Feb. 22, 1949. M. G. CROSBY 2,462,470

TELEGRAPHY RECEIVER WITH AUTOMATIC FREQUENCY CONTROL

Filed June 17, 1943 4 Sheets-Sheet 1

Fig. 1

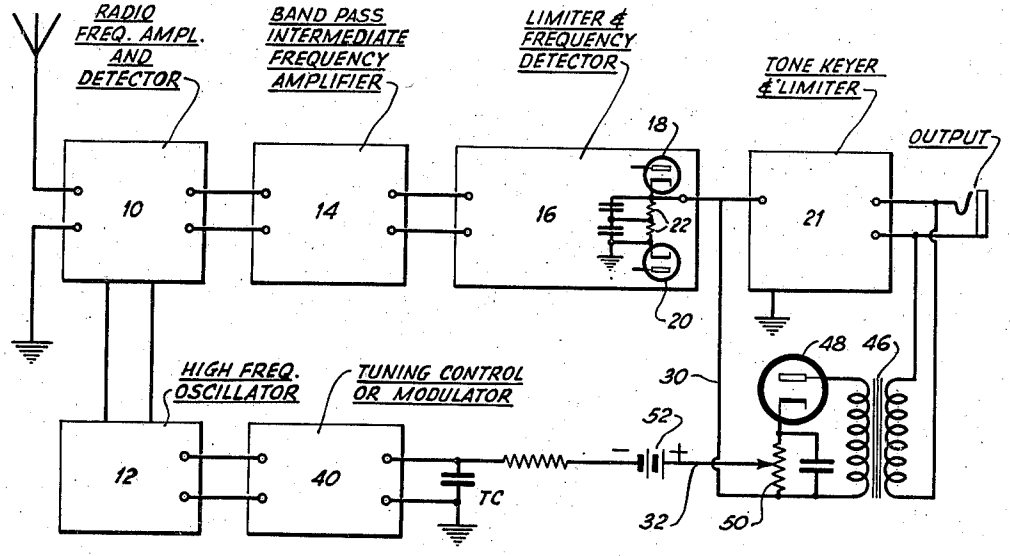
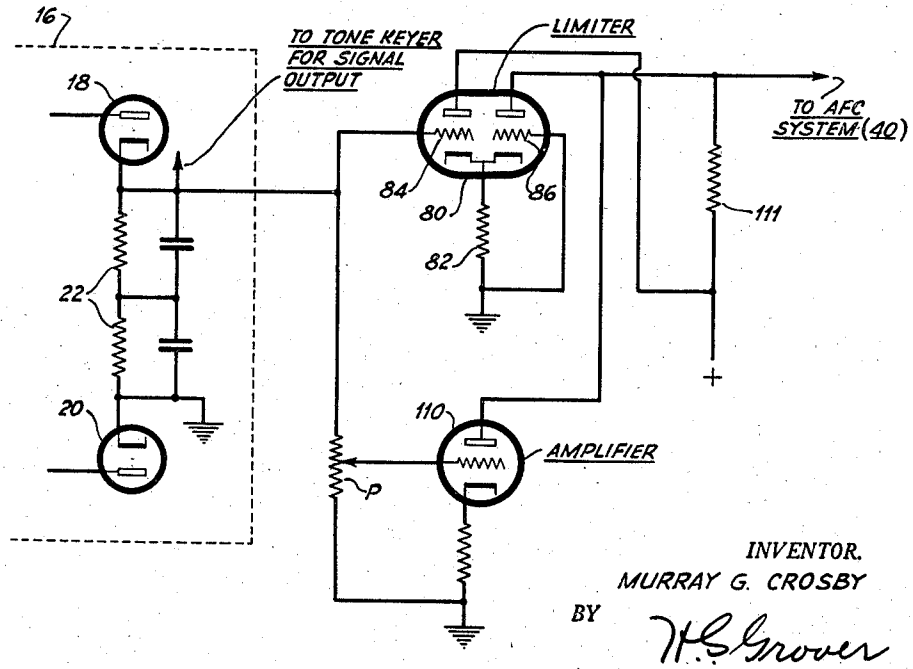


