Dec. 1, 1942.

W. A. PHELPS

2,304,017

CARRIER TELEGRAPH SYSTEM

Filed July 29, 1941

2 Sheets-Sheet 1

FIG. 1

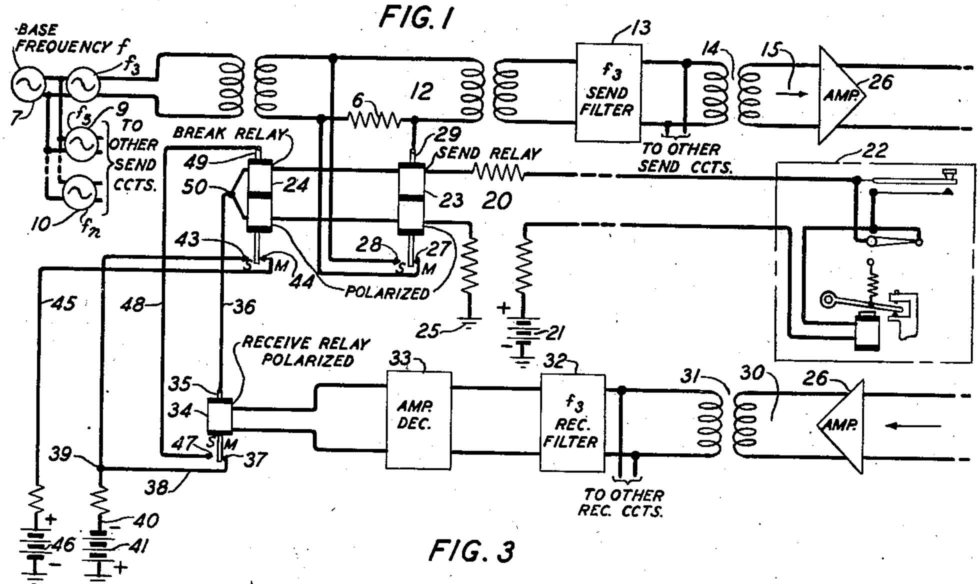


FIG. 3

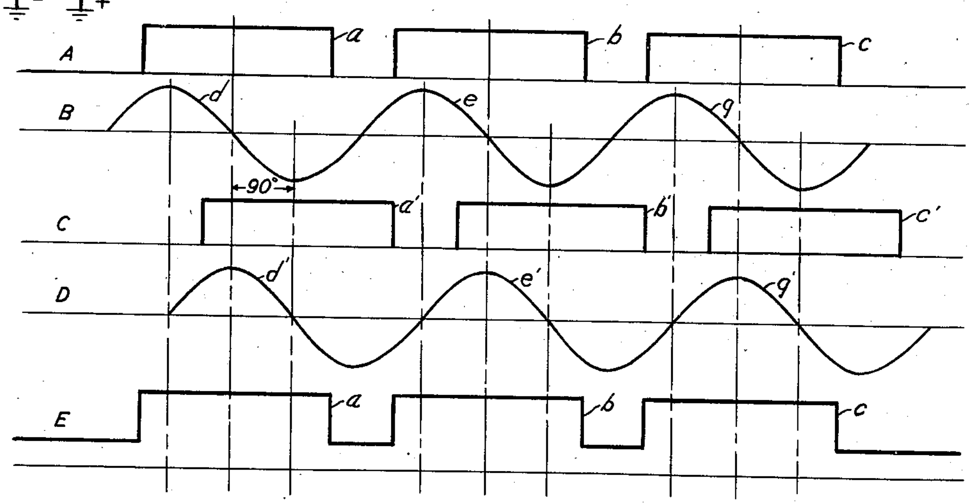
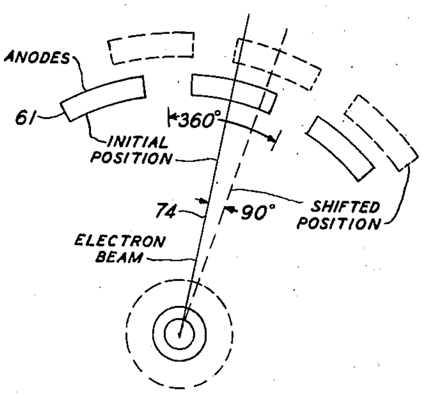


