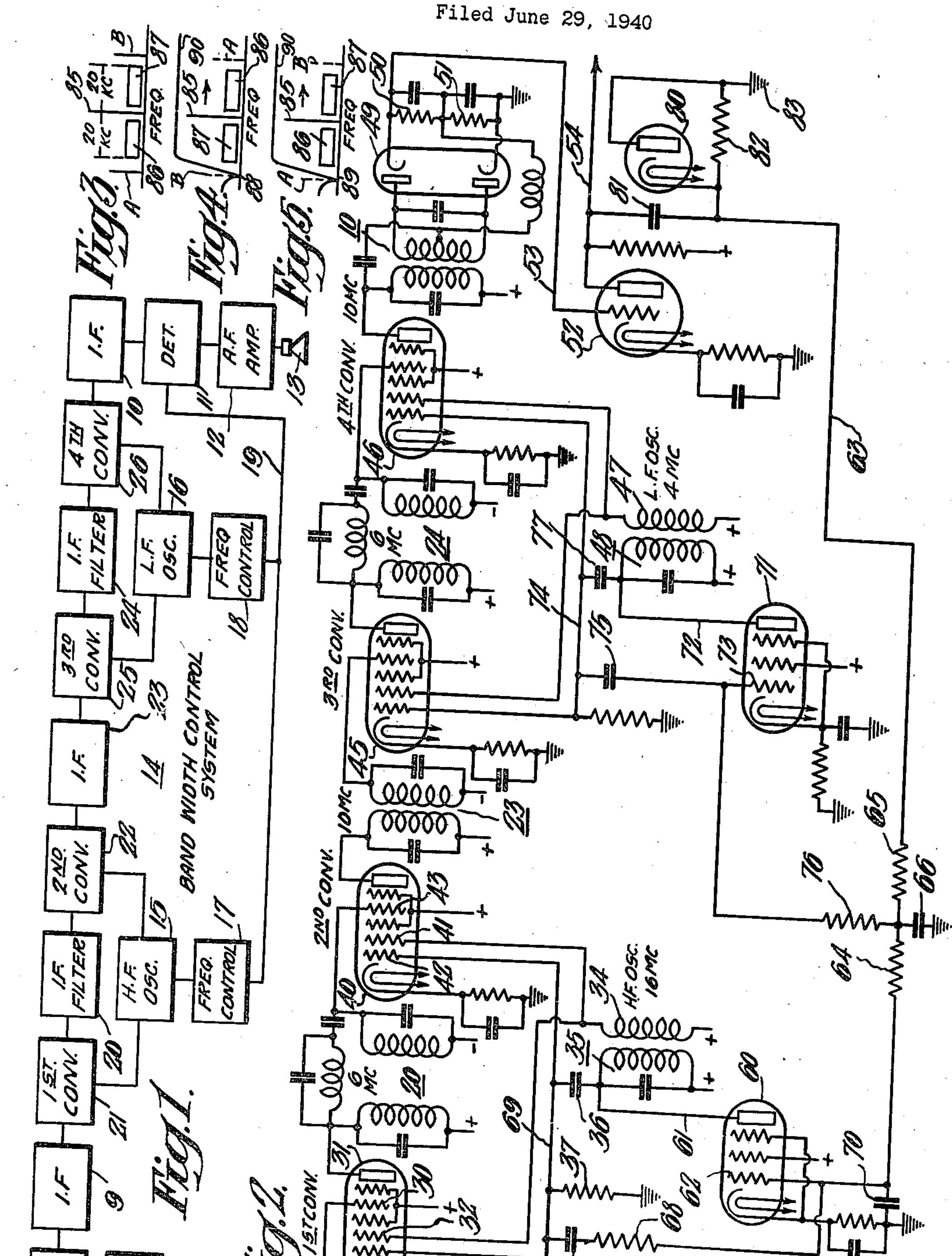

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RADIO SIGNAL RECEIVING SYSTEM

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12 Claims. (Cl. 250—20)

This invention relates to a radio signal receiving system having a variable-frequency band width within which it is responsive to received signals. More particularly, this invention relates to a frequency-modulated signal receiving system, the band width of which is responsive to variations in the modulation depth or frequency swing.

