

March 30, 1937.

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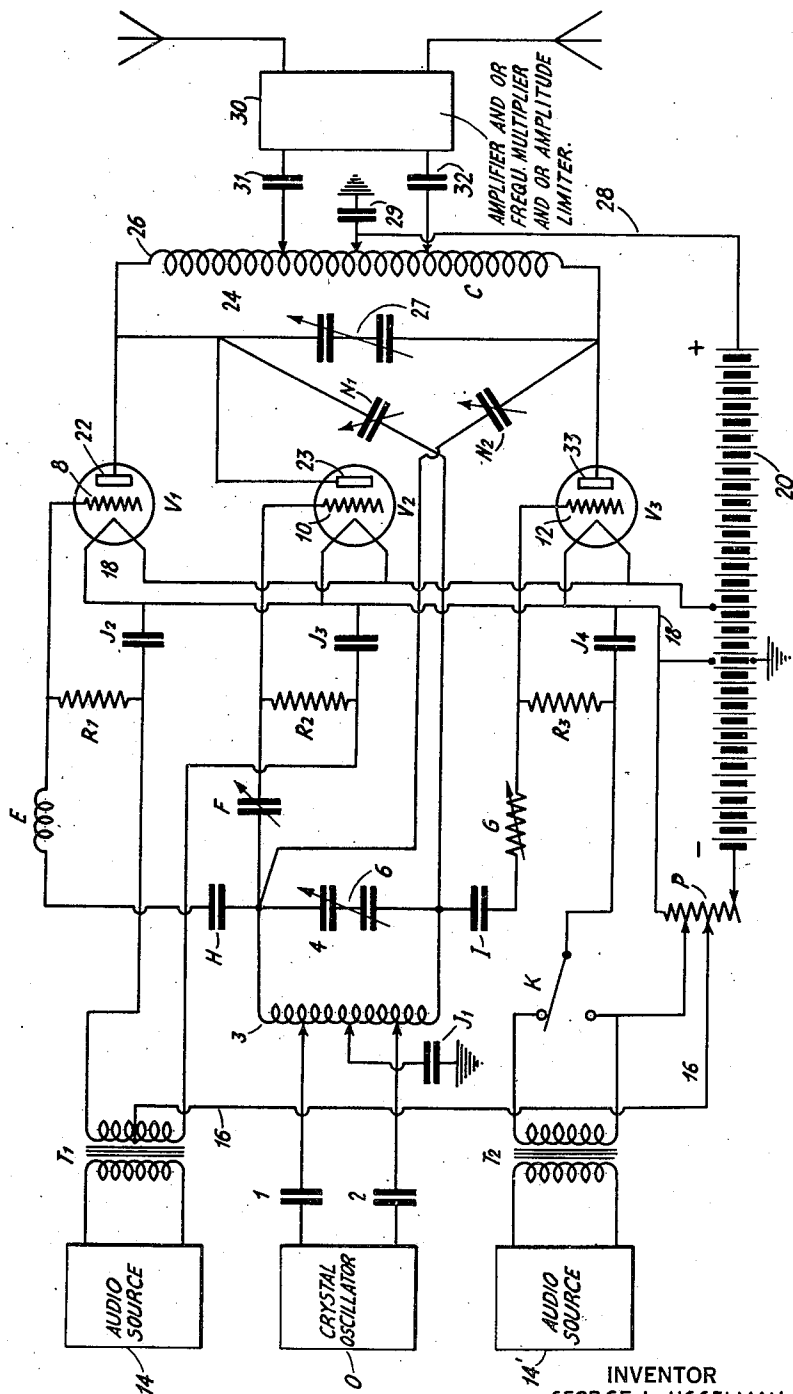
2,075,071

