July 22, 1941. M. G. CROSBY 2,250,296

PHASE MODULATION

Original Filed Sept. 21, 1933

Fig. 1

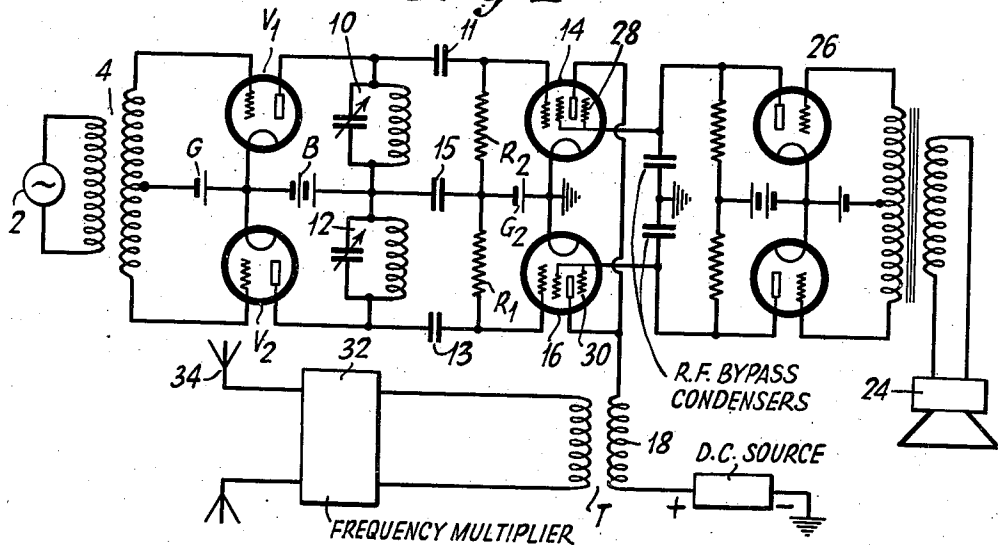


Fig. 2

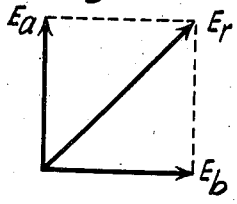
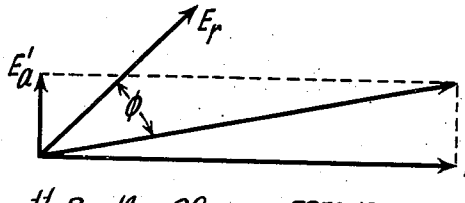


Fig. 3



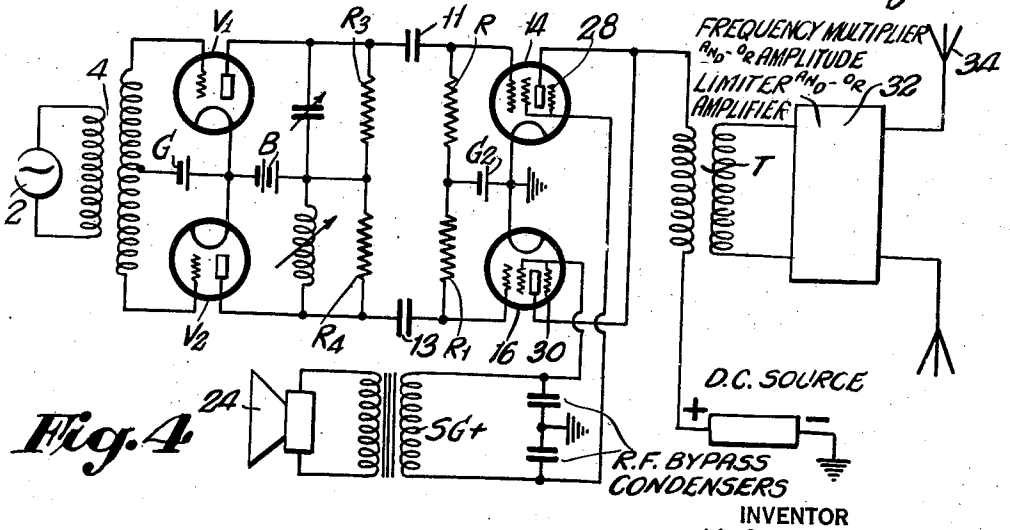


Fig. 4

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UNITED STATES PATENT OFFICE

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PHASE MODULATION

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Original application September 21, 1933, Serial No. 690,330, now Patent No. 2,165,229, dated July 11, 1939. Divided and this application October 6, 1938, Serial No. 233,539

4 Claims. (Cl. 179—171.5)

This invention relates to the signalling art and pertains especially to the transmission of intelligence from one geographically separated point to another by the use of phase modulated waves or carrier energy. This application is a division of my United States application Serial #690,330, filed September 21, 1933, now Patent #2,165,229 issued July 11, 1939.

