

June 25, 1940.

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2,205,762

VARIABLE BAND WIDTH RECEIVER

Filed Nov. 16, 1936

2 Sheets-Sheet 1

Fig. 1

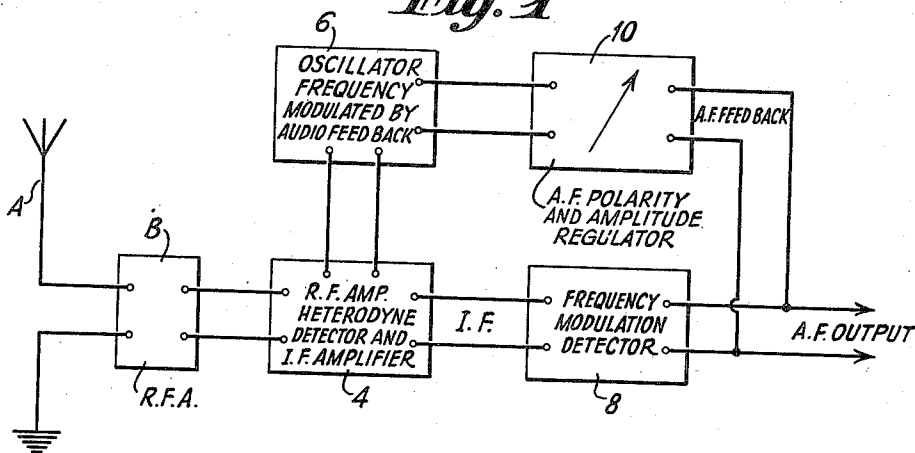


Fig. 2

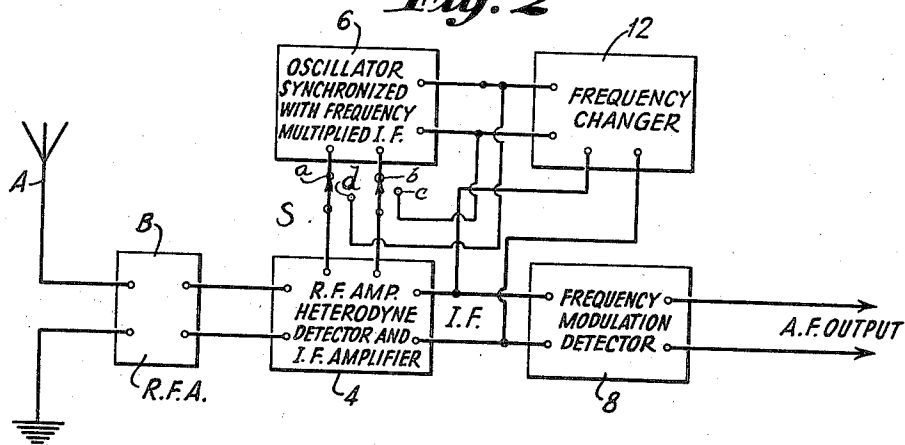


Fig. 3a

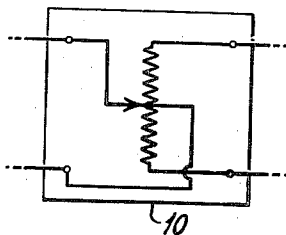


Fig. 3b

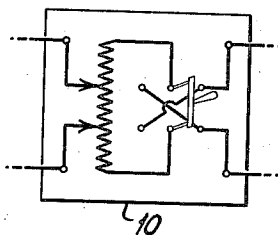
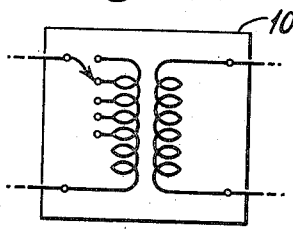


