

July 20, 1937.

M. G. CROSBY

2,087,428

PHASE MODULATOR

Filed Dec. 11, 1933

3 Sheets-Sheet 1

Fig. 1

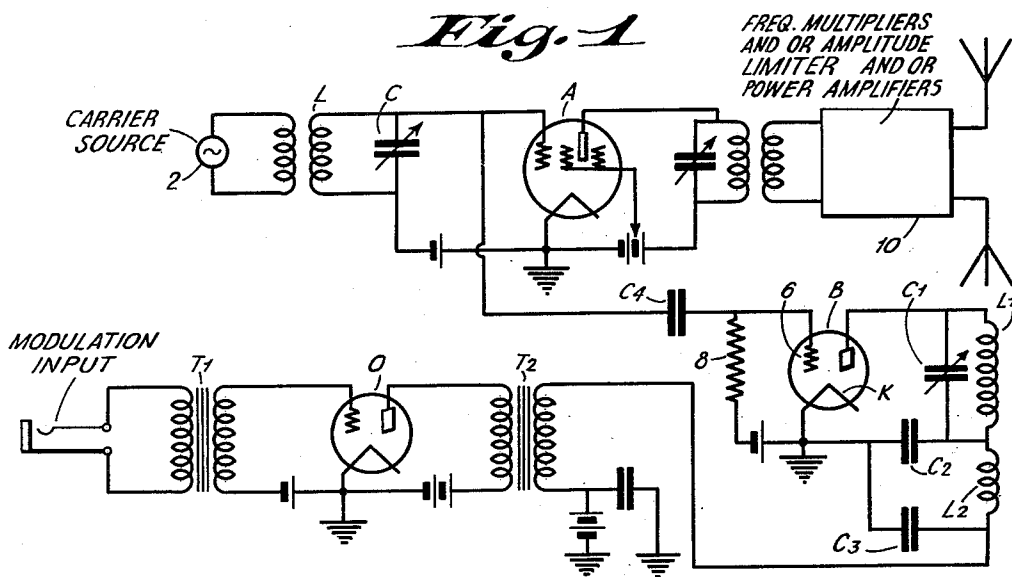
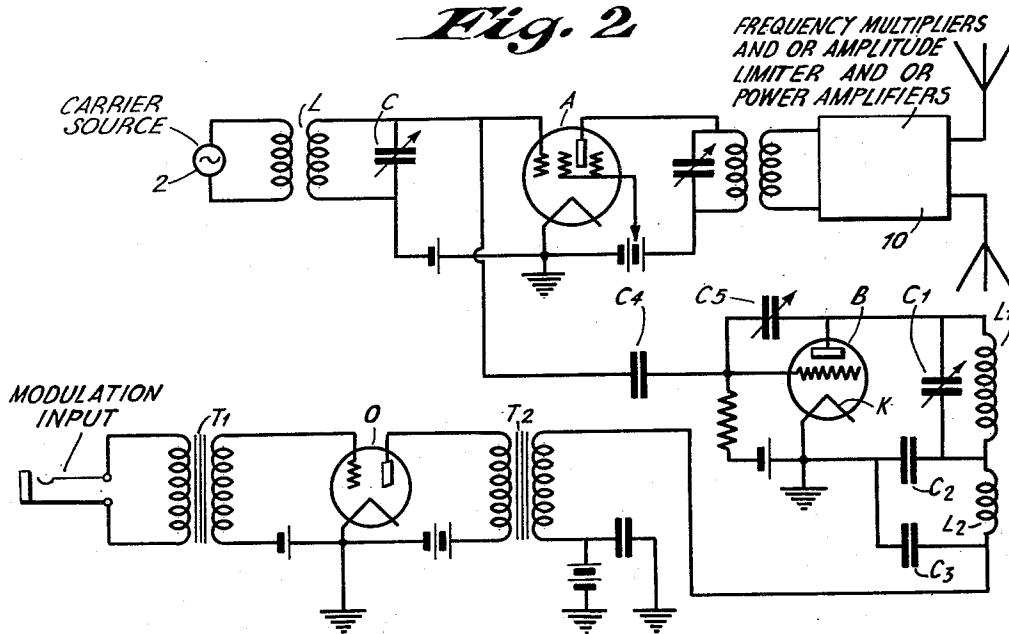


Fig. 2



INVENTOR
MURRAY G. CROSBY
BY *H. B. Grover*
ATTORNEY

July 20, 1937.

