Oct. 15, 1940. A. M. SKELLETT 2,217,774

ELECTRON DISCHARGE APPARATUS

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FIG. 1

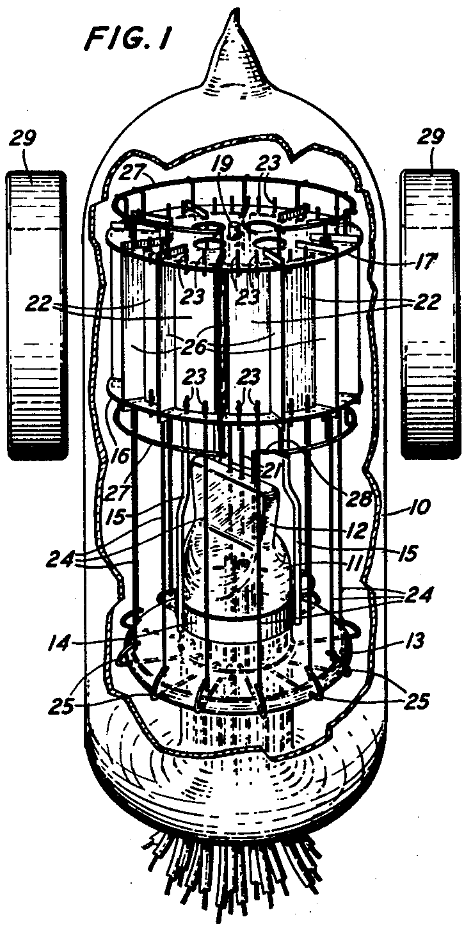


FIG. 2

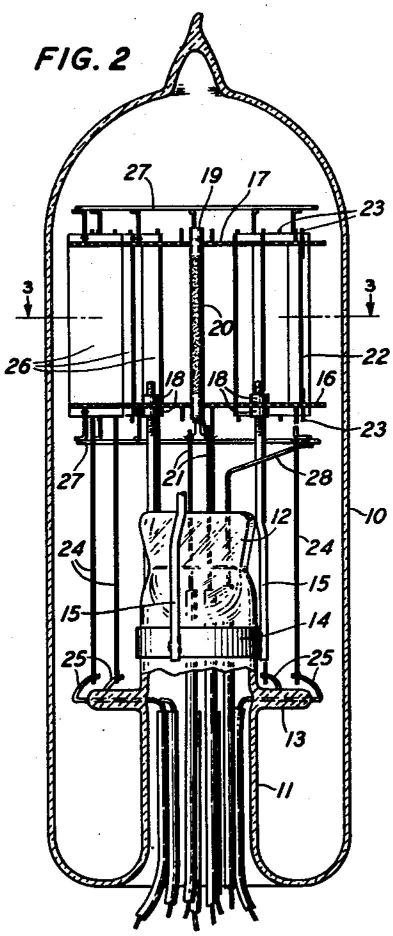


FIG. 5

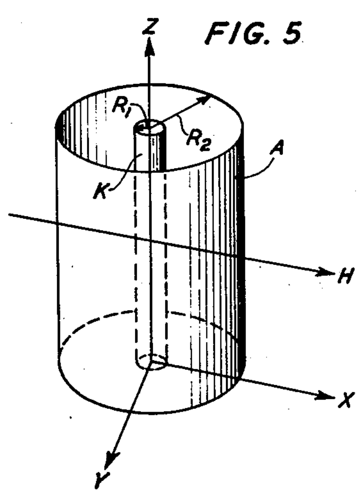
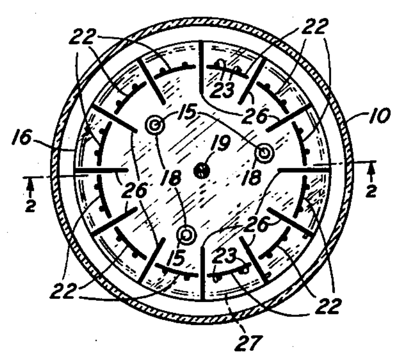


