March 31, 1936. G. L. USSELMAN 2,036,165

PHASE AND FREQUENCY MODULATION

Filed June 8, 1932 2 Sheets-Sheet 1

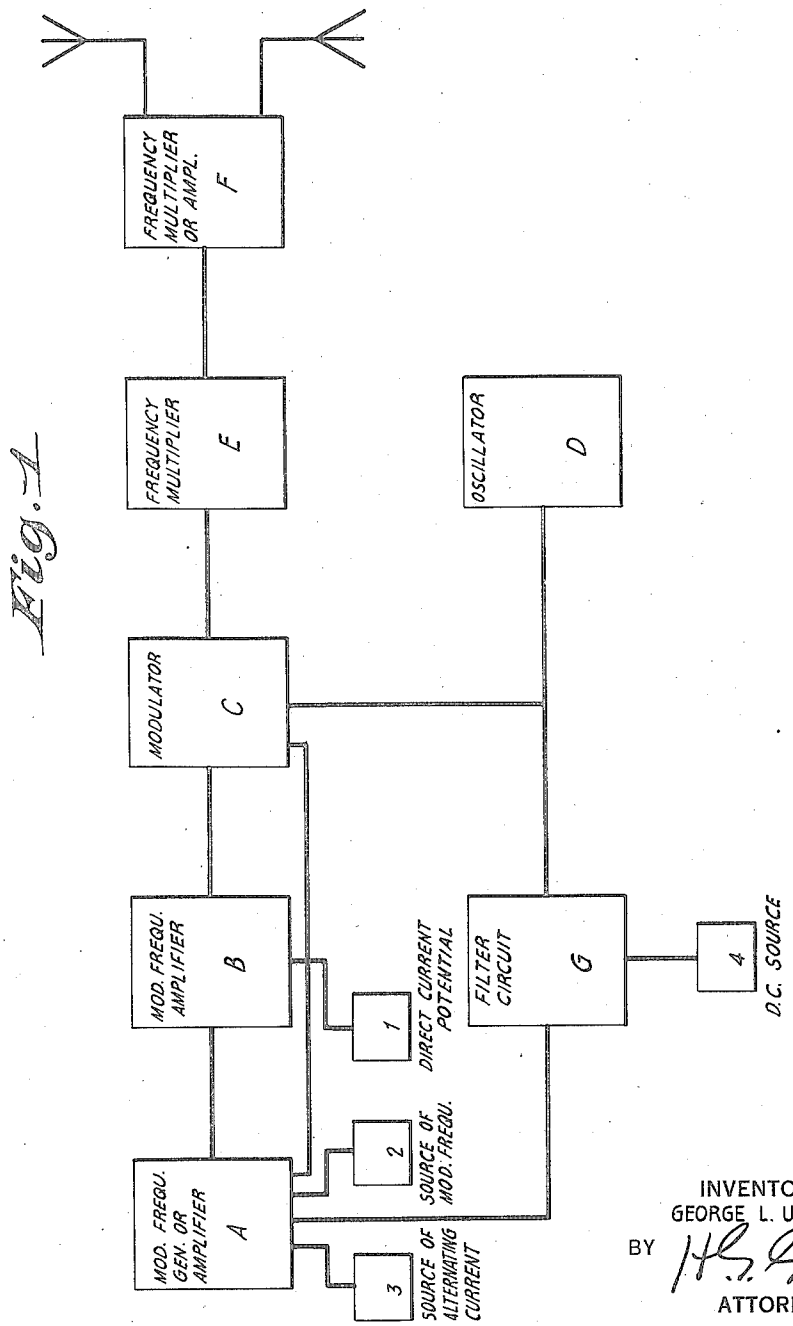

Fig. 1

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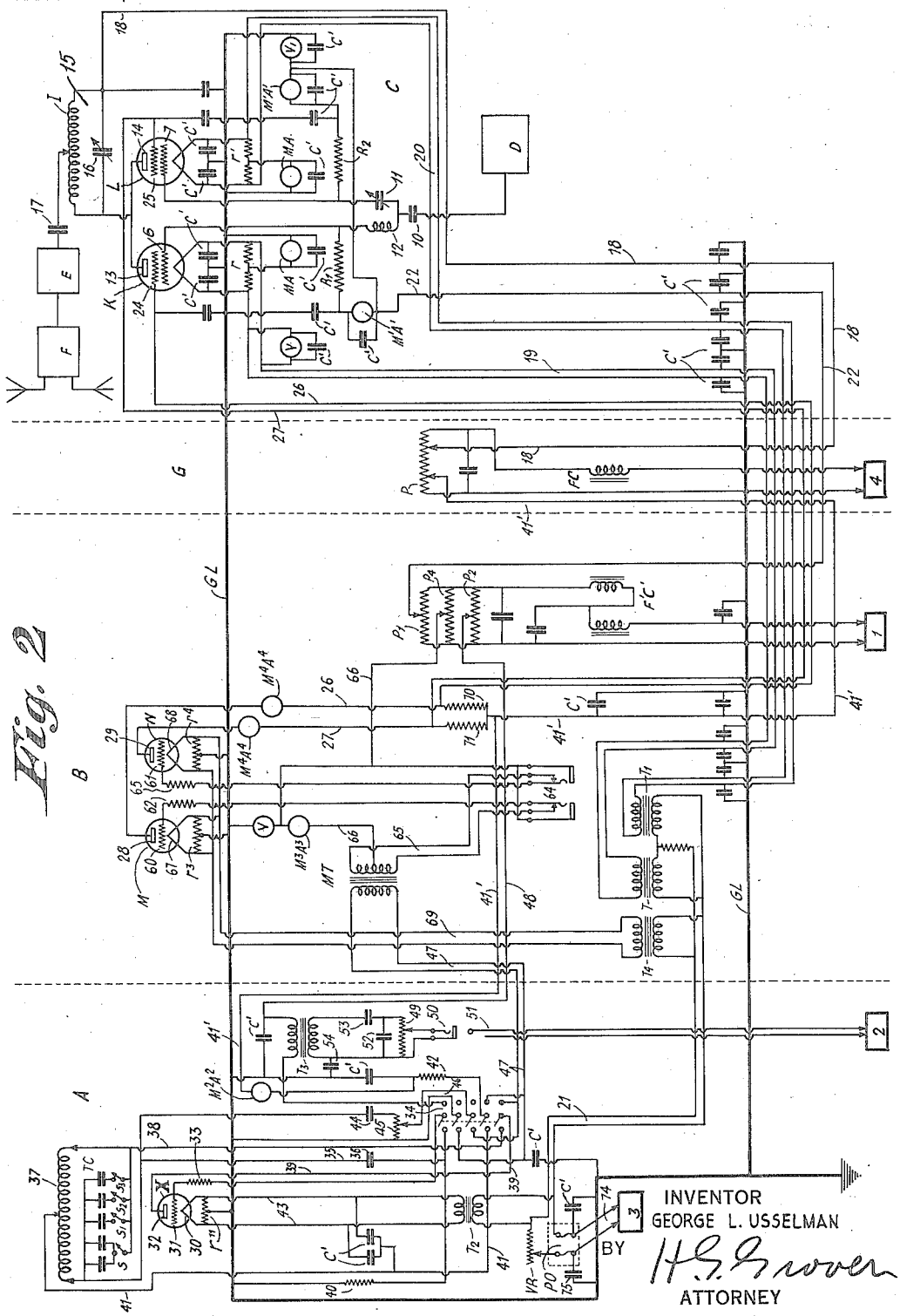

Fig. 2

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UNITED STATES PATENT OFFICE

2,036,165

PHASE AND FREQUENCY MODULATION

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Application June 8, 1932, Serial No. 616,026

7 Claims. (Cl. 250—17)

This invention relates to signalling means and in particular to means whereby the characteristics of high frequency oscillations, other than the amplitude, are varied in accordance with signals to be transmitted.

It has been found that ordinary amplitude modulated high frequency oscillations in transmission from the sending station to the receiving station are subject to what is known as fading effects. This is a decided disadvantage since it introduces drop outs and errors in the signal. Even where diversity receivers are used to receive the amplitude modulated signals the effect of fading is a serious disadvantage.

I have found that if the high frequency oscillations are modulated in phase or in frequency in accordance with the signal to be transmitted they are less subject to the effect of fading than amplitude modulated waves. The reason why phase or frequency modulated oscillations in telegraph transmission are subject to a less extent to fading effects is that this type of modulation produces a larger number of side frequencies than that produced by amplitude modulation, and the result in receiving a phase or frequency modulated signal on a simple receiving antenna is very similar to receiving an unmodulated signal on a diversity antenna. A phase or frequency modulated signal is of particular advantage for reducing fading when simple receiving antennas are used and this type of modulated signal is also beneficial for reducing the effects of fading when diversity receiving systems are used.

Phase and frequency modulated high frequency oscillations have many characteristics in common, as will appear more in detail hereinafter. If high frequency oscillations are phase or frequency modulated by a single modulating frequency they are physically indistinguishable. At least, at the present time, with the present analyzing means, this is true. When a band of modulating frequencies is used it may be shown that in phase modulation all modulating frequencies of equal amplitude have equal effect upon the carrier phase, whereas in frequency modulation the effect upon the phase of the carrier is inversely proportional to the modulating frequency. However, where a band of modulating frequencies is applied to the high frequency oscillations in phase modulation, the phase of the oscillations shift an extent or angle proportional to the amplitude of the applied modulating frequencies. Phase modulated oscillations are, however, less subject to fading effects than frequency modulated oscillations.

Obviously, this method of signalling is of the utmost importance since one of the main drawbacks to signalling is the effect of fading of the transmitted oscillations. Especially is this method desirable now since it is adaptable where diversity reception methods are not in use.