M. G. CROSBY

2,087,428

PHASE MODULATOR

Filed Dec. 11, 1933

3 Sheets-Sheet 2

Fig. 4

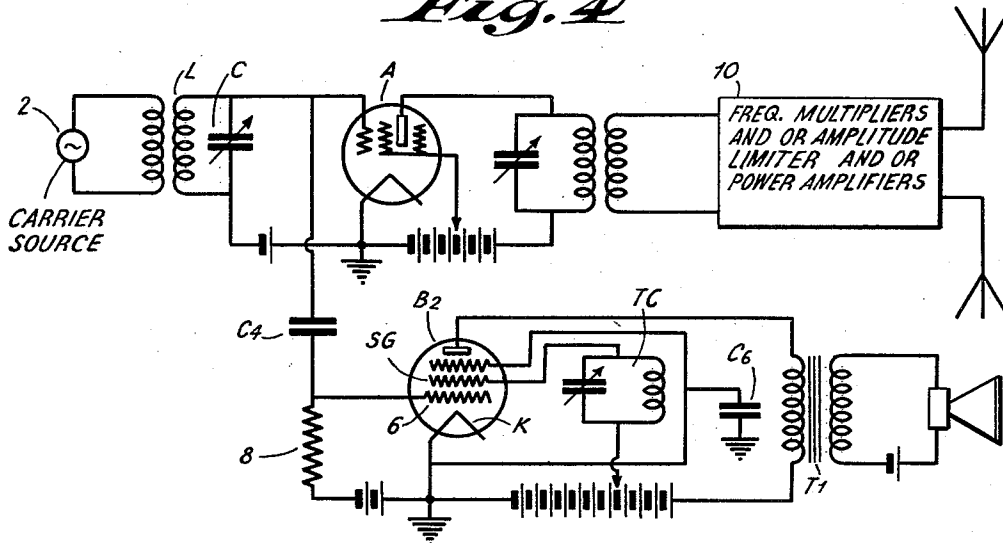
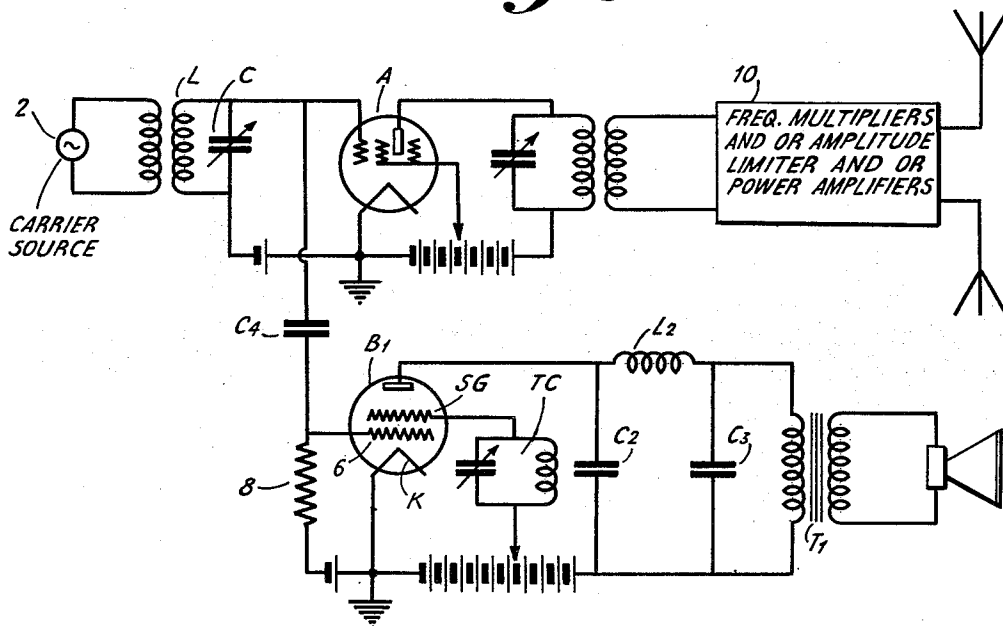


Fig. 3



July 20, 1937.

