March 16, 1948. P. J. REICH 2,437,970

PULSE COMMUNICATION

Filed Oct. 11, 1944

Fig. 1.

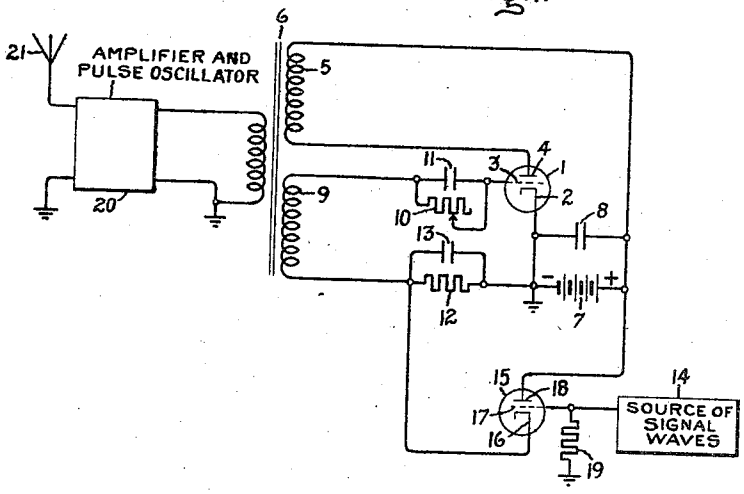
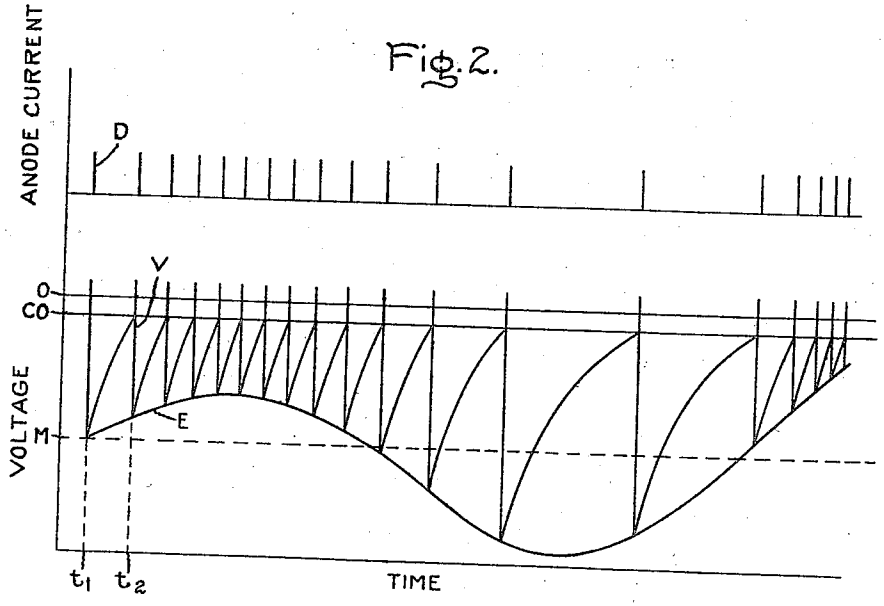


Fig. 2.



Inventor:
Philip J. Reich,
by Harry E. Dunham
His Attorney.

Patented Mar. 16, 1948

2,437,970

UNITED STATES PATENT OFFICE

2,437,970

PULSE COMMUNICATION

Philip J. Reich, Bridgeport, Conn., assignor to General Electric Company, a corporation of New York

Application October 11, 1944, Serial No. 558,149

5 Claims. (Cl. 179—171.5)

1

My invention relates to pulse communication systems, and more particularly to means for modulating pulse frequency in accordance with a desired signal.

It is a general object of my invention to provide new and improved means for modulating the frequency of recurrent electric pulses in accordance with a desired signal.

It is a further object of my invention to provide new and improved pulse frequency modulating apparatus having a very wide percentage frequency deviation from the mean frequency.

It is a still further object of my invention to provide a pulse frequency communication system having an improved signal-to-noise ratio.

It is still another object of my invention to provide means for modulating the repetition rate of a blocking or intermittently operating electron discharge oscillator.

My invention itself will be more fully understood and its objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing, in which Fig. 1 is a schematic circuit diagram of a pulse modulating circuit embodying my invention; and Fig. 2 is a graphical representation of certain of the operating characteristics of the circuit shown at Fig. 1.