The present invention relates to a new and novel method of and means for producing high frequency oscillations, phase and/or frequency modulating the same, and transmitting the resultant energy.

More in detail, the object of the present invention is to provide a new method of and means for producing high frequency oscillations and phase or frequency modulating the same in a novel manner with modulating oscillations or voice frequency modulations obtained from a novel thermionic tube arrangement which, by a single switching operation, may be made to operate as a modulating frequency oscillation generator, or as an amplifier for the voice frequencies, with which the high frequency oscillations are to be phase or frequency modulated. The modulating frequency oscillations generated by this novel tube arrangement and the amplified voice frequency potentials, whichever is used for modulating the high frequency oscillations, are passed through a symmetrical thermionic stage which affects the modulation in phase or frequency of the high frequency oscillations generated.

An apparent advantage to be gained by the use of the present novel method of and means for phase or frequency modulating high frequency oscillations is that increased efficiency in operation is obtained and that the range and traffic speed of the transmitter of a given power has been greatly increased.

Another advantage arising from the use of the present invention is that the thermionic tube used to produce the modulating oscillations may, by a mere reversal of position of a switch, be used as an amplifier for the voice frequency oscillations so that the phase or frequency modulated transmitter may be used either for code signalling or for voice frequencies without the use of additional tubes.

In addition to the above, it is noted that the present phase or frequency modulated transmitter is admirably adapted for use with receiving systems without diversity reception and, since phase or frequency modulated wave telegraph signalling systems are less subject to fading effects than systems known heretofore, the efficiency of reception is greatly increased.

Numerous other objects of the present invention, and advantages to be gained by the use

thereof, will become apparent from the following detailed description thereof and therefrom when read in connection with the attached drawings, throughout which like reference characters indicate like parts, and in which:

Figure 1 illustrates diagrammatically the several units included in a transmitter arranged in accordance with the present invention; while,

Figure 2 shows the circuit arrangements of certain units of Figure 1 which are constructed in accordance with the present invention.

In Figure 1, C indicates a phase or frequency modulating unit connected on the one hand to a source of constant high frequency oscillations D, which may include an output buffer stage, on the other hand to a frequency doubler E or several frequency doubles in cascade which may feed an antenna system by way of an amplifier and frequency multiplier F. The high frequency oscillations produced in D are supplied to C where they are caused to be modulated in phase or frequency by an amplitude modulating stage B, which is supplied with either low frequency modulating oscillations or with voice frequency potentials from a source A. The frequency multiplier or multipliers in E may be of any type known today, and, since this unit forms no part of the present invention, description thereof is thought unnecessary at this point. The same remarks apply to the frequency multiplier and/or amplifier F and the radiating system connected therewith.

The oscillation generator D may be of any type so long as the oscillations produced thereby are constant in frequency and of constant amplitude. This oscillator preferably is of the long line frequency control type or of the crystal control type. The oscillator D may include a buffer output or, if it does not include a buffer output, a buffer output may be interposed between the oscillator D and the phase or frequency modulator C if necessary.

The phase modulator C comprises means including thermionic repeater tubes in which the oscillations generated at D are repeated and varied in phase or frequency in a manner characteristic of the voice frequency potentials or the modulating frequency oscillations supplied from A by way of B.

The unit B includes thermionic repeaters or amplitude modulators by means of which the low frequency oscillations or audio frequency potentials originating in A are utilized in a novel manner to impress on the high frequency oscillations repeated in C characteristic phase or frequency modulations. The unit B includes also the grid biasing filter network and the grid biasing potentiometers necessary to supply biasing potentials to the units A, B and C. This filter network and potentiometer system is connected to a source 1 of direct current potentials. The unit B also includes the alternating current transformers necessary to supply filament current to the tubes in the units B and C.

The unit A includes a thermionic tube and novel circuits cooperating therewith in such a manner that the tube may function as a low frequency oscillation generator or as a voice frequency amplifier merely by a single movement of a switch cooperating with the circuits of the tube. The unit A also includes the audio frequency transformer necessary to impress voice frequencies from the source 2 on to the thermionic tube therein when the latter is to be used as a voice frequency amplifier.

Alternating current for the thermionic tubes in the units A, B, and C is supplied from an alternating current source 3 connected by way of leads to the unit A, which is in turn connected by leads to the unit B, in which the filament transformers are included. The filament transformers in B are connected by filtered leads to the thermionic tubes in the unit C.

The necessary plate voltages for the thermionic tubes of the units A, B, and C are supplied from a direct current potential source 4 by way of a unit G, which includes filtering means for the direct current potentials, and a potentiometer arrangement whereby the proper voltages may be supplied to the different thermionic tubes.

The manner in which phase or frequency modulations are impressed on the carrier will now be described. Reference will first be made to the unit C of Figure 2. A pair of thermionic repeaters K and L, of the screen grid type, have their control electrodes 6 and 7 connected through leads to a blocking condenser 10, which is in turn connected with any source of constant high frequency oscillations, as, for example, the source D. Oscillations from the source D are impressed by way of condenser 10 on to the electrodes 6 and 7 substantially cophasally. The relative phase of these oscillations is shifted, however, since the oscillations reaching the grid 7 pass through a phase advancing means in the form of a variable condenser 11, while the high frequency oscillations reaching the grid 6 pass through a phase retarding means in the form of an inductance 12.

