June 29, 1937. M. G. CROSBY 2,085,418

VARIABLE TERMINAL IMPEDANCE SIGNALING SYSTEM

Filed Dec. 27, 1933 4 Sheets-Sheet 1

Fig. 1

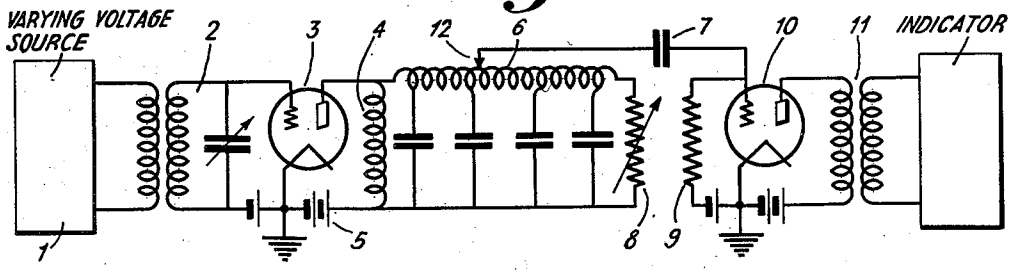


Fig. 2

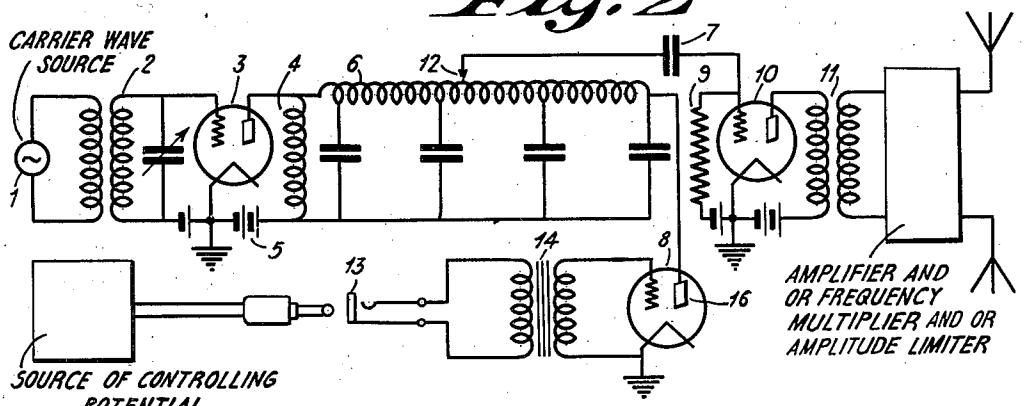
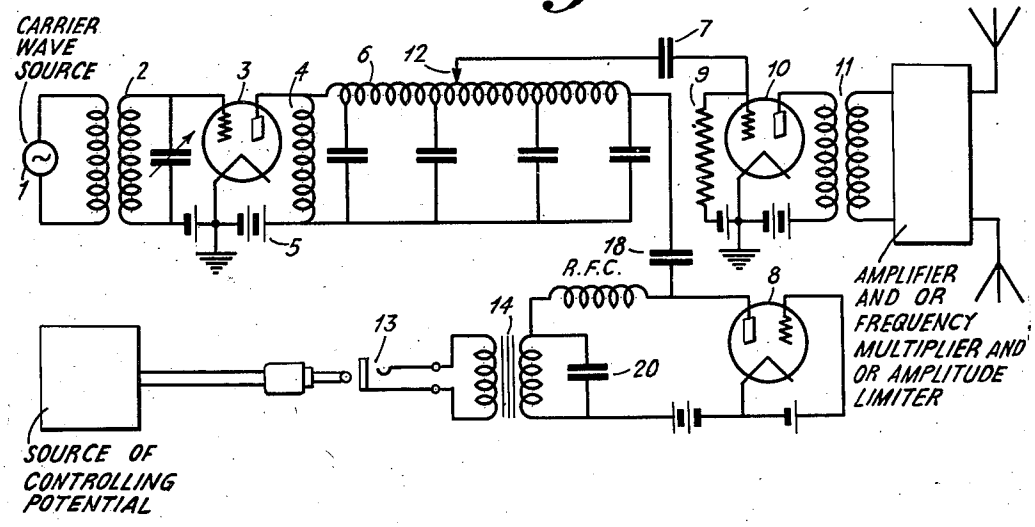


