April 18, 1944. G. L. USSELMAN 2,346,800

WAVE LENGTH MODULATOR

Filed May 27, 1942 2 Sheets-Sheet 1

Fig. 1.

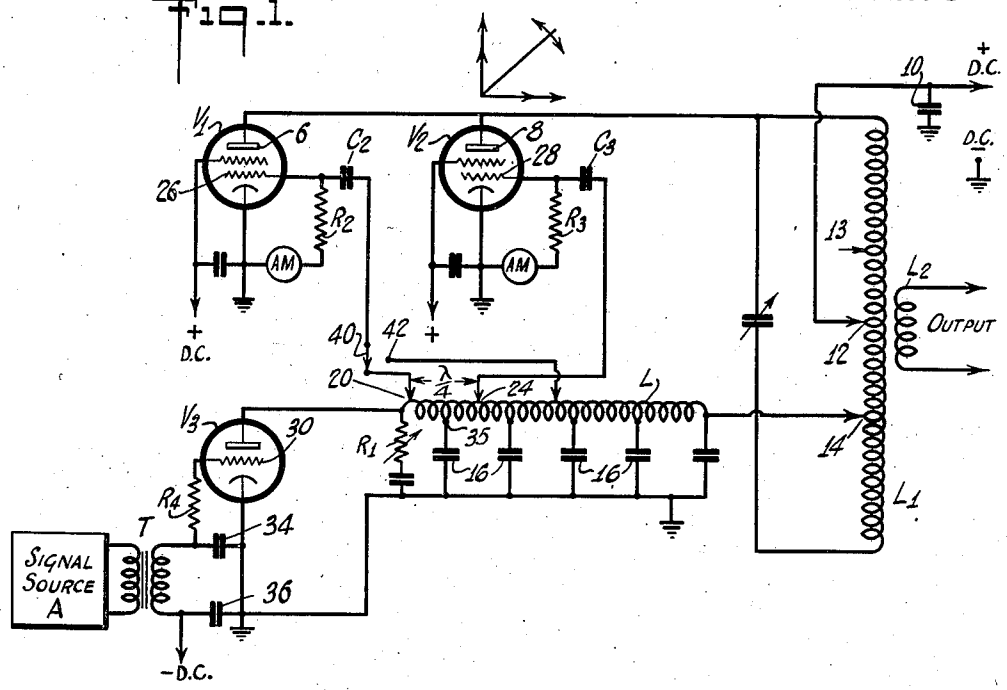
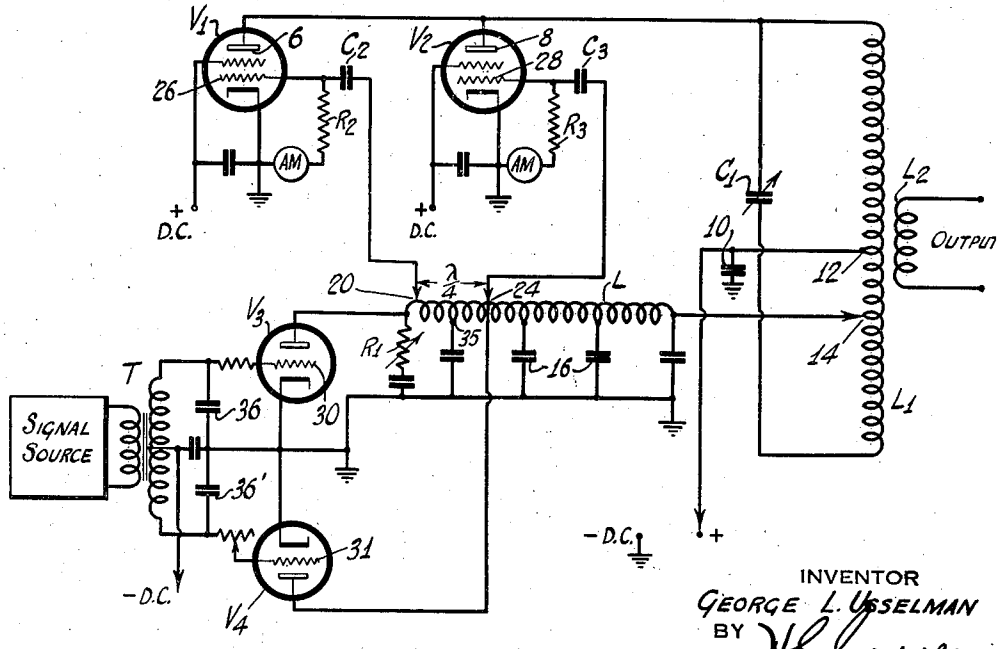


Fig. 2.



