April 19, 1949. M. S. WHEELER 2,467,793

RADIO COMMUNICATION SYSTEM

Filed May 19, 1945

Fig. 1.

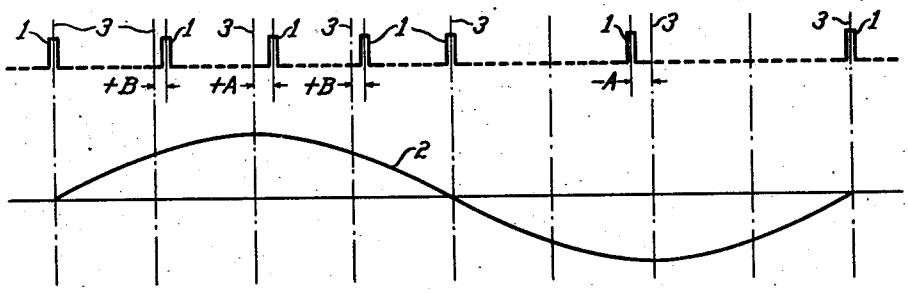


Fig. 2.

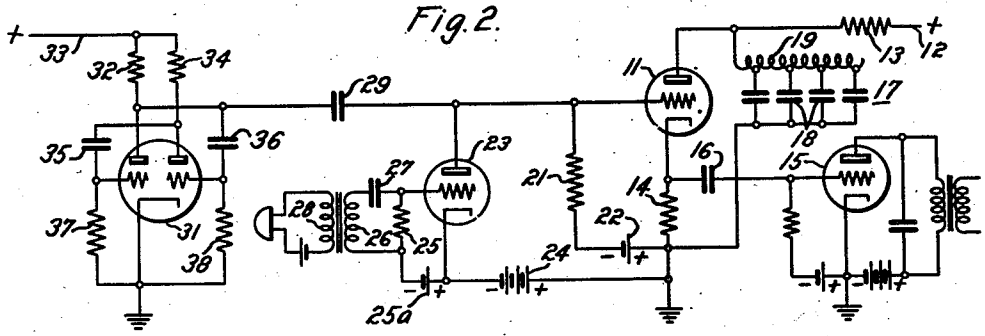


Fig. 3.

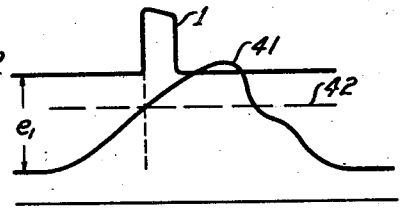
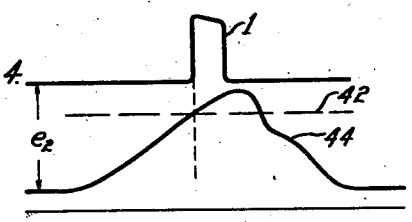


Fig. 4.



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RADIO COMMUNICATION SYSTEM

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5 Claims. (Cl. 332—9)

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My invention relates to radio communication systems and in particular relates to a system which transmits modulated energy in the form of intermittent pulses, the spacing of which is varied to convey the information being transmitted. The system may in fact be referred to as phase modulation of pulsed radio waves.

One object of my invention is to provide a system of radio communication in which intelligence is transmitted by employment of short intermittent pulses of varied time spacing.

Another object of my invention is to provide a system of radio communication in which intelligence may be transmitted on radio waves derived from oscillators or amplifiers which are unstable except in the neighborhood of a substantially constant plate voltage.

Another object of my invention is to provide a radio transmitting system which operates at low average power output but has high peak power output.

Another object of my invention is to devise a radio communication system which is comparatively insensitive to natural and man-made interference.

Another object of my invention is to provide a system of radio communication which would be insensitive to interference of audio frequency.

Still another object of my invention is to provide a system of radio communication in which the power required for modulation is comparatively low.

A further object of my invention is to provide a circuit for modulating the time spacing between output pulses of an electronic pulse-generator in accordance with an impressed control-quantity.

A still further object of my invention is to provide a circuit for modulating in accordance with a control quantity the time spacing of output pulses of an electronic generator of the type which has substantially larger outputs in the neighborhood of one or more values of plate voltage than it has at other values of plate voltage.

Other objects of my invention will become apparent upon reading the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a wave-form curve useful in explaining the mode of operation of my invention;

Fig. 2 is a schematic diagram of a circuit useful in one embodiment of a system for carrying out my invention; and

Figs. 3 and 4 are graphic curves showing the relationship between certain electrical quantities referred to in the following discussion,

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Referring to Fig. 1, my communication system utilizes intermittent pulses 1 of radio energy preferably of substantially the same amplitude and of approximately rectangular form which are spaced apart from each other by time intervals substantially larger than the duration of the separate pulses. The upper line in Fig. 1 shows a succession of pulses 1 of the form just referred to, it being understood that in most cases it will be desirable to have the pulses much shorter relative to the period of the sine waves shown in the lower line of Fig. 1, and to have many times as many pulses occur in that period, than it is possible to show without confusing the drawing in Fig. 1. The pulses 1 are preferably of substantially the same amplitude and width and approximate rectangular configuration.