Fig. 4



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VARIABLE TERMINAL IMPEDANCE SIGNALING SYSTEM

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Fig. 3

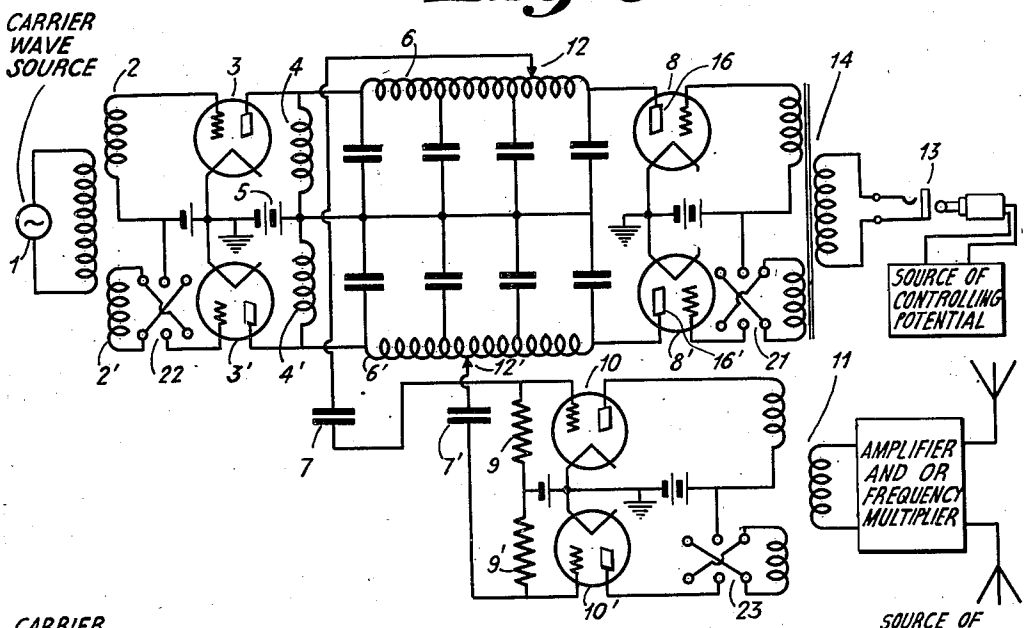
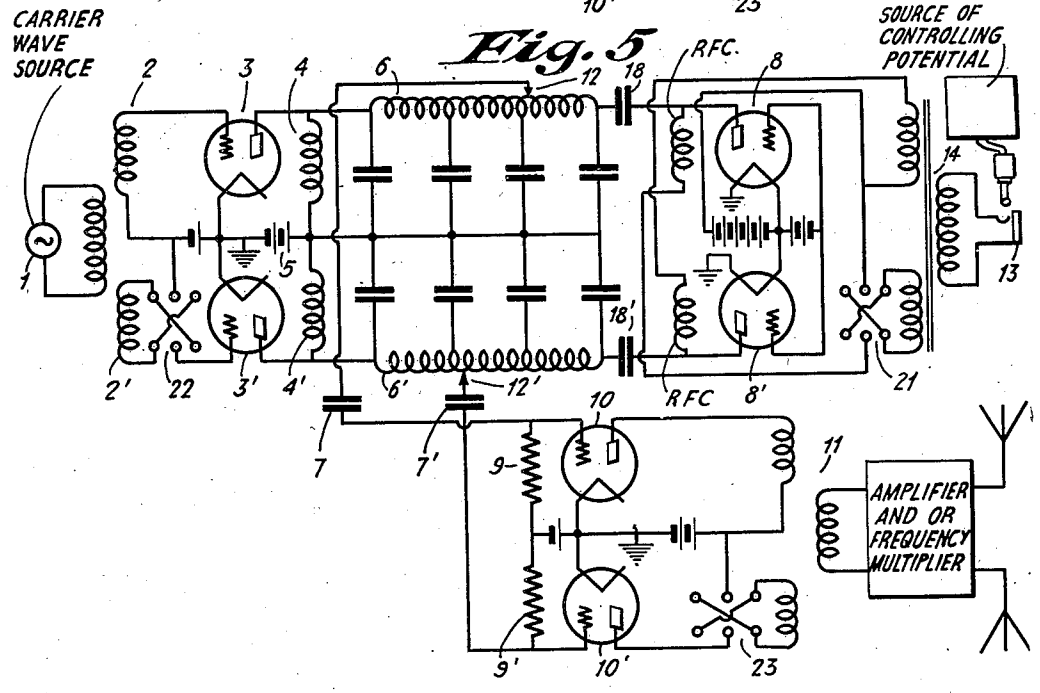


Fig. 5



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VARIABLE TERMINAL IMPEDANCE SIGNALING SYSTEM

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Fig. 6

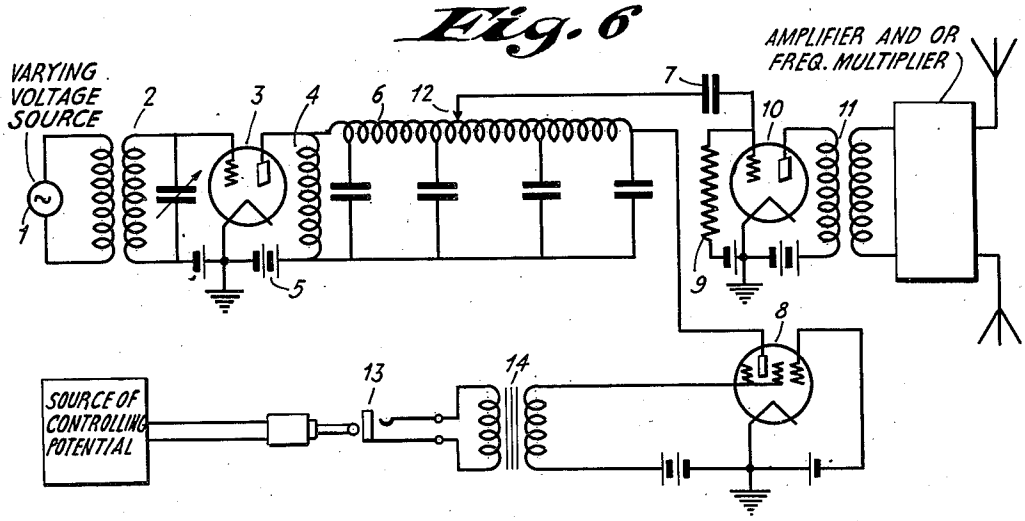
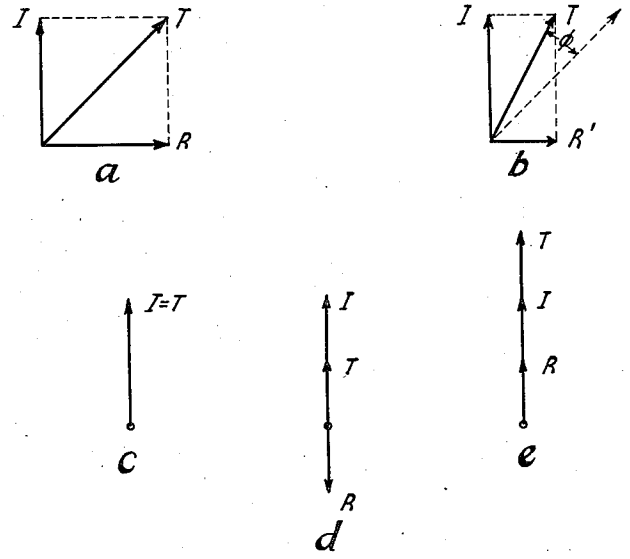


