

H. A. WHEELER

RECEIVER-TRANSMITTING ARRANGEMENT

[illegible]

INVENTOR
HAROLD A. WHEELER
BY *Harry B. Page*
ATTORNEY

UNITED STATES PATENT OFFICE

2,415,667

RECEIVER-TRANSMITTING ARRANGEMENT

Harold A. Wheeler, Great Neck, N. Y., assignor,
by mesne assignments, to Hazeltine Research,
Inc., Chicago, Ill., a corporation of Illinois

Application February 11, 1944, Serial No. 521,931

3 Claims. (Cl. 250-15)

1 This invention relates, in general, to receiver-transmitter arrangements of the regenerative type for receiving and transmitting modulated carrier-frequency wave signals. While the invention is subject to a variety of applications, it is especially suited for use as a wave-signal transponder system and will be particularly described in that connection.

In the description that follows the term "wave-signal transponder system" is intended to mean a wave-signal translating system which includes a receiving unit and a transmitting unit so arranged that a predetermined answer or reply signal is transmitted in response to a received interrogating signal, the reply and interrogating signals preferably comprising radiant-energy wave signals.

In certain regenerative-type transponder systems of the prior art, the receiving and transmitting units are completely discrete and separate circuit arrangements, but in others the receiving and transmitting units have some common circuit elements. One prior art arrangement in particular includes a single regenerative oscillatory circuit which is utilized as a superregenerative receiver for the reception of interrogating signals and as a radio-frequency transmitter for the transmission of reply signals. This dual function of the regenerative oscillatory circuit results from the operating potentials which are applied to the oscillator tube. In the system under consideration, a periodic quench voltage is applied to the control electrode-cathode circuit of the tube to provide superregeneration for wave-signal reception, while on the other hand, a modulated potential is applied to the control electrode-cathode circuit of the tube so that the regenerative oscillatory circuit comprises a high-power radio-frequency transmitter for wave-signal transmission.

The described arrangement has the advantage of minimizing the expense and space requirements of the transponder equipment but it has certain inherent limitations which may be objectionable in some installations. For example, in applying the control potentials to the control electrode-cathode circuit of the oscillator tube, it is customary to include high-impedance resistors in the control circuit in order to minimize power dissipation. These high-impedance elements have a tendency to develop excessive bias voltage during periods of oscillation, thereby undesirably to block the regenerative oscillatory circuit. Also, with the control potentials applied to the control electrode-cathode circuit, the operat-

2 ing frequency of the regenerative oscillatory circuit is the same for receiving and transmitting, which is undesirable in installations where the operating frequency of the system during signal reception is required to be different from that during transmission.

It is, therefore, an object of the invention to provide an improved regenerative-type receiver-transmitter arrangement which avoids one or more of the aforementioned limitations of prior art arrangements.

It is another object of the invention to provide an improved regenerative-type receiver-transmitter arrangement having an improved stability characteristic.

It is still another object of the invention to provide an improved regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals and having a predetermined shift in operating frequency as between intervals of wave-signal reception and transmission.

In accordance with the invention, a regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprises a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit. The arrangement also comprises means for supplying to the anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, the quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated. The arrangement includes means for deriving from the regenerative oscillatory circuit an output signal representing the modulation of the received signal. Additionally, the arrangement has means for supplying to the above-mentioned anode-cathode circuit a modulated potential for controlling the regenerative oscillatory circuit to transmit a modulated carrier-frequency signal. The operating frequency of the arrangement is influenced by the magnitude of the potential applied to the anode-cathode circuit and, in certain applications of the invention, the quench voltage and modulated potential are selected of such relative values as to effect a desired shift in the operating frequency as between intervals of wave-signal reception and transmission. It is also contemplated that means be included, in some embodiments of the invention, for effectively disabling either the quench or the modulated potential supply during inter-

vals when the other is to be effective in controlling the regenerative circuit.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 represents a wave-signal transponder system in accordance with the invention; Fig. 2, comprises a graph utilized in explaining an operating characteristic of the transponder system of Fig. 1; while Fig. 3 illustrates a modified form of a portion of the Fig. 1 arrangement.

