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AUTOMATIC FREQUENCY CONTROL FOR
PULSE TRANSMISSION SYSTEMS
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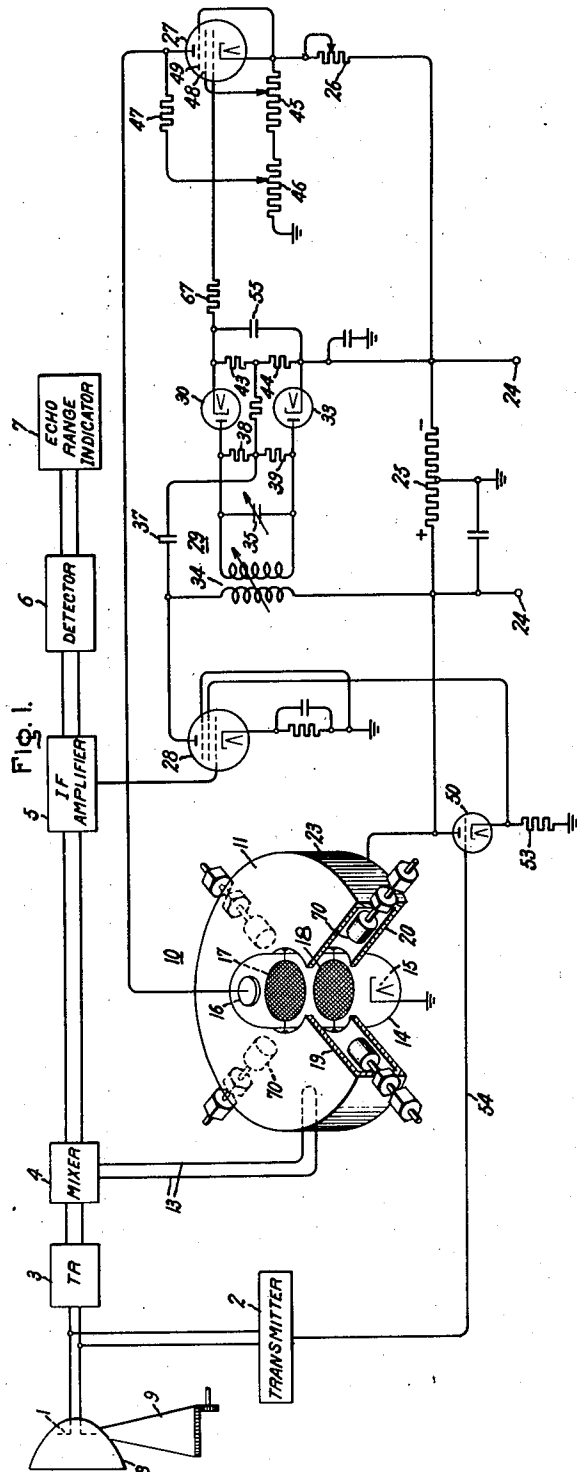


Fig. 4.

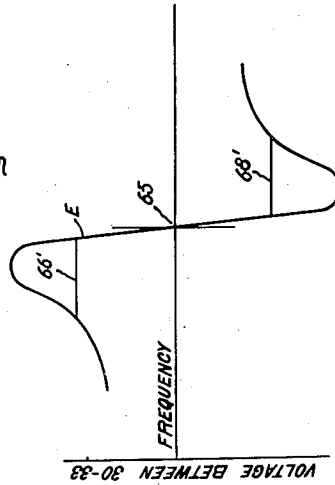


Fig. 2.

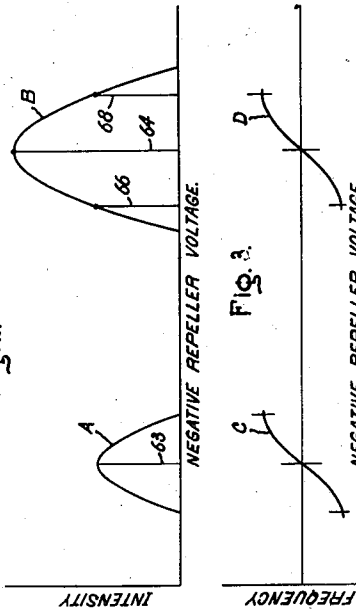
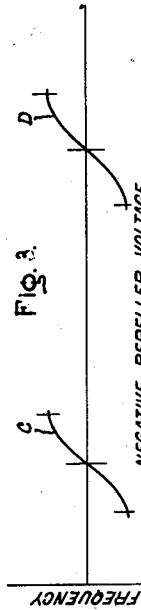


Fig. 3.



