

July 14, 1953

R. A. WESTERVELT ET AL
ELECTRONIC SCANNING APPARATUS

2,645,741

Filed March 29, 1948

3 Sheets-Sheet 1

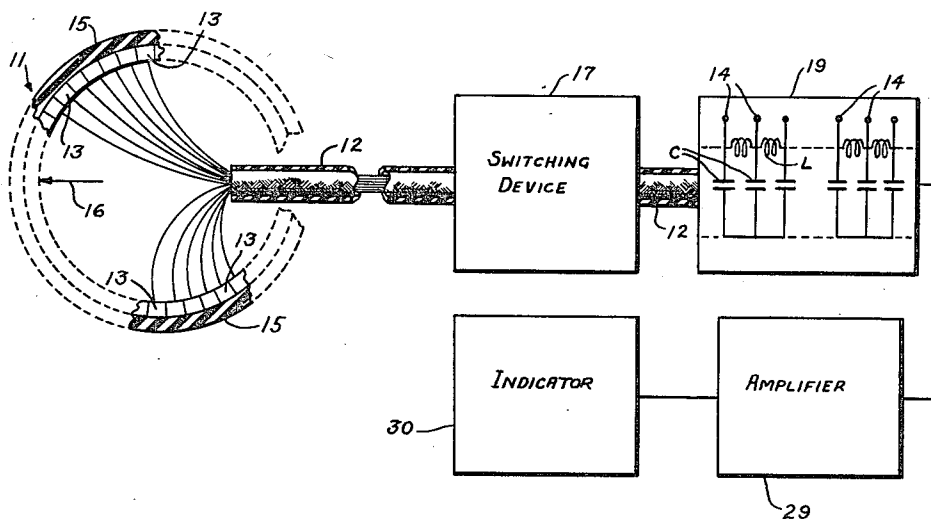


FIG. 1

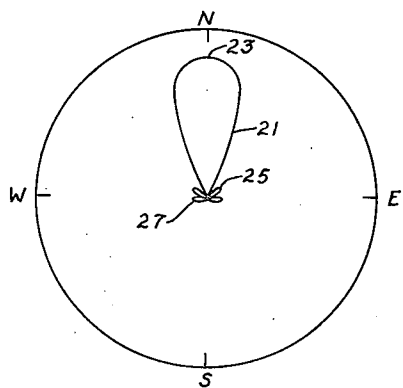


FIG. 2

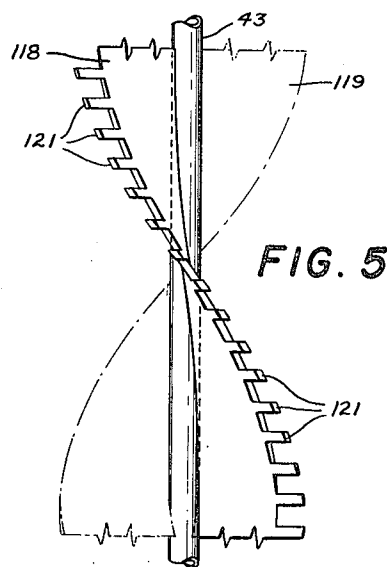


FIG. 5