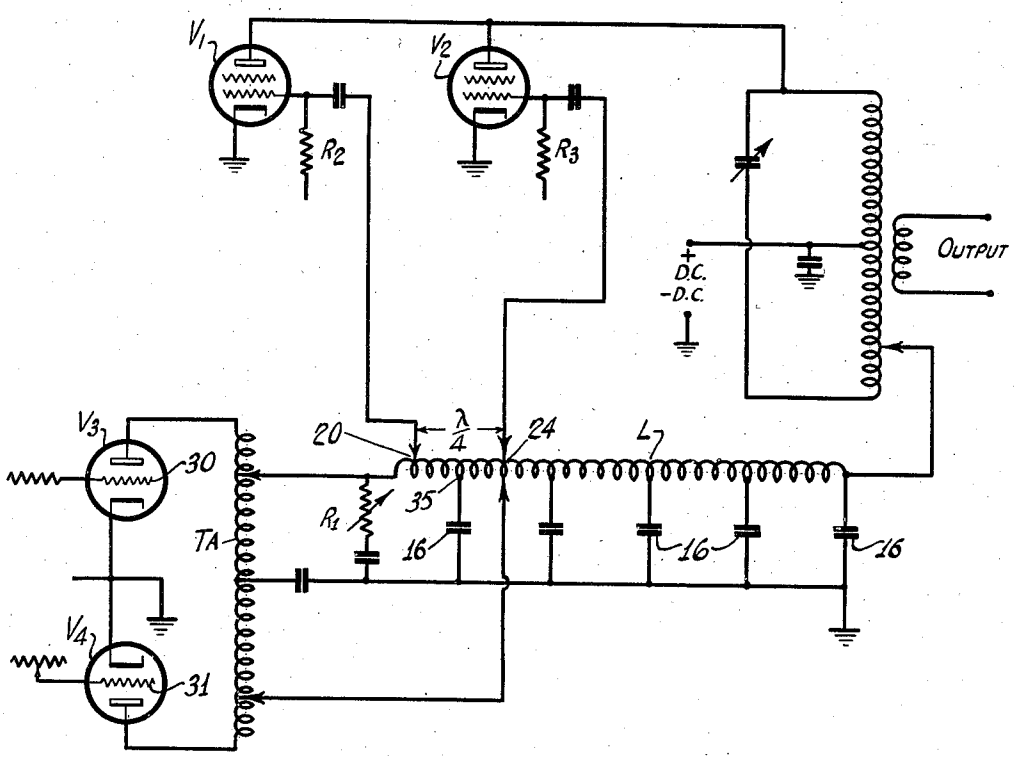
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Fig. 3.



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WAVE LENGTH MODULATOR

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Application May 27, 1942, Serial No. 444,634

10 Claims. (Cl. 179—171.5)

In this application I have disclosed a new and improved wave length modulation system wherein frequency modulation or phase modulation is accomplished in a new and improved manner.

An object of the present invention is to improve wave generators and wave length modulators.

In attaining this general object I provide a new and improved frequency modulation system, including wave generating and stabilizing means including tubes having output electrodes coupled to input electrodes by a transmission line of a length such that the circuits are regenerative. The line is terminated by a variable impedance equal to the line surge impedance. The variable impedance is modulated to produce reflection in the line to change the phase of feed back to the tube input electrodes to thereby change the frequency of operation. Some amplitude modulation may be produced and in a modification this undesired amplitude modulation is compensated by additionally modulating the potential supplied to an electrode of one tube in the proper sense.

Other objects and the manner in which they are attained will appear in the detailed description which follows.

In describing my invention reference will be made to the attached drawings wherein Figs. 1 and 2 each illustrates the essential features of two embodiments of my wave length modulation system. Fig. 3 is a modification of Fig. 2.