As is known, the band width in frequency-modulation signal receivers, such as the pass band of the intermediate-frequency amplifier, for example, is preferably variable automatically in response to variations in the frequency swing or modulation of a received signal, in order at all times to pass the desired signal while excluding undesired signals and noise potentials which would otherwise pass through to the output of the receiving system if the band width were maintained sufficiently wide at all times to accept signals with full modulation.

In frequency-modulation signal transmission and receiving systems, the percentage modulation is normally relatively low, being of the order of 20 to 50 percent. Assuming 100 percent modulation of a carrier or mid-frequency signal of 40 mc. to be ± 100 kc, deviation or frequency swing, the normal modulation may be of the order of ± 20 to 50 kc. deviation or frequency swing. Thus, the band width required to pass such signals with full modulation and without distortion, is from 39.9 to 40.1 mc. Considerable noise and undesired signal voltages may be conveyed through the signal receiving system if the wide band response is maintained for conditions of relatively low percentage modulation.

It is, therefore, desirable to vary the selectivity or the effective selectivity of frequency-modulation and similar wide band types of receiving systems, to prevent the transmission of noise and undesired signals therethrough, and it is an object of the present invention to provide an improved selectivity control system for wide band radio signal receiving apparatus which is automatically responsive to variations in signal strength, frequency swing, or modulation to pass the desired signal while excluding undesired signal and noise potentials.

It is a further object of the present invention to provide a band-width control system for a relatively wide-band signal receiving system which lacks certain inherent disadvantages of known variable band-width signaling systems. For example, it is known that in order to change the band width of the frequency response of a band-pass filter requires control of the circuit tuning, the coupling reactance and the terminating resistance, and that this may be accompanied by an undesirable change in signal gain through the system.

It is, therefore, a still further object of the present invention to provide means whereby the effective selectivity of a radio signal receiving system may be controlled automatically in response to variations in signal strength or frequency swing without appreciable change in gain through the receiving channel under band-width control.

In carrying into effect the objects of the invention as referred to, it has been found that the effective band width of the receiving system may be varied by passing the received signal through two successive filter networks substantially equal in design and frequency response characteristics and providing sharp signal attenuation at a frequency adjacent to but outside the useful side bands on one side of the carrier or mean frequency and varying the position of the carrier or the mean frequency with respect to the attenuation frequency of the filter network first on one side of the carrier and then on the other, successively, as the signal is passed through the signal receiving system, preferably in the intermediate-frequency amplifier portion thereof.

It is, therefore, a further object of the invention to provide a band-width control system automatically responsive to the strength or frequency swing of received signals, for securing a change in the effective selectivity of at least a portion of said system without appreciable change in gain therethrough by maintaining the signal carrier or mean frequency in variably spaced relation to the cut-off point of a dual filter network, thereby removing interference signals lying outside the side bands of the narrowest signal band desired.

In accordance with the invention, this is accomplished by changing the frequencies of two heterodyne oscillators, connected with converters in the signal channel in an opposite sense one with respect to the other, thereby to shift the carrier or mid-frequency with respect to the cut-off points of two filter networks through which the signal is passed. With this system, it has been found that the gain through the system may be substantially unaffected by change in effective selectivity.

The invention will, however, be further understood from the following description, when considered in connection with the accompanying drawing, and its scope is pointed out in the appended claims.

In the drawing,

Figure 1 is a block diagram of a radio signal receiving system embodying the invention,

Figure 2 is a schematic circuit diagram showing the signal conveying and control circuits of a portion of the system of Fig. 1, further illustrating the invention, and

Figures 3, 4 and 5 are graphs representing certain operating characteristics of the receiving system of Figs 1 and 2.