Fig. 3c



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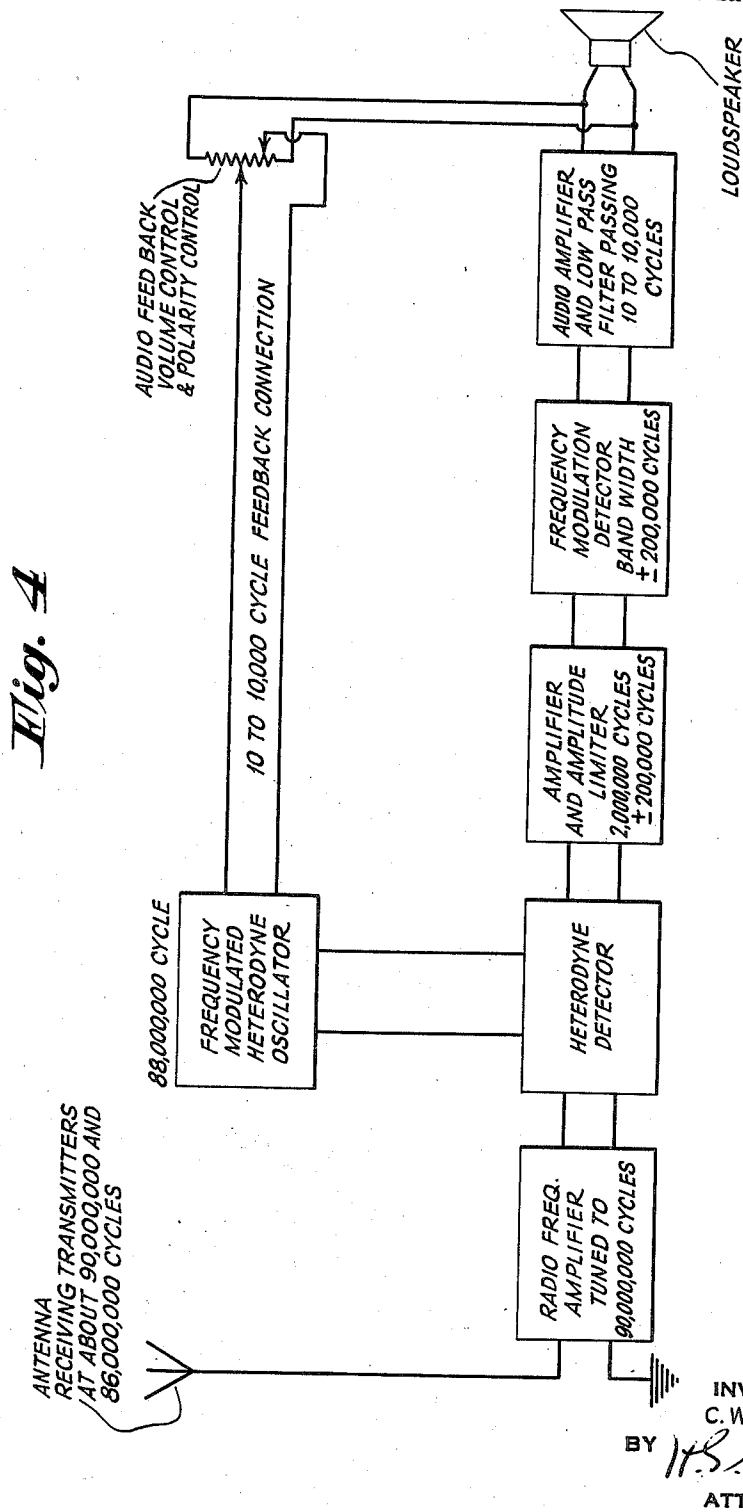
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VARIABLE BAND WIDTH RECEIVER

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2 Sheets-Sheet 2



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VARIABLE BAND WIDTH RECEIVER

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Application November 16, 1936, Serial No. 111,050

14 Claims. (Cl. 250—20)

A primary object of the present invention is to provide in a frequency modulation receiver a new and improved method of and means for controlling the band width to which the receiver is fully receptive to thereby increase said band width beyond normal, maintain it of normal width or reduce it below normal width.

