

June 11, 1940.

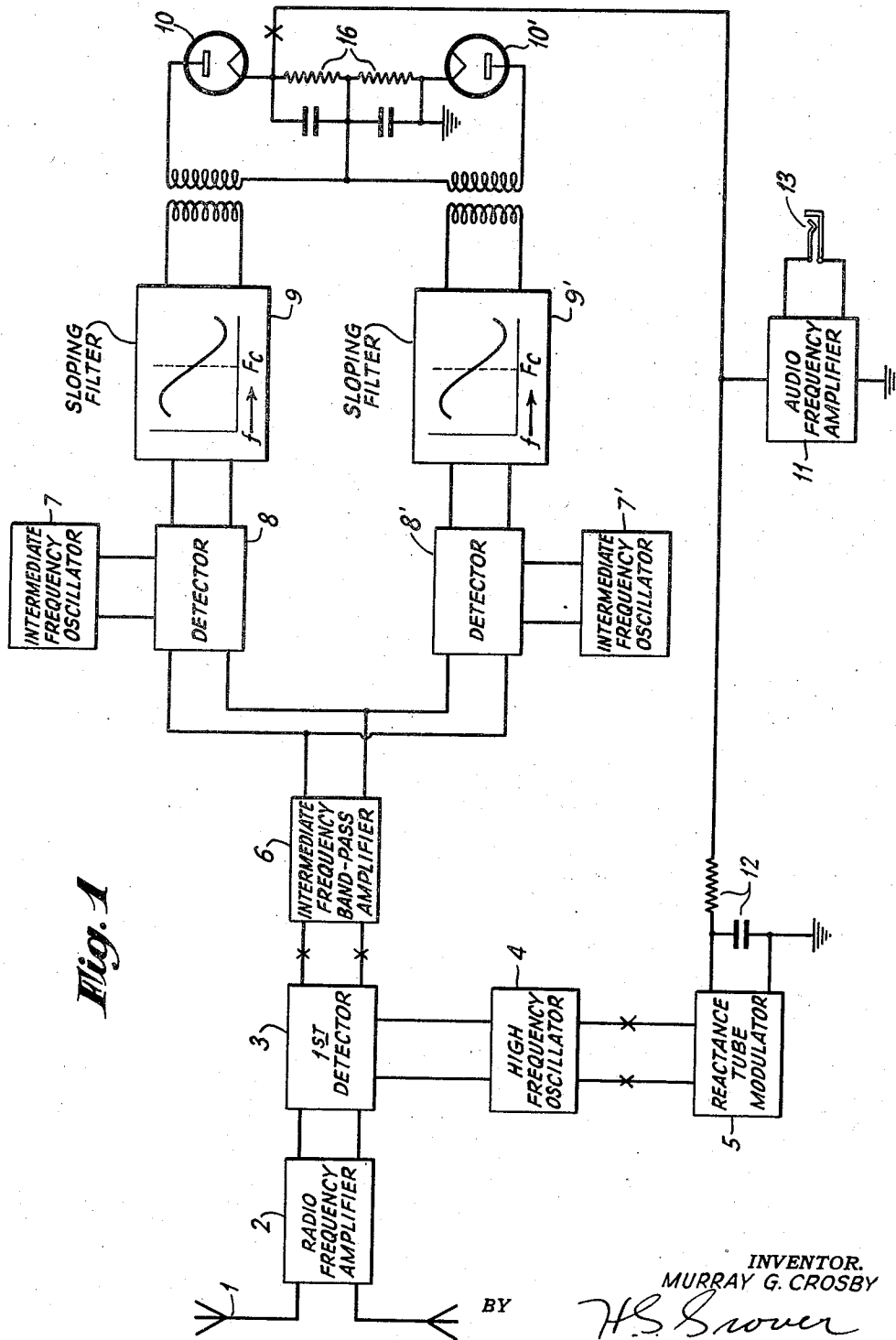
M. G. CROSBY

2,204,342

BACK-TO-BACK RECEIVER

Filed Dec. 6, 1938

3 Sheets-Sheet 1



June 11, 1940.