An object of my present invention is to provide a new and useful system for producing a phase modulated wave of substantially constant frequency and amplitude. To do so I provide an arrangement and a method wherein two carrier frequency voltages of substantially like frequency are combined less than 180 degrees out of phase, or any multiple of less than 180 degrees out of phase, to produce a resultant voltage. According to my invention the phase of the resultant voltage is varied at signal frequency by varying the relative values of the voltages combined at a signal frequency rate and an amount proportional to the amplitude of the signal frequency, limited, of course, by the phase shift referred to above imparted to the two portions of the carrier. The voltages may be phase shifted and amplitude modulated before combining or amplitude modulated and then phase shifted before combining.

Any amplitude modulation caused in the resultant phase modulated wave may be eliminated by limiting the resultant energy. To do so the energy may be passed through electron discharge devices operated at their saturation point.

More specifically, according to my present invention, I carry out the foregoing objects by introducing in the circuits of a pair of electron discharge devices voltages of like frequency a predetermined number of degrees out of phase such that the phase difference is not 0°, 180° or any whole multiple of 180°, although phase differences varying slightly from 0°, 180°, etc., are suitable. The outputs of the devices are so combined that there is a resultant voltage of like frequency. To vary the phase of this resultant voltage, or, in other words, the phase of the resultant carrier energy, I vary oppositely the internal impedances of the electron discharge devices. In a modification the order of the operations may be reversed or changed. The present invention relates to improvements in phase modulators of the type disclosed in my United States application Serial No. 588,309, filed January 23, 1932, now Patent #2,081,577, issued May 25, 1937.

As required by law, my present invention is defined with particularity in the appended claims. However, it may best be explained both as to its structural organization and mode of operation by referring to the accompanying drawing wherein:

Figure 1 is a wiring diagram of a phase modulation transmitting system according to my present invention;

Figures 2 and 3 are vector diagrams given in order to explain the operation of the system shown in Figure 1; while,

Figure 4 is a wiring diagram of a modified phase modulator arranged in accordance with the present invention.

Turning to Figure 1, illustrating a transmitter for generating and transmitting phase modulated energy, carrier energy or potentials from an oscillation generator **2** are fed to the primary winding of a transformer **4**, the secondary winding of which is symmetrically divided and connected as shown to the control grids of two discharge devices V_1 and V_2. The generator **2** may be a crystal controlled oscillator, or any other form of substantially constant frequency oscillation generator. The oscillations from **2** are applied in phase opposition to the control grids of V_1 and V_2. Biasing potentials for the control grids of V_1 and V_2 are supplied from the source G connected as shown.

The anodes of tubes V_1 and V_2 are connected, as shown, through tuned circuits **10** and **12** respectively and a source of anode potential B to the cathodes of said tubes, which are connected together, as shown. The anodes of tubes V_1 and V_2 are also connected, as shown, by way of blocking condensers **11** and **13** to the control grid electrodes of tubes **14** and **16** respectively. Biasing potentials for the control grid electrodes of tubes **14** and **16** respectively are supplied from a source G_2 connected, as shown, by way of resistances R_1 and R_2 to the control grids of tubes **14** and **16** respectively. The point of connection between the resistances R_1 and R_2 is connected, as shown, by way of a condenser **15** to the terminal of the source B. The anode electrodes of tubes **14** and **16** are connected together and to the cathodes by way of an inductance **18** and a direct current source. The inductance **18** may form the primary winding of a transformer T, the secondary winding of which may be connected to a utilization circuit.

The tuned circuits **10** and **12** serve as plate impedances of the coupling tubes and also as phase adjusters to adjust the phase of the amplified carrier fed to the grids of the modulator tubes **14** and **16** respectively. By tuning one of these tuned circuits, for example, **10**, on the in-

ductive side of resonance, and the other of the tuned circuits, as, for example, 12, on the capacitive side of resonance, the phase of the voltage applied to the grid of one of the tubes 14 and 16, is made lagging and to the other leading. Adjustment for a 45° lag and 45° lead will make a total phase difference of 90° difference. Since the carrier voltages are fed to the carrier tubes 180° out of phase by the push-pull input transformer 4, the total phase difference between the two modulator grid voltages will be 180° plus 90° or 270°. However, the optimum phase adjustment of the two differentially modulated voltages to produce phase modulation may be either 90° or any odd multiple of 90°, so that 270° is equally as effective as 90°. This has been explained in considerable detail in United States Application No. 588,309, filed January 23, 1932, now Patent #2,081,577, issued May 25, 1937.

The vectorial relationship of the voltages in circuits 10 and 12 is illustrated in Figure 2 for the particular case of 90 degrees separation where E_a illustrates the voltage in circuit 10 and E_b indicates the alternating voltage in circuit 12. These voltages are applied, as shown, to the control grids of tubes 14 and 16 to be amplified therein and consequently in the output circuit 18 of tubes 14, 16 there appears voltage E_r as shown in Figure 2. This is a resultant voltage which is of a frequency equal to the frequency of the voltage applied from source 2.

By oppositely varying the output of each of the two electron discharge devices 14, 16, the resultant may be made to shift between E_a and E_b as limits, as shown, in Figure 3. The shift may be from E_r to E'_r, as indicated. This shift in phase is accomplished by relatively decreasing the amplified voltage E_a appearing in the output circuit due to the amplifier action of tube 14 and relatively increasing amplified voltage E_b from tube 16 appearing in the output circuit and vice versa.