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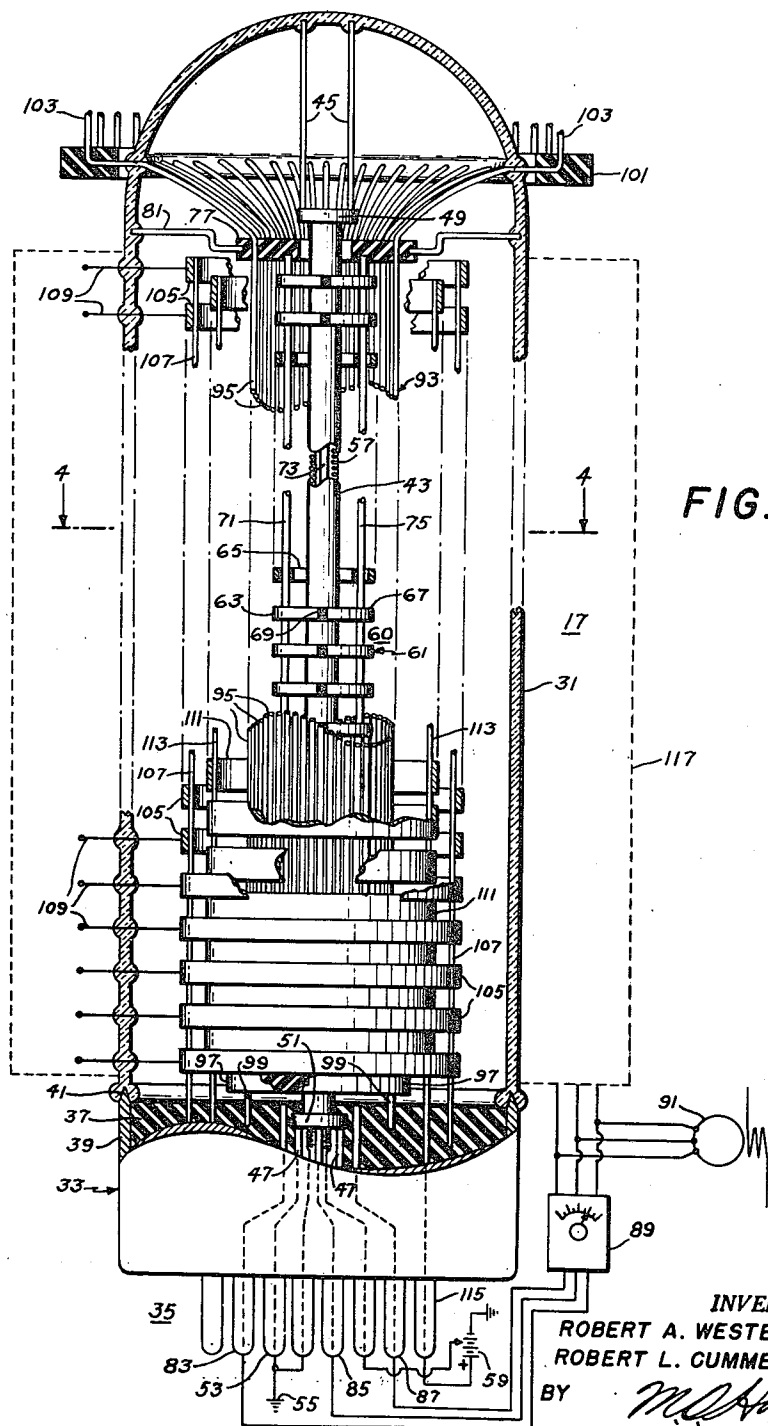


FIG. 3

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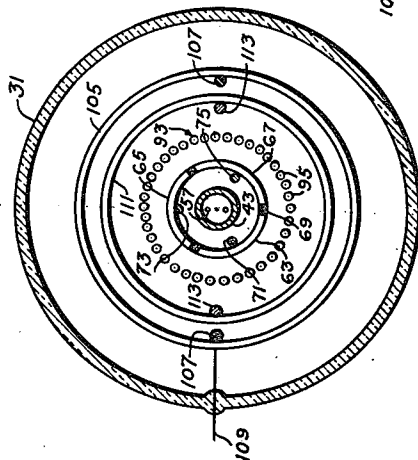
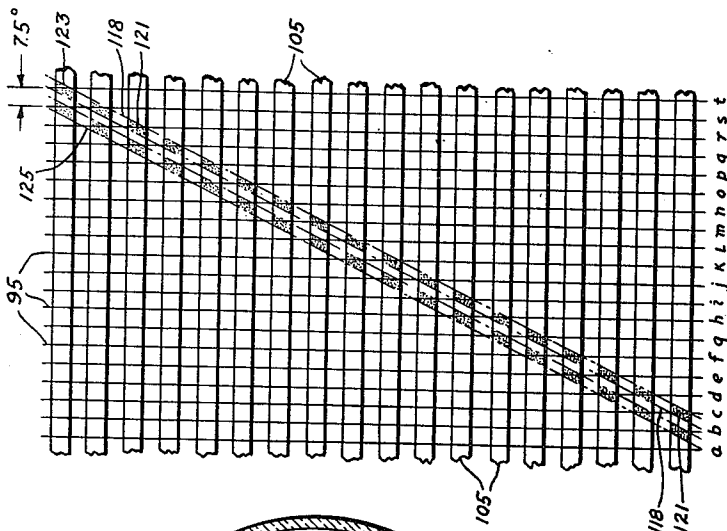
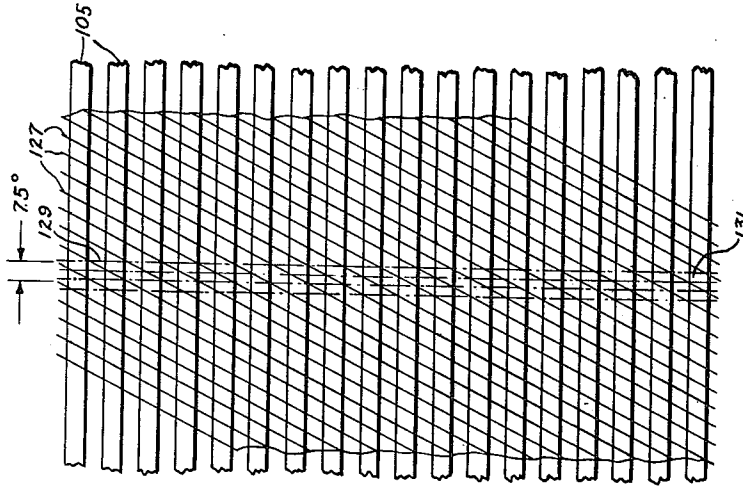
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2,645,741