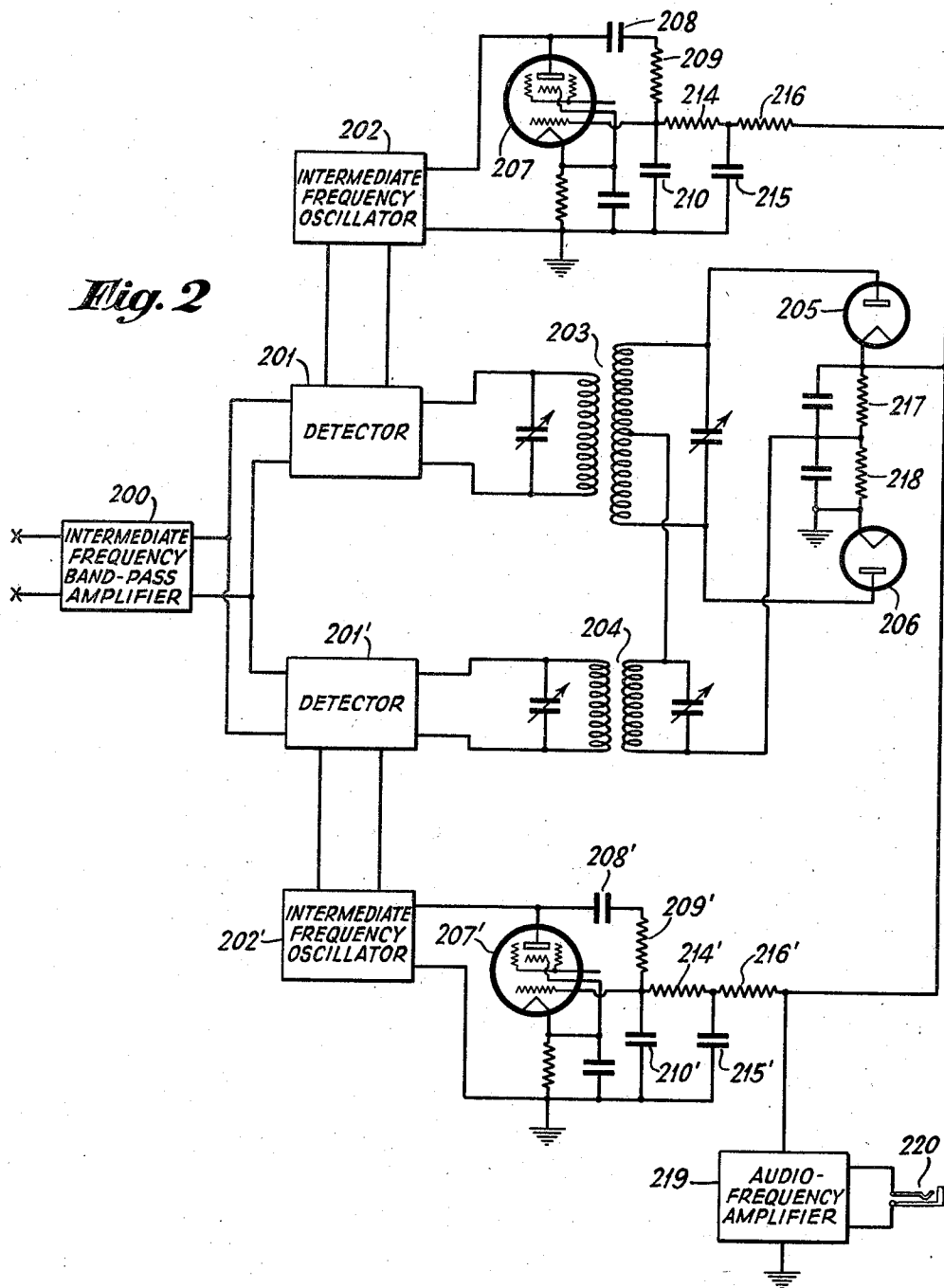
M. G. CROSBY

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BY

INVENTOR.
MURRAY G. CROSBY

H. S. Swover
ATTORNEY.