FIG. 3



INVENTOR
A. M. SKELLETT
BY
Walter C. Kiesel
ATTORNEY

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FIG. 6

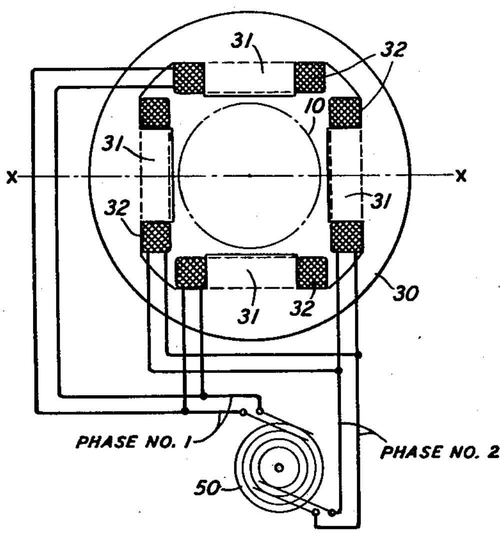


FIG. 8

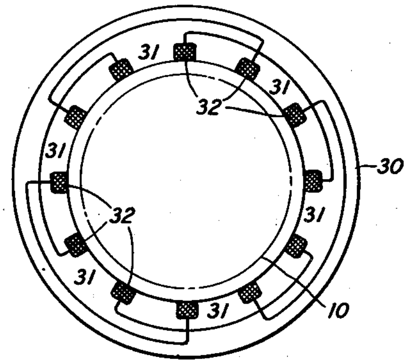


FIG. 7

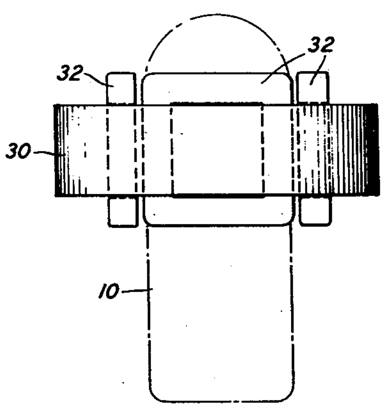


FIG. 9

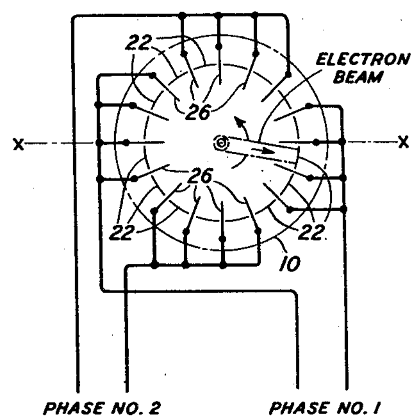
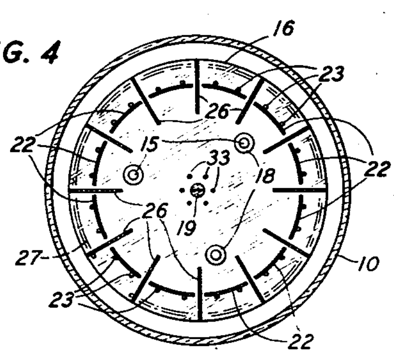


FIG. 4



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A. M. SKELLETT
BY
Walter C. Kiesel
ATTORNEY

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FIG. 10

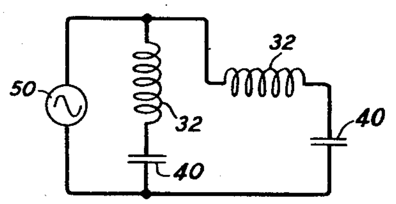


FIG. 11

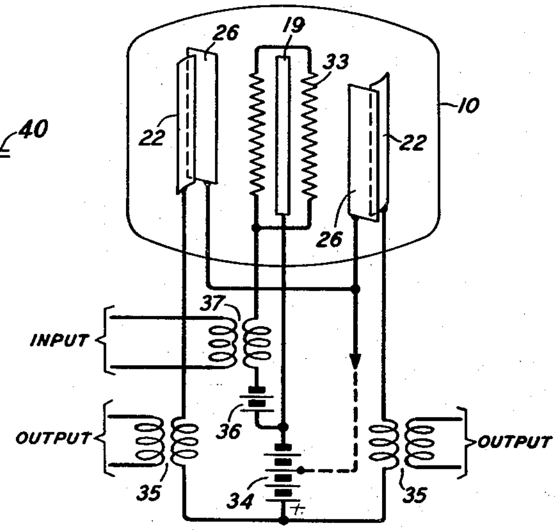
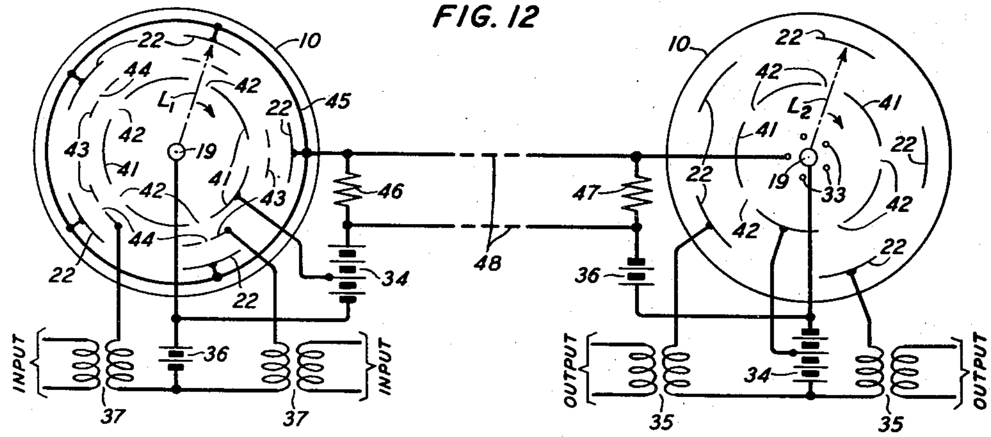