Fig. 5



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TELEGRAPHY RECEIVER WITH AUTOMATIC FREQUENCY CONTROL

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RECEIVER PROPERLY TUNED ON MEAN FREQUENCY

Fig. 2a

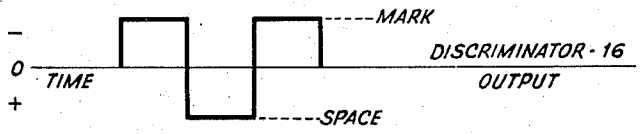


Fig. 2b

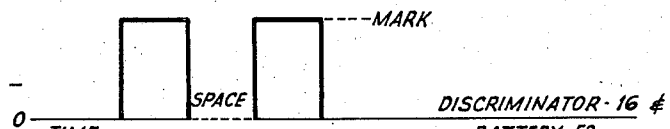


Fig. 2c

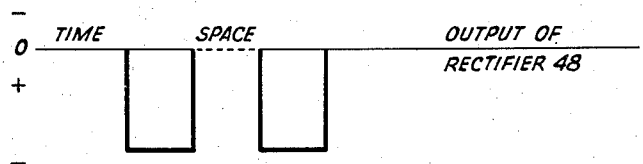
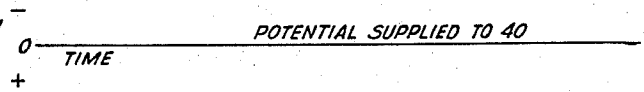


Fig. 2d



RECEIVER OFF TUNED TOWARD MARK FREQUENCY

Fig. 2e

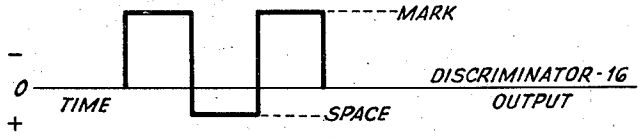


Fig. 2f

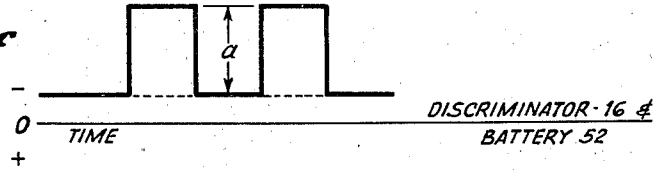


Fig. 2g

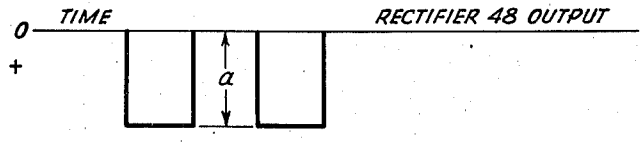
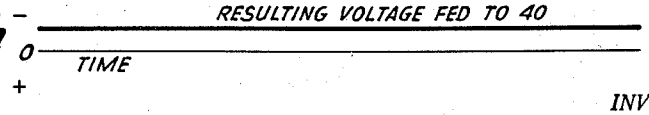


Fig. 2h



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TELEGRAPHY RECEIVER WITH AUTOMATIC FREQUENCY CONTROL

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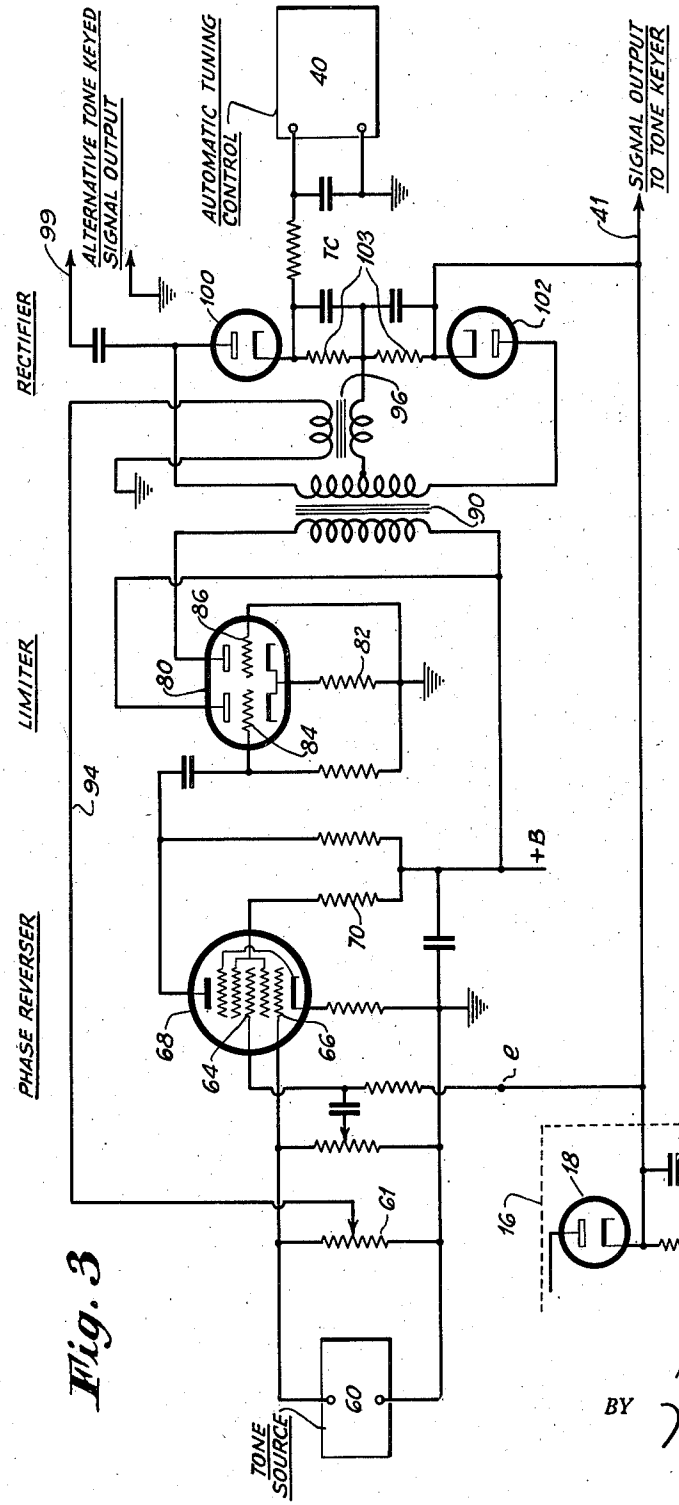