MODULATION

Filed July 23, 1932

2 Sheets-Sheet 1

Fig. 1



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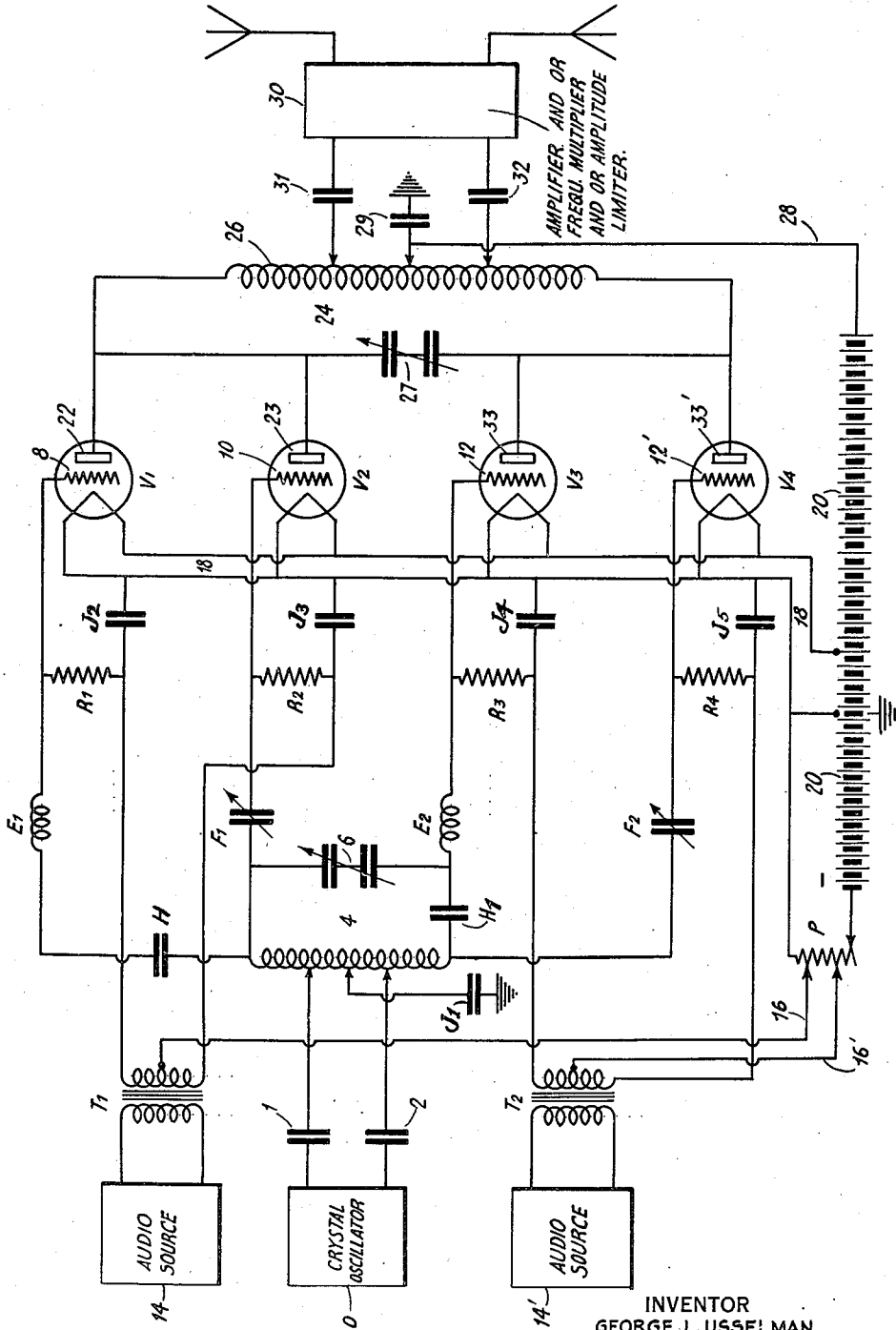
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Fig. 2



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MODULATION

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23 Claims. (Cl. 179—15)

The present invention relates to an improved method of and means for producing phase or amplitude modulated signals, or a combination of both, means for varying the phase amplitude or phase and amplitude of radio waves or oscillations in accordance with the signals to be transmitted, and means for regulating during operation of the transmitter the amount of phase amplitude or phase and amplitude modulation accomplished.

It has been discovered that most amplitude modulated transmitters have some phase modulation present in the signal. This in bad cases causes very objectionable distortion in the signal.

The present invention also involves means heretofore unknown in the art for balancing out any phase modulation inherently produced in amplitude modulating a carrier wave at signal frequency.

It is also known that in accomplishing phase or frequency modulation of a carrier some amplitude modulation thereof is accomplished. This amplitude modulation results in distortion of the signal in the receiver.

The present invention involves means unknown heretofore in the art for balancing out any amplitude modulation or extraneous hum inherently produced in accomplishing phase modulation of a carrier.

The invention also relates to a new and improved means for and method of multiplexing signals by means of phase or amplitude modulated waves or both.

In phase modulated transmitters, as disclosed in United States application Serial No. 602,487, filed April 1, 1932 and United States application Serial No. 607,932, filed April 28, 1932, Patent #2,036,164 dated March 31, 1936, phase modulation of a high frequency carrier in accordance with the signal to be transmitted has been accomplished.