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AUTOMATIC FREQUENCY CONTROL FOR
PULSE TRANSMISSION SYSTEMSGeorge W. Fyler, Stratford, Conn., assignor to
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5 Claims. (Cl. 343-13)

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My present invention relates to carrier wave reception systems of the heterodyne type, and particularly to such systems used in connection with pulse transmitters, as in pulse ranging or recognition apparatus.

One of the objects of my invention is to provide improved means for regulating the frequency of the local oscillator in such reception systems.

Another object of my invention is to effect such regulation free from interference effects produced by noise and the like during the period between transmitted pulses.

A further object of my invention is to effect such regulation in response to waves received only while the transmitter is operating, i. e. during the transmitted pulses.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents an embodiment of my invention; Figs. 2 and 3 represent certain characteristics pertaining to the oscillator employed therein; and Fig. 4 represents characteristics of the frequency discriminator employed therein.

Referring to Fig. 1 of the drawing, I have indicated in the upper left-hand corner an antenna 1 which may be supplied with carrier wave pulses from a transmitter 2 to be radiated into space and thereafter to be received in a receiver comprising the usual so-called transmit-receive device or TR box 3, mixer 4, IF amplifier 5, detector 6 and echo range indicator 7. The carrier wave transmitted may be one of short wavelength, as for example ten centimeters, and may be emitted by the antenna 1 as pulses of one to ten microseconds duration, for example. While the antenna may be one of any desired type, it is indicated as arranged within a parabolic reflector 8 arranged for variable orientation by mounting means 9.

The TR box may comprise the usual equipment adapted to protect the remaining portion of the receiver from the intense pulses produced by the transmitter, while permitting the transmission of received pulses reflected from remote objects to the mixer 4. For further information on various devices suitable for this purpose, reference may be made to "Principles of Radar," 2nd ed.,

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1946 (McGraw-Hill Book Co., Inc.), chapter XI, entitled "Transmit-receive devices."

The mixer 4 comprises means for mixing the received carrier wave pulses with an additional carrier wave which may be of either higher or lower frequency but which is generated by an oscillator 10 and supplied to the mixer 4 over conductors 13. These oscillations are mixed in the mixer 4 to produce oscillations of beat frequency corresponding to the difference in frequency between the two carrier waves. These beat frequency oscillations are amplified by the intermediate frequency amplifier 5, rectified by the detector 6 and supplied to the echo range indicator 7.

The local oscillator 10 comprises a cavity resonator 11 mounted about the evacuated envelope 14 of an electron discharge device. This electron discharge device comprises a cathode 15 and an anode, or repeller, 16 spaced apart and having interposed therebetween two electron permeable walls or grids 17 and 18, these walls being positioned in alignment with and electrically connected to the respective upper and lower walls 19 and 20 of the cavity resonator and forming in effect electrical continuations thereof within the envelope of the evacuated vessel 14. Thus both the upper and the lower walls of the resonator 11 are electrically continuous from the outer periphery 23 of the resonator to the central axis thereof along which the beam of electrons from the cathode to the anode passes, being broken only by the thickness of the glass wall of the evacuated vessel 14.

The resonator 11 is connected to the positive terminal of a source of operating potential the opposite conductors of which are indicated at 24. This source of voltage, for example, may be of the order of 500 volts, its positive terminal being at from 200 to 300 volts (e. g., in the neighborhood of 250 volts) positive with respect to ground and its negative terminal being at a desired voltage below ground. This source is shunted by a bleeder resistance 25 the intermediate point of which is grounded. This intermediate point may be at any suitable point on the resistance and not necessarily at the midpoint. The negative terminal of the source is connected through a variable resistance 26 to the cathode of an electron discharge device 27 the anode of which is connected to the anode 16 of the local oscillator 10. This discharge device 27 is connected to regulate the potential between the cathode 15 and repeller 16, thereby to regulate the frequency of the local oscillator to maintain the beat or in-

intermediate frequency supplied to amplifier 5 substantially constant.

