

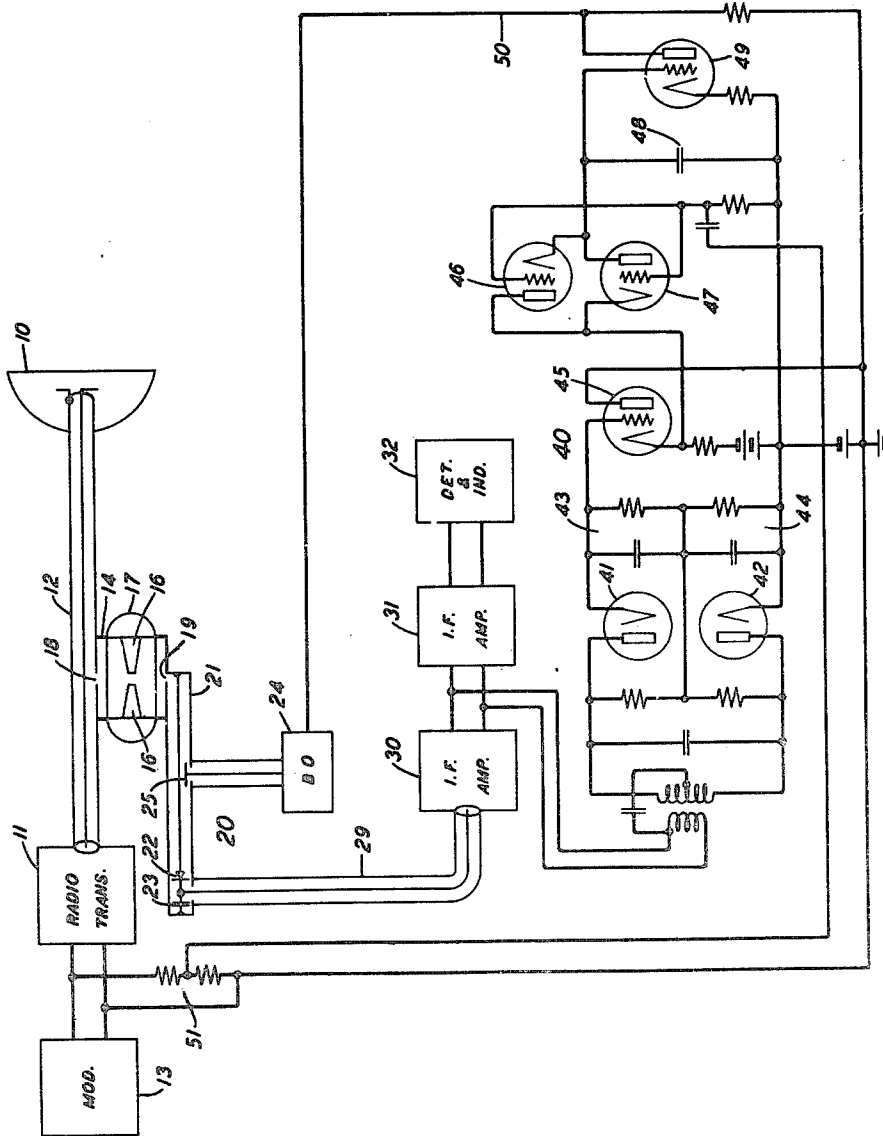
July 20, 1948.

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2,445,409

AUTOMATIC FREQUENCY CONTROL

Filed March 3, 1945



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2,445,409

AUTOMATIC FREQUENCY CONTROL

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Application March 3, 1945, Serial No. 580,814

5 Claims. (Cl. 343-11)

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This invention relates to automatic frequency control systems, particularly those for use in receivers of pulse reflection systems.

In the automatic frequency control of radio receivers operating in systems in which radio energy appears in pulses provision must be made to prevent the control from causing the frequency to be shifted during the intervals between pulses when no radio energy for operating the control is available. For the more usual type of system this is accomplished by giving the control circuit a time constant sufficiently long so that the frequency adjustment produced during any pulse will hold over until the next pulse. Such a system has the natural handicap that the same characteristic that causes the adjustment to hold over from pulses to pulse also results in a sluggishness of response of the control.

Such effects are particularly marked in the case of radars or other pulse reflection-ranging and direction-indicating systems, particularly those operating at very short waves. With such systems one of the preferred methods of operation is to tune the receiver in response to the outgoing pulse so that it will have a maximum response to reflections of that pulse, which will be of the same frequency. In such systems the interval between transmitted pulses is comparatively long since it must provide a time sufficient for the reflected pulses to return from targets at the maximum range. On the other hand the transmitter frequency may be comparatively unstable and particularly in scanning systems where the antenna is given a physical movement the variation in electrical conditions from position to position may be such as to materially affect the frequency. As a result there may be considerable variation in frequency from pulse to pulse. Accordingly, while the requirements for the reception of reflected pulses require the frequency regulation to be maintained over the long interval between transmitted pulses, other conditions require that a rapid readjustment be made within the short period of a transmitted pulse.

