Aug. 30, 1949. "R" L. HOLLINGSWORTH 2,480,820

WAVE LENGTH CONTROL OF WAVE ENERGY

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Fig. 1.

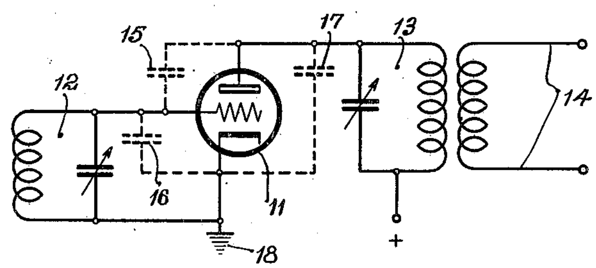

Fig. 2.

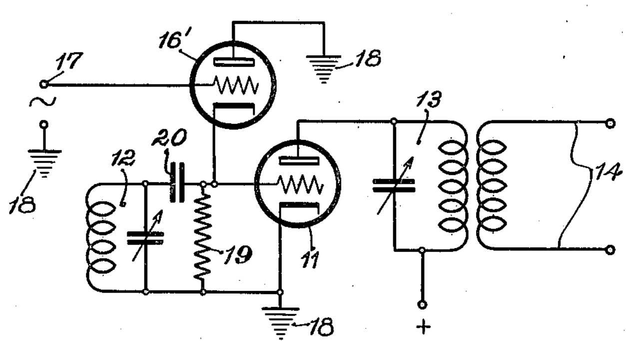

Fig. 2a.

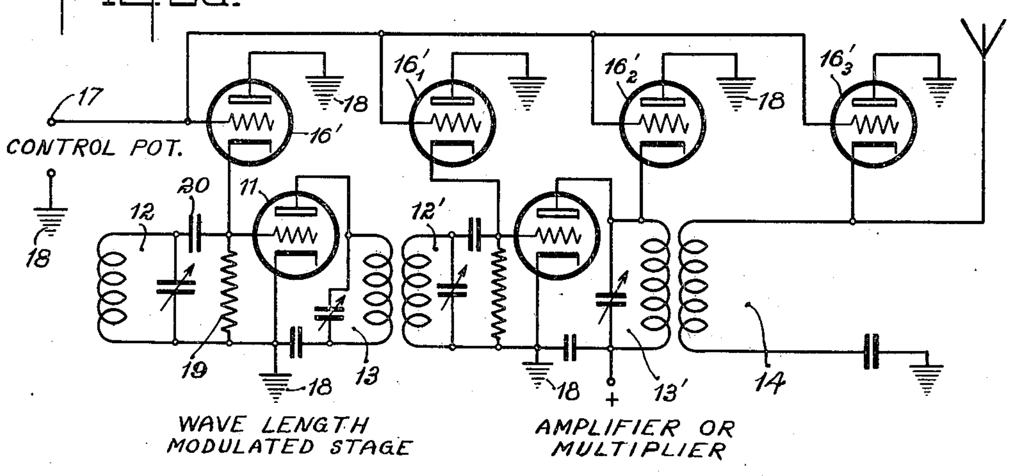

Fig. 2b.

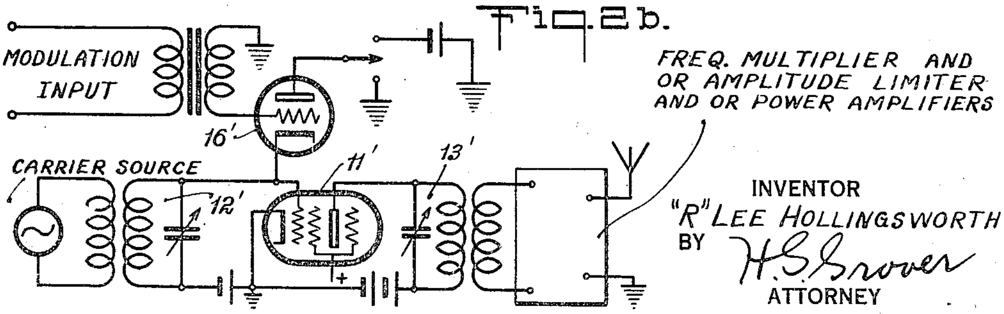

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Fig. 3.

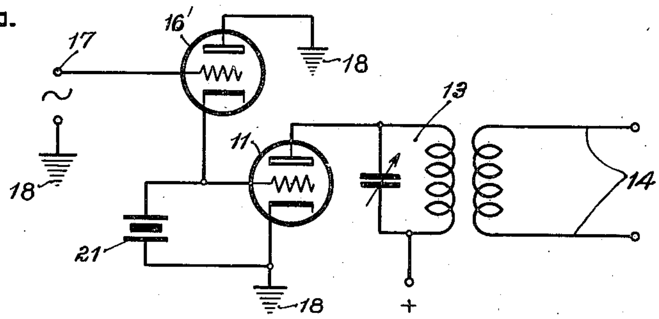


Fig. 4.