In my system, as illustrated in Fig. 1, two electron discharge devices V1 and V2 have their anodes 6 and 8 tied together and connected to a tuned tank circuit C1—L1. A point on this tank circuit is connected to ground by a bypass condenser 10 which shunts a source of direct current potential not shown. The cathodes of tubes V1 and V2 are grounded so that they are effectively connected for radio frequency voltages to the point 12 on the inductance L1. A transmission line designated at L is connected at one terminal to a point 14 on line L1. Line L is shown as a concentrated reactance having distributed capacity to ground, the distributed capacity being indicated by condenser 16. Since the point 12 is grounded at the generated frequency, the generated voltage between points 12 and 14 is fed to the line. The line may be a simple two-conductor arrangement, such as, concentric conductors or may comprise wound inductance as shown. Where the distributed capacity to ground is insufficient, additional capacities 16 may be supplied. The control grids 26 and 28 are connected to two points 20 and 24 on the line and are excited by the voltages fed back over the line. The points 20 and 24 are spaced on the line an amount substantially equal to $\lambda/4$, or an odd multiple thereof.

To obtain regeneration it is, of course, essential that the voltages on the grids 26 and 28 are substantially opposed to the voltages on the anodes 6 and 8. In my system, the control grids 26 and 28 are excited in phase quadrature, but the phase of the voltage at the intermediate point 35 between points 20 and 24 is opposed to the phase of the voltage on the anodes 6 and 8 so that the grid excitation voltages are sufficiently opposed to the anode voltages to insure generation of oscillations.

Then the feed-back voltage to the grids of tubes V1 and V2 is in opposition to the plate voltage except for the $\lambda/4$ shift which occurs between said median point 35 and the points 20 and 24. With this adjustment and dimensioning of the line regeneration is provided and oscillation generation assured.

Where the line L is connected to a point on L1 at which the voltage phase is opposed to the phase of the voltage at the anodes of V1 and V2 the length of the line between the said point on L1 and the median point 35 must be equal to $N(\lambda/2)$ where N is a whole even number equal to at least 2. Where the line L is connected to a point on line L1 at which the voltage phase is substantially the same as the voltage phase at the anodes of tubes V1 and V2, say point 13, then the length of the line between said point 13 on L1 and the median point 35 should be $N(\lambda/2)$ where N is a whole odd number at least equal to 1. This adjustment would be necessary when L is connected to L1 at a point, say 13, above the point on L1 grounded by condenser 16.

The line L is terminated by a variable resistance R1 which with tube resistance of V3 in the unmodulated condition is adjusted to match the surge impedance of the line. Two points 20 and 24 on the lines are connected to the grids 26 and 28 respectively of tubes V1 and V2. These connections include grid blocking condensers C2 and C3. The length of the line included between the points 20 and 24 should be substantially equivalent to $\lambda/4$. The points 20 and 24 may be moved along the line and moved relative to each other, provided the spacing between the two points is such that the reactance therebetween is substantially equal to $\lambda/4$, or an odd multiple.

The end of the line, as stated above, is shunted by an impedance and this impedance may comprise R1 and the impedance between the anode and cathode of the tube V3 or the latter impedance alone. The tube V3 is the modulator tube and has its control grid 30 coupled by resistance R4 to its cathode through the secondary winding of a modulation transformer T. The resistance R4 serves to supply the bias for grid 30 and also feeds the modulation to said grid 30. Blocking condenser 34 and by-pass condenser 36 completes this modulated circuit. The primary winding of this transformer is coupled to a modulation source A. The cathode of tube V3 is con-

nected to ground and to the ground side of line L.

For operation, the system is adjusted as follows: The tube V3 is biased and supplied with anode direct current voltage of such a value that the desired average current therethrough is obtained under conditions of no modulation. The tube at this point may have an output impedance substantially equal to the surge impedance of the line. However, where it has not, an additional resistance R1 is supplied. I now adjust the value of resistance R1 until the radio frequency voltages of the generated frequency fed to both tubes V1 and V2 are of equal amplitudes. Equality of these radio frequency currents is indicated by equal currents in the ammeters AM in the grid to cathode circuits of the tubes. When this point of equal radio frequency excitation on the grids 26 and 28 is reached, the surge impedance of the line is matched by R1 and the anode to cathode impedance of V3. Under these conditions, there is no reflection back along the line and no standing waves on the line. The tubes V1 and V2 will now generate oscillations of a substantially fixed frequency, which represents the carrier frequency of the transmission system.