M. G. CROSBY

2,087,428

PHASE MODULATOR

Filed Dec. 11, 1933

3 Sheets-Sheet 3

Fig. 5

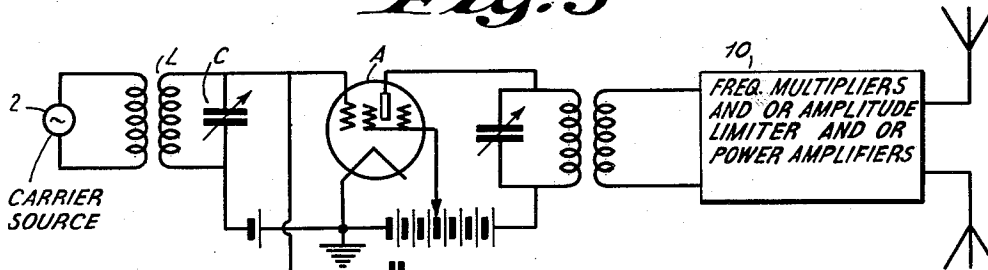


Fig. 5a

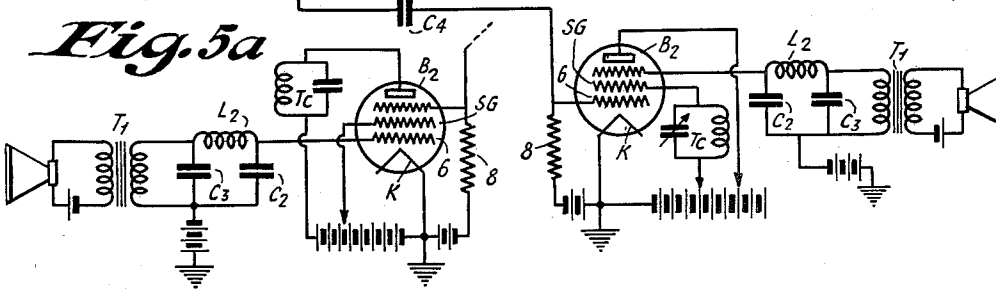
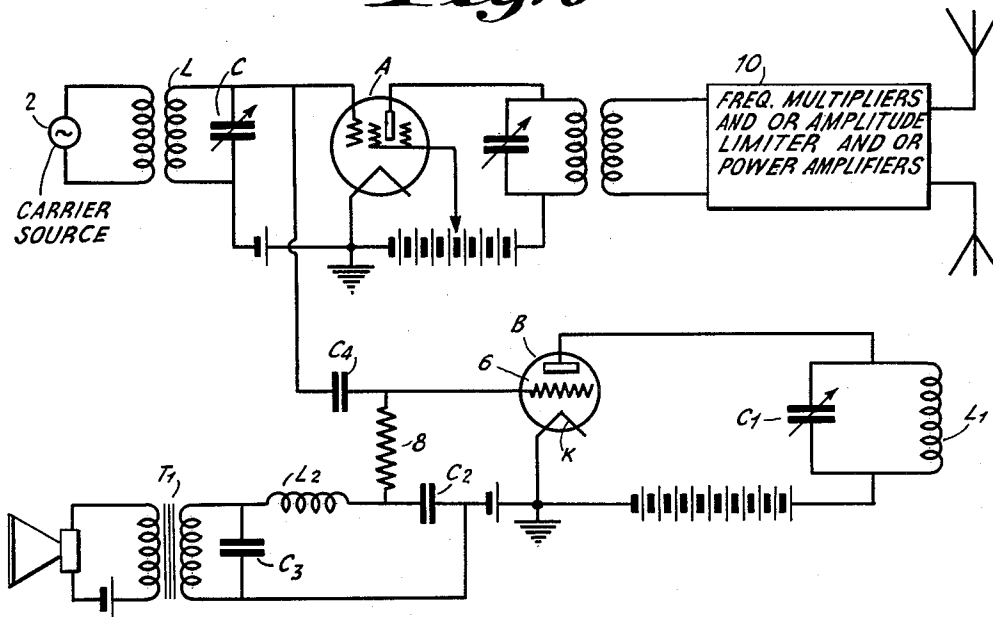


Fig. 6



INVENTOR
MURRAY G. CROSBY
BY *H. S. Snover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,087,428

PHASE MODULATOR

Murray G. Crosby, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation
of Delaware

Application December 11, 1933, Serial No. 701,797

17 Claims. (Cl. 179—171)

This invention discloses a phase or frequency modulator wherein the grid to filament capacity of a vacuum tube amplifier is caused to vary by varying the potential of an element of the tube at the desired frequency. This variable capacity so obtained may be placed across a tuned circuit of a relay or an amplifier to produce phase modulation of any carrier frequency oscillation therein or across a tuned circuit of an oscillator to produce frequency modulation of any oscillations of carrier frequency produced therein.

In the prior art of frequency modulation many schemes have been devised whereby a capacity may be varied by some mechanical means to produce frequency modulation. Other schemes involve devices wherein a glow tube variable condenser may be utilized, see my application Serial No. 569,144, filed October 16, 1931, Patent No. 2,012,710, August 27, 1935. Still another scheme for producing frequency modulation of oscillations is disclosed in my application Serial No. 608,383, filed April 30, 1932. In the latter application the variation, with variation in element or electrode voltages, of the internal capacitive impedance of a dynatron oscillator is utilized to obtain frequently modulation of the oscillations generated.

In the present invention frequency modulation is produced in a manner broadly similar to those mentioned above except that a novel kind of variable condenser is utilized in a novel manner and circuit to produce frequency modulation. The variable capacity of the present invention is not limited in speed of operation as is the mechanical or glow tube varieties. This capacity also has the advantage of large variation and is flexible in that it is readily applicable to any circuit to be modulated.

