July 10, 1945. C. W. HANSELL 2,379,900

RECEIVING SYSTEM

Original Filed Nov. 29, 1940 2 Sheets-Sheet 1

Fig. 1.

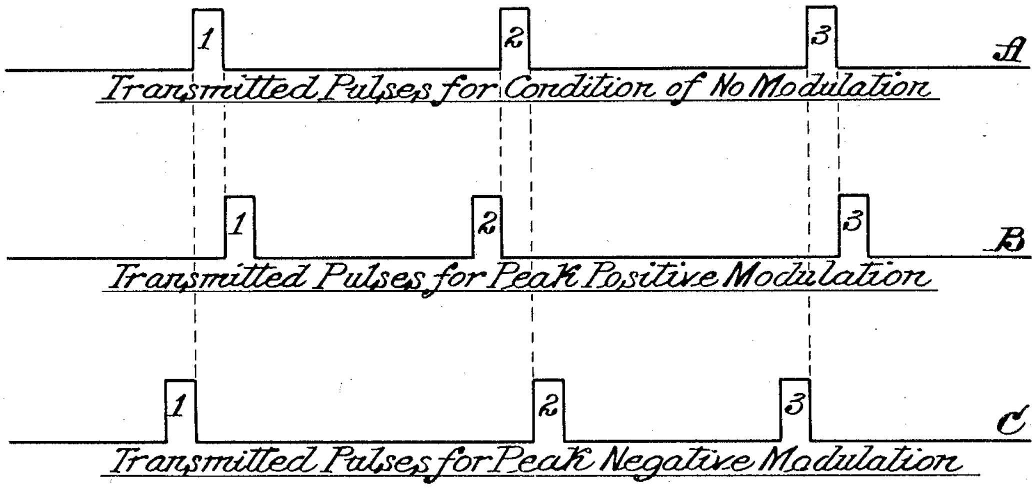

Fig. 2.