Fig. 7



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VARIABLE TERMINAL IMPEDANCE SIGNALING SYSTEM

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Fig. 8

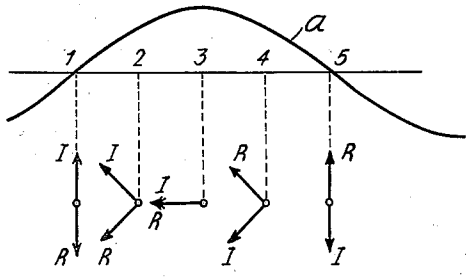


Fig. 9

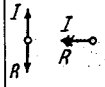
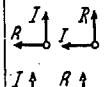
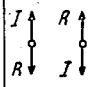
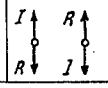
TAP POINTS	TAP POINT VECTOR RELATIONS	R. F. COMBINATION	RESULTING PARALLEL MODULATION	OUTPUT DIFFERENTIAL MODULATION
1&3		PARALLEL OR DIFFERENTIAL	PHASE MODULATION	AMP. MODULATION
2&4		DIFFERENTIAL OR PARALLEL	AMP. MODULATION	PHASE MODULATION
1&5		PARALLEL	ZERO OUTPUT	CARRIER ELIM. AMP. MOD.
1&5		DIFFERENTIAL	AMP. MODULATION	UN MODULATED OUTPUT

Fig. 10

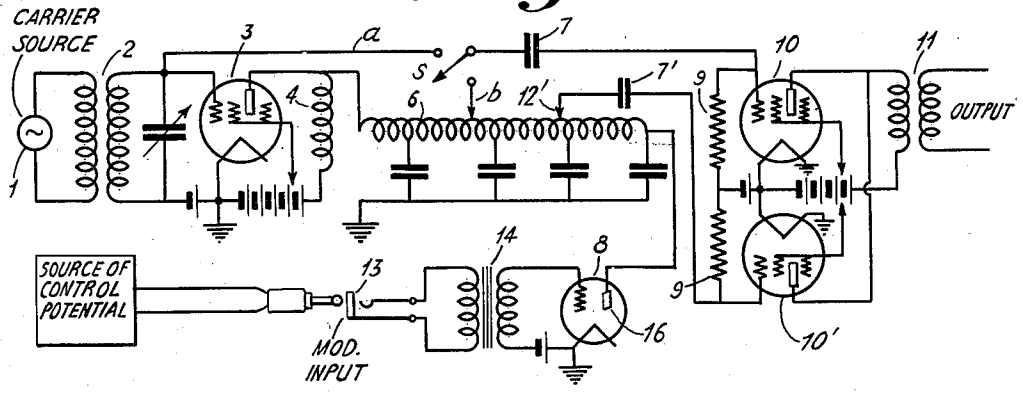
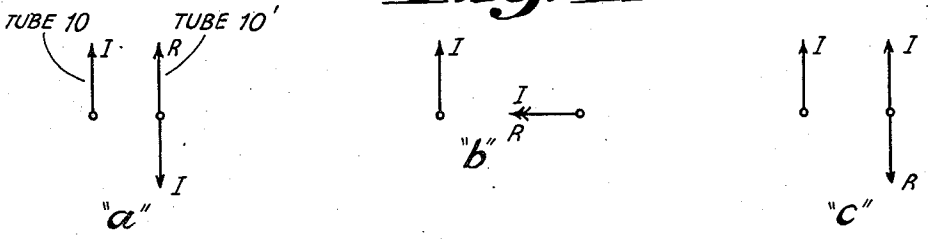


Fig. 11



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Patented June 29, 1937 2,085,418

UNITED STATES PATENT OFFICE

2,085,418

VARIABLE TERMINAL IMPEDANCE SIGNALING SYSTEM

Murray G. Crosby, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application December 27, 1933, Serial No. 704,121

28 Claims. (Cl. 179—171)

This invention concerns a new method of and means for producing impedance variations, applying the same to the terminal of an artificial line or filter circuit on which carrier waves have been impressed to produce relative changes in the reflected and incident wave, and of utilizing said changes for signaling.

More specifically, this invention relates to a new method of and means for a phase and amplitude modulation wherein the terminating impedance of a retardation circuit, such as an artificial line or wave filter, is in accordance with the present invention modulated to produce a phase or amplitude modulation of the voltage at certain points on the line. By varying the terminating impedance of such a circuit, the amplitude of the reflected wave is caused to vary so that the resultant voltage at certain points on the line, due to the combination of the incident and reflected waves, is varied in phase, and the resultant voltage at other points on the line is varied in amplitude. Consequently, by choosing the voltage at the proper point on the retardation circuit, either phase or amplitude modulation may be obtained.