FIG. 12



INVENTOR
A. M. SKELLETT
BY
Walter C. Kiesel
ATTORNEY

Patented Oct. 15, 1940 2,217,774

UNITED STATES PATENT OFFICE

2,217,774

ELECTRON DISCHARGE APPARATUS

Albert M. Skellett, Madison, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application May 27, 1939, Serial No. 276,055

15 Claims. (Cl. 250—27.5)

This invention relates to electron discharge apparatus and more particularly to electronic switches and distributors.

In a variety of signal translating systems, such, for example, as multiplex telephone systems, it is necessary to close successively and repeatedly a number of circuits having a common terminal. Among the means employed heretofore for this purpose are electron discharge devices of the type wherein an electron beam is deflected to impinge in succession upon a plurality of targets. One of the principal limitations of such devices is the restricted magnitude of the electron beam current that may be obtained. Furthermore, in such devices, relatively complex structure and apparatus are required to produce concentration and focussing of the electron beam upon the targets. In addition, such devices are of relatively large size and complex construction.

One general object of this invention is to facilitate the control of a multiplicity of circuits in a signal translating system.

More specifically, objects of this invention are:

To increase the power capacity of electronic switches and distributors;

To facilitate and improve the focussing of the electron beam in electron discharge devices of the beam type;

To simplify the structure of electronic switches and distributors;

To effectively segregate the several targets or anodes in such devices; and

To obtain highly efficient modulation in electron discharge devices of the multitarget electron beam type.

In one illustrative embodiment of this invention an electronic switch or distributor comprises an elongated cathode and a plurality of targets or anodes mounted in a cylindrical boundary encompassing the cathode and coaxial therewith.

In accordance with one feature of this invention, means are provided for producing a shifting or rotating magnetic field between the cathode and the targets or anodes, the lines of force of the field being normal to the longitudinal axis of the cathode. This field concentrates the electrons emanating from the cathode into two beams which are focussed to form electron images of the cathode upon two diametrically opposite targets or anodes in line with the magnetic lines of force. As the field rotates, the images are shifted accordingly so that the electron beams impinge upon the targets in succession.

In accordance with another feature of this invention, a plurality of shields, such as vanes, are provided, one between each two adjacent targets or anodes to prevent migration of any secondary electrons which may be emitted from any target or anode, to the next adjacent target or anode. These shields or vanes may be connected into groups and energized to produce a rotating electrostatic field in step with the magnetic field and phased so that the electric vector is parallel to the magnetic lines of force at all times. Thus, one of the two radial electron beams is suppressed and a single rotating beam impinging upon the targets or anodes in sequence is obtained.

The anode or target currents may be modulated by a grid adjacent and encompassing the cathode. Such a grid produces modulation by a true space charge action over the entire active cathode area and, therefore, enables attainment of a high efficiency.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of electron discharge apparatus, including an electron discharge device and coils for producing a magnetic field, illustrative of one embodiment of this invention, a portion of the enclosing vessel of the electron discharge device being broken away to show the internal structure more clearly;

Fig. 2 is a side view, mainly in section, of the electron discharge device illustrated in Fig. 1;

Fig. 3 is a view in section along plane 3—3 of Fig. 2;

Fig. 4 is a view in section similar to Fig. 3 of a modification of the electron discharge device illustrated in Figs. 1, 2 and 3;

Fig. 5 is a diagrammatic perspective view of a cathode and an associated anode with certain axes indicated to facilitate discussion of the effect of the magnetic field upon the electrons emanating from the cathode;

