

Oct. 16, 1945.

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2,387,045

ELECTRON BEAM ROTATION SYNCHRONIZING CIRCUIT

Filed July 17, 1942

2 Sheets-Sheet 1

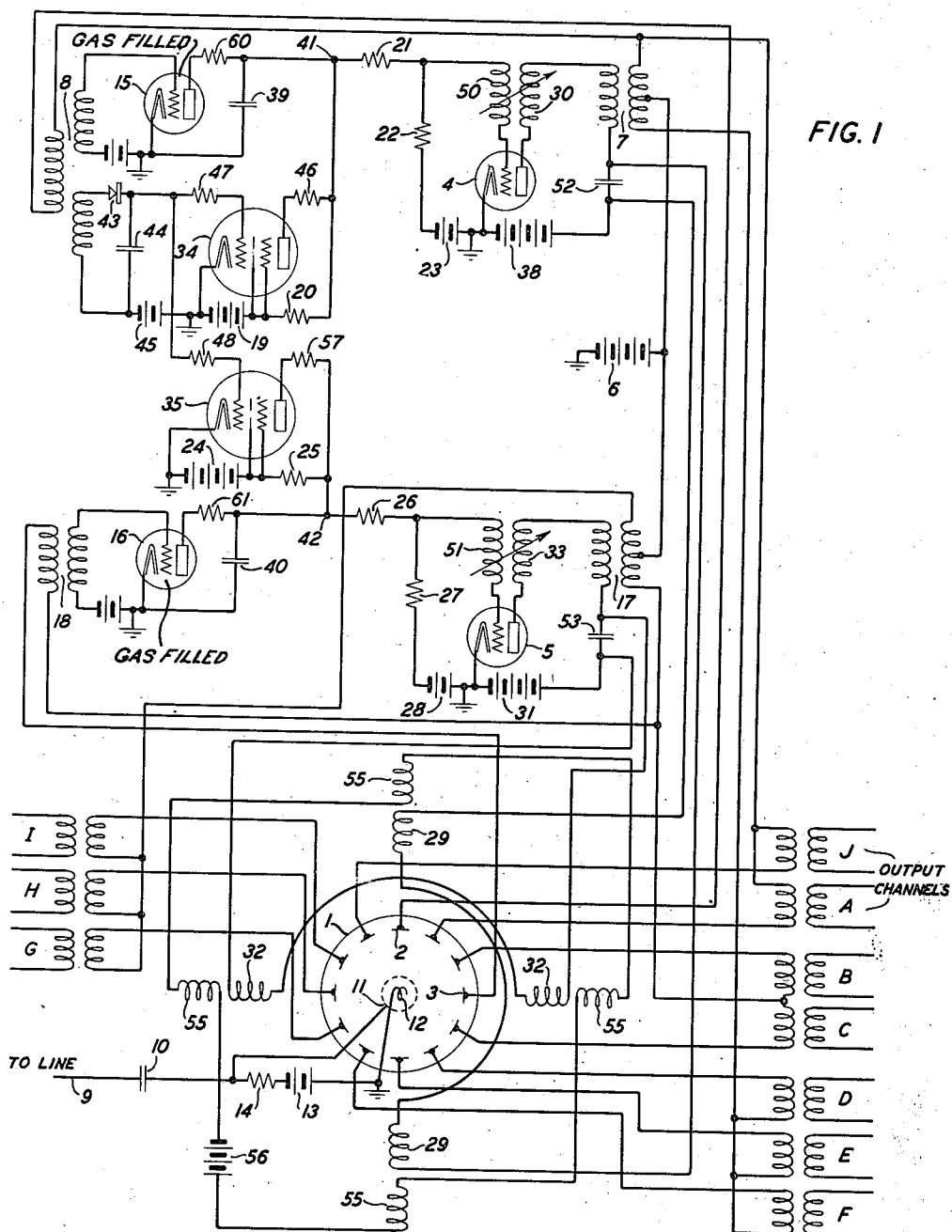


FIG. 1

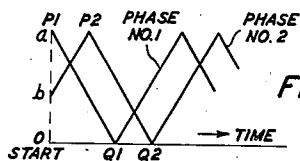


FIG. A

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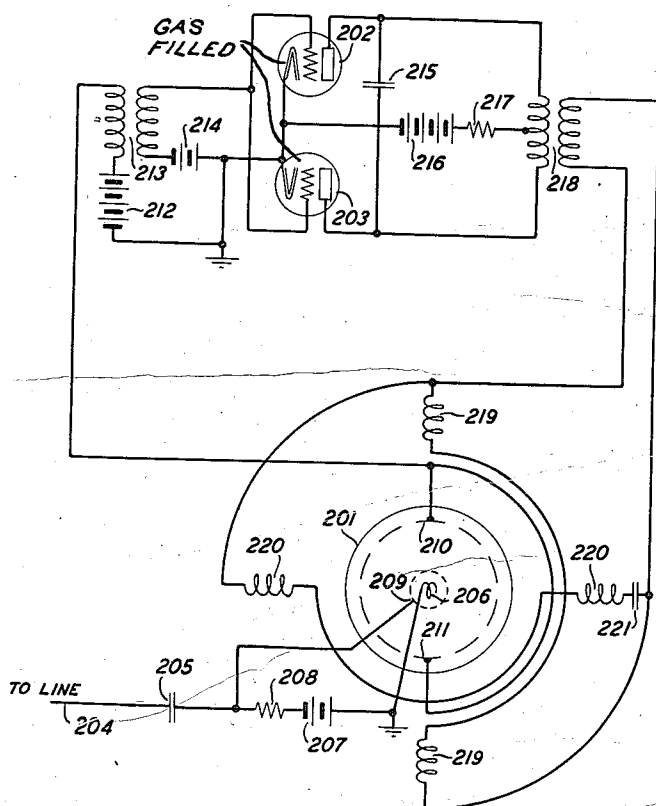
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2 Sheets-Sheet 2

FIG. 2



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ELECTRON BEAM ROTATION SYNCHRONIZING CIRCUIT

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Application July 17, 1942, Serial No. 451,355

13 Claims. (Cl. 178—53.1)

This invention pertains to the automatic synchronization of the rotation of electron beams in radial beam vacuum tubes, such as described in applicant's prior Patent 2,213,774 issued October 15, 1940. More particularly, the invention pertains to the automatic synchronization of the rotation of electron beams in radial beam vacuum tubes used as transmitting and receiving distributors in multiplex transmission over long distances in communication systems.

Multianode radial beam tubes will find many more applications in the electrical industry if satisfactory means are provided for rotating the electron beam in a receiving tube in synchronism with the rotating beam in a transmitting tube. It is particularly desirable in a number of these applications that the beams in both tubes rotate not only at the same rate but that the beams in both tubes be directed simultaneously at anodes in corresponding positions in both tubes.

The invention herein provides a rotating magnetic field for the electron beam in a multianode electron beam receiving tube which field is independent of the local power supply at the receiving station. Multianode beam tubes so arranged are suitable for instance in telegraph systems where the start-stop distributor is now used.

It is an object of the invention herein to provide instrumentalities for use in radial beam tubes in multiplex communication circuits for starting and maintaining their electron beams in synchronism even though they may be separated by great distances and supplied with independent sources of power not in synchronism at the transmitting and receiving station.

In certain multiplex circuits presently known which use radial electron beam vacuum tubes it is not possible to send current of the frequency to produce the revolving fields required for rotating the beam over one of the channels interconnecting the transmitter and receiver since the fundamental frequency of the pulses is considerably higher than that of the current supplied to the stators for revolving the beam. Conceivably, one might feed the pulses from