Aug. 15, 1933. R. S. BAIR ET AL 1,922,654

MODULATING DEVICE

Filed March 18, 1931

FIG. 1

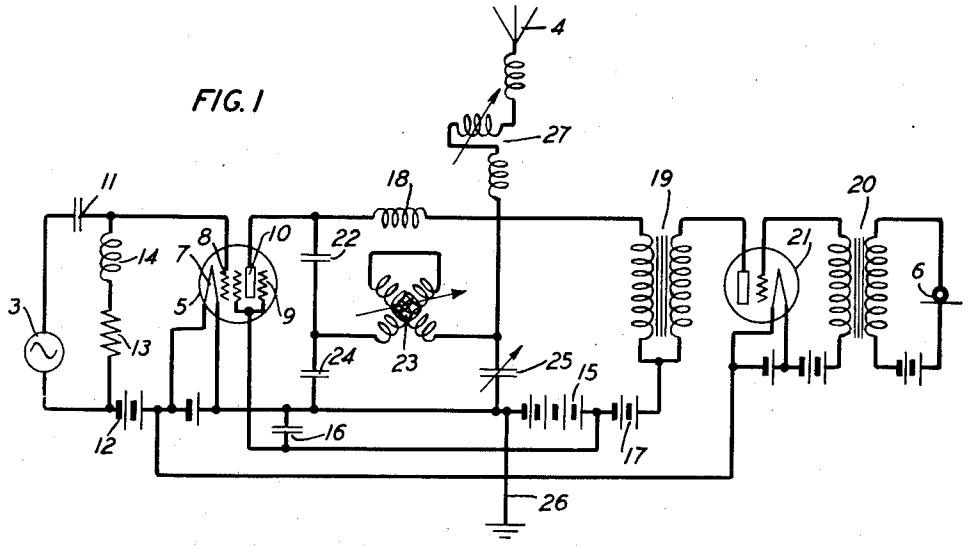
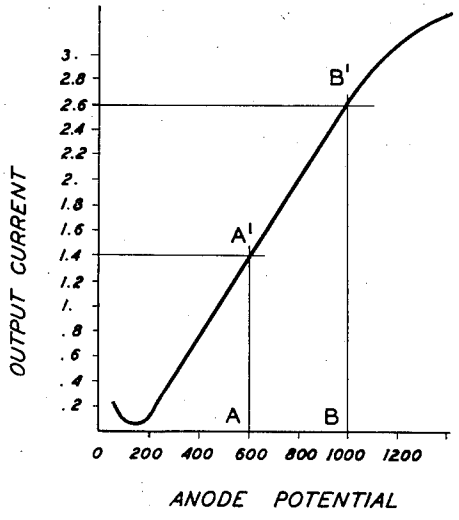


FIG. 2



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MODULATING DEVICE

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7 Claims. (Cl. 179—171)

This invention relates to modulators, modulating amplifiers and detectors, and more particularly to a modulating amplifier employing a four-electrode space discharge tube, the amplification of which is variable by means of the application of a modulating electromotive force to the anode.

To promote efficiency and economy in a modulating system it is essential that the system be capable of complete or 100% modulation of the carrier wave and that the actual power dissipated by the flow of modulating current in the device shall be small in comparison with the power transmitted in the modulated carrier wave.

In accordance with the invention a screen grid tube is provided with biasing potentials on the screen and anode respectively proportioned in such a manner that the power output of the tube can be controlled by a superposed variable potential on the anode. With the correct biasing potentials applied, there is a direct and substantially linear relation between the power output and the anode potential.

The usual adjustment of a four-electrode space discharge tube or screen grid amplifier is such that the power output is substantially unaffected by small variations of the anode potential. With the arrangement of the invention the power output may be varied from substantially zero up to four times the normal value, thus permitting complete modulation. The range of variation of the anode potential necessary is small compared with the voltage of the carrier wave which is controlled. The modulating voltage may be supplied by a space discharged tube of relatively lower power capacity than the modulating tube itself.

The invention is described in detail hereinafter with reference to the drawing in which:

Fig. 1 shows a radio transmitter embodying the invention; and

Fig. 2 is a plot showing the relation between the output current and the anode potential in a screen grid tube adjusted in accordance with the invention.