Fig. 6 is a top view, partly in section, and Fig. 7 a side view, of a two-phase structure suitable for producing a rotating magnetic field in the electron discharge device shown in Fig. 1, the device being shown in phantom;

Fig. 8 is a top view, partly in section, of a magnetic field producing structure utilizing polyphase excitation, the electron discharge device being shown in phantom;

Fig. 9 is a diagrammatic view illustrating the electrical association of the shields or vanes in the device shown in Fig. 1, for producing a single rotating beam;

Fig. 10 is a circuit diagram illustrating single-phase excitation of the field coils to produce a rotating magnetic beam;

Fig. 11 is a circuit diagram illustrating one manner of operating the electronic switch or distributor; and

Fig. 12 is a diagrammatic view illustrating a multiplex telephone system including electron discharge apparatus constructed in accordance with this invention.

Referring now to the drawings, the electron discharge device shown in Fig. 1 comprises a highly evacuated enclosing vessel 10 having a stem 11 at one end, the stem terminating in a press 12 and having intermediate its ends an annular flange or seal 13. Clamped about the stem 11 is a metallic band or collar 14 having affixed thereto a plurality of rigid metallic uprights or supports 15 which mount a unitary electrode assembly.

The electrode assembly, as shown more clearly in Figs. 2 and 3, comprises a pair of spaced parallel insulating members 16 and 17, such as mica discs, the lower disc 16 being secured to the uprights or supports 15 by nuts 18 threaded upon the uprights or supports and clamping the disc thereto. Extending between the discs 16 and 17 and fitted in central apertures therein is a linear cathode 19, which, as shown, may be of the indirectly heated equipotential type comprising a cylindrical metallic sleeve, a restricted portion of the outer surface of which is coated with thermionic material 20. Electrical connection to the cathode 19 and to the heater element (not shown) therefor may be established through leading-in conductors 21 sealed in the press 12. It will be understood, of course, that other forms of cathodes, for example cathodes of the filamentary type, may be utilized.

A plurality of similar, arcuate sheet metal targets or anodes 22 are mounted between the insulating members 16 and 17 and in a cylindrical boundary coaxial with the cathode 19. The targets or anodes 22 may abut the insulating members and are held in position, equally spaced from one another, by short wires or pins 23 affixed thereto, as by welding, and fitted in apertures in the insulating members 16 and 17. Individual electrical connection to the targets or anodes may be established through wires 24 connected to leading-in conductors 25 sealed in the flange 13.

Disposed between adjacent anodes or targets 22 are radially extending metallic shields or vanes 26 which are fitted in radial slits in the insulating members 16 and 17. The vanes or shields 26 may be connected together in one or more groups by a pair of tie-wires 27 one of which is connected to a leading-in conductor 28 sealed in the press 12. Although in the specific embodiment illustrated all of the shields or vanes are shown connected together, they may be connected in several groups, as will be pointed out more fully hereinafter.

During operation of the device, the targets or anodes 22 are maintained at a moderately high positive potential, for example of the order of 135 volts, with respect to the cathode 19, and individual output circuits are connected to each target or anode. The shields or vanes 26 may be maintained at a potential of the order of 75 volts positive with respect to the cathode or may have applied thereto an alternating potential as described hereinafter. Means are provided also for producing a uniform magnetic field between the cathode 19 and the targets or anodes 23, the lines of force of the field being normal to the longitudinal axis of the cathode. In a simple form shown in Fig. 1, the field producing means may comprise a pair of serially connected coils 29 mounted so as to be freely rotatable in unison about the enclosing vessel 10.

The effect of the magnetic field will be understood from the following considerations. In general, an electron moving in a magnetic field is subjected to a force by the field, which is perpendicular both to the direction of motion of the electron and to the field. The magnitude of this force is given by the product Hev, where H is the strength of the uniform magnetic field, e the charge on the electron, and v its velocity in a direction perpendicular to the magnetic field. The resulting electron path is curved. If the electron has a component of velocity in the direction of the magnetic field, it spirals around the lines of force of the field.

In a device such as indicated diagrammatically in Fig. 5, comprising a cylindrical cathode K of radius R_1 and a cylindrical anode A of radius R_2, coaxial with the cathode various paths for the electrons will obtain if the anode is maintained at a positive potential V to produce a radial electrostatic field and a uniform magnetic field H is produced parallel to the X axis. Any electron starting radially from the cathode at a point along its intersection with the $Y=0$ plane, will travel to the anode in a straight line parallel to the X axis, inasmuch as its velocity normal to the field H is zero.

