April 14, 1925. 1,533,157

W. E. BEATTY

MODULATING METHOD AND APPARATUS

Filed Dec. 11, 1919

Fig. 1.

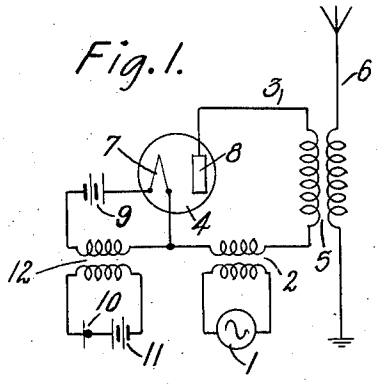


Fig. 2.

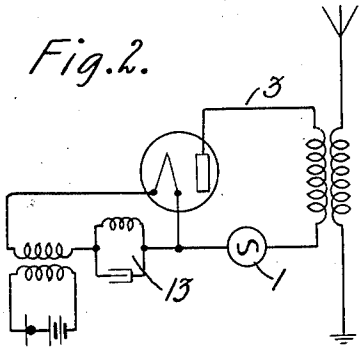


Fig. 3.

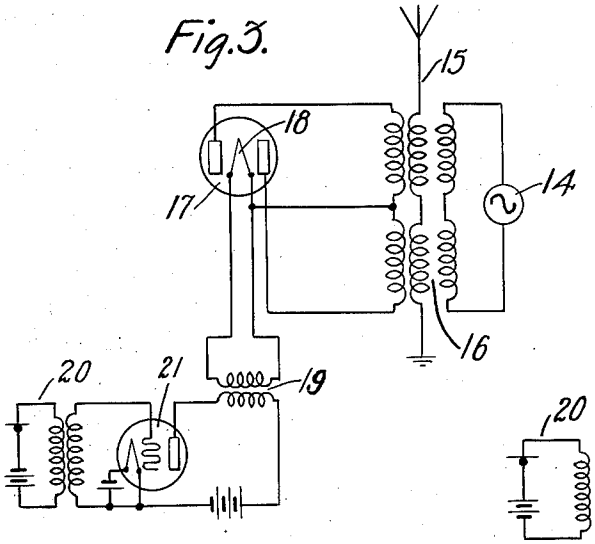
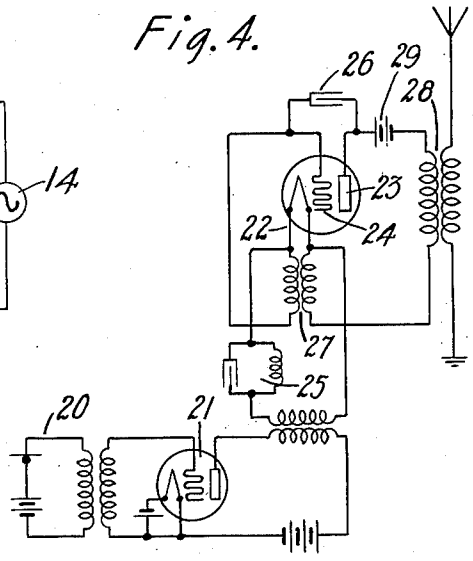


Fig. 4.



Inventor:
William E. Beatty
by C. C. Sprague.
Atty.

Patented Apr. 14, 1925. 1,533,157

UNITED STATES PATENT OFFICE.

WILLIAM E. BEATTY, OF BAYSIDE, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

MODULATING METHOD AND APPARATUS.

Application filed December 11, 1919. Serial No. 344,039.

To all whom it may concern:

Be it known that I, WILLIAM E. BEATTY, a citizen of the United States, residing at Bayside, in the county of Queens and State of New York, have invented certain new and useful Improvements in Modulating Methods and Apparatus, of which the following is a full, clear, concise, and exact description.

This invention relates to modulating methods and apparatus, and more particularly to methods and systems for modulating alternating currents by means of electron-discharge devices in which the electron-emitting power of the cathode is varied in accordance with signals or other low frequency waves or impulses.

An object of the invention is to provide a method for variably controlling the transmission of energy in accordance with the characteristics of a given energy wave.

Another object of the invention is to control the value of an alternating or other fluctuating electrical current by varying the ionic activity of a member which the current to be controlled is caused to traverse.

Another object of the invention is to provide a modulating device in which the electron emitting power of a cathode element may serve to vary the value of the discharge current passing through the device.

A feature of the invention is the provision of a modulator of the electron discharge type having normally no discharge current.

A further feature of the invention is a combined oscillator and modulator in which the amplitude of the oscillations produced may be varied according to the thermionic condition of a cathode.