a pilot channel into a subharmonic generator and from this derive the correct frequency for the stators but this method would present some problems of starting. To start a system utilizing the circuit described herein it is only necessary to turn on the pilot channel signals at the transmitter and the electron beam at the receiver will immediately start to rotate in exact synchronism with that at the transmitter, that is to say, the system becomes immediately operative.

The invention may be understood from the following description when read with reference to the associated drawings in which:

Fig. 1 is one embodiment of the invention which shows a multianode radial electron beam vacuum tube receiving circuit arranged to rotate an electron beam in receiving tube 1 in synchronism with a rotating beam in a corresponding transmitting tube at a distant transmitting station (not shown) so that the beams rotate uniformly and engage corresponding anodes in each tube simultaneously. Tube 1 has twelve anodes. Two of the anodes, anodes 2 and 3, are used for synchronizing. The output circuits connected to the other ten anodes connect to ten work channels, lettered A to J, through transformers. The circuit employs six complementary tubes to effect synchronization.

Fig. 2 is a simplified embodiment of the invention. In Fig. 2 only two complementary tubes are required.

Fig. A shows the voltage graph for two relaxation oscillators forming part of Fig. 1.

Refer now to Fig. 1. Before the operation of the circuit per Fig. 1 is described in detail, the manner in which it functions will be described in a general way to facilitate the understanding of the detailed description to follow.

In the system to be described the line 9 is assumed to be incoming from a distant transmitting station (not shown) where it is connected to a radial electron beam multianode transmitting tube having twelve anodes and corresponding generally to receiving tube 1. Two of the anodes in the distant transmitting tube correspond to anodes 2 and 3 of receiving tube 1 and serve as synchronizing anodes.

The anodes of multianode beam tubes are maintained at a positive potential relative to the cathode. When the grid is made positive relative to the cathode a stream of electrons is emitted from the cathode and flows toward a particular anode. The direction in which the stream of electrons flows is controlled by a magnetic field which pervades the space inside the envelope of the tube. In the present invention the stator of a 2-phase motor surrounds the glass envelope of multianode radial beam tube 1. The direction of the electron stream depends upon the magnetic field set up by the flow of current supplied to the stator coils from vacuum tubes 4 and 5.