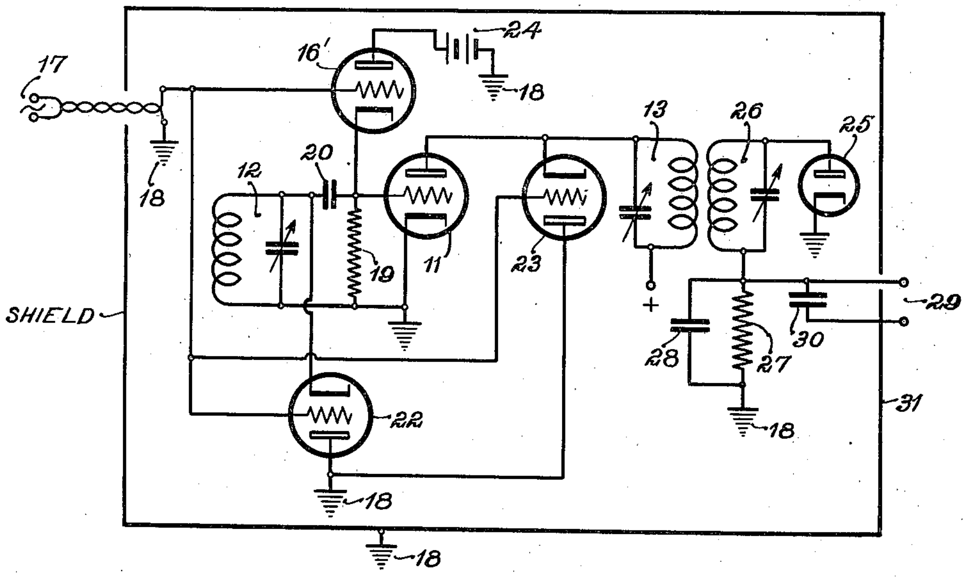
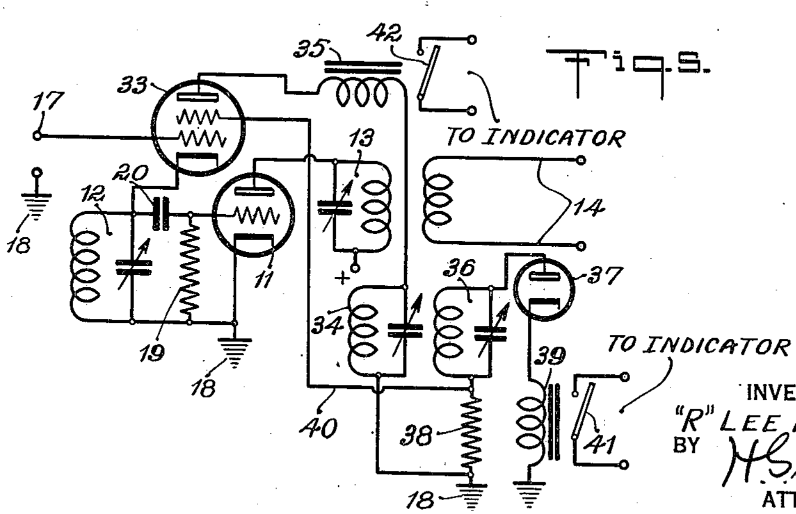


Fig. 5.



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WAVE LENGTH CONTROL OF WAVE ENERGY

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Fig. 6.

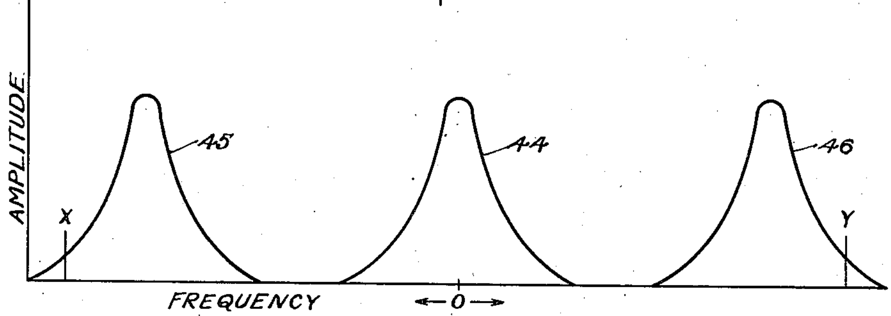


Fig. 6a.

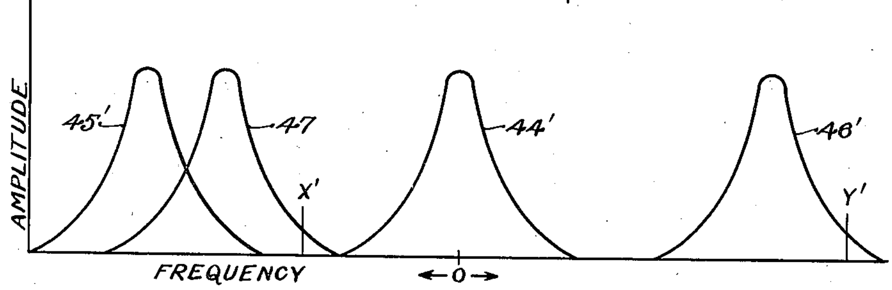
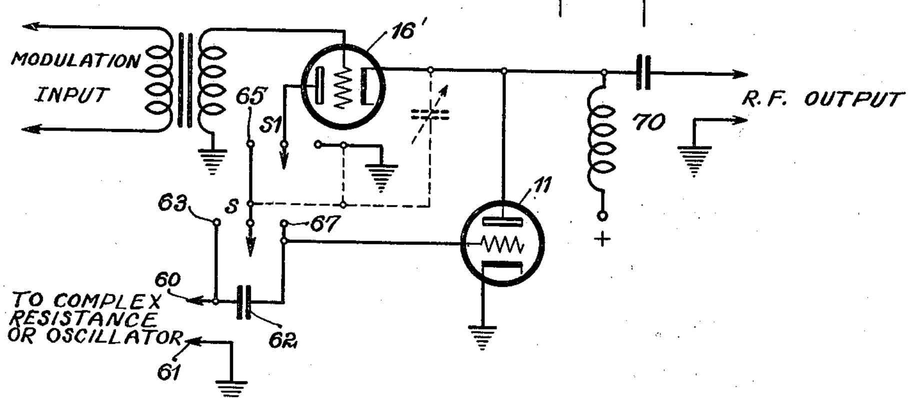


Fig. 7.