In the first described application phase rotation of the carrier wave relative to the normal wave is accomplished by the use of a phase retarding inductance and phase advancing capacity in the grid circuits of the symmetrical modulator tubes.

In the second referred to application phase modulation is accomplished by the use of lines of a different electrical length connecting the oscillation source substantially cophasally to the grids of a pair of tubes. One of the lines includes variable means, as, for example, a trombone tuning means.

In the above referred to applications in general the signal frequencies are applied to the impedances of the tubes so that a phase shift, the amount of which is determined by the amplitude of the signal, appears in the energy repeated in the tubes and consequently appears in the output of the tubes.

In practice it is often desirable to have a transmitter by means of which the degree of phase modulation effected in accordance with the signal may be varied during the operation of the transmitter so that signalling may continue during the adjustment of the degree of phase shift.

One of the main objects of the present invention is to provide a new and novel arrangement by means of which phase modulation may be accomplished and the degree of modulation may be varied during operation of the modulating means.

This is accomplished in accordance with the present invention by feeding unmodulated carrier energy to the tank circuit into which the phase modulated energy is fed and regulating the amount of unmodulated energy delivered to the tank circuit thereby regulating the degree to which the combined energy in the tank circuit is modulated in phase.

Under other conditions it is often desirable to transmit by means of the same transmitter phase modulated waves and amplitude modulated waves simultaneously so that two signals may be sent out at the same time, or to transmit either wave separately.

In its broadest aspect this is accomplished by applying phase modulations to a carrier at signal frequency and amplitude modulations to the carrier at signal frequency simultaneously or separately, and feeding the combined energy or the energy from one of the modulators to a tank circuit, from which it may be utilized.

Another object of the present invention is to provide means whereby the hum and extraneous amplitude modulation, which may be inherently present in a phase modulator, may be corrected, compensated, or otherwise removed from the energy resulting from the phase modulation which is to be transmitted.

This last object is accomplished in accordance with the present invention by opposing, in the tank circuit, any amplitude modulation inherently accomplished by phase modulation of the carrier, with equal and opposite modulation components furnished by the amplitude modulator described briefly in the second preceding paragraph.

Conversely, the hum and extraneous phase

modulation which might be inherently produced by an amplitude modulator may, in accordance with the present invention, be opposed, by equal and opposite phase modulation components resulting from phase modulation of the carrier. In this arrangement provision for varying the degree of phase modulation accomplished in the correction circuit, that is, the phase modulator, is desirable.

Where multiplexing of signals by the use of phase modulation and amplitude modulation is desired the same carrier wave may be modulated in phase by one signal, to be transmitted, and in amplitude by another signal to be transmitted, or the same carrier may be modulated in phase and in amplitude by the same signal. Moreover, the phase and amplitude modulators described above need not be used simultaneously but may be used separately.

Moreover, where multiplex transmission is desired the same carrier may be modulated in phase by two different sources of audio frequency currents so that multiplex signals may be sent out over the same transmitter, amplifier, and antenna system.

This is accomplished in accordance with the present invention by supplying high frequency oscillations from a tank circuit to the input electrodes of two phase modulators, the output electrodes of which are connected to the same tank circuit and applying to the impedance of the modulator tubes the signal oscillations to be transmitted.

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 advantages to be gained thereby will be understood by 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 and amplitude modulated transmitter which includes means by which the degree of phase modulation accomplished may be varied during operation of the transmitter and also means whereby the transmitter may be arranged to operate as a phase modulator or as an amplitude modulator; while

Figure 2 shows an arrangement whereby multiplex transmission is obtained and shows means whereby the same carrier may be modulated by several signal frequencies and the modulated carrier transmitted.

Referring to the drawings, and in particular to Fig. 1 thereof O indicates a high frequency oscillator of any known type such as a crystal oscillator which will produce oscillations of substantially constant frequency. The output of the oscillator O is connected, as shown, by way of blocking condensers 1 and 2 to the inductance 3 of a tank circuit 4 including a tuning condenser 6 connected in parallel with the inductance 3. The upper terminal of the tank circuit 4 is connected, as shown, by way of blocking condenser H and inductive reactance E to the grid 8 of a thermionic tube V₁ and by way of a capacitive reactance F to the grid 10 of a thermionic tube V₂. The lower terminal of the tank circuit 4 is connected by means of a blocking condenser I and variable resistance G to the control electrode 12 of an additional thermionic tube V₃. The high frequency input circuit of the tubes V₁, V₂, and V₃

is completed by way of a lead connecting a point on the inductance 4 to ground by way of capacity J₁.