With reference to Fig. 1, 3 is a source of carrier waves which is connected to a transmitting antenna 4 through a modulating amplifier 5 under the control of a microphone 6. The modulating amplifier 5 is a four-electrode space discharge device containing within an evacuated envelope a cathode 7, a control grid 8, a screen grid 9 and an anode 10, arranged in the manner of the ordinary screen grid tube. Source 3 is connected to grid 8 through a blocking condenser 11 and to the cathode 7 through a grid biasing battery 12, which battery is connected to the grid through a grid leak 13 and a high frequency choke coil 14. The screen 9 is biased at a positive potential by a battery 15 shunted by a by-pass condenser 16. The plate 10 is biased at a somewhat higher positive potential by the battery 15 augmented by an additional battery 17 to which latter the anode is connected through a high frequency choke coil 18 and one winding of a transformer 19. The microphone 6 is connected through a transformer 20, an amplifier 21 and the transformer 19 to the plate circuit of the modulating amplifier 5. The high frequency output circuit of the modulating amplifier 5 comprises the blocking condenser 22, the tuning variometer 23, a condenser 24 and a variable coupling condenser 25. The antenna 4 is connected to the ground 26 through a tuning variometer 27 and the condenser 25.

The system of Fig. 1 depends for its proper operation in accordance with the invention upon the proportioning of the biasing batteries 15 and 17. The voltage of the battery 15 is of approximately the same value as would be suitable if the tube 5 were to be used as an ordinary screen grid amplifier. The combined voltage of the batteries 15 and 17, however, is somewhat lower than would be suitable in a screen grid amplifier. The usual plate voltage would be sufficiently large to insure a saturation value of the plate current. For modulating in accordance with the invention, however, the plate voltage is set at a value which, together with the screen voltage, determines a normal plate current equal to about one half the saturation value.

The manner of determining proper values for the biasing potentials is best explained with reference to Fig. 2. The curve in the figure shows the alternating current output as a function of the anode potential and was plotted from measurements made with a Western Electric Company type 254-A vacuum tube acting as the modulating amplifier 5 in a circuit similar to that shown in Fig. 1. The output current was measured with a steady exciting voltage of high frequency impressed upon the grid of the tube and equal to about 250 volts R. M. S. The biasing potential on the screen was 225 volts. There was found to be a linear relation between the output current and the anode potential over a range of values extending from about 200

volts up to about 1,000 volts. Below 200 volts the plate is unable to draw any current directly from the filament because the positively charged screen takes all the electrons. The current which appears when the anode voltage is below 200 is a current in reverse phase made up of secondary electrons escaping from the anode and being attracted to the positively charged screen. When the anode potential exceeds 1,000 volts the output current tends toward a saturation value with the result that the curve of output current begins to flatten off. The straight portion of the curve in the region from 200 to 1,000 volts anode potential is suitable for the operating region of a modulating amplifier. In this region the output current ranges from zero up to approximately 2.6 amperes. In order to operate over this range the plate battery comprising 15 and 17 is fixed at 600 volts, of which amount battery 15 comprises 225 volts and battery 17 comprises 375 volts. A modulating voltage having a peak value of 400 volts applied in the plate circuit of the tube 5 by means of the transformer 19 will cause the output of the modulating amplifier to be completely modulated. The normal plate voltage is indicated in the figure by vertical line AA' and the upper limit of the operating range by BB'. The normal output of the amplifier in the absence of modulation is approximately 1.4 amperes. During complete modulation the output current varies from zero up to about twice its normal value. With this arrangement substantially complete modulation of the output current may be obtained with less than 100% variation in the plate potential. Additional measurements made upon this circuit have indicated that the efficiency of the system with reference to the amount of power dissipated in the plate circuit of the modulating amplifier is relatively high. It has been found that a power output of 25 watts approximately 100% modulated can be obtained with an accompanying plate dissipation of 21 watts.

The particular values of operating voltages for the screen and plate will vary with different types of tubes but the proper operating voltages may be readily found for any particular tube from data such as that used in plotting Fig. 2.