Referring now more particularly to the drawing, there is represented in Fig. 1 a regenerative-type receiver-transmitter arrangement, specifically, a wave-signal transponder system for operation in the ultra-high-frequency range and for receiving and transmitting carrier-frequency wave signals. For convenience of explanation, the system may be considered as a radio beacon adapted to transmit direction-finding information to inquiring aircraft. As represented, the radio beacon comprises a single regenerative oscillatory circuit including a vacuum-tube means 10 having anode, cathode and control electrodes and a resonant-circuit means provided by a variable inductor 11 and a condenser C. Condenser C is shown in broken-line construction since it may be comprised in whole or in part of the distributed capacitance of inductor 11 and the inter-electrode capacitance of the anode and control electrodes of tube 10. The resonant-circuit means is coupled to the anode of tube 10 through a coupling condenser 12 and has a direct-wire connection to the control electrode thereof. The mid-tap of inductor 11 is grounded by way of a radio-frequency choke 13 and the cathode of tube 10 is likewise grounded through a radio-frequency choke 14 and a low-impedance bias resistor 15 by-passed for radio-frequency currents by a condenser 16, thereby providing anode-cathode and control electrode-cathode circuits for tube 10.

The radio beacon includes means for supplying to the anode-cathode circuit of vacuum tube 10 a periodic quench voltage to provide superregeneration for wave-signal reception. This means comprises a quench-frequency oscillation generator 20 which produces a periodic quench voltage of rectangular wave form having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated. The output circuit of oscillation generator 20 is coupled to a quench-frequency amplifier 21 of one or more stages and a cathode-follower type vacuum-tube repeater 22. The cathode load impedance 23 of cathode follower 22 is coupled by means of a coupling condenser 24 and radio-frequency choke 25 to the anode-cathode circuit of tube 10.

A detector system is coupled to the regenerative oscillatory circuit through a coupling condenser 31 and constitutes means for deriving from the regenerative oscillatory circuit an output signal representing the modulation of the received signal. The detector system includes a diode detector 30 having as a load circuit a radio-frequency choke 32 and a resistor 33 which is by-passed for radio-frequency currents by a condenser 34. The output signal of the detector is supplied to a unit 40 which is responsive thereto for deriving a control effect. Unit 40 includes

an amplifier 41 of one or more stages having an input circuit coupled to resistor 33 and having one or more selector circuits arranged to select predetermined signal components of the output signal of the detector system. A rectifier 42 of conventional construction is coupled to the output circuit of amplifier 41 to rectify the signal component translated therethrough for the purpose of deriving a control voltage of negative polarity. This control voltage is applied to the input circuit of one or more stages of quench-frequency amplifier 21 to adjust the amplitude characteristic of the quench voltage so as to control an operating characteristic of the regenerative oscillatory circuit during intervals of wave-signal reception. This control arrangement is generally similar to that which forms the subject matter of application Serial No. 521,932, filed concurrently herewith, in the name of Harold A. Wheeler and assigned to the same assignee as the present invention.

The radio beacon further includes means for supplying to the anode-cathode circuit of tube 10 a modulated unidirectional potential for controlling the regenerative oscillatory circuit to transmit a carrier-frequency signal modulated in accordance with the modulation of the applied unidirectional potential. This means comprises a pulse-modulated signal generator 50 coupled to the anode-cathode circuit of tube 10 by means of a pulse amplifier 51, a pulse transformer 52, a quench-frequency trap circuit 53 and radio-frequency choke 25. Generator 50 may comprise a conventional trigger circuit such as a single-pulse relaxation oscillator which, when keyed, generates a single positive pulse of unidirectional potential having a substantially rectangular wave form. This pulse as applied to vacuum tube 10 has a substantially greater magnitude than the quench voltage. The input circuit of generator 50 is coupled to resistor 33 so that the generator is responsive to high-amplitude components of the detected signal output of the regenerative oscillatory circuit, as described more particularly hereinafter.

A single antenna-ground system 60 is utilized for both receiving and transmitting. This system is coupled to the regenerative oscillatory circuit through an inductor 61.