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Patented Aug. 30, 1949 2,480,820

UNITED STATES PATENT OFFICE

2,480,820

WAVE LENGTH CONTROL OF WAVE ENERGY

"R" Lee Hollingsworth, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application January 11, 1943, Serial No. 471,946

13 Claims. (Cl. 250—17)

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This application discloses a new and improved method and system of frequency modulation as applied to radio transmitting and receiving equipment.

In the present invention, I frequency modulate an oscillator by varying the electron stream capacity of a vacuum tube to change the capacity of an associated oscillator tube, or a component part of an oscillator circuit.

In another well known system of frequency modulation it has been the practice to phase modulate the oscillator of a frequency modulation transmitter in accordance with modified modulation currents, and with several frequency multiplying stages of amplification finally arrive at the assigned carrier frequency.

Yet in another method of frequency modulation, reactance tubes are used in association with the tank circuit of an oscillator to more directly produce frequency modulated waves.

It is, therefore, one of the purposes of this invention to produce frequency modulated electro-magnetic waves.

It is another purpose of this invention to render an amplitude modulation electro-magnetic wave receiver susceptible to frequency modulated electro-magnetic waves.

Still another purpose of this invention is to produce linear power conversion from an oscillator using only a small amount of control voltage, utilizing a suitable discriminator circuit in association with a suitable rectifier.

Yet another purpose of this invention is to limit automatically the modulation bandwidth of a frequency modulated transmitter.

Further, it is another purpose of this invention to frequency modulate a quartz crystal oscillator.

Also, it is a purpose of this invention to produce improved systems of uni-directional or single sideband frequency modulation.

It is another purpose of this invention to provide a capacity composed of the individual capacities between the electrons within an electron stream or cloud, and which is variable as a function of an applied control voltage.

A prime purpose of this invention is simplification of the system whereby those schooled in the art and science that it invokes, can easily assemble and use the same.

In describing my invention hereinbefore and hereinafter the term "frequency modulation" has been used. It is, of course, understood that the modulation carried out in my system may be termed "wave length modulation" and may have

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the characteristics of frequency modulation primarily or phase modulation primarily or may have modified forms of either thereof or characteristics of both phase and frequency modulation and modified forms thereof. Where the modulation or control is as to phase the modulating potentials are modified in amplitude in accordance with their frequency as disclosed in Crosby U. S. Patent No. 2,279,659, dated April 14, 1942.

In a thermionic vacuum tube having a cathode or electron emitter, hereinafter called a cathode, and a control grid for controlling the flow of electrons to a plate or electron collector hereinafter called a plate, the electrical capacity between these elements is somewhat different when the cathode is active. With all elements inactive such as when the cathode is not emitting electrons, and when there is no control voltage applied to the grid and likewise no voltage applied to the plate, the electrical capacity between these elements is constant. When the cathode is active and a stream of electrons is passing from the cathode to the plate, and the grid is tapped into or across this stream of electrons, the capacity between the various elements is somewhat different, and this capacity is variable with the mutual conductance of the vacuum tube. This can be explained by assuming that the hot capacity of a vacuum tube consists of the sum of the individual capacities between each electron and all other electrons within the electron stream or cloud. As small as these electrons are, their capacity may be relatively large in comparison to their surface area because of their close association. It is an established fact that the mutual conductance and capacity between the elements of a vacuum tube vary in direct relationship, that is, the greater the conductance or current flow from the cathode to plate, the greater is the electron stream capacity between the elements of the vacuum tube, and vice versa.

The description of the present invention follows and in the drawings,

Figure 1 illustrates the principal parts of a vacuum tube circuit showing the tube element capacities.

Figure 2 shows a tuned-plate tuned-grid oscillator circuit capable of being frequency modulated by an associated vacuum tube.

Figures 2*a* and 2*b* are modifications of the arrangement of Figure 2.

Figure 3 shows a similar embodiment for frequency modulating a quartz controlled oscillator.

Figure 4 illustrates how a power oscillator may be similarly frequency modulated by a small amount of power to produce large power output corresponding in frequency to the applied modulating voltage.

Figure 5 shows an oscillator capable of being frequency modulated, and furnished with associated circuits for controlling the modulation bandwidth automatically, and, if desired, to produce essentially single sideband transmission.

Figures 6 and 6a are graphical illustrations.

Figure 7 is a modification of the arrangement in Figure 2.

Figure 1 serves illustratively to explain the principle of this method of frequency modulation. Numerals indicating like parts begin with 11 which denotes a three element vacuum tube of a conventional and much used type. Shown at 12 is a parallel tuned circuit connected between the grid and cathode of tube 11. The inductance and capacity of this circuit usually determine the frequency at which the vacuum tube circuit will oscillate. In the plate output circuit is shown a like tuned electrical circuit 13, which serves to match the output circuit impedance to that of the vacuum tube, thus producing maximum power output to load circuit 14. The capacity between the grid and plate of the vacuum tube is shown at 15. This capacity 15 is of a value that is useful usually when self oscillations are desired, since it provides a feedback path through the tube. It can be varied to produce frequency modulation within an oscillator, and variation of this plate to grid capacity will be described within this specification. The grid to cathode capacity is shown at 16. This capacity 16 is always in parallel with the other capacities which tune the grid circuit. Therefore, when this capacity is varied, the frequency of the tuned grid circuit is changed in proportion to the capacity variations.

The plate to cathode capacity is shown by 17. This capacity 17 likewise constitutes a part of the grid tuning capacity, since it is effectively in shunt to circuit 12.