Now if we lower the output impedance of tube V3 by say increasing the positive grid potential thereof, the line surge impedance is no longer matched. This causes reflection on the line so that standing waves are set up on the line and the radio frequency excitation on the respective tube grids changes, that is, the grid excitation of these tubes is no longer equal so that the tubes no longer feed equal amounts of current to the tank circuit and the energy therein takes up a new phase, which is more nearly the phase of that tube feeding the greatest amount of energy to the tank circuit. In the arrangement shown the radio frequency on the grid of tube V1 drops when the impedance of tube V3 is lowered and the radio frequency excitation on the grid 28 of tube V2 goes up. When the output impedance of tube V3 is raised, the radio frequency excitation on the grid of tube V1 goes up and the radio frequency excitation on the grid of tube V2 goes down.

Since these two tubes have their grids excited in phase quadrature and since their anodes are connected in parallel to the tank circuit, the phase of the feed-back energy shifts between two limits set by the phase displacement of the excitation voltages, and since the system is regenerative, the action is accumulative and results in frequency modulation of the output in the tank circuit.

As stated above, the points of connection between the grids of V1 and V2 may be moved along the line provided the voltages picked off thereby are displaced by about 90°. Moreover, the position of the connections may be reversed and this may be done by moving the switch 40 to the contact 42.

One of the tubes, V1 or V2, may be omitted and the system will still operate to generate the frequency modulated carrier. However, in this modification amplitude modulation will be produced and more care must be taken in limiting the output.

In the system described above and illustrated in Fig. 1 some amplitude modulation may be caused due to the fact that the radio frequency voltages picked off or taken from the line and supplied to the control grids 26 and 28 may not vary equal amounts during modulation. To correct this, I supply an additional tube V4 and connect this tube in a push-pull circuit with tube V3 as shown in Fig. 2. The modulation excitation of the grid 31 is adjusted to the proper value for compensation purposes. The anode of this tube is connected to the grid 28 of tube V2 by a connection at point 24 as shown and since the arrangement is a push-pull modulator, additional modulation of the potential on the grid 28 in accordance with the modulation potentials is supplied. This modulation by tube V4 is in a direction to compensate for and balance out the amplitude modulation caused by tube V3 during the wave length modulation process.

In case it is desired to use high impedance tubes at V3 and V4 in Figs. 1 and 2 an auto-transformer TA may be used to step down the tube impedance looking into line L as illustrated in Fig. 3.

It will be understood that by modifying the modulating potentials in a well-known manner phase modulation may be accomplished in the system.

I claim:

1. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a tuned tank circuit, connections tying said anodes together and to one end of said tank circuit, a coupling between the cathode of said tubes and a point on said tank circuit, a two-wire transmission line comprising reactance including distributed capacity, a coupling between one end of said line and the reactance of said tank circuit, a variable impedance in shunt to the other end of said line, said variable impedance substantially matching the surge impedance of said line, connections coupling the control grids of said tubes and spaced points on said line to feed voltages to said control grids which substantially oppose the voltages on the anodes of said tubes whereby oscillations are generated in said tubes and set up in said tank circuit, the distance between said points being substantially equal $\lambda/4$, where λ is the length of the oscillations generated, and means for controlling said variable impedance in accordance with signals.

2. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control electrode, a tank circuit including an inductance, connections tying the anodes of said tubes together and to a point on said tank circuit, connections coupling the cathodes of said tubes together and to a second point on said tank circuit, a transmission line having a length equal to $N(\lambda/2)+\lambda/8$ where N is a whole number at least equal to 1, a connection between one end of said line and the inductance of said tank circuit, a surge matching impedance connected to the other end of said line, said surge matching impedance including the impedance between the output electrodes of an additional tube, connections coupling the control electrodes of said devices to points on said line spaced a distance substantially equal to $\lambda/4$, means for adjusting the impedance at the said other end of said line to a value at which it matches the surge impedance of said line, and means for modulating the impedance of said additional tube in accordance with signals.

3. In a wave length modulation system, an electron tube generator having a control electrode and having a tank circuit coupled to its anode, a transmission line having one end coupled to said tank circuit and the other end coupled to the control electrode of said tube to feed thereto a voltage the phase of which is substantially opposed to the phase of the generated voltage on the anode of said tube, a variable impedance sub-

stantially equal to the surge impedance of the line shunting said other end of said line, means for controlling said impedance in accordance with signals to thereby vary the phase and amplitude of the voltage fed to said control electrode of said tube and means for compensating the effect of said variations in the amplitude of said voltage fed to the control electrode of said tube.

4. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a tuned tank circuit, connections tying said anodes together and to one end of said tank circuit, a coupling between the cathode of said tubes and a point on said tank circuit, a two-wire transmission line comprising reactance including distributed capacity, a coupling between one end of said line and the reactance of said tank circuit, a variable impedance in shunt to the other end of said line, said variable impedance matching the surge impedance of said line, connections coupling the control grids of said tubes to points on said line, the distance between which is substantially equal to $\lambda/4$, means for controlling said variable impedance in accordance with signals, and means for compensating for undesired amplitude variation of the voltages in said line caused by variation of said impedance.

5. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a tank circuit including an inductance, connections tying the anodes of said tubes together and to said tank circuit, connections coupling the cathodes of said tubes together and to a point on said tank circuit, a transmission line having a length equal to $N(\lambda/2)+\lambda/8$ where N is a whole number at least equal to 1, a connection between one end of said line and the inductance of said tank circuit, a surge matching impedance connected to the other end of said line, said surge matching impedance including the impedance between the output electrodes of an additional tube, connections coupling the control devices of said devices to points on said lines spaced a distance substantially equal to $\lambda/4$, means for adjusting the impedance at the end of said line to a value at which it matches the surge impedance of said line, means for modulating the impedance of said additional tube in accordance with signals, a modulation compensating tube having output electrodes coupled to one of said first named devices and means for modulating the impedance of said second tube in accordance with said signals.

6. In a signalling system, wave generating means including a pair of electron discharge tubes each having an anode, a cathode, and a control grid, a tank circuit including an inductance, connections tying the anodes of said tubes together and to a point on said tank circuit, connections coupling the cathodes of said tubes together and to a point on said tank circuit, a transmission line having a length equal to N times $180°+\lambda/8$ where N is a whole number at least equal to 1 and λ is the length of the waves to be generated, a connection between one end of said line and the inductance of said tank circuit, a surge matching impedance connected to the other end of said line, said surge matching impedance including the impedance between the output electrodes of an additional electron discharge device, connections connecting the control grids of said tubes to points on said lines spaced a distance equal to $\lambda/4$, whereby wave energy is generated in said tubes and tank circuit, means for adjusting the impedance at the said other end of said line to a value at which it matches the surge impedance of said line and means for modulating the impedance of said device in accordance with said modulating potentials to correspondingly modulate the impedance at the said other end of the line and correspondingly modulate the length of the waves generated.

7. In a wave length modulation system, an electron tube generator having a control electrode and having a tank circuit coupled to its anode, a transmission line having a length about equal to N $(\lambda/2)$ where N is a whole number at least equal to 1, a coupling between one end of said line and said tank circuit, a coupling between the other end of said line and the control electrode of said tube to feed thereto generated voltage the phase of which is substantially opposed to the phase of the generated voltage on the anode of said tube whereby wave energy is generated in said tube, a variable impedance substantially equal to the surge impedance of the line shunting said other end of said line, connections for controlling said variable impedance in accordance with signals to correspondingly vary said phase relation of the voltages on the control electrode and the anode of the tube to thereby vary the length of the wave energy generated, and connections for compensating undesired amplitude modulation of the wave energy caused by variations of the amplitude of the voltage fed to said control grid due to controlling said impedance in accordance with signals.

8. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control electrode, a tank circuit, connections tying the anodes of said tubes together and coupling them to a first voltage point on said tank circuit, connections coupling the cathodes of said tubes together and to a second voltage point on said tank circuit, a transmission line having a length equal to N $(\lambda/2)+\lambda/8$ where N is a whole number at least equal to 1, a coupling between one end of said line and said tank circuit, a surge matching impedance connected to the other end of said line, said surge matching impedance including the impedance between electrodes of an additional tube, connections coupling the control electrodes of said devices to points on said transmission line spaced apart a distance substantially equal to $\lambda/4$, means for adjusting the impedance at the said other end of said transmission line to a value at which it matches the surge impedance of said line, and means for modulating the impedance of said additional tube in accordance with signals.

9. A system as recited in claim 8 wherein N is an odd number and said coupling between said one end of said line and said tank circuit and said point on said tank circuit to which the anodes are coupled are on the same side of the said second point on said tank circuit to which the cathodes are coupled.

10. A system as recited in claim 8 wherein N is an even number and said coupling between said one end of said line and said tank circuit and said point on said tank circuit to which the anodes are coupled are on opposite sides of the said second point on said tank circuit to which the cathodes are coupled.

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