July 12, 1938. M. G. CROSBY 2,123,716

AUTOMATIC TUNING CONTROL

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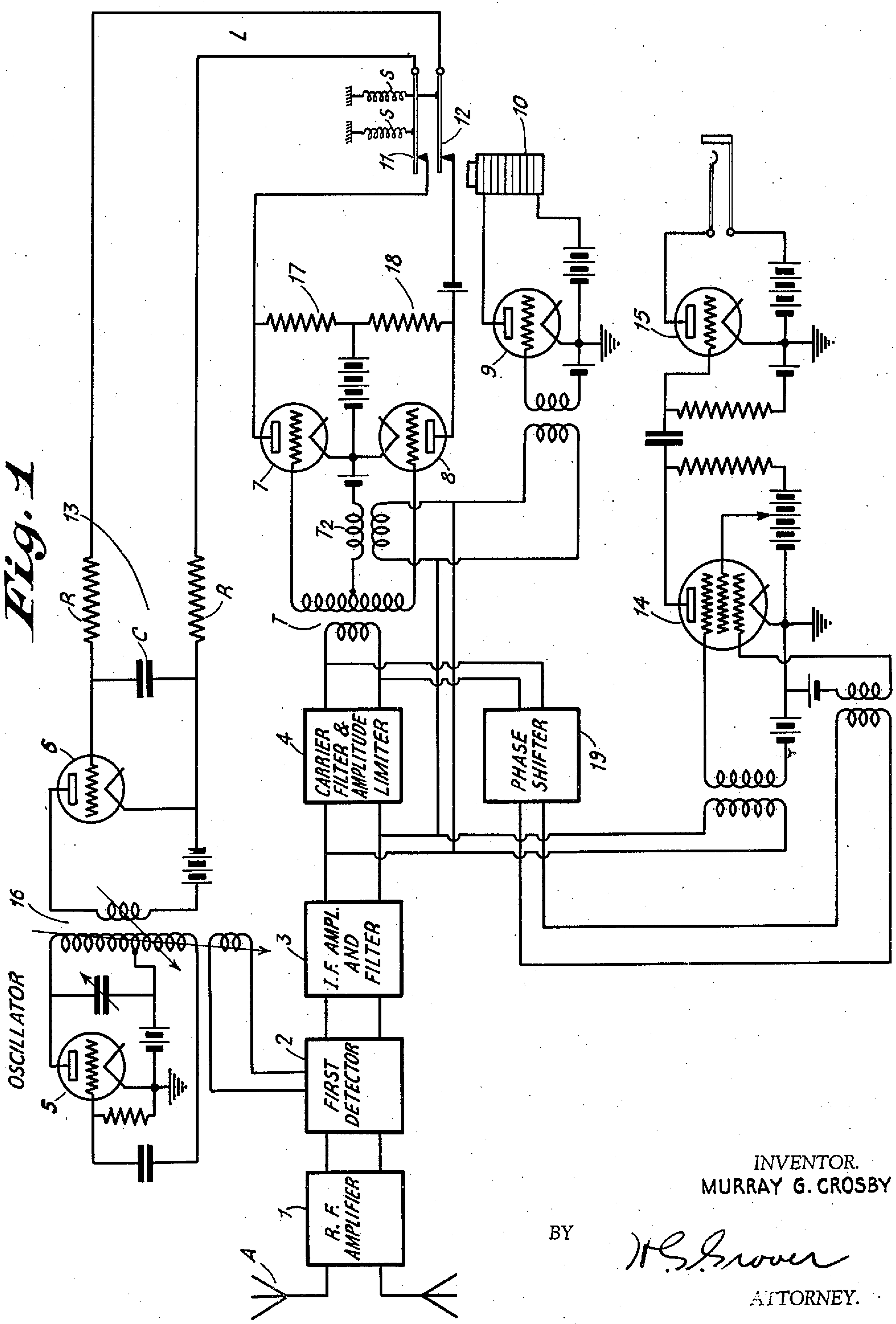