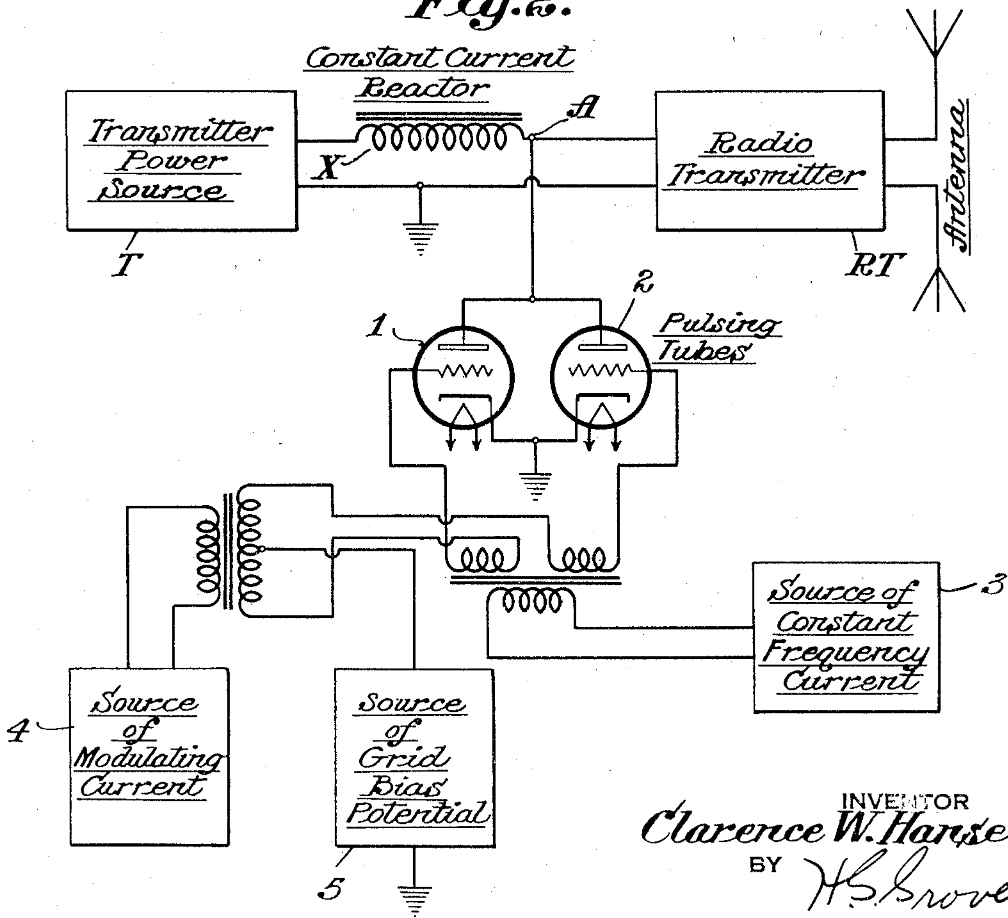

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Fig. 3.

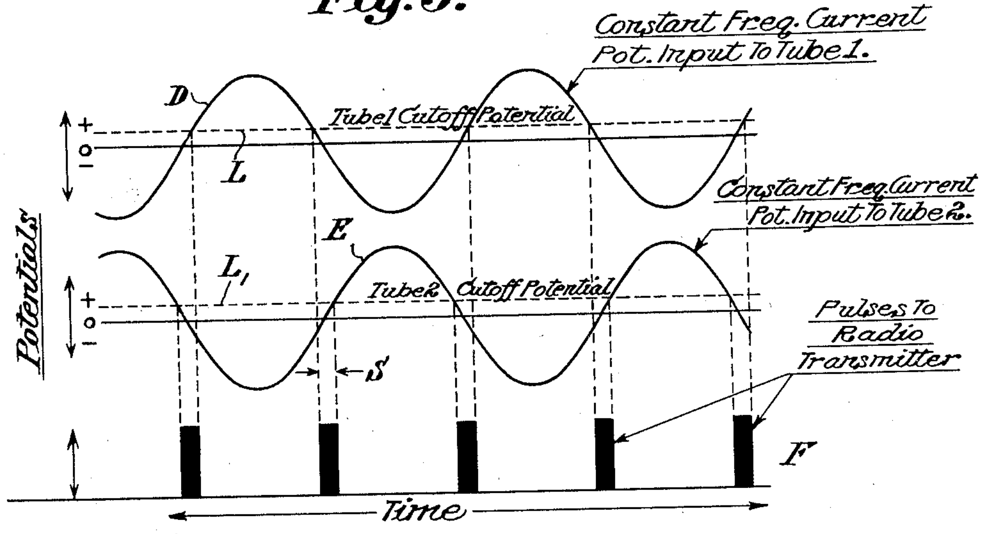
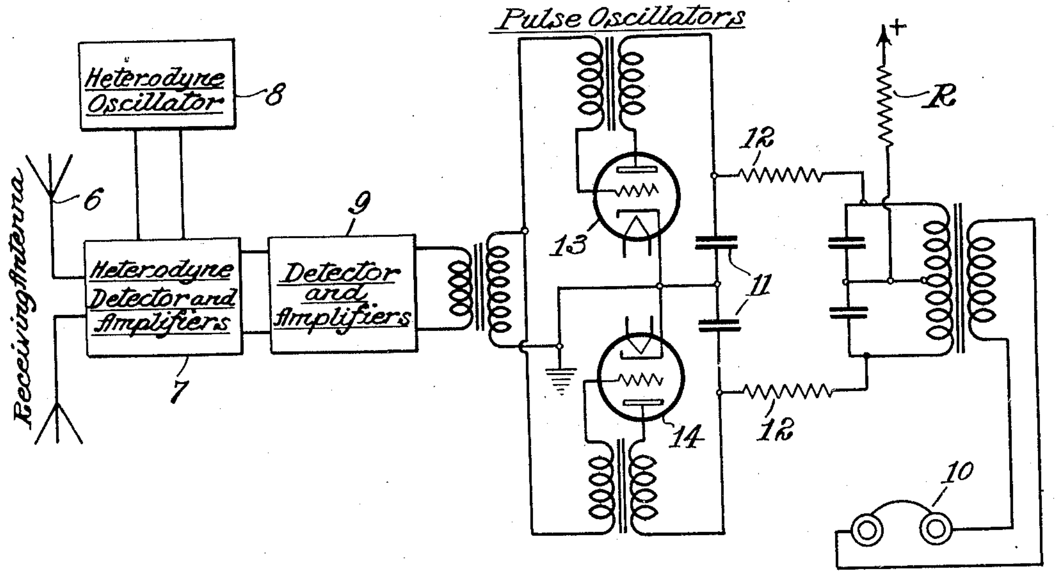


Fig. 4.



