March 31, 1936. G. L. USSELMAN 2,036,164

PHASE MODULATION

Filed April 28, 1932 3 Sheets-Sheet 1

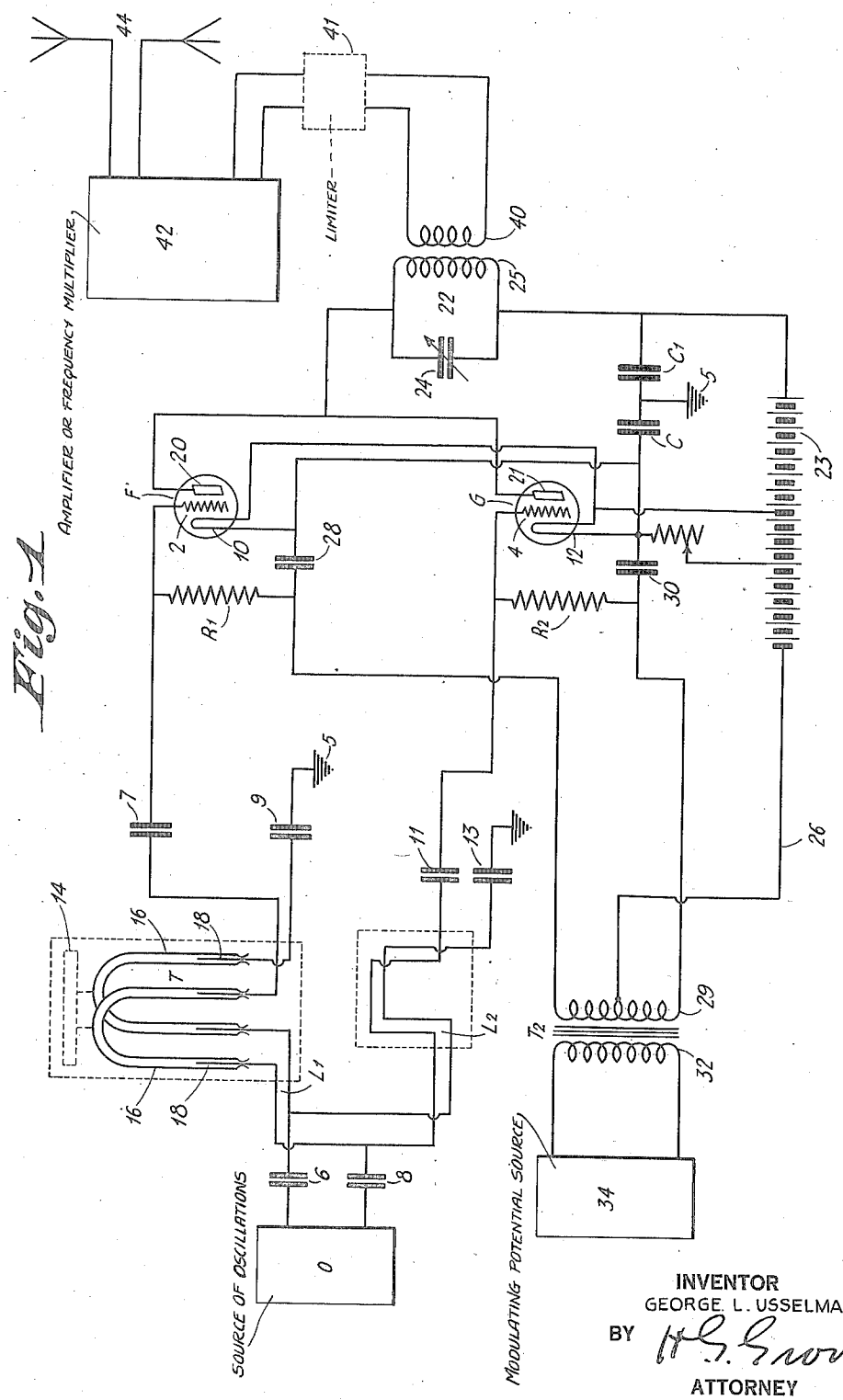