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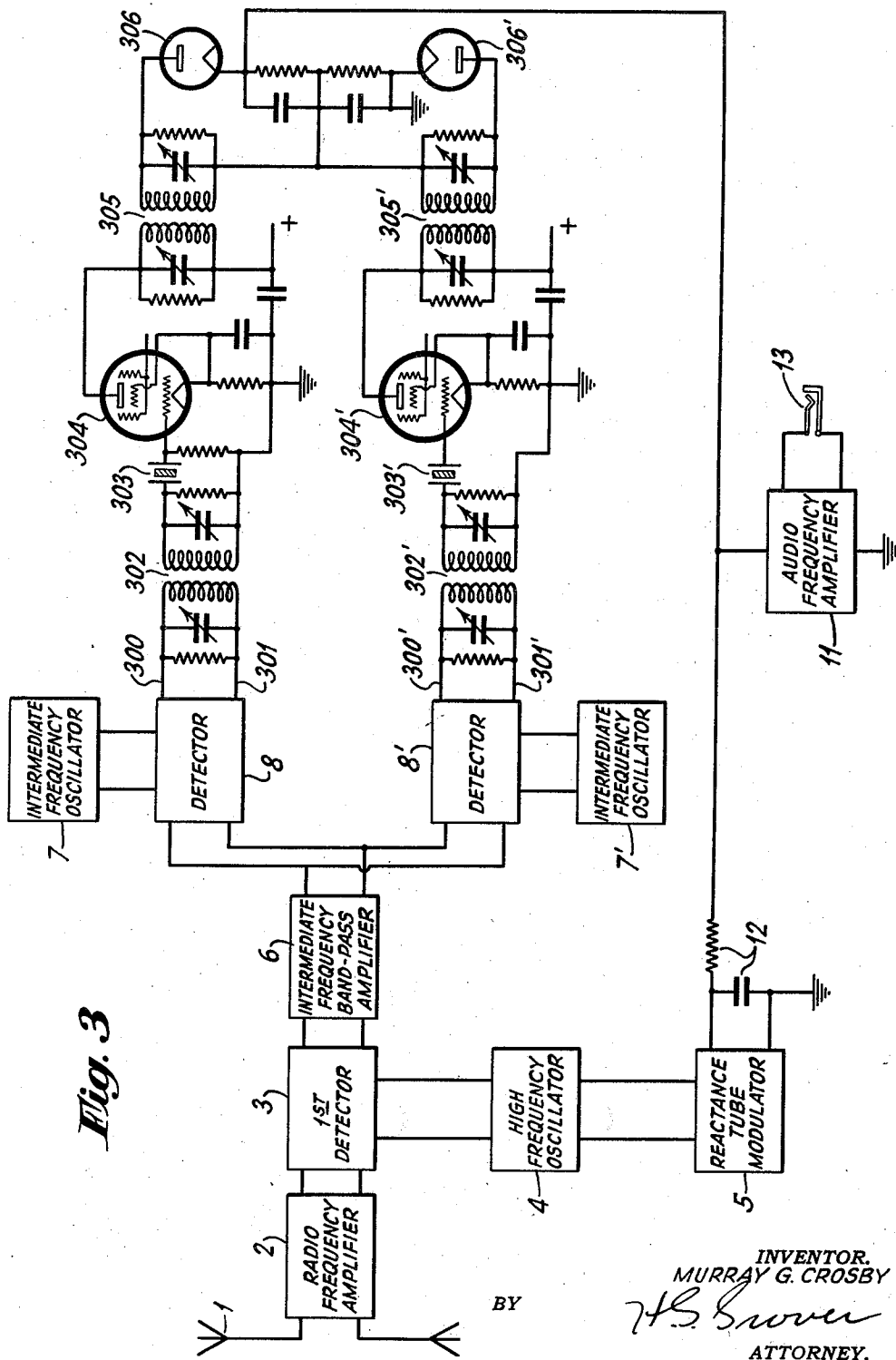
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BACK-TO-BACK RECEIVER