Another object is to provide a new and improved method of and means for reception of phase or frequency modulated waves which reduces the image band interference, common in superheterodyne receivers, without at the same time requiring the use of relatively complicated and expensive equipment such as preselection circuits and filters, etc. The suppression of image band interference according to the present invention may be of value in reception of phase or frequency modulated waves of any frequency but is particularly desirable for the reception of signals sent on waves of extremely high frequency. Other objects and advantages will appear as the description of means for carrying out the main object progresses.

In describing my invention reference will be made to Figures 1 and 2 in the drawings wherein I have shown schematically two means for accomplishing the band width control, and to Figures 3a, 3b, and 3c which illustrate details of an amplitude control and polarity reversing circuit used in Figure 1. Reference will also be made to Figure 4 which illustrates one set of operating conditions and adjustments for obtaining reduction of image band interference.

A receiver arranged in accordance with my novel invention may comprise an antenna system A or other means for intercepting and supplying radio frequency energy to amplifier B. Energy of the desired amplitude is supplied from B to the first detector of a heterodyne receiver certain parts of which are represented by block 4. The phase or frequency modulated wave, which may in both cases be said to be length modulated, impressed on the circuits in 4 is beat with oscillations from a local oscillator represented at 6 connected with the first detector in 4. The output of the first detector, that is, the intermediate frequency energy resulting from the beat action may be amplified in 4 or in an intermediate frequency amplifier not shown, connected with the output of 4 and supplied to a frequency modulation detector 8, the output of which comprises audio frequency currents characteristic of the signals causing the phase or frequency modulations of the wave impressed on the apparatus in 4. Preferably amplifier B and/or the circuits

in unit 4 should provide for limiting the currents to constant amplitude in the inputs to the detectors in 4 and in 8, but particularly in the inputs to the frequency modulation detector 8.

The audio frequency output may be supplied to any utilization circuit and also to the oscillator in 6. The audio frequency energy fed back to the apparatus in 6 frequency modulates the local or beating oscillator in 6. The frequency modulator circuit of 6 per se forms no part of the present invention. I contemplate the use of any known frequency modulator here, although I prefer a modulator of simple nature. I may use the frequency modulators of the frequency control circuits of Crosby application #616,803 filed June 13, 1932 Patent #2,065,565 dated December 29, 1936 or Crosby Patent No. 2,123,716, dated July 12, 1938, provided the time control constant of the circuit is made such that the modulation action follows the modulation frequencies supplied by the amplitude and polarity regulating circuit to the oscillator modulator elements in 6. By using one polarity or the other for the audio frequency energy fed back the phase and frequency modulation deviation at the intermediate frequency can be increased or decreased. The polarity of audio feedback which gives an increase or decrease in band width of signal modulation in the intermediate frequency circuits will depend upon the relative frequencies of the incoming frequency modulated carrier and the first beating oscillator. Moving the frequency of the first beating oscillator from one side to the other of the received frequency modulated carrier will reverse the polarity of modulation appearing in the intermediate frequency circuits and therefore reverse the polarity of audio output from the receiver. By choosing the correct combination of relative frequency of the first beating oscillator and polarity of audio feedback to modulate the first beating oscillator, a wide band frequency modulated wave received in 4 may be converted to a narrower band frequency modulated wave in the intermediate frequency output from 4, or to a wider band frequency modulated wave as desired. The degree of narrowing or widening may be controlled by controlling the strength and polarity of the energy fed back. In order to provide the proper polarity and strength of the audio frequency energy feedback to the oscillator and modulator in 6, an amplitude and polarity regulator represented by the block 10 may be interposed between the output of 8 and 6.