Fig. 1

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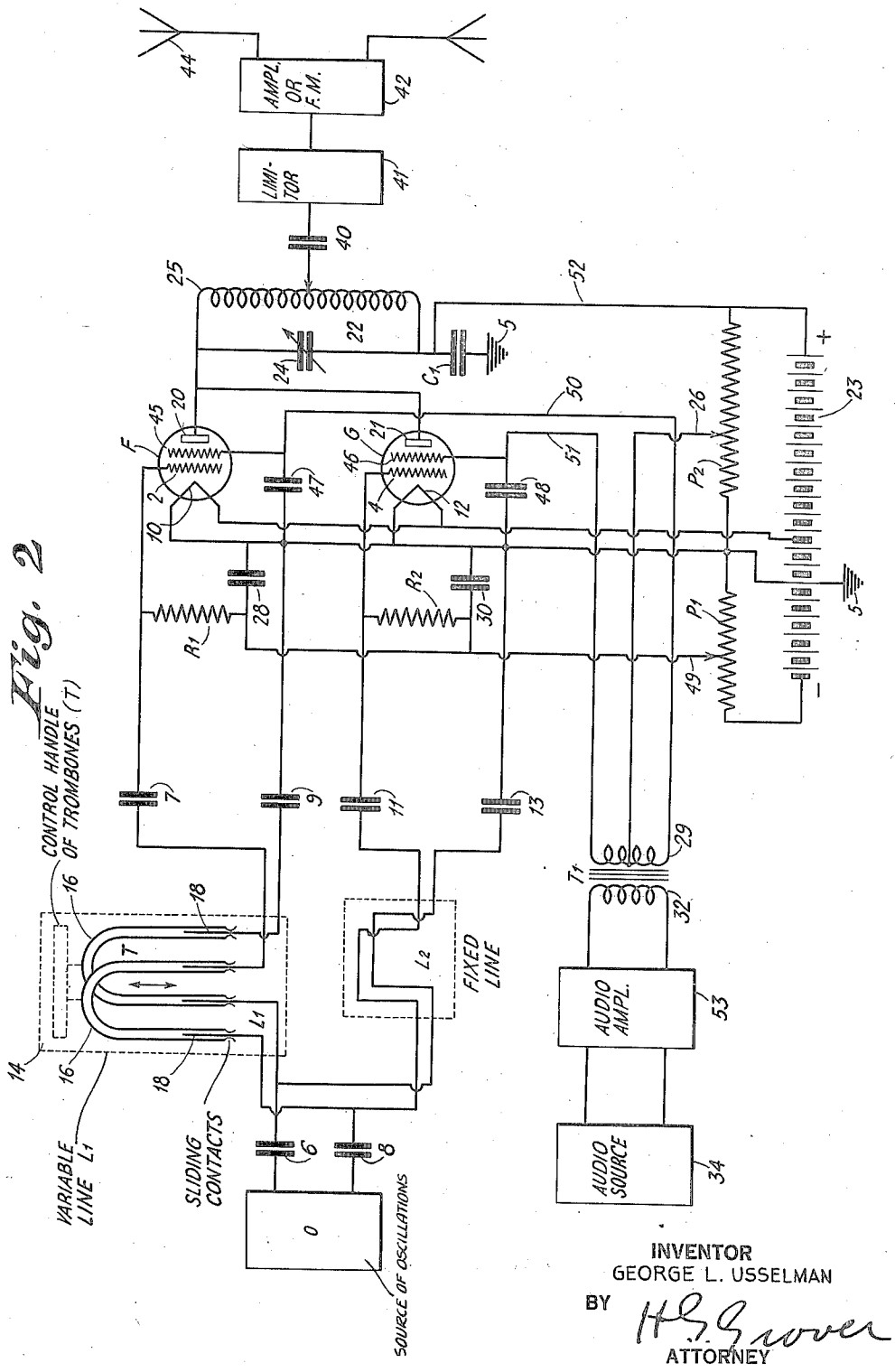