In the prior art of phase modulation, the variation in phase has usually been accomplished by differentially amplitude modulating two like frequency carriers adjusted to be less than 180 degrees apart in phase and combining these two modulations. See United States application No. 588,309, filed January 23, 1932. The modulator of the present disclosure broadly relates to the principle concerned in the said Crosby application except that here the controlling variations are utilized in a novel manner to control the terminating impedance of a line along which the carrier frequency travels and the inherent properties of said artificial line or wave filter so controlled are utilized to produce both the phase changes and the amplitude changes desired in the travelling wave. Hence, by this novel combination of operations, adjustments are made fewer and complications reduced.

In the prior art of amplitude modulation, the variation in amplitude is usually produced by varying an element voltage of a thermionic amplifier. In the present invention a variation of voltage between elements of a thermionic tube causes an impedance between the same or other tube elements to vary. This variable impedance so produced is utilized as the terminating impedance of a retardation circuit or line or artificial line so as to amplitude modulate the reflected wave of voltage in the circuit. Consequently, a new approach is provided to the problem of producing amplitude modulation of a carrier wave which is linear in accordance with the signal.

In one modification of my invention a simple push-pull arrangement of lines or retardation circuits and tubes is provided to enhance the ease of obtaining linear phase or amplitude modulation. In another modification the advantages of the push-pull arrangement may be obtained in a single line or circuit and a single tube.

An apparent advantage of the controlling devices or modulators herein described is that by the use of one circuit many different types of modulation are made available. For instance, in the push-pull modification, amplitude modulation, carrier eliminated amplitude modulation, and phase modulation are obtainable with appropriate alternative adjustments for each.

The novel features of my invention have been pointed out with particularity in the claims appended hereto.

The nature of my invention, the methods of signaling involved, and the means whereby said methods are carried out will be better understood from the following detailed description thereof and therefrom when read in connection with the drawings, throughout which like reference characters indicate like parts, and in which:

Figure 1 shows the essential elements of one of my novel circuits by means of which the character of varying potentials may be controlled in a novel way in accordance with my present invention;

Figures 2 to 6 inclusive and 10 show various circuit arrangements in which the method of and means for controlling the character of varying currents, as pointed out in connection with Figure 1, have been utilized for varying at signal frequency a carrier wave; while,

Figures 7, 8, 9 and 11 are vector diagrams illustrating the operation of the control means of Figures 1, 2, 4, 6, 3, 5 and 10 respectively.

Figure 1 shows a diagram of a phase shifter or amplitude control which illustrates the fundamental principle involved in the wave controlling or modulating devices of the present invention. The voltage to be varied in phase or amplitude is applied at 1, thence to tuned circuit 2 and to the coupling tube 3. The voltage applied to 1 may be of any frequency and amplitude. Voltage is fed to the anode of tube 3 from source 5 by way of radio frequency choke 4. The alternating voltage is amplified in 3 and is fed to line 6, which is terminated by a variable impedance 8. The im-

pedance 8 may be resistive, as shown, or inductive or capacitive. An output coupling tube 10 receives its control grid energy from the line 6 by way of tap 12 through blocking condenser 7. Grid leak resistance 9 furnishes operating bias to the control grid of tube 10. The energy produced by the arrangement is taken from transformer 11 and may be utilized in any manner.

Figure 2 illustrates a signaling circuit including among other features a phase modulator or amplitude modulator utilizing the principle involved in the circuit of Figure 1 except that the variable impedance 8 of Figure 1 is replaced by the anode to cathode impedance of a modulator tube 8. This modulator tube receives its anode voltage from battery 5 by way of radio frequency choke 4 and the inductance of line 6. The controlling wave which may be a signal is impressed on the grid of the modulator tube through jack 13 and transformer 14.

Figure 3 shows a push-pull arrangement similar to the arrangement of Figure 2. The arrangement of Figure 3 contains the same elements as Figure 2 with the addition of a tube 3', choke 4', additional line 6' tube 8', tap 12', and the other features as shown connected as shown including switches 21, 22 and 23, the purpose of which will be set forth in detail hereinafter.

Figure 4 shows the application of anode modulation which may be applied to either of the circuits of Figures 2 and 3 as an alternative method of varying the plate impedance of the tube 8. The modulation is applied on jack 13, via transformer 14 and radio frequency choke RFC, to the anode of the tube 8. Condensers 18 and 20 are blocking and by-pass condensers respectively. 6 is the line or filter circuit of Figure 2. In the push-pull arrangements two modulator tubes, 8 and 8', connected as shown in Figure 5, may be used. In this case the control tubes are fed by a push-pull modulation transformer 14 as shown in Figure 5.

Figure 6 shows a screen grid tube utilized as a modulator tube in accordance with the present invention. The circuit of Figure 6 is otherwise similar to the circuit of Figure 4. The controlling voltage is fed through jack 13 and transformer 14 to the screen grid electrode of the modulator tube 8. The varying potentials applied to the screen grid of this tube vary the characteristics thereof such as the amplification factor, the internal impedance conductivity, etc. The variations between the anode and cathode of 8 are applied to the terminal of line 6 for the purpose specified.

In Figure 7 vector diagrams are given to aid in the explanation of operation of the invention.

