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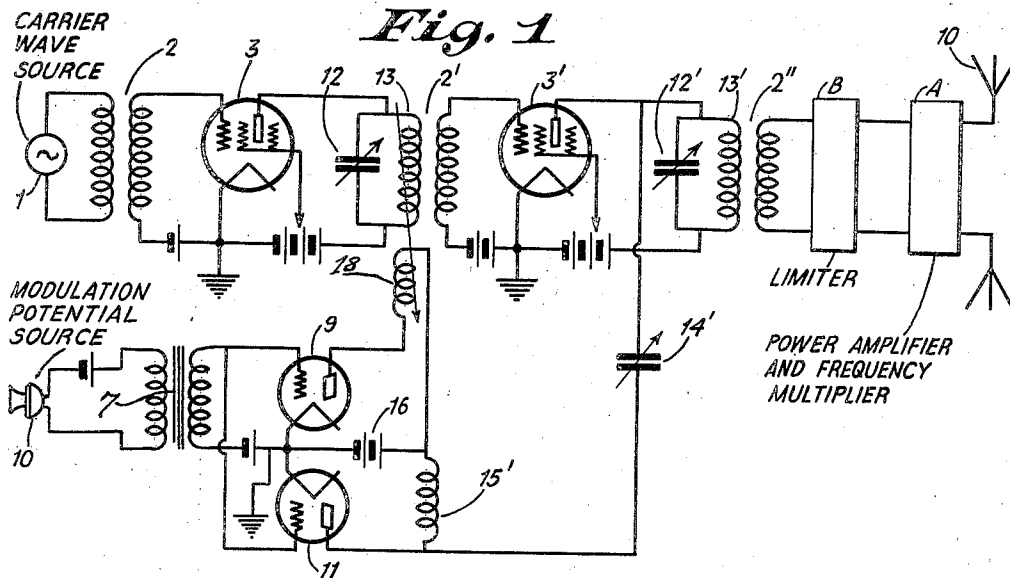
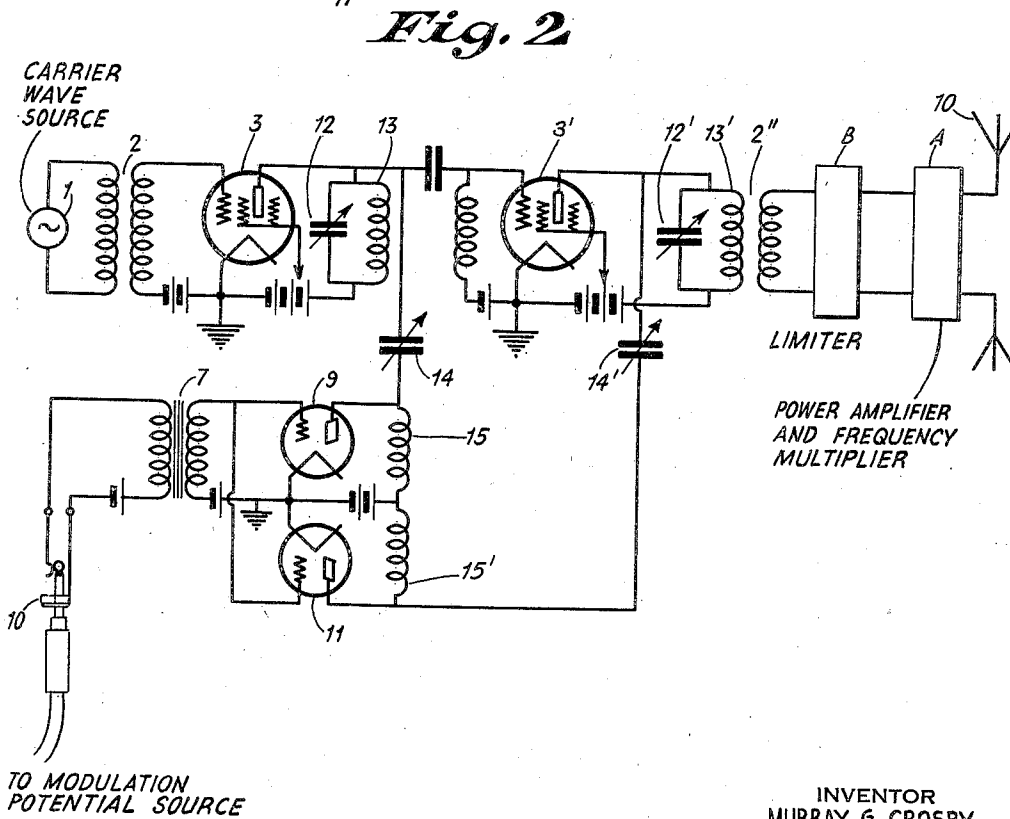
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2,104,318