In an oscillating vacuum tube circuit, when capacities 15, 16 and 17 are varied at a desired rate, frequency modulation of said oscillator is produced in proportion to the amount of capacity variation. The precise manner in which I accomplish this variation constitutes the basis of this invention.

Ground or common potential is shown in all drawings by numeral 18.

In Figure 2 is shown an oscillator consisting of a vacuum tube 11, grid leak 19, grid blocking condenser 20, tuned circuits 12 and 13, and output circuit 14. This conventional oscillator circuit is frequency modulated by vacuum tube 16', whose cathode is connected directly to the grid of the oscillator tube 11. The plate of vacuum tube 16' is connected directly to ground or cathode return so that the space between the plate and cathode of tube 16' is across tuned circuit 12.

The modulating voltage is applied to terminals 17 and 18, which places an alternating or pulsating potential on the grid of vacuum tube 16'. This potential variation causes the electron stream capacity of tube 16' to vary in relation to the applied voltage, namely a higher positive voltage producing an increased capacity across the grid circuit, and a less positive voltage decreasing the capacity across the grid circuit, thus producing relatively pure frequency modulation since the modulating voltage required to produce a desirable modulation bandwidth is very small especially at the higher radio frequencies.

In my system note that only the electron stream or electron cloud capacity is connected across the tuned circuit and it is unnecessary for current to flow to the plate so long as the electron cloud varies sufficiently to produce the required capacity change to give the desired bandwidth of modulation.

In an embodiment of this wave length modulator using a small tube of the 6.3 volt heater type I obtained a bandwidth of approximately 75 kilocycles at 6000 kilocycles in the spectrum with the heater voltage at 2 volts and —50 db. modulating voltage, and several megacycles bandwidth when using full heater voltge with the same —50 db. modulating voltage.

When phase modulation is desired, an arrangement as illustrated in Figure 2b is used. This system is the same as that of Figure 2 except that here the tube 11' is a wave relay or amplifier having its tuned input circuit 12' coupled to a carrier wave source and its tuned output circuit 13' coupled to frequency multipliers and/or an amplitude limiter and/or a power amplifier. The principle of operation is the same as in Figure 2 but since tube 11' is not a wave generator, the phase change caused by the capacity change of tube 16' is not regenerated to produce frequency modulation. Phase modulation is produced.

It will be appreciated, therefore, that unidirectional or single sideband frequency modulation is easily accomplished with this circuit, or any type of oscillator so frequency modulated, by connecting a direct current pulsating voltage across terminals 17. If the pulsating voltage variations be positive with respect to the cathode of vacuum tube 16', the resulting frequency change of the oscillator due to increased electron stream capacity will be lowered. If the pulsating voltage applied to the grid of vacuum tube 16' is negative with respect to the cathode of vacuum tube 16', the frequency of the oscillator due to decreased electron stream capacity will be increased.

Output circuit 14 may connect directly to an antenna, or to a frequency multiplying amplifier system of a relatively common variety. In either connection, if the modulation bandwidth desired is wide enough to necessitate tuning either the amplifying system or the antenna synchronously with the modulation to produce uniform radiation response, it will be appreciated that the amplifier and the antenna may in like manner be synchronously tuned to produce uniform radiation characteristics.

To synchronously tune an amplifier to give uniform response to very wide band frequency modulation such as may be used in a secret method of communication, the cathode and plate of the modulating tube or tubes are connected across one or all of the constants comprising the input and output tuning circuits of the amplifier similar to the tube connections shown in Figure 4. The modulating voltage is then applied to the grids of these tubes in step or synchronism with the modulating voltage applied to the tube 16' controlling the oscillator, thus keeping the amplifiers tuned to maximum over the modulating range and consequently delivering uniform power output to the antenna. An arrangement of this nature is shown in Figure 2a, which includes the features of Figure 2 and, in addition, two circuit bandwidth control tubes $16'_1$ and $16'_2$ coupled across tuned circuits 12' and 13' and controlled as to conductance by potentials applied at 17 in phase with the control of 16'.

To synchronously tune an antenna to produce uniform radiation over a wide frequency band, the cathode of a vacuum tube $16'_3$ is connected or coupled thereto as shown in Figure 2*a*. The plate of said tube is connected to ground or to a counterpoise system. The modulating voltage is applied to the grid of the vacuum tube, in the same phase relation as that applied to the oscillator and amplifier, that is, if the frequency of the oscillator is increased, the amplifier and antenna would be likewise tuned to a higher frequency in synchronism with the carrier shift due to modulation.

A vacuum tube may be connected across a tuned circuit of any desired variety, and the electron stream capacity of the vacuum tube varied as a result of applied grid voltage variations to change the natural frequency or resonant point of the tuned circuit in the ether spectrum.

It will be appreciated that a vacuum tube in like manner can be connected across or in parallel to a quartz plate that is used to produce stabilized oscillations in association with a vacuum tube in a conventional oscillator circuit to frequency modulate the quartz plate oscillator. Such a circuit is shown in Figure 3, where the oscillator tube is shown at 11. The tuned plate circuit is shown at 13 and the output circuit is shown at 14. The quartz plate 21, shown in a conventional manner, is connected between the grid and cathode. The modulating tube 16' is connected in parallel to the quartz plate. The modulating voltage is applied to the grid of vacuum tube 16' to produce capacity variations in parallel to the quartz plate, which varies the natural operating frequency of said quartz plate in proportion to the electron stream capacity change within the modulating tube.

Since the power of quartz oscillators is usually low, the output would usually feed into another amplifier before being connected to an antenna. The frequency of the quartz oscillator may be multiplied if desired.

