

July 6, 1937.

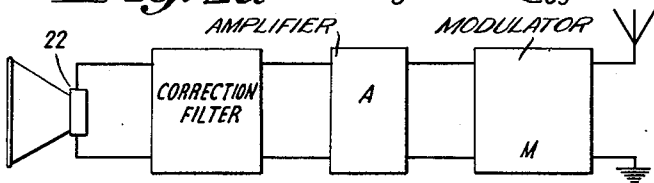
M. G. CROSBY

2,085,739

FREQUENCY OR PHASE MODULATION

Filed April 30, 1932

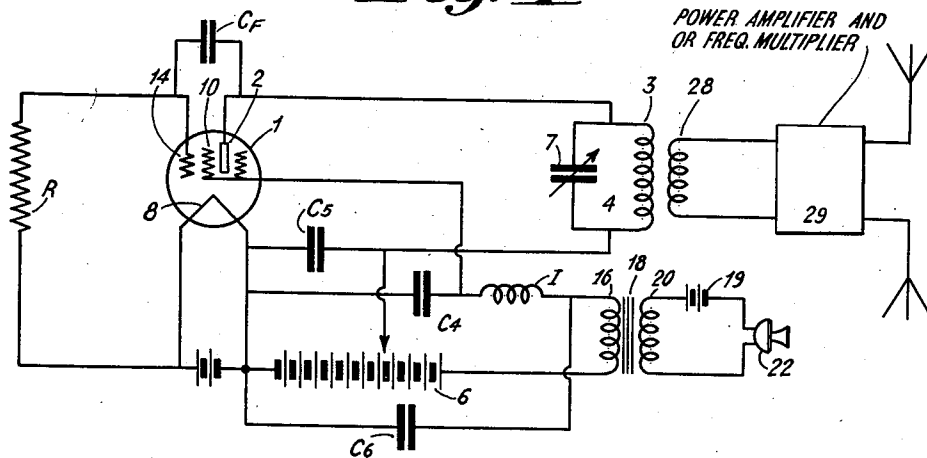
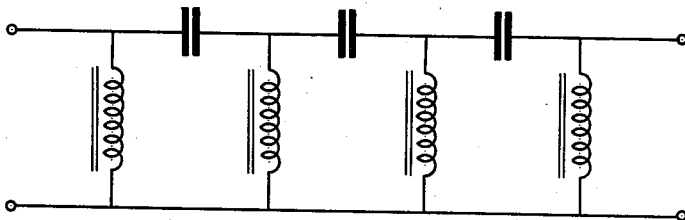
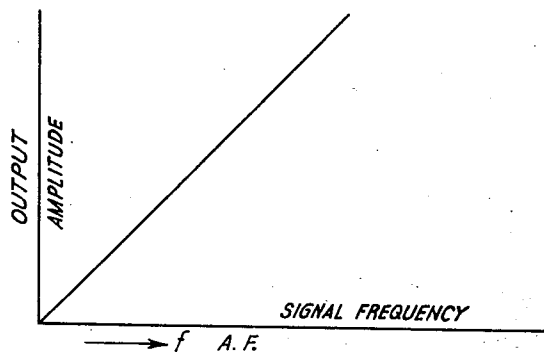
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FREQUENCY OR PHASE MODULATION