Fig. 2

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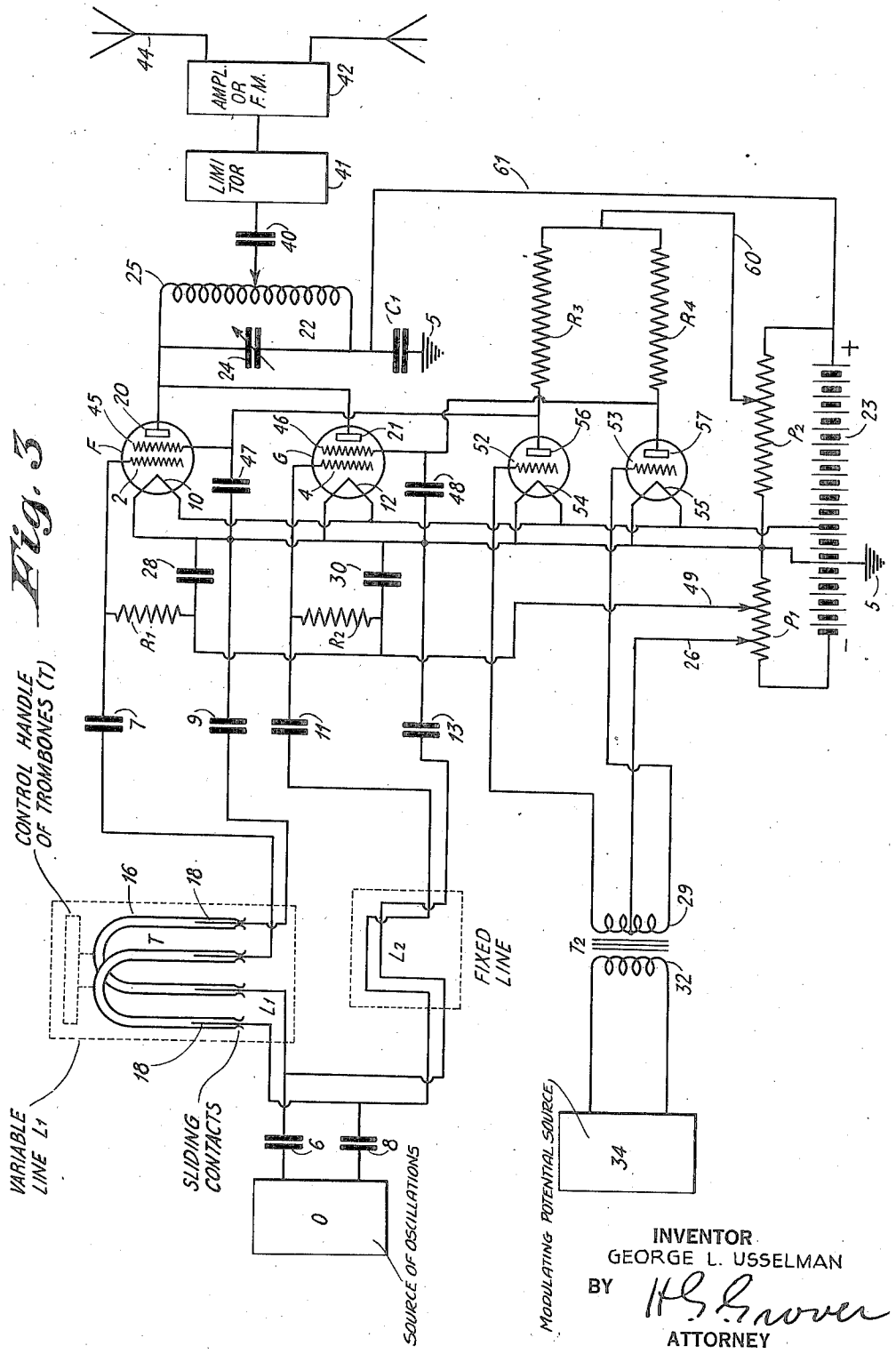


Fig. 3

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2,036,164

PHASE MODULATION

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Application April 28, 1932, Serial No. 607,932

5 Claims. (Cl. 250—17)

The present invention relates to an improved method of and means for varying the phase of radio waves or oscillations in accordance with the signals to be transmitted.