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Patented July 10, 1945 **2,379,900**

UNITED STATES PATENT OFFICE

2,379,900

RECEIVING SYSTEM

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Original application November 29, 1940, Serial No. 367,688. Divided and this application November 25, 1942, Serial No. 466,888

10 Claims. (Cl. 250—20)

The present invention comprises a pulse type radio communication system, and is a division of my copending application, Serial No. 367,688, filed November 29, 1940.

By operating the radio communication system of the invention in such manner as to transmit short pulses separated by relatively long spaces, I am able to achieve the following desirable results: (1) Higher peak power and much higher frequencies than would otherwise be possible, because of limitations due to heating of transmitting vacuum tubes, (2) an improvement in signal to noise ratio in view of the fact that the receiver is responsive only during time periods which may be occupied by the transmitted pulse, and (3) a degree of secrecy in signaling.

In brief, I propose to transmit short pulses separated by relatively large spaces, and to modify the relative timing of successive pulses in accordance with the useful modulation. Thus, if successive pulses are numbered 1, 2, 3, 4, 5, etc., one polarity of modulation potential moves pulses 1 and 2, 3 and 4, 5 and 6, etc., closer together but moves pulses 2 and 3, 4 and 5, 6 and 7, etc., further apart by an equal amount. Reversing the modulation potential will reverse the time displacements of successive pulses. With this type of pulse timing modulation, there is no change in the average pulse rate but only a variation in time spacing between adjacent or successive pulses. By means of this timing variation or modulation, I am able to carry out any kind of communication, provided the pulse rate or frequency is sufficiently greater than the highest significant modulating frequency.

A better understanding of the invention may be had by referring to the following description which is accompanied by drawings wherein:

Fig. 1 illustrates graphically three conditions for the transmitted pulses which are obtained in the transmitter of the invention;

Fig. 2 illustrates a pulse type transmitter circuit in accordance with the invention;

Fig. 3 graphically illustrates the action of the pulsing tubes of Fig. 2; and

Fig. 4 illustrates a receiving system in accordance with the invention for use with the transmitter of Fig. 2.

In Fig. 1 there are illustrated three pulse conditions A, B and C which might be obtained in a system if we assume that the shift in timing of each pulse is a maximum equal to the time length of each pulse. If the pulse rate is say 15,000 cycles per second, and the length of each pulse is $(1+150{,}000) \times (10)^6 = 6.67$ microseconds, then useful modulation may be assumed to have caused shifts in timing of individual pulses of 6.67 microseconds (equivalent to width of a pulse) for conditions B and C of Fig. 1, with respect to the timing for the unmodulated condition illustrated in A. It should be noted that for condition B, representing one polarity of modulation, the pulses 1 and 2 are closer together while pulses 2 and 3 are further apart relative to their respective times of occurrence in condition A which represents the unmodulated condition. Similarly, for condition B, pulses 3 and 4 and also pulses 5 and 6 will be closer together, while pulses 4 and 5, as well as 6 and 7, will be further apart. For condition C representing the other polarity of modulation, pulses 1 and 2 and also pulses 3 and 4 are further apart, while pulses 2 and 3 as well as pulses 4 and 5 are closer together in point of time relative to the timing for condition A.

Fig. 2 illustrates schematically one transmitter circuit in accordance with the invention for producing and transmitting pulse signals of the character illustrated in Fig. 1. In Fig. 2, electrical direct current from a transmitter power source T is held at a substantially constant value by means of a constant current high inductance reactor X, in a manner similar to that found in the Heising constant current transmitter modulation system. Source T supplies anode potential for the anode of the power amplifier vacuum tube in the radio transmitter RT. The current from the reactor divides itself at point A into two paths. One path is to the radio transmitter RT and the other path is to a pair of pulsing vacuum tubes 1 and 2.