For electrons starting at right angles to this direction, that is in the $X=0$ plane, for all values of field strength greater than a critical value, the curvature of the electron path will be so great that the electrons will not impinge upon the anode and will return to the vicinity of the cathode.

Electrons starting from any other point on the cathode K, because of the magnetic field, will traverse spiral paths in the general direction of the lines of force and flow to the anode. The spirals will be of opposite hand on the two sides of the cathode traversed by the X plane.

Thus, there will be produced two diametrically opposite radial electron beams parallel to the lines of force of the magnetic field. For certain conditions, the electron beams will be focussed upon the anode so that two electron images of the cathode will be produced upon the anode. One general condition for such focussing is that the radius of curvature of any electron path be small with respect to the radius of the cathode. A more specific condition is that each electron complete one or more half revolutions around the lines of force of the magnetic field during its transit time to the anode. In the latter case, it has been found that relatively weak magnetic fields may be employed, the radius of the electron path being substantially as great or greater than the radius of the cathode, to provide focussing which is adequate for most practical purposes. The parameters necessary for the attainment of such focussing may be determined from the following considerations.

The curvature of an electron path will be such that the centrifugal force upon the electron is just balanced by the centripetal force due to the magnetic field. This balance obtains when

$$\frac{mv^2}{r}=Hev \qquad (1)$$

where m is the electron mass, r the radius of curvature and the remaining symbols are as pointed out heretofore. Inasmuch as

$$Ve=\tfrac{1}{2}mv^2$$

the radius of curvature may be expressed as

$$r=\frac{\sqrt{2V\frac{m}{e}}}{H}$$

or in practical units

$$r=3.37\frac{\sqrt{V}}{H} \qquad (2)$$

where r is in centimeters, V in volts and H is in gauss.

The angular velocity, ω, of the electrons around the lines of force of the magnetic field may be expressed as

$$\omega = \frac{v}{r} = \frac{eH}{m} \tag{3}$$

Inasmuch as H is constant, all electrons will turn around the lines of force at the same angular rate.

The velocity component in the Z direction, of the electrons, is determinable from the relation

$$\frac{dZ}{dt} = \frac{e}{m}H(Y - Y_0) \tag{4}$$

where t is time and Y_0 is the Y coordinate of the point on the cathode at which the electron starts. From this expression it will be seen that when $Y = Y_0$, the velocity component in the Z direction is zero. As the electron crosses the Y_0 plane, the electrostatic force in the Y direction is very nearly zero and, disregarding the X component, the electron is thus moving in a substantially field-free space. The value of ω, then, may be ascertained at this point by comparing the direction of the electron at this point with its initial direction. Thus, it is seen that each electron passes through the Y_0 plane when $\omega = n\pi$, where n is an integer. In other words, if differences in transit times due to the curvature of the cathode surface are neglected, all electrons will pass through the Y_0 plane at equal intervals of time and focussing will obtain whenever ωt equals π, 2π, etc. Hence, if the electron transit time from cathode to anode is equal to that necessary for completion of one revolution ($\omega = 2\pi$), the electron beam will be focussed upon the anode and the resultant electron image will be upright and of the same size as the electron emitting portion of the cathode.

It can be shown that if the ratio of

$$\frac{R_1}{R_2}$$

is small the transit time T_1 or T_2 for electrons flowing from the cathode to the anode is determinable from the relations

$$T_1 = \frac{2(R_2 - R_1)}{\sqrt{\frac{2Ve}{m}}} K_1 \tag{5}$$

neglecting space charge and

$$T_1 = \frac{2(R_2 - R_1)}{\sqrt{\frac{2Ve}{m}}} K_2 \tag{6}$$

with space charge. K_1 and K_2 are variables various values of which in terms of the ratio of the electrode radii are as follows:

$\frac{R_2}{R_1}$	K_1	K_2
5	0.61	0.88
10	0.65	0.88
20	0.63	0.87
40	0.61	0.84
60	0.60	0.82
100	0.58	0.79

By equalizing the transit time with that required for one revolution, the following relation may be obtained for the relationship necessary for focussing:

$$H = \frac{\pi\sqrt{2V\frac{m}{e}}}{(R_2 - R_1)K} = \frac{10.5\sqrt{V}}{(R_2 - R_1)K} \tag{7}$$

where H is in gauss, V in bolts, R_2 and R_1 in centimeters, and K is determined from the table given above, having the value K_1 for conditions without space charge and K_2 with space charge.