An object of the invention is to increase the speed of response of automatic frequency control for pulse systems.

A further object of the invention is to provide for the receiver of a pulse reflection radio system, an automatic frequency control that responds to sudden changes in frequency of the transmitted pulses to adjust the receiver for maximum response to pulses of that frequency which is the characteristic of the reflected pulses and to main-

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tain the adjustment during the period between transmitted pulses.

In accordance with a preferred embodiment of the invention in a pulse reflection system a fast-acting circuit is employed for producing a voltage proportional to any deviation between the receiver input frequency and the frequency to which the receiver is tuned. The output of this circuit is supplied through an electronic switch to a storage or long time-constant circuit which is utilized to regulate the tuning of the receiver. The electronic switch is closed only during periods of transmission so that the tuning will be adjusted to the frequency of the outgoing pulses and, due to the long time constant of the storage circuit, will hold that adjustment for the periods between transmitted pulses. Thus, the receiver tuning is automatically adjusted by each outgoing pulse to give maximum response to the returning echo of that pulse and is held in adjustment until the next outgoing pulse arrives.

The invention may be better understood by reference to the following detailed description in connection with the drawing which is a schematic circuit diagram of a radar system embodying the invention.

In this radar system recurrent pulses of ultra-high frequency radio waves are transmitted from a directional antenna 10. During the periods between transmitted pulses the reflections from objects under scrutiny are received in the same antenna. By the observation of the detected pulses, for example on the screen of a cathode-ray oscilloscope (not shown), the distance to the reflecting object may be determined and when coordinated with the orientation of the antenna, the direction thereof can also be ascertained as is well understood in the art.

The ultra-high frequency radio waves are generated by a transmitter 11 which is coupled to the antenna 10 by a coaxial transmission line 12 or wave guide. The operation of the transmitter 11 is controlled by a modulator 13 that produces direct current pulses of the required length and recurrence rate. These direct current pulses are impressed on the transmitter 11 and cause the production of ultra-high frequency radio waves during each pulse.

A duplexing unit is provided for coupling a radio receiver to the coaxial line 12. This duplexing unit comprises a resonant cavity 14 tuned to the frequency of the radio oscillations produced by the transmitter 11 with a gas discharge tube mounted therein. The gas discharge tube comprises two electrodes 16 connected to the walls of

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the cavity 14 and enclosed in a partially-evacuated vessel 17. The cavity 14 is coupled to the coaxial line 12 by means of an aperture 18 in the common wall of the outer conductor of the line 12 and the cavity. A second aperture 19 in the opposite wall of the cavity 14 provides coupling to the radio receiver.

During transmission of pulses of radio waves by the transmitter 11 a voltage sufficiently high to break down the gap between the electrodes 16 is developed in the resonant cavity 14. As a result, the path from the coaxial line 12 to the radio receiver has a very low impedance shunt and consequently a high attenuation is introduced into the input path to the receiver. The attenuated pulse passes to the receiver and is used as described later to operate the automatic frequency control. In the absence of transmitted pulses the voltage is sufficiently low that the gap is not broken down and any waves received in the antenna 10 are transmitted to the receiver with practically no attenuation. The operation and detailed construction of such a duplexing unit is described in fuller detail in the patent applications of H. T. Friis, Serial No. 474,164, filed January 30, 1943, and A. L. Samuel, Serial No. 474,122, filed January 30, 1943.

The radio receiver comprises a converter 20 the intermediate frequency output of which is coupled through a coaxial line 29 to a preliminary intermediate frequency amplifier 30. The output of the intermediate frequency amplifier 30 is branched between an additional intermediate frequency amplifier 31 and an automatic frequency control circuit 40. A detector and indicator circuit 32 is connected to the output of the intermediate frequency amplifier 31.

The converter 20 employs a tuned coaxial input line 21 which is coupled at one end to the resonant cavity 14 through the aperture 19. At the other end of the line 21 there is provided a crystal detector or modulator 22 connected to the outer conductor of line 21 through a radio frequency by-pass capacitor 23 and to the inner conductor by means of the usual contact point. Heterodyne oscillations generated by the beating oscillator 24 are introduced by means of the capacitor coupling plate 25. The intermediate frequency output of the converter is taken off across the capacitor 23 by means of the coaxial line 29. This intermediate frequency output is fed to a first intermediate frequency amplifier 30 the output of which is divided between two branches.

One of these branches includes a second intermediate frequency amplifier 31 the output of which is supplied to the detector and indicator circuit 32.