Fig. 3

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TELEGRAPHY RECEIVER WITH AUTOMATIC FREQUENCY CONTROL

Filed June 17, 1943 4 Sheets-Sheet 4

Fig. 4a

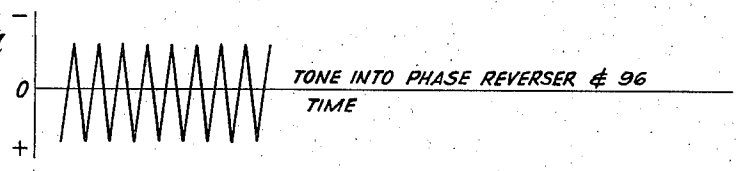


Fig. 4b

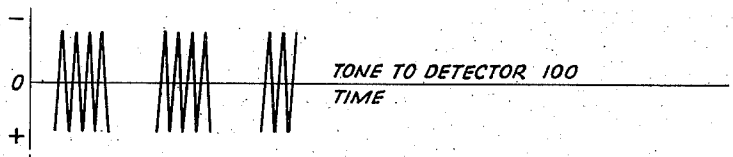


Fig. 4c

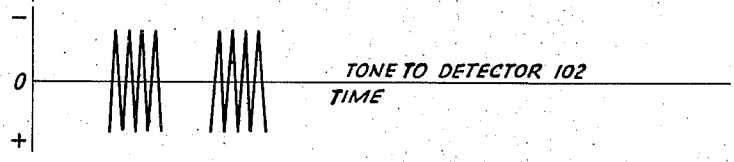


Fig. 4d

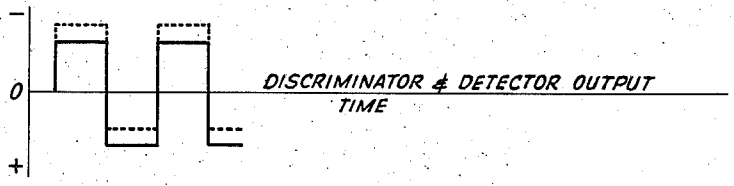


Fig. 4e

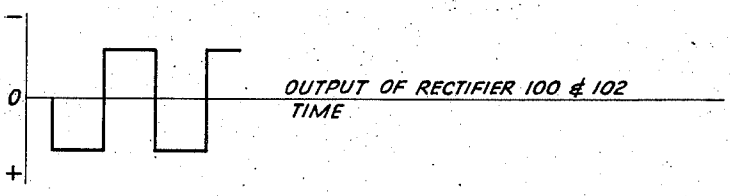
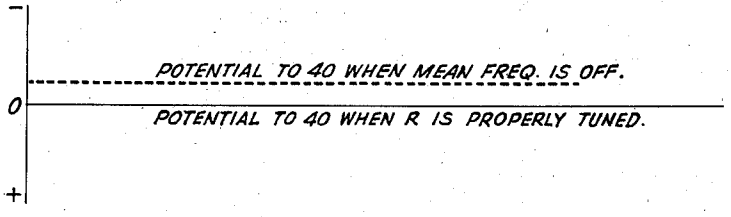


Fig. 4f



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Patented Feb. 22, 1949 2,462,470

UNITED STATES PATENT OFFICE

2,462,470

TELEGRAPHY RECEIVER WITH AUTOMATIC FREQUENCY CONTROL

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

Application June 17, 1943, Serial No. 491,106

18 Claims. (Cl. 250—40)

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This application concerns receivers of telegraphy signals of the type wherein wave energy is keyed in accordance with signals from a first frequency which may be designated the marking frequency to a second frequency spaced therefrom an appropriate amount, say for example, 1000 cycles which may be designated the spacing frequency and vice versa. Signals of this type have been referred to as space wave keying. The signals may be sent out in various manners, for example, by means of a transmitter of the type illustrated in Finch United States Patent #2,225,-691, dated December 24, 1940.