In considering the operation of the described arrangement, it will be assumed initially that no signals are intercepted by antenna-ground system 60. During this no-signal or quiescent operating condition, the quench voltage supplied by generator 20 controls the regenerative oscillatory circuit to function as a superregenerative receiver having a linear mode of operation for wave-signal reception. While functioning as a receiver, the regenerative circuit has predetermined bandwidth and sensitivity characteristics determined largely by the amplitude and frequency characteristics of the applied quench voltage but also determined by such factors as the characteristics of vacuum tube 10 and the resonant circuit coupled thereto. Oscillations are periodically produced in the regenerative circuit under the influence of the applied quench voltage in accordance with the characteristic operation of a superregenerative circuit. These oscillations which, for the quiescent condition under consideration, are initiated by the noise signals present in the regenerative circuit, have a relatively low amplitude and a frequency which corresponds to the operating frequency of the circuit. This operating frequency during intervals of wave-signal re-

5

ception has a predetermined value, determined jointly by the parameters of the resonant circuit and the electron transit time of tube 10, as will be described more fully hereinafter.

The generated oscillations are detected by detector 30, producing across resistor 33 a low-amplitude periodic signal voltage. This signal has frequency components corresponding to the frequency of the quench voltage and harmonics thereof as well as components corresponding to the noise signals of the regenerative circuit. A portion of this signal, such as the quench-frequency component thereof, is translated through amplifier 41 and rectifier 42 of unit 40 producing in the output circuit thereof a control voltage of negative polarity having a magnitude determined by the amplitude of the detected quiescent signal output of the regenerative circuit. This control voltage is utilized to control the operating characteristics of the regenerative circuit during intervals of wave-signal reception, as completely described in the above-mentioned copending application. The detected quiescent signal output of the regenerative circuit is also applied from resistor 33 to the input circuit of generator 50. However, this output signal which has a low-amplitude level is ineffective to trigger generator 50 so that the receiver operation of the regenerative circuit continues uninterrupted.

Let it be assumed now that an aircraft desiring direction-finding information from the radio beacon transmits thereto an interrogating signal comprising a pulse-modulated radio-frequency carrier signal. In general, this interrogating signal will have a high intensity with reference to the noise signals in the regenerative circuit so that the oscillations generated in each quench cycle occurring within the duration of each received pulse of the interrogating signal have a relatively high amplitude. During the intervals which intervene between pulses of the interrogating signal, the output signal of detector 30 comprises the low-amplitude quiescent signal described above. The resulting detected output signal, including both the high-amplitude and low-amplitude signal components, is supplied to unit 40 for controlling the operating characteristics of the regenerative circuit. However, the pulse-repetition frequency of the received interrogating signal is usually such that the high-amplitude components occur at such a low frequency as to have substantially no effect on the control voltage derived in unit 40. Therefore, this unit responds primarily to the selected component of the quiescent signal output of the detector to control the operating characteristics of the regenerative circuit in the manner indicated above.

This detected output signal is also applied to generator 50 which, in response to the first high-amplitude component derived from each pulse of the received signals, applies to the anode-cathode circuit of tube 10 a single positive pulse of unidirectional potential. Each applied pulse of unidirectional potential has a predetermined pulse duration, determined by the time constants of generator 50, and a magnitude which is substantially greater than that of the quench voltage applied to tube 10. This applied pulse of unidirectional potential has two significant effects on the operation of the regenerative circuit. In the first place, it controls the regenerative circuit to operate for a given interval as a high-power radio-frequency transmitter to transmit a single pulse of the reply signal having a pulse duration

6

corresponding to that of the applied pulse of unidirectional potential. Additionally, it is effective to establish the operating frequency of the regenerative circuit during each interval of wave-signal transmission at a value which is less than that obtaining during intervals of wave-signal reception. The manner in which this frequency shift is accomplished is to be explained presently. At the trailing edge of each applied pulse of unidirectional potential the quench voltage again becomes effective to control the regenerative oscillatory circuit for an interval of wave-signal reception as described above.

In the usual installation, the time constants of generator 50 are so adjusted that the applied unidirectional potential has a pulse duration substantially equal to that of the received pulses of the interrogating signal. Thus, in response to a received interrogating signal, the radio beacon transmits a reply signal comprising pulses of radio-frequency energy having the same duration and pulse-repetition frequency as the received interrogating signal. The inquiring aircraft is able to obtain bearing indications from the reply signal.

