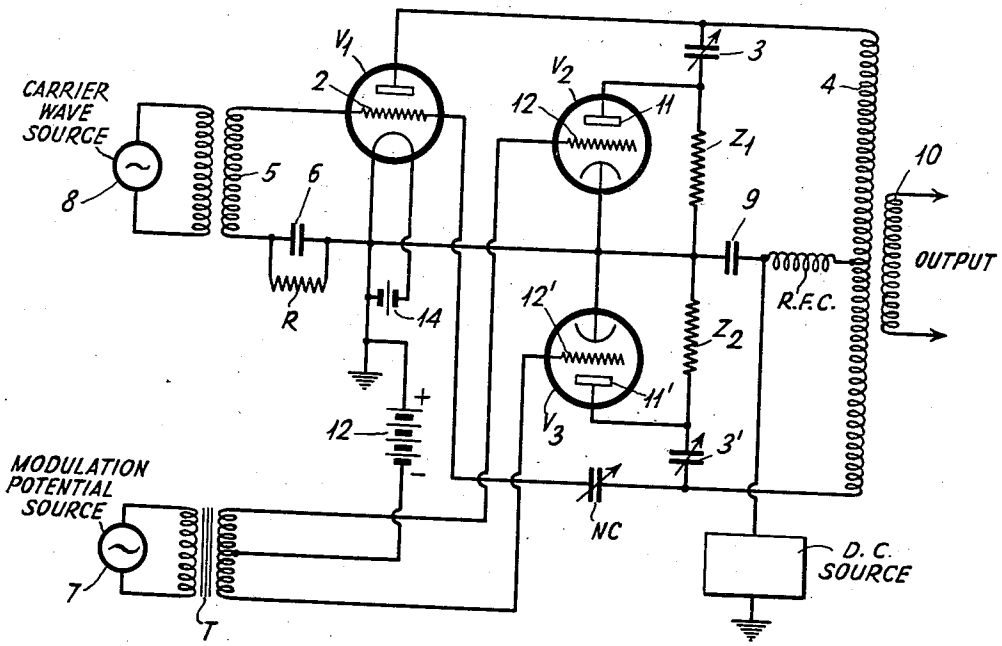
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PHASE MODULATION

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PHASE MODULATION

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7 Claims. (Cl. 179—171.5)

For various reasons it has been found desirable in the radio and allied arts to signal by means of alternating current of substantially constant amplitude, the current being modulated in one or more of its other characteristics at signal frequency. I propose to supply such a need by providing a novel and simple means whereby wave energy of substantially constant amplitude may be modulated in phase at signal frequency.

This application is a division of my United States application #46,857 filed October 26, 1935, U. S. Patent #2,159,237, dated May 23, 1939.

More in particular, this application concerns a phase modulator or oscillator, or high frequency vacuum tube relay stage, wherein phase modulation of the high frequency energy is obtained by virtue of the phase shift in the feedback energy occurring with over or undue neutralization or, in other words, by regeneration or degeneration. This effect may be accompanied by a small amount of amplitude modulation and a much larger amount of phase modulation if the change in neutralization is not carried too far, and especially if the driving energy or excitation energy is strong.

In a modification, I provide means for protecting the tubes of the modulator or oscillator stage or relay stage in the event of defective operation of any of the circuits thereof.

In describing the essential features of my invention, reference will be made to the drawing in which the single figure illustrates a circuit diagram in accordance with a preferred embodiment of the invention.

The single figure of the drawing shows, for purposes of illustration only, circuit arrangements comprising the essential features of a phase modulation system wherein phase modulation is accomplished by over-neutralizing or under-neutralizing the thermionic stage through which the wave energy is passed. In the circuit of the single figure wave energy to be modulated is fed to the input of an electron discharge tube having a plate circuit including a neutralizing portion and including two impedances controllable in opposition at signal frequency to thereby control the state of neutralization or lack thereof to control the phase of the output energy.