FIG. 4



INVENTOR
W. A. PHELPS
BY H. A. Burgess
ATTORNEY

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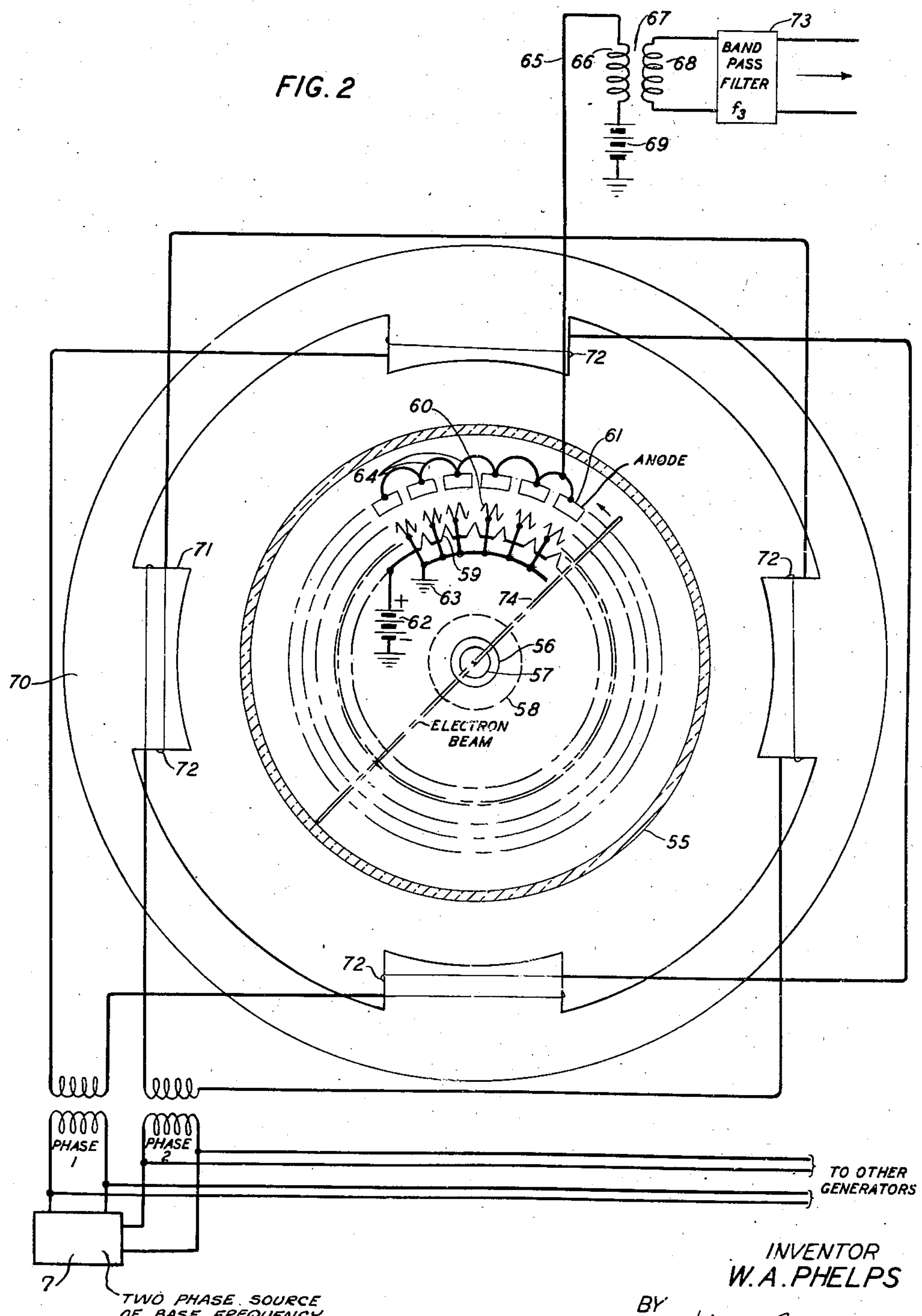
FIG. 2



INVENTOR
W. A. PHELPS
BY H. A. Burgess
ATTORNEY

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UNITED STATES PATENT OFFICE

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CARRIER TELEGRAPH SYSTEM

Walter A. Phelps, Madison, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 29, 1941, Serial No. 404,479

6 Claims. (Cl. 178—51)

This invention relates to a carrier current telegraph system, and more particularly to an arrangement for controlling the phase relation between the carrier current waves utilized in a multiplex carrier wave system.