Referring to Fig. 1, a superheterodyne type of radio signal receiving system is represented, by way of example, including a first detector or heterodyne converter **6** coupled to a signal source such as an antenna **7** and to the usual heterodyne oscillator indicated at **8**, to provide intermediate-frequency signals for intermediate-frequency circuits represented at **9** and **10**. These circuits are separated to include circuits hereinafter described and may contain the usual amplification and a frequency discriminator network at **10** preceding the second detector indicated at **11**, from which audio frequency signals are derived for the audio frequency amplifier indicated at **12** and the output device or loudspeaker **13** coupled thereto.

The receiving system referred to may be considered as representing any suitable signal receiving system, preferably of the superheterodyne type, providing an intermediate-frequency signal conveying system with or without amplification, in which band-width control means are provided.

Since the invention is more particularly adapted for use in connection with frequency-modulation receiving systems, it may be assumed, by way of example and for purposes of illustration, that the embodiment represented in Fig. 1, and as subsequently referred to in Fig. 2, is a frequency-modulation receiving system.

The intermediate-frequency circuits **9** and **10** in the present system are connected by a band-width control system **14** which forms a signal conveying channel having an effective band-width variation in response to the variation of the frequency of two oscillators **15** and **16**, the former being a relatively high frequency oscillator and the latter being a relatively low frequency oscillator, with respect to the i. f. carrier or mid-frequency.

Each of the oscillators is provided with frequency control means indicated at **17** and **18**, respectively, in turn connected through a control circuit **19** with the second detector **11** or other suitable source of variable frequency control potential responsive to variations in the percentage modulation or signal strength.

The signal channel between the i. f. circuits **9** and **10** comprises two conversion sections, one associated with each control oscillator. In the first section, coupled to the first i. f. circuit **9**, an intermediate-frequency band-pass filter **20** is coupled between a first converter **21** and a second converter **22** associated with the first or high frequency oscillator **15**. Between the two sections a connecting intermediate-frequency circuit **23** is provided.

The second section, coupled to the circuit **23**, is similar to the first and includes a second intermediate-frequency band-pass filter **24** coupled between a third converter **25** and a fourth converter **26** associated with the low frequency or second oscillator **16**. The fourth converter is coupled to the detector **11** through the discriminator network or intermediate-frequency circuit **10**.

The high frequency oscillator **15** supplies oscillations to the first and second converters on either side of the first i. f. band-pass filter **20**. Likewise, the low frequency oscillator **16** supplies signals to the third and fourth converters on either side of the second i. f. band-pass filter **24**. Both i. f. band-pass filters preferably have the same wide band-pass characteristic and sharp cut-off or side band attenuation characteristic for one side of the carrier and side bands. Variation in the oscillator frequencies causes the carrier or mean frequency of the signal in each section to move toward and away from the filter attenuation or cut-off point in response to variations in signal strength.

The first converter serves to invert or transpose the side bands, resulting in attenuation of the upper side band or the noise signals adjacent thereto, with low percentage modulation, in passing through the i. f. filter **20**, and the second converter serves to restore the side bands to their former position relative to the carrier or mean frequency and to restore the signal to the chosen intermediate frequency. The third converter is provided to change the intermediate-frequency signal, without inversion of the side bands, to the same frequency as that applied to the first intermediate-frequency filter, in order that the other side band or the undesired signals adjacent thereto may similarly be attenuated in the i. f. filter **24**. The fourth converter is for the purpose of restoring the i. f. signal to its former frequency for the i. f. circuit **10**, which may include the frequency discriminator preceding the detector **11**, in a frequency-modulation receiving system.

Having considered the general arrangement of the receiving system with reference to Fig. 1, the signal conveying and control circuits forming the band-width control system of Fig. 1 are shown and described in further detail with reference to Fig. 2, and the graphs of Figs. 3, 4 and 5, to which attention is now directed along with Fig. 1. In Fig. 2 the same reference numerals are used to refer to like circuits and circuit elements as in Fig. 1, for comparison with the general arrangement shown in Fig. 1.

In Fig. 2 the intermediate-frequency circuits **9** are provided by an intermediate frequency coupling transformer of the tuned primary-secondary type. This is coupled to the signal input grid **30** of the first converter which includes a converter tube **31**. Oscillations may be applied to the converter in any suitable manner. However, in the present example, the tube is of the combined oscillator-detector type having an oscillation anode electrode **32** and an oscillator grid **33** coupled through a tunable oscillator circuit comprising a feedback winding **34** in circuit with the anode electrode and a tuned grid circuit **35** coupled thereto and connected to the grid **33**, the usual grid coupling capacitor **36** and grid resistor **37** being provided in connection therewith.