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UNITED STATES PATENT OFFICE

2,204,342

BACK-TO-BACK RECEIVER

Murray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Application December 6, 1938, Serial No. 244,153

12 Claims. (Cl. 250—20)

This application concerns new and improved frequency and phase modulation receivers of the back-to-back type. In my novel receiver there are two branches which feed phase or frequency modulated wave energy to detectors with their outputs connected in push-pull. The normal procedure in this type of receiver is to provide two branches which convert the frequency or phase modulation on wave energy into corresponding amplitude modulations on wave energy, with the modulation envelopes 180 degrees apart in phase. This phase difference of the modulations is produced by the converting systems which convert the frequency or phase modulation on the wave energy to amplitude modulation for detection. In the novel receivers of the present application the reversal of phase of the modulation is accomplished in frequency converting or changing detectors which reverse the direction of the phase or frequency of the wave energy. This makes it possible for each branch of the back-to-back receiver systems for converting the phase or frequency modulation to amplitude modulation to be substantially identical, yet the detected outputs will be 180 degrees out of phase the same as in the prior receivers. As is known in the art, the 180 degree phase relation of the envelopes is desirable for different reasons, an important reason being that unwanted amplitude modulations on the phase or frequency modulated wave are cancelled in the detector outputs.

An advantage gained by the use of this method of reversing the polarity of the modulation is that the two branches of the receiver may utilize identical converting systems for converting the phase or frequency modulation to amplitude modulation for detection. This helps to obtain a more accurate back-to-back balance since it is easier to produce two identical systems for converting the frequency or phase modulation into amplitude modulation than it is to provide two systems which convert in a like manner but with reversed characteristics to get the 180 degree phase relations between the amplitude modulation envelopes desirable in the differential output of the detector system.

The principle upon which this system is based is that by heterodyning the incoming signal with oscillators tuned to opposite sides of zero-beat with the signal, instantaneous beat frequencies will be produced wherein the deviations in phase or frequency at signal frequency will be in opposed sense or phase or angular relation. For instance, in the case of frequency modulation

assume as an example a 450 kilocycle intermediate frequency which is to be heterodyned to 100 kilocycles. In the system of this invention two frequency converting detectors are arranged with one of the beating oscillators tuned to 350 kilocycles and the other to 550 kilocycles. The beat produced by the first oscillator is 450 kilocycles minus 350 kilocycles or 100 kilocycles, and that produced by the second oscillator would be 550 kilocycles minus 450 kilocycles or 100 kilocycles. Thus we have two intermediate frequency outputs of the same frequency and identical I. F. amplifiers and selector circuits can be used. Now, if the frequency shifts (in accordance with signals) to 451 kilocycles, the first oscillator beating with this shifted signal wave will produce a beat frequency equal to 451 kilocycles minus 350 kilocycles or 101 kilocycles, and the second oscillator beating with the shifted signal wave will produce a beat frequency equal to 550 kilocycles minus 451 kilocycles or 99 kilocycles. Note that the direction of frequency shift of one of the resulting intermediate frequencies is in one direction and the other in the other direction, in other words, the modulation of one I. F. is reversed with respect to the modulation of the other I. F. A phase shift (which may be considered as a small frequency shift) is reversed in the same manner.

This broad principle as outlined above is applicable to various types of phase or frequency modulated wave demodulators. The application thereof to three types of receivers will now be described by reference to the attached drawings wherein the three figures show three frequency or phase modulated receivers wherein identical systems for converting the original modulations to amplitude modulations with opposed modulation envelopes are shown.