Fig. 1

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Fig. 2

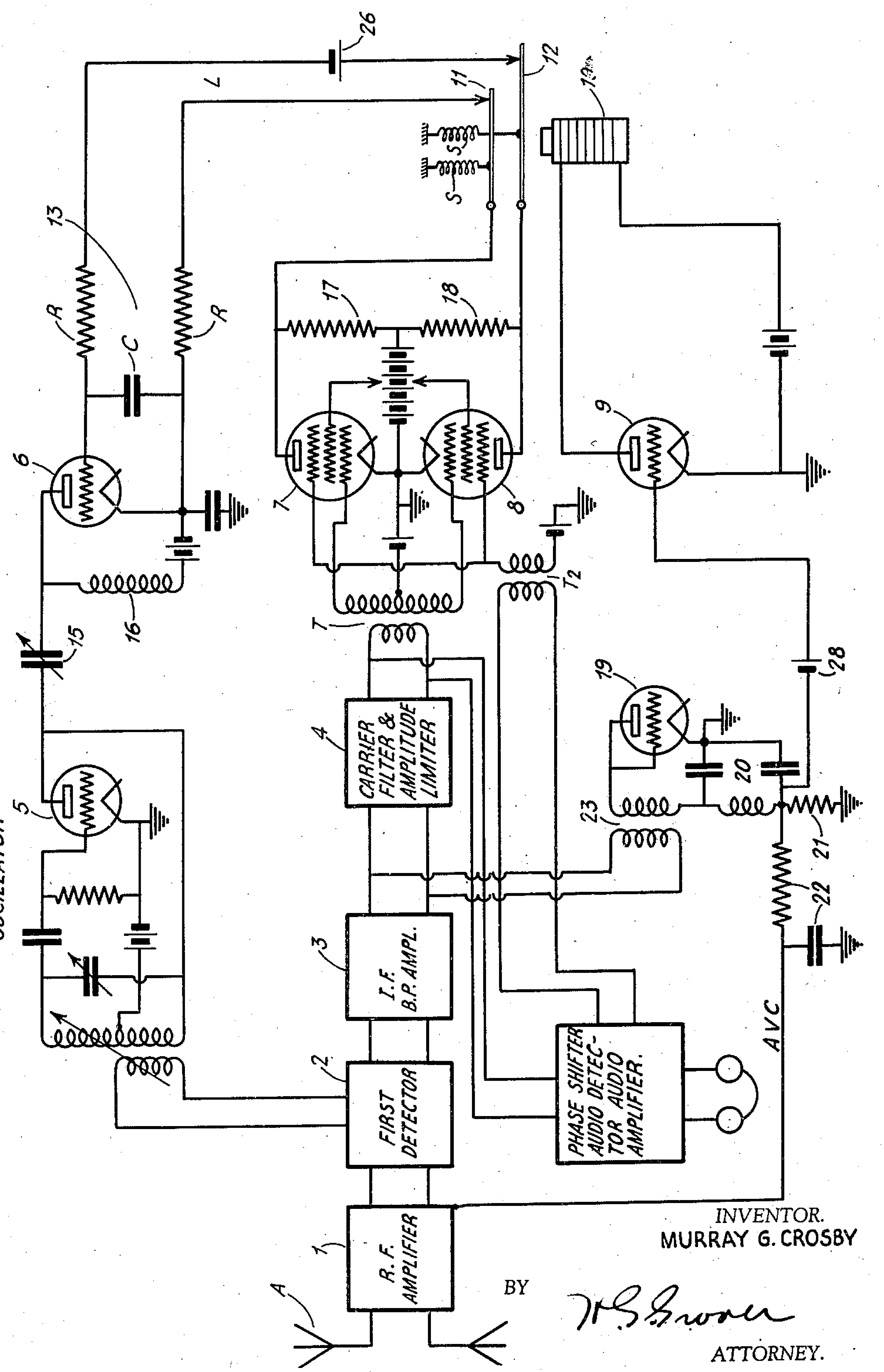

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Fig. 5

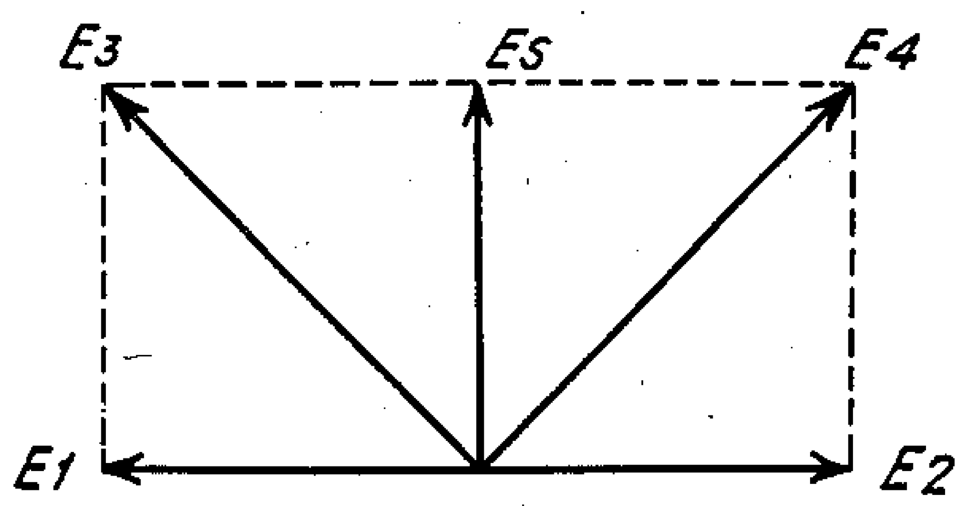


Fig. 6

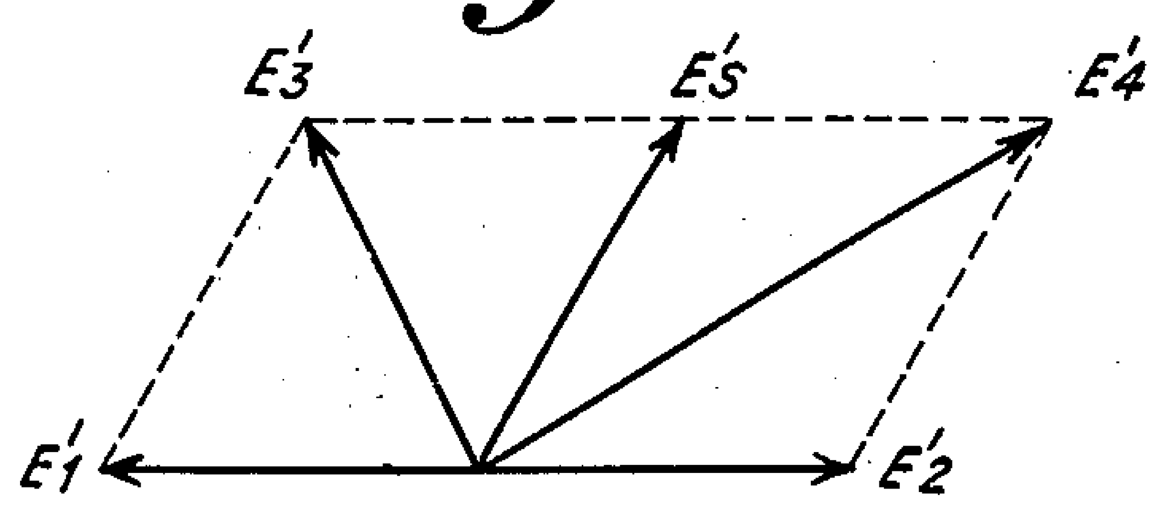


Fig. 7

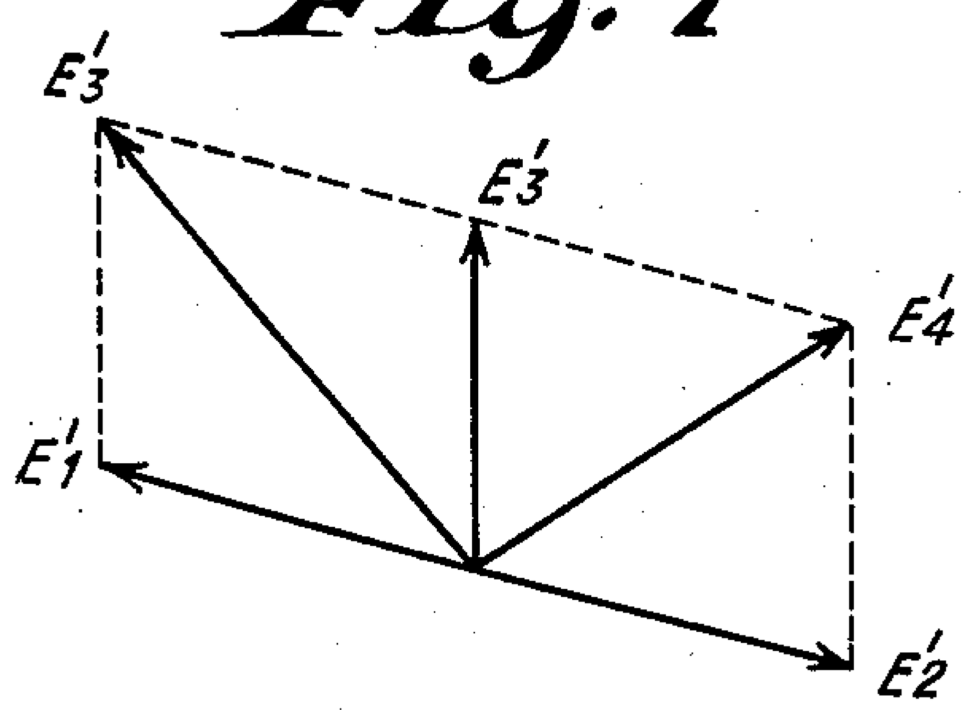


Fig. 3

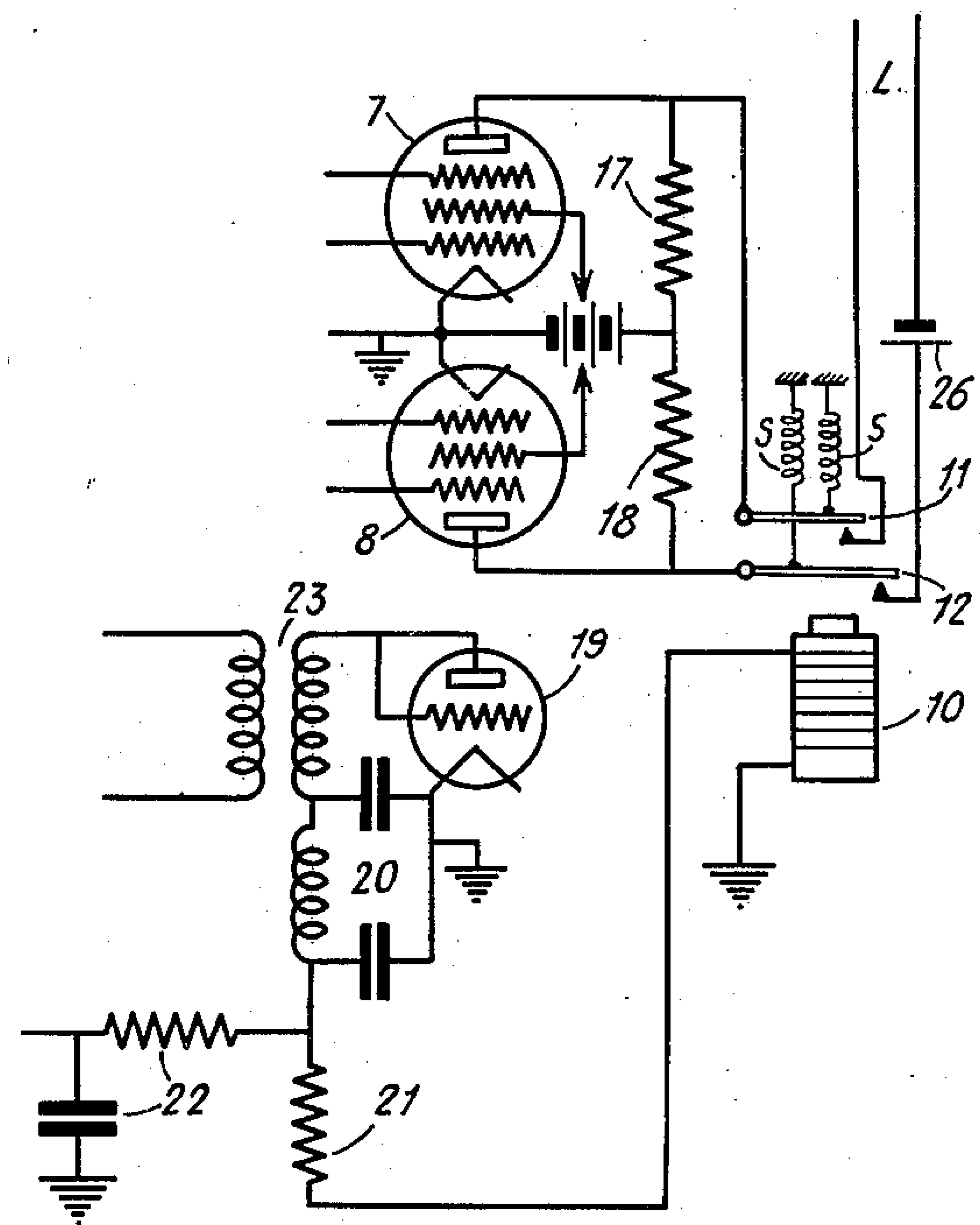
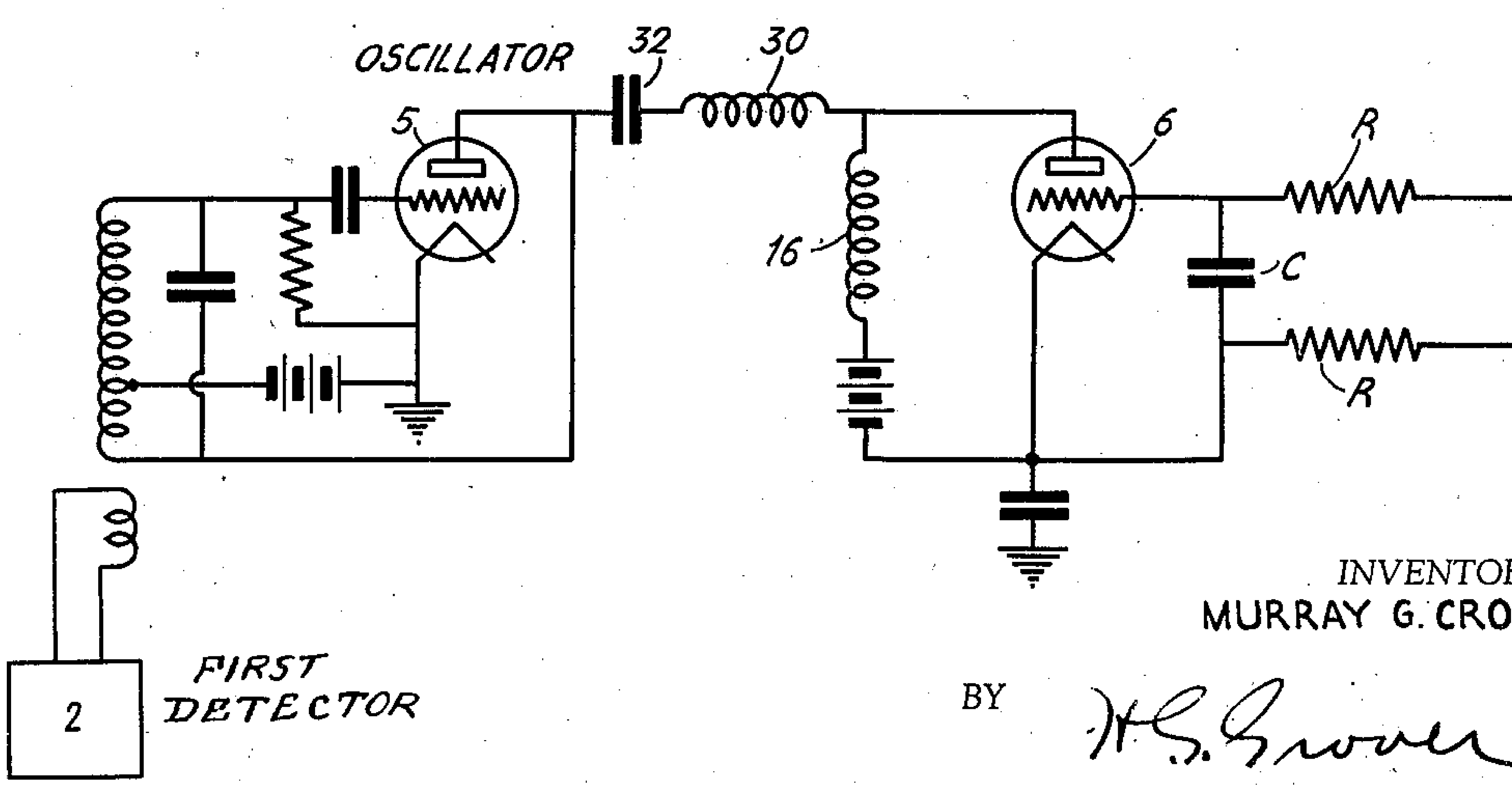


Fig. 4



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Patented July 12, 1938 2,123,716

UNITED STATES PATENT OFFICE

2,123,716

AUTOMATIC TUNING CONTROL

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Application April 16, 1935, Serial No. 16,591

17 Claims. (Cl. 250—20)

This invention relates to a novel method of and means for improving the operation of an automatic tuning control device of the type disclosed in my U. S. application Ser. No. 616,803, filed June 13, 1932 and issued on Dec. 29, 1936 as U. S. P. 2,065,565. In the present method and means, the incoming signal energy is utilized to turn the automatic tuning control on at the signal maximums and to turn the automatic tuning control off during the signal minimums. The tuning means, the control means for the tuning means, and the associated circuits are applicable to receivers of frequency or phase or amplitude modulated oscillations. The method and means of the present invention may be readily applied to new receivers or to receivers known heretofore in the art.