When proper electrical constants are used, the pulsing tubes 1, 2 pass current at a relatively low potential for most of the time but both tubes cut off their currents to cause source T and the reactor X to send short current pulses at relatively high potential to the radio transmitter. This combination, when properly designed and constructed, results in good power efficiency. While the pulsing tubes are passing current, i. e., when they are conductive, there is a tendency for current through the reactor X to increase. While the tubes are not passing current, i. e., when they are non-conductive, there is a tendency for the current through the reactor X to decrease. The low potential to ground from the reactor output terminal between A and ground for relatively long time periods, and the high potential for relatively short time periods (pulse periods) provide an average value substantially equal to the potential from the transmitter power source

T. During these relatively short time periods, the high potential supplied to the radio transmitter RT greatly exceeds the normal voltage supplied by T. Putting it another way, while vacuum tubes 1 and 2 pass current, there is a voltage drop through these tubes which is small, and, in effect, there is a low resistance short-circuit cross reactor X for which reason the current through the reactor tends to increase. When the pulsing vacuum tubes 1, 2 become non-conductive for spaced relatively short time periods, the short-circuit path across reactor X is removed, thus permitting the potential from anode source T to be applied to the radio transmitter RT with even greater effect than from a steady source. The reactor X, by holding substantially constant current, forces a peak current into the transmitter RT having a value substantially equal to the peak current from terminal A through tubes 1 and 2 even though this may require a sharp rise in potential. The current in reactor X stores energy in the magnetic field of the reactor so that the current cannot be diminished except by using up some of the stored energy.

The control electrodes of the pulsing tubes are supplied with a direct current biasing potential from a rectifier 5, and also supplied with alternating current from two sources 3 and 4. Source 3 is a "source of constant frequency current" which may operate at 7500 cycles per second if it is desired to transmit 15,000 pulses per second. Current from this source 3 is applied to the pulsing tube control electrodes in push-pull or 180° phase relation. Source 4 is a source of modulating current which is to be transmitted. It may be made up of telephone, multiplex-telegraph, facsimile, or other types of signaling current. If ordinary conversational telephone modulation is employed for source 4, it is preferred that the range of telephone frequencies be between 150 and 3000 cycles. Input from source 4 is also applied to the control electrodes of the pulsing tubes in push-pull or 180° phase relation.

When there is no modulation input applied from source 4, one or the other of the pulsing tubes 1, 2 is passing anode current at all times except when the input from the source of constant frequency current 3 is near the zero value of each cycle. At the time when the input from source 3 is near the zero value of each cycle, both pulsing tubes 1 and 2 cut off current at the same time, i. e., are simultaneously non-conductive, and cause a short and sharp pulse of current at relatively high potential to be passed into the radio transmitter. For this unmodulated condition, the pulses transmitted from the radio transmitter RT are uniformly spaced with respect to time. Fig. 3 illustrates qualitatively the action of the tubes in producing the pulses. Curve D of Fig. 3 represents the potential input with respect to time supplied to pulsing tube 1 by source 3 while curve E represents the potential input supplied to pulsing tube 2 by the same source 3. Both of these curves are shown as sine wave curves. The dotted lines L and L_1 indicate the current cut-off potential point for tubes 1 and 2 respectively. It should be noted that both tubes are simultaneously non-conductive only during a short time interval S near the zero value of both curves. Graph F indicates that pulses are produced only during the short times that both pulsing tubes are simultaneously non-conductive.

If, momentarily, modulation from source 4 produces a differential variation in bias potential on the grids of pulsing tubes 1 and 2, then alternate pairs of pulses will draw together. The tubes will act as though the bias on one pulsing tube was increased and the bias on the other pulsing tube was decreased. Reversing the differential potential will push these same alternate pairs of pulses apart. A complex wave form of modulating potential will produce a corresponding pulse timing modulation which may be utilized for communication purposes.

It is preferred that transmitter RT employ a carrier frequency above 30 megacycles.