MULTIPLE PHASE MODULATION

Filed Aug. 16, 1935

2 Sheets-Sheet 1



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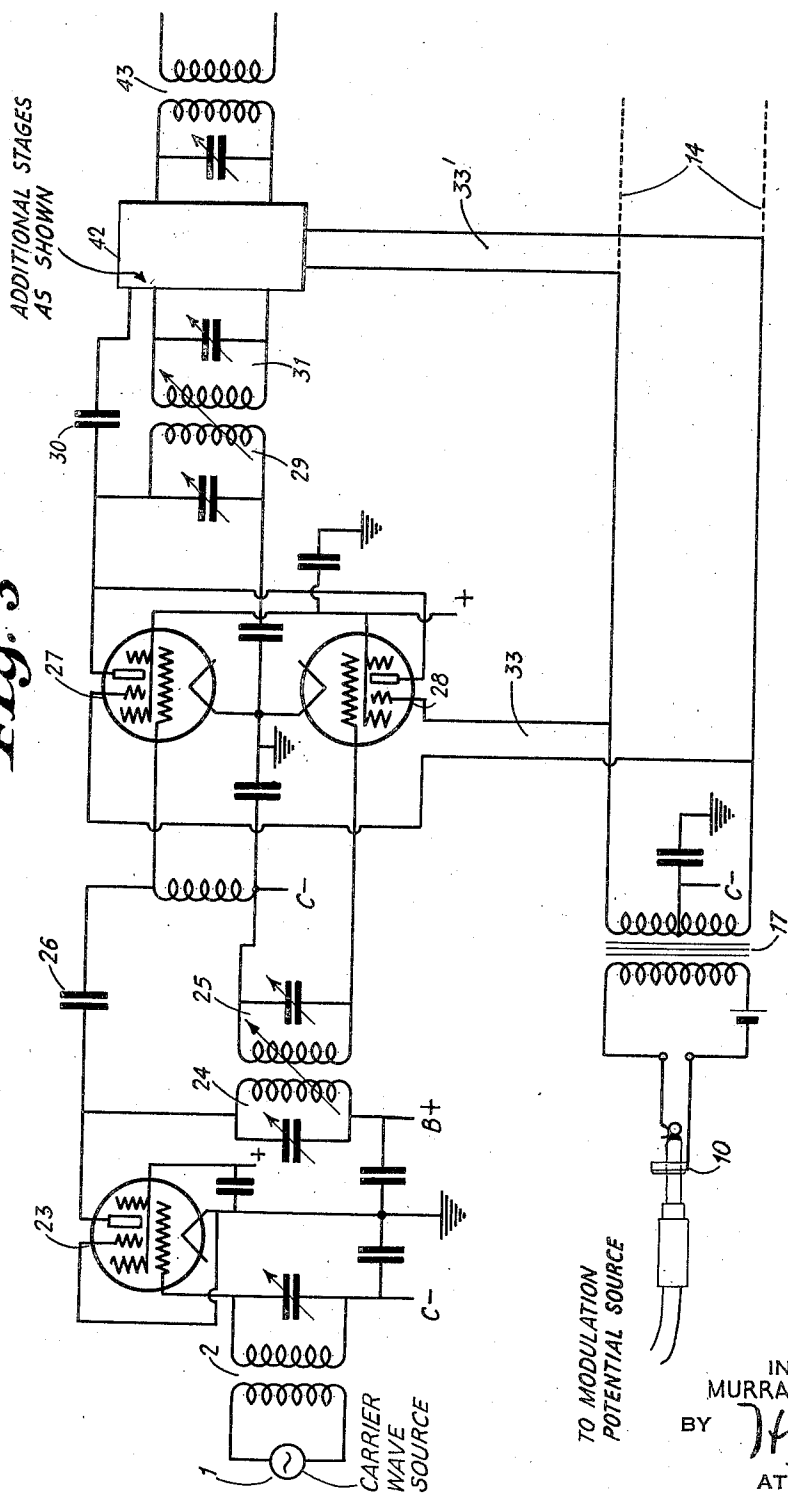
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Fig. 3