By means of this simple and inexpensive addition to a frequency modulation receiver the band

width accommodated by it may be adjusted at will by adjusting the amount and polarity of energy fed back either manually or automatically. Such amplitude control or energy control may be accomplished in 10 simultaneously with or in conjunction with polarity control. For example, all intermediate frequency circuits in this receiver may be designed for ordinary band frequency modulation and the simple addition of the controllable audio frequency feedback to modulate the first beating oscillator will adapt the receiver to reception of waves of wide band width. Widening the selectivity of receiver intermediate frequency circuits to accommodate wide band modulation reduces the gain per stage. Consequently, if it is advantageous to use wide band frequency modulation transmission the same can still be efficiently received by the use of my novel band reducing scheme as applied to the first detector of a heterodyne receiver having an efficient intermediate frequency amplifier of normal band width. This is of considerable advantage in commercial broadcast receivers due to increased complexity and cost which would be entailed by the use of wide band intermediate frequency amplifiers. In this case, for receiving wide band frequency modulated signals, the feedback is degenerative and tends to reduce distortions introduced in the receiver in accordance with the well known action of degenerative feedback in reducing distortion. Alternatively, all intermediate frequency circuits may be designed for wide band frequency modulation and the feedback used to increase the band width of ordinary band width signals. This latter arrangement permits use of higher intermediate frequencies which is an advantage in many cases, particularly in respect to obtaining frequency selectivity and freedom from image band interference. Thus my invention provides a flexibility in design and operation which can be of great value in many cases. The amplitude and polarity regulators in 10 may be of any type, such as, for example, those shown in Figures 3a, 3b, and 3c. They may include potentiometers, attenuators, variable ratio transformers, reversing switches or any other of the many known means for controlling polarity and amplitude of currents transferred from one circuit to another. Many different types of amplitude and polarity regulators in addition to those shown will occur to those skilled in the art. As a further refinement in a receiver such as that illustrated in Figure 2, I may employ a frequency selective filter in the output of the frequency modulation detector similar to that shown in Figure 4 described hereinafter, or in the leads carrying feedback energy to the frequency modulated heterodyne oscillator so that disturbing currents outside the desired audio band will have less effect upon the performance of the receiver.

As an alternative arrangement which can be used for reducing wide band frequency modulated waves to narrower band frequency modulated waves at a lower carrier frequency, I may employ the features illustrated in Figure 2. In this alternative arrangement, the intermediate frequency from the output of 4 may be multiplied up to the frequency of the first beating oscillator in 6 and then used to synchronize the oscillator. This may be accomplished by coupling a frequency changer such as a frequency multiplier 12 between the output of 4 and the input to 6 so that the frequency multiplied energy in the output of 12 takes control of the

oscillator in 6 to produce synchronized oscillatory energy. In this modification, as illustrated in Figure 2, the frequency of the oscillator in 6 is forced to follow frequency variations of the received carrier wave input to the apparatus in 4 so that the frequency variations, in the intermediate frequency carrier input to the frequency modulation detector 8, are considerably reduced. If, for example, the received carrier wave is deviated in frequency by, say 200,000 cycles, and the ratio of frequency multiplication in multiplier 12 is 9 to 1, then the resultant deviation in the intermediate frequency input to detector 8 will be only 20,000 cycles. To secure this result the oscillator in 6 must be adjusted so that its frequency is below the frequency of the incoming carrier waves whose frequency modulation is to be detected.

As an alternative arrangement which can be used for increasing narrow band frequency modulated waves to wider band frequency modulated waves at a lower carrier frequency, I may employ the arrangement of Figure 2 but adjust the oscillator in 6 so that its frequency is above the frequency of the incoming carrier waves whose frequency modulation is to be detected. In this case the band width of frequency modulation is increased by the ratio of frequency multiplication, in multiplier 12, minus 1.

In practice, the oscillator in 6 may be omitted by changing the switches at S from points a and b to points c and d, and output from multiplier 12 fed directly to the detector in 4 if the power gain between input and output of multiplier 12 is great enough and the received carrier wave is strong enough. Then the whole system, made up of the detector in 4 and frequency multiplier 12, becomes electrically regenerative and will produce self-oscillation or "singing" so that no separate self-oscillator such as included in 6 is required. In this case of self-oscillation the frequency selectivity of tuned circuits in amplifier B and in 4 and 12 constrain the oscillations to those taking place by virtue of beats with the desired received carrier wave.