Figure 1 shows a frequency modulated wave receiver including means for beating the frequency modulated wave with oscillations on opposite sides of the mean frequency of the modulated wave, demodulating means of the sloping filter type and automatic frequency control means associated with an oscillator in the receiver. Figure 2 shows a receiving system responsive to phase modulated wave energy. Figure 3 is a modification of the arrangement of Figure 2.

Figure 1 shows how this reversal of frequency or phase shift may be taken advantage of to produce a back-to-back frequency modulation receiver which uses converting filters having the same slope instead of opposite slopes as used in

the conventional back-to-back frequency modulation receiver such as disclosed in my United States Patent #2,071,113, issued February 16, 1937. The signal is received on antenna 1, amplified in radio frequency amplifier 2, and converted to intermediate frequency by detector 3 wherein the amplified signal is mixed with oscillations from high frequency oscillator 4. Intermediate frequency band-pass amplifier 6 selects the desired intermediate band of frequencies and feeds the same to two detectors 8 and 8'. These two detectors cooperate with oscillators 7 and 7' to convert the phase or frequency modulated first intermediate frequency wave into two new waves of a second intermediate frequency with the polarity or direction or sense of their frequency or phase modulations reversed. Oscillator 7 is tuned to one side of zero beat with the signal carrying first intermediate frequency while oscillator 7' is tuned to the other side of zero beat with the first intermediate frequency. For instance, if the frequency from 6 is 450 kilocycles, 7 may be tuned to 350 kilocycles and 7' to 550 kilocycles. The two sloping filters 9 and 9' connected to 8 and 8' respectively, have the same direction of slope as indicated by the curves, so that when fed frequency modulations of opposite phase the resulting amplitude modulations will have envelopes of opposite polarity. That is to say, the filters 9 and 9' are made identical and adjusted so that the I. F. carrier frequency at zero modulation is at the linear portion of the sloping part of their characteristics. When modulation is applied one I. F. increases, the other decreases, and such changes are changed in each filter to a corresponding amplitude variation. The amplitude modulations are detected in diodes 10 and 10' which are connected in series with the polarity of one of them reversed so as to combine the resulting detected outputs in phase. This reversal for differential output is obtained by grounding the cathode of one detector, say 10', and taking the added modulation voltages from a point on the resistance adjacent the cathode of the other diode 10. The detected and combined outputs are fed to audio frequency amplifier 11 and made available for utilization at jack 13. Control potentials for automatic frequency control are also taken from the diode resistors and fed through time constant circuit 12 to reactance tube modulator 5. Reactance tube modulators of the type involved here are well known in the art and have been disclosed in several of my pending applications and in my patents.

Figure 2 shows how this method for reversing the direction of phase shift may be utilized in a phase modulation receiver. Unit 200 consists of the band-pass intermediate frequency amplifier of a superheterodyne receiver, such as, for example, unit 6 of Figure 1. The selected intermediate frequency energy is fed from amplifier 200 to detectors 201 and 201' which cooperate with oscillators 202 and 202' tuned to opposite sides of zero beat with the I. F. phase modulated wave from 200 so as to reverse the direction of phase shift of the heterodyned outputs of one of the detectors 201 and 201'. These two heterodyned outputs are fed to the phase detector consisting of push-pull transformer 203, common leg transformer 204, and diodes 205 and 206 with their resistors 217 and 218. This phase detector is of a known type which detects the difference in phase between the two waves fed to the two input transformers. Somewhat similar demodula-

tors have been described in my prior applications and patents. See, for example, my United States Patent #2,065,565, dated December 29, 1936. In these detectors a phase quadrature relation at zero modulations, between the voltages induced by 203 and 204 on the detectors 205 and 206, is maintained. Then if the phase shifts (due to modulation) this phase relation is changed and the change in the resultant voltage on the detectors produces variations in their output commensurate with the extent of such variation. In this new system, however, if the wave from detector 201 shifts in phase 30 degrees in the positive direction, the wave from detector 201' will shift 30 degrees in the negative direction. The total phase difference will then be twice that existing on one wave alone so that this receiver has a sensitivity which is twice that of the ordinary type of receiver which detects the phase difference between the phase modulated wave and an unmodulated wave.