In multiplex carrier wave telegraph system involving the transmission of a relatively large number of individual carrier current waves, which may be harmonics of a wave of a base frequency, on a single transmission line embodying repeaters in order to provide a number of carrier channels corresponding to the number of carrier current waves, it has been found that the peaks of such waves tend to add up periodically to produce relatively high amplitudes that overload the repeaters. This is due to the gradual change in the relative phases of the carrier waves of the several channels. Such peaking of the carrier waves causes the production of undesirable modulation and intermodulation components extending over the frequency range of the signaling waves thereby causing a low signal-to-interference ratio in all signaling channels. Heretofore, such overloading has been partially overcome by the general scheme of synchronizing the generators of the several carrier current waves with the wave of base frequency in order to fix the phase relation between the former waves, and then reversing the leads of certain generators to produce a reversal of phase of the individual waves supplied thereby. A difficulty with such phase adjustment is that the phase change is limited to 180 degrees. In the development of new multichannel carrier current systems, such phase adjustment may be inadequate unless the repeaters are designed at further expense to embody a certain amount of extra load-carrying capacity to compensate for the inadequacy of the phase adjustment effected by lead reversals alone.

Specifically, one arrangement to prevent repeater overloading consists in the use of a harmonic generator energized by a wave of base frequency and arranged to apply its output to the control grids of a number of vacuum tube oscillators to control the latter such that the waves of individual frequency supplied thereby are synchronized with the desired harmonics of the base frequency. A phase shifter in the output of each oscillator then permits the adjustment of the phase of the wave supplied thereby. This controls the hereinbefore-described addition of the peaks of the individual waves so as to prevent overloading of the line repeaters. Another arrangement to prevent repeater overloading involves the provision of a carrier current source comprising a motor-driven inductor alternator in which each individual rotor produces a wave of different frequency, the rotors having numbers of teeth bearing a harmonic relation strip to each other. As all rotors are rigidly attached to the same shaft, the several waves of different frequencies generated thereby will be in synchronism with the wave of base frequency. However, it is not practical with such an arrangement to make an exact adjustment of the relative phases of the several waves generated, and it has, therefore, been necessary to depend upon a random phasing of the several waves to prevent the occasional production of excessive current peaks in the repeaters.

The present invention contemplates an arrangement for controlling the phase angles of individual carrier current waves in multiplex signaling systems.

The main object of the invention is to control the phase relation between a plurality of carrier current waves being transmitted on the same line.

Another object is to prevent overloading of line amplifiers embodied in multiplex carrier current systems.

A further object is to supply a plurality of carrier current waves to a transmission line such that the phase angles of individual waves may be varied in an expeditious manner.

Still another object is to simplify the design of multiplex carrier current signaling systems.

A still further object is to minimize undesirable modulation effects in a carrier current signaling system utilizing a large number of carrier current waves.

Another object is to maintain the signal-to-interference ratio in all channels of a multiplex carrier current signaling system at tolerable minimum levels.

In a specific embodiment of the present invention, each carrier wave generator comprises an electron device including a predetermined number of anodes and an electron beam to move thereover, and a multipole stator disposed externally of the device to actuate the electron beam. The individual stators are energized from a common source of electrical energy of certain frequency so that all electron beams are actuated in synchronism with the frequency thereof. The output frequency of each electron beam generator is equal to n times the frequency of the common source, where n is the number of anodes. The individual electron devices are positioned in a preassigned manner with respect to each other in their associated stators such that corresponding anodes of each of the electron devices are presented to the synchronized electron beams with a certain time interval therebetween to control the phase relation between the carrier current waves being transmitted on the line.