TO MODULATION
POTENTIAL SOURCE

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MULTIPLE PHASE MODULATION

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18 Claims. (Cl. 179—171)

This invention relates to signalling systems and more in detail to systems for producing phase modulation and transmitting electrical waves. This application is a continuation in part of my U. S. application Ser. No. 563,725, filed September 19, 1931, Patent #2,033,231 dated March 10, 1936.

Modulated electrical waves are known in the art as waves or oscillations having certain characteristics one or more of which are varied in accordance with signalling waves to be transmitted. The electrical waves may be modulated in amplitude, frequency, or phase in accordance with signal impulses. The present invention deals with a novel method of and means for modulating the phase of electrical waves.

Prior to my invention disclosed in the aforesaid application, of which this application is a continuation in part, phase modulation has been accomplished by somewhat complicated circuit arrangements. These arrangements, it has been found, are rather expensive and complex and require careful operation and maintenance. In my prior application, oscillations relayed in a thermionic stage are modulated in phase at signal frequency. The single stage phase modulator feeds a frequency multiplier in which the degree of phase modulation is increased. In order to obtain a high degree of modulation with a single modulator, a high degree of frequency multiplication must be used and the degree of modulation must be carried so far in the one stage that distortion is prone to appear. For the lower radiation frequencies, such a case is more likely to occur, since frequency multiplication is not used to such an extent. By applying the methods herein disclosed, these difficulties may be removed. Instead of using a single modulator, modulators are cascaded or a modulation is applied to more than one amplifier or frequency multiplier stage of a transmitter.

According to one particular embodiment of this invention, these objects are attained by utilizing capacitive and inductive couplings between the modulating device and the output circuits of two or more of the carrier current amplifying stages which are connected in cascade. The coupling between the modulating device may be by simple circuits or by circuits which include amplifying tubes.

Various features of this invention reside in the different circuit arrangements employed for coupling the modulating device to the several stages in the transmitter apparatus and will appear in the subsequent detailed disclosure.

The novel features of my invention have been pointed out with particularity in the claims appended hereto as required by law. The nature of my invention and the manner in which the same is carried out will be better understood by the detailed description thereof and therefrom when read in connection with the attached drawings throughout which like reference characters indicate like parts insofar as possible and in which:

Fig. 1 is a circuit diagram of a transmitting system adapted for phase modulation wherein a pair of signal amplifying tubes are coupled at their inputs to a source of modulating potentials and at their outputs to a plurality of carrier frequency amplifier stages by means of capacitive and inductive reactances;

Fig. 2 is an arrangement similar in some respects to Fig. 1, except that in Fig. 2 capacitive couplings are employed between the modulator tubes and both stages, instead of inductive and capacitive couplings, as in Fig. 1; while

Fig. 3 is a further modification of the system disclosed in the prior figures wherein the modulation source is coupled directly to several amplifier stages connected in parallel and cascaded.