3 Sheets-Sheet 2



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Fig. 6

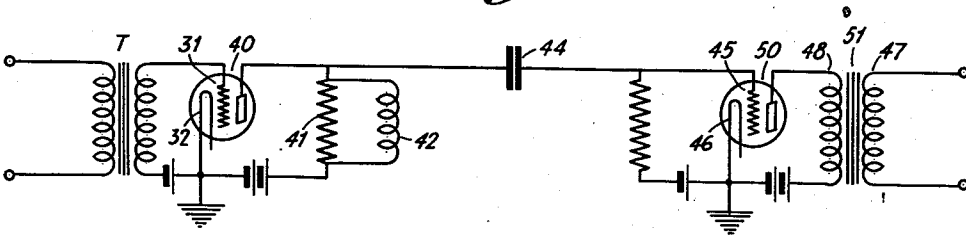


Fig. 7

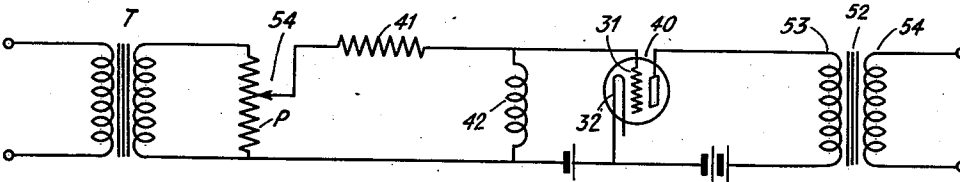


Fig. 7a

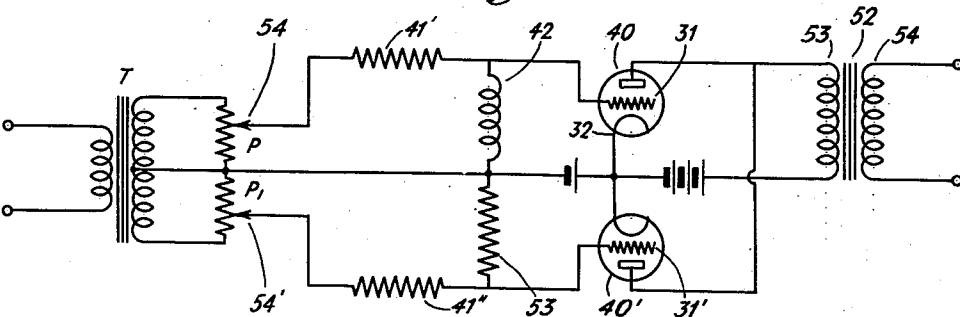
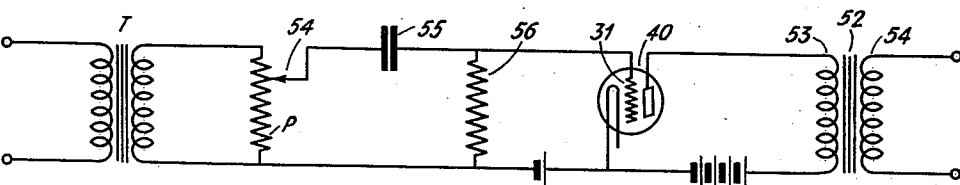


Fig. 8



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FREQUENCY OR PHASE MODULATION

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Application April 30, 1932, Serial No. 608,383

18 Claims. (Cl. 179—171)

This invention relates to signal transmission systems and more in particular to a system wherein high frequency waves or oscillations are produced or are relayed for transmission and are modulated or varied in some manner in accordance with signal indications before transmission.

Modulated electrical waves are known in the art as waves or oscillations having definite characteristics, one or more of which characteristics is varied in some manner in accordance with signals to be transmitted. This variation of the waves or oscillations may be as to amplitude or as to frequency, or as to phase, or as to a combination of any of the aforesaid variations. In any event, the variation of the characteristics bears a definite relation to the signal to be sent.

Circuits or systems for frequency or phase modulation of radio waves are known in the art. The systems generally are quite complicated in nature and in many cases are unsatisfactory in operation. The outstanding difficulty inherent in most frequency modulators known heretofore is that the modulation produced or imparted to the high frequency oscillations is not linear with respect to the modulating or signal wave. In systems known heretofore increases of signal wave voltage do not produce proportionate depths of frequency modulation.

The primary object of the present invention is to provide a new and improved method of an apparatus for applying frequency or phase modulations to high frequency oscillations or waves to be transmitted and a method of an apparatus for producing high frequency oscillations or waves and modulating the frequency or phase of the same in a new and improved manner.

An added object of the present invention is to provide a simple method of and means for producing high frequency oscillations and modulating the frequency or phase of the oscillations produced in accordance with signal voltages.

Briefly, the above objects are attained in accordance with the present invention by the use of a pliodynatron, the anode electrode of which is connected with an oscillation circuit normally resonant at the carrier frequency to be modulated and an auxiliary electrode of which is maintained at a positive potential higher than the potential applied to the anode so that the anode circuit has a negative resistance characteristic. This characteristic, as is well known, results in a strong tendency to produce oscillations in the signal resonant circuit, connected with the anode, at a frequency depending to a major extent upon the natural resonance of the tuned circuit con-

nected with the anode. The frequency of the oscillations generated depends to some extent on two other factors. In a tube of this type the capacity from anode to filament varies with applied voltage due to the fact that this capacity is composed of the anode as one plate of the condenser and a cloud of electrons around the filament as the other plate of the condenser. When the voltage applied by an element is varied the cloud of electrons is varied in distribution and density so that the plate to filament capacity is varied. Therefore, since this capacity is part of the oscillating circuit, the natural resonant frequency at which the tube and circuit oscillates is varied. The second variable factor which determines the frequency of the oscillations generated will now be described. Since the frequency of oscillations is dependent also upon the value of the negative resistance of the tube, variations in the voltage applied to an element which causes the negative resistance to vary in turn causes the frequency generated to vary. Of these two last effects the second is conceded to have the least effect or influence on the frequency determining characteristics of the tube and circuit.

Applicant makes use of the above phenomenon to apply frequency or phase modulations to the high frequency oscillations generated in an oscillation circuit associated with a tube of the type described hereinbefore. Frequency modulation is accomplished in accordance with the present invention by applying voltages at signal frequency to an electrode in a tube of the pliodynatron type which is producing high frequency oscillations as described above. Phase modulation of the oscillations is accomplished in accordance with the present invention by applying voltages to the high frequency oscillations at signal frequency which have been corrected in such a manner that the amplitude of said voltages is linear with respect to the frequency of the modulating signals. The frequency or phase modulations applied to the high frequency oscillations are proportional to the signal wave impressed.