Audio frequency signals from a source 14 are applied through transformer T₁ and resistances R₁ and R₂ respectively in phase opposition to the control electrodes 8 and 10 respectively of tubes V₁, V₂ respectively. The input circuit for the modulating signals is completed by a lead 16 connecting the center point of the secondary winding of transformer T₁ to a point on potentiometer P, which is in turn connected with the cathode circuit 18 of tubes V₁, V₂. Filament heating potential is supplied from the battery 20 as indicated. Biasing potential for the control electrodes 8 and 10 of tubes V₁, V₂ respectively is supplied by way of lead 16 from potentiometer P connected across a portion of the battery 20.

The anode 22 of tube V₁ and anode 23 of tube V₂ are connected as shown to one terminal of a tank circuit 24 comprising an inductance 26 and variable capacity 27. Charging potential for the anodes 22 and 23 is supplied by way of a lead 28 connected between the battery 20 and a point on the inductance 26. Radio frequency oscillations appearing in this tank circuit are shunted around the source 20 by way of a by-pass condenser 29.

The operation of this arrangement to accomplish phase modulation of the carrier supplied from O to the tubes V₁, V₂ in accordance with the signals supplied from 14 to said tubes has been described in considerable detail in the applications referred to hereinbefore. The operation thereof, however, will be repeated briefly here.

The high frequency oscillations supplied from O appear relatively displaced or shifted in phase on the control electrodes 8 and 10 of the tubes V₁, V₂ respectively. The shift in phase depends of course upon the values of the inductance E and capacity F inserted in the connections. Likewise, due to the repeating effect of the tubes V₁, V₂, the phase of the energy in the common tank circuit 24 will be advanced or retarded from the average phase position of the normal radio wave an angle, the sign of which depends upon which modulator tube is supplying the greater amount of power. The tube having lower instantaneous bias, which is in part, the result of the signal oscillations differently applied to the control electrodes thereof by way of transformer T₁, will, of course, have a greater controlling effect on the phase of the oscillations appearing in the common tank circuit 24. In effect the phase of the oscillations in the common tank circuit 24 will be advanced or retarded from the average phase position of the oscillations in a manner proportional to the controlling power of one modulator tube V₁ over the other modulator tube V₂. This controlling power of one modulator tube V₁ over the other modulator tube V₂ of course depends upon the effective bias applied to the control electrodes of the respective tubes. Since the primary winding of the transformer T₁ is energized by signal oscillations the control electrode biasing excitation of the two phase modulator tubes will vary at signal frequency. The power supplied by each of tubes V₁, V₂ to the tank circuit will vary in accordance with the signal potential variations and therefore the repeated energy in the common tank circuit will be varied in phase as the signal frequency applied to the transformer varies and will have an instantaneous phase which depends upon the effective bias applied to the control electrodes,

which bias is determined by the constant fixed potentials applied thereto by way of lead 16 and the modulating potentials applied thereto from the secondary windings of transformer T₁.

5 The phase modulated energy appearing in the tank circuit 24 may be supplied to an amplifier 30 by way of blocking condensers 31 and 32. This amplifier may include frequency multiplying means and may be connected to an antenna system, as shown, from which the phase modulated energy may be radiated.

The means whereby amplitude modulations at signal frequency may be applied to the carrier from O will now be described.

15 An audio frequency source 14' has its output circuit connected by way of transformer T₂, switch K, and resistance R₃ to the control electrode 12 of tube V₃ so that when switch K is closed, (in the upper position) modulating frequencies are applied to the control electrode 12. This input circuit for the modulating frequencies from 14' is completed by connecting the other terminal of the secondary winding of transformer T₂ to a tapped point on potentiometer P, which is in turn connected with the filament of tube V₃ by way of filament circuit 18. This tapped connection between the transformer winding and the potentiometer permits the value of the biasing potential applied to the grid 12 of tube V₃ to be regulated. The anode 33 of thermionic tube V₃ is connected, as shown, to the lower terminal of tank circuit 24.