In phase modulation transmitters as disclosed in United States application Serial Number 602,487 filed April 1, 1932, phase rotation of the wave relative to the normal wave is accomplished by the use of inductance and capacity in the grid circuits of the modulator tubes. In general, transmitters of the type referred to above and known heretofore in the art, which use the inductance and capacity in the grid circuits of the modulator tubes to cause phase rotation are satisfactory in operation except where they are to be used with very short waves. In very short wave signalling where ultrahigh frequency signalling oscillations are involved it is difficult to make coils and condensers which are easy to adjust. Especially is this true when a small amount of phase modulation is required.

The primary object of the present invention is to provide a novel phase modulation transmitter especially adapted to a shorter wave work.

Another object of this invention is to provide a novel phase modulation transmitter especially applicable to shorter wave work in which a special novel means is provided by means of which the phase shift of the wave may be easily and readily accomplished. In accordance with this invention the shift in phase may be accomplished in infinitely small increments or steps thereby making the present phase modulated transmitter especially applicable to shorter wave work.

Other objects of the present invention, and advantages to be gained by the use thereof, will appear from the detailed description thereof which follows:

In its broadest aspect the transmitter of the present invention comprises two tubes of which the anodes are connected to a common oscillating tank circuit, while the control electrodes are connected to the same excitation source through separate lines so that one control electrode is excited through one line and the other control electrode excited through the other line. These two lines are of different electrical length. Biasing potential for the control electrodes of the two tubes is supplied from a common fixed source. A signal frequency transformer is arranged to vary the bias of the two control electrodes in phase opposition according to the signal modulations impressed on the primary of the transformer. Since the two modulator tubes are excited from the same source each is excited at the same frequency, but since each tube is excited over lines of different electrical lengths the excitation of the tubes will be different in phase. In accordance with the present invention, one of these lines includes means for varying the electrical length thereof in minute increments. This comprises means similar to the trombone tuning means as disclosed in Lindenblad's United States Patent #1,821,386. Since the lines are different in length, obviously, the phase of the energy supplied to one tube will be in advance of the phase of the energy supplied to the other tube. Likewise, due to the repeating effect of the tubes, the phase of the energy in the common tank circuit will be advanced or retarded from the average phase position of a normal radio wave and angle, the sign of which depends upon which modulator tube is supplying the greater amount of power. The tube having the lower instantaneous control electrode bias, which is the result of the signal oscillations differentially applied, as hereinbefore described, and the constant direct current bias, will, of course, have a greater controlling effect on the phase of the oscillations in the tank circuit. In effect, the phase of the oscillations in the common tank circuit will be advanced or retarded from the average phase position of the oscillations in a manner substantially proportional to the anode current of one modulator tube over the other. This difference of anode current of one modulator tube over the other depends, of course, upon the effective bias applied to the control electrodes of the respective tubes. Since the signal frequency transformer primary is energized by signal oscillations the control electrode biasing excitation of the two phase modulator tubes will vary at signal frequency and therefore the repeated energy in the common tank circuit will be varied in phase as the signal frequency applied to the transformer varies.

In modifications the modulation frequencies are applied to the screen grid electrodes of screen grid tubes from a source of signal frequencies or by way of modulator tubes from a source of signal frequencies.

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

The nature of the invention and the mode of operation thereof and the various advantages to be gained thereby will be understood from the following description thereof and therefrom when read in connection with the drawings attached hereto, throughout which like reference numerals indicate like parts, and in which:

Figure 1 shows by way of illustration a phase modulation transmitter in which the novel features of the present invention are incorporated; while

Figures 2 and 3 show modifications of the arrangement of Figure 1.