An apparent advantage to be gained by the use of a frequency or phase modulating system as disclosed in the present invention, is that but a single tube is necessary to produce high frequency oscillations and modulate the high frequency thereof in accordance with the signals to be worked with.

Another advantage flowing from the use of a modulating system arranged in accordance with the present invention, as has been found in actual practice, is that a high degree of modu-

lation may be obtained. The degree of modulation that may be obtained is much higher than will be required in any frequency modulation system. Furthermore, the modulation accomplished here to a high degree is linear. That is, the variations in characteristics of the high frequency wave is linear with respect to the variations in the signal.

Practically any kind of a tube possessing a negative resistance characteristic and provided with the necessary electrodes may be used in this circuit. Furthermore, modulations may be produced by applying the signal wave on any one of the elements of any known type, which element has a controlling effect on the internal impedance and anode to filament capacity of the tube.

In a modification of the arrangement just described the phase or frequency modulation of the oscillations generated in the signal resonant circuit may be modulated by placing the plidynatron tube in a magnetic field, the intensity of which varies at signal frequency. The variation of the magnetic field intensity varies the characteristics of the tube, such as the direction of flow of the electron stream, the capacity effect between the electrode, the internal impedance of the tubes, etc.

If it is desired to work with ultra-high frequencies of the order of, say, 50 megacycles, a tube of the dynatron type may be arranged to generate strong oscillations at this high frequency by providing a negative resistance effect in the anode circuit, which is normally resonant at the ultra-high frequencies to be generated, and then providing an external capacity effect between the anode and control grid. The oscillations of ultra-high frequency developed by this novel generator are modulated in accordance with the present invention by impressing on the auxiliary grid electrode, which is used to provide the negative resistance characteristics, phase or frequency modulations at signal frequency.

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

The nature of the invention and the operation thereof will be clear when read in connection with the attached drawings in which:

Figure 1 illustrates a method of and system for producing frequency modulated waves or oscillations in accordance with the present invention;

Figures 2 and 4 show modifications of the arrangement of Figure 1;

Figure 3 is a curve illustrating the manner in which phase modulation by the arrangements of Figures 1, 2, and 4 is accomplished;

Figures 5, 6, 7, 7a, and 8 show a circuit used to obtain the results illustrated in Figure 3; while, Figures 1a and 2a show the arrangements of Figures 1, 2, and 4 as modified to phase modulate the signals.

Referring to Figure 1 of the drawings, 1 indicates a plidynatron having an anode 2 connected through an oscillation circuit 4 to a point on a source of potential 6 having its negative terminal connected to the cathode 8 of plidynatron 1 as shown. The oscillation circuit 4 is tuned by means of inductance 3 and capacity 7 to be normally resonant at the frequency of the wave which it is desired to produce and modulate.

The auxiliary electrode 10 is connected to a

point on the source 6 of higher potential than that applied to the anode 2. Anode 2, being maintained at a potential less than the potential applied to the auxiliary electrode 10, imparts to the anode cathode circuit a negative resistance characteristic such that, when the cathode is heated sufficiently, oscillations are produced in the resonant circuit 4. The frequency of these oscillations is to a major extent determined by the inductance 3 and capacity 7. High frequency oscillations produced in 4 are prevented from passing through the source 6 by by-pass condenser Cs. Any stray oscillations impressed on 10 from 2 or 4 are prevented from passing through the battery 6 by means of by-pass condenser C.

Although, as indicated above, the frequency of the oscillations produced in 4 depends to a major extent upon the constants of the circuit 4, it does to a less extent depend upon the value of the negative resistance characteristic and internal impedance of tube 1 and to a material extent on the capacitive effect between the anode and filament electrodes of tube 1. The value of these effects in turn depends upon the potentials applied to the internal impedances of the tube 1 by the grid electrode 14. For this reason in order to accomplish frequency modulation of the oscillations set up in 4, all that is necessary is to impress on 14 alternating current potentials representative of the signal. This is accomplished in accordance with the present invention by connecting the grid 14 and the cathode 8 in series with the secondary winding 16 of a transformer 18, the primary winding 20 of which is connecting with any source of signal oscillations, as, for example, to a microphone 22 as shown. Biasing potential for the primary winding of the transformer 18 is applied from the source 19. In order that any high frequency oscillations developed in 1 are prevented from reaching the transformer winding 16 and being impressed from said winding to the microphone, a choking inductance 21 is connected between the grid 14 and the terminal of the secondary winding 16. This filtering action is supplemented by condensers C₁ and C₂, the condensers when taken with the choking inductance 21 forming a low pass filter circuit. A direct current biasing potential for the control electrode 14 is supplied from a source S connected as shown. The signal oscillation circuit between the control electrode 14 and cathode 8 is completed by way of the capacity C₃.