Assuming that the transmitter is operating as described above to accomplish phase modulation 35 of the carrier produced in O. If the switch K is closed (i. e., in the upper position) audio frequency oscillations are impressed from 14' upon the control electrode of tube V₃ and higher frequency oscillations modulated in amplitude in accordance with the audio signals appear in the tank circuit 24 connected with the anode 33 of tube V₃. These audio frequency oscillations are transferred along with the phase modulated signals to the amplifier 30 and radiated. The tank circuit 24 is normally tuned to the frequency of the tank circuit 4, both of these tank circuits being tuned to the frequency of the oscillations generated in O.

At the receiving station two receivers may be 50 used or one receiver adapted to receive both audio frequency modulated waves and phase modulated waves and to separate the same. The carrier as transmitted by this arrangement has impressed thereon modulations in phase in accordance with the signals from source 14 and modulations in amplitude in accordance with signals from the source 14'. Sources 14 and 14' may be replaced by a single source in which case oscillations from O are modulated in phase in 60 V₁ and V₂ and in amplitude in V₃ by the same signals.

The amplitude modulator may be rendered inoperative by merely opening the switch K (down position) so that phase modulated signals 65 only may be sent out.

With this circuit any objectionable amplitude hum which may be present in phase modulation transmission may be balanced out by applying from 14' (switch K now being in the upper or 70 closed position) potentials of a frequency equal to the frequency of the objectionable hum but opposite in phase so that the supplied potentials will oppose the objectionable hum. In other words any amplitude modulation accomplished 75 in the phase modulator part of the transmitter

may be opposed in the tank circuit by amplitude modulation accomplished in V₃. By adjusting the direct current potential applied to the control electrode of tube V₃ or by adjusting the amplitude of the potentials supplied from 14' 5 the amplitude modulated signals applied from V₃ to the tank circuit 24 may be made equal in amplitude to the amplitude modulation inherently accomplished in the phase modulator part of the circuit and balance out the same so 10 that pure phase modulated signals are fed from the tank circuit 24 to the amplifier 30. Compensating potentials of the proper frequency phase and amplitude may be produced in 14' or supplied thereto from any source. 15

Conversely, where it is desired to transmit amplitude modulated signals entirely free of any hum and extraneous phase modulation which is inherently accomplished in the amplitude modulator, the amplitude modulator tube V₃ may be 20 energized to accomplish full amplitude modulation of the carrier from O and feed the amplitude modulated carrier to the tank circuit. 14 may supply current of a frequency equal to the frequency of the undesired phase modulation accomplished in the amplitude modulator V₃. The phase relation of this alternating current produced in 14 or supplied by way of 14 to V₁ and V₂ should be so adjusted that the phase modulation produced in the phase modulator will op- 30 pose and compensate the phase modulation produced in the amplitude modulator. The degree of phase modulation accomplished in the phase modulators V₁ and V₂ may be regulated by adjusting the value of the phase retarding and advancing means E and F respectively and, further, by regulating the direct current bias applied to the control electrodes of the tubes V₁ and V₂ by way of resistances R₁ and R₂ respectively. Furthermore, the amount of cur- 40 rent furnished by 14 to the phase modulator may be adjusted to a value such that the phase modulation components introduced into the tank circuit for correction purposes may be made opposite to the undesired phase modulation components introduced into the tank circuit from the amplitude modulator. 45

The manner in which the degree of phase modulation accomplished may be varied or adjusted will now be described. 50

If the key K is moved to the lower position so that the secondary winding of T₂ is open at one end, no audio frequency signals from source 14' can be applied to the control electrode of tube V₃. Now the amplification of this tube depends 55 upon the bias applied to the control electrode thereof. If the negative bias on the amplitude modulator V₃ is set high tube V₃ will supply only a small amount of unmodulated energy to the tank circuit 24 and the amount of phase modulated energy delivered to the tank circuit 24 from tubes V₁, V₂ will be relatively large. However, if the bias applied to the control electrode of the amplitude modulator V₃ is set low, that is, less negative, the amount of unmodulated energy delivered to the tank circuit 24 will be large and the amount of phase modulated energy delivered to the tank circuit 24 from tubes V₁, V₂ will be relatively small. The signal therefore in the first case will have a large degree of phase modulation while in the second case the signal will have a small degree of phase modulation. In both cases the transmitter output power will be the same or can be made the same if a limiter is 75 included in the amplifier 30, but the degree of

phase modulation can be made different. This arrangement therefore permits the degree of modulation in phase applied to the carrier from O to be varied between certain limits. This variation of the degree of phase modulation may be accomplished during operation of the transmitter.