An additional object of the invention is to provide a system for transmitting pure modulated waves.

According to this invention carrier oscillations to be modified or modulated are supplied to a circuit connected to the cathode and anode of an electron discharge device, or the device may be arranged, as is now well-known, so as to automatically supply oscillations to its own cathode-anode circuit when energized by an external source of electrical energy. The device is preferably of the highly evacuated type in which the energy is carried by a discharge of electrons from the cathode to the anode. It is, therefore, possible to control the electron emission power of the cathode as, for example, by varying its temperature and so to correspondingly vary the amplitude of the resulting oscillations in the external cathode-anode circuit. If a low frequency control or signal current circuit is so related to the cathode as to cause the low frequency current to vary the electron emissivity of the cathode in accordance with the low frequency signal or control current, and a transmission circuit is suitably associated with the external cathode-anode circuit, carrier oscillations varying in amplitude in accordance with the low frequency current may be supplied to the transmission circuit.

In the drawing, Fig. 1 illustrates a radio signaling system embodying a two-element electron discharge device operating in accordance with this invention as a modulator. Fig. 2 illustrates a modification of the system shown in Fig. 1 in which the cathode of the thermionic discharge device is normally without heating current. Fig. 3 illustrates a modification employing a double tube modulating device in an absorption system, and Fig. 4 a modified radio system making use of a combined oscillator and modulator.

Referring to Fig. 1, carrier oscillation source 1 is shown coupled by transformer 2 to a circuit 3 which includes the two-element electron discharge device 4 and primary winding of transformer 5 by means of which circuit 3 is coupled to an antenna or transmission circuit 6. The thermionic discharge device includes a hot filamentary cathode 7 and a plate or anode 8. Cathode 7 is heated to a definite temperature by current from a direct current source 9 in circuit therewith. A microphone 10 in series with a talking current source 11 and primary winding of a transformer 12 serves to impress upon the heating circuit of the cathode an additional current varying in accordance with signals.

In Fig. 2 the circuit arrangements are the same as in Fig. 1 with the exception that the heating circuit of the filamentary cathode includes no direct current source and that the oscillation source 1 is introduced directly into circuit 3. A closed loop circuit 13 is interposed in the cathode-heating circuit and is tuned to the frequency of carrier oscillation source 1.

Referring to Fig. 3, carrier oscillation source 14 is shown coupled to antenna or transmission circuit 15 by a transformer 16 having three sets of windings. An electric discharge device 17 having a hot filament or other cathode 18 and two plate electrodes is connected to antenna 15 by one set of the windings of the transformer 16 in such manner than an electromotive force induced in one of these windings from the carrier current source tends to make the corresponding plate electrode or anode positive with respect to the filament and at the same time to make the other anode negative with respect to the filament. The filamentary cathode is supplied with heating current by a transformer 19 connected to the signaling or control circuit 20 by an amplifying device 21, preferably of the thermionic type.

In Fig. 4, a three-element electron discharge device comprising a hot cathode 22, an anode 23, and an impedance control element or grid 24 has its input and output circuits so connected as to cause said device to act as an oscillator of well-known type. The cathode is heated by amplified signal or control currents in the same manner as in the system illustrated in Fig. 3, and the heating current circuit includes a tuned loop circuit 25 similar to circuit 13. A condenser 26 and inductances 27, which are preferably but not necessarily coupled to each other, constitute, with the primary winding of transformer 28, an oscillatory circuit which substantially determines the frequency of the oscillations generated. A source 29 serves to supply space current to the discharge device.

In the arrangement of Fig. 1 the filamentary cathode is heated to such a point that the electron emission will rapidly change as its temperature is increased. The cathodes employed in the discharge devices of this invention are preferably filaments specially designed to have high resistance, hence requiring small heating currents, and are preferably of small cross section in order to permit rapid heating and cooling. Preferably the temperature of the filament in Fig. 1 is normally such that for all lower temperatures substantially no electron emission occurs, while for higher temperatures the emission varies according to the energy supplied. Preferably, also, the high frequency electromotive force applied to the discharge circuit 3 is sufficiently large to saturate the tube or discharge device for the entire range of temperature operation of cathode 7. If this is the case the amplitude of the transmitted oscillations will vary directly as the electron emission power of the cathode. Consequently, as the electromotive force applied to the heating circuit from the signal circuit is varied, the electronic activity of the device is correspondingly varied and the value of the high frequency energy transmitted by the tube is accordingly changed. The carrier oscillations transmitted to the antenna 6 and radiated thereby will accordingly be of the nature of a modulated wave.