Oscillations produced and modulated in 1, as set forth above, may be utilized in any manner. For example, they may be impressed from the circuit 4 on to an inductance 26 connected with a power amplifier and/or frequency multiplier, and from there to an antenna circuit 28.

In the modification shown in Figure 2 oscillations are produced between the anode and screen grid electrode due to the negative resistance characteristic of said tube in a manner similar to that in which they were produced in the tube of Fig. 1. The normal frequencies of these oscillations are determined by an oscillation circuit 4 including a variable capacity 7 and inductance 3. This circuit serves as the tank circuit for the oscillations generated and modulated in the tube. The present modification, however, differs from the modification shown in Fig. 1 in that the frequency modulations are impressed on the oscillations generated by placing the tube 1 in the field of a winding W which is energized at signal

frequency from an amplifier A, the input circuit of which is connected with a source of modulating frequency 22. The magnetic field produced by the winding W is of an intensity determined by the amplitude of the modulating frequencies applied thereto from the amplifier A. This magnetic field acts on the disposition of the electron stream between the cathode and anode of tube 1 to cause the same to change in position as the strength or intensity of the magnetic field of winding W changes. This variation in the disposition of the electron stream within the tube 1 in turn varies the negative resistance or internal impedance of the tube and also the capacity effect between the anode and ground or cathode of the tube in a manner quite similar to the manner in which the same effects are varied in the modification shown in Fig. 1 by varying the voltage applied to the interelectrode space of the tube of Figure 1.

The field coil is placed, as shown, in Fig. 2 so that the direction of the field is perpendicular to the direction of electron flow. In this manner deflection of the electrons from their normal path by the magnetic field is insured. This in turn insures a variation in negative resistance or internal impedance of the tube and in the capacity between the plate and filament of the tube. In this modification a potential source S is connected between the control electrode 14 and the cathode 8 of the tube. Radio frequency oscillations are shunted around this source S by a capacity C₃. In this modification, as in Figure 1, the source 6 is shunted by a by-passing condenser C₄ while a by-passing condenser C₅ provides a short circuit path for the oscillations developed in circuit 4 to the cathode 8.

Where it is desired to generate and modulate in frequency ultra-short waves, as, for example, waves of a frequency up to 50 megacycles, an arrangement as illustrated in Fig. 4 may be used. In this arrangement a dynatron tube has its anode 2 connected through a resonate circuit 4 to a point on the battery 6 such that the anode is maintained at a positive potential less than the potential applied to the auxiliary electrode 10. This gives the negative resistance effect necessary to produce oscillations in the resonate circuit 4. The production of ultra high frequency oscillations is further insured by connecting the capacity C₇ between the anode 2 and control electrode 14 of tube 1 to furnish an additional driving effect.

In this arrangement, as illustrated in Figure 4, high frequency oscillations appearing in the tank circuit 4, connected between the anode 2 and cathode 8 of tube 1, are of a frequency determined to a major extent by the value of the inductance 3 and the variable capacity 7 included in the tank circuit 4. These high frequency oscillations are prevented from passing through the battery 6 by means of a by-passing condenser C₆. The control electrode 14 of this tube is maintained at the optimum potential by means of a resistance R₁ connecting said electrode to the cathode 8.

In this dynatron generator frequency modulation is accomplished, as in the prior arrangements, by varying the negative resistance effect of the tube, the internal impedance of the tube, and the capacitive effect between the anode and cathode of the tube. This is accomplished by connecting the auxiliary electrode 10 through a choking inductance I and a secondary winding 16 of a modulating frequency transformer 18 to the

positive terminal of the source of potential 6. The modulating frequencies from source 22 are applied to the secondary winding 20 of transformer 18 and act on the auxiliary electrode 10 to vary the capacity, internal impedance, and negative resistance effects in tube 1 to the extent necessary to produce the desired frequency modulation of the oscillations developed in oscillation circuit 4. High frequency oscillations appearing in 4, which may be impressed back on the auxiliary electrode 10, are prevented from reaching the modulating frequency source by way of primary winding 16 by means of the radio frequency choking inductance I and a by-pass condenser C₄ connecting the terminal of inductance I to the cathode 8. Filtering of the audio frequency circuit is further insured by a by-pass condenser C₅ connecting the other terminal of the radio frequency choking inductance I to the cathode 8 of tube 1.

In operation ultra-high radio frequency oscillations may be developed in 4 at a frequency determined to a major extent by the characteristics of the circuit 4. These oscillations, however, may be varied in frequency by impressing modulating frequency currents from the source 22 on to the auxiliary electrode 10, thereby varying the negative resistance effect of the tube, the internal impedance of the tube, and the capacity between the anode and cathode of the tube.