The detected output appearing across diode resistors 217 and 218 is fed to audio amplifier 219 which makes the output available for utilization at jack 220. This same detected output is also used for automatic frequency control on the beating oscillators 202 and 202'. The control voltage is fed through time constant circuit 216, 215 and grid resistor 214 to vary the control grid voltage of modulator reactance tube 207. Reactance tube 207 obtains its reactive plate circuit by virtue of the phase quadrature feedback through blocking condenser 208 and the phase shifting circuit consisting of resistor 209 and condenser 210. Oscillator 202' has reactance tube 207' connected to it and operates in the same manner as the other oscillator and reactance tube. If desired, the automatic frequency control to one of the beating oscillators may be omitted since to do so merely reduces the sensitivity of the control, but sufficient control will still be available. Corresponding numerals primed have been applied to the control circuit for reactance tube 207'. Reactance tube modulators for controlling the frequency of an oscillator are well known now in the art, and have been described in several of my prior applications, and it seems unnecessary to describe the same here. See, for example, my application Serial #165,056, filed September 22, 1937, now Patent #2,156,374, issued May 2, 1929, my application Serial #167,344, filed October 5, 1927, now Patent #2,156,375, issued May 2, 1939, my application Serial #233,719, filed October 7, 1938 and my application Serial #209,919, filed May 25, 1938.

Figure 3 shows how the off-neutralized crystal filter type of phase modulation receiver is connected to utilize this principle of reversing the polarity of phase modulation. The converting circuit of Figure 3 may replace the converting filters and diode detectors 9, 9', 10, and 10' of Figure 1. Detector 3 then feeds leads 300 and 301 and detector 8' feeds leads 300' and 301'. Transformers 302 and 302' feed identical crystal filters 303 and 303' which feed the diode-driver tubes 304 and 304'. Band-pass transformers 305 and 305' feed diodes 306 and 306' from which the detected output and the automatic frequency control potentials are obtained.

The crystal filters comprising piezo-electric crystals 303 and 303' may be both over- or under-neutralized. In any event, they are substantially identical and it is easier to produce two filters having substantially identical characteristics than two filters having opposed characteristics.

In operation, the reversed phase modulated waves are supplied to the two crystal filters from detectors 8 and 8'. The crystal filters are reactive in the same sense on both sides of their resonant frequencies. The crystal filters in the modification shown are series resonant at substantially the frequency of the second intermediate frequency at zero modulation. The filters have reactance characteristics such that the side band frequencies, normally out of phase with respect to their position in amplitude modulation, are shifted to a position at which they produce amplitude modulation in conjunction with the carrier. In this manner the phase modulations (now reversed) are converted into amplitude modulations with opposed envelopes for detection in tubes 306 and 306'.

For a more detailed description of the converting filters see my United States Patent #2,085,008, dated June 29, 1937, now Patent #2,085,008, issued June 29, 1937, my application Serial #192,196, filed February 24, 1938, my application Serial #165,056, filed September 22, 1937, now Patent #2,156,374, issued May 2, 1939, my application Serial #167,344, filed October 5, 1937, now Patent #2,156,375, issued May 2, 1939, my application Serial #195,041, filed March 10, 1938, my application Serial #178,655, filed December 8, 1937, now Patent #2,156,376, issued May 2, 1939, my application Serial #242,469, filed November 26, 1938 and my application Serial #186,273, filed January 22, 1938.