ELECTRONIC SCANNING APPARATUS

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15 Claims. (Cl. 315—21)

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sec. 266)

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The present invention relates broadly to electrical apparatus and systems, and more particularly, it relates to the art including electronic switching devices. The invention has for an object to provide a generally improved electronic switching arrangement capable of actuating selected ones of a relatively large number of electric circuits.

Systems are known wherein a relatively large number of electric signals are carried in individual channels, and wherein the latter are desirably actuated cyclically, or in any other sequential manner, to effectuate a desired mode of operation.

For example, object-detecting systems adapted for underwater operation utilize transducers having arrays of electro-mechanical elements of the piezoelectric or magnetostrictive type. Such elemental arrays cooperate with suitable lag or lead lines to determine directivity characteristics of the transducer, which define the power of the transducer to pick up and/or transmit compressional wave energy more effectively in a direction corresponding to its so-called directivity maximum and considerably less efficiently in other directions. Further, such systems are rendered capable of scanning or rotating the directivity maximum by means of arrangements for switching the connections between the transducer elements and the lag or lead lines associated therewith.

Heretofore, various mechanical and/or electrical switching arrangements have been proposed for accomplishing the switching function, but such arrangements as have been proposed are either excessively bulky or unwieldy, rendering the apparatus incapable of being operated at required high speeds of rotation, or the prior-known arrangements contemplate the use of such large numbers of electron discharge tubes, each of which are required to have substantially identical characteristics, as to render such arrangements practically impossible of attainment.

Accordingly, it is another object of the invention to provide a novel and improved switching arrangement that obviates the disadvantages of known arrangements in that it embodies no moving parts other than electrons moving under the influence of electric and magnetic fields, said system also being capable of actuating a relatively large number of individual circuits without requiring a correspondingly large number of electron tubes.

Another object is to provide an electronic switching device for actuating a plurality of cir-

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cuits seriatim, said device including a multi anode electron discharge tube of which the number of anodes corresponds to the number of circuits to be actuated, and means establishing a conductive path to individual anodes.

Still another object is to provide an improved electronic switching arrangement wherein a unitary electron discharge tube is arranged with a common source of electrons disposed axially in the tube, a plurality of longitudinally spaced anode rings arranged around the common source and radially spaced therefrom, and means cyclically establishing a conductive path between individual ones of the anode rings and the common source of electrons.

A further object is to provide an improved object-detecting system in which scanning is accomplished by means including a transducer having a plurality of pressure-responsive elements adapted to develop electric signals in accordance with wave energy incident thereon, a delay line for introducing predetermined amount of time lag between signals from individual elements, and an electronic switching tube for switching the connections between the individual elements of a transducer and the terminals of a delay line.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawing:

Fig. 1 is a block diagram, partly diagrammatic and partly schematic, of an object-detecting system incorporating the features of the invention.