Beat frequency oscillations from the amplifier 5 are supplied through an amplifier 28 to a frequency discriminating circuit 29 which, in conjunction with two diode rectifiers 30 and 33, operates to produce a voltage at the cathode of the rectifier 30, which is either positive or negative with respect to the negative terminal of the source 24 dependent upon the frequency of the oscillations supplied to the discriminator 29 and which is of magnitude dependent upon the variation in that frequency from the frequency to which the circuits of the discriminator 29 are resonant.

The operation of this discriminator circuit is well known to those skilled in the art but will be stated briefly.

The primary and secondary circuits of the transformer 34 are both resonant at the intermediate frequency to be maintained. Oscillations in the secondary circuit 35 are therefore in quadrature relation with the oscillations which appear across the primary winding of the transformer 34. The oscillations on the primary winding are supplied through condenser 37 to the anodes of the two diodes 30 and 33 in phase through resistances 38 and 39. The oscillations in the secondary circuit 35 are supplied to these anodes in opposed phase relation. Thus if the two oscillations on the two anodes are in exactly quadrature relation, equal voltages exist on the two anodes and equal and opposite unidirectional voltages are therefore produced on the two resistances 43 and 44 with the result that zero voltage is produced between the two cathodes of the rectifiers 30 and 33. If the frequency supplied to the discriminator changes from that to which the circuits of the transformer 34 are resonant, then the two oscillations on one of the two anodes become more nearly in phase while those on the other anode become more nearly in opposed phase with the result that the potential increases on one of the resistances 43 and 44 and decreases on the other. Of course, the reverse occurs if the frequency of the oscillations varies in the opposite direction. Thus a voltage appears at the cathode of rectifier 30 which is either positive or negative with respect to the negative terminal of the source 24 dependent upon the direction of the frequency variation and of magnitude dependent upon the extent of the variation. This potential is supplied to the control electrode of the discharge device 27 to control the conductivity thereof.

The cathode of the device 27 is connected to ground, which is more positive than the cathode, through two resistances 45 and 46 the anode thereof being connected through a load resistance 47 to a variable point on the resistance 46 and the screen grid 48 being connected to a variable point on the resistance 45. The suppressor grid 49 is connected directly to the cathode. Of course, current flowing in device 27 flows through resistance 47 and the potential on this resistance governs the potential on the repeller 16 with respect to the cathode 15 of oscillator 10.

The amplifier 28 is of the usual pentode type having its suppressor grid connected to ground and its screen grid connected to the cathode of a further electron discharge device 50, this cathode being connected to ground through a resistance 53. This latter discharge device 50 is normally nonconducting so that the potential across resistance 53 is zero and therefor the amplifier 28 is rendered inoperative by the zero potential on its screen grid. Device 50, however, is ren-

dered conducting by a pulse supplied from the transmitter 2 over conductor 54 during each radiated pulse. Current then flows in the resistance 53 during each radiated pulse rendering its cathode and hence the screen grid of device 28 positive. Thus this device 28 is then capable of supplying oscillations of intermediate frequency from the intermediate frequency amplifier to the discriminator to control the conductivity of the device 27 thereby to control the potential on the anode 16.

While as previously stated the TR box operates to protect the mixer 4 from the intense pulses produced by the transmitter, oscillations produced by the transmitter nevertheless are transmitted through the TR box to the mixer 4 during the radiation of pulses to an extent sufficient to produce a beat frequency which is supplied to the intermediate frequency amplifier and thence through amplifier 28 to the discriminator 29 to control the conductivity of device 27 thereby to control the potential on the anode or repeller 16. Since amplifier 28 is operative only during the radiated pulses, the control of the local oscillator frequency is not subject to noise voltage or other extraneous electromotive forces received during the intervals between the radiated pulses.

Condenser 55, which is connected in shunt with resistances 43 and 44, is of such a value that the unidirectional potential produced between the two cathodes of rectifiers 30 and 33 is maintained during the period between transmitted pulses and varies substantially only as the beat frequency varies during the radiated pulses.