In Figure 2 the circuits preceding the unit 200 have been omitted in the sake of brevity. Unit 200 may be connected to the output of a first detector, such as 3 of Figure 1. In this case the leads to 4 and 12 are disconnected at the points marked X in Figure 1.

What is claimed is:

1. The method of producing by means of phase or frequency modulated wave energy other wave energies modulated in opposed sense or polarity by phase or frequency modulations corresponding to the phase or frequency modulations on the said first wave energy which includes the steps of, generating oscillations of a frequency higher than the mean frequency of said wave energy, beating said original phase or frequency modulated wave energy with said generated oscillations of higher frequency to produce a first phase or frequency modulated beat note, or generating oscillations of a frequency lower than the mean frequency of said wave energy, beating said original phase or frequency modulated wave energy with said generated oscillations of lower frequency to produce a second phase or frequency modulated beat note in which the sense or polarity of phase or frequency modulation is opposite to the sense or polarity of the phase or frequency modulations on said first beat note.

2. The method of producing by means of phase or frequency modulated wave energy other phase or frequency modulated wave energies in which the modulations correspond to each other and to the modulations on the original wave energy but are of unlike polarity or sense which includes the steps of, producing oscillations of a frequency higher than the mean frequency of said wave energy, beating said original phase or frequency modulated wave energy with said produced oscillations of a frequency higher than the mean frequency of said original wave energy to produce a first beat note modulated in phase and frequency, producing oscillations of a frequency lower than the mean frequency of said wave en-

ergy, and beating said original phase or frequency modulated wave energy with said produced oscillations of a frequency lower than the mean frequency of said phase or frequency modulated wave energy to produce a second beat note, modulated in phase or frequency, of a mean frequency substantially equal to the mean frequency of said first beat note.

3. The method of producing by means of phase or frequency modulated wave energy other wave energies modulated in opposed sense by phase or frequency modulations corresponding to the phase or frequency modulations on the said first wave energy which includes the steps of, producing oscillations of a frequency exceeding the mean frequency of said modulated wave by a selected amount, producing other oscillations of a frequency equal to the mean frequency of said modulated wave minus said selected amount, beating said original phase or frequency modulated wave energy with said first oscillations to produce a first phase or frequency modulated beat note of a mean frequency equal to said selected amount, and beating said original phase or frequency modulated wave energy with said other oscillations to produce a second phase or frequency modulated beat note, of a mean frequency equal to said selected amount, in which the sense or polarity of phase or frequency modulation is opposite to the sense or polarity of the phase or frequency modulations on said first beat note.

4. The method of remodulating phase or frequency modulated wave energies in which the modulations are characteristic of the same signal potentials but are of unlike polarity or sense which includes the steps of, passing said energies through paths of substantially like characteristics which convert said phase or frequency modulations into corresponding amplitude modulations of opposed polarity and demodulating the energies passed by said paths to reproduce the signal.

5. The method of demodulating phase or frequency modulated wave energies in which the modulations correspond but are of unlike polarity or sense which includes the steps of, passing said wave energies through paths having substantially identical characteristics which convert the phase or frequency modulations on said wave energy to corresponding amplitude modulations with envelopes 180 degrees out of phase, demodulating the energies passed by said paths, and differentially combining the modulation components to produce the signal.

6. The method of demodulating wave energy modulated in phase or frequency which includes the steps of, providing oscillations of a frequency greater than the frequency of said wave energy, beating said original phase or frequency modulated wave energy with said oscillations of greater frequency to produce a first phase or frequency modulated beat note, providing oscillations of a frequency less than the frequency of said wave energy, beating said original phase or frequency modulated wave energy with said oscillations of less frequency to produce a second phase or frequency modulated beat note in which the sense or polarity of phase or frequency modulation is opposite to the sense or polarity of the phase or frequency modulations on said first beat note, passing said beat notes through paths having substantially identical characteristics for converting said modulations to corresponding

amplitude modulations, and combining the energies passed by said paths.