The receivers of these signals preferably include automatic tuning control means and my invention concerns a new and improved receiver for signals of this type including automatic tuning means.

Since these signals are interrupted and shifted in frequency in accordance with signals from space frequency to mark frequency or vice versa, obviously the usual automatic tuning control means known in the art might tend to follow such keying.

In my improved system, I provide means for maintaining the tuning of the receiver at some fixed point with respect to mark or space frequency. In the embodiments illustrated the tuning of the receiver is maintained at a fixed position in the frequency spectrum with respect to either the mark or space wave frequency.

A primary object of my invention then is to provide an improved telegraph receiver for frequency modulated telegraph signals which receiver includes improved automatic frequency control means which will maintain the tuning of the receiver at a fixed frequency with respect to either the mark or the space frequencies which tuning means will not tend to follow the said mark or said space frequency.

The manner in which the said primary object and other objects of my invention are attained will appear from the detailed description thereof which follows.

As to the novel principle involved, it may find application in numerous embodiments in addition to the several specific embodiments I show in the drawings and describe in the specification.

In accordance with my invention, I provide an output which follows the keyed spaced wave and varies above and below a base value symmetrically as long as the receiver is properly tuned. If the receiver becomes mistuned the excursions with respect to said base value are non-symmetrical and in a direction which depends on the direction in which the receiver is mistuned.

I also provide an output which follows the keyed spaced wave and varies above and below a base value symmetrically at all times irrespective of whether the receiver is properly tuned or mistuned. This last output may be obtained by limiting the said first output.

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The two outputs are combined in opposed relation and their amplitudes relatively adjusted so that when the receiver is properly tuned the outputs cancel. When the receiver is mistuned these outputs no longer cancel and a resultant output, which is of a value and direction depending on the direction of mistune of the receiver, is provided for tuning purposes.

In the description which follows reference is made to the attached drawings, wherein Fig. 1 illustrates mainly by block diagram the essential features of a telegraph receiving system and tuning control means therefor arranged in accordance with my invention.

Figs. 2*a* to 2*h* are graphs illustrating the operation of telegraphy receivers arranged in accordance with embodiments illustrated in Fig. 1.

Fig. 3 illustrates a modification of the tuning control means of Fig. 1.

Figs. 4*a*, 4*b*, 4*c*, 4*d*, 4*e* and 4*f* illustrate graphically the operation of the receiver when modified as illustrated in Fig. 3.

Figure 5 illustrates a modification of a portion of the receiving system shown in Figure 1.

In Fig. 1, unit 10 is a radio frequency amplifier and detector wherein the keyed spaced wave is received and amplified and mixed with high frequency oscillations from an oscillator 12. A beat frequency is selected from unit 10 and supplied to band pass intermediate frequency amplifiers in unit 14, wherein it is amplified and supplied to a current amplitude limiting, frequency discriminating and amplitude modulation detecting system in unit 16. The amplitude limiting, frequency discriminating and detecting means in unit 16 may be conventional and it is believed the same does not need detailed description here. In unit 16 the frequency and amplitude modulated wave resulting from the conversion in the discriminating circuits, however, is supplied to two differentially connected diode detectors 18 and 20, wherein it is rectified to produce in a known manner a differential potential drop across the resistors 22 which is characteristic of the spaced wave keying. This modulation output which has been shown graphically in Fig. 2*a* keys on and off oscillations from a source unit in 21. The circuits and apparatus in unit 21 as controlled by the output of the detectors in 16 have become known in the art as a tone keyer, and at the output thereof is supplied tone pulses the recurrence and duration of which represent the keyed mark frequency. The amplitude of these tone pulses is held constant by limiting or other means which are part of the tone keyer. This output may be supplied by a jack to utilizing circuits such as, for exam-

ple, over tone lines to a recorder at the remotely located receiver.

The output of the differential diode detectors 18 and 20 which follows the keyed spaced waves is also supplied by line 30 and line 32 to a time constant network TC and thence to a tuning control mechanism or modulator in unit 40 which acts on the high frequency oscillator in unit 12 to correct the tuning thereof in such a sense as to cause the output of the mixer in unit 10 to be at a desired frequency. Note that as the system is now described the oscillator in unit 10 would be keyed or would follow the keyed output of the detectors 18 and 20, which is undesirable. Some of the keyed tone output of unit 24 is supplied to a transformer 46 and thence to a rectifier 48 which has a load resistance 50 in its cathode circuit. This load resistance 50 is included in the circuit comprising leads 30 and 32 as is the direct current source 52.