In Fig. 1 is shown a complete radio transmitting system adapted for the production and transmission of high frequency electrical waves. In Fig. 1, the member 10 represents a suitable radiation circuit or transmitting circuit connected to a power amplifier and frequency multiplier A. The power amplifier and frequency multiplier A is in turn connected to an amplitude limiter B which may in turn be coupled to the output of the phase modulation circuits of the present invention. The amplifier and multiplier A and the amplitude limiter B are not shown or described in detail in this specification since they have been disclosed hereinbefore in the art, are well-known, and per se form no part of the present invention. The waves to be phase modulated and impressed on B originate in a carrier wave source 1 which is connected by transformer 2 to a thermionic amplifier tube 3 of the screen grid type. A tuned circuit connected between the anode and cathode of tube 3 comprises a variable condenser 12 and an inductance 13 connected in shunt to said condenser. The inductance 13 forms the primary winding of a second transformer 2' having its secondary winding coupled to the control grid of an additional amplifier tube 3' of the screen grid type. The anode and cathode of the additional amplifier 3' are connected by a tuned circuit comprising a variable capacity 12' shunt-

ed by an inductance 13'. The inductance 13' comprises the primary winding of a third transformer 2'', the secondary winding of which is coupled to the limiter B. A source of modulating potentials 10 is coupled in phase by way of a transformer 7 to the control grids of a pair of modulator tubes 9 and 11. The anode circuit of tube 9 is completed by way of an inductance 18 and a source of potential 16. The direct current anode circuit of the tube 11 is closed by way of a radio frequency choke inductance 15' and source 16. The alternating current anode circuit of tube 11 is completed by way of a coupling capacity 14', the anode-to-cathode impedance of tube 3', and ground. The inductance 18 is variably coupled to the inductance 13 of the tuned circuit connected to the output electrodes of tube 3.

Although for purposes of illustration, the amplifier tubes 9 and 11 have been shown as triodes, while the tubes 3, 3', etc., have been shown as screen grid tubes, it will be understood that any type of tubes may be substituted for the tubes shown, e. g. triode, pentode or screen grid tubes may be employed.

Condenser 14', it is noted, is connected in series with the plate impedance of modulator tube 11 and effectively connected in parallel with condenser 12'. Consequently, any variation of the plate impedance of tube 11, such as may be caused by message waves impinging on the diaphragm of microphone 10, will cause a variation of the effective capacity of condenser 14'. This variation of the effective capacity of 14' will vary the resultant capacity of the tuned circuit 12', 13' in such a manner that the output of the amplifier 3' is phase modulated in accordance with the signal wave.

Phase modulation of the wave in the preceding stage 3 is accomplished in a similar manner and in synchronism with the phase modulation accomplished in stage 3'. In stage 3, however, the effective inductance of the tuned circuit 12, 13, instead of the capacity, is modulated. This is accomplished by means of inductance coil 18 in the output of modulator tube 9, which is coupled to the tuned circuit inductance coil 13. In this particular circuit, no radio frequency choke coil is included in the output circuit of the modulator tube. Any variation of the plate impedance of the modulating tube 9 will vary the phase of the amplifier output in accordance with the signal wave in the same manner as mentioned above in connection with the description of the effect of the other half of the modulator circuit on the amplifier tube 3'.

If the impedance of tube 9 is lowered by the signal potentials the effect is the same as would be obtained by shorting a portion of 13. This produces an effective increase in the capacity of the circuit 12, 13. Increasing the impedance of tube 9 has an opposite effect which results in decreasing the effective capacity of 12, 13. Lowering the impedance of tube 11 increases the effective capacity of the circuit 12', 13'. Thus, we see that irrespective of the nature of the coupling between the anodes of tubes 9 and 11 and the circuits 12, 13 and 12', 13' respectively, we get a phase shift in the wave relayed in each stage in the same sense or direction when modulating potentials act in phase on 9 and 11. Although I have shown the plate of tube 9 coupled to the output circuit of amplifier 3 through the inductance coil 18 and the plate circuit of the other modulator tube 11 coupled to the out-

put of the amplifier circuit of 3' through a capacity 14, it will be understood that my invention is not limited to such couplings. In some cases, it may be preferable to connect the anode of 9 to a movable tap on inductance 13. Moving this tap along 13 permits variation of the degree of plate modulation accomplished.