The other branch leads to the automatic frequency control circuit 40. This circuit includes a frequency discriminator of known type including the diodes 41 and 42 with their respective capacitor-resistor output circuits 43 and 44. As is well understood in the art when the input to such a discriminator is of the proper frequency (the intermediate frequency carrier) the voltages developed across the networks 43 and 44 are equal and opposite producing a net voltage of zero across the output terminals formed by connecting the two networks in series. As the input frequency departs from this value, the voltage of one network goes up while the other goes down. This produces a voltage across the output terminals varying in sign and magnitude with the departure of the input frequency from the required value.

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In the circuit of this invention the networks 43 and 44 are given such short time constants that their voltages are readily readjusted during the time of a pulse at which the system is operated.

The output voltage comprising the sum of the voltages across the networks 43 and 44 is supplied to the control grid of vacuum tube 45 that is operated as a cathode follower amplifier stage. The output of this amplifier is connected through an electron switch comprising the triode tubes 46 and 47 to a storage capacitor 48. The voltage developed across the capacitor 48 is amplified by a tube 49 and supplied through the connection 50 to the beating oscillator 24 where it is utilized for regulating the frequency of its output. This may be, for example, by the control of the voltage of the repeller electrode of a velocity-modulation oscillator of the reflection type.

Under normal conditions both the tubes 46 and 47 are blocked by virtue of having their grids maintained at or beyond cut-off and the voltage of the capacitor 48 is maintained at substantially the voltage to which it was last adjusted. During the transmission of a pulse by the radio transmitter 11, a voltage obtained from the voltage-divider 51 connected across the output of the modulator 13 is applied to the grids of the tubes 46 and 47. This causes both tubes to be conductive and permits the voltage of the capacitor to readjust itself to the voltage of the output of discriminator as amplified by the amplifier 45. Upon the termination of the transmitted pulse, the tubes 46 and 47 again become non-conducting and the charge on the capacitor 48 remains constant until it is readjusted when the succeeding pulse again renders the tubes 46 and 47 conducting.

What is claimed is:

1. In a pulse reflection system, a receiver for reflected pulses, a frequency discriminator, a storage capacitor, a normally open electronic switching circuit between the output of said discriminator and said storage capacitor, means for closing said electronic switching circuit during the transmission of pulses, and means responsive to the charge on said capacitor for regulating the tuning of said receiver.

2. In a pulse reflection system, a source of recurrent pulses to be transmitted, a receiver for reflected pulses, a frequency discriminator having such a short time constant that its output follows variations in frequency between adjacent transmitted pulses, a storage capacitor, electronic switching circuit between the output of said discriminator and said storage capacitor, means for closing said electronic switching circuit to interconnect said discriminator and said capacitor only during the transmission of pulses, and means for regulating the tuning of said receiver in accordance with the charge on said storage capacitor.

3. In a pulse reflection system a source of recurrent pulses of oscillations to be radiated, a receiver for reflected pulses including voltage responsive means for regulating the tuning thereof, a fast-acting frequency discriminator responsive to oscillations from said source for producing a voltage proportional to variations between the tuning of said receiver and the frequency of said oscillations, a storage capacitor, electronic switching means for supplying the output of said frequency discriminator to said storage capacitor only during the transmission of pulses by said source, and means for supplying the voltage on

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said storage capacitor to said voltage responsive means.

4. In a pulse reflection system a source of recurrent pulses of oscillations to be radiated, a receiving system responsive to transmitted and reflected pulses and including voltage-responsive means for controlling the tuning thereof, a fast-acting frequency discriminator for producing a voltage proportional to variations between the tuning of said receiver and the frequency of the input thereto, a storage capacitor, an electronic switching circuit connecting the output of said frequency discriminator to said storage capacitor and comprising a pair of oppositely-directed space discharge paths connected in parallel, means for normally maintaining said space discharge paths non-conducting, and means for rendering said space discharge paths conductive during the transmission of pulses by said system.

5. In a pulse reflection system a source of recurrent pulses of oscillations to be transmitted, an antenna for transmitting said pulses and receiving reflections thereof from objects under

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scrutiny, a receiver comprising a beating oscillator, means for combining incoming oscillations with the output of said beating oscillator and highly selective means responsive to the output of the combining means, a duplexing system for connecting said source and said receiver to said antenna to permit the transmission of pulses received in said antenna to said receiver with a low attenuation while highly attenuating the output of said source impressed on said receiver therethrough, a rapid acting frequency discriminator responsive to the output of said combining means for producing a voltage proportional to the deviation of said output from the frequency of said highly selective means, a storage capacitor, electronic switching means for supplying the output of said frequency discriminator to said storage capacitor only during the transmission of pulses by said source, and means for regulating the frequency of said beating oscillator in accordance with the voltage of said storage capacitor.

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