Equation 7, it may be noted, neglects initial electron velocities and the effects of the magnetic field on the space charge. The effect of initial electron velocities is quite small. The magnetic field increases the space charge somewhat and, hence, results in an increase in the transit time. However, considering the fact that the electrons traverse spiral paths, the magnetic field does not greatly affect the order of magnitude of the focussing field as determined by Equation 7. It may be noted also that Equation 7 neglects the effect of the curvature of the cathode on the transit time and is valid, therefore, only for the regions where the angle between the normal to the cathode surface and the direction of the magnetic field is not great. However, Equation 7 does give an approximation, for practical purposes, of the magnetic field strength necessary for focussing of the beams upon the anode. In some cases the field strength to be used for producing a good focus may be greater than, for example, from 1.5 to 3 times as great as the value computed from Equation 7.

The position of the electron images is determined solely by the direction of the magnetic field. Hence, in a structure such as shown in Fig. 1, the electron beams may be shifted from one anode to another by shifting the magnetic field. If the field is rotated continuously, the beams likewise will rotate and impinge upon the anodes in succession whereby the circuits connected between each anode and the cathode may be closed and opened in sequence.

Two illustrative structures for producing a uniform rotating magnetic field are shown in Figs. 6, 7 and 8. In the arrangement shown in Figs. 6 and 7, the electron discharge device 10 is positioned within a magnetic core 30, for example of iron, having four equally spaced poles 31 each of which carries a coil 32. The core 30 may be of a depth substantially equal to the length of the electrode assembly. Diametrically opposite coils 32 are connected and poled so that opposite poles 31 are opposite in polarity. As illustrated in Fig. 6, the coils may be connected to be excited by two-phase alternating current, as from an alternator 50.

Polyphase exciting currents also may be employed. For example, Fig. 8 illustrates a core and the coil connections for excitation by three-phase current, the coils being poled, as in Fig. 6, so that diametrically opposite poles 31 are of opposite polarity.

In some cases, for example where a polyphase supply is not available, the rotating magnetic field may be obtained with single excitation, using a core 30 having four poles 31 and four coils 32 as shown in Fig. 6. The connections for single phase excitation are illustrated in Fig. 10 wherein each coil 32 represents two diametrically opposite coils of the structure shown in Fig. 6. As illustrated in Fig. 10, condensers 40 are provided in circuit with the coils 32, the impedances of the coils and condensers being made such that the currents through the coils 32 (in Fig. 10) are 90 degrees out of phase.

It may be pointed out that this invention enables the attainment of focussed electron beams in a facile manner and with a simple structure. Furthermore, it will be appreciated that, inasmuch as magnetic focussing enables bringing to a focus electrons which leave the cathode in a wide range of directions, relatively large electron beam currents may be utilized and electronic switches or distributors of large power capacity obtained. Moreover, magnetic focussing brings the electrons together only at the actual focal point so that diverging action of the space charge of the electrons is greatly reduced.

As pointed out heretofore, the uniform rotating field results in two diametrically opposite electron beams. In some applications it is desirable to have but a single rotating electron beam. Such apparatus may be achieved in accordance with one feature of this invention by utilizing an electrostatic field which varies with the angle taken around the longitudinal axis of the electron structure. In one specific embodiment of this invention, means are provided for producing a potential adjacent the electron receiving surface of the targets or anodes 22 which rotates in synchronism with the rotating magnetic field and varies as the sine of the angle taken around the longitudinal axis of the electrode structure. That is, the potential V_e at any point in the cylindrical boundary in which the anodes or targets lie is

$$V_e = V \sin \alpha$$

where α is an angle reckoned from an axis at right angles to the direction of the magnetic field.

For such potential distribution, the electric vector in the electron discharge device is parallel at all times to the magnetic field and the electric field is the same as that which would be produced by parallel planes with the cathode midway between them physically and electrically. The electric field has a constant magnitude and a uniform rate of rotation. At any particular instant, the electric field on one side of the cathode is positive and an electron beam is formed. On the diametrically opposite side of the cathode, however, the electric field is negative and thus prevents the formation of a second beam diametrically opposite the first.

The electric field, of course, will affect the electron transmit time and, hence, necessitate use of a different magnetic field strength for producing focussing of the beam upon the anodes or targets. The magnitude of the magnetic field required may be ascertained approximately, neglecting the effect of cathode curvature and the effects of the magnetic field upon space charge, by the relation

$$H = \frac{10.6\sqrt{V}}{R_2 - R_1} \qquad (8)$$

neglecting space charge or

$$H = \frac{7.0\sqrt{V}}{R_2 - R_1} \qquad (9)$$

with space charge.