A more detailed explanation of the manner in which this reduction of intermediate frequency deviation is accomplished is set forth in detail in my United States application Serial #708,338 filed January 26, 1934, see also Osborn Patent #2,039,657 issued May 5, 1936.

In the first arrangement of this invention the controlled feedback to modulate the beating oscillator in 6 may be combined with means for automatic tuning of the receiver through control of the first beating oscillator frequency. Ordinarily the automatic tuning will be operated by differential variation in the output currents of a balanced detector system through time delay circuits or low pass filters, while the audio feedback for increasing or decreasing the band width as disclosed in the present application will be more nearly instantaneous in action. The tuning control follows frequency deviations which occur over a comparatively long period of time but does not follow frequency deviations at signal frequency. The audio feedback control of the present invention responds to the frequency modulations on the received wave. The polarities of the slow and rapid feedback may be like or opposite, depending upon whether or not the band width is to be decreased or increased. One type of frequency control means has been disclosed in my United States application #611,050 filed May 13, 1932 Patent #1,999,902 dated April

30, 1935, and in Crosby United States application Serial #616,803 filed June 13, 1932 Patent #2,065,565 dated December 29, 1936.

Although I have described a system in which a heterodyne detector is used in unit 4 of Figure 1, it will be understood by those skilled in the art that the circuits in unit 4 may also be a single side band modulator so that the output from 4 is at a higher frequency than the received wave. Likewise, in Figure 2, the apparatus in unit 4 may be a single sideband modulator if unit 12 is a frequency dividing instead of a frequency multiplying amplifier. These latter arrangements may be useful in connection with relatively low frequency phase of frequency modulated waves. Since single sideband modulators and frequency dividing means are already well known in the art it is considered unnecessary to describe them here.

To illustrate my method and means for reducing image band interference reference may be made to Figure 4, in which I have indicated an assembly of parts, each one of which may be provided in accordance with the known art. Each part has been labeled to indicate its function and one skilled in the art can easily provide one or more types of devices to carry out each indicated function.

Assume for purposes of explanation and illustration that we wish to receive a transmitter which is operating with a carrier frequency of 90,000,000 cycles per second and whose frequency is modulated by an audio band of frequencies ranging from 10, to 10,000 cycles per second. The peak frequency deviation may be held to a maximum of plus and minus 10,000 cycles.

Energy from the transmitter is picked up by the antenna, amplified and applied to a heterodyne detector. The detector may also be supplied with energy from an 88,000,000 cycle frequency modulated heterodyne oscillator. In the output of the heterodyne detector the transmitter signals may appear at an intermediate frequency of, say, 2,000,000 cycles per second. The intermediate frequency energy is amplified, limited to constant amplitude and then applied to a frequency modulation detector. Output from the frequency modulation detector is further amplified in an audio amplifier and filtered to substantially eliminate energy of all frequencies outside the 10 to 10,000 cycle audio band. Most of the final 10 to 10,000 cycle power is then applied to a loudspeaker or any other utilization device.

A controllable portion of the 10 to 10,000 cycle output is fed back to the heterodyne oscillator and used to modulate the oscillator frequency. If the correct polarity and strength of audio input to the frequency modulated heterodyne oscillator is used the frequency deviation of the signal at the intermediate frequency, instead of being limited to the plus and minus 10,000 cycle band of the transmitter, may be increased to say plus and minus 200,000 cycles. It is, of course, assumed that the frequency modulation detector was designed for this wide band.