The invention will be readily understood from the following description taken together with the accompanying drawings, in which:

Fig. 1 is a schematic circuit showing one terminal of a duplex carrier current telegraph system to which the invention is expeditiously applicable;

Fig. 2 is a schematic circuit illustrating an electron beam carrier current generator which may be employed in practicing the invention in connection with Fig. 1;

Fig. 3 embodies curves representing action obtainable in Figs. 1 and 2 both with and without practicing the invention; and

Fig. 4 is a schematic representation of the invention embodied in Fig. 2.

Referring to Fig. 1, a generator 8 of alternating current sine waves of frequency f_3, which is the third odd multiple of a base frequency f supplied by a source 7 and which will be hereinafter explained, is applied through a sending circuit 12, channel filter 13 and line transformer 14 to an outgoing transmission line 15 embodying one or more thermionic amplifiers 26 of suitable type. A subscriber's sending and receiving loop 20 includes source 21 of direct current potential whose negative terminal is grounded, sending and receiving apparatus 22, winding of sending relay 23, winding of break relay 24 and ground 25. The sending relay 23 embodies armature 29, marking contact 27 and spacing contact 28.

The wave generator 8 illustrated in Fig. 2 is an electron beam tube 55 of a type disclosed in the patent of A. M. Skellett, No. 2,217,774, granted October 15, 1940, and comprising a cathode 56, cathode heater 57, control grid 58, a plurality of screen electrodes 59, a plurality of suppressor grids 60, and a plurality of anodes 61. The respective screen and suppressor electrodes 59 and 60, control grid 58 and anodes 61 are disposed about the cathode 56 in a curvilinear path.

The screen electrodes 59 are connected to the positive terminal of a source 62 of direct current potential whose negative terminal is grounded. The suppressor electrodes 60 are connected to ground 63. Adjacent anodes 61 joined by individual links 64 are applied over lead 65 and primary winding 66 of an output transformer 67 to the positive terminal of a source 69 of direct current potential whose negative terminal is grounded. The secondary winding 68 of the transformer 67 is impressed across the input of a filter 73.

Positioned externally of but concentrically with the tube 55 is a magnetic stator 70 formed of iron and having four equally spaced poles 71 each of which has applied thereon a coil 72. The stator 70 may be of a depth equal substantially to the length of the above-mentioned electrode assembly. Diametrically opposite coils 72 are connected and poled so as to produce magnetic poles of opposite polarity. As shown in Fig. 2, diametrically opposite pairs of coils 72, 72 are connected to individual phases of a two-phase source 7 of alternating current voltage having the two phases adjusted to be 90 degrees apart and having a certain frequency. These two phases may be derived from a two-phase generator wound for the purpose or they may be derived from a single phase using a capacitor individual to each pair of coils 72, 72, both of which methods are disclosed in the Skellett patent, supra. This produces within the space defined by the stator poles a magnetic field which rotates in synchronism with the frequency of the two-phase source 7.

In this magnetic field is disposed the radial electron beam tube 55 in which electrons from the cathode 56 are focussed on the individual anodes 61, successively, as the radial beam 74 rotates in synchronism with the rotating magnetic field as explained in the Skellett patent, supra. As the electric field drawing the electron beams from the cathode 56 to the anodes 61 is produced by a direct potential applied to all anodes 61, the rotating electron beam consists of two oppositely directed beams which will have the effect merely of providing two parallel paths for space current. The rotating beam 74 produces a pulsating current idealized in Fig. 3A, in the primary winding 66 of the transformer 67, Fig. 2. In this connection a certain amount of separation is provided between the individual anodes 61, depending on the amount of overlap of the electron beam 74 between adjacent anodes 61.

In general, this ovelap prevents the pulsating current from dropping to zero between successive pulses as illustrated in Fig. 3E but, however, such direct current component is removed by the effect of the transformer 67. It is to be understood that the respective screen and suppressor electrodes 59 and 60 perform the same function as corresponding electrodes in the well-known pentode tube. The pulsating current applied to the primary winding 66 of the transformer 67 induces in the secondary winding 68 thereof a current whose frequency is n times the frequency of the two-phase source 7, where n is the number of individual anodes 61 in the electron tube 55. Band filter 73, Fig. 2, connected to the secondary winding 68 serves to remove the direct current component and harmonics of the base frequency and so to smooth out the wave of the current therein so that such wave has a substantially sine form as illustrated in Fig. 3B.