In the lower line of Fig. 1, the curve 2 represents a sinusoidal modulating signal to be transmitted by the communication system employing the pulses 1. The pulses 1 are not uniformly spaced from each other but vary from the uniform spacing represented by the dash and dot lines 3 by a time interval which is proportional in magnitude and sign to the instantaneous values of the modulating wave 2. Thus, where the modulating curve 2 passes through zero, the pulses 1 coincide in time with the dot and dash line 3. On the other hand, at the positive maximum of the curve 2, the center line of the pulse 1 is spaced away from the dot and dash line 3 by an amount +A. At a point where the curve 2 is intermediate in value between zero and its positive maximum, the pulse 1 is spaced away from the dot and dash line 3 by an amount +B which is smaller than the amount +A just mentioned. Similarly, where the curve 2 in Fig. 1 passes through its maximum negative values, the pulse 1 is spaced away from the dot and dash line 3 by an amount —A and an analogous rule holds for the spacing of the pulses 1 at points where the curve 2 is intermediate in value between zero and its negative maximum. The pulses 1 are accordingly individually of the same amplitude and duration but may be referred to as phase modulated in accordance with the modulating curve 2 of Fig. 1.

One specific circuit by which it is possible to produce radio pulses of the type just referred to is shown in Fig. 2 in which a pulse generator 11, serving as a modulator for a radio frequency oscillator, which may be, for example, a gas filled hot cathode tube of the thyratron type has its anode supplied with current through a suitable impedance 13 from the positive terminal 12 of a suitable direct-current source of which the negative

terminal is grounded. The cathode of the tube 11 is connected through a cathode-resistor 14 to ground. An output circuit capable of causing radiation or transmission of the output waves of the generator 11 over a transmission channel is connected across the terminals of the resistor 14. To take a specific example, radio frequency oscillator 15 may be connected to the nongrounded terminal of the resistor 14. Between the anode of the tube 11 and ground is connected a network having substantially the properties of a transmisson line with distributed inductance and capacity; for example, this network 17 may comprise capacitors 18 connected at uniform intervals between points on an inductance 19 and ground, one terminal of the inductance 19 being connected to the anode of tube 11.

Between the control electrode of the tube 11 and ground is shunted a resistor 21 in series with a suitable direct-current voltage source 22. There is also connected between the control electrode of the tube 11 and ground a high-vacuum triode 23 in series with a voltage supply 24. Between the control electrode and the cathode of the tube 23 is connected a suitable resistor 25 in series with a bias source 25a, the common terminal of the cathode and source 25a being connected to the negative terminal of source 24. The resistor 25 is shunted by a secondary winding 26 of an audio frequency transformer in series with a capacitor 27. The primary winding 28 which cooperates with the secondary winding 26 is impressed with modulating signals by any of the well known arrangements conventional in the art.

The anode of the tube 23 is connected through a capacitor 29 to one anode of what may be termed an unbalanced multivibrator 31 of a type well known in the art. The cathode of the multivibrator 31 is connected to ground and its abovementioned anode is connected through a resistor 32 to the positive terminal 33 of a direct-current voltage source having its negative terminal grounded. A second anode of the multivibrator 31 is likewise connected to the positive terminal 33 through a resistor 34 and is connected to a control electrode associated with the first-mentioned anode through a capacitor 35. The first-mentioned anode is similarly connected through a capacitor 36 to a control electrode associated with the second-mentioned anode of the multivibrator 31. The control electrodes just mentioned are connected to the cathode of the multivibrator 31 through a pair of suitable resistors 37, 38.

The mode of operation of the circuit just described is substantially as follows. The multivibrator 31 generates a series of intermittent pulses of voltage of substantially uniform time-spacing corresponding to the dot and dash lines in Fig. 1. When no control modulations are impressed through the primary winding 28, these pulses, which have substantially the wave form of curve 1 in Fig. 3, are impressed through the capacitor 29, the resistor 21 and voltage source 22 on the control electrode of tube 11. As is well known in the gaseous discharge tube art, the tube 11 remains substantially nonconductive until the voltage impressed on its control electrode exceeds a certain critical value represented by the line 42 in Figs. 3 and 4. The voltage of source 25a is made such that current flow from source 22 through resistor 21 and tube 23 makes the voltage e_1 impressed on the grid of tube 11 less than this actual value. While the tube 11 is nonconductive, the capacitors 18 charge up substantially

to the voltage of the positive terminal 12 and remain so charged until the tube 11 becomes conductive. When the pulse 1 impressed on the control electrode of tube 11 exceeds the value 42, current flow suddenly starts between the anode and cathode of tube 11. The network 17 thereupon discharges through the tube 11 producing a substantially rectangular voltage pulse shown at 1 in Fig. 3. It will be noted that the leading edge of the voltage pulse 1 coincides substantially in time at the point which the curve 41 crosses the line 42 in Fig. 3. The amplitude and duration of the voltage pulse 1 is determined by the electrical constants of the network 17 and tube 11, resistor 14 and source 12 as will be evident to those skilled in the art. After the production of a single pulse 1, the tube 11 becomes nonconductive; the capacitors 18 charge up again and another pulse is formed only after the impression of another voltage pulse from the multivibrator 31 on the control electrode of tube 11.