If now we have, instead of our desired 90,000,000 cycle transmitter, another but undesired frequency modulated transmitter at about 86,000,000 cycles this transmitter also will produce intermediate frequency energy at 2,000,000 cycles and so be a source of image band interference. However, the audio feedback to the frequency modulated heterodyne oscillator will, in this case, reduce the modulation frequency deviation at the

intermediate frequency because the interfering frequency has been subtracted from the local oscillator to obtain the 2,000,000 cycle intermediate frequency, whereas the desired wave is above the local oscillations and the local oscillations are subtracted from it to obtain the intermediate frequency. Thus, if the 86,000,000 cycle transmitter initially has a maximum modulation frequency deviation of plus and minus 10,000 cycles the feedback in the receiver will reduce this deviation to $\frac{1}{20}$ of its original value or to plus and minus 500 cycles. Thus, assuming only one transmitter at a time, due to the audio feedback to the frequency modulated heterodyne oscillator, the receiver will respond to the 90,000,000 cycle transmitter with an output which is 400 to 1 in voltage or current, 160,000 to 1 in power or 52 decibels greater than it will respond to an 86,000,000 cycle transmitter. This gain of 160,000 to 1 in power ratio in this assumed case is in addition to any discrimination between the two received frequencies provided in the receiver ahead of the heterodyne detector. Taking one transmitter at a time, the feedback principle, with the receiver adjusted as described, improves the useful signal to image band signal ratio by 52 decibels. Other degrees of feedback may, of course, be used to obtain more or less discrimination against image band reception.

If both the desired transmitter and an interfering transmitter in the image frequency band are operating simultaneously a more complicated situation exists. The frequency selectivity ahead of the heterodyne detector will ordinarily be sufficient to reduce the strength of the interfering transmitter to a level considerably below the desired transmitter but often it will not alone be sufficient to prevent serious interference. In the ordinary amplitude modulation superheterodyne receiver the most noticeable interference is produced when the heterodyne oscillator of the receiver is so adjusted that the desired transmitter and the interfering transmitter carriers produce intermediate frequencies differing by an amount equal to some audible frequency. Then, as the heterodyne oscillator frequency is varied a whistling note of variable frequency is heard in the output of the receiver. The same kind of phenomena is observable in a frequency modulation superheterodyne receiver such as that shown in Figure 4.

If we should adjust the receiver to bring the whistle note to zero or near zero frequency then it will ordinarily not be heard. Also the frequency modulation of the undesired transmitter, if the transmitter is relatively weak when it reaches the heterodyne detector is heard weakly if at all and is always much weaker than the carrier whistles would be when adjusted to be of audible frequency. The audio feedback to the first beating oscillator will increase part of the time and decrease part of the time the strength of the modulation of the undesired transmitter appearing in the output of the receiver, depending upon the phase relations of the two intermediate frequency carrier components.

If we adjust the receiver to make the two intermediate frequency carriers give an audible beat frequency receiver output then the audio feedback to the heterodyne oscillator causes the audible output to frequency modulate itself and so spread its energy out over a band of frequencies so that the characteristic whistling note is obscured and the actual and apparent interfering noise is much reduced.

If we adjust the two intermediate frequency carriers to give a difference frequency above 10,000 cycles then the low pass filter in the receiver output suppresses the beat between them so that it is neither heard nor fed back to the heterodyne oscillator. Ordinarily, because of the wide intermediate frequency band of the receiver, we can always move the whistle between two carriers in the desired and image bands up out of audibility without appreciably affecting the performance of the receiver for the desired station. If, for example, the whistle comes at say 1000 cycles, when the receiver is adjusted so that the desired transmitter produces an intermediate frequency at the center of the frequency modulation detector band, then it is only necessary to alter the receiver first beating oscillator mean frequency by 4500 cycles, or say for practical purposes 5000 cycles in order to move the whistle up to a frequency above the cut-off frequency of the audio output filter. This causes a misadjustment, or off centering, of the intermediate frequency produced by the desired transmitter of only 4500 to 5000 cycles in a whole band of 400,000 cycles. Its only effect is to limit the modulation frequency swing of the desired transmitter by 5000/200,000 or 2.5%. We may easily design the frequency modulation detector, or adjust the strength of feedback to the first beating oscillator so that the frequency band limit of modulation at the detector is not exceeded.

