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H. O. PETERSON

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FREQUENCY CONTROL

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2 Sheets-Sheet 2

Fig. 2.

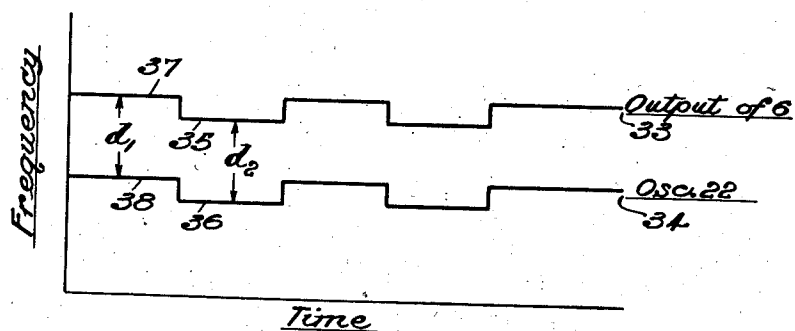
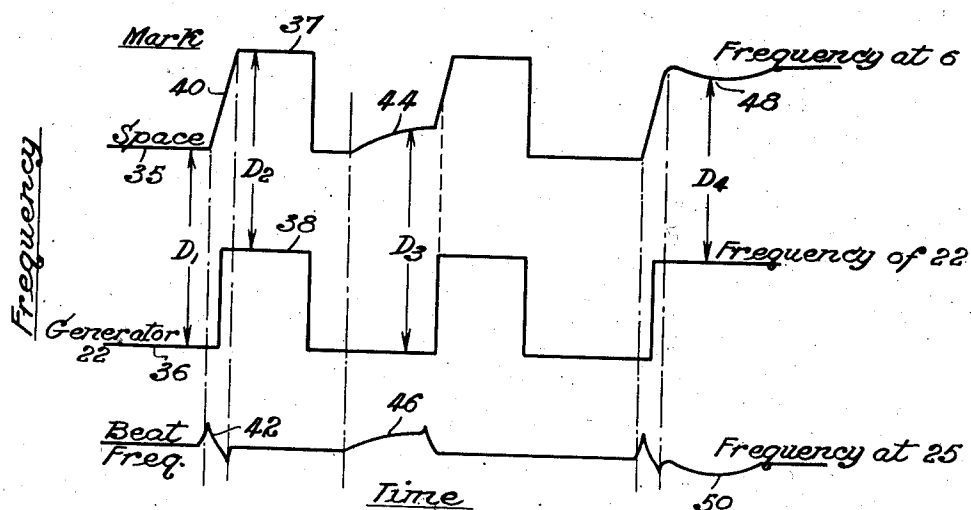


Fig. 3.



INVENTOR
Harold O. Peterson
BY *H. S. Grover*
ATTORNEY

UNITED STATES PATENT OFFICE

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FREQUENCY CONTROL

Harold O. Peterson, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

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This application concerns an improved method of and means for automatic frequency control in a receiver arranged to receive mark and space wave keying. In spaced wave keying wave energy is modulated or keyed from a first frequency which may be referred to as the spacing frequency to a second frequency then referred to as the marking frequency. My novel frequency control also includes keyed compensation.

Mark and space wave keying may be used for telegraphy, facsimile, photo radio by CFVD, teletype printers, and other forms of communication. It is essentially a form of frequency modulation. An object of this application is to describe a method of applying automatic frequency control in a receiver for mark and space wave keying.

Figure 1 is a block diagram of the novel receiving system including the automatic frequency control devices. Figures 2 and 3 are graphs of the frequency versus time characteristic of the signalling voltages in the receiver and will be used to help explain the operation of the automatic frequency control.

Referring to Figure 1, the incoming signal is picked up by an antenna 1 and conducted to the input of high frequency circuits and apparatus in unit 2. The high frequency means of unit 2 includes a mixer tube, radio frequency amplifiers and intermediate frequency amplifiers. In this high frequency unit the signal is passed through selective circuits and a heterodyne converter in which it is combined with a high frequency voltage from a source of oscillations supplied in unit 5 to produce an intermediate frequency which is conducted to intermediate frequency circuits and apparatus in unit 3. The circuits in unit 3 may include selective circuits, a mixer tube, amplifiers operating at the first intermediate frequency and amplifiers operating at the second intermediate frequency. In the intermediate frequency unit 3 the signal passes through selective circuits followed by another heterodyne converter in which the first intermediate frequency combines with a voltage from a source of oscillations in unit 4 to form a second intermediate frequency. The second intermediate frequency is passed through selective circuits and amplifiers which may also be included in unit 3. The second intermediate frequency is then conducted to amplitude limiting circuits in unit 6 which may be of one of the forms generally used in frequency modulation receivers.