In the prior art of phase modulation a known means of producing the phase modulation is by differentially amplitude modulating two like frequency carriers less than 180 degrees apart in phase. Such a scheme has been disclosed in my application Serial No. 588,309, filed January 23, 1932. Since this type of modulation is newer to the art, the means for producing it are fewer. My United States application Serial No. 569,144, filed October 16, 1931, describes the use of a novel glow tube type variable capacity to vary the capacity of a tuned amplifier circuit to produce phase modulation.

In the present invention phase modulation is produced by a novel variable capacity utilized in a novel manner which is very broadly similar to the schemes referred to above. The variable ca-

capacity of the present invention has the same advantages when applied to phase modulation as it has when applied to frequency modulation.

The novel features of my invention have been pointed out with particularity in the claims appended hereto.

The nature of my invention and the method of operation of the same will be better understood from the following detailed description thereof and therefrom when read in connection with the drawings, throughout which like reference characters indicate like parts, and in which:

Figure 1 is a circuit diagram of a signalling device including the novel means of the present invention for producing capacity variations which are linear with respect to signal potentials by means of a triode tube. The circuit of Figure 1 also includes novel means for utilizing said capacity variations for producing phase modulation of carrier frequency oscillations at signal frequency.

Figure 2 is a modification of the arrangement of Figure 1. In Figure 2, additional coupling is supplied between the anode and control grid of the tubes used for producing capacity variations.

Figure 3 is a modification of the prior arrangements. In Figure 3 a multi-electrode tube is utilized for producing capacity variations which are linear with respect to signalling potentials.

Figure 4 is a modification of the arrangement of the prior figures. In Figure 4, additional auxiliary grid electrodes are utilized in the tube producing the variations in capacity. In this circuit, an additional electrode serves to prevent radio frequency energy from reaching the modulating potential source.

Figures 5 and 5a are modifications of the arrangement of Figure 4, while Figure 6 is a modification of the arrangement of Figure 1.

In Figure 6, the modulating potentials are applied to the grid electrode of the tube in which the capacity variations are produced, whereas in Figure 1 the modulating potentials are applied to the anode electrode.

Figures 1 and 2 show novel circuit diagrams arranged for phase modulation. The carrier frequency to be modulated is fed from any source 2 to the tuned circuit LC and thence to the grid of the carrier frequency amplifier tube A. The source 2 may include a generator of any known type, preferably one which produces oscillations of constant frequency, and a frequency multiplier if desired. The carrier frequency potential side of the condenser C is also connected, via blocking condenser C₄ to the grid electrode 6 of

tube B. A resistance 8 in series with a source of potentials between the control grid and filament supplies the control grid with the desired direct current potential. This resistance is of high impedance to the oscillations from the source 2 appearing across the grid and cathode of tube B. Thus, C has the capacity appearing between the grid 6 and filament K of tube B added to it. If the capacity of C is varied the phase of the oscillations in said circuit will be varied. The anode of tube B is connected with tuned circuit L_1C_1 , which may be tuned to the frequency of the carrier from 2 or may be replaced by any finite impedance such as an inductance or capacity. Tube B has its anode voltage modulated by means of the modulating voltage fed via transformer T_1 , modulation frequency amplifier tube O, output transformer T_2 , and radio frequency filter C_3, L_2, C_2 . The filter C_3, L_2, C_2 prevents radio frequency oscillations from reaching the modulating potential circuits. The circuit L_1, C_1 furnishes the external anode-to-cathode impedance for tube B to insure therein the desired amplification. The phase modulated carrier is fed from the tuned anode circuit of A to the frequency multipliers and/or amplitude limiters and/or power amplifiers 10 for transmission.

The same circuit as Figure 1 would apply for the production of frequency modulation except that the carrier source and its associated coupling coil be removed, and tube A would be caused to oscillate by replacing it with a triode or introducing feed-back. Tube A would then oscillate as a tuned-grid, tuned-plate oscillator with the modulated variable condenser connected across its grid tuned circuit.

The manner in which the capacity in parallel with the grid and cathode of tube A is varied and utilized to produce frequency modulation where A is an oscillator or phase modulation where A is a relay or amplifier of oscillations will now be described.

As stated hereinbefore a phase change is produced when the capacity of a tuned circuit of an amplifier is varied. By varying this capacity the circuit is made either capacitive or inductive to the applied oscillation so that the voltage across the circuit leads or lags the applied voltage. It has also been stated that variation of the capacity across a tuned circuit of an oscillator varies the frequency of the oscillation generated. The novelty of this invention resides in the method of and means for producing the capacity which is variable and the novel method of and means for producing the capacity change in accordance with the modulating wave and modulating in phase or frequency the carrier wave.