At different times different outputs are supplied from vacuum tubes 4 and 5 to the stator coils to control the electron beam in tube 1 in different manners. While no signals are being received over the line 9 from the multianode transmitting

tube the outputs of tubes 4 and 5 are under control of individual potentiometers which supply steady potentials from a local power source to the input circuits of tubes 4 and 5. When signals are being received over the line the inputs of tubes 4 and 5 are, in effect, transferred so that they are responsive to the signals incoming over the line from the transmitter.

The distant transmitting tube is arranged in a manner well known in the art so that the first stream of electrons which its cathode emits, as the stream is simultaneously established and started to rotate, is directed at an anode in the distant transmitting tube in a position corresponding to the position of anode 2 in receiving tube 1.

The circuit of the invention herein is arranged so that when no signals are being received from the transmitting tube and while the receiving tube 1 is awaiting the first signal pulse over the line 9 from the distant transmitter, steady currents are supplied from the outputs of tubes 4 and 5 to their respective coils in the stator surrounding tube 1. The relative magnitude of the output current of tubes 4 and 5 is such that the fields which are established by the stator coils tend to direct any electrons emitted by the cathode toward anode 2.

While no signals are being received by tube 1 from the distant transmitter there is no electron beam in tube 1. There are, however, magnetic fields set up in the stator coils surrounding the glass envelope of tube 1 tending to direct any electrons which may be emitted by the cathode of tube 1 toward anode 2.

Thus, the first signal received over the line 9 will be as a result of the direction of a stream of electrons in the transmitting tube in the distant station at an anode in a position corresponding to the position of anode 2 in receiving tube 1. A stream of electrons will be emitted from cathode 12 in response to the reception of the first signal. The effect of the preestablished magnetic field will direct the beam instantly at anode 2.

The impinging of the first stream of electrons on anode 2 will result, in a manner to be described, in the starting of the generation of two saw-tooth shaped voltage waves. The period of the waves and their relation to each other is controlled, once they are started, by the impinging of beams on anodes 2 and 3. The waves are maintained in quadrature. They are translated into substantially sinusoidal voltage waves in quadrature which are impressed by vacuum tubes 4 and 5 on their respective stator coils surrounding tube 1. This will rotate the beam in tube 1 in substantial synchronism with the rotation of the beam in the distant transmitting tube. Any slight difference in the speeds of rotation of the two beams will be corrected once per revolution in a manner to be described so that once started the receiving tube beam is maintained in synchronism with the beam of the transmitting tube. Furthermore, the beam in the receiving tube 1 is directed at a particular anode in tube 1 simultaneously with the direction of the beam in the distant transmitting tube at a corresponding anode in the distant tube.

It has been pointed out above and it is emphasized that during the waiting period before signals are received over the line from the transmitting station by tube 1, a steady current is supplied from tubes 4 and 5 to the coils of the stator surrounding the envelope of tube 1 so as to generate a steady magnetic field which tends to direct a stream of electrons if generated toward

anode 2. The steady output from each of tubes 4 and 5 necessary to direct the first beam at anode 2 is obtained by impressing a steady potential between the grid and cathode of each of tubes 4 and 5 by means of an individual potentiometer which controls each tube during the waiting period before the reception of signals.

The grid voltages are chosen so as to maintain the proper output current in each tube so that the resultant of the magnetic field in the stator tends to direct a beam, if emitted, at anode 2.

Simultaneously with the reception of the first pulse from the distant transmitter by receiving tube 1 and in response to its reception, the character of the output of tubes 4 and 5 is changed in a manner to be described so that these tubes deliver substantially sinusoidal voltages in quadrature to the stator coils. The period of oscillation of the sinusoidal voltages impressed on the stator coils of tube 1 while signals are being received from the transmitter is maintained the same as the period of rotation of the electron beam in the transmitting tube at the distant station.

The circuit of Fig. 1 features two relaxation oscillators which generate two saw-toothed voltage waves in quadrature. These two voltage waves are indicated by the curves in Fig. A. When the first stream of electrons impinges on anode 2 in response to the reception of the first voltage pulse from the distant station, the generation of the saw-toothed voltage wave by one of the relaxation oscillators is inaugurated. When the stream of electrons impinges on anode 3 of tube 1 which is separated from anode 2 by 90 degrees, a saw-toothed voltage wave generated by the second relaxation oscillator in Fig. 1 is inaugurated. The saw-toothed voltage wave generated by one relaxation oscillator is impressed on the input of tube 4 which responds by delivering a substantially sinusoidal wave to its respective stator coil in its output circuit. The second saw-toothed voltage wave generated by the second relaxation oscillator in Fig. 1 is impressed on the input of tube 5 which responds by delivering a substantially sinusoidal voltage wave in quadrature with that delivered by tube 4 to its respective stator coils in the output circuit of tube 5.