In order to cause this opposite variation in voltages in tubes 14, 16, modulation energy from a suitable source 24 and amplified by push-pull amplifier 26 is fed as indicated in opposite phase to the screen grids 28, 30 of tubes 14, 16. Consequently, the internal impedances of tubes 14 and 16 are varied oppositely and, as a result, their outputs are varied inversely to their internal impedances, thereby causing a phase shift of the resultant energy appearing in the output circuit 18 of the tubes. The phase modulated energy so appearing in the output circuit 18 of electron discharge devices 14, 16 may then be amplitude limited, and/or frequency multiplied, and/or amplified by a suitable device in 32 and radiated or propagated through space in the form of electromagnetic wave energy by means of a suitable antenna 34, or may be utilized directly from 18.

As will be evident from an inspection of Figure 3, the greatest amount of phase shift possible with the scheme so far described is a value less than 180 degrees, or with 90 degrees phase displaced voltages, 90 degrees; and it is also evident that this arrangement introduces a small amount of amplitude modulation. To eliminate the amplitude modulation a thermionic relay device in 32 may be operated at all times at its saturation point. To increase or augment the relative amount of phase modulation, the apparatus 32 may include also some form of frequency multiplier.

The arrangement of Figure 4 resembles the arrangement of Figure 1 in some respects. In Figure 4, as in Figure 1, the carrier frequency oscillations are fed by way of transformer 4 in phase opposition to the control grids of tubes V_1 and V_2. In Figure 4, however, the phase shift is obtained by means of the resistance capacity combination in the anode circuit of V_1 and the inductance resistance combination in the anode circuit of coupling tube V_2. A 45° phase lead is obtained by means of the resistance capacity circuit in the anode of V_1, and a 45° phase lag is obtained by means of the resistance inductance combination in the anode lead of V_2. This will be clear when it is remembered that if equal capacity and inductance were presented in these circuits, the capacity reactance drop would lead 90° and the inductive reactance drop would lag 90°. Hence, by adding parallel resistance to the capacity and inductance, as shown, the drop is made partially resistive and partially reactive. By making the resistive and reactive components equal, the phase lead or lag is 45°. Thus, the voltages of the two anode circuits are 90° plus 180°, due to the push-pull carrier input transformer, or a total of 270° out of phase, which is an optimum amount. Of course the same results would be obtained if the carrier frequency oscillations were fed in phase to the grids of tubes V_1 and V_2 in a manner similar to that in which they are fed to the grids of the tubes in the arrangement of Figure 4 of the parent case.

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

1. A signalling system comprising, a source of carrier frequency oscillations, a source of modulating potentials, a pair of thermionic tubes, each having an anode, a cathode, and a control grid, an input circuit connected between the control grid and cathode of each of said tubes, said input circuits being coupled to said source of carrier frequency oscillations, physically and electrically independent phase shifting means in each of said input circuits, means for applying modulating potentials from said source to the screen grid electrodes in said tubes in phase opposition, and a load circuit coupled to the output electrodes of said tubes.

2. A phase modulating system comprising, an output circuit, a source of modulating potentials, a source of high frequency oscillations, a pair of thermionic tubes having their anode circuits coupled to said output circuit, phase shifting circuits, each of which includes resistance and reactance coupling the input electrodes of said tubes to said source of high frequency oscillations to apply relatively phase shifted carrier frequency waves to said tubes, and circuits for applying modulating potentials to like auxiliary electrodes in said tubes in phase opposition, whereby the carrier frequency waves applied to said tubes are differentially modulated in amplitude and combined in the output circuit to produce a phase modulated wave.

3. A signalling system comprising, a source of carrier frequency oscillations, a source of modulating potentials, a pair of thermionic tubes, each having an anode, a cathode, and a control grid, symmetrical input circuits connecting the control grids and cathodes of said tubes, said input circuits being coupled to said source of carrier frequency oscillations, phase shifting output circuits including resonant loop circuits connected to the output electrodes of each of said tubes, differential amplitude modulating circuits connected with each of said output circuits, said modulating circuits each including a tube and a load circuit

coupled to the output electrode of each of said tubes.

4. A signalling system comprising, a source of carrier frequency oscillations, a source of modulating potentials, a pair of electron discharge tubes, each having an anode, a cathode and a control grid, similar input circuits interconnecting the control grids and cathodes of said tubes, means coupling said input circuits to said source of carrier frequency oscillations, an output circuit connected to the anode and cathode of each of said tubes, tuned reactances in each of said output circuits, for tuning one of said output circuits to a frequency slightly above the frequency of said carrier frequency oscillations, and for tuning the other of said output circuits to a frequency slightly below the frequency of the carrier frequency oscillations, said reactances serving to relatively phase shift the carrier frequency oscillations in the two output circuits, differential amplitude modulating circuits connected with said output circuits, and a load circuit coupled to said output circuits.

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