The means herein described for producing the variable capacity utilizes a phenomena present in a triode and other multi-electrode tubes. The effective grid to filament capacity of a thermionic tube is made up of two condensers in parallel, one comprising the actual capacity between the grid and filament and the other comprising the capacity between the grid and anode and the circuit from the anode to ground. With an impedance in the anode circuit, the anode circuit voltage will be higher than the applied grid voltage by a factor equal to the amplification factor of the tube. Consequently, that condenser comprising the grid to anode capacity and the anode circuit to ground in series will have a charging voltage equal to the sum of the grid

and anode alternating voltages. Hence, the grid to anode, thence via the anode circuit to ground, capacity is multiplied by a factor equal to the ratio between the sum of the grid and anode alternating voltages, and the grid alternating voltage to determine the effective capacity. In the case of a resistive anode this ratio becomes $(k+1)$ where k is the amplification of the tube. The total effective grid to filament capacity then is given by $Cg-f+(k+1)Cg-p$ where $Cg-p$ is the grid-to-anode and anode-to-grid capacity. For the case of inductance, capacity or a tuned circuit in the anode, the phase of the anode alternating voltage must be taken into account to determine the sum of the grid and anode alternating voltages.

Since the grid to filament capacity is dependent upon the amplification of the tube, k , if an element or electrode voltage is varied to cause k to vary, the resultant grid to filament capacity is varied in accordance with said voltage. In this way a modulating voltage may be applied to either the grid or anode of the tube to produce a grid to filament capacity variation in accordance with the modulating wave. This variable capacity is applied to an amplifier circuit, as shown in Figure 1, to produce phase modulation or to an oscillator circuit to produce frequency modulation.

More specifically, the modulation voltages from T_1 , amplified in O, and applied to the anode of B, produces variations in the effective capacity between 6 and K, which are linear with respect to the modulating potentials. Moreover, there is no time lag between the modulation changes and the capacity changes. The effective capacity changes are in parallel with C and add to or subtract from the same to produce the desired result.

In cases where a large variation in capacity is desired, the grid to anode capacity inherent in a tube and resulting from the capacity in the anode cathode circuit may be increased by adding an external capacity. This may be accomplished by placing a capacity C_s between the grid and anode of tube B as shown in Figure 2. If this capacity were designated by C_s the variable grid and filament capacity would then be represented by $Cg-f+(Cg-p+C_s)(k+1)$ in the case of resistive anode impedance.

In the arrangement of Figures 1 and 2 I have utilized the capacity between the control grid and cathode of tube B of the triode type as the variable capacity and have varied this capacity linearly as signal frequency. My invention contemplates the use of tubes other than triodes as the medium for producing the variable capacity for modulation purposes.

I have found that, by the use of multi-grid tubes in a manner set forth more in detail hereinafter as the variable capacity, highly improved results may be obtained. Larger capacity variations can be obtained. The larger capacity variations are truly linear with respect to the modulating potentials. Furthermore, the additional electrodes permit the elimination of radio frequencies from the modulating potential circuits and thereby insure that the modulating potentials and radio frequency potentials do not react on each other in the tube in which the capacity variations are produced to cause distortion. For example, as shown in Fig. 3, I may utilize a tube B_1 of the screen grid electrode type as the variable condenser. In this tube the capacity between the control grid 6 and cathode 75

K is variable and is varied linearly at signal frequency by applying the modulating potentials, as shown, between the anode and cathode of tube B₁. The screen grid electrode SG is connected to the cathode by way of a tuned circuit TC and a source of potential as shown. The tuned circuit TC in the screen grid circuit may be tuned to the frequency of the carrier or be replaced by any finite impedance and produces an amplification from control grid circuit to screen grid circuit. In some cases the amplification from control grid to screen grid circuit may be obtained by replacing the circuit TC by a resistance or by any known impedance which gives an amplification from control grid circuit to screen grid circuit. The variable capacity between the control grid electrode 6 and the cathode K, as in the prior modification, is added to the capacity of the condenser C in the tuned grid circuit of the amplifier or relay stage A. Any radio frequency oscillations appearing in B₁ are prevented from reaching the modulation frequency transformer T₁ and the microphone by the radio frequency by-pass filter C₂, C₃ and L₂. The circuit of Figure 3 is otherwise similar to the prior modification.