As long as the beam in tube 1 continues to rotate, the relaxation oscillators controlled by anodes 2 and 3 will continue to generate their saw-toothed voltage waves. This in turn will result in the continued generation of the substantially sinusoidal voltage waves in quadrature by oscillators 4 and 5. On the instant that the reception of voltage impulses from line 9 connecting receiving tube 1 to the distant transmitter ceases, the generation of the saw-toothed wave by the relaxation oscillators will also cease responsively. Steady potentials will again be impressed instantly on the inputs of tubes 4 and 5 by their respective potentiometers. A steady magnetic field tending to direct electrons toward anode 2 will be set up in the stator coils surrounding the envelope of tube 1 so that the tube will be in condition to start.

The circuit per Fig. 1 will now be described in detail. When the system of Fig. 1 is in condition to receive signals, but before signals are actually received, the circuit of Fig. 1 sets up a magnetic field in the stator coils surrounding the envelope of multianode beam tube 1 such that any electrons which may be emitted from the cathode 12 in response to the reception of a signal will be

directed toward anode 2. This is achieved as a result of current flowing in the output circuit of tubes 4 and 5 through windings 29 and 32 of the stator surrounding the envelope of tube 1. Coil 29 is included in the output circuit of tube 4. Coil 32 is included in the output circuit of tube 5. Tubes 4 and 5 are normally activated during the waiting interval and the resultant of the effects of current in coil 29 from tube 4 and coil 32 from tube 5 tends to direct any electrons which may be emitted from cathode 12 of tube 1 toward anode 2.

Normally, that is, while signals are not being received by multianode beam tube 1, gas-filled trigger tubes 15 and 16 and secondary emission tubes 34 and 35 described in my copending application Serial No. 321,852, filed March 2, 1940, are deactivated. Steady potentials are impressed between the grid and cathode of tubes 4 and 5 by potentiometers connected to their input circuits to maintain the grid of each at the proper negative potential with respect to its cathode so as to provide steady outputs from tubes 4 and 5. This is effected by means of an individual potentiometer associated with the input circuit of tubes 4 and 5. The potentiometer circuit for tube 4 may be traced from ground through positive battery 19, resistance 20, resistance 21, resistance 22, negative battery 23 and back to ground. The grid of tube 4 is connected through coil 50 to the junction between resistances 21 and 22. The potentiometer circuit for tube 5 may be traced from ground through positive battery 24, resistance 25, resistance 26, resistance 27, negative battery 28 and back to ground. The grid of tube 5 is connected through coil 51 to the junction between resistances 26 and 27. The output circuit for tube 4 may be traced from positive battery 38 through stator coils 29, shunting condenser 52, and through the primary of transformer 7 and coil 30 to the anode of vacuum tube 4 and to its cathode to ground. The output circuit for tube 5 may be traced from positive battery 31 through stator coils 32, shunting condenser 53, and through the primary of transformer 17 and coil 33 to the anode of vacuum tube 5 and to its cathode to ground. A steady current flows in the output circuit of each tube. The relative magnitudes of the currents are maintained by a proper choice of circuit constants so that the fields set up by these stator coils tend to direct the first electron beam emitted by cathode 12 toward anode 2.

A circuit may be traced from positive battery 6 through the upper portion of the winding of the secondary of transformer 7, through the primary of transformer 8 to anode 2 of multianode beam tube 1. The potential of grid 11 of tube 1 is normally negative with respect to cathode 12 due to negative battery 13 which is connected from the grounded cathode 12 through resistance 14 to grid 11. The conductor 9 is connected at its distant end to a multianode beam vacuum tube transmitter arranged with twelve anodes and having two anodes corresponding to anodes 2 and 3 arranged as synchronizing and starting anodes. The circuit extends through condenser 10 to the junction between grid 11 and the upper terminal of resistance 14. In response to an incoming signal the grid 11 is made momentarily positive with respect to its cathode 12. A stream of electrons will be emitted from cathode 12 and, as a result of the effect of the stator magnetic field, it will be directed at anode 2.

Attention is called to the condensers 39 and 40. Condenser 39 is connected between the junction

41 of potentiometer resistances 20 and 21 and ground. The anodes of tubes 15 and 16 are also connected through resistances 50 and 46, respectively, to junction 41. Condenser 40 is connected between junction 42 of potentiometer resistances 25 and 26 and ground. The anodes of tubes 16 and 35 are also connected through resistances 51 and 57, respectively, to junction 42.

The constants of the elements of the potentiometer circuits are chosen so that while no signals are being received by tube 1 the potential across condenser 39 is indicated in Fig. A by the ordinate *oa*. The potential across condenser 40 for the same condition is indicated in Fig. A by the ordinate *ob*. These potentials are applied between the anode and cathodes of trigger tubes 15 and 16, respectively.

In response to the directing of the first electron beam at anode 2, a current pulse will flow through the primary of transformer 8. A voltage pulse will be generated in the primary and induced and inverted in the secondary windings of the transformer. As a result of the positive voltage pulse in the top secondary winding of transformer 8 tube 15 is fired instantly. The firing point is indicated at point *Pi* on the curve phase 1 in Fig. A.

Negative battery 45 is normally connected between ground and the grids of tubes 34 and 35 through the bottom secondary winding of transformer 8, rectifier 43 and resistances 47 and 48, to maintain tubes 34 and 35 deactivated.