The anode electrodes 13 and 14 are connected together and to the terminal of a tank circuit 15 which includes an inductance I and a variable capacity 16. The tank circuit 15 is tuned to resonance at the frequency of the oscillations supplied from D. The high frequency oscillations, slightly shifted in phase, and impressed on to the control electrodes 6 and 7, are repeated and amplified in the tubes K and L, and the energy from K and L appears in the tank circuit 15 shifted in phase an amount determined by the phase shift impressed on the energy by the elements 12 and 11. This energy may be supplied from the tank circuit to the radiating system by way of the units E and F through a direct current blocking condenser 17. Anode potential for the tank circuit 15 is supplied by way of a lead 18 from a potentiometer P included in the unit G and supplied with energy from the source 4 by way of filter circuit FC.

Energy for the filaments of the tubes K and L is supplied by leads 19 and 20 respectively from the secondary windings of transformers T and T_1 respectively included in the unit B and supplied by way of leads 21 from the source 3 connected with unit A. In order that the amount of low frequency hum impressed on the thermionic repeaters K and L from the filament energizing source may be held at a minimum, the filament circuits thereof include hum filtering means in the form of resistances r and r' connected in parallel with the filaments of tubes K and L respectively, said resistances being tapped at the electrical center and connected by way of space current indicating meters MA and by-pass condensers C' to ground GL. The resistances r and r' also form a low impedance path to ground for the low frequencies appearing in the input or output circuits. The low frequencies are in this manner shunted around the high impedance of

the filament transformer windings, and by-pass condensers C'—C'

A low impedance path for the high frequency oscillations repeated in K and L is provided by by-passing condensers C' connected, as shown, in series across the terminals of the filaments of each tube and having their electrical center connected, as shown, to ground GL. Voltmeter V, shunted by by-pass condensers C', may be connected across the terminals of the filament to indicate the voltage applied thereto. Normal direct current biasing potentials for the control electrodes 6 and 7 of tubes K and L is supplied by way of resistances R_1, R_2 from lead 22 connected to a movable point on a potentiometer resistance P_1 associated with a filtering circuit F'C' comprising choking inductances and parallel condensers and connected with the direct current biasing source 1. The current drawn by the control electrodes 6 and 7 of tubes K and L may be indicated by meters M'A' inserted in the biasing current paths between 22 and the terminals of P and P' and shunted by by-pass condensers C'. The direct current biasing potential applied to the control electrodes is indicated by a voltmeter V_1.

Applicant has now described the manner in which the high frequency oscillations originating in D are applied shifted in phase, but in a sense cophasally, to the control electrodes of the tubes K and L, amplified and repeated therein, and transferred therefrom substantially in phase to the tank circuit 15, from which they may be utilized.

The manner in which these oscillations are modulated in phase or frequency at signal frequency will now be pointed out.

In the present embodiment of the invention, the modulation is accomplished by impressing the modulating frequencies in phase opposition on the screen grid electrodes 24 and 25 of tubes K and L respectively by way of shielded leads 26 and 27 connected, as shown, to the anodes 28 and 29 of thermionic tubes M and N respectively. The manner in which the modulating potentials are caused to appear at the terminals of leads 26 and 27 will be described hereinafter.

The effect of said potentials being applied in phase opposition to the screen grid electrodes 24 and 25, and the manner in which said signal oscillations are applied thereto in opposition, modulated in phase or frequency, and the high frequency oscillations repeated therein, will be set forth now.

Assume that no modulating frequencies are applied to the screen grid electrodes of tubes K and L. The same direct current biasing potential is supplied to the control electrodes, and the high frequency oscillations impressed on the control electrodes are substantially in phase, being shifted only in different senses by the impedances of the inductance 12 and capacity 11. The anode circuit of tube K will supply, therefore, to the tank circuit, energy equal in amount to the energy supplied to the tank circuit 15 from the anode of tube L. The energies from these tubes will be of different phase and the energy supplied from the tank circuit to the frequency doubler or next stage will have a resultant phase determined by the phase of the separate energies supplied from the tubes K and L so that in this case the carrier oscillations will have no change or shift in phase.

The energy supplied to the tank circuit 15, from the tube which has the highest modulating potential applied to the screen grid electrode, will be greater in amplitude than the energy supplied to the tank circuit 15 from the tube having a lesser modulating potential applied to its screen grid. This is due to the fact that the effective potential applied to the screen grid of a screen grid tube governs the internal impedance of the tube, the amplification factor thereof, and other characteristics. Each of these variables in turn effect the amount of energy supplied to the anode circuit of the tube. Therefore, varying in phase opposition the effective potentials of the screen grid electrodes of the tubes K and L, by modulating potentials from the lines 26 and 27, varies the amount of energy said tubes will supply to the tank circuit 15.