The operation of this phase varier amplitude modulator carrier elimination modulator depends upon the fact that when a retardation circuit, consisting of an artificial line or wave filter, is not terminated by an impedance equal to the characteristic impedance of the retardation circuit, a reflection occurs at the termination of the line and standing waves are formed along the line. These standing waves consist of alternate points of current or voltage maxima or minima due to the resultant of the combination of the incident and reflected waves. Hence, when the reflected wave is in phase with the incident wave, a maximum will occur, due to the adding of the two waves. Likewise, when the reflected wave is in opposite phase with respect to the incident wave, a minimum will occur. The phase of combination of the two waves depends upon the point of the line selected. Between the points of maxima and minima the phase of combination is an angle which varies between zero and 180 degrees. Thus, for points between maxima and minima, as the amplitude of the reflected wave is varied, the resultant of the combination is varied in phase as well as amplitude. Hence, by choosing a point where a maximum or minimum occurs, a change of the terminal impedance will cause amplitude modulation; and, by choosing a point between a maximum and a minimum, the change will cause phase modulation.

Figure 1 shows a circuit which could be used either for a manually operated phase shifter or volume control. As a phase shifter, impedance 8 is made zero and tap 12 adjusted to a point between a maximum and a minimum. Then, by varying 8 between zero and the characteristic impedance of the line, a 45 degree phase shift in the energy at the tap 12 may be produced. By continuing the variation of 8 between the characteristic impedance and open circuit impedance, an additional 45 degree phase shift may be produced making a 90 degree total.

In Figure 7 the vector diagram *a* represents the condition of zero terminating impedance where I represents the current of the incident wave, R represents the current of the reflected wave, and T represents the resultant of both currents. When the terminating resistance 8 is varied so that R is reduced, as given by R' in vector diagram *b* of Figure 7, the resultant T' is shifted or moved in phase by the amount ϕ.

When Figure 1 is to be used as a volume or amplitude control, the top 12 may be adjusted to a point of maximum or minimum potential with the line 6 open or shorted at the termination. Then, with 8 adjusted to a value equal to the characteristic wave impedance of the line, there will be no reflected wave on the line. This has been portrayed by the vector diagram *c* of Figure 7. When 8 is adjusted in one direction away from the characteristic line impedance, the reflected wave tends to buck the incident wave to thereby reduce the resultant amplitude T, as shown in vector diagram *d* of Figure 7. When 8 is adjusted in the opposite direction, the reflected wave tends to add, with the incident wave, as shown in diagram *c* of Figure 7. Thus, the amplitude of the voltage at the point of tap-off 12 varies, dependent upon the value of the impedance 8.

Figure 2 shows a signaling device including a modulator circuit making use of the same principles as the phase and volume control of Figure 1 except that the terminating impedance 8 of Figure 1 is replaced by the anode to cathode impedance of a modulator tube 8 so that the terminating impedance may be varied at the frequency rate of the signal wave applied from the controlling potential source by way of jack 13 to the control grid of 8. Thus, by adjusting tap 12 to a point of maximum, as described in connection with Figure 1, amplitude modulation of the carrier wave from source 1 is effected. Likewise, by adjusting the tap 12 between maximum and minima, phase modulation of the wave from 1 is effected in the manner described in connection with Figure 1 when used as a phase shifter.

The push-pull circuit of Figures 3 and 5 lend themselves to many arrangements for producing amplitude and/or carrier elimination and phase modulation.

In Figure 8 of the drawings the curve "*a*" shows the voltage distribution of a section of the

line 6 or 6' and below it are shown the vector diagrams of the incident and reflected voltages, I and R for the voltage points on the line indicated by the dotted lines which extend from the vectors to the curve "a". The table of Figure 9 shows eight of the possible combinations which may be had with this circuit. Aside from the various line adjustments, as portrayed by the vector diagrams of Figures 8 and 9, there is the possibility of combining the radio frequency energy in parallel or differentially. With the parallel radio frequency combination switches 22 and 23 are both moved into the right hand closed position for cophasal addition of the unmodulated carrier in the windings 2 and 2' and of the controlled wave in transformer 11. With the differential combination, either one of these switches may be adjusted for cophasal, and the other for phase opposition combination of the respective waves. Also, by selecting the position of switch 21, the controlling voltage may be applied cophasally or in phase opposition, or in other words, in parallel or differentially to the modulator tubes.

The table of Figure 9 illustrates the different types of modulated output obtained under certain circumstances and different positions of the taps 12 and 12' on the lines 6 and 6'.

For instance, in the first column the first line indicates that one artificial line tap, (say 12) would be on point 1 of Figure 8 and the other line tap (say 12') would be on point 3 of curve 8 of Figure 8. The second column (first line) indicates the vector relations of the incident and reflected currents on the two lines at the tap points selected. The third column (first line) indicates the radio frequency combination of the carrier as determined by the position of switch 22 and the modulated carrier combination as determined by switch 23. Right hand closed for cophasal addition in parallel combination and either one moved to left hand closed for differential combination. The fourth and fifth columns give the resulting output, modulated or otherwise for the two manners of applying the carrier to the line.

In the same manner, the other cases of the table of Figure 9 show the adjustments for the other types of modulation. These main cases show the principal variations. Other adjustments may also be made which are between the adjustments shown.

In the arrangements where a phase shift or modulation is accomplished, there might be an amplitude change introduced as well as a phase change. This amplitude change may be removed by passing the shifted or modulated energy through amplitude limiters whose output remains constant regardless of the variation of the input within certain limits. A thermionic tube which is loaded to saturation will serve as an amplitude limiter.

It will be apparent that my invention contemplates the use of screen grid or multi-element tubes in place of the triodes shown in the prior figures. Triodes are employed merely for diagram simplicity.

Figures 4 and 6 show how plate modulation and screen grid modulation may be employed to modulate the plate impedance of the modulator tube in the same manner that control grid modulation is employed in Figures 2 and 3.