In order that the arrangement including the thermionic tubes V_1 , V_2 , V_3 may be balanced to some extent with respect to the tank circuit 4 the resistor G should be non-inductive and should be adjusted to equalize the load on both sides of the tank circuit, that is, since tank circuit 4 supplies the control electrodes of two tubes V_1 , V_2 from one terminal and the control electrode of V_3 only from the other terminal, some provision must be made to balance or equalize the load on this tank circuit. This resistor G permits this balance to be obtained.

In order to prevent the effects of coupling due to the inherent capacity of the electrodes in the tube from unbalancing the system, neutralizing condensers N_1 , N_2 may be connected, as shown, between the terminals of the tank circuit 24 and the opposite terminals of the tank circuit 4.

Although, for purposes of illustration, I have shown my novel modulating circuits as including thermionic tubes of the three-electrode type, it will be understood that my invention is not limited to the use of any specific type of tubes since screen grid or multi-grid tubes may be used in place of the tubes shown. Furthermore, the use of such tubes in place of the tubes now shown in the present invention is thought to be within the scope of the present invention. Where screen grid tubes are used in place of the triodes shown neutralization of the tubes may not be necessary. Furthermore, where screen grid tubes are used the modulating frequencies may be applied to the screening grid electrode rather than to the control electrode, as shown. Where multi-grid tubes are used appropriate changes may be made in the circuit to derive from the use of said tubes the optimum results. The means whereby oscillations may be modulated in phase by several signals will now be described. In this description reference will be made to Fig. 2.

In the arrangement shown in Fig. 2 the oscillator O is connected to the thermionic tubes V_1 , V_2 , by way of tank circuit 4 and phase shifting means E_1 , F_1 connecting the same terminal of tank circuit 4 to the control electrodes 8 and 10 of tubes V_1 , V_2 in the same manner in which the tank circuit 4 is connected to the same electrodes in the arrangement of Fig. 1. Moreover, the modulating frequencies from source 14 are applied by way of resistances R_1 , R_2 to the control electrodes 8 and 10 of tubes V_1 , V_2 in a manner similar to that in which the modulating frequencies were applied from the same source to the same electrode of Fig. 1. The output electrodes of tubes V_1 , V_2 are likewise connected in parallel to the same terminal of tank circuit 24 in the same manner in which they were connected in the arrangement of Fig. 1. However, in the arrangement of Fig. 2 an additional thermionic tube V_4 cooperates with tube V_3 to accomplish phase modulation of the oscillations produced in O in accordance with the energy of signal frequency from source 14'. Since the manner in which phase modulation of the oscillation produced in O in accordance with the signal frequency energy from 14' is accomplished in V_3 , V_4 is the same as the manner in which os-

cillations produced in O are modulated in phase in accordance with the signalling energy appearing in 14, a description of this part of the modulator of the present invention is thought unnecessary here. It will be noted, however, that oscillations from O are impressed by way of blocking condensers 1 and 2 to tank circuit 4 and from tank circuit 4 by way of phase shifting elements E_2 and F_2 to the control electrodes 12 and 12' of tubes V_3 and V_4 . Further that signal potentials are supplied by way of transformer T_1 and resistances R_3 and R_4 to the control electrodes 12 and 12' in phase opposition. Direct current potential for the control grids of tubes V_1 and V_2 is supplied by way of lead 16 and the secondary winding of T_1 and to the control electrodes of V_3 and V_4 by way of lead 16'. The anodes 33 and 33' of tubes V_3 and V_4 are connected as shown in parallel to the same terminal of tank circuit 24.

In operation multiple modulation in phase of the high frequency oscillations produced in O in accordance with the signals in 14 and 14' is accomplished in the tubes V_1 , V_2 , V_3 , and V_4 . These oscillations are modulated in phase in accordance with two signals and appear in the tank circuit 24. The phase of the energy in the tank circuit 24 is determined by the phase of the energy in the tubes from the pair, V_1 , V_2 and V_3 , V_4 , which is supplying the most energy to the tank circuit at a particular instant. The multiple phase modulated oscillations are fed from the tank circuit 24 to the amplifier 30, as in the prior arrangement. The amplifier 30 may include frequency multipliers or amplitude limiters, etc. The energy from the amplifier 30 may be fed to an aerial system from which it may be radiated.

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

1. Signalling apparatus comprising a pair of tank circuits tuned to the same frequency, means for impressing high frequency oscillations on one of said tank circuits, a phase modulator and an amplitude modulator each having their input circuits connected to said last named tank circuit and their output electrodes connected to the other of said tank circuits, and a source of signalling potentials connected with each of said modulators.