While the system is illustrated as embodied in a radio transmitter it is evident that the oscillator 3 may be made to have any desired frequency and the microphone 6 may be replaced by a source of modulating current of any desired sort and may generate currents of any desired range of frequencies. The antenna 4 may be replaced by a wire transmission line or by a local receiving circuit. The circuit may also be used as a heterodyne demodulator the rearrangement following the known plan of substituting for the carrier and the signal input waves an incoming modulated wave and a local heterodyne wave respectively. The output then includes a heterodyne beat or difference frequency wave which may be utilized in any well known manner.

What is claimed is:

1. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a utilization circuit connected between said cathode and said anode, a source of carrier waves connected between said cathode and said control electrode, means for applying a positive biasing potential to said screening electrode, means for biasing said anode to a positive potential at least twice as great as the biasing potential of said screening electrode, but substantially less than required to produce a saturation value of the output current, a source of modulating current connected between said anode and said cathode for superposing a variable potential upon the biasing potential of said anode whereby carrier waves repeated in said utilization circuit are modulated in accordance with the successive values of said modulating current.

2. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a source of carrier waves connected between said control grid and said cathode, a source of modulating current connected between said anode and said cathode, means for biasing said anode and said screening electrode at different positive potentials, the biasing potential of the anode being greater than that of the screen by such an amount that the amplified carrier wave, in the absence of modulating current, has approximately half the amplitude of its saturation value.

3. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a source of carrier waves connected between said control grid and said cathode, a source of modulating current connected between said anode and said cathode, means for applying a positive biasing potential to said screening electrode, means for applying to said anode a positive biasing potential at least twice that on said screen, but materially less than sufficient to produce saturation of the output current, whereby the output current from the tube corresponding to a fixed alternating voltage input becomes a linear function of the anode voltage for a wide range of anode voltages above and below the anode polarization voltage.

4. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a utilization circuit connected between said cathode and said anode, a source of carrier waves connected between said cathode and said control electrode, means for applying a positive biasing potential to said screening electrode, means for biasing said anode to a potential more positive than the biasing potential of said screening electrode, but substantially less than required to produce a saturation value of the output current, a source of modulating current connected between said anode and said cathode for superposing a variable potential upon the biasing potential of said anode, the amplitude of the modulating current from said source being such that the resulting anode potential is always above the biasing potential of the screening electrode.

5. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a utilization circuit connected between said cathode and said anode, a source of carrier waves connected between said cathode and said control electrode, means for applying a positive biasing potential to said screening electrode, means for biasing said anode to a potential more positive

than the biasing potential of said screening electrode, but substantially less than required to produce a saturation value of the output current, a source of modulating current connected between said anode and said cathode for superposing a variable potential upon the biasing potential of said anode, the amplitude of the modulating current from said source being such that the resulting anode potential is always above the biasing potential of the screening electrode, and below the above mentioned potential required to produce a saturation value of the output current.

6. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a utilization circuit connected between said cathode and said anode, a source of carrier waves connected between said cathode and said control electrode, means for applying a positive biasing potential to said screening electrode, means for biasing said anode to a potential more positive than the biasing potential of said screening electrode but substantially less than required to produce a saturation value of the output current, a source of modulating current connected between said anode and said cathode for superposing a variable potential upon the biasing potential of said anode, the amplitude of the modulating currents of said source being such as to superpose upon said anode an alternating voltage substantially equal to the difference between the biasing potentials of said screening electrode and said anode.

7. A modulating system comprising a space discharge device having a cathode, an anode, a control grid and a screening electrode positioned between said control grid and said anode, a utilization circuit connected between said cathode and said anode, a source of carrier waves connected between said cathode and said control electrode, means for applying a positive biasing potential to said screening electrode, means for biasing said anode to a potential more positive than the biasing potential of said screening electrode but substantially less than required to produce a saturation value of the output current, a source of modulating current connected between said anode and said cathode for superposing a variable potential upon the biasing potential of said anode, the amplitude of the modulating currents of said source being such that the superposed alternating voltage upon said anode is less than the difference between the biasing potentials of said anode and said screening electrode.

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