Referring to the drawings, and in particular to Figure 1 thereof, O represents a master oscillator by means of which oscillations at the frequency at which it is desired to signal are generated. This oscillator may be any type of oscillator known today and is preferably an oscillator which produces oscillations of a constant frequency, for instance, a long line controlled oscillator or a crystal controlled oscillator. The oscillator O supplies excitation to the control electrodes 2 and 4 of thermionic modulator tubes F and G over two pairs of lines L_1 and L_2. Lines L_1 and L_2 are connected to the oscillator O through blocking condensers 6 and 8. The line L_1 is connected to the control electrode 2 of tube F through blocking condenser 7 and by way of blocking condenser 9 to ground 5 and from there to the cathode 10 of tube F. Line L_2 is completed between the oscillator O and the control electrode 4 of modulator tube G by way of blocking condenser 11 and to the cathode 12 by way of blocking condenser 13, which is connected to ground 5. In this manner potential oscillations at signal frequency appearing in the lines L_1 and L_2 are impressed between the control electrodes and cathodes of tubes F and G, and normally these oscillations would appear in like phase on the said control electrodes. The applicant has, however, provided as a part of the present invention a novel means whereby the phase of the signal oscillations from O, reaching the control electrodes of tubes F and G respectively, are shifted a predetermined amount. This is accomplished in accordance with the present invention by making the line L_2 of a constant predetermined electrical length, as indicated, and by providing in line L_1 tuning means or means for adjusting the electrical length of the line L_1 in the form of trombones T connected, as shown, and operated by means of a control element 14. Since these trombones per se form no part of the present invention a detailed description thereof is thought unnecessary here. However, it must be understood that in operation the trombones T are slid up and down so that the amount of the elements 16 thereof exposed to the elements 18 thereof, determines to a certain extent the electrical length of the line L_1. It will be further understood that by the use of these trombones to adjust the electrical length of the line, small changes in the electrical length of the line L_1 can be made. Consequently, minute phase shifts between the energies reaching the control electrodes of the tubes F and G may be made. Large changes in phase shift are to be accomplished by changing the relative lengths of lines L_1 and L_2. The high frequency oscillations impressed from O through lines L_1 and L_2 are repeated in the tubes F and G and appear on the anodes 20 and 21 of tubes F and G respectively. These oscillations are impressed in parallel on a common tank circuit 22 connected at one terminal to anodes 20 and 21 and at the other terminal to a direct current potential source 23. Radio frequency oscillations are shunted around the source 23 by by-pass condensers C and C_1. Since the high frequency oscillations are applied co-phasally on the control electrodes 2 and 4, the repeated oscillations appear co-phasally on the anodes 20 and 21 and, assuming the lines L_1 and L_2 are of equal length, they add in phase in the tank circuit 22. However, since a certain desired phase shift has been accomplished in the lines L_1 and L_2, the oscillations appear in 22 in different phase depending upon the retardation applied thereto in L_1. The tank circuit 22 is tuned to the normal frequency of the oscillations generated in O by a variable capacity 24 and an inductance 25.

In order that the characteristic or nature of the energy in the tank circuit 22 will be representative of signal oscillations impressed thereon, applicant has provided the following means. Direct current biasing potential is applied to the control electrode of tube F by way of resistance R_1 and to the control electrode of tube G by way of resistance R_2 from the source 23 by way of a lead 26 connected to the center point of the secondary winding 29 of a transformer T_2, which will be described more in detail hereinafter. The lower potential terminals of resistances R_1 and R_2 are connected to the terminals of the secondary winding 28 of modulation frequency transformer T_2. The primary winding 32 of transformer T_2 is connected with a source of signal oscillations 34.