In the transmitter of Figure 4 I utilize a thermionic tube B₂ having three grid-like electrodes. The variable capacity of which I make use here, as in the prior modifications, is between the control grid 6 and cathode K. The impedance which insures amplification from control grid to the screen grid circuit is the tuned circuit TC connected between the screen grid electrode SG and cathode K by way of a source of potential. The suppressor grid is connected to a point of low or negative potential and may be connected, as shown, to the cathode. A by-pass condenser C₆, connected directly between the suppressor grid and ground, by-passes the radio frequency oscillations to ground to prevent the same from reaching the anode circuit and the modulation transformer T₁ connected therewith. The modulating potentials applied from the modulation frequency source to the anode, due to the amplification between the control grid and the screen grid circuit, produce the capacity variations between the control grid 6 and cathode K which are linear with respect to the modulating potentials and which may be added to the capacity C, as shown, to produce phase modulation of the oscillations relayed in A. The circuit of Figure 4 is otherwise similar to the circuits of the prior modifications except that it may be unnecessary to interpose a filter circuit between the transformer T₁ and the tube B₂.

In the arrangement of Figure 5 the modulating potentials are applied to the suppressor grid instead of the anode. A radio frequency filter circuit L₂, C₂, C₃ is connected, as shown, between the modulating potential transformer T₁ and the suppressor grid to prevent radio frequency oscillations from reaching the modulating frequency circuit. Here, as in Figure 4, a tuned impedance TC between the screen grid SG and the cathode K insures amplification from control grid to screen grid electrode. The capacity between the control grid 6 and K is varied at signal frequency and is added to the capacity C in the tuned input circuit of A. The arrangement of Figure 5 is otherwise the same as the arrangement of the prior figures. It will be apparent to those versed in the art that by placing TC in the plate circuit of B₂ as shown in Figure 5a, the function of the control and suppressor grids may be inter-

changed; that is, the modulating potentials may be applied to the control grid and C₄ and 8 connected to the suppressor grid. The tube B₂ and associated circuits may be disconnected from C₄ in Figure 5 and be replaced by the circuit of Figure 5a, the screen grid of which would then be connected to C₄.

In place of the anode modulation shown in the prior modifications, grid modulation may be used as shown in Fig. 6, wherein the modulating voltage is applied by way of the radio frequency filter C₂, C₃, L₂ and grid biasing resistance 8 to the control grid 6 and cathode K of tube B. If desired the resistor 8 may be replaced by a radio frequency choking inductance of the proper value. Here, as in Figure 1, amplification is insured by the tuned circuit C₁, L₁ and the variable capacity between 6 and K is added to the capacity C in the tuned grid circuit of tube A.

The circuits of Figures 2 to 6 inclusive may be converted for frequency modulation by removing the carrier source 2 and causing A to produce oscillations due to a tuned impedance in the output circuit and a tuned input circuit or due to feedback introduced between the circuits and/or electrodes of tube A. When this change has been made tube A will oscillate as a tuned grid, tuned plate oscillator. The oscillations produced will vary in frequency in accordance with the variations in capacity between 6 and K which are added to the capacity C in the tuned input circuit.

Having thus described my invention and the operation thereof, what I claim is:

1. A variable condenser tube used with a radio frequency circuit comprising, a thermionic tube having an anode, a cathode, a control grid, a shielding grid and an auxiliary grid-like electrode, an impedance connected between the control grid and cathode of said tube, a high frequency impedance connected between said shielding grid and the cathode of said tube by way of a source of direct current potential, a source of modulating potential connected between the anode of said tube and the cathode of said tube to produce variations in capacity between the control grid and cathode of said tube, which may be utilized to tune said radio frequency circuit, and means connected with said auxiliary grid-like electrode for preventing radio frequency oscillations from said radio frequency circuit from appearing in the circuit including said source of modulating potentials.

2. A variable condenser to be used with a radio frequency circuit comprising, a thermionic tube of the multi-grid electrode type having an anode and cathode electrode, a resistance connected between the control grid and cathode of said tube, a tuned circuit connected between another of said grids and the cathode of said tube by way of a source of direct current potential, a source of modulating potential connected between the anode and cathode of said tube to produce variations in capacity between the control grid and cathode of said tube which may be utilized to tune said radio frequency circuit, and means for preventing radio frequency oscillations from said radio frequency circuit from appearing in the circuit connected between said anode and cathode.

3. An arrangement for producing phase modulation of carrier frequency oscillations at signal frequency comprising, a thermionic tube having a grid circuit tuned to the frequency of said oscillations and an anode electrode connected with a utilization circuit, a second thermionic tube having its control grid and cathode connected