Many other combinations of carrier and intermediate frequencies may be utilized according to the whim of the designer or the requirements of the services in which he is interested. Having understood the principles of image suppression illustrated in the example I am confident that one skilled in the art may readily choose his frequencies and assemble devices and means commonly known in the art for satisfactorily performing each of the indicated functions and for making practical use of the invention.

It will also be readily understood by one skilled in the art that the system may be utilized for receiving phase modulated waves by simply substituting a phase modulation detector in place of the frequency modulation detector and a phase modulated heterodyne source in place of the frequency modulated heterodyne oscillator of Figure 4. Phase and frequency modulation are very similar and differ only in the relative degree of phase deviation or frequency deviation of the carrier wave in response to modulation of different modulating frequencies. It is now well known, for example, that a phase modulator may be made to serve as a frequency modulator by distorting or increasing the relative strength of modulating input at less than the maximum modulating frequency, in inverse proportion to the modulating frequency. Likewise a frequency modulator may be made to serve as a phase modulator by distorting or decreasing the relative strength of modulating input at less than maximum modulating frequency, in proportion to the modulating frequency.

It is also now well known that some types of phase modulation detectors may be utilized for reception of frequency modulation, and some types of frequency modulation detectors may be utilized as phase modulation detectors, by simply distorting or varying their outputs at various modulating frequencies to give relative output strengths changed in proportion to, or inverse proportion to, the modulation frequency.

It is because of the close similarity between

phase modulated waves and frequency modulated waves that some workers have failed to distinguish between them clearly, even though the means for producing and detecting the two types of modulation can differ so widely as to justify a sharp and clear distinction between them. In the present invention the similar natures of phase modulation and frequency modulation enable me to apply the principles of image band suppression to both.

I claim:

1. The method of changing the band width of frequency modulated wave energy which includes the steps of, rectifying said wave energy to produce audio frequency components characteristic of the frequency modulations on the wave energy, frequency modulating said wave energy in accordance with said audio frequency components and controlling the polarity of said audio frequency components to cause said last named frequency modulation to modify the extent of the frequency modulations on said wave energy.

2. The method of changing the width of the intermediate frequency band obtained by beating oscillatory energy with frequency modulated wave energy which includes the steps of, rectifying said intermediate frequency energy to produce audio frequency components characteristic of the frequency modulations on the wave energy, frequency modulating said oscillatory energy in accordance with said audio frequency components and controlling the polarity of said audio frequency components to cause said last named frequency modulation to modify the extent of the frequency modulations on said wave energy.

3. The method of controlling the band width of wave length modulated wave energy which includes the steps of, reducing the frequency of said wave energy, rectifying said wave energy of reduced frequency to produce audio frequency components characteristic of the frequency modulations on the wave energy, increasing the frequency of said wave energy of reduced frequency, and impressing on said oscillations energy characteristic of said increased frequency to control the frequency of said oscillations.

4. In a receiver of wave energy modulated in instantaneous frequency at signal frequency, a detector having an input and an output, a local oscillator coupled to said detector, a circuit responsive to the frequency modulated wave connected to the input of said detector, said detector serving to beat oscillations from said local oscillator with said modulated wave energy to produce a correspondingly modulated output of lower frequency, and a frequency multiplier coupled to the output of said detector and to said local oscillator to frequency multiply said output of lower frequency up to a frequency of the order of operation of said oscillator and entrain said oscillator by the oscillations of multiplied frequency.

5. The method of changing the wave length deviations of wave length modulated current including the steps of beating the modulated current with a second current to obtain a third wave length modulated current, demodulating the third current to obtain output current corresponding to the modulations of the modulated current and using a portion of the output current to modulate the wave length of the second current to thereby change the extent of wave length modulation on the third current.

6. The method of changing the wave length deviations of wave length modulated currents in-

cluding the steps of beating or heterodyning the modulated current with a second current to obtain a third wave length modulated current, frequency multiplying or frequency dividing a portion of the third current and utilizing the frequency multiplied or divided current to control or to supply the second current.