The discriminator output supplies a potential over leads 30 and 32 to the time constant network TC and thence to the control circuits in unit 40 (disregarding for the time being the direct current source 52 and assuming no potential drop in resistance 50) which shifts from a base value (taken as zero here but not necessarily zero) to a negative value when mark is received or to a positive value when space is received, all as shown graphically in Fig. 2*a*. Now disregarding the drop in unit 50 as specified above the direct current source 52 is so poled as shown, and of such a value that the potentials on space, i. e., those which swing positive from the base value are just wiped out so that the control tube in unit 40 would receive the base value potential on space and a negative potential about twice as much as it would receive in the absence of direct current source 52 on mark, as shown in Fig. 2*b*. The keyed tone output acting from transformer 46 and rectifier 48, however, which represents mark is rectified in rectifier 48 to produce a potential drop in resistance 50 as shown in Fig. 2*c*, which when the receiver is tuned propely is of a positive potential such that it just cancels out the negative potential supplied by the discriminator output and battery. I then supply to the control means in unit 40 a potential of a base value as illustrated in Fig. 2*d* and no change is made in the oscillator frequency when the receiver is properly tuned.

Now assume that the receiver is out of tune in a direction toward mark. The discriminator output now becomes non-symmetrical as shown in Fig. 2*e*, with the negative potentials of higher than normal value and the positive potentials of less than normal value. This output then when considered with the direct current source 52 is as represented in Fig. 2*f* and is not cancelled by the output of the rectifier 48. The output of the rectifier is constant in amplitude since the output of the tone keyer is limited to a constant value. It therefore has the constant wave form as shown in Fig. 2*g* when out of tune and also as shown in Fig. 2*c* when in tune. This leaves a residual potential acting through the time constant network as illustrated in Fig. 2*h* and this potential operates on the control means in unit 40 to retune the oscillator in unit 12 in a direction to bring the receiver in tune so that the intermediate frequency supplied to the discriminator circuit falls at the point of intersection on the sloping characteristic of the discriminator circuit.

In Fig. 3, I have shown a modification of the arrangement in Fig. 1. In Fig. 3, unit 60 represents the tone source from which voltages of the tone frequency are fed to a resistance 61 and thence in relatively adjustable amounts to the two grids 64 and 66 of a phase reversing tube 68. The tube 68 has its second grid supplied with potential by an unbypassed resistor 70 and operates as disclosed in detail in my U. S. application Serial No. 393,339, filed May 14, 1941, Patent #2,380,947 dated August 7, 1945, to supply to its anode tone oscillations the phase of which is reversed by application of a potential to one of the control grids, say at *e*, to control grid 64. As disclosed in detail in said application, when the proper value of unbypassed resistor 70 is used in a two grid tube the phase of the voltage amplified by the first grid is reversed. At the same time, the phase relation of the voltage amplified by the third grid 64 is unaffected, so that if voltages of the same phase are fed to both grids they will oppose in the output. By controlling the potential on one grid, say 64, the voltages amplified by one grid can be made to vary in magnitude so that the voltage out reverses in phase as the control potential is varied.

The control potential in this application supplied at *e* is derived from the rectifiers 18 and 20 in the discriminator and rectifier arrangement in unit 16 so that at the output of tube 68 are supplied tone oscillations the phase of which is reversed as the space wave keyed input to the receiver and at unit 16 in Fig. 1 is keyed from mark to space and vice versa.

This phase reversed output is supplied to a limiter tube 80, which has two tube systems, and thence to the primary winding of a transformer 90. The limiter tube 80 has its cathodes connected to ground by a common resistor 82 so that the potential drop in this resistor is fed to the grid 84 of one tube system and to the grid 86 of the other tube system. The first anode is connected substantially directly to a source while the second anode is connected to the primary winding of the transformer 90. This limiter tube is adjusted and operated in such a manner that the first grid 84 is effective for negative grid limiting of the negative half cycles of the input signal. This is because the bias is such that on the negative half cycles the tube is cut off at a selected point so that an increase of applied negative potential has no further effect on the tube output. The second grid, due to phase reversal of its grid cathode voltage with respect to the grid cathode voltage of the first tube, is effective for negative grid limiting on the positive half cycles of the input wave. This is because on positive half cycles the positive drop in resistance 82 grows to a point at which the grid 86 is biased negative to cutoff so that further increases in applied positive potential have no effect on the output. This limiter has been described in my U. S. Patent No. 2,276,565, dated March 17, 1942.

The secondary of transformer 90 is accordingly supplied with tone frequency the phase reversals of which follow the mark and space keying of the spaced wave being received. The tone output is also supplied by line 94 to the primary winding of a transformer 96 and from the secondary winding in parallel to the rectifiers 100 and 102. The tone output to the phase reverser and to the transformer 96 is as illustrated in Fig. 4*a*. Since the rectifiers 100 and 102 are excited differentially by tone of reversing polarity from transformer 90, and in parallel by the tone output through transformer 96, the input to recti-

fiers 100 and 102 will be as illustrated in Figs. 4b and 4c, i. e., the voltages in the secondary windings of transformers 90 and 96 will alternate from in phase to 180° out of phase as the phase reverser tube 68 is keyed by the discriminator output, and the voltages will add on one side and oppose on the other side and the one voltage i. e., the one in the secondary winding 90 will reverse so that the detectors are alternately excited by the keyed tone oscillations of limited amplitude.