In the prior art, automatic tuning control methods and means and/or automatic frequency control methods and means have been subject to the disadvantage that, during the intervals of low signal strength caused by fading or other phenomena, noise or other interfering signals may become predominant over the signal energy in the receiver, and thereby cause the tuning control and/or frequency control to be shifted outside of its proper range. Hence, when the signal energy reappears, the receiver may be out of tune, and in some cases so far out of tune that the control circuits may be unable to start functioning to retune the receiver.

It is the purpose of the present invention to provide a method and means whereby the reduction of the signal energy below a certain level causes the tuning control or frequency control system to be switched off so that the tuning remains fixed at the point at which it was left when the signal disappeared until the signal energy reappears. In this manner, the frequency control means or tuning control means functions on the signal peaks and is fixed, that is, ceases to operate during the time minimum signal strength is received. Consequently, the effects due to fading are removed.

The novel features of my invention have been pointed out in the claims appended hereto. The nature of my invention and the operation thereof will be understood from the following detailed description thereof and therefrom, when read in connection with the drawings throughout which like reference characters indicate like parts insofar as possible and in which:

Fig. 1 illustrates a receiver of the heterodyne type including a novel frequency control circuit, a novel control system for the frequency control circuit, and signal indicating means;

Fig. 2 shows a modification of the arrangement of Fig. 1;

Figs. 3 and 4 illustrate modifications of portions of the circuit in Fig. 2; while

Figs. 5, 6 and 7 are vector diagrams illustrating the operation of certain portions of the receiver circuits.

The circuit of Fig. 1 shows a specific embodiment of my invention. The receiver of Fig. 1 may comprise an aerial system A connected as shown with a radio frequency amplifier 1. The radio frequency amplifier 1 may be connected as shown to a first detector 2. The first detector 2 is coupled at its output to an intermediate frequency amplifier and filter 3. The intermediate frequency energy is supplied to a carrier filter circuit 4. The circuit 4 may also include an amplitude limiter of any known type. The intermediate frequency energy in 4 is stripped of all side frequencies by the filter therein and is fed in phase opposition by way of a transformer T to the control grids of a pair of thermionic differential detectors 7 and 8. The intermediate frequency energy from the output of the intermediate frequency amplifier 3 is fed directly by way of a transformer T2 cophasally to the control grids of differential detectors 7 and 8. The differential control voltage or resulting voltage from the anodes of the detectors 7 and 8 are fed to resistances 17 and 18 and from said resistances by way of contacts 11 and 12 and a frequency control line L, and time constant circuit 13, comprising resistances R and a capacity C, to the control grid of a modulator tube 6. The anode of the tube 6 is connected with inductance 16, which may be coupled to the tuning inductances of the local oscillator 5 which supplies local oscillations to the first detector for demodulation purposes.

The manner in which the differential currents act in differential detectors 7 and 8 to produce a resultant in 17 and 18 which operates through modulator 6 to control the local oscillator will be understood by reference to the vector diagrams in Figs. 5, 6 and 7. The filtered and limited energy is applied from 4 in phase opposition to control grids of tubes 7 and 8, as shown by vectors E1, E2 of Fig. 5. At the same time, unfiltered carrier energy is supplied from the output of the intermediate frequency amplifier 3 to transformer T2 and from the secondary thereof in phase to the control grids of tubes 7 and 8, as indicated by the vector ES of Fig. 5. The resultant voltages may now be represented by the vectors E3 and E4 when the intermediate frequency obtained by beating oscillations from 5 with the received wave is at the peak of the filter in 4. Now, if the frequency of the oscillator 3 or received signal should change, the vectors of Fig. 5 may shift to positions E'1 and E'2, as shown in Fig. 6, due to the phase change of E1 and E2, as effected by the crystal filter. The resultants E'3 and E'4 are no longer equal. Differential currents appear in 17 and 18 and act through the line L, time control device 13 and modulator 6 to retune the local oscillator 5. If the shift of frequency occurs in the opposite direction, the vectors might be as shown in Fig. 7 and the differential current would act in the opposite direction to retune the oscillator 5 to compensate for said shift. The time constant of the line L and time constant device 13 is such that it responds to frequency changes but does not respond to frequency modulations. The plate impedance of tube 6 is placed across coil 16, which is coupled to the oscillating circuit of oscillator tube 5. Thus, the control voltage produced in 6 functions to change the effective inductance of the tuned circuit of 5 and thereby vary the frequency of the high frequency oscillator to a point such that the differential detectors 7, 8 cease to produce control voltage.

Thus far, the circuit including the tuning control means, the filter circuit, the limiter, etc., are substantially the same as the corresponding elements of the automatic frequency control circuit disclosed in my aforesaid patent. In the present circuit, however, a rectifier tube 9 has its control grid connected as shown to the output of the intermediate frequency amplifier and filter 3 to be energized by unfiltered signal voltage, so that relay 10 may be set to operate at any predetermined value of signal voltage. Hence, the rise in signal voltage will cause the relay to close the contacts 11 and 12 by attracting the same toward the armature of relay 10. This will connect the output of the differential detectors 7 and 8 to the line L and thereby apply the differential voltage to the input of the modulator tube 6. Now, assume that the signal voltage falls off or decreases; the relay contacts 11 and 12 under action of springs S, open, breaking the circuit between L and 17, 18, so that condenser C of time constant circuit 13 remains charged and holds the bias of tube 6 at a fixed point until the signal strength rises again. The function of the relay 9, 10, then, is to disconnect condenser C from the differential detector plates so that C will not discharge through 17, 18 during fading intervals. If the relay 9, 10 were not present, C would quickly discharge through resistors 17 and 18. This would change the tune of 5, that is, detune the receiver. When the signal returned, C would have to be recharged before the receiver would be automatically tuned to the signal. Thus, the tuning control might actually be tuned outside of the range within which it would automatically operate.