The maximum possible phase deviation of the carrier is determined by the adjustment of impedances 11 and 12 of the grid phase shifting circuits. The phase shift, therefore, of the resultant energy in the tank circuit 15, is limited by the adjustments applied to the phase shifting circuits. The frequency of the phase deviation of the carrier is determined by the modulating frequency. The amount of phase deviation of the carrier is determined by the amplitude of the modulating frequency and is proportional to the amplitude of the modulating frequency. The amount of phase shift or deviation of the carrier or the tank circuit oscillations may, accordingly, be limited by the adjustments of the phase shifting circuits connected with the input of the tubes. The amount of phase shift or deviation of the carrier or the tank circuit oscillations is determined by the amount or difference of power delivered by one tube over the power delivered by the other tube, and by the phase difference of the energy delivered by both tubes. In other words, the phase shift of the oscillations in the tank circuit 15 is the result of the increase of energy delivered by one tube while the energy delivered by the other tube decreases a like amount because of the phase difference in the alternating current energy delivered by each tube, and is proportional to said increase and decrease.

The phase shifts which take place, as indicated above, will be multiplied or increased by a frequency multiplier in case the oscillations from the tank circuit 15 are fed by way of a frequency multiplier or multipliers to the utilization circuit.

As pointed out briefly hereinbefore, one of the novel features of applicant's invention resides in the means for supplying, by the use of a single tube, either low frequency oscillations or amplified voice frequency potentials to the unit B, wherein they are utilized to apply in phase opposition the modulating potentials to the screen grid electrodes of the phase modulator C by way of leads 26 and 27.

The low frequency oscillation generator or amplifier comprises a thermionic tube X having a cathode 30, control electrode 31, and anode 32. When the tube is to be used as a low frequency oscillations generator the movable blades of the switch 34 are moved to the left and the control electrode 31 is connected by way of parasitic prevention resistor 33, switch 34, and lead 35 including blocking condenser 36, to one terminal of an inductance 37, the other terminal of which is connected by way of lead 38 and switch 34 to lead 39, which is connected to the anode 32. The direct current grid bias circuit is completed by way of a grid leak resistance 40 connected between one terminal of the condenser 36 and ground, which is the same as connecting the grid 31 to the

ground by way of resistance **40**. The voltage drop across grid leak resistor **40**, caused by the rectified grid current passing through it, supplies grid bias voltage to the grid of tube X when it acts as an oscillation generator. The direct current anode circuit which furnishes the charging potential to the anode **32** is completed by a lead **41** connected to a movable point on the inductance **37** and passing by way of switch **34**, resistance **42**, and current indicating device M^2A^2 to a point on the potentiometer resistance P. This point on P is moved to a position at which charging potentials, of a value such that sufficiently strong oscillations are produced in the tube X, are applied to the anode of the tube. The meter M^2A^2 in the lead **41** permits checking of the direct current flowing in the anode circuit of tube X when it acts as an oscillator. The filament **30** of tube X is supplied with alternating current from the secondary winding of a transformer T_2, the primary winding of which is connected with the line **21**.

When the electrodes of the tube X are energized, sustained oscillations are produced in the circuit including the inductance **37** and capacitors TC which are coupled between the anode **32** and control electrode in a well known manner. The frequency of these oscillations generated is determined by the amount of capacity connected in parallel with the adjustable inductance **37**. The amount of capacity connected in parallel with the inductance **37** may be changed in predetermined increments by connecting one or more of the circuit tuning condensers TC in parallel with the inductance **37** by closing one or more of the keys S, S_1, S_2 and S_3. The oscillations produced in the anode grid circuit of tube X are short-circuited around the anode potential source and associated resistances by a pair of by-pass condensers C′ connected, as shown, between the lead **41** and the two leads **43** between the filament **30** and the secondary winding of the transformer T_2. In order to prevent any hum at the filament energizing current frequency from occurring in the tube X and associated anode circuit, and also to act as a by-pass to ground for low frequency current, the electrical center of the balancing resistance r^2 is connected to ground GL. The low frequency alternating current potentials developed in the tank circuit including the inductance **37** and the selected tuning condenser TC are supplied by way of coupling condenser **44** to the terminal of a potentiometer resistance **45**, the other terminal of which is connected directly to ground GL, thereby supplying a potentiometer load circuit.

These potential variations at the frequency determined by the oscillation circuit **37**, TC, are fed by way of leads **46** from potentiometer **45** and switch **34** to a line **47** which terminates in the primary winding of a modulation frequency transformer MT, from which they may be utilized to act through the unit B to modulate in frequency or in phase the oscillations from unit D repeated in the unit C in a manner which will be pointed out hereinafter. In order that the amplitude of these modulations may be adjustable or varied, one of the leads **46** is connected to a movable point on the resistance **45**, as shown. Most of the oscillations which appear in the direct current charging circuit **41**, are filtered out by way of a by-pass condenser C′ connecting one terminal of the resistance **42** to ground.