The rectifiers 100 and 102 have their cathodes connected differentially by resistances 103 which are in series with the differential resistances 22 of the output of the detectors 18 and 20 of the discriminator 16. The output of the receiver discriminator and detectors 18, 20, when the receiver is in tune, will be as illustrated by full lines in Fig. 4d. The output of the rectifiers 100 and 102 will be as illustrated by full lines in Fig. 4e. These outputs are combined in series as shown and cancel out so that a base potential which may be zero, as shown by the full line in Fig. 4f, is supplied to the automatic control means 40 which permits the oscillator to hold the proper frequency for supplying to the discriminator a beat frequency the mean frequency of which falls at the intersection of the sloping characteristic of the discriminator circuit.

Now suppose that the wave reaching the discriminator circuit is off tune, so that its average or mean frequency is biased towards mark. The discriminator output will be as illustrated by dotted lines in Fig. 4d. Note now that the keyed wave is no longer symmetrical. Due to the presence of the limiter, which functions to make the mark and space excursions equal, the output of the rectifiers 100 and 102, however, remains as before, so that in the series output circuits the output of rectifiers 100 and 102 no longer cancels the output from the discriminator rectifiers 18 and 20. This has been shown by dotted lines in Fig. 4d and Fig. 4f, and the potential supplied to the automatic frequency control means 40 is no longer the base potential. This residual potential operates through the controlling means to retune the receiver in such a direction that the beat frequency supplied to the discriminator again falls at the intersection of the discriminator sloping characteristic.

The signal output may be taken from lead 41 and used as desired. For example, it may be used to key a tone source and limiter similar to that shown in Fig. 1. Output in the nature of tone oscillations keyed in accordance with the signals may also be taken between lead 99 and ground. This output could be represented by the graph in Fig. 4b.

A simplified embodiment of my means is illustrated in Fig. 5. The discriminator and detector output from tubes 18 and 20 (as illustrated in Fig. 4d by dotted lines when the receiver is out of tune by full lines when the receiver is in tune), is fed to a limiting stage including a tube 80 connected and operated for full wave limiting substantially as described in connection with Fig. 3. The output of the discriminator detectors 18 and 20 is also fed to an amplifier 110 through a potentiometer P.

The output of the amplifier follows the output of the discriminator detector. The output of the limiter also, in a sense, follows the output of the discriminator detector, but the excursions are limited and are as illustrated by full lines in Fig. 4e at all times, irrespective of whether the receiver is in tune or out of tune.

These outputs are combined in a common plate circuit of the limiter 80 and amplifier 110, and the combined output may be derived from resistance 111. By virtue of the common cathode resistance 82, there are two reversals in the wave form in the limiter 80 and a single reversal in the amplifier 110, so that the outputs combine in opposition. By adjusting the relative amplitudes of the two outputs at potentiometer P, they are caused to cancel when the receiver is in tune, because then the two outputs are as illustrated in full lines in Figs. 4d and 4e. The resultant base potential as shown by the solid line in Fig. 4f is fed to the control circuit.

When the receiver is mistuned, the output of the limiter (full lines Fig. 4e) does not change but the output of the amplifier changes (say similar to the change shown by dotted lines in Fig. 4d), and there is a resultant potential (dotted line Fig. 4f) at the resistance 111 which is fed to the tuning control 40.

I claim:

1. In apparatus for deriving a potential which changes when the mean frequency of wave energy changes, which wave energy is modulated from a first frequency through said mean frequency to a second frequency by signals, means excited by said wave energy for deriving an output which is correspondingly shifted between two values which change with reference to a base value when said mean frequency changes, additional means for deriving a second output which is shifted between two values which are fixed with respect to a base value regardless of changes in said mean frequency, and means for combining said derived outputs in opposed relation to derive a resultant combined output which is representative of the direction and extent of changes in the mean frequency of said wave energy.

2. In apparatus for deriving a potential which changes when the mean frequency of wave energy changes, which wave energy is modulated from a first frequency to a second frequency by signals, a detector excited by said wave energy for deriving an output which is correspondingly shifted between two values which are symmetrically related to a base value when said mean frequency is of a selected value and unsymetrically related to said base value when said mean frequency changes from said selected value, additional means including said detector excited by said wave energy for deriving a second output which is shifted between two values symmetrically related to a base value irrespective of changes in the mean frequency, and means for combining said outputs in opposed relation to derive a resultant output which is representative of the changes in the mean frequency of said wave energy.