The positive voltage induced in the bottom secondary winding of transformer 8 is applied through rectifier 43, across condenser 44 and through resistances 47 and 48 between the grids and cathodes of secondary emission tubes 34 and 35.

Both tube 34 and tube 35 are activated instantly.

Condenser 44 is charged to a relatively high potential by the effect of the current flowing in response to the single voltage surge through the bottom secondary of transformer 44. Rectifier 43 is arranged so that it offers a low resistance to the charging current. The voltage developed across the condenser is fed through high resistances 47 and 48 to the grids of tubes 34 and 35. Because of the magnitudes of these resistances the grids of tubes 34 and 35 are maintained at about the same potential as their cathodes.

On each negative half-cycle condenser 44 starts to discharge through rectifier 43 in the high resistance direction. The discharge is relatively slow. Before it can discharge sufficiently, as a result of the rotation of the beam in a manner to be described, the beam in tube 1 will be positioned so that it again impinges on anode 2 and condenser 44 will be recharged. In other words once rotation is started condenser 44 will receive relatively heavy surges of charging current once per rotation of the beam in tube 1 and condenser 44 will be discharged so slowly between charging intervals that tubes 34 and 35 will remain activated as long as the beam rotates. It is pointed out that the manner in which the sinusoidal voltages in quadrature are generated to rotate the beam will become apparent from the following.

Attention is especially directed to the fact that tubes 34 and 35 are activated simultaneously. Both tube 34 and tube 35 are activated in response to the impinging of the first stream of electrons on anode 2 in tube 1 and the response is instantaneous.

To return now to a consideration of the effect

of the firing of tube 15. Tube 15 fired instantly in response to the impinging of the first stream of electrons on anode 2 in tube 1. When tube 15 fires it provides a discharge path through the tube for condenser 39. As condenser 39 discharges through tube 15 its potential decreases from the indicated by ordinate *oa*, as shown by the curve phase 1 in Fig. A, until it reaches a point at which tube 15 is deactivated. From this point the potential across condenser 39 increases due to the effect of the current flowing in the output circuit of tube 34, which as has been explained, remains conducting. The potential across condenser 39 rises again to a peak equal to its original potential *oa* as indicated by the curve phase 1. Then tube 15 is refired by the effect of a stream of electrons impinging on anode 2 a second time due to the rotation of the electron beam in a manner to be explained.

Refer now to the curve marked phase 2 in Fig. A. As explained above, the potential across condenser 40 before the first signal impulse is received from the distant station is indicated by ordinate *ob*. It was also explained that tube 35 was activated simultaneously with the activation of tube 34 at the instant the first electron beam impinged on anode 2 in tube 1. Condenser 40 is connected in the output circuit of tube 35. The instant tube 35 is activated the potential across condenser 40 starts to rise as indicated by the curve phase 2 in Fig. A. The potential across the condenser will continue to rise until tube 16 is fired in response to the impinging of the electron beam on anode 3 in tube 1 as the beam is rotated.

When the electron beam in tube 1 impinges on anode 3, as the beam is rotated, current will flow from positive battery 6 through the bottom portion of the secondary of transformer 17, through the primary of transformer 18, to anode 3 of tube 1 through the space separating the anode 3 and anode 12 of tube 1 and to ground. A voltage pulse will be generated in the primary of transformer 18 which will be induced and inverted in the secondary of transformer 18 to fire tube 16 which is normally deactivated by the effect of negative battery 61 connected between its ground-cathode and grid.

Tube 16 will fire at point P2 on the curve phase 1 in Fig. A. After the tube fires the condenser will discharge through the tube. The potential across condenser 40 will decline as indicated along the line P2Q2 until a point is reached at which the tube 16 is deactivated, when it will again rise due to the effect of the charging current in the output circuit of tube 35.

The potential across condenser 39 between anode 41 and ground will be applied between the grounded cathode and grid of tube 4 through resistance 21 and coil 50. The potential across condenser 40 will be applied between the ground-cathode and grid of tube 5 through resistance and coil 51. The slopes of the curves phase 1 and phase 2 can be controlled by a proper choice of the constants of the elements comprising their circuits.

In response to the impressing of the saw-tooth voltage wave of the curve phase 1 on the input of tube 4, a sinusoidal voltage wave is generated in the output circuit of tube 4 which is applied to the stator coils 29. In response to the impressing of the saw-tooth voltage wave of the curve phase 2 on the input of tube 5, a sinusoidal voltage wave is generated in the output circuit

of tube 5 which is applied to stator coils 32. As shown in Fig. A the two saw-toothed voltages are displaced in phase. The first peak of the curve of phase 1, as has been shown, occurs at the instant when the electron beam in tube 1 impinges on anode 1. The corresponding first peak of the sinusoidal voltage wave impressed on stator coils 29 will occur at the same instant. The generation of the sinusoidal voltage wave in tube 5 will start at the same instant that the beam in anode 1 impinges on anode 2, as the voltage across condenser 40 is raised above the normal voltage at which it is maintained during the interval before the reception of the first signal impulse by tube 1.