To receive signals or modulations transmitted from the equipment of Fig. 2, I may employ a receiving system of the kind illustrated in Fig. 4. In this system a superheterodyne type of receiver is utilized to provide an output current made up of the time modulated pulses from the transmitter. An antenna 6 collects the pulse signals and passes them on to a heterodyne detector and amplifier 7. A local oscillator 8 supplies the beating frequency. The intermediate frequency output from 7 is further detected, amplified and reduced to an audio frequency signal in 9. The pulses from 9 are delivered to two pulsing oscillators 13, 14, similar to those used to produce saw-tooth potentials in television receivers, each adjusted to have a natural period of oscillation substantially equal to half the average frequency of the pulses from the transmitter, i. e., 7500 cycles. The pulse oscillators 13 and 14 are provided with a common anode circuit resistance R for the purpose of making them tend to operate substantially 180° out of phase. The received pulses are utilized to synchronize the operation of the pulse oscillators and, obviously, alternate received pulses are automatically effective in controlling the timing of each oscillator 13 or 14. However, each pair of received pulses produces opposite effects upon the timing of the oscillators 13 and 14 and these effects balance out so far as the pulsing rate of the combined oscillators is concerned. When a received pulse advances the time of tripping of one oscillator 13 or 14, it retards the time of tripping of the other 14 or 13. Both pulse oscillators are locked together through the common anode circuit resistance R and the other circuits so that, in effect, the received pulses modulate the phase or timing of oscillations of each pulse oscillator but not the oscillation frequency. During the time when both pulse oscillators 13 and 14 are not passing current, the condensers 11, 11 are being charged up through resistors 12, 12. The rate of charging of these condensers controls the timing of the operation of the pulse oscillators. In effect, the time constants of condensers 11, 11 and resistors 12, 12, in combination with the tube potential adjustments, controls the operating frequency. The received pulses serve to differentially vary the tripping time of the oscillators, thus differentially varying the average current passing through the oscillator tubes. The common anode resistor R also affects the operating frequency to some extent because the drop in the resistor affects the input potential and therefore the charging rate of condensers 11, 11 through resistors 12, 12.

Once the oscillations have dropped into synchronism with the received pulses, the average anode currents to the pulse oscillator tubes 13 and 14 will be differentially modulated by the pulse modulation and this differential current may be utilized to provide the useful modulation output from the received system which can be heard in the headphones **10** or recorded by some equivalent circuit.

The polarity of the audio output from the pulse oscillators **13**, **14** with respect to the pulse modulation, will be in one direction or the other, depending upon the phase relations which happen to be established when the locking of the receiving oscillators **13** and **14** by transmitted pulses is started.

The system just described provides a considerable degree of privacy or secrecy since any ordinary amplitude, phase, or frequency modulation receiver now known or utilized in the art will be substantially unresponsive to the type of modulation provided. Intelligible reception is, in general, only possible with equipment specially designed and adjusted to operate at the pulse frequencies utilized at the transmitter and with the type of modulation proposed.

Because the receiver pulse oscillators **13** and **14** are in a condition to be tripped by received power for only brief time periods including the time periods occupied by transmitted pulses, there will be an improvement in the signal to noise ratio and also less interference from undesired signals. Noise occurring during spacing periods will have no effect because the oscillators **13**, **14** are not in a condition to trip during these periods.

Circuits ahead of the receiver pulse oscillators must be made broad enough in frequency pass band to pass the pulses. If the carrier frequency is 30 megacycles, for example, then these circuits should have a pass band of 30 megacycles ± 15,000 cycles or more. This is a band width greater than that required to pass double side bands of the useful modulation alone. As a result of the broadness in band width, ignition and similar man made noises are much shorter in time duration than they would be in the common type of receiver now in use. This reduces the probability of a noise pulse affecting the receiver pulsing oscillators.

The effective or narrowest selectivity of the system appears in the action of the receiver pulse oscillators which may have an effective selectivity as great as desired by controlling the amount of energy from the receiver utilized to control the oscillators and by controlling the degree to which each oscillator can determine its own timing. The degree of locking between the two oscillators, tending to make them operate 180° out of phase, is controllable to control the sensitivity of the pulsing oscillators as detectors. To summarize, by controlling the pulse input power, the degree of locking between the pulse oscillators, and the other electrical adjustments, I can control the effective selectivity and sensitivity of the final detector of the system over a large range.