In considering the operation of the wave-signal transponder system it has been stated that the operating frequency of the regenerative circuit during intervals of wave-signal reception is determined jointly by the parameters of its resonant circuit and the electron transit time of tube 10. This will be apparent from the following consideration.

An oscillator essentially comprises an amplifier in which a component of the output voltage is fed back to the input circuit in such a way that the feed-back voltage is in phase with the input voltage required in the input circuit. Oscillations may only be sustained when this phase relation exists. Usually, the output circuit of the amplifier consists of a resonant circuit and the voltage derived therefrom has a phase-shift-frequency characteristic as represented by the graph of Fig. 2. Where the effect of transit time in the amplifier tube may be neglected, the desired phase relation is obtained at the resonant frequency f_0 of the resonant circuit so that oscillations may be sustained with the amplifier operating at this frequency value. On the other hand, where the circuit is operated in the ultra-high-frequency range, as in the present case, the transit time of the tube becomes important and may not be neglected. It imparts a lagging phase to the current in the tube and hence to the voltage across the resonant circuit. Therefore, in order to obtain the phase relation required for sustaining oscillations, the operating frequency of the oscillatory circuit adjusts itself to some value, as represented by the ordinate line f_r of Fig. 2, such that a compensating leading phase is imparted to the voltage by the resonant circuit. Consequently, sustained oscillations occur at a frequency which is less than the resonant frequency of the resonant circuit. Thus, the operating frequency of the arrangement of Fig. 1, when functioning as a super-regenerative receiver, has a predetermined operating frequency f_r determined jointly by the parameters of its resonant circuit and the electron transit time of tube 10. Since the applied quench voltage may have a relatively low amplitude for a linear mode of operation of the receiver circuit, the electron transit time of tube 10 may be a substantial part of the period of oscillation so that this operating frequency f_r is

considerably less than the resonant frequency of the resonant circuit provided by inductor 11 and condenser C.

During intervals of wave-signal transmission the regenerative circuit is powered by the unidirectional potential supplied by unit 50 as described above. This unidirectional potential which has a substantially greater magnitude than the quench voltage is effective to reduce the control electrode-anode component of the electron transit time of tube 10. This reduction in the electron transit time produces a proportionate decrease in the phase-lag effect of tube 10 so that a smaller phase-compensating effect is required to be obtained from the resonant circuit coupled thereto. Consequently, during intervals of wave-signal transmission, the operating frequency of the regenerative circuit has an increased value as indicated by the ordinate line f_1 of Fig. 2.

The coupling circuits of the described transponder system which couple the resonant circuit to the control electrode and cathode of vacuum tube 10 to provide a control electrode-cathode circuit therefor have an impedance which is substantially lower than the impedance of the vacuum tube at frequencies less than that of the quench voltage. This produces a desirable stability characteristic inasmuch as it obviates the undesirable blocking tendency of certain prior art receiver-transmitter arrangements, mentioned above, which include a high-impedance resistor in the control electrode-cathode circuit of the oscillator tube. Furthermore, by applying the quench voltage and the pulse-modulated unidirectional potential to the anode-cathode circuit of tube 10 a desired shift in the operating frequency of the regenerative oscillatory circuit as between intervals of wave-signal reception and transmission is possible. This result is not obtained in the prior art arrangements which apply the control potentials to the control electrode-cathode circuit of the oscillator tube since the control electrode-cathode component of the electron transit time has a substantially stabilized value.

It will be apparent from the foregoing description that during intervals of wave-signal transmission the quench voltage is present in the anode-cathode circuit of tube 10. However, during such intervals the applied unidirectional potential effectively overwhelms the quench voltage which is rendered substantially ineffective. If desired, the receiver-transmitter arrangement may be modified, as indicated in Fig. 3, to include means responsive to the unidirectional potential for effectively disabling the supply circuit of the periodic quench voltage during intervals of wave-signal transmission. Fig. 3 represents that portion of the Fig. 1 arrangement included within broken-line rectangle 10 and shows the cathode circuit of cathode follower 22 grounded through the secondary winding of pulse transformer 52. With this modified circuit, during intervals of wave-signal transmission the cathode of cathode follower 22 is driven positive to block the cathode follower and disable the supply circuit for the quench voltage.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and

modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including resonant-circuit means and vacuum-tube means coupled thereto having an anode-cathode circuit, means for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception and to determine the electron transit time of said vacuum-tube means so that said regenerative oscillatory circuit has a predetermined operating frequency during intervals of wave-signal reception determined jointly by the parameters of said resonant-circuit means and said electron transit time, said quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, and means for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal and having a substantially greater magnitude than said quench voltage so as to effect a predetermined modification of said electron transit time of said vacuum-tube means, thereby to produce a related modification of said operating frequency of said regenerative oscillatory circuit during intervals of wave-signal transmission.

2. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including resonant-circuit means and vacuum-tube means coupled thereto having an anode-cathode circuit, means for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception and to determine the electron transit time of said vacuum-tube means so that said regenerative oscillatory circuit has a predetermined operating frequency during intervals of wave-signal reception determined jointly by the parameters of said resonant-circuit means and said electron transit time, said quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, and means for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal and having a substantially greater magnitude than said quench voltage so as to reduce said electron transit time of said vacuum-tube means a predetermined amount, thereby to increase said operating frequency of said regenerative oscillatory circuit to a predetermined value during intervals of wave-signal transmission.

3. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, means for supplying to said anode-cath-

ode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, said quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, means for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal, and means responsive to one of said periodic quench voltage and said modulated potential for effectively disabling said means for supplying the other of said quench voltage and said modulated potential to said anode-cathode circuit.

4. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, means for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, said quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, means for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal, and means responsive to said modulated potential for effectively disabling said means for supplying said periodic quench voltage during intervals of wave-signal transmission.

5. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, means including a vacuum-tube repeater for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, said quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, and means responsive to said output signal for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal and for blocking said repeater to disable said means for supplying said periodic quench voltage during intervals of wave-signal transmission.

6. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, means for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, said quench voltage having a frequency which is low with reference to the carrier frequency of the

signal to be received and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, and means responsive to said output signal for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal and for disabling said means for supplying said periodic quench voltage during intervals of wave-signal transmission.

7. A regenerative-type wave-signal transponder system for transmitting a pulse-modulated reply signal in response to a received pulse-modulated interrogating signal comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, means for supplying to said anode-cathode circuit a periodic quench voltage to provide superregeneration for wave-signal reception, said quench voltage having a frequency which is low with reference to the carrier frequency of said received signal and high with reference to the highest modulation frequency thereof to be translated, means for deriving from said regenerative oscillatory circuit an output signal including high-amplitude components determined by the pulse modulation of said received signal, and means responsive to said high-amplitude components for supplying to said anode-cathode circuit a pulse-modulated potential for controlling said regenerative oscillatory circuit to transmit a pulse-modulated reply signal.

8. A regenerative-type receiver-transmitter arrangement for receiving and transmitting modulated carrier-frequency wave signals comprising, a single regenerative oscillatory circuit including vacuum-tube means having an anode-cathode circuit, an oscillation generator for supplying a periodic quench voltage having a frequency which is low with reference to the carrier frequency of the signal to be received and high with reference to the highest modulation component thereof to be translated, a vacuum-tube repeater connected in cascade with said oscillation generator for applying said quench voltage to said anode-cathode circuit to provide superregeneration for wave-signal reception, means for deriving from said regenerative oscillatory circuit an output signal representing the modulation of said received signal, and means for supplying to said anode-cathode circuit a modulated potential for controlling said regenerative oscillatory circuit to transmit a modulated carrier-frequency signal.

HAROLD A. WHEELER.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,045,224	Gerhard	June 23, 1936
2,333,688	Shepard, Jr.	Nov. 9, 1943
1,650,250	Bronk	Nov. 22, 1927
2,171,293	Plastino	Aug. 29, 1939
2,262,838	Deloraine et al.	Nov. 18, 1941
2,024,138	Armstrong	Dec. 17, 1935

FOREIGN PATENTS

Number	Country	Date
795,456	French	Jan. 6, 1936
463,938	British	Apr. 5, 1937