Fig. 2 is a diagram representing an operating characteristic of the system of Fig. 1.

Fig. 3 is a side view, mainly in longitudinal section and partly schematic, of an electronic switching device constructed according to the present invention.

Fig. 4 is a cross-sectional view taken along the line 4—4 of Fig. 3.

Fig. 5 is a fragmentary diagrammatic view illustrating a skewed electronic lamina and radial beam arrangement that is developed and utilized in the tube of Fig. 3.

Fig. 6 is a fragmentary developed view of one form of grid structure that may be employed in the tube illustrated in Fig. 3, and

Fig. 7 is a fragmentary developed view of a modified form of grid structure that may be utilized with the tube of Fig. 3.

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like reference characters are utilized throughout the drawing to designate like parts.

Fig. 1 illustrates the listening branch of a sub-sonic, sonic or supersonic object-detecting system embodying the features of the present invention. It should be understood clearly, however, that, although the invention is herein described in connection with a compressional-wave object-detecting system, it is by no means limited thereto, it being readily applicable to other systems as, for example, radar, and/or other communications systems, electronic calculating devices, and similar electrical arrangements where a relatively large number of signals carried in individual channels are selectively utilized to perform a stated function.

As shown in Fig. 1, the listening apparatus comprises a hydrophone or transducer 11, diagrammatically illustrated, and which may be of any conventional type having a plurality of pressure-responsive elements 13 suitably mounted and arranged in cylindrical array within a substantially cylindrical water-proof container or boot adapted to be submerged and fixedly supported beneath the surface of the water with its structural axis vertical.

As is well known, compressional wave energy striking the active face of the boot 15, is transmitted therethrough to the elements 13 causing the latter to generate alternating-current signals of magnitude and frequency corresponding to the amplitude and frequency, respectively, of the incident wave energy.

The signals from the transducer elements 13 are fed, by means of a multi-conductor cable through a switching device 17, hereinafter to be described, and thence to a delay network 19, which is in the form of a multi-unit multi-terminal network of inductances L and capacitances C.

Terminals 14 are provided at the junction of adjacent units, to individual ones of which terminals are connected (not shown) pairs of conductors from corresponding transducer elements 13 disposed on opposite sides of a predetermined reference of direction 16 of transducer 11.

In this manner, predetermined amounts of phase shift are introduced among the signals derived from said pairs of elements 13, resulting in the production of a receiving sensitivity maximum that is colinear with the reference 16 of the transducer 11.

A typical receiving sensitivity or directivity maximum is illustrated by the curve 21 in Fig. 2 showing a maximum response characteristic at point 23 and supernumerary side lobes 25, 27. The side lobes are relatively unimportant for the present discussion and will not be described further. The amplitude of the directivity pattern, however, is of interest, and its magnitude in relation to the general shape of the curve 21 is useful in determining the directional characteristics of the transducer, which in turn, determine the usefulness of the transducer and the listening system as a search instrument.

By cyclically switching the connections between the elements 13 of the transducer 11 and the terminals 14 of the delay network 19, the directivity pattern is caused to rotate or scan through any desired angle in azimuth or elevation. After suitable amplification of the switched signals in a conventional amplifier 29, visual indications of energy received during scanning of a directivity pattern may be provided by a suitable indicator 30 so that objects that lie within range of the listening branch and, which either

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themselves emit, or permit wave energy of suitable frequencies to be reflected therefrom, may readily be located as the scanning operation proceeds.

A switching device 17 embodying the principles of the present invention is shown in Figs. 3 and 4, consists in an electron-discharge tube having substantially cylindrical envelope 31, which may be of glass, and a base assembly 33. Base assembly 33 may be of any conventional design and type such as are used for vacuum tubes, generally, for anchoring support rods, and through which conductors may be drawn connecting electrodes within the envelope 31 and pins or terminals 35 mounted exteriorly of the base assembly. To this end, base 33 may be formed of some moldable insulation material 37 such as a phenolic condensation product contained within a metallic cup 39, the open end of which is feathered as at 41 for bonding to the adjacent end of the envelope 31 in a conventional air-tight seal so as to maintain a vacuum within the envelope 31.