The tube 14 may be an audio detector and serves to produce indications of the received wave for recording purposes. The detector 14 may have its grids adjusted on the linear portions of their dynamic characteristics. The unfiltered signal energy is fed from the output of 3 to one grid of tube 14. The filtered or carrier stripped energy is fed from the output of 4 to another grid of the tube 14. The filtered or stripped energy may be passed through the phase shifter 19 to obtain the desired phase relation between the filtered and unfiltered energies on the two grids. This phase relation will be 90° or any odd multiple of 90°, such as 270° or 450° etc., for the reception of phase modulation and 0 or any multiple of 180°, such as 360° or 540° etc., for amplitude modulation. The demodulator 14 may have its output coupled as shown to a low frequency amplifier 15 which in turn may be coupled to an indicator. The demodulator 14 and its associated circuit has been completely described and claimed in my U. S. application Ser. No. 716,469, filed March 20, 1934, Patent No. 2,063,588, December 8, 1936, and needs no further description in this paper.

The circuit of Fig. 2 shows the application of my novel method and means to a receiver which includes an automatic volume control device in addition to my tuning control device. The elements of the circuit of Fig. 2 are designated by numbers or characters utilized to designate the corresponding elements of Fig. 1. The circuit of Fig. 2 corresponds to the circuit of Fig. 1, except for the differences which will now be described. The detectors 7 and 8 of Fig. 1 are in Fig. 2 replaced by multi-grid detectors connected as shown, and these detectors, as in Fig. 1, produce the differential potentials in 17 and 18 for automatic frequency control purposes. These detectors 7 and 8 may have their grids biased to such values that the tubes operate on the curved portion of their characteristic curves to thereby obtain a more marked controlling result. This circuit also differs from the circuit of Fig. 1 in that the anode of the modulator tube is coupled as shown by way of a variable capacity 15 to the anode of the oscillator tube 5. Thus, in Fig. 2, a capacitive control of the frequency of the high frequency oscillator 5 is obtained instead of an inductive control, as in Fig. 1. As the control voltage on the control grid of tube 6 is varied, the plate impedance of tube 6 is varied so that the effective value of capacity 15 is varied. Since capacity 15 is placed across the tuning circuit of the high frequency oscillator, the variation of the effective value of 15 varies the frequency of the high frequency oscillator. In this manner, the tuning of the oscillator 5 and consequently of the receiver circuit is varied until the differential detectors 7 and 8 are balanced and the differential potentials in 17 and 18 oppose and are neutralized so that the control energy no longer flows in line L. Battery 26 furnishes bias for modulator 6. 16 is a radio frequency choke.

In the modification of Fig. 2, the intermediate frequency signal energy is fed from the output of unit 3 by way of transformer 23 to a rectifier tube 19, which is to supply energy for automatic volume control purposes. The filter circuit 20 connected with the output electrodes of 19 removes the intermediate frequency components from the rectifier output, and the rectifier output is set up across resistance 21, connected as shown between filter circuit 20 and ground, the circuit being completed by grounding the cathode of 19. The voltage variations produced in 20 and appearing in 21 are fed by way of an automatic volume control circuit (AVC) to the radio frequency amplifier 1, to determine therein the biasing potential of a control grid, or some other electrode, of a tube thereof to thereby determine the amplification characteristic of the amplifier. The circuit AVC includes a time control device 22 which determines the rapidity with which the variations in the control circuit follow the variations in the signaling potentials applied to 23.

This circuit of Fig. 2 further differs from the circuit of Fig. 1 in that the control relay 10, which connects the line L to the output of 7 and 8 for material signal potentials and disconnects the same therefrom for unsubstantial signal potentials, is supplied with energy from the resistor 21. The relay is, however, actuated as in Fig. 1 by the plate current of tube 9. The control grid of tube 9 is connected by way of a biasing source 28 to a point on 21. When the signal is strong, the voltage across resistor 21 will be high and negative so that tube 9 will be biased to a low value of plate current or cutoff. Springs S will then close contacts 11 and 12 to apply the differential voltages from 7 and 8 to line L and thence to the modulator tube 6. When the signal fades, the voltage across 21 decreases towards zero, so that tube 9 draws more plate current. The spring-biased arms will then be pulled toward the magnet of relay 10, thereby opening the contacts 11 and 12 and removing the tuning control energy. Hence, by proper adjustment of relay 10 and the bias of the control grid of 9, by adjusting battery 28 connected with the grid of tube 9, the tuning control may be arranged to turn on at any desired signal level.

The tube 9 may be dispensed with, as shown in Fig. 3, by placing the relay 10 directly in the output circuit of rectifier 19 in series with resistance 21. The relay contacts may then have to be changed to the other side of the spring-biased arms in order to compensate for the 180° phase reversal of tube 9. The same result can, of course, be accomplished by reversing the direction in which the contact arms are biased by springs S.

In the circuit of Fig. 4, condenser 15 may be replaced by an inductance 30 in series with a blocking condenser 32. The plate resistance of modulator tube 6 is now in series with an inductance and the combination of the inductance, blocking condenser and variable plate resistance of tube 6 is placed across the oscillator tuned circuit, as shown. The variation of frequency of the oscillator 5 is in this case effected by varying the effective inductance of the tuned circuit.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What is claimed is:

1. In combination a receiver of the heterodyne type including a first detector and a local oscillator, a pair of differential detectors having like control electrodes coupled in phase and in phase opposition to the output of said first detector, a transmission line and a modulator tube coupling the output of said differential detectors to said local oscillator, contacts in said transmission line, and a relay tube cooperating with said contacts, said relay tube having its input electrodes coupled to the output of said first detector.