In the system of Fig. 2, the circuit 13 prevents current of the high frequency supplied by source 1 from traversing the heating circuit of the cathode and being impressed upon the low frequency signaling circuit. During non-signaling periods the cathode of this modification is not heated and, inasmuch as any flow of high frequency energy in circuit 3 depends upon the activity of the electron discharge device, no high frequency energy is transmitted at such times. This cathode is preferably of a type which will not require initial heating to bring it to electron emitting condition and the electron emissivity of which will vary in accordance with the energy of the low frequency current supplied. This modification, like that of Fig. 1, accordingly serves to transmit modulated waves.

In the modification of Fig. 3, source 14 serves to supply high frequency currents to the antenna 15 and tube 17 coupled to the antenna serves as an absorbing device to variably divert energy from the antenna. The amount of energy diverted depends upon the temperature of cathode 18 of discharge device 17 and this temperature varies in accordance with the value of the signal currents in circuit 20. Inasmuch as device 17 has two asymmetrically conducting paths reversely connected to the antenna, it acts to absorb energy during both half cycles of the high frequency current. Amplifier 21 serves to increase the variations in the filament temperature and so to make the electron emissivity of the cathode 18 to vary in accordance with the amplitude of low frequency signal waves in circuit 20. The unabsorbed energy of antenna 15 is, therefore, transmitted as a wave varying in amplitude with the low frequency signal or control currents.

In the system of Fig. 4, the electron discharge device operates in conjunction with the oscillatory circuit 26, 27 to produce oscillations of a frequency determined chiefly by the electrical constants of the oscillatory circuit, and of an amplitude which is a function of the space current of the discharge device. This space current depends directly upon the number of available electrons emitted from the cathode, and hence upon the value of the variable current supplied by low frequency signaling circuit 20. Modulated oscillations will, therefore, be supplied to the antenna, the discharge device serving both as an oscillator and as a modulator. During non-signaling periods, the cathode is thermionically inactive and no oscillations are produced.

For telegraphic or control energy transmission, the microphone circuit may be replaced by a key controlled buzzer circuit. In lieu of the antenna shown for radio transmission, conducting lines may be substituted for transmission by electric currents.

Although the invention has been described in connection with certain specific radio signaling systems, it is applicable to teledynamic operation generally, whether by radio or wire transmission. In certain aspects the invention is not limited to transmission but relates broadly to the control of varying current. The invention is, therefore, not to be limited by the specific disclosure but only by the scope of the appended claims.

What is claimed is:

1. The method of variably controlling a current in accordance with signal waves which comprises causing said current to pass as an electron discharge from a cathode normally electronically inactive and simultaneously maintaining the electron emissivity of said cathode substantially proportional to the amplitude of said signal wave.

2. The method of transmission which comprises causing periodic energy to pass as an electron discharge from a cathode normally electronically inactive and constantly maintaining the electron emissivity of said cathode substantially proportional to the amplitude of a given low frequency wave.

3. The method of signal transmission which comprises causing carrier current to pass as an electron discharge from a cathode normally electronically inactive and simultaneously varying the electronic emissivity of said cathode in substantially direct proportion to the amplitude of a signal wave.

4. The method of pure modulated wave transmission which comprises impressing a high frequency electromotive force between an anode and a cathode which is normally electronically inactive and causing said cathode to become electron emitting in substantially direct proportion to the amplitude of a low frequency modulated wave.

5. An electron discharge device comprising a cathode normally electronically inactive, an anode and means for varying the electronic activity of said cathode substantially directly in proportion to a given signal current.

6. An electron discharge device comprising a cathode normally electronically inactive, an anode, means for impressing a periodic electromotive force between said cathode and said anode to produce an electron discharge therebetween, and means for varying the electronic activity of said cathode substantially in accordance with the amplitude of a low frequency wave.

7. An electron discharge device comprising a cathode normally electronically inactive, an anode, means for varying the electronic activity of said cathode in accordance with the amplitude of a given low frequency wave, and means for impressing between said cathode and said anode a periodic electromotive force of intensity sufficient to saturate said discharge device throughout the range of the electronic activity of said cathode.

8. An electric discharge device comprising a cathode and an anode, means for setting up an electro-motive force between said cathode and said anode, said cathode being normally electronically inactive, and means for causing said cathode to become electronically active in accordance with low frequency currents.

9. A modulator comprising an electric discharge device having a cathode and an anode, means for setting up an alternating electromotive force between said cathode and said anode, said cathode normally emitting substantially no electrons, and means controlled by signals for rendering said cathode electron emitting.

In witness whereof, I hereunto subscribe my name this 8th day of December A. D., 1919.

WILLIAM E. BEATTY.