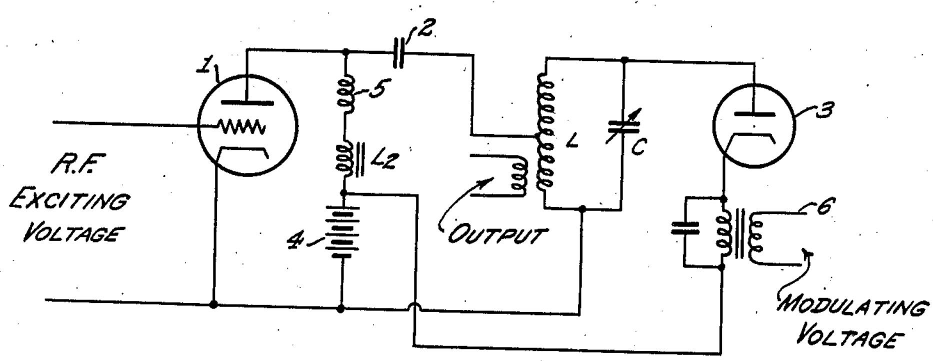
Dec. 22, 1942. F. E. TERMAN 2,305,911

HIGH EFFICIENCY LOSS MODULATOR

Filed Dec. 21, 1940

FIG.1.



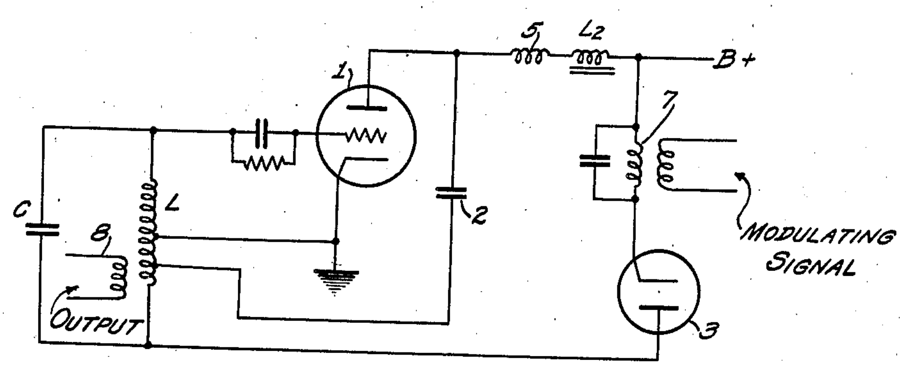


FIG.2.

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HIGH EFFICIENCY LOSS MODULATOR

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2 Claims. (Cl. 179—171.5)

This invention relates to modulators, and more particularly to absorption or loss modulators of relatively high efficiency.

In the past loss modulators, that is, modulators which operate in conjunction with high frequency generators or amplifiers by varying the radio frequency losses at modulation frequencies have been proposed. However, these modulators have in general been relatively low in efficiency.

In my prior Patent No. 2,152,753, issued April 4, 1939, is disclosed a loss modulator in which the efficiency of such a modulator is improved by the provision of an arrangement for maintaining the anode direct current substantially constant.

According to my present invention the efficiency of a modulator of the type disclosed in the above-named patent is further improved by using a rectifier in the system as a losser tube, and connecting the rectifier to oppose the direct current anode supply potential of the high frequency generator or amplifier tube.

A better understanding of my invention and the objects and features thereof may be had by the particular description of embodiments thereof with reference to the accompanying drawing, in which:

Fig. 1 is a circuit diagram showing my invention applied to the modulation of energy supplied from an amplifier; and

Fig. 2 shows my invention applied to modulation of energy in an oscillation generator.

It has been disclosed in my prior Patent 2,152,753, to utilize a losser modulator tube in the form of a triode connected in the output of a tube which may be the output of a radio frequency amplifier or an oscillation generator. In the present application a similar type of losser modulator using a rectifier in place of the triode is disclosed.

In Fig. 1 is shown a tube 1 which may be excited by radio frequency exciting voltage, either as the output of a radio frequency amplifier or by an oscillation generator. Tube 1 is provided with the tank circuit LC to which the energy is fed over a coupling condenser 2. A rectifier 3, preferably a diode, is shunted across the tank circuit LC, the anode of tube 3 being connected to a point in the tank circuit and the cathode being connected to a positive potential point on the battery 4 which furnishes the anode direct current for tube 1.

In order that the current drawn from battery 4 may be maintained substantially constant, a high impedance choke coil L_2 is provided in the anode lead from battery 4. In series with L_2 is provided a radio frequency choke 5. By this choke coil arrangement the rado frequency energy supplied to valve 1 may be modulated to a reasonably high percentage with satisfactory linearity. This linearity may be obtained even when a triode is used in place of the rectifier tube.