As indicated in Fig. 1, the second converter likewise receives oscillations from the same source as the first converter and includes a tube **40** which likewise may be of the oscillator-detector type, provided with an oscillator anode electrode **41** and an oscillator grid electrode **42** connected in parallel with the corresponding electrodes in the first converter. Signals from the first converter are conveyed through the band-pass filter 20 to the signal input grid 43 of the second converter. The second converter is followed by the i. f. circuits 23 with preferably are the same as the i. f. circuits 9 and tuned to the same frequency.

The second section of the band-width control system is preferably the same as the first section, in order that it may have the same frequency characteristics, thereby to impart to the signal conveyed therethrough the same attenuation characteristics on opposite sides of the carrier or mid-frequency, although the second section may have other characteristics, if desired.

In the present system the third converter, indicated by the tube 45, and the fourth converter, indicated by the tube 46, are coupled in the same manner as the first and second converters, on opposite sides of the second band-pass filter 24, and are provided with similar oscillator circuits comprising a feedback winding 47 and a tuned oscillator circuit 48, the oscillator elements being connected in parallel with the circuit elements in order to impart the same frequency to both the third and the fourth converters.

The i. f. circuit 10, coupled to the output of the fourth converter 46, is in the form of a frequency discriminating network for the detector which is a double diode rectifier 49 having a differential output impedance 50—51 for deriving and rectifying an amplitude-modulated signal from the frequency-modulated signal and applying the same to the remainder of the receiving system through an amplifier 52 coupled through a lead 53 to the detector output impedance. The output connection for the amplifier 52 is indicated by the output lead 54 through which audio frequency signals are conveyed to further amplifier means and an output device or loudspeaker, as indicated in Fig. 1.

The low frequency and high frequency oscillators are each controlled in frequency by suitable means such as a reactance tube 60 having an anode circuit 61 coupled to the tuned circuit 35 for the high frequency oscillator and having a control grid 62 connected with a variable bias control circuit 63 through a filter network 64—65—66 for applying to the grid 62 a variable bias potential, whereby the reactance of the tube 60 and the frequency of the oscillator as established by the tuned circuit 35 is varied within predetermined limits.

For reactance control of both oscillators jointly, the grid 62 is coupled through a capacitor 67 and a series high resistance element 68 to the grid circuit 69 of both oscillators, thereby being coupled back to the anode through the grid capacitor 36. The grid 62 is further coupled to the cathode 69 of the reactance tube through a capacitor 70.

Likewise, the third and fourth converter low frequency oscillator circuit 48 is controlled by a reactance tube 71, the anode circuit 72 of which is connected with the circuit 48 while the control grid 73 is coupled to the common oscillator grid circuit 74 through a capacitor 75. The grid 73 is further connected with the control circuit 63 through a resistor element 76. Coupling between the anode circuit 72 and the grid 73 is provided through the oscillator grid capacitor 77.

The frequency control means for both oscillators is responsive to variation in a single bias potential means, receiving variations in the control potential through the control lead 63. The controlling potential is derived from the signal channel of the system following the detector 11, and in the present example, in connection with the audio frequency output circuit 54 from the first audio frequency amplifier stage 52.

In this connection, a rectifier 80 is coupled to the circuit 54 through a suitable coupling capacitor 81, and the output impedance of the rectifier, indicated at 82, is connected between ground 83 and the control lead 63, thereby to provide a variable positive bias potential on the grids 62 and 73 of the reactance tubes 60 and 71, respectively, in response to received signals, the bias potential increasing with an increase in percentage modulation or frequency swing.