In the description of the unit A, given above, it was assumed that low frequency oscillations were to be developed therein and impressed on the unit B, from which they were to cause frequency or phase modulation in the oscillations repeated in C. It will now be assumed that instead of modulating with low frequency oscillations other audio frequency potentials, as, for example, voice frequencies, are to be used to modulate the carrier repeated in C and, further, that the tube X of the unit A is to amplify these potentials or voice frequencies before they are fed to the unit B to be used to modulate the high frequency energy repeated in C. To use the tube X as an amplifier the blades of the multiple switch **34** are moved into a right hand position to close the circuits associated with the right hand row of contacts. In this position the grid electrode **31** of tube X is connected through switch **34** in series with the secondary winding of a transformer T_3 and by way of lead **48** to a point on a resistance P_2 connected in parallel with the filter F′C′ which is energized from the direct current source **1**. The connection **48** supplies direct current biasing potential to the grid electrode **31** by way of parasitic prevention resistance **33** to charge the grid to a point at which the tube X operates as a good linear amplifier. The transformer T_3 has its primary winding connected in parallel with a potentiometer resistance **49**, which is connected by way of leads **50** and jack **51** to the source of audio frequency oscillations **2**.

In order that the amplitude or magnitude of the audio frequency oscillations applied to the primary winding of transformer T_3 may be adjustable, one of the leads **50** is connected to a movable point on resistance **49**. The input circuit for the modulating frequencies impressed on to the secondary winding of the transformer T_3 is completed by way of an audio frequency by-passing condenser C′ connecting the low potential terminal of the secondary winding of T_3 to ground GL and to the electrical center of the cathode **30**. In this manner modulating frequencies from the source **1** are impressed upon the input circuit of the tube A for amplification. The modulating potentials or currents amplified in the tube X appear on the anode **32** and are fed by way of lead **39** and switch **34**, and one of the pair of leads **47**, to the primary winding of transformer MT, and from the primary winding of transformer MT by way of the other lead of the pair of leads **47**, switch **34**, resistance **42**, current indicating means M^2A^2, and lead **41′** to the movable point on the potentiometer resistance P. In this manner a charging potential is applied to the anode of tube X in the same manner in which it was applied when the tube X was used as an oscillations generator. The alternating current anode circuit is completed by way of audio frequency by-pass condenser C_3 connected between one of the leads **47** and ground and cathode **30**. Condenser C′ prevents oscillations appearing in this anode circuit from being transferred by way of lead **41** to the resistance P to modulate therein any other oscillations which may appear from the other units. Further and more complete filtering of this circuit is insured by a by-pass condenser C′ connected between one terminal of resistance **42** and ground GL.

The modulating frequencies appearing in the source **2** are impressed by way of transformer T_3 on to the input electrodes of tube X, are repeated and amplified therein, and are impressed on the primary winding of the transformer MT for a purpose which will appear hereinafter.

Any radio frequency oscillations appearing in the lines 50 from source 2 are prevented from reaching the transformer T_3 by means of radio frequency by-pass condensers 52 and 54 connected as shown. Condenser 53, connected in series with the primary winding of transformer T_3, prevents any direct current from source 2 from reaching said winding and also acts as an impedance to reduce the volume of the low frequency voice currents which are normally overemphasized in an audio frequency transformer.

The manner in which the oscillations at modulating frequency appearing in the primary winding of the transformer MT in the unit B, whether they originate in the tube X, acting as an oscillation generator, or originate in the source 2 and are amplified in X, are utilized by the unit B to produce frequency or phase modulation of the carrier repeated in the unit C will now be described.

Two thermionic tubes M and N have their control electrodes 60 and 61 respectively connected by way of parasitic prevention resistances 62 and 63 respectively and normally closed contacts of the jack 64 and leads 65 to the opposite terminals of the secondary winding of transformer MT. In this manner modulating frequencies or voltages are applied in opposition to the control electrodes of tubes M and N. Equal direct current biasing potentials for the control electrodes 60 and 61 are supplied by way of a lead 66 connected on the one hand to a movable point on the resistance P_4 connected in parallel with the filter circuit F'C' supplied with energy from the source 1, and on the other hand through a current indicating device M^3A^3 to the electrical center of the secondary winding of the transformer MT, from which winding it is applied by way of leads 65 and jacks 64 to the control electrodes 60 and 61. The filaments 67 and 68 of tubes M and N are supplied with alternating heating current over lines 69 connected with the secondary winding of a transformer T_4, the primary winding of which is connected with the supply leads 21.

The thermionic tubes M and N are balanced with respect to the oscillations in the filament heating circuit by connecting the electrical midpoint of balancing resistances r^3 and r^4 connected across the cathodes 67 and 68 respectively to ground GL. These resistances r^3 and r^4 furnish low impedance by-pass paths around transformer T_4 to ground for low frequency oscillations. These resistances also tend to prevent any hum at the frequency of the energizing source from being developed.