Referring now to the drawing, and particularly to Fig. 1, I have shown an intermittently operating oscillator comprising an electron discharge device 1 having a cathode 2, a control electrode 3, and an anode 4. The anode 4 is connected through the primary winding 5 of a transformer 6 to the positive terminal of a battery 7, the negative terminal of which is connected to ground and to the cathode 2. A suitable high frequency by-pass condenser 8 is connected across the battery 7. The grid circuit of the oscillatory discharge device 1 comprises the secondary winding 9 of the transformer 6 connected between the cathode 2 and control electrode 3 of the discharge device 1 through a variable grid leak resistor 10 shunted by a capacitor 11 and a resistor 12 shunted by a by-pass capacitor 13. The resistor 12 has one terminal connected to the grounded cathode 2 of the discharge device 1. The transformer windings are closely coupled, but need not be tuned to a particular frequency. Each winding has a certain amount of stray and distributed capacitance which renders it inherently resonant to a certain frequency, but with close inductive coupling tuning of the windings to the same frequency is unnecessary.

2

It is understood by those skilled in the art that the circuit thus far described will produce oscillations of the discharge device 1 by reason of the magnetic feedback between the anode and control electrode circuits of the discharge device 1 through the primary and secondary windings 5 and 9, respectively, of the transformer 6. Furthermore, it is also understood that, if, as herein contemplated, the time constant of the grid leak resistor and capacitor combination 10, 11 is sufficiently large so that the negative grid bias built up by grid current is relatively stiff or non-responsive to variations in the amplitude of oscillation, the oscillations will be interrupted at a repetition rate determined by the time constant of the grid leak resistor and capacitor 10, 11. This operation arises from the fact that any slight irregularity tending to reduce the amplitude of oscillations will cause the oscillations to die out by reason of the failure of the grid circuit to respond immediately to reduce the negative bias and thereby increase the gain of the discharge device. After each cessation of oscillations, the grid condenser 11 gradually discharges through the grid leak resistor 10, thereby to reduce the negative bias of the control electrode to such a point that the discharge device 1 is again rendered conductive. Thus, effectively, the discharge device 4 oscillates intermittently in short bursts or pulses of oscillation occurring at a normal or mean repetition rate determined by the time constant of the circuit 10, 11. In the instant application it is desired that the pulses be of very short duration, and for the purpose the circuit constants may be such that the device 4 oscillates for only a portion of a cycle at each pulse.

In order to modulate the repetition rate of the intermittent oscillations in the discharge device 1, I provide means for superposing upon the grid circuit of the discharge device 1 a potential derived from a source of signal waves 14. For this purpose, I provide a second electron discharge device 15 having a cathode 16, a control electrode 17, and an anode 18. The control electrode 17 is connected to ground through a grid leak resistor 19 and to the source of signal waves 14. The anode 18 is connected to the positive terminal of the battery 7. The cathode 16 is connected to the ungrounded terminal of the resistor 12 in the grid circuit of the discharge device 1, so that the resistor 12 acts as a cathode resistor in the signal frequency anode-to-cathode circuit of the discharge device 15. In this manner signal potentials derived from the source

of signal waves 14 are impressed upon the negative terminal of the resistor 12 and, thus, through the transformer winding 9 and grid leak resistor 10 upon the control electrode 3 of the discharge device 1.

Output pulses from the discharge device 4 are amplified and supplied to a pulsed high frequency oscillator, as indicated schematically at 20, and the pulse modulated high frequency oscillations are radiated from an antenna 21.

The operation of my new and improved pulse frequency modulating apparatus described above will now be understood by referring more particularly to Fig. 2.

In the absence of the signal amplifying discharge device 15 oscillations in the discharge device 1 occur intermittently, as previously explained, and at a repetition rate determined by the time taken for the condenser 11 to discharge through the resistor 10 sufficiently to reduce the negative grid voltage of the tube 1 to a predetermined value where oscillations will again begin. As soon as oscillations are again initiated, they rapidly build up to their maximum intensity and the resulting grid current rapidly restores the maximum negative potential to the control electrode 3. Thus, if the oscillator circuit is permitted to oscillate intermittently at its natural repetition rate, the voltage of the control electrode 3 will vary between predetermined minimum and maximum values. At Fig. 2, I have shown a time-voltage curve where the control electrode cut-off voltage is indicated by a line CO parallel to the time axis and the maximum negative control electrode voltage at the mean or average repetition rate of the oscillator is indicated by a line M parallel to the time axis. The instantaneous control electrode voltage is represented by a curve V. The first cycle of the curve V illustrates the operation of the oscillator circuit without the imposition of any voltage across the resistor 12 from the signal amplifier 15. Under such conditions, the curve V shows that, at a time t_1 when oscillation of the discharge device 1 begins, the control electrode voltage is first driven slightly positive and is then rapidly driven negative to the maximum value M. The positive peak of grid voltage is due to high frequency alternating potential induced in the grid circuit from the anode circuit through the transformer 6. When the grid is positive grid current flows and drives the grid negative. As previously explained, when the control electrode voltage reaches the maximum negative value M, any slight irregularity causing a small decrease in amplitude of the oscillations causes the oscillations abruptly to cease. After oscillation is interrupted, the control electrode voltage falls from its maximum negative value along an exponential curve until the voltage of the control electrode reaches cut off at a time t_2. At the time t_2 another pulse of oscillations is initiated. Accordingly, the anode current of the discharge device 1 may be represented by a series of pulses D shown at Fig. 2 on a time-current curve.