The reactance controlling elements of the tubes 60 and 71 are arranged to cause the high frequency oscillator to vary in frequency in one direction, while the low frequency oscillator varies in frequency in the opposite direction. Accordingly, the shunt capacitor 70 in the frequency control circuit for the high frequency oscillator may have a relatively low reactance compared with the series resistance of the element 68, while, in the low frequency oscillator control system, the series capacitor 75 may have a low reactance compared with the shunt resistance of element 76.

With this arrangement, as the positive bias through the lead 63 increases with increased frequency swing or signal strength, the high frequency oscillator circuit 35 is increased in frequency, while the low frequency oscillator 48 is decreased in frequency, this being in directions to cause a decrease in the selectivity of the band-width control system, that is, a relatively wider frequency response or band width.

The operation of the system may be better understood by considering, for example, that a 10 mc. i. f. signal is applied to the first i. f. circuit 9 from the heterodyne converter. The first converter serves to transpose or invert the signal, so that the upper and lower side bands are transposed in the signal which is passed through the first i. f. filter 20.

The high frequency oscillator operates at a frequency above the i. f. frequency and, in the present example, may be assumed to operate at a normal frequency of 16 mc., thereby providing a 6 mc. signal through the filter 20 with the side bands inverted. The inversion is repeated through the second converter 40, so that the signal with the side bands restored to normal relation to the mid-frequency is again at 10 mc. in passing through the second i. f. circuit 23.

Referring particularly to Figs. 3 and 4, assuming an i. f. signal at 10 mc., indicated at 85, with side bands 86 and 87, and that the side bands are those provided in response to normal or relatively low modulation such as 20 kc. on either side of the mid-frequency 85, interfering signals or noise signals A and B adjacent to the side bands on either side thereof may be passed through with the signal and side bands to the output of the system, if the system is maintained at all times sufficiently broad in its response to accommodate full modulation.

In the present system, following the conversion in the first converter, the side bands are inverted as indicated in Fig. 4, together with the noise signals A and B, and the filter 20 is provided with a sharp attenuation characteristic on one side of the signal, such as the low frequency side as indicated at 88, to cut off the interfering signal B, which is on the high side of the signal band normally.

The second i. f. filter **24** is provided preferably with the same attenuation characteristic, as indicated at **89** in Fig. 5, and the second converter serves to restore the side band relation as shown in Fig. 5 to the normal relation, which is preserved through the second section of the band width control system, since the second oscillator operates at a frequency lower than the intermediate frequency, for example, at 4 megacycles, as indicated, thus producing in connection with the 10 mc. signal at **23**, a 6 mc. signal at **24**.

Both i. f. filters **20** and **24**, therefore, are arranged to provide substantially identical frequency and attenuation characteristics, and in the present example to attenuate signals on the low frequency side of the mid-frequency, while the response on the opposite side of the carrier or mid-frequency is relatively broad, as indicated by the characteristic at **90**. As indicated in Fig. 4, this broad characteristic would include one of the interference signals A which, however, is cut-off in the second i. f. filter, as indicated in Fig. 5, assuming normal or low modulation or frequency swing.

As the signal strength increases or the frequency swing becomes wider, the control potential for the frequency control means of both oscillator circuits **35** and **48** is increased to cause the high frequency oscillator to increase in frequency, while the low frequency oscillator is decreased in frequency, thereby shifting the mid-frequency **85**, as indicated in Figs. 3, 4 and 5, away from the attenuation points of the filter characteristics and permitting the wider frequency modulation to pass through the signal channel. This causes the effective band width of the signal channel to vary with signal strength or frequency swing and, since the variation is effected by means of oscillator frequency variation, the gain through the system is not changed thereby, as in certain band width control systems heretofore known.

By changing the frequency of the two control oscillators with variations in signal strength or frequency swing, the signal may be placed close to the cut-off points of the filters, and noise and undesired signals, and any portion of the high frequency side band may be attenuated in the first i. f. filter **20**, while any portion of the low frequency side bands and the noise and undesired signals adjacent thereto may be attenuated in the second i. f. filter **24**.

Thus, it is desirable to provide both filters **20** and **24** with the same attenuation characteristics and of the order of those indicated in Figs. 4 and 5, so that the same frequency characteristic and attenuation is imparted to the signal on both sides of the mean frequency or carrier.