In Figure 4 the tube 8 is connected as shown to apply the modulating potentials from any source by way of the jack 13 and transformer 14 to the anode electrode. The anode circuit includes, as shown, the secondary winding of the transformer 14 in parallel with a capacity 20, both of which are in series with radio frequency choking inductance RFC. The modulating potentials are applied by way of a coupling condenser 18 to the terminal of the line 6 so that here, as in the prior case, the terminal impedance of the line 6 comprises the anode to cathode impedance of the modulator tube 8. The capacity 18 is small enough to prevent the controlling frequency energy from reaching the line 6, but is large enough to insure connection of the impedance between the anode and cathode of 8 to the terminal of the line 6.

In Figure 6 the tube 8 is of the screen grid type. Here the anode to cathode impedance is connected in parallel with the terminal of the line 6 and the modulating potentials are applied from any source by way of jack 13 and transformer 14 to the screen grid electrode of tube 8. The control grid is biased negatively, as shown, and the anode electrode is supplied by operating potentials from the source 5 by way of the radio frequency inductance 4.

Of course, the principles of control illustrated in Figure 4 may be utilized in a push-pull circuit as shown in Figure 5. In this circuit modulation is accomplished in the same manner in which it is accomplished in Figure 4. Figure 5, however, includes the switches 21, 22 and 23 shown in Figure 3 and described in connection with Figure 3. The switch 22 permits carrier waves to be applied in opposition or in phase to the artificial line 6'. The switch 21 permits the controlling voltages to be applied in parallel or in opposition to the modulating tubes, while the switch 23 permits the controlled wave to be added in phase or in phase opposition before application to the utilization circuit.

In Figure 10 I have shown a simplified single coupling tube and single artificial line which permits attainment of the results obtained with the push-pull type circuits of Figures 3 and 5. The carrier from 1 may be applied as shown by way of the coupling tube 3 to the line 6 and from the line 6 by way of tap *b* and switch S to the control grid and by the tap 12' to the control grid of 10'. Here as in the prior arrangements the terminating impedance of line 6 is varied at signal frequency so that the reflected wave on the line 6 shifts relative to the incident wave to produce a resultant that shifts as to amplitude or as to phase or both.

With the switch S connected to *b* as indicated above, the wave form along the line 6 being as indicated at *a* in Figure 8, the taps *b* and 12' may be moved to various points on the line 6 to produce all of the various outputs shown in the fourth column of Figure 9 resulting from parallel modulation of the tubes. In other words the simplified circuit of Figure 10 when operated above gives the same results as the arrangements of Figures 3 and 5 when switches 22 and 23 are in the right hand closed position.

With switch S of Figure 10 on wire "a", the vector relations of the voltages on tubes 10 and 10', with the line tap on point 1 of Figure 8 are shown in Figure 11 "a". For the condition of Figure 11 "a" the resulting output would be carrier eliminated amplitude modulation. Likewise, Figures 11 "b" and 11 "c" show the vector relations for the line tap on points 3 and 5 which produce outputs of phase modulation and amplitude modulation, respectively.

Any other system of modulating an impedance may be employed whether the system includes thermionic tubes or not. Moreover in some cases the line may require some reactance in addition to the ohmic resistance shown at its terminal to damp it. I contemplate adding the necessary reactance either inductive or capacitive in parallel or in series with the tube impedance or with the resistance at the end of the line of each of the circuits shown where necessary. With the addition of such reactance the resistive component of the terminal impedance would still be supplied by the plate cathode impedance of the control or modulator tube and said impedance would in turn be controlled or modulated by the signal.

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

1. The method of signaling by controlling the phase relation of reflected and incident waves on a transmission line to which said incident waves have been applied, said transmission line being terminated by a variable impedance which includes the steps of varying said variable impedance terminating said line at signal frequency and deriving energy from said line for signaling purposes.

2. The method of signaling by varying the combined characteristic of reflected and incident waves along a line the terminal of which is shunted by the impedance of a thermionic tube and to which line the incident waves have been applied which includes the step of varying the impedance of said tube at signal frequency.

3. The method of signaling by varying the combined characteristic of reflected and incident waves along a line terminated by an impedance to which line the incident waves have been applied which includes the steps of, varying the said terminal impedance of said line at signal frequency and utilizing resultant energy from said line for signaling purposes.

4. The method of producing variations in the characteristic of carrier waves at signal frequency which includes the steps of, impressing said waves on a transmission medium having a predetermined terminal impedance in which medium standing and incident waves are produced, and varying the terminal impedance of said medium at signal frequency.

5. The method of producing variations in the characteristic of carrier waves at signal frequency which includes the steps of, generating carrier waves, impressing said waves on a transmission medium terminated by an impedance, producing signal potentials, and varying the terminal impedance of said medium at the frequency of said signal potentials.

6. The method of producing carrier waves, one or more characteristics of which vary in accordance with modulating potentials which includes the steps of, impressing a carrier wave on a transmission medium of known terminal impedance to produce in said medium an incident and a reflected wave, varying the terminal impedance of said medium in accordance with the modulating potentials to produce relative changes in the reflected and incident wave, and diverting energy from said medium at a selected point to produce the desired variations characteristic of the modulating potentials in the energy resulting from the diverted combined incident and reflected wave.

7. The method of producing carrier waves, one or more characteristics of which vary in accordance with modulating potentials which includes the steps of, impressing a carrier wave on a transmission medium of variable shunt impedance to produce in said medium an incident and a reflected wave, simultaneously varying the shunting impedance of said medium in accordance with the modulating potentials to produce relative changes in the reflected and incident wave, diverting energy from said medium at a selected point to produce the desired variations characteristic of the modulating potentials in the energy resulting from the diverted combined incident and reflected wave and transmitting said energy.