Radio frequency oscillations appearing in the input circuit of tubes F and G are shunted to cathodes 10 and 12 respectively by way of by-pass condensers 28 and 30 respectively connected between the terminals of biasing resistance R_1 and R_2 respectively. This prevents said radio frequency oscillations from being impressed on the transformer T_2 and from there to the source of modulating frequencies. The condensers 28 and 30 also serve as blocking condensers with respect to the secondary winding 29 of transformer T_2, which will be described more in detail hereinafter. The impedance which the resistances R_1 and R_2 present at the frequency of the oscillation generated in O must be equal to the surge impedance of the lines L_1 and L_2 respectively so that there will be no reflections taking place along the line and no constant waves of the oscillator frequency built up therealong.

The operation of the transmitter described above and the manner in which the energy appearing in the tank circuit 22 is made to be characteristic of the signal oscillations will now be pointed out. In describing this operation it will be assumed that the oscillator O is generating oscillations at the desired frequency and that the frequency of said oscillations is constant. The control electrodes of tubes F and G will receive excitation over the two pairs of lines L_1 and L_2. The line L_2 is, as disclosed above, of a predetermined fixed electrical length, while the line L_1 may be varied as to electrical length to be shorter, equal to, or longer than the electrical length of line L_2, as desired, by means of the trombones T. The difference in the electrical lines L_1 and L_2 determines the amount of phase displacement between the excitation delivered to the control electrode of tube F and the control electrode of tube G. This phase displacement or phase difference may be made large or small by adjusting the electrical length of line L_1 by moving the trombones T in or out. The phase difference of the excitation to the control electrodes of tubes F and G remains fixed so long as the electrical lengths of lines L_1 and L_2 remain unchanged. The phase of the oscillations in the common tank circuit 22 is controlled by the power delivered from tubes F and G. The tank circuit 22 should be and is tuned to the frequency

of the oscillator O. In normal operation the phase of these oscillations will move about this frequency, that is, shift with respect to this frequency as an average. The power delivered from each of the modulator tubes is controlled by the biasing potential applied to the control electrode thereof. Both tubes have, as described hereinbefore, the same fixed biasing potential applied to their control electrode. In addition, however, the control electrode of each tube is excited or energized in phase opposition by the secondary winding 29 of transformer T_2 so that when the modulating signals from source 34 are applied to the primary winding of transformer T_2 the biasing potential of the control electrodes of tubes F and G will be varied in opposite directions. This varies differentially the amount of energy delivered to the tank circuit 22 by the tubes F and G. Since the phase of the excitation of these tubes is different there is also a phase difference in the power delivered by the tubes to the tank circuit. The phase of the energy in tank circuit 22 therefore varies towards the phase of the energy of that tube delivering the most power to the tank circuit and this change will be substantially in proportion to the amount of current delivered by the said one modulator tube over that delivered by the other modulator tube.

The phase modulated energy appearing in the tank circuit 22 may be utilized in any manner. For example, it may be fed by way of an inductance 40 coupled to the inductance 25 to an amplifier and/or frequency multiplier 42, the output circuit of which is connected to an aerial system 44. This unit 42 amplifies and/or multiplies the phase modulated energy and delivers it to the antenna.

While ordinarily there will be no appreciable amplitude modulation imparted to the oscillations developed at O, by means of this novel phase modulation system if any amplitude modulation is accomplished the energy appearing in tank circuit 22 may be passed to the amplifier and/or frequency multiplier 42 by way of an amplitude limiting device 41 as shown by dotted lines in Figure 1. This amplitude limiting device will correct any amplitude modulation which may take place.

In the modification shown in Figure 2 the radio frequency circuits and the phase splitting means are in general similar to the corresponding elements of Figure 1, and the operation in each case is in general the same.