One manner of producing the desired electric field is illustrated in Fig. 9, wherein the shields or vanes 26 are shown connected in four groups and are energized from a two-phase source, such as the alternator 50 in Fig. 6, diametrically opposite groups being oppositely poled. In this figure, the vanes are physically related for use in conjunction with a core of the form shown in Fig. 6 with the axis X—X of the device 10 as shown.

It will be understood, of course, that a source of more than two phases may be used for energizing the vanes. For example, a three-phase supply source could be employed in which case the shields or vanes would be connected in six groups. The number of groups for any polyphase supply would always be double the number of phases.

The coils 32 and vanes or shields 26 may, of course, be energized from the same alternating current source. Thus, for a two-phase supply, with the electron discharge device having the vanes connected as in Fig. 9 and related with the core 30 of Fig. 6 as indicated by the reference axis X—X, correspondingly labeled conductors, as to phase, would be connected together.

The shields or vanes 26 project inwardly of the electron receiving surfaces, as shown clearly in Fig. 3, and thereby prevent migration of any secondary electrons which may be liberated at any one of the targets or anodes 22, to the next adjacent anodes or targets.

In some applications, it is desirable to modulate the electron beam or beams in accordance with a simple or complex signal. This may be accomplished through the agency of a cylindrical grid 33, shown in Fig. 4, adjacent, coextensive with and encompassing the cathode 19 and coaxial therewith. Preferably, the grid 33 is of the self-supporting basket-weave type of coarse mesh and fine wire construction in order to minimize reduction of the current to the anodes or targets by the interception of electrons by the grid wires.

It will be appreciated that, from the standpoint of modulation, magnetic focussing has a marked advantage, for the modulation is accomplished by a true space charge action over the entire active cathode area whereas in devices employing electro-static focussing, modulation results in variation of the cathode area from which the electrons start.

A typical circuit illustrating a use of the electronic switch or commutator is shown schematically in Fig. 11. The anodes 22 are maintained at a positive potential with respect to the cathode 19 by a source such as a battery 34, each anode-cathode circuit including an output element such as the primary winding of a transformer 35. The control grid 33 may be biased with respect to the cathode, as by a battery 36, and a desired simple or complex signal voltage may be impressed thereon through an input transformer 37. The shields or vanes 26 may be connected to an intermediate positive terminal on the battery 34, for two-beam operation, or may have alternating potentials applied thereto to produce a single rotating beam as described heretofore with reference to Fig. 9.

Electron discharge apparatus constructed in accordance with this invention may be used in multiplex telephone systems as illustrated in Fig. 12. In this figure, the electron discharge devices are generally similar to those described heretofore. However, each may include, in place of the vanes 26, an accelerating electrode 41 having therein a plurality of slots 42 each aligned with one of the targets or anodes 22. The sending distributor i. e., the device to the left in Fig. 12, includes also a plurality of plates 43, one opposite each of the anodes or targets 22, each plate having an aperture 44, of the same size as the projected area of the emissive portion of the cathode 19, in alignment with a corresponding aperture in the accelerating electrode 41. The receiving distributor, i. e., the device to the right in Fig. 12, includes a grid 33.

Electron beams L_1 and L_2 rotating in synchronism are produced at the distributors by a rotating magnetic field as described heretofore, the beams being focussed upon the anodes or targets 22. At the sending distributor, the electron current to each anode is modulated by potentials impressed upon the plates 43 through the input transformers 37. The targets or anodes 22 are connected together, as by a conductor 45, and maintained at a positive potential, for example of the order of 100 volts, with respect to the cathode. The accelerating electrode 41 may be held positive, for example of the order of 75 volts, with respect to the cathode and the plates 43 may be biased negatively, for example of the order of 45 volts, with respect to the cathode.

It will be apparent that the current flowing in the output resistor 46 will be composed of the complex currents to the several anodes. Potentials corresponding to this multiplex current may be impressed across the input resistance 47 of the receiving distributor through a suitable transmission channel 48. Hence, the electron currents to the anodes 22 at the receiving distributor will be modulated and, inasmuch as the beams L_1 and L_2 are in synchronism, the current flowing in the output circuit of each anode at the receiving distributor will correspond to the input to a corresponding one of the plates 43 at the sending distributor.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising an evacuated vessel housing a cathode and a plurality of anodes mounted in a cylindrical boundary encompassing said cathode, and means for concentrating electrons emanating from said cathode into a rotating beam impinging upon said anodes in succession, said means including a magnetic system for producing a uniform rotating magnetic field between said cathode and said anodes having its lines of force normal to the longitudinal axis of said cathode.