- with the control grid and cathode of said first named tube, a high impedance connected between the control grid and cathode of said second named tube, a circuit tuned to a frequency of the order of the frequency of said carrier frequency oscillations connected between an electrode in said second named tube and the cathode of said second named tube, a source of signal potentials, means for applying signal potentials from said source to the anode electrode in said second named tube, and means connected with said second named tube for preventing said carrier frequency oscillations from being impressed on said source of signal potentials.
4. An arrangement for producing phase modulation of carrier frequency oscillations at signal frequency comprising, a thermionic repeater having an input circuit tuned to the frequency of said oscillations and an output circuit connected with a utilization circuit, a second thermionic tube having its control grid and cathode connected in parallel with the control grid and cathode of said first named tube, an impedance connected between the control grid and cathode of said second named tube, a tuned inductance connected between an additional electrode in said tube and the cathode of said tube, a capacity connected between said control grid and said last named electrode, a source of signal potentials, and means for applying signal potentials to an electrode in said auxiliary tube.
5. In a phase modulating system, a source of carrier frequency oscillations, a thermionic relay tube having a control grid connected by way of a tuned circuit including a variable capacity to said source of carrier frequency oscillations and an anode coupled with a load circuit, an auxiliary tube having its control grid connected to the control grid of said first named tube and its cathode connected to the cathode of said first named tube, a reactance tuned to the frequency of the oscillations from said source of high frequency oscillations connected between another electrode in said auxiliary tube and the cathode of said auxiliary tube, and a circuit for varying the internal impedance of said auxiliary tube in accordance with signals.
6. A phase modulating system comprising, a source of carrier frequency oscillations, a thermionic relay tube having a control grid connected by way of a tuned circuit including a variable capacity to said source of carrier frequency oscillations and an anode coupled with a load circuit, an auxiliary tube having its control grid connected by way of a capacity to the control grid of said first named tube and by way of an impedance to ground and to the cathodes of said tubes, a tuned inductance connected between another electrode in said auxiliary tube and the cathode of said auxiliary tube, a source of modulating potentials, a circuit connecting said source of modulating potentials to said auxiliary tube for varying the internal impedance of said tube in accordance with signals, and means connected with said auxiliary tube for preventing carrier frequency oscillations from reaching said source of modulating potentials.
7. A phase modulating device comprising, a thermionic relay tube having a control grid connected by way of a tuned circuit including a variable capacity to a source of carrier frequency oscillations and an anode coupled with a load circuit, an auxiliary tube having its control grid connected by way of a capacity to the control grid of said first named tube and by way of an impedance to ground and to the cathodes of said tubes, a tuned inductance connected between another electrode in said auxiliary tube and the cathode of said auxiliary tube, a source of modulating potentials, a circuit connecting said source of modulating potentials to said auxiliary tube for varying the internal impedance of said auxiliary tube by modulating potentials, and means for preventing reactions between the energy from said source of carrier frequency oscillations and said source of modulating potentials.
8. In a system for relaying oscillations of carrier wave frequency and modulating the same in phase at a modulation frequency rate, a source of carrier frequency oscillations, a source of modulating potentials, a thermionic tube having an anode, a cathode, a control grid, and a screen grid, a circuit comprising a coupling inductance connected between the control grid and cathode of said tube, said inductance being coupled to said source of carrier frequency oscillations, a capacity in parallel with said inductance, a circuit including an inductance shunted by a capacity connected by a source of potential between the anode and cathode of said tube, a connection between said screen grid and a point on said source of potential whereby the carrier frequency oscillations produced by said source of carrier frequency oscillations are relayed by said tube, and means for modifying the phase of the oscillations being relayed at signal frequency comprising, a second thermionic tube having a cathode electrode and a pair of cold electrodes including a control grid, a resistance connected between said control grid and cathode of said second tube, a capacity connecting the terminal of said resistance adjacent the control grid of said second named thermionic tube to the control grid of said first named tube, a circuit connecting the other terminal of said resistance to the cathode of said first named tube, a high impedance comprising a tuned reactance in the form of a parallel capacity and inductance connected between the other of said cold electrodes of said second tube and the cathode of said second named tube, a circuit interposed between said source of modulating potentials and a pair of electrodes in said second named tube for applying modulating potentials to the impedance in said second named tube between said pair of electrodes, and means associated with said second named tube to prevent oscillations of carrier frequency in said first named tube from reaching said source of modulating potentials by way of said second named tube.
9. In a signalling system a source of high frequency oscillations and means for modulating the phase of the high frequency oscillations comprising, a thermionic amplifier tube having an anode, a cathode and a control grid, an input circuit coupling the cathode and control grid of said amplifier tube to said source of high frequency oscillations, a thermionic device having a control grid, a cathode and an auxiliary electrode, a circuit connecting the control grid and cathode of said device to said input circuit, said last named circuit including a direct current impedance between the control grid and cathode of said device, an additional electrode in said device, a tuned reactance connecting said additional electrode to the cathode of said device, means for varying the tune of said input circuit at signal frequency by varying the capacity between the control grid and cathode of said device comprising a source of signal potentials, a circuit con-

necting said source of signal potentials to said auxiliary electrode and cathode of said device, and means for preventing radio frequency oscillations from appearing in said last named circuit.

10. A system as recited in claim 9 wherein said auxiliary electrode is the anode of said device and wherein said last named means includes radio frequency reactances in said circuit connecting said source of modulating potentials to said auxiliary electrode.