2. A multiplexing system comprising a tank circuit, a plurality of sources of potential of signal frequency, a source of high frequency oscillations, a plurality of modulators interposed between said source of high frequency oscillations and said tank circuit, and means interposed between each of said sources of potential and said modulators for impressing phase modulations on the oscillations impressed on said modulators from said source of high frequency oscillations.

3. A phase modulator comprising a source of oscillations, a source of signal potentials, a pair of thermionic tubes having their control electrodes connected through elements of different electrical length to said source of oscillations and connected in opposition to said source of signal potentials, a tank circuit connected with the anodes of said tubes, and means for determining the degree of phase modulation accomplished comprising a thermionic tube having a control electrode connected to said source of oscillations and to a variable source of potential and its anode connected to said tank circuit.

4. A multiplex system comprising, a source of high frequency oscillations, a tank circuit, a pair

of electron discharge tubes having their anodes connected to one end of said tank circuit and their control electrodes connected through phase shifting elements to said high frequency source, means for applying signals in phase opposition to the control electrodes of said tubes, an additional electron discharge tube having its anode connected to the other terminal of said tank circuit and its control electrode connected to said high frequency source, and means for impressing other signals on the control electrode of said last named tube.

5. In a system for adjusting the degree of modulation impressed on a high frequency carrier by means of a thermionic modulator comprising, a pair of thermionic tubes having their input electrodes connected through reactances of different character to a tank circuit tuned to the carrier frequency and to a source of modulating potentials and their anodes connected to an output circuit, an additional thermionic tube having its control electrode connected to said tank circuit and its output electrode connected to said output circuit, and means for varying the gain of said additional tube.

6. In a system for adjusting the degree of phase modulation impressed on a high frequency carrier wave by means of a thermionic modulator comprising a pair of thermionic tubes having their input electrodes connected through phase shifting devices of different character to a circuit energized by said carrier wave and means for impressing signal potentials on said tubes, an additional thermionic tube having its control electrode connected to said circuit, means for varying the gain of said additional tube, and a tank circuit connected with the output electrodes of all of said tubes.

7. A multiplex system comprising, a source of high frequency oscillations, a tank circuit, a pair of thermionic tubes having their anodes connected in parallel to one end of said tank circuit and their control electrodes connected to phase shifting elements which are in turn connected co-phasally to said high frequency source, means for impressing modulating potentials on the internal impedances of said tubes, an additional thermionic tube having its anode connected to the other terminal of said tank circuit and its control electrode connected to said source, and means for impressing other modulating potentials on the control electrode of said last named tube.

8. Signalling means comprising a source of high frequency oscillations, a pair of tubes having their control grids connected through impedances of different character to one terminal of said source, and a third tube having its control grid connected to the other terminal of said source through a non-inductive resistance, a source of modulating potentials connected with an electrode in each tube of said pair of tubes, and a source of modulating potentials connected with an electrode in said third tube.

9. Means for modulating in phase high frequency oscillations comprising, a pair of tubes having their control grids energized at high frequency through impedances of different character, and means for varying the degree of modulation accomplished comprising a third tube having its control electrode energized at high frequency through a non-inductive resistance.

10. A multiplexing system comprising in combination a tank circuit, a source of high frequency oscillations, a plurality of sources of signal potentials, a pair of thermionic tubes inter-

posed between each source of signal potential and said tank circuit, the tubes of each pair of said tubes having their input electrodes connected to a separate source of signal potentials and their output electrodes connected to said tank circuit, and means for applying high frequency oscillations to the input electrodes of each of said tubes, the phase of the oscillations applied to said tubes being relatively shifted.

11. An arrangement as claimed in claim 10 in which said means for supplying high frequency oscillations to the input electrodes of each of said tubes includes phase shifting elements connected with the input electrodes of each of said tubes.

12. In a high frequency transmitter, a tank circuit, a source of high frequency oscillations, a plurality of sources of signal potentials, a plurality of pairs of thermionic tubes, each pair having its anode electrodes connected in parallel to said tank circuit and its control electrodes connected in phase opposition to one of said sources of signal potentials, and elements of different electrical character connecting the control electrodes of said tubes to said source of high frequency oscillations for applying high frequency oscillations to the control electrodes of each of said tubes.

13. The combination, with a high frequency work circuit, of a source of high frequency oscillations, a plurality of sources of potentials of signal frequency, a plurality of pairs of thermionic modulator tubes, circuits connecting the input electrodes of each pair of tubes to a different one of said sources of potentials of signal frequency, and separate phase shifting elements connecting the input electrodes of each of said modulator tubes to said source of high frequency oscillations.