The fourth converter serves to restore the intermediate frequency to the normal value as in the input circuit **9** for conversion to amplitude-modulated signals in the frequency discriminator network **10** and detector **49**.

Since the oscillators must be operated to provide a frequency shift in opposite directions the same number of kilocycles, the reactance tubes must be connected so that one gives a positive reactance and the other a negative reactance, as indicated in Fig. 2, in order that both may be controlled by the same control voltage from the circuit **63**.

While the invention has been described in connection with a preferred embodiment thereof for a frequency modulation signal receiving system, it is obvious that it may be applied to any signal receiving system adapted for band width control in an intermediate portion of the signal channel.

I claim as my invention:

1. In a frequency modulated signal receiving system, means for varying the effective selectivity of said system with substantially constant gain, comprising two band pass filter networks each having a predetermined frequency response and attenuation characteristic providing relatively sharp attenuation on one side of the pass band of the network, means for passing a received signal through one of said filter networks with the side bands inverted, and means for shifting the mid-frequency of a received signal with respect to the attenuation side of the pass band in each filter network in accordance with variations in the output signal voltage of said system.

2. In a frequency modulated signal receiving system, means for varying the effective intermediate frequency selectivity of said system with substantially constant gain, comprising two intermediate frequency band pass filter networks each having substantially the same frequency response and attenuation characteristic providing relatively sharp attentuation on one side of the pass band of the network, means for passing a received signal through one of said filter networks with the side bands inverted and through both filter networks at the same mean frequency, and means for shifting the mid-frequency of a received signal with respect to the attenuation side of the pass band in each filter network in accordance with variations in the output signal voltage of said system.

3. In a frequency modulated signal receiving system, means for varying the effective intermediate frequency selectivity of said system with substantially constant gain, comprising two intermediate frequency band pass filter networks each having a predetermined frequency response and attenuation characteristic providing relatively sharp attenuation on one side of the pass band of the network, means for passing a received signal through one of said filter networks with the side bands inverted, and means for shifting the mid-frequency of a received signal with respect to the attenuation side of the pass band in each filter network in accordance with variations in the frequency swing of a received signal.

4. In a radio signal receiving system, means for varying the effective selectivity of said system with substantially constant gain, comprising an intermediate frequency amplifying channel, two band pass filter networks in said channel each having a predetermined frequency response and attenuation characteristic providing relatively sharp attenuation on one side of the pass band of the network, a converter connected with one filter network to apply an inverted side band signal thereto at a predetermined frequency, a variable frequency oscillator coupled to said converter and tuned above the intermediate frequency, a second converter for restoring the signal with normal side bands, a third converter connected with the filter network to apply the restored side band signal thereto at a predetermined frequency, a second variable frequency oscillator coupled to said third converter and tuned below the intermediate frequency, and means responsive to variations in the frequency swing of a received signal for jointly varying the

frequency of said oscillators to vary the signal relative to the cut off frequency of said filter networks thereby to vary the effective selectivity of said system.

5. In a radio signal receiving system, means for varying the effective selectivity of said system with substantially constant gain, comprising an intermediate frequency amplifying channel, two band pass filter networks in said channel each having a predetermined frequency response and attenuation characteristic providing relatively sharp attenuation on one side of the pass band of the network, a converter connected with one filter network to apply an inverted side band signal thereto at a predetermined frequency, a variable frequency oscillator coupled to said converter and tuned above the intermediate frequency, a second converter for restoring the signal with normal side bands, a third converter connected with the filter network to apply the restored side band signal thereto at a predetermined frequency, a second variable frequency oscillator coupled to said third converter and tuned below the intermediate frequency, a frequency discriminator network for receiving the signal output through said filter networks, frequency control means for said oscillators for varying the frequency thereof in opposite directions one with respect to the other, a single control circuit for said frequency control means, and means for deriving a control potential from said discriminator network for said control circuit.

6. In a frequency modulated signal receiving system, band width control means comprising a dual filter network and means for maintaining the signal mean frequency in variably spaced relation to a cut-off frequency of said filter network, means for inverting the signal preceding one portion of said filter network, and means responsive to variations in frequency swing of a received signal for controlling said second named means whereby the effective selectivity of said system is variable between predetermined limits.