2. In combination a receiver of the heterodyne type including a first detector and a local oscillator and an intermediate frequency amplifier, a pair of differential detectors having like control electrodes coupled in phase to said intermediate frequency amplifier and in phase opposition to a filter connected to said intermediate frequency amplifier, a modulator tube connected at its input to the output of said differential detectors and at its output to said local oscillator, contacts in one of said connections, and a relay tube cooperating with said contacts, said relay having its input electrodes coupled to the output of said intermediate frequency amplifier.

3. In combination a receiver of the heterodyne type including a first detector and a local oscillator, a pair of differential detectors having their control electrodes coupled to the output of said first detector, a transmission line and a modulator tube coupling the output of said differential detectors to said local oscillator, a contact in said transmission line, a relay tube cooperating with said contact, said relay tube having its input electrodes coupled to the output of said first detector, and automatic volume control means coupled between the output of said first detector and the input of said first detector.

4. In combination a receiver including a first detector and a source of local oscillations, an intermediate frequency amplifier coupled at its input to the output of said first detector, a pair of differential detectors having like control grids connected in phase opposition to the output of said intermediate frequency amplifier, said detectors also having like electrodes connected in like phase relation to the output of said intermediate frequency amplifier, a filter circuit in one of said connections, a frequency control circuit coupled to the output of said differential detectors at its input, a modulator tube coupled to the output of said frequency control circuit, a coupling between said modulator tube and said source of local oscillations, contacts in said frequency control circuit, a rectifier having its input electrodes coupled to the output of said intermediate frequency amplifier, an electromagnet cooperating with the contacts in said frequency control circuit, and a circuit connecting said electromagnet to the output of said rectifier.

5. In combination a receiver including a radio frequency amplifier, a first detector and a source of local oscillations, an intermediate frequency amplifier coupled to the output of said first detector, a pair of differential detectors having a pair of like control grids connected in phase opposition to the output of said intermediate frequency amplifier, said detectors also having other like electrodes connected in like phase relation to the output of said intermediate frequency amplifier, a filter circuit in one of said connections, a frequency control circuit coupled to the output of said differential detectors, a modulator tube coupled at its input to the output of said frequency control circuit, a coupling between said modulator tube and said source of local oscillations, contacts in said frequency control circuit, a rectifier having its input coupled to the output circuit of said intermediate frequency amplifier, an automatic volume control circuit connecting the output of said rectifier to said radio frequency amplifier, an electromagnet cooperating with the contacts in said frequency control circuit, and a circuit connecting said electromagnet to the output circuit of said rectifier.

6. In a receiver, a radio frequency amplifier, a first detector coupled thereto, a source of local oscillations coupled to said first detector, an intermediate frequency amplifier coupled to said first detector, a filter coupled to said intermediate frequency amplifier, a pair of differential detectors, circuits coupling the control electrodes of said differential detectors in phase opposition to the output of said filter, circuits connecting

the control electrodes in said differential detectors in phase to the output of said intermediate frequency amplifier, a pair of resistors connected between the output electrodes of said differential detectors, a line including contacts connected to said pair of resistors, a time control device in said line, a modulator tube connected at its input to said line, a reactive circuit connecting the output of said modulator tube to said source of local oscillations, an electromagnet cooperating with said contacts, a tube coupled at its input to the output of said intermediate frequency amplifier and at its output to said electromagnet, and a demodulator coupled to the output of said filter circuit and to the output of said intermediate frequency amplifier, one of said last named couplings including a phase shifter.

7. In a receiver, a radio frequency amplifier, a first detector coupled thereto, a source of local oscillations coupled to said first detector and an intermediate frequency amplifier coupled to said first detector, a filter tuned to the mean intermediate frequency coupled to said intermediate frequency amplifier, a pair of differential detectors, circuits coupling like control electrodes of said differential detectors in phase opposition to the output of said carrier filter, circuits connecting other like control electrodes in said differential detectors in phase to the output of said intermediate frequency amplifier, a pair of resistors connected between the output electrodes of said differential detectors, a line including contacts connected to said resistors, a time control device in said line, a modulator tube connected at its input to said time control device, a reactive circuit connecting the output of said modulator tube to said source of local oscillations, an electromagnet cooperating with said contacts, a rectifier coupled at its input to the output of said intermediate frequency amplifier, a circuit coupling the output of said rectifier to said electromagnet, a filter circuit connected to the output of said rectifier, and a volume control circuit coupling a point on said filter circuit to said radio frequency amplifier.

8. In combination, a receiver including a first detector and a source of local oscillations, an intermediate frequency amplifier coupled at its input to the output of said first detector, a pair of differential detectors having like control electrodes connected in phase opposition to the output of said intermediate frequency amplifier, a circuit connecting said like electrodes in phase to the output of said intermediate frequency amplifier, a frequency control circuit coupled at its output to the output of said differential detectors, a modulator tube coupled to the output of said frequency control circuit and to said source of local oscillations, means for interrupting the coupling between said modulator tube and said frequency control circuit, and a relay coupling said last named means to the output of said intermediate frequency amplifier.

9. In a radio receiver, a signal wave amplifier of controllable gain, a demodulator having an input coupled to said amplifier, said demodulator having an output, tuning means for said demodulator, an automatic volume control circuit coupling said demodulator to said amplifier to control the gain thereof, a tuning control circuit coupling the output of said demodulator to said tuning means to control the tuning of said demodulator, and a relay coupled to the output of said demodulator and to said control circuit to control the operativeness thereof.