The foregoing represents the operation of the circuit of Fig. 2 when no modulating quantity is impressed on the primary winding 28. The voltage pulses 1 in Fig. 1 are then uniformly spaced in time from each other and coincide with the dash and dot lines 3 in that figure. When now a modulating signal is impressed on the primary winding 28, it reacts on the control electrode of the tube 23 to alternately reduce and increase the internal impedance of that tube. This impedance may be considered to be connected in multiple with the resistor 21 which in turn is in series with the capacitor 29. Reduction of the internal impedance of the tube 23 will increase current flow from source 22 through resistor 21, thereby increasing the negative bias impressed on the grid of tube 11 from e_1 to e_2; and will also have two effects on the voltage pulse impressed by multivibrator 31 on the control electrode of tube 11. These effects are a reduction in amplitude of the voltage pulse and also a reduction in the time constant of the CR circuit comprising capacitor 29 and the parallel impedances 21 and 23. This reduction in time constant tends to retard the phase of the voltage pulse 41. The net effect is to produce a voltage pulse of the form indicated by the curve 44 in Fig. 4 which will cross the line 42 at a later time than curve 41 did. In effect, therefore, a reduction in the internal impedance of the tube 23 delays the ignition of the tube 11 and causes the pulse generated by that tube to be delayed in time from the uniformly spaced periods represented by the dot and dash lines in Fig. 1.

Conversely, an increase in the resistance of the tube 23 tends by parity of reasoning to advance the time of the voltage pulse 1 through the tube 11. In short, the above-described circuit modulates the phase of the voltage pulses 1 of Fig. 1 in accordance with the amplitude of the modulating signal wave tube.

The voltage pulses 1 generated by tube 11 obviously pass through the cathode resistor 14 and impress themselves on the plate or control electrode of the radio frequency oscillator 15, to produce pulses of electromagnetic energy which are phase modulated in correspondence with the signals impressed on the primary winding 28.

As an alternative form the tube 15 may be replaced by a magnetron or other form of oscillation generator of a type which oscillates only when its anode-to-cathode voltage exceeds a certain value.

I claim as my invention:

1. The method of transmitting intelligence which comprises generating rectangular energy pulses of electromagnetic energy having a duration small compared with the time-intervals separating them, but of substantially the same duration, modulating said time-intervals by displacing all said pulses from a constant periodicity by times which are proportional to the contemporaneous instantaneous amplitude of a modulating signal, and impressing said pulses on a transmission channel.

2. The method of transmitting intelligence which comprises generating rectangular energy pulses of electromagnetic energy having a duration small compared with the time-intervals separating them, but of substantially the same amplitude and duration, modulating said time-intervals by displacing all said pulses from a constant periodicity by times which are proportional to the contemporaneous instantaneous amplitude of a modulating signal, and impressing said pulses on a transmission channel.

3. In combination with a gaseous discharge tube having a control electrode, means for shunting said control electrode across a first current channel embodying a first impedance, a capacitance device connected to discharge through said discharge tube, an output circuit connected to derive energy from current flow through said discharge tube, a second current channel embodying an electrical discharge tube having a control electrode and connected in multiple with at least a portion of said first current channel, means for impressing a pulsating voltage to energize said first and second current channels, and means for impressing on the last-mentioned control electrode a voltage varying with a controlled quantity.

4. In combination with a gaseous discharge tube having a control electrode, means for shunting said control electrode across a first current channel embodying a first impedance, a capacitance device connected to discharge through said discharge tube, an output circuit connected to derive energy from current flow through said discharge tube, a second current channel embodying an electrical discharge tube having a control electrode and connected in multiple with at least a portion of said first current channel, means for impressing a pulsating voltage to energize said first and second current channels, and means for impressing on the last-mentioned control electrode a voltage varying with a signal to be transmitted.

5. In combination with a gaseous electrical discharge tube having a control electrode, a voltage source for current to energize said discharge tube, a transmission channel for energy pulses coupled to derive energy from current flow through said discharge tube, a network embodying capacitance connected to be charged from said voltage source and to discharge through said discharge tube, a first current channel connected to impress voltage on the control electrode of said discharge tube, a second current channel embodying an electron tube having a control electrode and connected in multiple with said first current channel, a source of pulsating voltage connected to cause energy flow through both said current channels and means for impressing on the last-mentioned control electrode a voltage varying in accordance with a controlled quantity.

MYRON S. WHEELER.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,873,786	Ranger	Aug. 23, 1932
2,113,214	Luck	Apr. 5, 1938
2,280,707	Kell	Apr. 21, 1942
2,297,926	Usselman	Oct. 6, 1942
2,379,899	Hansell	July 10, 1945
2,392,114	Bartelink	Jan. 1, 1946
2,394,389	Lord	Feb. 5, 1946
2,406,019	Labin	Aug. 20, 1946
2,416,328	Labin	Feb. 25, 1947