The output of the limiter in unit 6 is conducted to a frequency modulation discriminator and detector circuit in which the frequency modulation is converted into amplitude modulation. I may use a discriminator such as dis-

closed in Crosby United States application Serial No. 618,154, filed June 20, 1932, Patent No. 2,229,640, dated January 28, 1941, or as shown in Seeley United States Patent No. 2,121,103, dated June 21, 1938. In a preferred embodiment I use a system comprising parallel tuned circuits 7 and 8 coupled to winding 9 and tuned one to pass the mark frequency and a group of frequencies thereabout and the other to pass the space frequency and a group of frequencies thereabout. The rectifiers 10 and 11 are connected with output resistances 12 and 14 shunted by by-pass condensers 13 and 15. The polarity of the rectifiers is such that the current outputs thereof flow in opposite directions in the resistances 12 and 14 to produce thereacross a resultant potential of a polarity which depends on which rectifier has the greatest output. The resultant potential is supplied from resistances 12 and 14 to any desired utilization means. For example, the amplitude modulation output may be conducted to recording apparatus.

The output of the frequency modulation detector circuit is also impressed from resistance 16 by way of resistance 37 on the control grid G of a keyer tube 18 the anode of which is in a circuit including a source 19 and a resistance 20 which supplies a voltage that excites a reactance tube circuit 21 associated with oscillator 22. This reactance tube modulator 21 and its cooperation with the generator in 22 may be as disclosed in Crosby United States application Serial No. 136,578, filed April 13, 1937, now U. S. Patent No. 2,279,659, dated Apr. 14, 1942. The output of the oscillation generator in unit 22 combines in converter 23 with energy of the second intermediate frequency from the limiter in unit 6 to provide energy of a third intermediate frequency which is conducted to a limiter in unit 24 and thence to a frequency modulation detector circuit comprising windings 25, 26, 27, rectifiers 28, 29, and output resistances 30, 31. The output of this frequency modulation detector circuit is conducted by lines L to an automatic frequency control device 32 which operates on the oscillation circuits in unit 5. Preferably the frequency control or modulator means in unit 32 may comprise a motor, a relay excited by the potential supplied by lines L for controlling the direction of rotation of the motor and a tuning element connected to the motor and associated with the means in source 5. In a preferred embodiment of this control means I use an electron tube controlled motor of the type shown in Crosby United States application Serial No. 393,339, filed May 14, 1941. However, the unit 32 may comprise a reactance tube modulator of the type disclosed in Crosby United States application Serial No. 136,578,

filed April 13, 1937, now U. S. Patent No. 2,279,659, dated Apr. 14, 1942.

It may be assumed that in signalling the transmitter frequency is keyed so that one frequency is radiated for the condition of "mark" and another frequency is radiated for the condition of "space" so that for the most part the transmitted frequency is on either one or the other of these two frequencies. As stated above the demodulating means including circuits 7 and 8, rectifiers 10 and 11, etc., produce potentials which are of different values in the marking and spacing conditions. I connect the input of keyer tube 18 so that when the space frequency is transmitted the grid receives positive voltage and when the mark frequency is transmitted the grid receives negative voltage from the potentiometer 16. For the condition of negative voltage tube 18 is caused to pass through cut-off so that there will be no voltage drop across resistor 20. Moreover, for the condition of positive voltage on keyer 18 a certain definite negative voltage appears across resistor 20. This is, for instance, accomplished by means of a resistor in series with the grid of tube 18, as, for instance, the resistor 37. Thus, for instance, mark and space keying of the transmitter causes definite shifts in frequency of the oscillations continuously produced and supplied by the means in 22 and by means of adjustments 16 and 20 the shift in the frequency of these oscillations produced in 22 is made practically the same as the shift of the transmitter frequency.