8. The method of producing carrier energy, the phase of which varies at signal frequency which includes the steps of, applying said carrier energy to a transmission medium of predetermined terminal impedance, varying the terminal impedance of said transmission medium at signal frequency to produce reflected and incident waves of the desired phase relationship in said medium, and diverting energy from said medium at a point at which the phase relation of the reflected and incident wave is such as to produce resultant energy, the phase of which varies in accordance with variations in the terminal impedance of said medium.

9. A circuit for controlling the characteristics of a carrier wave including, an artificial line having series inductance and parallel capacity and terminating in an impedance, the value of which is such as to normally eliminate standing waves along said line, means for applying said carrier wave to said line, and means for varying the impedance at the terminal of said line at signal frequency to produce incident and reflected waves along said line of varying phase and amplitude, to thereby produce a resultant of the incident and reflected wave along the line of amplitude and phase which varies in accordance with said signals.

10. A circuit for controlling the characteristics of a carrier wave including, a pair of artificial lines each having series inductance and parallel capacity and terminating in an impedance, the value of which is such as to normally eliminate standing waves along said lines, means for applying said carrier wave to said lines, and means for varying the impedances at the terminal of said lines at signal frequency to produce incident and reflected waves along said line of a phase which varies at signal frequency.

11. A circuit for controlling the characteristics of a carrier wave including, a pair of artificial lines each having series inductance and parallel capacity and terminating in an impedance which includes the impedance between electrodes in a thermionic tube, means for applying said carrier wave to the input terminals of said lines to produce incident and reflected waves therealong, means for varying the impedance of said tubes at signal frequency to thereby vary the phase and amplitude of the resultant of the incident and reflected wave along the lines in accordance with said signals, and a movable tap on each of said lines for diverting therefrom energy which is a resultant of incident and reflected waves of the desired phase relationship.

12. Means for modulating the phase of a carrier wave at signal frequency comprising an artificial transmission line including series inductance and parallel capacity, said line being terminated by an impedance, means for applying the carrier wave to be varied to the input terminal of said line

whereby reflected and incident waves of variable phase relationship are set up in said line, means for adjusting said impedance at signal frequency to produce points of maximum and minimum in the combined reflected and incident wave in said line, means for selecting energy from said line at a point between one of said maximum and minimum points, and means for utilizing said selected energy for signaling.

13. A device for modulating the amplitude of carrier frequency waves at signal frequency comprising an artificial line including series inductance and parallel capacity, said line terminating in an impedance, means for applying the carrier waves to be modulated to the input terminal of said line to produce incident and reflected waves thereon, means for varying the terminal impedance of said line at signal frequency to produce points of maximum and minimum in the resultant of the combined incident and reflected wave, and means for selecting energy from a point on said line at which a minimum or maximum occurs and utilizing said energy for signaling.

14. Means for modulating the phase of a carrier wave at signal frequency comprising an artificial transmission line including series inductance and parallel capacity, said line being terminated by the impedance between the electrodes in a thermionic tube, means for applying the carrier wave to be varied to the input terminal of said line whereby reflected and incident waves of variable phase relationship are set up in said line, varying said tube impedance to produce points of maximum and minimum in the combined reflected and incident wave in said line, means for selecting energy from said line at points between maximum and minimum energy points on said line, and a pair of thermionic tubes having their control grids connected to said last named means.

15. Means for modulating the phase of a carrier wave at signal frequency comprising a pair of artificial transmission lines each including series inductance and parallel capacity, said lines each being terminated by the impedance between electrodes of a thermionic tube, means for applying the carrier wave to be varied to the input terminal of said line whereby reflected and incident waves of variable phase relationship are set up in said line, means for varying the impedances of said tubes in parallel or in phase opposition at signal frequency to produce points of maximum and minimum in the combined reflected and incident wave in said line, which shift at signal frequencies, a pair of thermionic tubes and a connection between a point on each line and an electrode in each of said tubes.

16. A device for modulating the amplitude of carrier waves at signal frequency comprising a pair of artificial lines each including series inductance and parallel capacity, said lines each terminating by the impedance between electrodes in a thermionic tube, means for applying the carrier waves to be modulated to the input terminals of said lines to produce incident and reflected waves thereon, a circuit for applying modulating potentials in the desired phase relation to like electrodes in each of said tubes to produce shifting points of maximum and minimum in the resultant of the combined incident and reflected wave, a work circuit and a pair of thermionic tubes each having a control electrode connected to a selected point on a different one of said lines and output electrodes coupled to said work circuit.

17. Means for varying the phase and amplitude of carrier waves at signal frequency comprising, an artificial line having its input terminals energized by the carrier wave and its output terminals connected with a variable impedance, and thermionic means for varying said impedance at signal frequency.

18. The method of producing carrier waves one or more characteristics of which vary in accordance with signal waves for signaling purposes which includes the steps of, impressing a carrier wave of substantially constant frequency on a transmission medium having a predetermined terminal impedance to produce in said medium incident and reflected waves, varying the terminal impedance of said medium at the frequency of said signal waves to produce relative changes in the reflected and incident waves in said medium, diverting energy from said medium at selected points, combining said energy differentially or additively and signaling with the resultant of the combined energy.

19. In a phase modulator, a source of carrier wave oscillations, a source of signal potentials, a thermionic tube having a plurality of electrodes, a transmission line comprising series and parallel reactances, a connection between one end of said line and said source of oscillations, a circuit connecting a pair of the electrodes of said tube in shunt to said line, and a connection between said source of signal potentials and a pair of electrodes in said tube.