3. In apparatus for deriving a potential which changes when the mean frequency of wave energy changes, which wave energy is modulated from a first frequency to a second frequency by signals, a frequency responsive circuit and detector excited by said wave energy for deriving a potential which is correspondingly shifted between two values which change with reference to a base value when said mean frequency changes, additional means including said frequency responsive circuit and detector excited by said wave energy for deriving a second potential which is shifted between two values which are fixed with respect to a base value at all times, and means for com-

bining both said derived potentials in opposed relation to derive a resultant potential which is representative of the changes in the mean frequency of said wave energy.

4. In a receiver of wave energy which is modulated from a first frequency through a mean frequency which may vary in an undesired manner to a second frequency by signals, a tunable amplifier excited by said wave energy, said amplifier having an output, a detector excited by said wave energy for deriving a potential which is shifted from a first value through a base value to a second value, said first and second values being symmetrically related to said base value when said amplifier is properly tuned and unsymmetrically related to said base value when said amplifier is improperly tuned, additional means including said detector for deriving a second potential which is shifted between two values symmetrically related to a base value, means for combining said derived potentials in opposed relation to derive a resultant potential which is representative of the changes in the mean frequency of said wave energy, and connections to said tunable amplifier to control the tuning thereof in accordance with said resultant potential.

5. In a system for receiving wave energy keyed from a first frequency to a second frequency, a tunable amplifier for said wave energy, a frequency responsive circuit and detector coupled to said amplifier for deriving a voltage keyed from a first value to a second value as the wave energy is keyed from said first frequency to said second frequency, a control circuit coupled to said tunable amplifier for tuning the same, connections between said detector and said control circuit, and a voltage limiter excited by said keyed voltage and having an output included in said connections for combining the output of said detector and the output of said limiter in opposed relation.

6. In a system for receiving wave energy keyed from a first marking frequency to a second spacing frequency a tunable amplifier for said wave energy, a frequency discriminator and detector excited by said keyed wave energy for deriving therefrom a voltage keyed from a first value through a base value to a second value as the wave energy is keyed from said first frequency to said second frequency, said voltages of said first and second values being symmetrically related to said base value when said amplifier is properly tuned and unsymmetrically related to said base value when said amplifier is not properly tuned, a control circuit coupled to said tunable amplifier for tuning the same, connections between said detector and said control circuit, means controlled by said derived voltage for deriving a second voltage which varies between two values symmetrically related to a base value irrespective of the tuning of said amplifier, and connections between said last named means and said control circuit.

7. In a system for receiving wave energy keyed from a mark frequency to a space frequency, a tunable amplifier for said wave energy, a frequency discriminator and detector coupled to said amplifier for deriving a voltage keyed from a first value to a second value as the wave energy is keyed from a mark frequency to a space frequency, a control circuit coupled to said tunable amplifier for tuning the same, connections between said detector and said control circuit, a source of potential in said connections of a value and polarity such as to oppose and cancel the

keyed voltage corresponding to space or mark and a voltage amplitude limiter excited by said keyed voltage and having an output connected with said control circuit, said limiter providing a potential to cancel the other of said voltages when the amplifier is properly tuned.

8. In a system for receiving wave energy keyed from a first marking frequency to a second spacing frequency, a tunable amplifier for said wave energy, a frequency discriminator and detector excited by said keyed wave energy for deriving therefrom a voltage keyed from a first value through a base value to a second value as the wave energy is keyed from said first frequency to said second frequency, a control circuit coupled to said tunable amplifier for tuning the same, connections between said detector and said control circuit, a source of potential in said connections of a value and polarity such as to oppose and cancel the derived voltage excursions on one side of said base value and to add to the derived voltage excursions on the other side of said base value, a tone keyer controlled by said derived voltage, and a rectifier coupled to said tone keyer and having an output impedance in said connections, said rectifier providing a potential in said impedance of a magnitude sufficient to cancel the added voltage when the amplifier is properly tuned.

9. In a tunable receiver for wave energy the frequency of which is keyed from a first value to a second value in accordance with signals including, a discriminator and detector for deriving from said keyed wave a voltage of a magnitude which shifts substantially symmetrically above and below, respectively, a base value when said wave energy is keyed from said first frequency to said second frequency and when the tuning of said receiver is such that the mean frequency of the wave energy supplied to the said discriminator and detector is of the proper frequency, connections from said detector to said tunable receiver for controlling the tuning thereof, a tone source, a phase reverser coupled to said tone source and controlled by said derived voltage, an amplitude limiter coupled to said phase reverser, and a rectifier coupled to said amplitude limiter, said rectifier having an output included in said connections for supplying a voltage which compensates said first voltage when the receiver is properly tuned and for providing a residual voltage for retuning said receiver when the same is not properly tuned.