In Fig. 2, the electron beam tube 55 and associated stator 70, transformer 67, and filter 73 are assumed to constitute the wave generator 8 of Fig. 1. As the wave generators 9—10, Fig. 1, are assumed to be duplicates of the wave generator 8, the former are therefore assumed to comprise individually the elements identified above as constituting the wave generator 8. The generators 8, 9—10 are caused to produce alternating current waves having different frequencies by varying the number of individual anodes 61, as pointed out above. Thus, the frequency change effected by each wave generator 8, 9—10 is equal to the frequency of the two-phase source 7 multiplied by the number of individual anodes 61. Assuming the two-phase power source 7 to have a frequency of 85 cycles per second, then the successive frequencies of the wave generators 8, 9—10 could comprise odd multiples of 85 beginning with the third and ending with the *nth*, that is, frequencies f_3, f_5—f_n, by appropriately varying the number of individual anodes 61 in each of the electron beam tubes 55, Fig. 2, constituting the respective wave generators 8, 9—10. As the wave generators 8, 9—10 are synchronized with the two-phase source 7, the individual electron beams are therefore driven in synchronism with the respective harmonics of the frequency of the two-phase source 7.

Referring again to Fig. 1, incoming transmission line 30 embodying one or more thermionic amplifiers 26 of suitable type is connected through line transformer 31, channel filter 32, amplifier-detector 33 and winding of receiving relay 34 whose armature 35 has one terminal connected over lead 36 to the balanced loop circuit 20. Marking contact 37 of the receiving relay 34 is connected over lead 38 to a common point 39, thence over lead 40 to the negative terminal of source 41 of direct current voltage whose positive terminal is grounded, and over lead 42 to spacing contact 43 of the break relay 24. Marking contact 44 of the latter relay is connected by lead 45 to the positive terminal of source 46 of direct current voltage whose negative terminal is grounded. Spacing contact 47 of the receiving relay 34 is extended by a lead 48 to the armature 49 of the break relay 24. It is understood that the subscriber's apparatus pointed out above in connection with the wave generator 8 is also duplicated in the same manner for the individual wave generators 9—10.

In the operation of Fig. 1, a subscriber transmits individual signaling elements by actuating his sending apparatus 22 to operate the armature 29 associated with the respective sending relay to its marking and spacing contacts. The armature 29, when closed on the marking contact 27, short-circuits resistance 6 on one side of the sending circuit 12 to apply effectively waves f_3 from the wave source 8 to the outgoing line 15; and the armature 29, when closed on the spacing contact 28, is connected in shunt of the sending circuit 12 thereby effectively disconnecting the wave source 8 from the outgoing line 15 to prevent the application of the waves f_3 thereto.

Waves f_3 from a remote subscriber's station, not shown, incoming on the line 30 are selected by the filter 32, amplified and rectified in the usual manner in the amplifier-rectifier 33, and thereafter utilized to actuate the armature 35 of the receiving relay 34 to its respective marking and spacing contacts 37 and 47. This serves to effect corresponding actuations of the subscriber's sending and receiving apparatus 22. This operation is well understood in the art. At the same time a distant subscriber may send a "break" signal to the subscriber, then sending, to interrupt such operation in order to gain control of signal transmission. Such break signal serves to operate the armature 35 of the receiving relay 34 to its spacing contact 47, thus applying a positive battery to the apex 50 of the balanced loop circuit 20. Actuation of the key of sending and receiving apparatus 22, then no longer causes operation of the sending relay 23 which remains on its marking contact 27. This operation is disclosed in the patent of A. Weaver, No. 1,569,055, granted January 12, 1926.