Thus in response to the reception of the first signal impulse by tube 1 and the impinging of the first electron beam on the anode 2 of tube 1, two different voltage waves are instantly impressed on the input of tubes 4 and 5. The respective magnitudes of the two voltage waves impressed on the inputs of tubes 4 and 5 are controlled by a choice of circuit constants so that, in response thereto, the outputs of tubes 4 and 5, when impressed on their respective stator coils 29 and 32, rotate the electron beam in tube 1 so that when it impinges on anode 3, separated from anode 2 by 90 degrees, during the first revolution it will receive a synchronizing pulse which has been directed at an anode in a corresponding position in the transmitting tube at the distant station. This synchronizing pulse will fire tube 16. The time of occurrence and voltage across the condenser 40 at the instant is indicated by the time and voltage ordinates of the point P2 in Fig. A, at which point in voltage and time tube 16 fires. This point marks the maximum voltage attained by condenser 40. Its magnitude is controlled so that it is equal to voltage *oa*. The time is controlled so that it is separated from P1 by one quarter of a full voltage change cycle.

After tube 16 fires, the voltage across condenser 40 will decline as indicated in Fig. A by the line P2Q2. Tube 16 is deactivated at point Q2. Then the voltage across condenser 40 will again rise as indicated by the curve phase 2 in Fig. A due to the charging of condenser 40 by the output of tube 35.

Each time the beam in tube 1 is rotated it will receive one synchronizing impulse from the transmitting tube when it impinges on anode 2 and a second synchronizing impulse from the transmitting tube when it impinges on anode 3. Trigger tube 15 will be alternately activated during the first half of its cycle while condenser 39 discharges through it and inactivated during the succeeding half cycle while the voltage across condenser 39 rises. During a cycle displaced by 90 electrical degrees, trigger tube 16 will be alternately activated during the first half of its cycle while condenser 40 discharges through it and inactivated during its succeeding half cycle while the voltage across condenser 40 rises.

The net result is, as indicated by the curves phase 1 and phase 2 in Fig. A, the generation of two saw-toothed voltage waves displaced with respect to each other by 90 electrical degrees, with the period of each wave controlled by its corresponding synchronizing pulse in the distant transmitter. Any tendency of either wave to depart from synchronism is corrected once per cycle.

The two saw-toothed voltage waves in quadrature are applied to the inputs of tubes 4 and 5 which in response thereto generate two sinusoidal voltage waves in quadrature which are ap-

plied to their respective stator coils to rotate the beam in tube 2 in synchronism with the rotating beam in the transmitting tube.

The translation of the saw-toothed waves into waves which are substantially sinusoidal is achieved by the filtering action of the tube circuits. It depends upon two factors: 1, negative resistance furnished by the tube in the regenerative circuit and, 2, the turning of the stator coils in the plate circuit to resonance at the cyclic frequency of the waves. The regenerative action is adjusted so that the negative resistance introduced is less than the positive resistance of the tuned circuit, that is, just under the condition of oscillations.

Coils 55 are connected in series to battery 56. There is one coil 55 for each coil 29 and 32. Their windings are arranged so that they neutralize the effect of the direct current component in the output of vacuum tubes 4 and 5.

When the rotation of the electron beam in the distant transmitting tube stops, synchronizing pulses will no longer be received. Condenser 44 will have time to discharge. Tubes 34 and 35 will be deactivated by negative battery 45 connected to their grids. The potentiometers connected to tubes 4 and 5 will impress the proper potentials on the input circuits of tubes 4 and 5 so that the magnetic field developed by the stators in their output circuits will again tend to direct electrons emitted in response to the first signal pulse received by tube 1 toward anode 2. The potentials impressed across condensers 39 and 40 under control of their individual potentiometer circuits will again be as indicated by the ordinates *oa* and *ob* and the circuit will be again in condition to start.

It is necessary to suppress one of the electron beams, as two electron beams separated by 180 degrees tend to be emitted by the cathode. The manner in which this is performed is described in A. M. Skellett Patent 2,217,774 of October 14, 1940.

The two phase anode supply required for suppressing one of the two electron beams is obtained from transformers 7 and 17 in the anode circuits of tubes 4 and 5. The secondaries of these transformers are also shown as connected to anodes 2 and 3. The positive battery between the center taps of these secondaries and ground is sufficient to make anodes 2 and 3 operative with no alternating current flowing, that is at the time of starting and the alternating current is of sufficient magnitude to neutralize this battery for the unwanted beam. At the start both beams, spaced 180 degrees apart, will therefore be operative and a false signal in the anode diametrically across from anode 2 will be produced by the starting function. This false signal which is limited to a single pulse in the anode circuit directly opposite anode 2 should not cause any serious inconvenience for most applications.