Referring to Figure 2, let trace 34 represent the frequency of oscillator 22 and let trace 33 represent the intermediate frequency from the limiter in unit 6. Due to the keying of the transmitter, the intermediate frequency from the limiter in unit 6 is shifted back and forth between two frequencies 35 and 37 as indicated by trace 33. The action of the receiver is such when operating normally that the oscillations from 22 are simultaneously shifted between two frequencies 36 and 38 as indicated by trace 34. The shifts indicated in traces 33 and 34 are substantially equal so that the difference frequency $d1$ and $d2$ remains substantially constant unless there is a slow drift in the intermediate frequency from the limiter in unit 6. A slow drift in the frequency from limiter 6 causes a change in the difference between traces 33 and 34 which in turn causes a change of the frequency feeding the frequency modulation detector 25, 26, 27, 28, 29, 30, 31 which is thereby caused to operate through the modulator in 32 and the oscillator in 5 to restore the frequency from the limiter in 6 to a proper value.

It should be noted that keyer tube 18 does not operate for small shifts of the frequency from limiter 6. For instance, if the difference between the mark and space frequencies is 1000 cycles, I so adjust the circuit that keyer tube 18 will not operate until the signal frequency has shifted 500 cycles. Thus for a 400 cycle change of the intermediate frequency from limiter 6, oscillator 22 will remain at constant frequency and there will be a 400 cycle shift in the difference frequency transmitted to limiter 24 and subsequently there will be a proper control voltage transmitted to 32 to operate so as to correct the shift of the frequency from limiter 6. There are appropriate time constant elements TC in the circuit controlling 32 to prevent oscillator 5 from tending to follow the keying frequency of the communications circuit.

More in detail, assume that the output of limiter 6 comprises a wave wherein one condition of keying, say space, is of a frequency indicated at 35 in Figure 3 and then is frequency modulated or shifted to a marking frequency 37. Assume further that the marking wave 37 is of a frequency 1000 cycles higher than the spacing frequency 25. Under the adjustment assumed above the frequency of oscillator 21 remains as it was, line 36, when the shift in frequency started until a change of about 500 cycles is made at point 40. Tube 18 is keyed and the generator 22 shifts in frequency an amount such that the difference $D2$ equals the difference frequency $D1$. The beat frequency at 25 stays constant except for a brief time, at 42, when the generator 22 first goes into action. This disturbance in the difference frequency cancels and/or is taken care of by the time constant TC. Now assume the modulation has continued and in space the frequency, due to causes at the transmitter or in generator 5, starts to rise slowly at point 44. The adjustment of 18 and 21 being such that a 500 cycle change in the output of 6 is required to modulate oscillator 22 the frequency thereof remains constant. $D3$ is greater than $D1$ and a change 46 is caused in the beat frequency at 25 which acts through 32 to adjust oscillator 5 to bring the frequency at 6 back to normal. If the frequency of the wave during mark should fall as indicated at 48, oscillator 22 continues operating at the same frequency and the difference frequency $D4$ is less than the difference $D1$ and a correcting change in the frequency at 25 occurs as indicated at 50 to again act on the generator 5 to return the frequency at 6 to normal.

The device above described may be used in a similar manner to control a transmitter frequency with respect to a local standard frequency by controlling the frequency of a wave generated in the transmitter.

I claim:

1. The method of detecting variations in the frequency of signals comprising wave energy the frequency of which varies abruptly in accordance with control potentials from a first frequency indicating a first signalling condition to a second frequency indicating a second signalling condition separated one from the other by a difference frequency which includes the following steps, producing oscillating voltages which are shifted in frequency from one frequency to another frequency as said wave energy varies from said first to said second frequency, inhibiting shifts in the frequency of said produced voltages in the presence of variations in the frequency of said wave energy of less extent than said variations in accordance with said control potentials, combining said wave energy with said produced voltages to produce other wave energy the frequency of which varies in accordance with the difference between said wave energy and said produced voltages, and detecting the frequency changes in said other wave energy.

2. The method of detecting variations in the frequency of wave energy the frequency of which is shifted abruptly in accordance with control potentials from a marking frequency to a spacing frequency separated one from the other by a difference frequency which includes the following steps, producing oscillating voltages which are shifted between two frequencies correspondingly related to the marking and spacing frequencies of said wave energy, inhibiting shifts

in said produced voltages in the presence of variations in the frequency of said wave energy of less extent than said variations in accordance with said control potentials, combining said wave energy with said produced oscillations to produce other energy the frequency of which varies when the difference frequency between said wave energy and said produced voltage changes, and detecting the frequency changes in said other wave energy.