In Figure 4 a power conversion circuit is shown. Vacuum tube 11 is shown connected in an oscillator circuit similar to that shown in Figure 2. Here modulating tube 16' is shown to have a positive voltage applied to the plate from battery 24 to increase the electron stream capacity between the cathode and plate. The increased grid bias is negligible since it may be counteracted by the modulating voltage connected at terminals 17 and 18. Modulating tubes 22 and 23 in shunt respectively to tuned circuits 12 and 13 serve to illustrate that additional modulating tubes may be connected in any part of an oscillator circuit to use their electron stream capacity for varying the frequency of the oscillator to a greater degree if so desired. Such a tube may also be connected between the grid and plate of the oscillator tube 11, thereby adding the cathode-to-plate capacity of the modulating tube to that of the grid-to-plate capacity of the oscillator tube. The modulating voltage is applied to the grid of the modulating tube or tubes as heretofore explained.

The action of the circuit of Figure 4 is as follows: The circuit is assumed to be generating a desired amount of radio frequency power. Modulating voltage at a desired or variable frequency is applied to terminals 17 and 18. Vacuum tubes 16', 22 and 23 add or subtract electron stream capacity to or from the oscillator circuit in proportion to the applied modulating voltage. Circuit 26 is coupled to circuit 13 and is tuned to resonance with circuit 13, causing rectifier tube 25 to pass maximum current through resistance 27 which is filtered by condenser 28. The resulting power output appears across terminals 29. Condenser 30 is a radio frequency bypass condenser to prevent transfer of radio frequency energy from the oscillator past the shield 31 in which the oscillator is housed.

This circuit, Figure 4, may operate to deliver maximum power across terminals 29 with no modulating voltage applied, and act to give reduced power across terminals 29 when the modulation is applied, or the oscillator may be detuned to a point where essentially no power would appear across terminals 29, and with modulation applied it would deliver full or proportionate power (at terminals 29) comparable to the applied modulating voltage. The latter method of operation would save power, since the oscillator circuit would draw the maximum power from the power supply source only during the time that the modulation tunes it to maximum output. In the language of the art, zero modulation level would require a minimum of power to be drawn by the oscillator from the power source, and 100% modulation would cause the oscillator to draw the maximum amount of power from the power source.

A commonly known push-pull type of oscillator may be frequency modulated in the manner heretofore explained, and in fact, any type of oscillator can in this manner be frequency modulated, whose frequency can be changed by adding or subtracting capacity to or from any component part of the oscillator in question, without departing from the scope of this invention.

Further, a coupled circuit in association with an oscillator may be shunted by a vacuum tube as heretofore described, and the electron stream capacity of the vacuum tube varied to produce inductive or capacitive loading that would change the frequency of the oscillator, thus producing frequency modulation of said oscillator, without departing from the scope of this invention.

In Figure 5 the same principle is employed to modulate the conventional oscillator shown. In this embodiment another method of producing single sideband transmission is shown, together with a means for automatically controlling the modulation bandwidth, and a means for visually indicating full modulation. The modulator tube 33 is shown to be a commonly known screen grid type. The cathode of tube 33 is connected across the grid tuning circuit 12 to ground. Modulation is accomplished as heretofore shown by applying the modulating voltage to terminals 17 and 18. The plate of the modulator tube is connected through the inductance of tuned circuit 34, which is coupled to circuit 13, and through solenoid switch winding 35 to ground. Tuned circuit 36 is coupled to circuit 13 and connected to the plate of rectifier tube 37. When the rectifier draws current, the path of said current is through the inductance winding of tuned circuit 36, resistance 38 and through the winding of solenoid switch 39.

The action of this circuit shown in Figure 5 can best be described with reference also to Figure 6. Let us assume that the oscillator is in operation and that its position in the frequency spectrum is shown to be that of resonance curve 44, and the oscillator is assumed to be unmodulated. Further, let us now assume that the positive half-cycle of modulation is applied at terminals 17 and 18 at sufficient voltage to produce full or 100% modulation. The position of the oscillator in the frequency spectrum instantly assumes the position shown by resonance curve 45. When the positive half-cycle of modulation is completed, the carrier frequency is again at its assigned position in the frequency spectrum. As the negative half of the modulating cycle is applied, the frequency of the oscillator suddenly assumes the position in the frequency spectrum represented by resonance curve 46. When the negative half of the modulating voltage cycle is completed, the carrier frequency is again at its assigned frequency shown by resonance curve 44.

Points X and Y represent the points for properly indicating 100% modulation, and a method of indicating these points visually is provided in Figure 5 and is explained as follows: When the frequency is moved down as a result of full positive potential modulation, tuned circuit 36 is in resonance at point X in the frequency spectrum, and induced voltage from plate load circuit 13 causes rectifier 37 to pass current through resistance 38 and solenoid switch coil 39. The negative voltage across resistance 38 is carried via lead 40 to the screen grid of tube 33, to counteract any further increase in the electron stream capacity of tube 33 in case the positive modulating voltage tended to rise to a higher value. At the same time solenoid switch 41 closes due to the rectifier current, and lights an indicating light which is not shown in the drawing, in favor of simplicity, thereby visually indicating full modulation. When the modulating voltage is of negative potential with respect to the cathode of the modulating tube, the frequency of the carrier is moved up in the frequency spectrum, and when full or 100% modulation is reached in this direction, tuned circuit 34 is at resonance at point Y and energy induced therein from tank circuit 13 causes plate current through tube 33 to increase thereby increasing the electron stream capacity of tube 33, preventing further possible increase of the frequency due to increased negative modulating voltage. This increased plate current operates switch 42 to produce an indication of full modulation. Thus is shown and illustrated a means for automatically keeping a frequency modulation transmitter within its normal assigned operating channel in the frequency spectrum, and a method of indicating full or 100% modulation.