When the impedance of tubes 9 and 11 are increased, the increased impedance of 11 tends to release the shunting effect of condenser 14', thereby decreasing the total effective capacity, and the increased impedance of tube 9 tends to decrease the shunting effect of coil 18, thereby increasing the total effective inductance and decreasing the capacitive effect. In this manner, the phase of the energy in the output of the amplifiers 3 and 3' is modulated by modulating the effective inductance and capacity of the tuned circuits 12, 13 and 12', 13' simultaneously and in synchronism in the same sense. The phase modulation accomplished in 3 is supplemented by the phase modulation imparted to the carrier of 3' to thereby increase the amount of phase modulation.

The operating characteristics of the accumulative modulators 9 and 11 as to their effect on 3 and 3' may be regulated or controlled by adjusting the value of 14' and the coupling between 18 and 13.

Any amplitude modulation in the circuit which may be undesired, may be removed from the system by employing limiters or overloaded amplifiers whose output is limited to a definite value, regardless of how much the input is increased. An ordinary vacuum tube amplifier will serve this purpose if it is overloaded in such manner that its output does not increase in proportion to its input. Such limiting devices are well known in the art. If desired, frequency multipliers may be used to multiply the phase displacement of the modulated wave.

In the circuit of Fig. 2, cascaded modulation is applied by using the capacity modulators disclosed in my U. S. appln. Ser. No. 563,725, filed Sept. 19, 1931, patent #2,033,231 dated March 10, 1936. In this arrangement, which except as otherwise noted hereinafter is similar to the arrangement of Fig. 1, the transformer 2' of Fig. 1 has been replaced by capacitive coupling. The anode of tube 11 is coupled, as shown by way of a condenser 14', to the tuned circuit 12', 13', while the anode of tube 9 is coupled by a similar circuit including a condenser 14 to the tuned circuit 12, 13. Modulating potentials are fed to the modulator tubes 9 and 11 by way of a jack 10 and transformer 7 so as to modulate the plate-to-filament impedances of the modulator tubes 9 and 11 in phase. The plate impedances of the modulators 9 and 11 are in series with condensers 14 and 14' respectively and the series combination of condensers and plate resistances or impedances are placed across the tuned circuits 12, 13 and 12', 13' respectively. Stages 3, 3' of Figs. 1 and 2 may operate as amplifiers or frequency multipliers. As the modulation varies the plate resistance of the modulator tubes, the effective capacities of condensers 14 and 14' are varied. Since these condensers are across tuned circuits 12, 13 and 12', 13', the tuning of the tuned circuits will be varied in accordance with the modulating potentials so that the phase of the energy in the tuned circuits will be varied. Part of this phase variation is imparted to the energy as it passes through the first tuned circuit, and a further amount is added as the energy passes through the second tuned circuit.

In place of the condensers 14 and 14', in-

ductances and blocking condensers may be inserted. This would place an inductance in series with a variable resistance across the tuned circuits. The variation of the modulator plate resistance would then vary the effective inductances of the tuned circuits. Hence, the tuning of the circuits and in turn the phase of the carrier waves relayed thereby will be modulated in accordance with the modulating potentials applied to the grids of the modulators. The manner in which phase modulation will be produced in these circuits is similar to the manner in which modulation is produced in the circuits of Fig. 1, and description thereof is thought unnecessary here.