While I have shown in Fig. 4 an arrangement in which the modulating frequencies are impressed on the auxiliary electrode of the dynatron it will be understood that the oscillations developed in the oscillating circuit connected between the anode and cathode may be modulated in frequency by applying the modulating frequencies to the control grid or anode, or to a circuit between the anode and auxiliary electrode.

Phase and frequency modulated signals have many characteristics in common. Phase modulation broadly is shifting the phase of the oscillations a number of degrees, whereas frequency modulation is shifting the rate of change of phase a number of cycles. Thus frequency modulation may be defined as the rate of change of phase. Consequently, in one case the phase is varied, while in the other case its rate of change is varied.

The expression for a phase modulation wave is well known to be:

$$e = E_m \sin(\omega t + \phi \sin pt) \quad (1)$$

where E_m is the peak amplitude of the wave, $\omega = 2\pi f$ where f is the modulated frequency, ϕ is the peak phase deviation, and $p = 2\pi fm$ where fm is the modulation frequency.

The equivalent expression for frequency modulation with the same starting conditions as the above phase modulation is also well known to be:

$$e = E_m \sin(\omega t - fd/fm \cos pt) \quad (2)$$

where fd is the peak frequency deviation.

Comparison of Equations (1) and (2) indicates that frequency modulation is equal to phase modulation with a peak phase deviation equal to fd/fm instead of ϕ and having an audio phase difference given by the difference between $+\sin$ and $-\cos$. Disregarding the audio phase difference, we can produce phase modulation on a frequency modulation transmitter by keeping fd/fm constant and equal to the effective value of ϕ we desire to produce. In order to keep the quantity fd/fm constant for all modulation frequencies, fd must be made proportional to fm .

Since f/d is the depth of frequency modulation, the depth of frequency modulation must be made proportional to the modulation frequency.

The circuits above have been described as operating as frequency modulators. They may, however, be used to produce phase modulated oscillations by merely inserting an audio frequency correction circuit in a proper point of the circuit. The audio frequency correction circuit may take the form of an audio filter circuit composed of capacities and inductances as illustrated in Fig. 5. The constants of the elements of this circuit are such as to insure that the amplitude of the signal oscillations at the output of the correction circuit is directly proportional to the frequency of the signal oscillations or waves applied at the input of the circuit, as indicated in the curve shown in Figure 3.

Preferably, the correction circuits to be used for converting a frequency modulator into a phase modulator may take the form of the arrangements shown in Figures 6, 7, 7a or 8 of the drawings.

In Figure 6 the signal frequencies are impressed by means of an audio frequency transformer T on the input electrodes 31, 32 of a correction tube 40, the gain of which is dependent upon the impedance of its plate circuit. The anode circuit of 40 includes a resistance 41, and an inductance 42 connected in parallel, the parallel circuit being connected in series with a potential source 10 as shown. The resistance 41 and the inductance 42 are of such values that the high signal frequencies will be emphasized by means of the inductance 42 connected in parallel with the resistance 41 in the output circuit of the tube 1. In practice the value of 41 is very high. In some cases 41 may be omitted. The impedance of 42 is then the controlling factor of this parallel circuit. The impedance 42 is inductive and increases with frequency. The gain of 40 also increases with frequency. The impedance of this parallel resistance and inductance is high at the higher signal frequencies, and low at the lower signal frequencies. Consequently, the gain of the tube 40, which depends upon the plate circuit impedance, will be high at the higher signal frequencies, and low at the lower signal frequencies. In this manner the potentials appearing at the terminals of the parallel circuit 41, 42 are made to vary directly with variations in the frequency of the impressed signal on the input electrodes of tube 40, as indicated in Figure 3. These potential variations may be applied through a coupling condenser 44 to the input terminals 45 and 46 of a linear amplifier 50 which is connected as shown to act as a coupling tube. The amplified potentials may be utilized from the secondary winding 47 of the transformer 51 having its primary winding 48 connected as shown between the output electrodes of tube 50. In this manner the signal frequencies can be converted into a resultant which will cause phase modulation of the carrier in a frequency modulator.

In some cases two stages, similar to the stage 40, 41, 42, T, etc., are necessary to give the proper correction effect to the modulating frequencies.

Similar correction of the modulating signal may be accomplished by an arrangement, as shown in Figure 7, in which the inductance 42, connected in parallel with the input electrodes 31 and 32 of tube 40, offers a high impedance to the higher signal frequencies, and a low impedance to the lower signal frequencies so that the higher signal frequencies excite in a greater

amount the input electrodes 31, 32 of the tube 40. Here the resistance 41 is very high. This makes the current through elements 41 and 42 substantially dependent upon resistance 41 so that a constant current independent of frequency flows through these two elements. The drop across inductance 42, since it is given by $2\pi fLI$, where L is the inductance, I the current and f the frequency, will therefore be proportional to the frequency since L and I are constant. In this circuit, as well as that of Figure 7a, the resistance of potentiometers P and P₁ should be low compared to resistances 41, 41', and 41''. The corrected signal frequencies appear in the primary winding 53 of transformer 52 and the secondary winding 54 may be connected to the modulator tubes of Figures 1, 2 and 4. The amount of signal energy passed from the transformer T to the input correction circuit may be regulated by moving the grid connection tap 54 along the resistance P, and initially by selecting the value of resistance 41.