14. In signalling apparatus, a source of carrier waves, a source of modulating potentials, an amplitude modulator connected to both of said sources, an output circuit connected with said amplitude modulator, and means for balancing out any phase modulation accomplished in said amplitude modulator comprising, a phase modulator of the electron discharge type connected to said carrier wave source and to said output circuit.

15. In signalling apparatus the combination of a source of carrier waves and a source of modulating potentials, a phase modulator of the electron discharge tube type connected to both of said sources and to an output circuit, and a device for balancing out any amplitude modulation accomplished in said phase modulator comprising, an amplitude modulator of the electron discharge tube type connected to said carrier wave source and to said output circuit.

16. In a phase modulation signalling system, a pair of electron discharge tubes each having an anode, a cathode and a control grid, an output circuit connected to the anodes of said tubes, a source of high frequency wave energy, reactances of different character connecting said source of high frequency wave energy to the control grids of said tubes, a circuit for applying modulating potentials to like electrodes of said tubes in phase displaced relation whereby wave energy modulated in phase in accordance with said modulating potentials is set up in said output circuit when said tube electrodes are energized by means for balancing out any amplitude modulation inherently produced in said aforesaid circuits comprising, an additional electron discharge tube having a control electrode connected to said source of high frequency wave energy and an

output electrode connected to said output circuit, said tube also having a cathode electrode, and a circuit for applying modulating potentials characteristic of the amplitude modulation inherently produced in said aforesaid circuits on the impedance between the control electrode and cathode of said additional tube.

17. The combination with a phase modulator including a pair of electron discharge tubes each having a control electrode, and an anode and a cathode, and having their control electrodes energized by high frequency oscillations impressed from a high frequency source through phase shifting reactances on said control electrodes, their inter-electrode impedances varied in phase opposition at signal frequency by potentials characteristic of signals and their anodes connected together, of means for adjusting the degree of phase modulation accomplished in said aforesaid tubes and circuits including an additional electron discharge tube having a control electrode and an output electrode and a cathode, a connection between the control electrode of said additional tube and said high frequency source, a source of biasing potential, the value of which may be varied, connected between the control electrode and cathode of said additional tube, and a connection between the output electrode of said additional tube and the anode electrodes of said tubes of said phase modulator.

18. Signalling means including an output circuit, a source of high frequency oscillations, an amplitude modulator tube having an anode, a cathode and a control grid, a connection between said control grid and said source of high frequency oscillations, a circuit for applying modulating potentials between the cathode of said tube and another electrode of said tube to produce amplitude modulation of said high frequency oscillations appearing in said output circuit, and means for balancing out any phase modulation accomplished in said amplitude modulator tube comprising, a pair of electron discharge tubes each having an anode, a cathode and a control electrode, phase shifting reactances of different character connecting the control electrodes of said pair of tubes to said source of

high frequency oscillations, circuits for applying modulating potentials to an electrode in each of said tubes, said potentials being displaced in phase on said electrodes, and a circuit connecting the anode electrodes of said pair of tubes to said output circuit.

19. Signalling means as recited in claim 18 wherein a resistance is connected between the control electrode and cathode of each tube of said pair of tubes and in which a variable source of biasing potentials is connected between the control grid and cathode of said amplitude modulator tube.

20. A system as recited in claim 18 wherein said output circuit is tuned to a harmonic of the frequency of the oscillations in said high frequency source.

21. A system as recited in claim 18, wherein the inter-electrode capacities of said tubes are neutralized.

22. In combination, a source of signal waves, a source of carrier waves, means combining waves from both of said sources whereby in the combined waves there are present desired components and undesired phase modulation components, means independent of the aforesaid means, to combine other portions of waves from said sources to produce phase modulated waves corresponding to said undesired phase modulation components, and means combining said desired components, undesired components and said phase modulated waves so that the resultant will be the desired component and a reduced undesired phase modulation component.

23. In combination, a source of carrier waves, a source of signal waves, means for amplitude modulating a portion of the carrier waves with a portion of said signal waves, the modulated waves having also present undesired phase modulated waves; means utilizing another portion of said signal waves and another portion of said carrier waves to produce phase modulated waves, and means for combining the latter waves with the first mentioned modulated waves to substantially reduce the undesired phase modulated waves so that the remainder of the waves are substantially only amplitude modulated waves.

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