3. The method of detecting variations in the frequency of signals comprising wave energy the frequency of which varies in accordance with control potentials from a first frequency indicating one signalling condition to a second frequency indicating another signalling condition separated one from the other by a difference frequency which includes the following steps, producing oscillating voltages which are shifted between two frequencies as said wave energy varies from said first to said second frequency, inhibiting shifts in the frequency of said produced voltages in the presence of variations in the frequency of said wave energy of less extent than said variations in accordance with said control potentials, combining said wave energy with said produced oscillations to produce other energy the frequency of which varies when the difference frequency between said wave energy and said produced voltage changes, limiting the amplitude of said other energy, and detecting the frequency changes therein.

4. The method of detecting variations in the frequency of signals comprising wave energy the frequency of which varies in accordance with control potentials from a first frequency indicating one signalling condition to a second frequency indicating a second signalling condition separated from the first frequency by a predetermined frequency difference including the following steps, utilizing said wave energy to produce voltages which are shifted between two frequencies as said wave energy varies from said first to said second frequency, preventing shifts in said produced oscillations in the presence of fast variations of said wave energy of less extent than said variations in accordance with said control potentials, beating said wave energy with said produced voltage to produce beat energy, and detecting variations in the frequency of said beat energy.

5. The method of detecting changes in the frequency of signals comprising wave energy the frequency of which varies in accordance with control potentials from a first frequency to a second frequency separated from the first frequency by a predetermined band of frequencies which includes the steps of, utilizing said wave energy to produce voltages which are shifted between two frequencies as said wave energy varies from said first to said second frequency, preventing shifts in said produced voltage in the presence of slow variations of said wave energy and fast variations in said wave energy of less extent than said variations in accordance with control potentials, beating said wave energy with said produced voltages to produce beat energy, and detecting the variations in the frequency of said beat energy.

6. The method of signalling with wave energy the frequency of which varies in accordance with control potentials from a first frequency to a second frequency separated from the first frequency by a difference frequency which includes the following steps, producing oscillating voltages which are shifted between two frequencies as said

wave energy varies from said first frequency, said second frequency, inhibiting shifts in the frequency of said produced voltages corresponding to variations in the frequency of said wave energy of less extent than said variations in accordance with control potentials, combining said wave energy with said produced voltages to produce other energy the frequency of which varies when the difference frequency between said wave energy and said produced voltage changes, and controlling the average frequency of said first mentioned wave energy in accordance with variations in the frequency of said other energy.

7. The method of receiving signals comprising wave energy the frequency of which varies in accordance with control potentials between a first frequency and a second frequency separated one from the other by a predetermined difference frequency which includes the following steps, producing oscillating voltages which are shifted in frequency between two frequencies as said wave energy varies from said first to said second frequency, inhibiting shifts in the frequency of said produced voltages corresponding to variations in the frequency of said wave energy of less extent than said variations in accordance with control potentials, combining said wave energy with said produced voltages to produce other energy the frequency of which varies in accordance with the difference between said wave energy and said produced voltages, limiting the amplitude of said other energy, and controlling the average frequency of said first mentioned wave energy in accordance with variations in the frequency of said other energy.

8. The method of signalling with wave energy the frequency of which varies in accordance with control potentials from a first frequency to a second frequency separated from the other by a difference frequency which includes the steps of, producing oscillating voltages which are correspondingly shifted between two frequencies correspondingly related to the first and second frequencies of said wave energy, inhibiting shifts in said produced voltages corresponding to variations in the frequency of said wave energy of less extent than said variations in accordance with control potentials, combining said wave energy with said produced oscillations to produce other energy the frequency of which varies when the difference frequency between said wave energy and said produced voltage changes, and controlling the mean frequency of said first wave energy in accordance with variations in the frequency of said other energy.

9. In a receiver of wave energy the frequency of which is alternately modulated from one frequency corresponding to marking to another frequency corresponding to spacing for signalling purposes, an amplifier having an input excited by said wave energy and having an output, an oscillation generator, a frequency discriminating circuit including a rectifier system, said circuit having an input coupled to the output of said amplifier, means coupling said rectifier system to said oscillation generator to control the frequency of operation thereof in accordance with current flow in said rectifier system, a converter coupled to said oscillation generator, a coupling between the output of said amplifier and said converter, and means for detecting changes in the frequency of energy derived from said converter.

10. Means for detecting variations in the frequency of wave energy modulated at signal fre-

quency between a first and second frequency comprising, a frequency discriminating circuit including a pair of rectifiers having their corresponding electrodes connected in opposed relation by an impedance, a source of local oscillations, means coupled with said impedance for modulating the frequency of said oscillations in a manner corresponding to the variations of said wave energy between said first and second frequencies, means for preventing modulation of said oscillations in the presence of changes in the frequency of said wave energy of less extent than said modulation of said first wave energy, means for heterodyning said local oscillations against said first-mentioned wave energy to derive a beat note, and means for detecting changes in the frequency of said beat note.