Refer now to Fig. 2 which shows a simplified receiving circuit arranged to rotate an electron beam in synchronism with the rotation of a beam in a transmitting tube at a transmitting station. The circuit per Fig. 2 employs only two complementary tubes instead of six as in Fig. 1. The two complementary tubes in Fig. 2 are arranged in push-pull relation. The circuit results in the supplying of two substantially sinusoidal voltage waves in quadrature to the stator coils.

In Fig. 2 tube 201 is a mutianode radial electron beam vacuum tube. Tubes 202 and 203 are each gas-filled trigger tubes. The conductor 204

is connected at the distant transmitting station (not shown) to a mutianode radial electron beam vacuum tube having the same number of anodes as tube 201 and generally corresponding thereto. The line is connected through condenser 205 to grid 209. Grounded cathode 206 is connected through negative battery 207 and resistance 208 to grid 209. A circuit may be traced from ground through positive battery 212, primary of transformer 213 to anodes 210 and 211 connected in parallel. The cathodes of tubes 202 and 203 are connected in parallel to ground and negative battery 214 is impressed through the secondary of transformer 213 to the grids of tubes 202 and 203 in parallel. A circuit may be traced from the cathodes of tubes 202 and 203, arranged in parallel, through positive battery 216 and resistance 217 to the mid-point of the primary of transformer 218 from which parallel branches extend through the upper and lower portions of the primary winding of the transformer to the anodes of tubes 202 and 203 in parallel. Condenser 215 is connected between the anodes of tubes 202 and 203. A circuit may be traced from the bottom terminal of the secondary of transformer 218 through stator windings 219 which are connected in parallel with stator windings 220 and condenser 221 and the circuit returns over a common branch to the top terminal of the secondary of the transformer 218.

The circuit of condenser 215 and the primary of transformer 218 is tuned to resonate at the cyclic frequency of rotation of the beams which may be of the order of 60 cycles.

When tube 201 is awaiting a pulse there is no field in the stator coils surrounding the envelope of tube 201. Tubes 202 and 203, which are gas-filled trigger tubes, are deactivated. When a signal impulse is received over the line, grid 209 is made more positive with respect to its cathode 206. Electrons will be emitted from cathode 206 and some of them will be attracted to anode 210. A negative pulse will be impressed across the primary of transformer 213. The pulse will be induced and inverted in the secondary of transformer 213.

The output circuit of tubes 202 and 203 is arranged in a manner well known in the art as a parallel inverter. Condenser 215 serves as a commutator to deactivate one tube in response to the activation of the other by impressing a negative potential on the anode of one in response to the activation of the other. This will be described herein briefly.

It will be assumed that the voltage of battery 216 is 115 volts. While tubes 202 and 203 are deactivated the anode of each tube and each terminal of condenser 215 will be at substantially the same potential as that of the right-hand or positive terminal of battery 216 or at positive 115 volts.

In response to the first pulse one or the other of tubes 202 or 203 will fire depending upon which is faster or on the circuit constants. The other tube will remain deactivated for the first half of the cycle. It will be assumed that tube 202 fires. Current will flow from the right-hand terminal of battery 216 through resistance 217 and upwardly through the top portion of the primary of transformer 218, through tube 202 from anode to cathode and back to the left-hand or negative terminal of battery 216. The voltage drop across the tube is about 15 volts. The potential of the anode of tube 202 and the top terminal of condenser 215 will be changed to positive 15 volts.

The potential of the anode of tube 203 and the bottom terminal of condenser 215 will drop to positive 15 volts, which is so low that tube 203 will not be fired immediately thereafter by the effect of the same pulse which fired tube 202. The time constants of the circuits must be adjusted so that the voltage of the anode of tube 203 will rise at least to a potential high enough to permit it to be fired by the effect of the succeeding impulse impressed through transformer 213 between the grid and cathode of the tube 203.

When the beam in tube 201 is rotated, in a manner to be described, so that it impinges on anode 211, tube 203 will be activated. The potential of the anode of tube 203 and the bottom terminal of condenser 215 will be changed from plus 115 volts to plus 15 volts, a reduction of 100 volts, and the potential of the top terminal of condenser 215 will be correspondingly reduced for a transient interval, until equilibrium is restored, to negative 85 volts. This will extinguish tube 202.

Current will flow from battery 216 through resistance 217, bottom portion of the primary of transformer 218, from the anode to the cathode of tube 203 and back to the negative terminal of battery 216.

Tubes 202 and 203 will be alternately activated and deactivated on each half cycle in response to the synchronizing pulses received each half cycle by tube 201.

Although the grids of tubes 202 and 203 are connected in parallel and both receive impulses whenever a beam impinges on either anode 210 or 211 which are also connected in parallel, the impulse on only one of the grids will be effective after either tube has been fired, because the other tube is fired and in this condition its grid has no control.

The voltage induced in the secondary of transformer 218 will be reversed each half cycle under control of the incoming pulses from line 204. Coils 219 connected in parallel with coils 220 and condenser 221 arranged in series generate substantially sinusoidal voltage waves in quadrature in response to these reversals.