In the arrangement in Figure 2, however, modulation of the phase of the oscillations generated at signal frequency is accomplished in a somewhat different manner. In Figure 2 the thermionic tubes F and G are of the screen grid type, whereas the tubes F and G of Figure 1 are of the three electrode type. In Figure 2 direct current biasing potential only is applied to the control electrodes 2 and 4 respectively by way of a lead 49 connected to a point on potentiometer P_1 connected in parallel with a portion of the battery 23. The modulating frequencies are applied from the terminals of the secondary winding 29 of audio frequency transformer T_1 over leads 50 and 51 to the control electrodes 45 and 46 of tubes F and G respectively. In the prior modification the source 34 was connected directly to the modulating circuit. In Figure 2, however, an audio frequency amplifier 53 is interposed between the source 34 and the primary winding 32 of the modulating transformer T_1 so that the audio frequency currents are amplified before they are impressed upon the screen grid electrodes of tubes F and G. Charging potential for the screen grid electrodes of the tubes F and G is supplied by way of a lead 26 connecting the electrical center of the secondary winding 29 to a point on potentiometer resistance P_2 connected in parallel with a portion of the battery 23. The screen grids 45 and 46 are connected to ground by way of capacities 47 and 48 respectively. These capacities should be large enough to have a low impedance for the oscillator frequency but they should be small enough in capacity to have high impedance for the signal frequency. The anodes 20 and 21 of tubes F and G obtain their charging potential from the source 23 by way of lead 52 connected to a terminal of the tank circuit 22. The phase modulated energy appearing in tank circuit 22 is transferred by way of coupling capacity 40 to an amplifier and/or frequency multiplier 42 from which it is impressed on the aerial system 44 for radiation. Here, as in Figure 1, any amplitude modulation may be taken care of my passing the phase modulated energy through an amplitude limiter 41 which may be interposed between the tank circuit 22 and the unit 42.

The operation of this arrangement is so similar to the operation of the arrangement disclosed in Figure 1 that a detailed description of the operation thereof is thought unnecessary here. It will be noted, however, that only a normal negative biasing potential is applied to the control electrodes 2 and 4 of tubes F and G. Audio frequency oscillations applied to the screen grid electrodes 45 and 46 vary the internal impedance and other characteristics including the amplification factor of the tubes F and G respectively at audio frequency, thereby varying the amount of energy applied by the respective tubes to the tank circuit 22. As pointed out before, the energy in the tank circuit 22 is the resultant of the combined energies supplied by tubes F and G. The phase of the energy in the tank circuit 22 is determined by the phase of the energy from the tubes F or G which is supplying the greatest amount of energy at the particular instant to the tank circuit 22 because this energy will predominate and to a large extent determine the phase of the resultant energy in 22. In this manner phase modulation of the energy in the tank circuit 22 is accomplished at signal frequency.

In the arrangement shown in Figure 3 the control electrodes of the tubes F and G respectively are excited only from the oscillator O and are maintained at a constant direct current biasing potential from potentiometer P_1 by way of lead 49. The screen grid electrodes 45 and 46 are excited by the signal frequency from the source 34 through the audio frequency transformer T_2 and the amplitude modulator tubes H and I which have their control electrodes 52 and 53 connected to the opposite terminals of the secondary winding 29, the electrical midpoint of which is connected through a lead 26 to a point on potentiometer resistance P_1 to supply the biasing potential to the control electrodes 52 and 53. The anode electrodes 56 and 57 of tubes H and I are connected in parallel with the screen grid electrodes 45 and 46 of tubes F and G respectively. The charging potential for the screen grid electrodes 45 and 46 of tubes F and G respectively and the anode electrodes 56 and 57 of tubes H and I respectively is supplied from a potentiometer P_2 connected in parallel with battery 23 by way of lead 60 and resistances R_3 R_4 respectively. Any change in the intensity of current flowing in

the anode circuits of tubes H and I will obviously affect the potential applied to the screen grid electrodes 45 and 46 connected in parallel with said anode circuit. The filaments 54 and 55 of tubes H and I respectively are supplied with current from the source 23 by connecting the same in parallel with the filaments 10 and 12 of tubes F and G respectively.