The modulating potentials impressed in opposition from the transformer MT to the control electrodes of the tubes M and N are repeated in inverse sense and amplified therein and appear in phase opposition on the anode electrodes 28 and 29 thereof respectively. The direct current anode circuit of tube M is completed by way of a current indicating device M^4A^4, lead 26, resistance 70, and lead 41' to a point on the resistance P connected in parallel with the filtering circuit FC supplied from the high voltage source 4. The anode direct current circuit of the tube N is completed by way of current indicating device M^4A^4, lead 27, resistance 71, and lead 41' to a point on the resistance P. Most of the audio and substantially all of the higher potential oscillations are by-passed around the anode direct current energizing source by way of a by-pass condenser C' connected between the terminals of the resistances 70 and 71 and the ground GL. In some cases the resistances 70 and 71 may be replaced by choke coils. However, in most cases the resistance gives the more desirable wave form and is, accordingly, used.

The conductivity of the tubes M and N depends upon the effective potential applied to the control electrodes thereof. The effective potential applied to the control electrodes of the tubes M and N depends upon the constant direct current potential and the modulating potentials applied adding or in opposition thereto. The current which flows in the anode circuits of the tubes M and N is determined by the conductivity of the tubes. It therefore follows that the amount of current which flows in the anode circuits of tubes M and N varies at modulating frequency and depends upon the amplitude of the modulating frequency. Since the current flowing in the anode circuits of tubes M and N respectively varies at modulating frequency, the potential drop through resistances 70 and 71 also varies at modulating frequency. This potential drop through 70 and 71 being in negative sense to the potential supplied by line 41 from P is applied directly by way of leads 27 and 26 respectively to the screen grid electrodes 25 and 24 of tubes L and K respectively. As pointed out hereinbefore, the effective voltage on the screen grid electrodes of the repeater tubes K and L determines the conductivity of said tubes and therefore determines the amount of current the respective tubes supply to the tank circuit 15. Obviously, the potential variations at signal frequency, applied from the terminals of resistances 70 and 71 through lines 26 and 27 modulate in unit C the carrier frequency energy repeated in tubes K and L supplied from the source D. As pointed out before the carrier frequency supplied to the grids 24 and 25 of tubes K and L is of equal amplitude by shifting oppositely an equal amount in phase so that the carrier frequency repeated by tubes K and L is also shifted oppositely but equally in phase. However, as the signal varies, tubes K and L have their screen grid potentials varied in phase opposition and consequently the amplitude of the carrier output energy of these tubes is varied or modulated according to the signal. But since the anodes 13 and 14 of tubes K and L are connected in parallel to the same point on tank circuit 15, the amplitude modulation cancels and disappears but phase modulation will appear. The phase of the oscillations in tank circuit 15 will approach that of the tube supplying the most carrier energy. This phase shift of the oscillations in the tank circuit 15 will be proportional to the amount of energy supplied by one tube over that supplied by the other. The degree of phase deviation will be proportional to the intensity or amplitude of the signal and the frequency of phase shift will be the signal frequency.

Alternating current for the filaments of all of the tubes in each of the units A, B, and C is supplied from a source 3 by way of protection devices PO and lines 21. The amplitude of this current may be determined by the variable resistance VR connected in series with one side of the line 21. Any oscillations which have not been bypassed to ground by the by-pass condensers described hereinbefore are shunted around the source 3 by by-pass condensers C' connecting each side of the line 74 to ground GL.

To further insure that the oscillations, etc., developed and worked with in the several units,

are confined to said units, the leads, such as 41 and the leads between the transformers T and T_1 and the filaments of the tubes energized thereby, are filtered by way of by-pass condensers C' connected as shown between said leads and ground GL. In a like manner the corresponding leads, where they enter the unit C after passing from the units B and G, are again filtered by means of by-pass condensers C', there being a by-pass condenser connected between each line and the ground GL.

In practice it is important that the tubes M and N of the unit B impart to the modulating frequency the same amplification or are otherwise balanced in such a manner that the potentials appearing at the terminals of resistances 70 and 71 are similar in amplitude in order that the proper phase or frequency modulation is impressed on the carrier.

In order that the effect of tubes M and N on the modulating frequency may be determined and regulated, a jack 64 is connected, as briefly described hereinbefore, in the input circuit thereof in order that a monitoring circuit may be utilized to check on the modulating characteristics of this unit. The monitoring circuit forms no part of the present invention and will not be described herein.

The above description, and the drawings referred to therein, have been given merely for purposes of illustration since, obviously, many changes may be made therein without departing from the scope of the present invention. For example, different types tubes could be used in the unit A wherein the modulating frequency oscillations are developed or the modulating potentials energized and, likewise, many changes could be made in the circuit thereof. In a like manner, different type tubes, arranged in different circuits, could be used in the unit B. Furthermore, it is clearly understood that other tubes than those shown might be used in place of the thermionic tubes in the unit C and that likewise the circuits in which said tubes are connected may be departed from materially, without departing from the scope of the present invention.