20. In a circuit for controlling the characteristic of a carrier wave, a reactive line terminating in an impedance, the value of said impedance being such as to normally eliminate standing waves along said line when energized by said carrier wave, means for applying said carrier wave to said line and means for varying the impedance at the terminal of said line at signal frequency, to produce incident and reflected waves along said line of varying character to thereby produce a resultant of the incident and reflected wave along the line, the character which varies in accordance with said signals.

21. In a circuit for controlling the characteristic of a carrier wave, a pair of lines each having reactances, and each being connected with an impedance which may be varied, means for applying carrier wave energy to said lines to produce in said lines incident and reflected waves, means for varying said impedances at signal frequency to thereby vary the phase and amplitude of the resultant of the incident and reflected wave in the lines in accordance with signals, and means for deriving resultant energy from said lines for signaling purposes.

22. In a device for modulating carrier frequency oscillations at signal frequency, a line including inductive and capacitive reactances, said line terminating in an impedance, means for applying the oscillations to be modulated to said line to produce in said line incident and reflected waves, means for varying the terminal impedance of said line at signal frequency to produce points of maximum and minimum in the resultant of the combined incident and reflected waves and means for selecting energy from points on said lines at which a minimum or maximum occurs in the combined waves and utilizing said selected energy for signaling.

23. In a signaling system, a source of oscillations of carrier wave frequency, a load circuit, a source of modulating potentials, a transmission line comprising series and parallel reactances, said transmission line having an input, a circuit coupling the input of said line to said source of

oscillations, a variable impedance, a circuit coupling said line to said variable impedance, a connection between said variable impedance and said source of modulating potentials and a circuit coupling a point on said line to said load circuit.

24. A signaling system as recited in claim 23 wherein an electron discharge coupling device having input and output electrodes is inserted in said circuit coupling the input of said line to said source of oscillations with its input electrodes coupled to said source of oscillations and its output electrodes coupled to the input of said line and in which said variable impedance is the impedance between the output electrodes of an additional electron discharge device and in which said connection between said variable impedance and said source of modulating potentials comprises a coupling between a control electrode of said additional device and said source of modulating potentials and in which a third electron discharge device having input and output electrodes is inserted in said circuit connecting points on said line to said load circuit with its input electrodes coupled to said points on said line and its output electrodes coupled to said load circuit.

25. In a signaling system, a source of high frequency oscillations, a source of modulating potentials, a load circuit, a transmission line comprising reactances, said line having an input and an output, a first electron discharge device having input and output electrodes, a circuit coupling the input electrodes of said first discharge device to said source of high frequency oscillations, a circuit coupling the output electrodes of said first discharge device to the input of said line, a second electron discharge device having input and output electrodes, a circuit coupling the input electrodes of said second electron discharge device to said line, a circuit coupling the output electrodes of said second discharge device to said load circuit, a third electron discharge device having a control electrode and having its impedance coupled in shunt to a portion of said line and a circuit coupling the control electrode of said third device to said source of modulating potentials.

26. In a signaling system, a source of high frequency oscillations, a source of modulating potentials and a load circuit, a plurality of lines, each including reactances and each having an input and an output, a first pair of electron discharge devices each having input and output electrodes, separate circuits coupling the input electrodes of said discharge devices to said source of oscillations, means in one of said circuits for reversing the phase of the oscillations applied from said source to the input electrodes of the corresponding discharge device, a coupling between the output of each of said devices and the input of a different one of said lines, a second pair of electron discharge devices each having a cathode and a plurality of auxiliary electrodes, circuits coupling the cathode and an auxiliary electrode in each of said tubes to said source of modulating potentials, means in one of said circuits for reversing the phase of the modulation potentials applied thereby to the electrodes in the corresponding tube, a coupling between another auxiliary electrode and cathode in each of said last named pair of devices and spaced points on a different one of said lines, a third pair of electron discharge devices each having input and output electrodes, circuits connecting the input electrodes of said third pair of tubes to different points on said lines, separate circuits coupling the output electrodes of said third pair of discharge tubes to said load circuit and means in one of said last named separate circuits for reversing the phase of the oscillations transferred to said load circuit.

27. In a signaling system, a source of high frequency oscillations, a source of modulating potentials, a transmission line having inductive and capacitive reactances and having an input and an output, a load circuit, an electron discharge device having input and output electrodes, a circuit coupling the input electrodes of said discharge device to said source of high frequency oscillations, a circuit coupling the output electrodes of said discharge device to the input of said line, a second electron discharge device having a control electrode and a cathode, a circuit coupling the impedance of said second discharge device in shunt to a portion of said line, a circuit coupling the control electrode and cathode of said second discharge device to said source of modulating potentials, a pair of electron discharge devices each having a control electrode, a cathode, and an output electrode, a circuit coupling the output electrodes of said pair of discharge devices to said load circuit, a connection between the control electrode of one of said devices of said pair of devices and a point on said line and means including a switch for connecting the control electrode of the other of said discharge devices of said pair of discharge devices to a point on said line or to said source of high frequency oscillations.

28. In a modulation system, an artificial line having input terminals on which wave energy to be modulated may be impressed, said line having output terminals from which modulated wave energy may be derived, an electron discharge device having electrodes, means connecting the internal impedance between two of the electrodes of said electron discharge device with said artificial line to supply a variable terminating impedance therefor, a source of modulating potentials, and means connecting said source of modulating potentials to a pair of said electrodes of said electron discharge device to vary said impedance between said two electrodes of said electron discharge device in accordance with said modulating potentials to thereby modulate the wave energy in said line.

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