Referring to the drawing, and in particular to the single figure of the drawing, V_1 is an electron discharge tube of the thermionic type having its control grid 2 coupled by a grid circuit 5, 6, R to an inductance coupled with a source of carrier wave energy 8. The tube V_1 has its anode connected by an inductance 4 and choking inductance RFC and blocking condenser 9 to its cathode. The inductance 4 is coupled to the inductance 10 in an output circuit which may lead to any utilized device directly or by way of amplifiers and frequency multipliers and amplitude limiters, etc. The circuit 3, 4, may be tuned to the frequency of the source 8 in the event the oscillations are to be repeated or amplified only, or to a harmonic of said frequency in the event the stage V_1 is also to act as a frequency multiplier. A point on the inductance 4 may be coupled to the control grid 2 by means of a neutralizing condenser NC. The circuit described herein comprises a high frequency relay or amplifier or frequency multiplier. The means for phase modulating the high frequency energy in the relay will now be described.

Modulating potentials from source 7 are impressed by way of a transformer T in phase opposition on the control grids 12, 12' of modulator tubes V_2 and V_3. Impedance elements Z_1 and Z_2 are connected across the inductance 4 by means of the variable capacities 3, 3'. The anodes 11 and 11' of tubes V_2, V_3 are connected as shown to the impedances Z_1 and Z_2. The cathodes of tubes V_2 and V_3 are connected to the other terminals of the impedances Z_1, Z_2 and to the cathode of V_1 and to ground. The impedances Z_1, Z_2 may be inductive or may be a combination of inductance and resistance. Potential for the anode of tube V_1 is supplied from a direct current source connected to the inductance 4 by way of the radio frequency choke RFC. Biasing potential for the grids of tubes V_2, V_3 is supplied from a source 12, connected as shown between a point on the secondary of T and the cathodes of tubes V_2, V_3. Heating current for the cathode of tube V_1 is supplied from any source 14 connected therewith, as shown.

In describing the operation of the phase modulator of the single figure of the drawing, it will be assumed that the stage V_1 is normally neutralized by the circuits including the condenser NC. In this case, the reactance of the condenser NC equals the plate-to-grid reactance of tube V_1. Also assume that the stage V_1 is receiving high frequency wave energy from 8 and delivering the high frequency energy amplified or frequency multiplied or amplified and frequency multiplied to the output circuit 10. Also assume that the audio frequency energy from source 7 is being supplied to the transformer T, and in addition, take an instant when the grid 12 of modulator tube V_2 is positive, and the grid 12' of modulator tube V_3 is negative. This condition causes the combined impedance of Z_1 and V_2 to decrease and that of Z_2 and V_3 to increase. Now, the tank circuit 3, 4 is unbalanced so that it is no longer neutralized with respect to the grid circuit 5, 6, R. In this case, regeneration takes place or there is a tendency to regeneration because energy is fed back through the neutralizing condenser NC (now being at a higher radio frequency voltage) to the grid 2 of V_1, thereby overbalancing the energy fed back by way of the

internal capacity of the tube from the anode to the grid. In this case, the phase of the energy or oscillations in the anode circuit 3, 4 is advanced ahead of the phase of the oscillations in the grid tank circuit 5, 6.

Now, if we assume an instant in the radio frequency cycle when the grid of V_3 is positive and the grid of V_2 is negative, conditions will be reversed. The combined impedance of V_3 and Z_2 will be reduced and the combined impedance of V_2 and Z_1 will be increased. This causes an unbalance in neutralizing again because the high frequency voltage of the anode and of the circuit 3, 4 is now higher than the high frequency voltage of the neutralizing end of the tank circuit 3, 4. In this case, more energy is fed to the grid 2 of tube V_1 from the anode thereof than by way of NC, thereby causing degeneration or a tendency of degeneration, and the phase of the high frequency oscillations in the circuit 3, 4 is retarded with respect to the high frequency oscillations in the grid circuit 5, 6.

It will be seen that with reversal of the direction of current from the audio frequency source 7, corresponding changes in phase will take place in the high frequency energy in the output of stage V_1. The frequency of phase shift corresponds to the audio frequency and the degree or amount of phase shift or modulation corresponds to the intensity or amplitude of audio frequency energy. The direction of phase shift corresponds to the direction of audio current.