Fig. 3. shows a novel circuit in which several differential modulators are cascaded to obtain the desired degree of linear phase modulation at signal frequency. The fundamental idea of this type of modulator is disclosed in Crosby U. S. appln. Ser. No. 588,309, filed Jan. 23, 1932, Patent No. 2,081,577, May 25, 1937, and further modifications are disclosed in Crosby U. S. appln. Ser. No. 690,330, filed Sept. 21, 1933. In this modulator, two phase differentiated portions of the carrier energy are differentially modulated. The carrier energy is supplied from source 1 by way of transformer 2 and coupling tube 23 to tuned circuit 24. The grid of modulator tube 27 is fed directly from tuned circuit 24 by means of a coupling condenser 26. The grid of modulator tube 28 is fed by way of a tuned circuit 25, which is in turn inductively coupled to the tuned circuit 24. By virtue of the transformer action of the inductive coupling of tuned circuits 24 and 25, the voltage fed to the grid of modulator 28 is 90° out of phase with respect to the high frequency voltage fed to the grid of modulator tube 27. Hence, phase differentiated carrier energy is fed to these two grids. The suppressor grids of the modulator tubes are fed by signal energy from any source by way of jack 10 and transformer 17. A differential modulation is effected by means of the push-pull transformer 17, that is, the phase displaced carrier waves on the grid of 27 and 28 are differentially modulated at signal frequency by wave energy fed from transformer 17 by way of lines 33 to the suppressor grids of tubes 27 and 28. The differentially modulated carrier wave energy portions are combined in 29 to produce a resultant, the phase of which approaches the phase of the energy in that tube which is supplying the most energy at the particular instant to the circuit 29. The resultant phase modulated energy is fed by means of a coupling condenser 30 which is similar to 26 to an additional differential phase modulator similar to the one described hereinbefore, which may be enclosed in unit 42. Phase displaced energy is also fed from the circuit 29 by transformer action to the circuit 31, and thence to an additional thermionic device in 42, so that differential phase modulation may be again accomplished in 42 in the same manner in which it is accomplished in stages 27 and 28. Modulating potentials in phase displaced relation are supplied to the devices in 42 by way of a line 33' connected to the line 14, in turn connected with the secondary winding of transformer 17. Additional modulators to the one shown at 27, 28 and 42 may be connected to the line 14.

It will be readily seen that any number and kind of phase modulators may be cascaded and without regard to the number and kind or combination. In the more common amplitude modulation such promiscuous modulation would not be possible, but with phase modulation no impair-

ment results and it is here that the novelty in applicant's invention lies.

What is claimed is:

1. The method of producing material modulation of the phase of wave energy at signal frequency which consists in producing energy characteristic of signals and modulating the phase of said wave energy in accordance with said produced energy in successive accumulative steps.
2. The method of phase modulating wave energy in accordance with signals which consists in, modulating the phase of said wave at signal frequency, and modulating the phase of the resultant energy at the same signal frequency.
3. In an improved phase modulated wave signalling system, a plurality of relays connected in cascade and energized by waves to be modulated, a source of modulating potentials and circuits connecting said source of modulating potentials to each of said relays for modulating the phase of the waves in each relay simultaneously.
4. In an improved phase modulated wave signalling system, a plurality of electron discharge tubes connected in cascade, circuits for applying waves to be modulated to the first of said tubes, a utilization circuit coupled to the last of said tubes, a source of modulating potentials and circuits connecting said source of modulating potentials to each of said tubes to modulate the phase of the waves in each tube simultaneously.
5. A communication system for transmitting message waves comprising, a source of continuous oscillations, a transmitting medium, a plurality of tuned coupling devices in cascade intermediate said source of oscillations and said medium, and means for modulating the phase of the oscillations supplied to said medium comprising, modulating elements for varying the tune of each of said coupling devices whereby the phase of the oscillations passed from said source to said transmitting medium is varied.
6. In a communication system for transmitting message waves, a source of continuous oscillations of constant amplitude, a transmitting medium, a plurality of electron discharge coupling devices having input and output electrodes connecting the devices in cascade intermediate said source of oscillations and said medium, and means for modulating the phase of the oscillations supplied to said medium comprising a source of signal potentials and modulating elements coupling said last source of signal potentials to each coupling device whereby the phase of the oscillations supplied by said first source to said medium is varied in accordance with said signal potentials.
7. A communication system comprising a source of carrier current, a load circuit, a plurality of reactive circuits in cascade between said load circuit and said source of carrier current, and means for modulating the phase of the oscillations transferred to said circuits from said source to said load circuit comprising, a modulating circuit, and a reactive coupling between said modulating circuit and each of said reactive circuits.
8. A communication system comprising a source of carrier current, a plurality of electron discharge amplifier tubes and tuned circuits coupling said amplifier tubes in cascade with said source for amplifying said carrier current, and means for modulating the phase of the amplified carrier current at signal frequency comprising, a source of signals, a modulating circuit connected to said source of signals, and a reactive coupling