By this same method of modulation control, single sideband frequency modulation may be accomplished by proper adjustment of the tuned control circuits 34 and 36. Let us assume that it is desired to transmit only the sideband of the modulation to the higher side of the assigned frequency. Tuned circuit 36 is adjusted to a position in the frequency spectrum represented by resonance curve 47 of Figure 6*a*. At point X' on that curve, when positive potential modulation is applied rectifier 37 in the same manner as heretofore explained draws current to produce a negative voltage that is applied to the screen grid of modulating tube 33, thus limiting any further lowering of the carrier frequency. When the negative modulating voltage is applied, the frequency of the oscillator is allowed to increase to point Y' and is limited as heretofore explained at that full or 100% modulation point. Thus, instead of allowing the oscillator to be moved both sides of center, from position 44' to position 45' and again through position 44' to position 46' and again to position 44', the operation is limited to the region between points indicated by X' and Y', thus for all practical purposes producing single sideband frequency modulation transmission.

It will be appreciated that I may use two rectifiers operating as a result of excitation from circuits 34 and 36 properly tuned above and below the carrier, one rectifier delivering positive control voltage, while the other rectifier delivers negative control voltage with respect to the cathode of tube 33 of Figure 5, to thus provide a similar means of channel width control. In this embodiment the tuned circuit 36 and rectifier 37 may be connected to operate as described above, then the anode of tube 33 is connected to ground (as is tube 16', Fig. 2, or Fig. 4) and the circuit 34 is connected to a rectifier and resistance and solenoid winding (say, for example, like rectifier 37, resistance 38 and solenoid winding 39) with the rectifier anode end of the resistance grounded and the cathode end thereof connected to the screen grid of tube 33 to supply the positive potential which appears as the generated frequency swings up to full modulation to limit such modulation by increasing the current through the tube 33.

When a capacity tube of the nature described herein and shown at 16' in the prior figures is connected between the grid and plate of a second tube to vary the capacity therebetween, an arrangement as illustrated in Figure 7 may be used. In Figure 7 the leads 60 and 61 may be connected to any complex resistance or tuned oscillator circuit, the reactance of which is to be controlled. This circuit may be the input circuit of an oscillator as shown in Figure 2, or the tank circuit of a regenerative generator. In both cases tube 11 may represent the generator tube. The lead 61 is grounded, while that at 60 is connected by blocking condenser 62 to the grid of tube 11. The lead 60 is also connected to the contact 63 of a switch S. The capacity tube 16' has its control grid coupled by a transformer to its source of control or modulating potential, and its cathode connected to the anode of tube 11. A second switch S1 is connected to the anode of tube 16' so that this anode may be connected by contact 65, switch S and contact 63 to the lead 60 and by blocking condenser 62 to the grid of tube 11 or may be connected more directly by contact 65 and contact 67 to the grid of tube 11, or, the plate of tube 16' may be connected to ground, thereby connecting this capacity tube 16' in shunt to the anode and cathode of tube 11. When the contact of S1 is on 65 and the contact of S is on 63 or 67, the tube capacity 16' is connected between the anode and grid of tube 11. The polarity of tube 16' may be reversed, if more capacity due to plate current is desired. Connected as shown no plate current flows through tube 16'. The capacity of tube 16' is shown by the dotted condenser connected in shunt therewith. The output of the system is shown at 70.

A method of frequency modulation has been shown with various useful methods of application and control features related to frequency modulated electro-magnetic wave transmission.

The main principle used in this invention is also applicable to radio receivers, to cause a normal amplitude modulation receiver to faithfully receive frequency modulated waves.

Again referring to Figure 2, let us assume that this oscillator circuit is employed as the conversion oscillator of a commonly used type of superheterodyne receiver. Disregarding the action produced by modulating tube 16′, we can assume that the receiver would receive amplitude wave modulations in a normal manner. Now, if inaudible frequency wave energy is applied after preferably being rectified to terminals 17 and 18, the frequency of the oscillator will be tuned to one side at the rate of the applied inaudible frequency, producing a discriminating effect to allow the detection of frequency modulated waves as the oscillator frequency is varied in and out of tune with the associated tuned circuits of the receiver. The radio frequency amplifiers ahead of the conversion oscillator circuit of such a superheterodyne receiver, and the intermediate frequency amplifiers after the conversion oscillator circuits, and the associated discriminator circuit may in the same manner as heretofore explained be tuned and detuned in step with the swing of the oscillator to cause the receiver to be susceptible to broad sweep or wide band frequency modulated waves. The discriminator circuit may be adjusted to be delivering zero output until the same or separate high frequency modulation is applied to frequency modulate its tuning in a manner to cause it to deliver maximum power at a point in the frequency spectrum where the transmitter's modulation reached 100%. Such a discriminator circuit would not be unlike that shown by circuit 26 of Figure 4, though it would be shunted by the modulating tube such as heretofore shown and explained.

Thus, by throwing a switch to energize an associated oscillator, any superheterodyne radio wave amplitude modulation receiver may become an efficient receiver of frequency modulated radio waves.

Another application of this principle in a radio receiving system is to produce flat top characteristics in radio wave amplifiers, especially in intermediate frequency amplifiers such as are used in superheterodyne receivers. This is accomplished by rapidly tuning and detuning the stages of amplification to cause the maximum response to traverse a given frequency band in the frequency spectrum.