In the above operation of Fig. 1, the wave generators 8, 9—10 provide waves f_3, f_5—f_n which are impressed on the outgoing line 15, or are arriving on the incoming line 30, without particular regard to their phase relation, except in a manner that will be subsequently pointed out. For the purpose of this description, it is assumed that the several phase control arrangements discussed hereinbefore are not utilized. Consequently, it is found that the peaks of the waves f_3, f_5—f_n having but accidental phase adjustment therebetween tend to add up periodically on the lines 15 or 30 to effect relatively large amplitudes that overload momentarily the line amplifiers 26 in the manner explained in my copending application, Serial No. 356,128 filed September 10, 1940.

In accordance with the present invention, the wave generators 8, 9—10 are mutually arranged such that a certain phase relation is provided between the waves f_3, f_5—f_n being transmitted on the outgoing line 15. To accomplish this, the several tubes 55 constituting wave generators 8, 9—10 are positioned in their associated stators 70 in a preassigned manner to vary the phase angles of the individual waves f_3, f_5—f_n in a manner that will be presently described.

In this connection, Fig. 3A shows the successive undirectional pulses a, b, c impressed on the primary winding 66 of the transformer 67 as the electron beam 74 moves over the successive anodes 61 in Fig. 2; and the curve 3B shows the correspondingly successive alternations d, e, g in the output of filter 73, Fig. 2. For the curves of both Figs. 3A and 3B the tube 55 is assumed to be so positioned in its associated stator 70 that the location of the anodes 61 may be represented by the solid line segments of Fig. 4.

Next, the tube 55 is rotated in its associated stator 70 in a clockwise direction by an amount such that the anodes 61 are caused to assume the positions shown by the broken line segments in Fig. 4. Now the electron beam 74 passes over substantially the mid-point of the middle anode 61, as illustrated in the broken lines in Fig. 4, at a later time than over the mid-point of this segment when in its initial position. For the purpose of this description, it is assumed that the previously mentioned rotation of the tube 55 in its stator 70 as represented in Fig. 4 causes a 90-degree shift of the corresponding anodes 61. Referring to Fig. 3C, it is seen that the successive unidirectional pulses a', b', c' corresponding to the successive pulses a, b, c of Fig. 3A are impressed 90 degrees later on the primary winding 66 of the transformer 67. Consequently, the successive alternations d', e', g' of Fig. 3D occasioned by the pulses a', b', c' of Fig. 3C, are also effective 90 degrees later at the output of the filter 73, Fig. 2. In other words, the respective unidirectional pulses of 3C and alternations of 3D are effective at the output of the filter 73, Fig. 2, substantially 90 degrees later than the correspondingly respective unidirectional pulses a, b, c of Fig. 3A and alternations d, e, g of Fig. 3B.

It is apparent that the tube 55 may be shifted in its associated stator 70 in clockwise or counterclockwise directions to provide a change in the phase angle of the wave f_3 in the output of the filter 73 extending somewhere between 0 and 360 degrees. Accordingly, the electron beam tube 55 and associated elements in Fig. 2 constituting the wave generators 9 and 10 as previously pointed out may be individually rotated in their associated stators 70 in preassigned amounts to provide the waves f_5—f_n with different phase angles. As the electron beams of the individual tubes 55 are synchronized with the frequency of the base-wave source 7, the adjustments of the individual electron beam tubes 55 in a preassigned manner in the associated stators 70, constituting the respective wave generators 8, 9—10 serve to present corresponding individual anodes 61 of the several electron devices 55 to the synchronized electron beams 74 with a certain time interval between each corresponding anode 61 to provide each wave f_3, f_5—f_n with a certain phase angle. Accordingly, a certain phase relation may be provided between the waves f_3, f_5—f_n on the outgoing line 15. Thus, controlling the time difference between corresponding unidirectional pulses of the wave generators 8, 9—10 in the manner explained above in connection with Figs. 3 and 4, enables control of the phase relation between the waves f_3, f_5—f_n on the line 15.

A suitable cathode ray oscillograph applied to the line 15 may be utilized to observe such phase relation so as to determine which of the waves, if any, requires further phase adjustment and the amount thereof. As the wave generators 8, 9—10 are synchronized with the frequency of the base-wave source 7, the waves f_3, f_5—f_n will tend to maintain the preassigned phase relation on the line 15 thereby to minimize deleterious effects on transmission in the entire system in the manner discussed in my copending application, supra.