The beam in tube 201 is rotated in response to the rotation of the magnetic fields produced by the coils in response to the incoming signals. Any tendency to vary from synchronism with the beam in the transmitting tube will be corrected each time a beam impinges on anodes 210 and 211.

The circuit per Fig. 2 is suitable for radial beam tubes having an odd number of anodes or an even number of anodes since two pulses per cycle or the control of the gas-filled trigger tubes may be obtained with either arrangement.

For teletypewriter use, in place of the usual rotary start-type distributor well known in the telegraph art a twelve-anode radial beam tube could be suitable. The tube would be arranged so that both beams were operative and opposite anodes would be connected together. This would give five channels for the teletypewriter code and be for synchronism.

What is claimed is:

1. A multianode radial beam vacuum signal receiving tube, an incoming communication circuit connected thereto, a cathode in said tube, a plurality of anodes, spaced each from the other, each of said anodes arranged to engage a rotatable electron beam in said tube and means connected to said tube for directing said electron beam when emitted by said cathode in said tube

in response to the reception of the first of a train of signals from said circuit, toward a particular preselected one of said anodes in said tube.

2. In a communication receiving circuit a multianode radial beam vacuum signal receiving tube, a cathode in said tube, a plurality of anodes in said tube, an electron beam direction control connected to said tube, and means in said direction control for tending to direct electrons, to be emitted in response to the reception of the first of a train of signals by said tube, toward a particular anode, during the interval while no signals are being received by said tube.

3. In an electrical circuit a multianode radial electron beam vacuum tube, an electron beam directing device associated with said tube, a plurality of controls connected to said device, means responsive to one of said controls operating to tend to direct an electron beam toward a particular anode in said tube and means responsive to another of said controls for rotating an electron beam in said tube.

4. A multianode radial electron beam vacuum tube, an input circuit connected to said tube, a plurality of anodes, spaced each from the other, each of said anodes arranged to engage a rotatable electron beam in said tube and means responsive to the reception in said tube, from said input circuit, of the first of a train of signals, for directing said electron beam toward a particular preselected anode in said tube.

5. The method of operating an electron beam tube having a plural number of anodes with associated means for establishing an electron beam in the tube and means for controlling the beam which comprises establishing electrical conditions, when no electron beam is directed to an anode, tending to direct an electron beam to a particular preselected anode and thereafter, while maintaining said conditions, creating an electron beam directed to said anode.

6. In a multianode electron beam receiving tube, the method of controlling an electron beam in said tube which comprises generating, through the output circuit of said tube, a saw-toothed voltage wave, each voltage impulse of which wave has a slope the reverse of the preceding voltage impulse and causing the period of said wave to be controlled by incoming signals.

7. In a multianode electron beam receiving tube the method of controlling the rotation of an electron beam in said tube which comprises as steps: (1) the generation of a saw-toothed voltage wave having a period controlled by incoming signals, (2) the translation of said saw-toothed wave into a substantially sinusoidal wave, and (3) applying the effect of said sinusoidal wave to the rotation of said beam.

8. In a multianode electron beam receiving tube the method of controlling the rotation of an electron beam in said tube which comprises as steps: (1) the generation of magnetic fields tending to direct an electron beam at a particular anode while no signals are being received, (2) the generation of a rotating field having a period of rotation controlled by incoming signals while signals are being received.

9. In a communication system a multianode receiving tube, an input and an output circuit connected thereto, a relaxation oscillator in said output circuit means for controlling the start of operation of said oscillator by the impinging of an electron beam on a particular anode in said tube and means responsive to said start of oper-

ation for changing the beam directing conditions in said tube.

10. In a synchronizing device for a multianode radial beam tube, a plurality of anodes in said tube connected to a plurality of relaxation oscillators means for controlling the start of operation of said oscillators by the impinging of an electron beam on a particular anode in said tube and means responsive to said start of operation for controlling the phase relationship of the voltages generated by said oscillators to control the movement of said beam.

11. In a rotating electron beam synchronizing device for a multianode receiving tube in a communication system, a beam directing device, means for supplying current of uniform magnitude to said device while said tube is awaiting the reception of signals, means responsive to said current of uniform magnitude for establishing a condition within said tube, tending to direct an electron beam emitted by said tube in response to the reception of the first signal element of a train of signal elements by said tube, first at a particular preselected one of a plurality of anodes in said tube, means responsive to the reception

of said first signal element for directing said beam at said preselected anode and means responsive to the reception of said first signal element for changing said current to a variable current to rotate said beam.

12. In a synchronizing device for a rotating electron beam in a multianode radial electron beam tube in a communication signal receiving circuit, means for charging a condenser in response to the impinging of an electron beam on a particular anode, means for controlling the rate of discharge of said condenser, a radial electron beam directing device and means responsive to voltage variations of said condenser for controlling said directing device.

13. In a communication system, a multianode radial electron beam receiving tube arranged to receive signals from a corresponding transmitting tube and means comprising a parallel inverter connected between the output of said receiving tube and a beam rotating device for said tube for synchronizing the rotation of the electron beams in each tube.

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