The arrangement of Figure 7 can be modified, as illustrated in Figure 7a, by adding thereto a tube 40', as indicated, having its input electrodes 31', 32' connected across a resistance 53 which is energized, as shown, from transformer T through a high resistance 41''. This arrangement provides for varying the amount of correction which is applied to the signal frequency. With the tube 40' switched off full correction will be obtained by the correction tube 40. With tube 40' switched on the amounts of signal frequency applied to the input circuits of tubes 40 and 40' may be adjusted by moving the taps 54 and 54' connected with the control electrodes 31 and 31', along the resistance P₁, P₂. The tube 40 applies a corrective effect to the signal impressed on its input circuit. The tube 40' applies no corrective effect to the modulating signal relayed therein. In this manner corrected and uncorrected signal in varying amounts may be applied to the primary winding 53 of transformer 52 connected in parallel with the output impedance of tubes 40 and 40'. In this manner the resultant signal can be corrected in the desired amount.

Phase modulation of a carrier in a frequency modulator may be accomplished by the arrangement of Fig. 7a or the circuit may be adjusted to give a result which is a combination between frequency and phase modulation of the carrier.

In Figure 8, capacity 55 must be of such a value as to substantially determine the current through elements 55 and 56. Potentiometer P must be of low resistance compared to capacities 55 and 56 in series. With the current through resistance 56 determined by the capacity 55, whose impedance is dependent on frequency, the drop across resistance 56 will be dependent on frequency. Thus, 55 and 56 are chosen so that their series impedance is given substantially by $1/2\pi fC$ where C is capacity 55. The current will then be $I = E/X_c = EX/2\pi fC$ so that the current will be proportional to frequency. The drop across resistance 56 will then be $RI = REX/2\pi fC$ so that with R, E, and C constant, the voltage passed on to tube 40 will be proportional to frequency. This circuit therefore also insures that the potentials appearing in the output circuit of tube 40 are directly proportional to the frequency of the modulating signal, as illustrated in the curve of Figure 3. In this modification, where more correction is necessary than can be obtained by the use of one tube, a second tube may be connected in cascade there-

with to impart more corrective effect to the modulating frequencies.

If phase modulation is to be accomplished by the arrangement shown in Figures 1 and 4, any one of the correction filters indicated in Figs. 5 to 8 inclusive may be interposed between the elements 22 and transformer 18 as indicated in Figure 1a, or between the elements 22 and A of the modification shown in Fig. 2 as illustrated in Fig. 2a. More in detail, the correction circuit of Figure 6 may be inserted in the frequency modulators of Figs. 1 and 4 by connecting the signal source 22 to the primary winding of the transformer T and by replacing the transformer 18 of the frequency modulator circuits by the transformer 52 of the correction circuits of Figs. 7, 7a, or 8. When the frequency modulators are so modified phase modulation of the carrier repeated in the modulator is accomplished when signals are impressed on to the circuits from the source 22.

The correction circuit of Figure 6 may be included in the frequency modulator arrangement in Figure 2 by connecting the signal source 22 to the primary winding of transformer T and by connecting the output winding of the transformer 51 to the input electrodes of the first thermionic tube in the amplifier A, as indicated in Figure 2a.

The correction circuits of Figures 7, 7a and 8, may be included in the frequency modulator circuit of Figure 2 in the same manner in which the correction circuit of Figure 6 is included therein, as indicated above, except that the secondary winding of the transformer 52 of the correction circuits of Figs. 7, 7a and 8 is connected with the input electrodes of the first thermionic tube in the unit A. When the frequency modulator of Fig. 2 is so modified to include one of the correction circuits, phase modulations of the carrier frequency relayed therein will be accomplished.

The circuits modified, as indicated above, may be more clearly visualized by reference to Fig. 1a, in which the correction circuit or filter is indicated by a square interposed between the element 22 and the transformer 18. In this illustration the unit M may include the modulator tube 1 of Figs. 1 and 4 and its associate circuit including the power amplifiers or frequency modulators of the unit 29, excluding the antenna or any combination of such elements.

In Figure 2a the unit M may include all of the elements of Figure 2 at the right of the unit A except the aerial 28 or it may include any combination of such elements.

I claim:

1. The method of producing oscillations of substantially constant amplitude and frequency, and modulating the phase of said oscillations at signal frequency by means of a thermionic tube including electrodes connected in an oscillation circuit having a negative resistance characteristic which includes the steps of, producing voltages, the amplitudes of which are proportional to the signal frequency, and applying the produced voltage to the space between said electrodes, thereby varying the internal impedance of the tube.