In operation it will be assumed that high frequency oscillations are being generated and applied to the control electrodes of tubes F and G and appear in the tank circuit 22 thereof shifted in phase due to the effect of the lines L_1 and L_2 on the high frequency oscillations. When the control electrodes 52 and 53 of tubes H and I respectively are modulated or varied at the signal frequency applied through the secondary winding 29 the anodes 56 and 57 draw current in different amounts depending upon the effective potential applied to the control electrodes. These varying currents in the anode circuits cause voltage drops in R_3 and R_4 which are characteristic of the amplitude of the modulating frequencies. These voltage drops which are varying in characteristic are applied to the screen grid electrodes 45 and 46 of tubes F and G. As pointed out in connection with the modification shown in Figure 2 the phase of the energy in the tank circuit is determined by the phase of the energy repeated in the anode circuit of the tube which is supplying the most energy to the tank circuit. In this manner phase modulation of the energy in the tank circuit is accomplished at signal frequency. The energy from the tank circuit 22 may be utilized in the same manner in which the energy from the tank circuit 22 of Figure 2 is utilized.

I claim:

1. Means for modulating the phase of high frequency oscillations from a source comprising a pair of thermionic relay tubes each having an anode, a cathode, a control electrode and an auxiliary electrode, means connecting the anodes of said tubes in parallel with a tank circuit, a line of fixed length connecting said source of oscillations to the control electrode and cathode of one of said tubes, a second line connecting said source of oscillations to the control electrode and cathode of the other of said tubes, tuning means having uniform distributed capacity and inductance inserted in said last named line, and a circuit for applying oscillations which vary at signal frequency in phase opposition to the auxiliary electrodes in each of said tubes.

2. In a signalling system, a pair of thermionic tubes, a load circuit connected in parallel between the anodes and cathodes of said tubes, resistances connected between the control grid and cathode of said tubes, means for applying modulating potentials in phase opposition to the terminals of said resistances, high frequency conductors connected between the control grids and between the cathodes of each of said tubes, means in at least one of said conductors for varying the electrical length thereof, and means for applying high frequency oscillations in displaced phase relation to said conductors.

3. In a signalling system, a pair of thermionic tubes each having an anode, a cathode, a control electrode and an auxiliary electrode, a work circuit connected in parallel with the anodes and cathodes of said tubes, impedances connected between the control grids and cathodes of said tubes, means for applying variable biasing potentials to similar points on said impedances, high frequency conducting lines connected between the control grids of each of said tubes and between the cathodes of each of said tubes, variable reactances having distributed capacity and inductance in each of said conducting lines, means for applying high frequency oscillations to said lines, and a source of modulating potentials connected to the auxiliary electrodes of said tubes to apply modulating potentials in phase opposition to said electrodes.

4. In a signalling system, a pair of thermionic tubes of the screen grid type, a work circuit connecting the anodes of each of said tubes to the cathodes of each of said tubes, means for applying biasing potentials to the control grids of said tubes, high frequency conductors including capacitive and inductive reactances connected between the control grids of each of said tubes and between the cathodes of each of said tubes, one of said reactances in each of said conductors being variable, means for applying high frequency oscillations displaced in phase to said conductors, a pair of thermionic amplifiers, each having its anode electrode connected to the screen grid electrode in a different one of said first named tubes, and means for applying modulating potentials in phase opposition to the control electrodes of said thermionic amplifiers.

5. A phase modulator comprising a pair of thermionic tubes each having an anode, a control electrode, a cathode and an auxiliary electrode, means for energizing the control electrodes of said tubes by phase displaced oscillations of like frequency, a tank circuit connected to the anodes and cathodes of said tubes, said anodes and cathodes being connected in parallel, a source of modulating potentials, an impedance, a circuit connecting said source of modulating potentials to said impedance for impressing said modulating potentials on said impedance, and a circuit connecting points on said impedance at which said modulating potentials are of unlike phase to the auxiliary electrodes of said tubes, thereby varying in unlike manner the conductivity of said tubes in accordance with potential variations in said impedance.

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