Phase modulated energy output from stage V_1 may be used in any manner desirable. It may be amplified, multiplied in frequency, limited as to amplitude, or one or more of said operations may be accomplished and the energy may then be transmitted over wires or over an antenna.

I claim:

1. In a phase modulation system a thermionic tube having an anode, a cathode, and a control grid, alternating current circuits connected between the control grid and cathode of said tube and between the anode and cathode of said tube, means for impressing wave energy to be modulated on said grid and cathode, means for neutralizing the capacity between the anode and control grid of said tube, and means connected with said tube for upsetting and restoring said state of neutralization at signal frequency to produce degeneration and regeneration in said tube and circuits to thereby vary at signal frequency the phase of the wave energy in the alternating current circuit connected with the anode and cathode of said tube relative to the phase of the impressed wave energy.

2. In a phase modulation system, a thermionic tube having an anode, a cathode and a control grid, an alternating current circuit connected between the control grid and cathode of said tube, an output circuit connected to the anode and cathode of said tube, means for causing wave energy to be modulated to flow in said circuits, a voltage transfer path, including a reactance of the order of the reactance in the path between the anode and control grid of said tube, connected between a point on said output circuit and the grid end of said alternating current circuit whereby said tube and circuits are neutralized as to the wave energy flowing in said circuits, and means operated at signal frequency for controlling the voltage transferred over said respective baths.

3. In a phase modulator, a thermionic tube having an anode, a cathode and a control grid, a circuit for applying wave energy to said control grid and cathode, an alternating current circuit coupled to said anode and cathode, a neutralizing circuit coupled between said alternating current circuit and said control grid to neutralize the capacity between the anode and control grid of said tube, a variable impedance connected with said neutralizing circuit, and a source of modulating potentials connected with said variable impedance.

4. In a phase modulator, a thermionic tube having a control grid, a cathode and an anode, an alternating current circuit connected to the control grid and cathode, an alternating current circuit including an inductance connected with the anode and cathode, a neutralizing condenser connecting a point on said inductance to the control grid of said tube, variable reactances connected in series in shunt to said inductance, a source of modulating potentials connected in phase opposition to said variable reactances, and means for applying a driving potential to the control grid of said tube.

5. In a phase modulator, a thermionic tube having a control grid, a cathode and an anode, an alternating current circuit connected to the control grid and cathode, an alternating current circuit including an inductance connected with the anode and cathode, a neutralizing condenser connecting a point on said inductance to the control grid of said tube, variable impedances connected in series in shunt to said inductance, a connection between a point on said impedances and the cathode of said tube, means for applying modulating potentials in phase opposition to said variable impedances, and means for applying a driving potential to the control grid of said tube.

6. In a phase modulator in combination, amplifying means including an electron discharge tube system having electrodes including a grid and anode connected in input and output circuits respectively wherein high frequency currents are caused to flow, a reactance in said output circuit connected to said anode, a pair of dissimilar voltage feedback paths from said output to said input circuit, one of said paths comprising the capacity between said anode and control grid and the other path comprising a capacity coupling said reactance to said input circuit, and means for varying the ratio of energies fed back through said feedback paths in accordance with signalling potentials to thereby vary the phase of the high frequency currents caused to flow in said output circuit comprising a pair of modulating tubes having their impedances shunting said reactance and modulated differentially by signal potentials.

7. In a phase modulator in combination, an electrone discharge tube system having electrodes connected in input and output circuits wherein high frequency currents are caused to flow, a reactance in said output circuit, a pair of dissimilar feedback paths from said output to said input circuit one of said paths comprising a capacity between tube electrodes the other comprising a capacity connecting said reactance to said input circuit, an impedance of the tube type connected in shunt to said reactance and differentially modulated in accordance with signalling potentials to thereby differentially control the voltage fed back over said respective paths and consequently vary the phase of the currents flowing in said output circuit.

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