7. The method of improving the ratio of demodulated energy resulting from the demodulation of a desired frequency modulated wave as compared to the energy incidentally produced during said demodulation process by an undesired modulated wave which includes the steps of, producing oscillations of a frequency intermediate the frequencies of said modulated waves, beating said produced oscillations with desired modulated wave energy to produce an intermediate frequency, demodulating said intermediate frequency to obtain energy characteristic of the modulations on the desired wave and modulating said produced oscillatory energy in frequency in a sense to increase the frequency modulation of the resultant intermediate energy and consequently reduce the energy produced by beating action between said undesired modulated wave and said produced oscillations.

8. The method of reducing the effect of image frequencies on the energy obtained by demodulating a frequency modulated wave which includes the steps of, producing oscillatory energy of a frequency intermediate the frequency of a desired carrier wave and any other interfering wave, beating said produced oscillator energy with said desired wave to produce intermediate frequency wave energy, demodulating said intermediate frequency wave energy to obtain energy characteristic of the modulations on the modulated wave, modulating said produced oscillatory energy in frequency in accordance with said characteristic energy and adjusting the polarity of the said characteristic energy to modulate said produced oscillatory energy in a sense to increase the frequency modulations on said intermediate frequency and consequently decrease modulations of any intermediate frequency produced by beating action of said undesired carrier wave and said produced oscillatory energy.

9. The method of improving the ratio of demodulated energy resulting from the demodulation of a desired frequency modulated wave as compared to the energy incidentally produced during said demodulation process by an undesired modulated wave which includes the steps of, producing oscillations, beating said produced oscillations with desired modulated wave energy to produce an intermediate frequency, demodulating said intermediate frequency to obtain signal components and modulating said produced oscillatory energy in frequency in a sense to increase the frequency swing of the resultant intermediate energy and consequently increase the intensity of said signal components as compared to other demodulation components.

10. A heterodyne receiver including image band reducing means comprising in combination a circuit responsive to modulated wave energy, a detector having an input coupled to said circuit, said detector having an output, a source of local oscillations coupled to said detector tuned to a frequency intermediate the frequency of the desired carrier wave and the wave causing the image band it is desired to reduce, a demodulator coupled to the output of said detector, a modulating circuit coupled to said local oscillator and phase reversing and amplitude regulating means coupling said demodulator to said local oscillator to modulate the frequency of oscillations thereof in accordance with the output of said detector.

11. In a system for changing the frequency deviations of current modulated in frequency at signal frequency, circuits for beating the frequency modulated current with a second current, means for modulating the frequency of said second current in accordance with the modulations on the first current, and means for maintaining substantially fixed the degree of modulation of the second current with respect to the degree of modulation of the first current.

12. The method of increasing the amount of frequency modulation of a carrier current modulated in frequency at signal frequency including the steps of, heterodyning the frequency modulated carrier current to a lower frequency by means of a second current, and modulating the frequency of the second current in synchronism with the frequency modulations on the carrier current and in a reverse sense.

13. In a system for changing the extent of frequency deviation of current modulated in frequency at signal frequency, circuits for beating the frequency modulated current with a second current, means for modulating the frequency of said second current in accordance with the frequency modulations on the first current, means for controlling the magnitude of the frequency modulation of the second current, and means for controlling the polarity or sense of frequency modulation of the second current relative to the frequency modulations on the first current.

14. In a receiver of wave energy modulated in wave length at signal frequency, a combined detector and modulator having an input energized by said wave energy and having an output, means responsive to modulating potentials of a frequency of the order of the modulations on the wave length modulated wave energy connected to said detector and modulator for selecting modulation components to modulate the wave length of the wave energy, and a modulation potential polarity adjusting means coupling said detector output to said responsive means to cause the modulation of the length of said wave to oppose or aid the wave length modulations of the wave energizing the input of said detector and modulator.

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