The modulating voltage is applied from coil 6 in series with the diode, and the tank circuit LC is so adjusted that the peak radio frequency voltage applied to the diode under carrier conditions, that is with no modulation signal being applied, is just greater than the direct current bias of the cathode. In the present case where the full plate voltage is applied to the cathode this means that the peak voltage is slightly greater than the D. C. plate voltage for tube 1.

With this arrangement most of the radio-frequency energy absorbed from tank circuit LC by losser tube 3 is returned to the plate supply system in the form of D. C. current in reverse polarity, and subtracts from the total current consumed from the battery. If the internal impedance of the diode is zero, and in practice the impedance is so low as to be nearly negligible, all of the power absorbed by the losser tube under carrier conditions will be returned to the system resulting in high overall efficiency. Thus, if the modulated tube has a class C amplifier efficiency of 75%, a power input to the plate circuit of the tube 1 of 1333 watts will produce 1000 watts of radio-frequency energy. Half of this represents the carrier output, while the remaining 500 watts is taken by the losser circuit. Assuming all of the losser power is returned to the system, the net input required to generate 500 watts carrier is 1333—500 or 833 watts. This represents an efficiency of 60%.

For complete modulation, the audio-frequency modulating voltage must be sufficient to vary the potential between the cathode and ground of diode 3 from zero to twice the plate-supply voltage. At the same time the audio-frequency current that flows through the diode has a peak value very nearly equal to the D. C. current through the losser under carrier conditions. With complete modulation this means that the modulating power is approximately $P/2$ where P is the carrier power. For the degree of modulation m the modulating power is accordingly $m^2P/2$. This is slightly less than the amount of audio-frequency energy required for plate modulation. The overall efficiency of the system considering the input power to be that supplied by the battery plus the audio modulating power, and the output power to be the modulated wave, rises slightly with modulation, being substantially 69% for complete modulation of the 500 watt carrier in the numerical case given above.

It is possible with this arrangement to obtain substantially linear modulation up to greater than 90% modulation. The limit of depth of modulation is set by the fact that although the load impedance offered to the modulating voltage by the diode circuit is substantially constant for most of the operating range, this impedance drops abruptly to a very low value when the envelope of the modulated wave reaches zero. This limitation is not particularly severe, however, and actual experimental results have indicated less than 10% distortion with 95% modulation without the use of any negative feedback to improve the operation.

In designing a modulation system of this type it is to be noted that a rectifier having negligible impedance should be used. Many of the rectifier tubes now on the market, as well as some triodes re-connected as diodes, realize this ideal to a very satisfactory degree. To the extent that the diode impedance is negligible, the power losses in the diode are zero. In practical cases the losses are so small that the diode dissipation is only a secondary design factor, the primary factor being the voltage rating of the diode.

In Fig. 2 is shown a circuit wherein an oscillation generator is used as the source of the radio frequency waves. In this system the tube **1** is supplied with a tank circuit LC connected between the anode and grid of the tube through a coupling condenser **2**. The direct current plate supply for tube **1** is provided over a high impedance choke L_2 and RF choke **5**. Diode **3** is connected with its anode to a point on the tank circuit LC, and its cathode is connected over the coupling coil **7** to the positive anode voltage for tube **1**. The output for the modulated signal is coupled by means of a coil **8** to the coil of the tank circuit L.

The modulating system which has been here described is relatively simple and is capable of virtual complete modulation. For a given carrier output the circuit requires slightly less modulating power than a corresponding plate modulated system. The efficiency that can be realized is in the order of 60% unmodulated and 70% when fully modulated.

Although I have shown only two examples of circuits utilizing the present invention, it is clear that many other circuits may be devised within the scope of the present invention. It is merely necessary that the broad principles outlined above be adhered to in order that the desired results of high efficiency loss modulation be obtained.

What I consider to be my invention and upon which I desire to secure protection is embodied in the accompanying claims.

What I claim is:

1. A modulation system comprising an electron discharge device having an output circuit to which oscillating power is supplied by said device, anode potential supply means for said device, a circuit including a source of modulating voltage and a rectifier connected in series, and means for connecting said series circuit between a point in said output circuit and a positive potential point of said anode potential supply means.

2. A modulation system comprising an electron discharge device having an output circuit to which oscillating power is supplied by said device, a source of anode potential for said device, means intermediate said source of anode potential and said electron discharge device for maintaining the direct anode current of said electron device constant, a circuit including a source of modulating voltage and a rectifier connection in series, and means for connecting said series circuit between a point in said output circuit and a positive potential point of said anode potential source.

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