What is claimed is:

1. Means for receiving pulses of carrier current modulated as to time of occurrence, comprising a superheterodyne receiver for reducing the frequency of the received carrier current pulses to audio frequency pulses, a pair of electron discharge device audio frequency oscillators each having a grid, a cathode and an anode, means coupling the output of said receiver to said grids to apply potentials to said grids in like phase with respect to each other, a connection between said cathodes, time constant circuits coupled to said anodes to control the timing of the operation of said oscillators, said time constant circuits having such values as to cause each of said oscillators to have a natural period of oscillation substantially equal to half the average frequency of the pulses received by said receiver, and a resistor in common to said anodes, whereby the phase or timing of oscillations of each oscillator, but not the oscillation frequency is modulated by the received pulses.

2. A receiving system in accordance with claim 1, characterized in this that the anode of each oscillator is coupled to its grid through an audio frequency transformer, and the time constant circuit for each oscillator includes a condenser and a resistor through which the condenser is charged.

3. A system for demodulating current pulses modulated in timing but not in mean frequency, comprising two pulsing oscillators, each operating at approximately half the frequency of the carrier current pulses, the anodes of said oscillators having a common anode resistor for constraining said oscillators to operate at approximately 180° phase relation.

4. A system according to claim 3, comprising means to apply the pulses to be demodulated to the two oscillators in like polarity.

5. A system for demodulating current pulses modulated in timing but not in mean frequency, comprising two pulsing oscillators, each operating at approximately half the frequency of the carrier current pulses, means for constraining said oscillators to operate at approximately 180° phase relation, means to apply the pulses to be demodulated to the two oscillators in like polarity, and means for coupling to the oscillators differentially for deriving modulation frequency currents.

6. Means for receiving pulses of carrier current modulated as to time of occurrence, comprising a superheterodyne receiver for reducing the frequency of the received carrier current pulses to audio frequency pulses, a pair of electron discharge device audio frequency oscillators each having a grid, a cathode and an anode, means coupling the output of said receiver to said grids to apply potentials to said grids in like phase with respect to each other, a connection between said cathodes, a feed back circuit including an inductance coil in series with a concentrated capacity, in the order named, coupled between the anode and cathode of each oscillator, a connection from the junction point of the inductance coil and capacity in each feed back circuit to a common anode resistor, said last connection including a resistor and a condenser in series with each other, and an audio frequency utilization circuit coupled across the condensers of said last connections.

7. A system for demodulating current pulses modulated in timing but not in mean frequency, comprising two pulsing oscillators each having a grid, a cathode and an anode, an audio transformer for each oscillator having a primary winding coupled between the grid and cathode and a secondary winding coupled between the anode and cathode, a connection between the cathodes, means for supplying the grids of both oscillators cophasally with the pulses to be demodulated, a common anode resistor, and a connection from a point on said resistor to that terminal of each of said secondary windings which is nearest to the cathode, said connection including a condenser and a resistor in series.

8. A system for receiving pulses of carrier frequency, comprising means for reducing the frequency of the received carrier current to audio frequency current, a pair of oscillators operating substantially 180° out of phase relative to each

other and receiving said audio frequency current pulses, means in circuit with said oscillators for controlling the timing of the operation of said oscillators, whereby each oscillator has a natural period of oscillation substantially equal to half the average pulse rate of the transmitted pulses, and means in common to the output of said oscillators for insuring the phase or timing modulation of said oscillators in accordance with the timing of the received pulses but without varying the oscillation frequency.

9. A system for receiving pulses of carrier frequency, comprising means for reducing the frequency of the received carrier current to audio frequency current, a pair of pulsing oscillators operating substantially 180° out of phase relative to each other and receiving said audio frequency current pulses cophasally, means in circuit with said oscillators for controlling the timing of the operation of said oscillators, whereby each oscillator has a natural period of oscillation substantially equal to half the average pulse rate of the transmitted pulses, and means including a resistor in common to the output of said oscillators for insuring the phase or timing modulation of said oscillators in accordance with the timing of the received pulses but without varying the oscillation frequency.

10. A demodulator of communications modulations transmitted by means of differential timing modulations of successive pulses of current, said demodulator comprising two pulse oscillators each having a natural frequency of oscillation nearly equal to half the frequency of received pulses, means to make one oscillator respond in timing to one succession of alternate pulses and to make the other oscillator respond in timing to the other succession of alternate pulses, and means to derive an output current responsive to differential timing variations of the two pulse oscillators.

CLARENCE W. HANSELL.