2. Means for adapting a frequency modulation system, comprising a thermionic tube having an oscillation circuit and a source of signals connected therewith to impress frequency modulations thereon, to the production of phase modulated signals comprising, a coupling tube having an input circuit and an output circuit, said in-

put circuit including elements for stressing the higher signal frequencies to such an extent that the amplitude of alternating currents in the output of the tube are directly proportional to the frequency of the alternating currents in the input circuit, and a coupling between the input circuit of said coupling tube and said signal source and between the output circuit of said coupling tube and electrodes in said first named tube.

3. The method of producing frequency modulated oscillations of ultra-high frequency for signalling purposes by means of a thermionic tube having its anode and cathode electrodes connected in an oscillation circuit having negative resistance characteristics which includes the steps of, providing an external coupling between two of said electrodes to add a regenerative effect to the negative resistance effect of said tube to insure sustained oscillations of substantially constant amplitude and varying the potential of an additional electrode in said tube in accordance with signal potentials to thereby modulate the frequency of the oscillations produced at signal frequency.

4. Means for producing high frequency oscillations the phase of which is characteristic of a signal comprising, a thermionic tube having an anode, a cathode, and a control grid electrode, a circuit connected between the anode and cathode of said tube, said circuit having a negative resistance characteristic, means for normally tuning said circuit to the frequency of the oscillations to be modulated, and a circuit for varying the impedance of said tube at signal frequency an amount directly proportional to the frequency of the signal.

5. Modulating means comprising, a thermionic tube having a pair of electrodes connected in an oscillation circuit of negative resistance characteristics and means for applying phase modulations to the oscillations in said circuit including a circuit for impressing on the internal impedance of the tube signal voltages which vary at signal frequency, and means in said circuit to produce a linear relation between the amplitude of the impressed voltages and the signal frequency.

6. The method of producing oscillations modulated in phase in accordance with signal voltages by means of a thermionic tube having an oscillatory circuit connected between two of its electrodes, said circuit having negative resistance characteristics which includes the steps of, producing voltages, the amplitude of which varies linearly with respect to the frequency of the signal voltages producing a magnetic field the intensity of which varies in accordance with the amplitude of said voltages, and utilizing the variations of intensity of said field to vary the internal impedance and the capacity between electrodes in said tube.

7. The method of producing signal modulated oscillations of constant amplitude by means of a thermionic tube having an oscillatory circuit connected between two of its electrodes, said circuit having negative resistance characteristics which includes the steps of, producing voltages, the amplitude of which varies linearly as the frequency of the modulating potentials, producing a magnetic field the intensity of which varies in accordance with said voltages, utilizing the variations of intensity of said field to vary the impedance, the capacity, and the negative resistance effect of said circuit, and frequency multiplying the modulated oscillations.

8. Means for producing phase modulation of high frequency oscillations comprising a source of modulating potentials, a frequency modulator connected therewith and a signal frequency correction circuit interposed between said source and said modulator, said correction circuit including series and parallel reactances the reactive value of one or more of which varies as the frequency of the modulating potentials vary whereby the amplitude of the modulating potentials at the output terminals of said circuit is directly proportional to the frequency of the modulating potentials applied from said source to the input terminals of said correction circuit.

9. Means for producing high frequency oscillations the frequency of which is characteristic of a signal comprising a thermionic tube having an anode, a cathode, a control grid, and an auxiliary electrode, a resistance connected between said control grid and cathode, a high frequency oscillation circuit and a source of potential connected between the anode and cathode of said tube, a source of potential greater than said first named source connected between said auxiliary electrode and said cathode whereby a negative resistance effect is produced in said tube and oscillation circuit to produce oscillations in said oscillation circuit, means for enhancing the tendency of said tube to oscillate including a capacity connected between the anode and control grid, means for normally tuning said circuit to the frequency of the oscillations to be modulated, means for impressing signal potential variations between the auxiliary electrode and cathode of said tube to vary the impedance of said tube at signal frequency, and a power amplifier and frequency multiplier coupled to said oscillation circuit.

10. Means for producing high frequency signal modulated oscillations the amplitude of which are constant comprising a thermionic tube having an anode, a cathode, a control electrode and an auxiliary electrode, a high frequency oscillation circuit connected between the anode and cathode of said tube, a source of potential in said connection, a capacity connected between the anode and control grid of said tube, means for normally tuning said circuit to the frequency of the oscillations to be modulated, means for applying a potential to the auxiliary electrode of said tube, the potential applied to the auxiliary electrode being higher than the potential applied to the anode, a circuit for impressing signal potential variations between the control electrode and cathode of said tube and reactances in said circuit of such value as to insure that the amplitude of the signal potential variations is linear with respect to the frequency of the signal potential variations.