Further, an oscillator used in checking the characteristics of amplifiers can be frequency modulated in the manner shown in this invention, in the place of using the commonly known motor driven condenser for varying the frequency while visual characteristics are being observed during final adjustments.

Further reference to Figure 5 will show that there is inherently incorporated in this circuit a means for preventing a radio receiver from drifting away from the desired station being received. Assume that the oscillator is that of a conversion oscillator of a superheterodyne amplitude modulation receiver, and further assume that tuned circuits 34 and 36 are tuned immediately above and below the desired frequency channel to be received. If the oscillator drifted higher in frequency than the desired channel, the energy induced into circuit 34 would increase the plate current through tube 33 to cause a capacity increase that would again lower the frequency of the oscillator to the desired frequency. If the oscillator drifted lower in frequency, circuit 36 would produce rectifier current to increase the negative voltage on the screen grid of the modulator tube to decrease the electron stream capacity of this tube, thus causing the capacity of the oscillator to be lowered, increasing the frequency of the oscillator to the normally desired channel. It may be assumed that the oscillator is unusually powerful and that only a part of its output is being used by the receiver for frequency conversion purposes, or that tuned circuits 34 and 36 are located at the output end of the intermediate frequency amplifier, where a suitable amount of signal energy is available.

Thus is shown a means for holding an oscillator within a given frequency band which may be used in either radio receivers or transmitters, or wherever a controlled oscillator can be used to advantage.

It will be further appreciated that this type of frequency modulation is essentially basic in nature, and that there are many possible uses for such a variable electron stream or electron cloud capacity, such as, for instance, to displace the directivity of a directive antenna to cause the beam to cover a wider area, such displacement to take place at a variable or voice frequency, or at a constant rate of variation such as would be used in radio telegraph communication to cover effectively a wider area, and to reduce fading somewhat at the higher frequencies such as are used for long distance communication.

It will be still further appreciated that all of the elements of tubes 16′ and 11 may be housed in the same bulb or container if so desired.

The applications of this type of variable capacity seem to be so numerous, that in the claims to follow, one basic claim therefore appears to protect this invention in the broad field that it encompasses. An application of the principle chiefly involved in this invention is employed in my United States Patent No. 2,243,423.

What is claimed is:

1. In a wave generating and wave frequency control, an electron stream capacity in a tube comprising a heated cathode, a plate, and at least one control grid, said electron stream flowing from the cathode to the plate, a generator tube having a grid and a cathode, a conductive connection connecting said cathode of the first tube to the grid of the generator tube, a conductive connection between the plate of said electron stream capacity tube and the cathode of said generator tube, and connections for applying a control potential to the grid of said electron stream capacity tube to vary the electrical capacity of the electron stream to control the frequency of the oscillations generated by said generator tube.

2. In a wave generating and wave frequency modulating system, an oscillation generator including an electron discharge device having as electrodes an anode, a cathode and control grid and including generating circuits including a quartz crystal coupled with the device electrodes, an electron stream capacity in a tube comprising a heated cathode, a plate, and a control grid, said electron stream flowing from the cathode to the plate, a substantially direct connection between the cathode of said tube and the grid of said device, a substantially direct connection between the anode of said tube and the cathode of said device, and connections for applying a controlling potential to the grid of said electron stream capacity tube to vary the electrical capacity thereof and in turn modulate the frequency of the oscillations generated in said device as controlled by said quartz crystal.

3. In a power conversion system, an oscillation generator comprising a discharge device having a control grid electrode and cathode electrode and having output electrodes, means coupling said two first-named electrodes in an oscil-

lation generating circuit including a tuned circuit, an output circuit, a tuning reactance coupling said output circuit to said output electrodes, a modulator tube having a cathode coupled to the control grid of said device and having an anode coupled to the cathode of said device, said modulator tube having a control grid, a second modulator tube having a cathode and an anode coupled with said tuning reactance, said second modulator tube having a control grid, and means for applying a control potential to be converted simultaneously to the control grids of said modulator tubes.

4. In a system of the class described, an oscillation generator comprising a tube having a control grid and a cathode, an electron stream capacity comprising an electron discharge device having a cathode, a plate and a control grid electrode, said electron stream flowing from the cathode to the plate of said device, means for connecting the cathode of said device to the control grid of said tube, a connection between the plate of said device and the cathode of said tube, and connections for applying a pulsating negative electromotive force to the grid of said electron stream capacity device to reduce the electrical capacity of the electron stream to thereby increase the frequency of the oscillations generated, thus producing uni-directional or single sideband wave length modulation.

5. In a system of the class described, an oscillation generator comprising a tube having a control grid and a cathode, an electron stream capacity comprising an electron discharge device having a cathode, a plate and a control grid electrode, said electron stream flowing from the cathode to the plate of said device, means for connecting the cathode of said device to the control grid of said tube, a connection between the plate of said device and the cathode of said tube, and connections for applying a pulsating positive electromotive force to the grid of said electron stream capacity device to increase the electrical capacity of the electron stream to thereby decrease the frequency of the oscillations generated, thus producing uni-directional or single sideband wave length modulation.

6. In a system of the nature described, an electron discharge tube having input and output electrodes including a control grid, an anode, and a cathode with a tuned circuit coupled between the grid and cathode, an electron stream capacity comprising an electron discharge device having a heated cathode, a plate, and a control grid, the electron stream in said device flowing from the cathode to the plate, a conductive connection between the cathode of said device and the control grid of said tube, a connection between the anode of said device and the cathode of said tube, and means for connecting a pulsating or alternating current source to the control grid of said device to vary the electrical capacity of the electron stream to thereby vary the tuning of said tuned circuit.