7. The method of demodulating phase or frequency modulated wave energy which includes the steps of, beating said original phase or frequency modulated wave energy with oscillations of a frequency greater than the mean frequency of said original wave energy to produce a first beat note modulated in phase or frequency, beating said original phase or frequency modulated wave energy with other oscillations of a frequency less than the mean frequency of said phase or frequency modulated wave energy to produce a second beat note, modulated in phase or frequency, of a mean frequency substantially equal to the mean frequency of said first beat note, passing said beat notes through identical modulation converting baths, demodulating the energies passed by said baths, and differentially adding the demodulation components to reproduce the signal.

8. In a system for converting phase or frequency modulations on wave energy into wave energies correspondingly modulated in phase or frequency but of opposite sense, means for producing oscillations of a frequency lower than the frequency of said wave energy, means for beating said phase or frequency modulated wave energy with said lower frequency oscillations to produce a first phase or frequency modulated beat note, means for producing oscillations of a frequency higher than the frequency of said wave energy, and means for beating said phase or frequency modulated wave energy with said higher frequency oscillations to produce a second phase or frequency modulated beat note the modulations on which are of a sense opposite to the phase or frequency modulations on the first beat note.

9. In a system for demodulating phase or frequency modulated wave energy, means for providing oscillations of a frequency lower than the frequency of said wave energy, means for beating said phase or frequency modulated wave energy with said lower frequency oscillations to produce a first phase or frequency modulated beat note, means for providing oscillations of a frequency higher than the frequency of said wave energy, means for beating said phase or frequency modulated wave energy with said higher frequency oscillations to produce a second phase or frequency modulated beat note the modulations on which are of a sense opposite to the phase or frequency modulations on the first beat note, means for converting the modulations on said beat notes into corresponding amplitude modulations and means for detecting the amplitude modulations.

10. In a system for demodulating phase or frequency modulated wave energy, two sources of

oscillations one of which supplies oscillations of a frequency greater than the mean frequency of said wave energy the other of which supplies oscillations of a frequency less than the frequency of said wave energy, a first heterodyning detector excited by said wave energy and by oscillatory energy from that one of said sources which supplies oscillations of a frequency greater than the mean frequency of said wave energy, a second heterodyning detector excited by said wave energy and by other oscillatory energy from the other of said sources which supplies oscillations of a frequency less than the mean frequency of said frequency or phase modulated wave energy, a pair of differential detectors, and frequency discriminating circuits coupling each of said heterodyne detectors to said differential detectors.

11. In a system for demodulating phase or frequency modulated wave energy, a first source of oscillations of a frequency equal to the mean frequency of said wave energy plus a constant, a second source of wave energy of a frequency equal to the mean frequency of said wave energy, minus said constant, a first heterodyning detector excited by said wave energy and by oscillatory energy from said first source of a frequency equal to the mean frequency of said wave energy plus a constant, a second heterodyning detector excited by said wave energy and by oscillatory energy from said second source of a frequency equal to the mean frequency of said wave energy minus said constant, a pair of differential detectors, and substantially equivalent frequency discriminating circuits coupling each of said heterodyne detectors to said differential detectors.

12. The method of demodulating wave length modulated wave energy which includes the steps of, beating said original wave length modulated wave energy with the oscillations of a frequency greater than the mean frequency of said original wave energy to produce a first beat note modulated in wave length, beating said original wave length modulated wave energy with other oscillations of a frequency less than the mean frequency of said wave length modulated wave energy to produce a second beat note, modulated in wave length, of a mean frequency substantially equal to the mean frequency of said first beat note, passing said beat notes through substantially identical modulation converting paths, demodulating the energies passed by said paths, differentially adding the demodulation components to produce a resultant characteristic of the signal and controlling the frequency of both of said oscillations used in said beating processes to produce said first and second beat notes, in accordance with said resultant.

MURRAY G. CROSBY.