11. Transmitting means comprising, a thermionic tube having an anode, a cathode, a control grid and an auxiliary electrode, a condenser connected between the anode and control grid of said tube, an oscillation circuit connected between the anode and cathode of said tube, a source of potential in said connection, means for normally tuning said circuit to a predetermined carrier frequency, a resistance connected between the control grid and cathode of said tube, means for applying a potential to the auxiliary electrode of said tube, the potential applied to the auxiliary electrode being higher than the potential applied to the anode, whereby a negative resistance effect is produced in said tube and circuit to thereby produce oscillations in said oscillation circuit and

means for modulating the frequency of the oscillations produced including a circuit for impressing signal potential variations between the auxiliary electrode and cathode of said tube whereby the frequency of the oscillations produced in said tube is varied at signal frequency.

12. Signalling means comprising, a thermionic tube having a plurality of cold electrodes and a cathode electrode, circuits including a source of potential connecting a pair of cold electrodes and said cathode in an oscillation producing arrangement having negative resistance characteristics, means for producing a coupling effect between one of said pair of cold electrodes connected in said circuits and another cold electrode to enhance the tendency of said tube and circuits to produce oscillations and means for modulating the frequency of the oscillations produced including a filter circuit connected on the one hand to a source of signal voltages and on the other hand to electrodes in said tube for impressing on the internal impedance of the tube voltages which vary at signal frequency.

13. In a signalling system, a thermionic tube having an output electrode, a cathode and a pair of auxiliary electrodes, a circuit connecting one of said auxiliary electrodes to the cathode of said tube, a tuned circuit connected between said output electrode and said cathode, a source of direct current potential connected to said output electrode, a circuit for applying a direct current potential from said source to the other of said auxiliary electrodes of greater value than the potential applied to said output electrode, whereby said tube has a negative resistance effect and oscillations are produced in said tube and tuned circuit of a frequency determined in part by said tuned circuit, and means for modulating the frequency of the oscillations produced comprising a source of modulating potentials connected by way of a filter between said other auxiliary electrode and the cathode of said tube to thereby vary the internal impedance of said tube in accordance with said modulating potentials.

14. The method of producing frequency modulated oscillations by means of a thermionic tube having an output electrode, a cathode and a pair of auxiliary electrodes with a tuned circuit connected between said output electrode and cathode and a higher direct current potential applied to one of said auxiliary electrodes than is applied to said output electrode whereby negative resistance effect in said tube produces oscillations in said tuned circuit which includes the steps of, producing a magnetic field the intensity of which varies in accordance with the amplitude of signal potentials and impressing said field of varying intensity on the electrodes in said tube to vary the internal impedance and the capacity between the electrodes of said tube to thereby vary the frequency of the oscillations produced.

15. In a system for producing high frequency oscillations and for varying the phase of said oscillations at signal frequency, an electron discharge tube having an anode, a cathode, a control grid and an auxiliary electrode, an oscillatory circuit connected between said anode and said cathode, means for energizing the electrodes of said tube by potentials such as to produce a negative resistance characteristic in said tube and said oscillatory circuit to produce oscillations therein, and means for modulating the phase of the oscillations produced including a source of modulating potentials, a modulation potential amplifying tube having a control grid, a cathode

and an anode, a circuit connecting the control grid and cathode of said amplifying tube to said source of modulating potentials, a circuit connecting the anode and cathode of said amplifying tube to a pair of electrodes in said electron discharge tube, and an impedance connected across one of said last two named circuits, said impedance being of such value as to attenuate the lower modulating potential frequencies.

16. A system as recited in claim 15 wherein said impedance is an inductive reactance and wherein said impedance is connected across the circuit coupling the output electrodes of said modulation potential amplifying tube to a pair of electrodes in said electron discharge device.

17. A system as recited in claim 15 in which a reactance is connected between the anode and cathode of said electron discharge tube to provide regenerative effects in said discharge tube and oscillatory circuit.

18. In a system for producing high frequency oscillations of constant amplitude, the length of which vary at signal frequency, an electron discharge device having an anode, a cathode, a control grid and an auxiliary electrode, an oscillatory circuit connected between said anode and said

cathode, means for tuning said circuit to the frequency of the oscillations to be produced, means for energizing the electrodes of said tubes in such a manner as to produce a negative resistance characteristic in said tube and said oscillatory circuit to produce oscillations therein, and means for modulating the length of the oscillations produced comprising a source of modulating potentials, an impedance connected with said source, a pair of modulating potential amplifiers each having a control grid, a cathode, and an anode, circuits coupling the control grids of said modulating potential amplifier tubes to movable points on said impedance, a connection between the cathodes of said pair of tubes and said impedance, a reactor in shunt to the control grid and cathode of one of said tubes, said reactor being selectively responsive in different degrees to different frequencies of said modulating frequency potentials, a non-reactive impedance in shunt to the control grid and cathode of the other of said tubes, and a circuit coupling the anodes and cathodes of said pair of tubes to a pair of electrodes of said electron discharge device.

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