It is understood that the individual electron beam tubes shown in Fig. 2 may be so mounted mechanically with a suitable scale that they can be readily rotated through relatively small angles until the optimum relative angular positions are found. Then, the individual electron beam tubes may be locked in their respective positions. Such optimum relative angular positions may be realized when the lowest possible peaks are attained as all carrier current waves are simultaneously applied to the sending line 15.

It is further understood that while the invention is disclosed with individual electron beam tubes, it is not necessarily limited thereto, and would operate equally satisfactorily with the several individual pluralities of anodes and associated electron beam combined in a single envelope; and in addition that individual stators may be calibrated such that a preassigned time difference between individual waves may be initially provided. In the latter connection, such time difference is understood to mean a preassigned time difference between corresponding anodes of individual electron devices.

What is claimed is:

1. In combination, a utilization circuit, means to apply a plurality of discrete alternating current waves of different frequencies to said circuit, said wave means comprising a plurality of individual electron devices, each embodying a predetermined number of targets and an electron beam to move thereover, and means of certain frequency to actuate said electron beams in synchronism therewith, corresponding targets of individual electron devices being oriented with respect to time so as to be presented to associated electron beams at different time intervals to control the phase relation between said waves in said circuit.

2. In combination, a transmission line, means to generate a plurality of discrete alternating current waves of different frequencies, and signaling means to control the effective application of said waves to said line, said wave generating means comprising a plurality of individual electron devices each embodying a certain number of anodes, and an electron beam, and electrical means of specific frequency to actuate said electron beams in synchronism therewith over said anodes, including a stator disposed externally of each of said devices such that therein said devices occupy a preassigned relation with respect to each other to present corresponding anodes of each of said devices to said electron beams in a certain time relation to control the phase relation between said waves on said line.

3. In combination, a transmission line, means to generate a plurality of discrete alternating current waves of different frequencies, and signaling means for controlling the effective application of said discrete wave generating means to said line, said wave generating means comprising a plurality of electron devices, each embodying a certain number of anodes disposed in a curvilinear path, an electron beam to move thereover, and a multipole stator concentrically positioned externally of said electron device to move said electron beam over said anodes, and a common source of alternating current voltage of certain frequency to energize simultaneously said stators to synchronize said movement of said electron beams with said certain frequency of said common source, said devices being individually positioned in a preassigned manner with respect to each other in said stators to present corresponding anodes of each said devices to said synchronized electron beams at different time intervals to control the phase angles of individual waves of said plurality of waves on said line.

4. An alternating current telegraph system comprising a line, means to generate a plurality of discrete alternating current waves of different frequencies for transmission on said line, and means to control effectively the application of said waves to said line to represent individual signaling elements, said wave generating means comprising a plurality of individual electron tubes each embodying a predetermined number of targets, an electron beam to move thereover, and a stator concentrically disposed externally thereof, and a common source of alternating current voltage of certain frequency to energize said stators of said plurality of tubes to cause said electron beams to move in synchronism with the frequency of said source so that each of said tubes produces an alternating current wave whose frequency is equal to the product of the number of said anodes and said certain frequency, said tubes being individually positioned in said stators in a preassigned manner with respect to each other to present corresponding anodes of each of said tubes to said synchronized electron beams with a preassigned time difference between each of said corresponding anodes to control the phase relation between said waves on said line.

5. In combination in a circuit to produce a group of alternating current waves having a predetermined phase relation therebetween, a plurality of groups of targets arranged such that corresponding targets of individual groups have a preselected electrical time relation, an electron beam individual to each group of targets and movable thereover, and means comprising an alternating voltage of certain frequency to move said electron beams in synchronism over said targets.

6. In combination, in a circuit to supply alternating current waves having a predetermined phase relation therebetween, means to produce a plurality of alternating current waves, comprising a plurality of electron devices each embodying a plurality of targets and an electron beam movable thereover, said devices occupying such relative positions that corresponding targets of individual devices possess preselected relative electrical time, and a source of alternating voltage of certain frequency to move said electron beams in synchronism at the certain frequency of said source.

WALTER A. PHELPS.