7. In a radio signal-conveying system, the combination of a pair of filter circuits, means including a variable frequency oscillator connected with the first filter circuit for applying an inverted signal thereto, means for reinverting said signal, means including a second variable frequency oscillator connected with the second filter circuit for applying thereto said reinverted signal, means in said filter circuits for imparting thereto attenuation characteristics of the same order, and frequency control means for varying the frequencies of said oscillators in an opposite sense one with respect to the other, thereby to vary the effective band width of said signal-conveying channel through said filter circuits.

8. In a radio signal-conveying system, the combination of a pair of filter circuits, means including a variable frequency oscillator connected with the first filter circuit for applying an inverted signal thereto, means for reinverting said signal, means including a second variable frequency oscillator connected with the second filter circuit for applying thereto said reinverted signal, means in said filter circuits for imparting thereto attenuation characteristics of the same order, and frequency control means responsive to variations in amplitude of the audio frequency output of said system for varying the frequencies of said oscillators in an opposite sense one with respect to the other, thereby to vary the effective band width of said signal-conveying channel through said filter circuits.

9. In a radio signal-conveying system, the combination of a pair of filter circuits, converter means connected with the first filter circuit for applying an inverted signal thereto, a second converter means for reinverting said signal, a third converter means connected with the second filter circuit for applying thereto said reinverted signal at the same frequency as said inverted signal, means in said filter circuits for imparting thereto attenuation and frequency response characteristics of the same order and band width, an oscillator coupled to said first and second converters and operating at a normal frequency above the signal frequency, a second oscillator coupled to said third converter and operating at a normal frequency below the signal frequency, and frequency control means for varying the frequencies of said oscillators in an opposite sense one with respect to the other, thereby to vary the effective band width of said signal conveying channel through said filter circuits.

10. In a radio signal receiving system, the combination of two filter networks having predetermined signal attenuation characteristics, means for passing a received signal through said filter networks successively including variable frequency oscillator and converter means connected with the input and output ends of one of said filter networks for inverting the side bands of a received signal preceding said filter network and restoring said side bands to a normal position relative to the carrier or mid-frequency following said filter network in the signal channel, means for converting the signal to the frequency of the second filter network including a variable frequency oscillator tunable below the signal frequency in the filter network, frequency control means connected with said oscillators to vary the frequency thereof in an opposite sense one with respect to the other, and means responsive to variations in the signal strength of a received signal for applying a controlling potential to said frequency control means, thereby to effectively shift a received signal in frequency with respect to the cut-off frequency of each of said filter networks, thereby to vary the effective selectivity of the receiving system automatically in response to variations in signal strength with substantially constant gain.

11. In a frequency modulated signal receiving system, the combination with an intermediate frequency portion of said system, of a pair of variable frequency oscillators one having an operating frequency above and the other having an operating frequency below the intermediate frequency of said system, a pair of frequency converters connected with one of said oscillators, a filter network interposed in circuit between said converters, a second pair of converters, a second filter network interposed between said converters, said filter networks having substantially equal frequency response and band pass characteristics and a relatively sharp cut-off for signal attenuation on one side of a mean pass band frequency, and means for deriving a controlling potential from said system which varies in accordance with variations in frequency swing of a received signal, and means responsive to variations in said potential for varying the frequency of said oscillators in an opposite sense one with respect to the other, thereby to vary the effective selectivity of said receiving system through said filter networks.

12. In a frequency modulated signal receiving system, band width control means comprising successive signal conveying portions having predetermined cut-off frequencies, a frequency discriminator and detector network coupled to said band width control means, means for maintaining the signal mean frequency in variably spaced relation to the said cut-off frequencies of said band width control means, means for presenting the signal successively to different portions of said band width control means at least once with the side bands inverted, and means connected with said frequency discriminator and detector network responsive to variations in frequency swing of a received signal for controlling said second-named means, whereby the effective selectivity of said system is variable between predetermined limits.

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