11. In a system for amplifying and demodulating wave energy modulated in accordance with signals between a first frequency and a second frequency, means including a tunable oscillator for heterodyning said modulated wave to correspondingly modulated wave energy of lower frequency, a frequency discriminating circuit coupled to a rectifier system having electrodes coupled with signal output means, means for impressing said wave energy of lower frequency on said discriminating circuit, and means for controlling the tuning of said oscillator comprising a second source of oscillations, means for modulating the frequency of the oscillations from said second source in a manner corresponding to variations in the output of said rectifier system, means for preventing modulation of said oscillations in the presence of changes in the frequency of said wave energy of lower frequency of less extent than the modulations thereof, means for heterodyning said oscillations so modulated against said wave energy of lower frequency to derive a beat note and means for controlling the tuning of said tunable oscillator in accordance with variations in the frequency of said beat note.

12. In means for amplifying and demodulating wave energy modulated in accordance with signals, apparatus including a tunable oscillator for heterodyning said modulated wave energy to lower frequency correspondingly modulated wave energy, a frequency discriminating circuit coupled to a pair of rectifiers having their electrodes connected in opposed relation by an impedance to signal output means, connections for impressing said wave energy of lower frequency on said frequency discriminating circuit, and means for controlling the tuning of said tunable oscillator comprising a second source of oscillations, means controlled by current in said impedance for modulating the frequency of the oscillations of said second source in a manner corresponding to the variations of said first wave energy in accordance with signals, means for preventing modulation of said oscillations in the presence of changes in the frequency of said first wave energy of less extent than the modulations thereon, means for heterodyning said oscillations so modulated against said wave energy of lower frequency to derive a beat note, means for limiting the amplitude of said beat note, means for detecting changes in the frequency of said beat note, and means for adjusting the tuning of said tunable oscillator in accordance with variations in the frequency of said beat note.

13. In a receiver of wave energy the frequency

of which is alternately modulated from one frequency to another frequency for signalling purposes, an oscillation generator, a frequency responsive circuit having an input, means for impressing said modulated wave energy on the input of said frequency responsive circuit, a coupling between said frequency responsive circuit and said oscillation generator to control the frequency of operation thereof in accordance with the energy passed by said frequency responsive circuit, means in said coupling for preventing control of said oscillation generator in accordance with changes in the frequency of said wave energy of less extent than the changes caused by modulation thereof, a converter coupled to said oscillation generator, means for impressing said modulated wave energy on said converter, and means for detecting changes in the frequency of energy derived from said converter.

14. In a system for amplifying and demodulating wave energy modulated in accordance with signals from a first frequency to a second frequency separated from said first frequency by a substantial band of frequencies, a frequency responsive circuit coupled to a rectifier system having electrodes coupled with signal output means, connections for impressing said wave energy on said frequency responsive circuit, and means for preventing deviations in the mean frequency of said first-mentioned wave energy comprising a source of oscillations, means excited by said first-mentioned wave energy for shifting the frequency of said oscillations between two frequencies separated by a band of frequencies of the order of said first band of frequencies, means for preventing shifts in the frequency of said oscillations in the presence of variations in the frequency of said wave energy of less extent than the modulations in accordance with signals, means for heterodyning said oscillations against said first mentioned wave energy to derive a beat note, and means for controlling the frequency of said first mentioned wave energy in accordance with variations in the frequency of said beat note.

15. In a system for amplifying and demodulating wave energy modulated for signalling purposes between a first frequency and a second frequency, and for stabilizing the mean frequency of said wave energy, a frequency responsive circuit coupled to a demodulator having electrodes coupled with signal output means, means for impressing said first-mentioned wave energy on said frequency responsive circuit, an oscillation generator, keying means coupled to said generator and controlled by the output of said demodulator for changing the frequency of the generated oscillations in a manner corresponding to variations in the output of said demodulator which exceed a selected value, means for heterodyning said generated oscillations against said first mentioned wave energy to derive a beat note, a second frequency discriminator circuit having an input coupled to said last named means, a second demodulator coupled to said second frequency discriminator circuit, said second demodulator having an output, and means for controlling the frequency of said first mentioned wave energy by currents derived from said last-named demodulator output.

HAROLD O. PETERSON.