2. Electron discharge apparatus in accordance with claim 1 comprising means for modulating the electron currents to said anodes.

3. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing and coaxial with said cathode, an evacuated enclosing vessel housing said cathode and said anodes, and means for producing a uniform rotating magnetic field having its lines of force normal to the longitudinal axis of said cathode and for focussing the electrons emanating from said cathode upon said cylindrical boundary, whereby electron images of said cathode are produced upon said anodes in succession.

4. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing and coaxial with said cathode, an evacuated enclosing vessel housing said cathode and said anodes, and means for producing a uniform rotating magnetic field having its lines of force normal to the longitudinal axis of said cathode, said means including a magnetic core encompassing said vessel and having pairs of diametrically opposite poles and coils on said poles for polarizing diametrically opposite poles oppositely.

5. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing said cathode, means for producing a uniform rotating magnetic field for focussing electrons emanating from said cathode upon said anodes, and shield members spaced from said cathode and mounted between each two adjacent anodes.

6. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing said cathode, means for producing a uniform rotating magnetic field having its lines of force normal to the longitudinal axis of said cathode and for focussing electrons emanating from said cathode upon said anodes in succession, and radially extending vanes interposed between successive anodes and spaced from said cathode.

7. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing said cathode, means for producing a uniform rotating magnetic field having its lines of force normal to the longitudinal axis of said cathode and for concentrating electrons emanating from said cathode into a beam focussed upon said anodes, and a cylindrical grid adjacent and encompassing said cathode.

8. Electron discharge apparatus comprising a linear cathode, a plurality of anodes mounted in a cylindrical boundary encompassing and coaxial with said cathode, and means for producing a uniform rotating magnetic field between said cathode and said anodes, said field having its lines of force normal to the longitudinal axis of said cathode and being of such intensity that electrons spiralling around the lines of force complete one or more half revolutions in flowing to said cylindrical boundary.

9. Electron discharge apparatus comprising an evacuated enclosing vessel housing an elongated cathode and an anode parallel thereto, means for focussing electrons emanating from said cathode upon said anode including means for producing a magnetic field substantially coextensive with said cathode, the lines of force of said field being parallel to the discharge path between said cathode and said anode, and means for modulating the current to said anode including a grid between said cathode and said anode.

10. Electron discharge apparatus comprising an evacuated enclosing vessel, a cathode and a plurality of anodes within said vessel, said anodes being substantially equally spaced from said cathode, means for producing a magnetic field the lines of force of which are normal to said cathode, said field being shiftable to move its lines of force parallel to the discharge path between said cathode and each anode and of such strength that the electrons emanating from said cathode are focussed upon the anode at any instant in alignment with the cathode and the lines of force.

11. Electron discharge apparatus comprising a cathode, a plurality of spaced anodes in cooperative relation with said cathode, means for producing a shifting magnetic field of uniform intensity having its lines of force normal to the longitudinal axis of said cathode, and means for producing a shifting electrostatic field in step with said magnetic field and having the electric vector thereof parallel to the lines of force of said magnetic field.

12. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted about said cathode, and means for concentrating the electrons emanating from said cathode into a single, radial beam inpinging in turn upon said anodes including means for producing a shiftable uniform magnetic field having its lines of force normal to the longitudinal axis of said cathode.

13. Electron discharge apparatus comprising a

cathode, a plurality of anodes disposed about said cathode, means for producing a rotating magnetic field having its lines of force normal to the longitudinal axis of said cathode, and means for producing a rotating electrostatic field in synchronism with said magnetic field and having the electric vector thereof parallel to said lines of force.

14. Electron discharge apparatus comprising a cathode, a plurality of anodes parallel to said cathode and mounted in a cylindrical boundary encompassing and coaxial with said cathode, means for producing a rotating magnetic field between said cathode and said anodes and substantially normal to the longitudinal axis of said cathode, and means for producing a rotating electrostatic field in synchronism with said magnetic field and having its electric vector parallel to the lines of force of said magnetic field.

15. Electron discharge apparatus comprising a cathode, a plurality of anodes mounted in a cylindrical boundary encompassing said cathode, means for producing a rotating magnetic field between said cathode and said anodes including a core disposed about said anodes and having pairs of diametrically opposite poles and windings on said poles for polarizing diametrically opposite poles oppositely in polarity, and means for producing a rotating electrostatic field in synchronism with said magnetic field and having its electric vector parallel to the lines of force of said field, said last means including a plurality of auxiliary electrodes mounted between successive anodes.

ALBERT M. SKELLETT.