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

1. Means for producing phase modulated oscillations comprising, high frequency oscillation generating means, repeating means including a pair of electron discharge tubes each having, an anode, a cathode, and a control electrode, means for connecting the anodes of said tubes in parallel, means for applying oscillations from said generating means in phase displaced relation to the control electrodes of said discharge tubes, a thermionic device having an anode, a cathode and a control grid, a circuit resonant at modulating potential frequency, a source of modulating potentials, switching means for connecting said resonant circuit between the anode and control grid and cathode of said device to produce oscillations, or the control grid and cathode of said device to said source of modulating potentials to act as an amplifier of the modulating potentials, and means connected between the anode of said last named device and said repeaters to vary in opposite directions the operating characteristics of said repeaters.

2. A device for producing phase or frequency modulated waves comprising, the combination of a carrier wave generator, a low frequency oscillator and a source of voice frequency potentials, a phase modulator having its input circuits connected to said carrier wave generator, a frequency multiplier connected to the output of said phase modulator, a load circuit coupled to said frequency multiplier and switching means for connecting said low frequency oscillator to said phase modulator to transmit phase or frequency wobbled waves to said load circuit or to connect said voice frequency potential source to said phase modulator to transmit telephony modulated waves to said load circuit.

3. A device for producing phase or frequency modulated waves comprising, the combination of a carrier wave generator, a phase modulator having its input electrodes coupled to said carrier wave generator, an audio frequency amplifier connected with electrodes of said phase modulator, a phase and frequency multiplier coupled with the output electrodes of said phase modulator, a radio frequency amplitude increaser coupled with the output of said phase and frequency multiplier, a load circuit coupled with the output of said last named amplitude increaser, a source of signals, a source of low frequency oscillations, and circuits for impressing signals from said first source on said audio frequency amplifier to transmit wave energy modulated in phase or frequency in accordance with said signals from said transmitter or for impressing oscillations from said second source on said audio frequency amplifier to transmit waves wobbled in phase or frequency in accordance with said low frequency oscillations from said transmitter.

4. A device for phase or frequency modulating a carrier wave by telegraphy or telephony signals comprising, the combination of a low frequency oscillator and a source of voice frequency potentials, a phase modulator having its input energized by said carrier wave, a frequency multiplier connected to the output of said phase modulator, a load circuit coupled to said frequency multiplier and means for connecting said low frequency oscillator to said phase modulator to transmit telegraphy signals to said load circuit or to connect said voice frequency potential source to said phase modulator to transmit telephony signals to said load circuit.

5. A device for phase or frequency modulating a carrier wave by telephony or telegraphy signals comprising, the combination of an audio frequency amplifier, a phase modulator having its input electrodes energized by said carrier wave energy, an audio frequency amplifier connected with electrodes of said phase modulator, a phase and frequency multiplier coupled with the output electrodes of said phase modulator, a radio frequency amplitude increaser coupled with the output of said phase and frequency multiplier, a radiating circuit coupled with said last named amplitude increaser, a source of voice frequency signals, a source of low frequency oscillations, and means for impressing signals from said first source on said audio frequency amplifier to transmit telephony signals modulated in phase or frequency in accordance with said signals from said first source from said transmitter or for impressing low frequency oscillations from said second source on said audio frequency amplifier to transmit wave energy modulated in phase or frequency in accordance with said low frequency oscillations from said transmitter for telegraphy signaling.

6. In a phase modulator, a pair of thermionic tubes each having an anode, a cathode, a control electrode and an auxiliary electrode, a circuit in-

cluding an inductance connected to the control electrode of one of said tubes, a circuit including a condenser connected to the control electrode of the other of said tubes, means for applying high frequency oscillations in phase to said circuits to thereby energize the control electrodes of said tubes by phase displaced oscillations of like frequency, an output circuit connecting the anodes of said tubes 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 across said impedance, a circuit connecting a point on said impedance to the cathode of said tube, and circuits 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.

7. In a telegraphy or telephony signalling system, a circuit tuned to oscillate when energized at a modulation frequency rate, a source of voice frequency potentials, a thermionic device having input and output electrodes, a pair of thermionic tubes each having input electrodes, means for applying high frequency oscillations of like frequency but displaced in phase to the input electrodes of said pair of tubes, an impedance, a circuit connecting said impedance to the output electrodes of said device, whereby potentials are impressed from said device onto said impedance when the input electrodes of said device are energized, circuits connecting different points on said impedance to like electrodes in said pair of tubes to apply modulating potentials in phase opposition to said like electrodes in said tubes, and a multiple switch and contacts cooperating with said source of voice frequency potentials to couple the same to the input electrodes of said device in one position of said switch when it is desired to signal by telephony, said switch cooperating with said resonant circuit to couple the same to the input electrodes of said device to produce oscillations in said tuned circuit in another position of said switch when it is desired to send telegraphy signals.

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