between said last circuit and a plurality of said tuned circuits whereby the phase of said amplified current is varied in successive steps in accordance with signals from said source.

9. In a communication system, a source of carrier current, a plurality of amplifier circuits connected in cascade with said source for amplifying said carrier current, and means for modulating the phase of the amplified carrier current at signal frequency comprising, a modulating potential source, and reactive couplings of different character between said source of modulating potentials and each of said amplifier circuits whereby the phase of the amplified currents is varied in successive steps in accordance with potentials from said modulating potential source.

10. In a communication system, a source of carrier current, a plurality of amplifier circuits connected therewith for amplifying said carrier current, and means for modulating the phase of the amplified carrier current comprising, a modulating potential source, and reactive couplings of like character between said source of modulating potentials and each of said amplifier circuits whereby the phase of the amplified currents is varied in successive steps in accordance with the potentials of said second named source.

11. In a communication system, a source of carrier wave energy, a plurality of electron discharge devices, a source of modulating potentials, circuits coupling the input electrodes of a pair of electron discharge devices to said source of carrier wave energy, phase shifting means in one of said circuits, a second pair of electron discharge devices, circuits connecting said second pair of electron discharge devices to the outputs of said first pair of electron discharge devices, phase shifting means in one of said last named circuits, and a circuit connecting said source of modulating potentials in phase opposition to the devices in each of said pairs of devices.

12. The method of signalling by varying the phase of a carrier wave in accordance with signal potentials which includes the steps of relatively phase shifting portions of carrier wave energy of like frequency, differentially amplitude modulating the phase shifted energy portions in accordance with the signal potentials, combining the resultant energies, relatively phase shifting portions of the combined energy, differentially

amplitude modulating the latter energy portions, and combining the same to produce resultant energy for signalling purposes.

13. In a communication system, a source of carrier wave energy, a utilization circuit, a plurality of reactive circuits connected in cascade between said utilization circuit and said source of carrier wave energy, and means for modulating the phase of the oscillations transferred by said reactive circuits from said source of carrier wave energy to said utilization circuit comprising a source of modulating potentials and a coupling between said source of modulating potentials and each of said reactive circuits.

14. A system as recited in claim 13, wherein at least one of said reactive circuits is tuned substantially to a harmonic of the frequency of the wave energy.

15. In a communication system, a source of carrier frequency current, a plurality of relay circuits connected in cascade with said source for relaying said current of carrier frequency, and means for modulating the phase of the relayed current of carrier frequency at signal frequency comprising, a source of modulating potentials, and couplings of different character between said source of modulating potentials and each of said relay circuits whereby the phase of the relayed currents is varied in successive steps in accordance with potentials from said source of modulating potentials.

16. A system as recited in claim 15 wherein at least one of said relay circuits is tuned to a frequency which is a harmonic of the frequency of the current of carrier frequency.

17. In a communication system, a source of current of carrier frequency, a plurality of relay circuits connected therewith for relaying said carrier frequency current, and means for modulating the phase of the relayed carrier frequency current comprising, a source of modulating potentials, and reactive coupling of like character connecting said source of modulating potentials to each of said relay circuits whereby the phase of the relay currents is varied in successive steps in accordance with the modulating potentials.

18. A system as recited in claim 17 wherein one or more of said relay circuits is or are substantially tuned to a frequency which is a harmonic of the frequency of the carrier current.

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