11. In a signalling system a source of high frequency oscillations and means for modulating the phase of the high frequency oscillations comprising a thermionic amplifier tube having an anode, a cathode and a control grid, an alternating current input circuit coupling the cathode and control grid of said amplifier tube to said source of high frequency oscillations, a thermionic device having a control grid, a cathode and three auxiliary electrodes, a circuit coupling the control grid and cathode of said device in shunt to said alternating current input circuit, a direct current circuit connected between the control grid and cathode of said device, a circuit connecting the cathode of said device to one of said auxiliary electrodes, means for varying the capacity of said input circuit at signal frequency comprising a source of signal potentials and a circuit connecting said source of signal potentials to another of said auxiliary electrodes and to said cathode, means for increasing the impedance of said device comprising a tuned reactance connected between another of said auxiliary electrodes and the cathode of said device, and means for preventing radio frequency oscillations from said high frequency source from appearing in said circuit connecting said source of signal potentials to said one of said auxiliary electrodes.

12. In a signalling system, a tunable circuit, an electron discharge device having a control electrode, a cathode and an auxiliary electrode, a circuit connecting the control electrode and cathode of said device with said tunable circuit, to add to the same the reactive effects between said control grid and cathode, a reactance of high impedance to oscillations of a frequency of the order of the frequency to which said tunable circuit is tuned connected between said auxiliary electrode and said cathode, a source of modulating potentials connected with one of said electrodes and said cathode to control the conductivity of said tube in accordance with said modulating potentials to thereby vary the reactance between said control electrode and cathode, and an additional electrode in said tube between said control grid and said electrode to which said source of modulating potentials is connected for shielding the latter electrode from said control electrode.

13. In a signalling system, a tunable circuit, an electron discharge device having a cathode, a control grid and a plurality of auxiliary electrodes, a circuit connecting said control grid and cathode to said tunable circuit, a parallel circuit tuned substantially to the frequency to which said tunable circuit is tuned connected between one of said auxiliary electrodes and the cathode of said device, and a source of modulating potentials connected with another of said auxiliary electrodes and the cathode of said device.

14. In a variable condenser, an electron discharge tube having a cathode, a control electrode, and a plurality of auxiliary electrodes, and means

for producing a condenser effect between said control electrode and cathode of substantial value including a tuned circuit and a source of potential connected between one of said auxiliary electrodes and said cathode to provide a high external impedance and thereby increase the gain of said tube, and a circuit applying potentials which vary between another auxiliary electrode and the cathode of said tubes to produce predetermined variations in the condenser effect of substantial value between the control electrode and cathode of said tube.

15. In a phase modulation system, an electron discharge tube having input electrodes on which wave energy to be phase modulated may be impressed, said tube having output electrodes from which phase modulated wave energy may be derived, a tunable circuit connected between a pair of the electrodes of said tube, an auxiliary electron discharge tube having its control grid connected by way of a capacity to a point on said tunable circuit and its cathode connected to another point on said tunable circuit, a tuned inductance connected between an additional electrode in said auxiliary tube and the cathode of said auxiliary tube, said tuned inductance being of high impedance to increase the gain of said auxiliary tube, a source of modulating potentials, and a circuit connecting said source of modulating potentials to said auxiliary tube for varying the internal impedance of said auxiliary tube in accordance with said modulating potentials to thereby vary the condenser effect between the control grid and cathode of said auxiliary tube and consequently vary the tuning of said tunable circuit.

16. In a signalling system, a tunable circuit, an electron discharge device having a cathode, a control grid and a plurality of auxiliary electrodes, a circuit connecting said control grid and cathode to said tunable circuit, a circuit of high impedance to the frequency to which said tunable circuit is tuned, connected between one of said auxiliary electrodes and the cathode of said device, a source of modulating potentials connected with another of said auxiliary electrodes and the cathode of said device, and means for shielding said source of modulating potentials from potentials of higher frequency appearing on the electrodes in said device.

17. In a signalling system, a tunable circuit, an electron discharge device having a control electrode, a cathode and an auxiliary electrode, a circuit connecting the control electrode and cathode of said device with said tunable circuit to add to the same the reactive effects between said control grid and cathode, a reactance of high impedance to oscillations of a frequency of the order of the frequency to which said tunable circuit is tuned, connected between said auxiliary electrode and said cathode, said reactance of high impedance serving to increase the amplification of said tube, to thereby increase the reactive effects between said control grid and cathode, a source of modulating potentials connected with one of said electrodes and said cathode to control the conductivity of said tube in accordance with said modulating potentials to thereby vary the reactance between said control electrode and said cathode, and means for shielding said source of modulating potentials with respect to potentials of a higher order appearing in said tube electrodes and circuits.

MURRAY G. CROSBY.