10. In a system for receiving wave energy key from a first marking frequency to a second spacing frequency, a tunable amplifier for said wave energy, a frequency discriminator and detector coupled to said amplifier and excited by said keyed wave energy for deriving a voltage keyed from a first value through a base value to a second value as the wave energy is keyed from said first frequency to said second frequency, a control circuit coupled to said tunable amplifier for tuning the same, a coupling tube in a first path between said detector and said control circuit, and a second path between said detector and said control circuit including a voltage amplitude limiter having an input coupled to said detector, said voltage limiter having an output, and a coupling between the output of said voltage limiter and said control circuit.

11. In a tunable receiver for wave energy the frequency of which is keyed from a first value to a second value in accordance with signals including, a discriminator and detector for deriving

from said keyed wave a voltage of a magnitude which shifts substantially symmetrically above and below, respectively, a base value when said wave energy is keyed from said first frequency to said second frequency and when the tuning of said receiver is such that the mean frequency of the wave energy supplied to the said discriminator and detector is of the proper frequency, connections from said detector to said tunable receiver for controlling the tuning thereof, a source of current in said connections poled to oppose and cancel the effect of said voltage on one side of said base value and to add to said voltage on the other side of said base value, a tone source keyed by said derived voltage, a second rectifier excited by the output of said tone source to produce in said connections a third voltage which compensates the added voltage when the receiver is properly tuned and to provide a residual voltage for retuning said receiver when the mean frequency of the wave energy supplied to said discriminator is not of the proper frequency.

12. The method of maintaining substantially constant the mean frequency of wave energy which may vary in an undesired manner and which is shifted from a first frequency through said mean frequency to a second frequency in accordance with signals which includes these steps, producing a potential which varies substantially symmetrically about a base value as said wave energy is shifted when said mean frequency is of the proper value, and varies unsymmetrically about said base value as said wave energy is shifted when said mean frequency is not of the proper value, producing a second potential which varies substantially symmetrically about a base value as said wave energy is shifted irrespective of changes in said mean frequency, opposing said produced potentials to obtain a resultant potential, and stabilizing said mean frequency in accordance with said resultant potential.

13. The method of obtaining from potentials the mean and peak amplitude values of which may vary, potentials the amplitude of which is characteristic of variations of said mean value which includes these steps, limiting potentials corresponding to said first mentioned potentials to obtain potentials of constant peak amplitude, and combining said limited potentials and first mentioned potentials in opposed polarity relation to obtain said second mentioned potentials.

14. The method of obtaining a potential which varies in accordance with variations in the mean frequency of wave energy of variable frequency which includes these steps, deriving from said wave energy a potential the peak value of which varies in accordance with variations in the mean frequency of said wave energy, deriving from said wave energy a potential the peak value of which is constant irrespective of changes in the mean frequency of said wave energy, and opposing said derived potentials to obtain said first named potential.

15. The method of maintaining substantially constant the mean frequency of wave energy which may vary in an undesired manner and which is shifted about a mean frequency in accordance with signals which includes these steps, producing a potential which varies substantially symmetrically about a base value as said wave energy is shifted when said mean frequency is of the proper value, and which varies unsymmetrically about said base value as said wave energy is shifted when said mean frequency is not of the proper value, producing a second potential which varies substantially symmetrically about a base value as said wave energy is shifted irrespective of changes in said mean frequency, said produced potentials being of substantially like magnitude when said first potential varies substantially symmetrically about said base value, opposing said produced potentials to obtain a resultant potential, and stabilizing the mean frequency of said first mentioned energy in accordance with said resultant potential.

16. In means for producing direct current potential of substantially zero value from recurring potentials of substantially like value and opposed polarity which appear alternately and for producing a residual potential when said recurring potentials are of unlike value, a resistance and condenser in a series circuit excited by said recurring potentials, an amplitude limiter having an output circuit including a portion at least of said series circuit, said limiter having an input, connections for impressing said first mentioned recurring potentials on the input of said limiter, and connections for deriving said produced potential from the series circuit.

17. In means for producing direct current potentials of substantially zero value from alternating potentials of substantially like value and opposed polarity and for producing a residual potential when said alternating potentials are of unlike value, a resistance and a condenser in a series circuit excited by said alternating potentials, a source of oscillation keyed by said alternating potentials, a current amplitude limiter excited by the keyed oscillation from said source, a rectifier having an input coupled to said limiter, an output for said rectifier including a portion at least of said series circuit, and connections for deriving the produced direct current potentials from said series circuit.

18. In means for producing direct current potentials of substantially zero value from recurring potentials of substantially like value and opposed polarity alternately present and for producing a residual potential when said recurring potentials are of unlike value, a resistance and condenser in a series circuit excited by said recurring potentials, a first path having an input excited by said recurring potentials and having an output including a part at least of said series circuit, a second path having an input excited by said recurring potentials and having an output including a portion at least of said series circuit, an amplitude limiter in said second path, and a potential phase reverser in one of said paths.

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