It may now be recalled that the resistor 12 in the grid circuit of the discharge device 1 is connected also as the cathode resistor for the signal amplifying discharge device 15. Therefore, signal frequency current through the discharge device 15 superposes upon the resistor 12, and thus upon the control electrode 3, a potential varying in accordance with instantaneous signal amplitude. This signal potential is illustrated at Fig. 2 as a voltage curve E. The superposition of the signal potential E upon the control electrode 3 varies, in accordance with the signal, the time required after each interruption of oscillations for the control electrode voltage to decrease to its minimum or starting value A through discharge of the condenser 11. It will be evident from Fig. 2 that, as the signal voltage increases or decreases the normal maximum negative bias upon the control electrode 3, the frequency of recurrence of pulses in the oscillatory discharge device 3 is decreased or increased accordingly.

By way of illustration of the practical utility of my invention, it will be of interest to note that one-half microsecond pulses were produced at a mean or average repetition rate of 15 kilocycles per second with an apparatus built in accordance with Fig. 1 and having the following circuit constants:

Discharge device 1	½ 6SL7
Discharge device 15	½ 6SN7
Condenser 11	.001 microfarad
Resistor 11	100,000 ohms
Resistor 12	20,000 ohms
Capacitor 13	2,200 micromicrofarads
Resistor 19	.47 megohm
Capacitor 8	.1 microfarad

The apparatus described above was found capable of effecting substantially line or signal variations of the repetition rate over a range of plus or minus 7 kilocycles per second.

It will of course be understood that the above example is illustrative only and that my invention is in no way limited to the particular apparatus used therein or to the particular period or frequency of pulses produced thereby.

While I have shown and described a preferred embodiment of my invention by way of illustration, many modifications will occur to those skilled in the art and I therefore, wish to have it understood that I intend in the appended claims to cover all 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, an electron discharge device including an anode circuit and a control electrode circuit coupled to produce oscillations, a grid leak resistor and a capacitor connected in parallel circuit relation in said control electrode circuit, said capacitor and resistor having a time constant sufficiently large intermittently to interrupt said oscillations at a predetermined mean repetition rate, a source of signal waves, a second resistor in said control electrode circuit, and means for impressing across said second resistor a signal potential derived from said source thereby to modulate said repetition rate in accordance with said signal.

2. In combination, an electron discharge device having an anode, a cathode, and a control electrode, an anode circuit and a control electrode circuit associated with said discharge device and coupled to produce oscillations therein, said control electrode circuit including a grid leak resistor and a shunting capacitor having a time constant sufficiently large intermittently to interrupt said oscillations at a predetermined mean repetition rate, a second resistor in said grid circuit having one end connected to a point of predetermined fixed potential, a second electron discharge device having an anode, a cathode, and a control electrode, said second cathode being connected to the opposite end of said second re-

sistor, and means for controlling the conductivity of said second electron discharge device in accordance with a desired signal thereby to modulate said repetition rate.

3. In combination, an electron discharge device including an anode circuit and a control electrode circuit coupled to produce oscillations, said control electrode circuit including a time constant circiut and a resistor whereby said oscillations are intermittently interrupted at a predetermined mean repetition rate, a source of signal waves, and means for impressing across said resistor a signal potential derived from said source thereby to modulate said repetition rate in accordance with said signal.

4. In combination, an electron discharge device having an anode, a cathode and a control electrode, an anode circuit and a control electrode circuit associated with said discharge device and coupled to produce oscillations therein, said control electrode circuit including a grid leak resistor and a shunting capacitor having a time constant sufficiently large intermittently to interrupt said oscillations at a predetermined repetition rate, a second resistor in said control electrode circuit, a source of signal waves, and means for impressing across said second resistor a signal potential derived from said source thereby to modulate said repetition rate in accordance with said signal.

5. In combination, an electron discharge device including an anode circuit and a control electrode circuit coupled to produce oscillations, said control electrode circuits including a resistor and a time constant circuit whereby said oscillations are intermittently interrupted at a predetermined mean repetition rate, a second electron discharge device having an anode-to-cathode circuit including said resistor, and means including a source of signal waves for impressing across said resistor a potential at signal frequency thereby to modulate said repetition rate in accordance with said frequency.

PHILIP J. REICH.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,621,034	Slepian	Mar. 15, 1927
1,649,753	Strauss et al.	Nov. 15, 1927
2,252,293	Ohl	Aug. 12, 1941
2,363,571	Chaffee	Nov. 28, 1944