The discharge device 14 is commercially available and is known by the commercial designation 107B. This device operates by the passage of electrons from the cathode to the anode 16 through the two electron permeable walls or grids 17 and 18. If it be assumed that oscillations are excited in the resonator 11 due to variations in the electron stream, it will be understood that electrons which are in the space between walls 17 and 18 when wall 17 is positive with respect to wall 18 are accelerated. Similarly electrons in this space when wall 17 is negative with respect to wall 18 are decelerated. The distance between the upper and lower walls 17 and 18 is such that an electron traverses this space in a half cycle or less. The result is that electrons leaving the wall 17 and traveling toward the anode 16 are in alternate groups of fast and slow electrons. The fast electrons, due to their velocity, may impinge upon the anode 16 and produce current in the anode circuit. The slow electrons are repelled by the negative voltage of the anode 16 and travel back toward the wall 17 and enter the space within the resonator. If the distance which they travel from the wall 17 toward the anode 16 and then back to the wall 17 is such that the groups of slow electrons arrive back in phase with the oscillations in the resonator, they operate to enhance or sustain the oscillations within the resonator. As this distance varies, however, as would be the case if the potential on the repeller 16 varied, then the electrons arrive back at the wall 17 in phase to produce a shifting of the frequency of the oscillations within the device. In this way, by varying the voltage on the repeller, the frequency of the oscillations within the resonator may be varied over a range of frequencies.

Of course, the variation in potential on the repeller 16 not only varies the distance traveled by the slow electrons toward the repeller, but

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it also varies the velocity of the electrons passing from wall 17 toward the repeller, and these two effects may be counteracting. In practice, however, it is found that if the repeller voltage is increased in a negative sense with respect to the cathode 15, the frequency is increased.

A plurality of plungers 70 are arranged in the cavity on screw-threaded stems which project through the wall thereof and which are provided with nuts on the outside adjustable to vary the position of the plungers thereby to vary the frequency of resonance of the cavity.

Fig. 2 represents certain characteristics of this oscillator. This figure shows by curves A and B the relation between the intensity of oscillations produced plotted as ordinates and the negative repeller voltage plotted as abscissa. While the device may have several modes of operation, only two are indicated by Fig. 1, one at a repeller voltage represented by the point 63 and another at a repeller voltage represented by the point 64, on the abscissa, the oscillations of each mode having maximum intensity when the repeller voltage is of the value corresponding to the respective points 63 and 64 and reducing in intensity as the repeller voltage either increases or decreases. If the negative repeller voltage increases, however, the frequency of the oscillations increases, whereas if the negative repeller voltage decreases, the frequency decreases. This relationship is illustrated in Fig. 3 by curves C and D. The shape of these curves varies with the repeller voltage and may be nearly linear. Thus by proper regulation of the repeller voltage, the frequency of the local oscillator may be varied to maintain the intermediate frequency constant, notwithstanding variations in frequency of the carrier wave produced by the transmitter 2.

It is desirable, however, that the intensity of these oscillations should not become too small for satisfactory operation of the converter or mixer 4, and satisfactory productions of oscillations of intermediate frequency, and that it should not vary beyond values represented by lines 66 and 68. Such variation is prevented by the limiting action of device 27 presently to be described.

In Fig. 4, the curve E represents the relation between unidirectional voltage produced between the cathodes of diodes 30 and 33 plotted as ordinates and frequency of oscillations supplied through amplifier 28 plotted as abscissa, the fixed frequency to which the circuits of the transformer 34 are tuned being represented by the point 65. When the frequency is at the correct value, the unidirectional voltage between the two cathodes of the two diodes 30 and 33 is zero. As the frequency decreases from this value, this voltage increases with one polarity, and as the frequency increases the voltage increases with the opposite polarity. If the voltage increases in the positive sense, it causes discharge device 27 to become increasingly conductive until a value is reached, represented by the line 66' in Fig. 3, at which the control electrode of discharge device 27 becomes positive with respect to the cathode and therefore draws current through resistance 67. This resistance is sufficiently great so that the control electrode cannot become more positive. If the unidirectional potential between the cathodes of the diodes 30 and 33 varies in the opposite direction to a value represented by the line 68', then the cutoff point of the device 27 is reached and it becomes nonconductive so that

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no further change in the repeller voltage occurs. The adjustment of the variable contacts on resistances 45, 46 and 26 may be such that these two lines 66' and 68' correspond to vertical lines 66 and 68 drawn in the curve B of Fig. 2, showing the extent to which the repeller voltage may be varied and the extent of the resultant variation in frequency and intensity of oscillations produced. The limiting effect of the device 27 at the two points, namely, that at which the control electrode becomes positive and that at which the device becomes nonconducting, prevents the oscillations of the local oscillator from becoming of too low intensity for satisfactory reception due to variation in the repeller voltage through the control action of the regulator.

Of course, due to the amplifying action of device 27 the repeller voltage changes much more rapidly with the change in frequency than does the unidirectional voltage between cathodes of diodes 30 and 33.