7. In a system of the class described, a plurality of electron discharge devices coupled in cascade by a plurality of tuned circuits with means for setting up oscillations in the first of said stages and deriving amplified oscillations from the last of said stages, a plurality of electron stream capacity tubes each having a heated cathode, a plate and a control grid with the electron stream flowing from the cathode to the plate, there being a tube for each of the tuned circuits it is desired to control, connections between the cathodes of each of said tubes and one side of a different one of said tuned circuits, connections between the anodes of each of said tubes and the other side of a different one of said tuned circuits, the arrangement being such that the impedance between the anode and cathode of each of said tubes is connected across a different one of said tuned circuits, a source of control potential, and connections for applying control potential from said source to the control grids of each of said tubes in phase synchronism.

8. In an arrangement of the class described, a wave generator device having a grid and a cathode, an electron stream capacity produced in a thermionic vacuum tube consisting of a heated cathode, a plate, and at least two control grids, said electron stream flowing from the cathode to the plate to comprise a wave length modulator tube, a connection between the cathode of the tube and the grid of said device, a connection between the plate of said electron stream capacity tube and the cathode of the device, said connection including a solenoid switch winding and an inductance of a first tuned radio frequency circuit attuned to the upper side of the generator's unmodulated frequency, a second tuned radio frequency circuit coupled to the wave generator and attuned to the lower side of the generator's unmodulated frequency and connected in series with a resistance and a solenoid winding and further connected to the plate and cathode of a rectifier, means for applying an electromotive force to a first control grid of the electron stream capacity tube to vary the frequency of said generator, and a coupling arrangement including a connection between said resistance and another control grid of the tube whereby the first of said tuned circuits and the second of said tuned circuits become energized when full modulation is accomplished to either increase or decrease the capacity of the electron stream within the modulating tube in opposition to the capacity change as a result of the electromotive force applied to the first control grid of the electron stream capacity tube.

9. In an arrangement of the class described, a tuned circuit wherein oscillations, the wave lengths of which are to be controlled, flow, said circuit including a controllable reactance comprising an electron stream capacity produced in a thermionic vacuum tube, connected to said tuned circuit to wave length modulate the oscillations, said tube having two grids, means for applying an alternating current electromotive force to one grid of said tube to control its capacity, a second tuned radio frequency circuit coupled to the first tuned circuit and attuned very close to the frequency of the oscillations when not modulated, and means for applying the energy induced in said second tuned circuit to another grid of the electron stream capacity tube to eliminate the modulation on one side of the unmodulated wave length when modulation is applied, thus producing uni-directional or single sideband wave length modulation.

10. In an arrangement of the class described, a tuned circuit wherein wave energy to be modulated flows, said circuit including an electron stream capacity produced in a thermionic vacuum tube having a cathode and at least two other electrodes including an anode and cathode, connections coupling the anode and the cathode of said electron stream capacity tube to said tuned circuit, two closely associated tuned circuits attuned above and below the desired operating

frequency of said first tuned circuit and coupled thereto, and circuits for applying the currents from the respective tuned circuits to said two other electrodes to produce a capacity change to oppositely oppose frequency drift of the wave energy in said tuned circuit.

11. In a system of high deviation frequency modulation transmission, a master oscillator, means for modulating the master oscillator including an electron stream capacity vacuum tube, means for controlling the bandwidth of the modulation applied to the master oscillator, a frequency multiplier-amplifying system coupled to the oscillator, means for tuning said frequency multiplier-amplifying system in synchronism with the modulation applied to said master oscillator, an antenna system coupled to said frequency multiplier and a means for tuning the same in synchronism with the modulation of the master oscillator and with the synchronous tuning of the associated frequency multiplier-amplifying system.

12. In signalling apparatus, means for producing wave energy comprising an electron discharge device having an anode, a cathode, and a control grid, with wave energy producing circuits connected thereto, an electron stream capacity in the form of a thermionic vacuum tube having a heated cathode, a control grid and an anode, the capacity being formed by the electron stream between the cathode and anode, a connection, of low impedance to voltages of the frequency of the wave energy produced, between the anode of said tube and the cathode of said device, a connection, of low impedance to voltages of the frequency of the wave energy produced, between the cathode of said tube and the control grid of said device, and connections to the control grid and cathode of said tube for varying the potential on the control grid relative to the cathode to modulate the frequency of the wave energy produced in said device, the arrangement being such that the wave energy may be modulated a portion of a cycle thereof or through several megacycles.

13. In a signalling system, a first alternating current circuit tuned to a selected frequency, means for setting up alternating current wave energy in said circuit of a frequency determined by the tuning thereof, an electron stream capacity in a tube having electrodes including a heated cathode, an anode, and at least one control grid, the capacity being formed between the anode and cathode of said tube, connections connecting the anode and cathode impedance of said tube in shunt to said tuned alternating current circuit, a connection to the control grid of said tube for applying a control potential thereto for varying the electron stream between the anode and cathode of said tube to thereby vary the capacity of the tube and the tuning of said alternating current circuit and the frequency of the wave energy therein, a second alternating current circuit excited by current set up in said first circuit and tuned to a frequency above said selected frequency, means connected with said second tuned circuit for rectifying current set up therein for producing a potential and applying the same to an electrode in said tube to control the capacity thereof when the frequency of the alternating current in said first circuit attains the frequency to which said second circuit is tuned, a third circuit excited by current set up in said first circuit and tuned to a frequency below said selected frequency, means connected with said third circuit for rectifying current set up therein for producing a potential and applying the same to an electrode in said tube to control the capacity thereof when the frequency of the alternating current in said first circuit attains the frequency to which said third circuit is tuned, and an output circuit coupled to said first mentioned alternating current circuit.

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