10. In a superheterodyne receiver of the type including a detector circuit tuned to a desired signal frequency, a local oscillator circuit having a tank circuit tuned to a frequency differing from the signal frequency by an operating intermediate frequency, means coupling said detector and oscillator circuits, an auxiliary frequency determining element operatively associated with said tank circuit, means, responsive to a frequency shift of the intermediate frequency energy from said operating value, for controlling said auxiliary element in a sense to maintain said energy at said operating value, and additional means, responsive to a decrease in the signal carrier amplitude below a desired level, for automatically rendering said controlling means ineffective.

11. In combination with a signal detector tuned to a desired signal frequency, an oscillator circuit electrically associated with the detector to produce beat energy in the detector output, main and auxiliary frequency determining elements operatively associated with the oscillator circuit, said main element tuning the latter to a frequency differing from the signal frequency by an assigned beat frequency, an automatic frequency control circuit, responsive to a frequency shift of the beat energy from the assigned beat frequency, for varying the magnitude of said auxiliary element, and a signal controlled circuit, responsive to variations in signal carrier amplitude, for automatically regulating the effectiveness of said frequency control circuit.

12. In a combination with a signal detector tuned to a desired signal frequency, an oscillator circuit electrically associated with the detector to produce beat energy in the detector output, main and auxiliary frequency determining elements operatively associated with the oscillator circuit, said main element tuning the latter to a frequency differing from the signal frequency by an assigned beat frequency, an automatic frequency control circuit, responsive to a frequency shift of the beat energy from the assigned beat frequency, for varying the magnitude of said auxiliary element, and a signal-controlled circuit, responsive to variations in signal carrier amplitude, for automatically regulating the effectiveness of said frequency control circuit, said signal-controlled circuit comprising a signal rectifier, and means for applying the rectified signals to said frequency control circuit.

13. In a radio receiver of the superheterodyne type, a first detector network, a local oscillator network, means for tuning the detector and oscillator networks to different station settings, an intermediate frequency transmission network coupled to the first detector network, means for rectifying intermediate frequency energy appearing in said intermediate frequency network and deriving therefrom a direct current voltage whose value is dependent upon the frequency difference between an operating intermediate frequency and the frequency of said intermediate energy, frequency control means electrically connected between said rectifying means and said oscillator network, and responsive to said direct current voltage, for automatically adjusting the frequency of the oscillator supplementally of said tuning means, and means, responsive to a decrease in the amplitude of the intermediate energy below a desired level, for automatically rendering ineffective said frequency control means.

14. In a radio receiver system of the superhet-

erodyne type, a first detector network, a local oscillator network, means for tuning the detector and oscillator networks to different station settings, an intermediate frequency transmission network coupled to the first detector output circuit, means for rectifying signal energy appearing in said intermediate frequency network and deriving therefrom a uni-directional voltage whose magnitude is dependent upon the amplitude of the intermediate carrier frequency, an automatic frequency control circuit having an input network coupled to said intermediate transmission network and deriving from said intermediate energy a second uni-directional voltage whose magnitude is dependent upon the difference in frequency between the operating intermediate frequency and the said intermediate carrier frequency, additional means responsive to said second uni-directional voltage for automatically adjusting the frequency of the oscillator supplementally of said tuning means, and means responsive to said first uni-directional voltage for regulating the effectiveness of said frequency control circuit.

15. In a radio receiver system of the superheterodyne type, a first detector network, a local oscillator network, means for tuning the detector and oscillator networks to different station settings, an intermediate frequency transmission network coupled to the first detector output circuit, means for rectifying signal energy appearing in said intermediate frequency network and deriving therefrom a uni-directional voltage whose magnitude is dependent upon the amplitude of the intermediate carrier frequency, an automatic frequency control circuit having an input network coupled to said intermediate transmission network and deriving from said intermediate energy a second uni-directional voltage whose magnitude is dependent upon the difference in frequency between the operating intermediate frequency and the said intermediate carrier frequency, additional means responsive to said second unidirectional voltage for automatically adjusting the frequency of the oscillator supplementally of said tuning means, means responsive to said first uni-directional voltage for regulating the effectiveness of said frequency control circuit, and additional means responsive to said first uni-directional voltage for controlling the transmission efficiency of a portion of said receiver preceding said intermediate transmission network in a sense to maintain the carrier amplitude at the input of said frequency control circuit substantially uniform.

16. A method of signal reception in a receiver of the type including at least a tunable selector network and a demodulator, which includes the steps of collecting signal energy, impressing the collected energy on said tunable selector network to select signal energy of a desired carrier frequency, transmitting the selected signal energy to said demodulator, deriving a uni-directional voltage from the selected signal energy which is dependent in magnitude upon the frequency difference between the selected carrier frequency and a predetermined carrier frequency value, effecting an auxiliary tuning of said selector network with said voltage and in a sense to maintain the signal energy transmitted to the demodulator substantially at said predetermined frequency value, and utilizing the selected carrier energy to suppress said auxiliary tuning in response to a substantial decrease in carrier amplitude.

17. A method of signal reception in a receiver of the type including at least a tunable selector network and a demodulator, which includes the steps of collecting signal energy, impressing the collected energy on said tunable selector network to select signal energy of a desired carrier frequency, transmitting the selected signal energy to said demodulator, deriving a uni-directional voltage from the selected signal energy which is dependent in magnitude upon the frequency difference between the selected carrier frequency and a predetermined carrier frequency value, effecting an auxiliary tuning of said selector network with said voltage and in a sense to maintain the signal energy transmitted to the demodulator substantially at said predetermined frequency value, deriving a second uni-directional voltage from the selected signal energy which is dependent in magnitude upon the selected carrier amplitude, and suppressing the said auxiliary tuning with said second voltage.

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