The adjustment of the variable contact on resistance 46 determines the anode operating voltage of device 27 and hence selects the load line on which device 28 operates. That is, if the anode-current anode-voltage characteristics of device 28 be drawn for different values of grid voltage, a so-called "load line" may be drawn across these characteristics for each value of anode voltage. A particular load line is selected by the position of the variable contact on resistance 46. This adjustment may be such that the repeller voltage of device 10 varies about the point 63 or 64 of Fig. 2. The range of repeller voltage variation may be adjusted by varying the position of the contact on resistance 45 thereby varying the screen grid voltage of device 27. The cathode resistance 26 determines the bias on device 26 and the point on the particular load line about which the grid voltage is varied by variation in voltage between the cathodes of diodes 30 and 33.

While I have shown a particular embodiment of my invention, it will of course be understood that I do not wish to be limited thereto as different modifications both as to the circuit arrangement and the instrumentalities employed may be made, and I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, in a carrier wave pulse system, a carrier wave pulse transmitter, a carrier wave pulse receiver having a local oscillator, said receiver being arranged to receive the carrier wave pulses transmitted by said transmitter and to combine them with oscillations produced by said local oscillator to produce a beat frequency, means responsive to said beat frequency to control the frequency of oscillations produced by said local oscillator to maintain said beat frequency constant irrespective of variation in frequency of the carrier wave of the transmitted pulses, and means to maintain said last means normally inoperative and to render it operative only during said transmitted pulses.

2. In combination, a carrier wave pulse transmitter, a receiver arranged to receive the carrier wave pulses transmitted thereby, said receiver having a local oscillator heterodyning with said received carrier wave pulses to produce oscillations of a beat frequency, a frequency discriminator, normally inoperative means to supply said oscillations of said beat frequency to said discriminator, means controlled by said discrimina-

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tor to regulate the frequency of said local oscillator to maintain said beat frequency constant, and means to render operative said normally inoperative means during the period of each transmitted pulse.

3. In combination, a carrier wave pulse transmitter, a receiver arranged to receive carrier wave pulses from said transmitter, said receiver having a local oscillator comprising an anode, a cathode, and a cavity resonator having walls interposed between said anode and cathode through which electrons pass to excite oscillations in said cavity resonator, means to combine said oscillations with oscillations received from said transmitter to produce oscillations of a beat frequency, means controlled by said beat frequency to regulate the potential between said anode and cathode to maintain said beat frequency constant, and means to maintain said last means inoperative and to render it operative during pulses transmitted by said transmitter.

4. In combination, means to transmit oscillations in recurrent pulses, means to receive said oscillations both directly and after reflection from a remote body, a local oscillator heterodyning with said received oscillations to produce a beat frequency, means to produce a unidirectional potential of value dependent upon said beat frequency when said oscillations are received directly, means to maintain said unidirectional potential throughout reception of said oscillations after reflection, and means to regulate the frequency of said local oscillator in accord with said unidirectional potential.

5. In combination, means to transmit oscillations in recurrent pulses, means to receive said

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oscillations both directly and after reflection from a remote body, an oscillator heterodyning with said received oscillations to produce a beat frequency, said oscillator comprising an electron discharge device having an anode and a cathode and being adapted to produce oscillations of frequency dependent upon the potential between said anode and cathode, means to produce a unidirectional potential between said anode and cathode dependent upon the frequency of said beat note produced only during reception of said directly received oscillations, and means to maintain said potential throughout the interval between said transmitted pulses and during reception of said oscillations after reflection.

GEORGE W. FYLER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 21,691	Freeman	Jan. 14, 1941
2,189,549	Hershberger	Feb. 6, 1940
2,231,368	Mountjoy	Feb. 11, 1941
2,233,165	Goldman	Feb. 25, 1941
2,268,643	Crosby	Jan. 6, 1942
2,421,020	Earp	May 27, 1947

FOREIGN PATENTS

Number	Country	Date
113,233	Australia	June 2, 1941

Disclaimer

2,469,875.—*George W. Fyler*, Stratford, Conn. AUTOMATIC FREQUENCY CONTROL FOR PULSE TRANSMISSION SYSTEMS. Patent dated May 10, 1949. Disclaimer filed Jan. 31, 1952, by the assignee, *General Electric Company*.

Hereby enters this disclaimer to claims 1, 2, 4, and 5 of said patent.
[*Official Gazette March 4, 1952.*]

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