For providing a copious supply of electrons within the envelope, a cathode or electron emitter unit comprising an elongated hollow tube 43, of which the exterior surface may be coated with an electron-emissive material is mounted coaxially of the envelope 31 and is supported at its opposite ends by means of rods 45 and 47. At one end, the rods 45 are embedded in the wall of envelope 31 and at the other, the rods 45 are fixed, as by spot-welding, to a disk 49 to which the adjacent end of tube 43 is also securely affixed. The rods 47 are spot-welded to a ring 51 to which the opposite end of tube 43 is fixed, while the opposite ends of rod 47 are anchored in the insulation material 37. One of the rods 47 is preferably connected to pin 53 through which it may be connected to ground, as at 55.

A heater filament 57 is mounted within the cathode tube 43 and is adapted, upon energization by a current from a battery or other suitable potential supply 59, to cause electrons to be emitted from the surface of tube 43.

Radially spaced from the cathode 43 and supported in coaxial alignment therewith is a beam-suppressing grid assembly 60 comprising a longitudinal array of segmented rings 61, each said ring being formed of three equal-length arcuate conductive segments 63, 65, and 67 spaced by substantially smaller insulating segments 69. The segmented rings 61 are preferably uniformly spaced axially along the tube and supported on three conductive rods or supports 71, 73, and 75, to which the sections 63, 65 and 67, respectively, are suitably connected, as by spot welding or silver soldering, with the rods 71, 73, 75 disposed at the mid-points of the respective sections 63, 65, 67, as shown in Fig. 4.

For supporting the upper ends of the rods 71, 73, and 75, an insulating ring 77 is mounted so that the cathode 43 passes through a central aperture therein, the ring 77 being rigidly positioned and held by means of radial struts 81 molded or embedded in the envelope 31.

The lower ends of the rods 71, 73 and 75 are brought out through the base 33 to pins 83, 85 and 87, for connection to a three-phase electrical generator 91. An adjustable phase-control device 89 is connected in the energization line to the beam-suppressing grid 60 for purposes that will presently appear.

A signal grid assembly 93 is coaxially disposed within the envelope 31 and surrounds the suppressor grid 60 and cathode 43 just described. The signal grid comprises a squirrel-cage formed

of longitudinal wires or rods 95 the lower ends of which are embedded in an insulating ring 97, which, in turn, is supported from the base 33 by means of studs 99. The upper ends of the signal grid wires 95 are brought out, through suitable openings in the insulating ring 77 and through vacuum-tight seals in the envelope 31, to an enlarged insulating ring 101 to provide input terminals 103 for connection to the conductors of cable 12 (Fig. 1) and thence to the pressure-responsive elements 13 of transducer 11.

While it may appear from Fig. 3 that the individual wires or rods forming the signal grid are of diameter of the same order of magnitude as the spacing between adjacent wires or rods, it will be understood that the showing is exaggerated, and that commonly, the diameters of the signal grid wires or rods are substantially less than the spacing therebetween.

Anodic ring electrodes in the form of cylindrical metallic plates or rings 105 are longitudinally spaced and arrayed coaxially with the cathode, suppressor grid and signal grid assemblies, above described. The rings 105 carried by insulating standards 107 which, in turn, are suitably anchored in the base 33. The rings 105 may be secured to the standards in any suitable manner, and carry output leads 109, which are passed through vacuum-tight seals in the envelope 31 to enable connection to the terminals 14 of the delay network 19 (Fig. 1).

Shielding electrodes in the form of cylindrical metallic plates or rings 111, generally similar to the anode rings 105, are also axially spaced from each other and coaxially mounted within the tube 17 on conductive rod supports 113. Supports 113 are anchored in the base 33, and one such support is brought out to a pin 115 for conductive connection to the positive terminal of the battery 59. Rings 111 are diametrically dimensioned for disposition between the signal grid assembly 93 and the anode rings 105, and are preferably interpolated between adjacent anode rings 105 so as to shield the signal grid wires 95 from the output rings 105, and, at the same time, to define annular gaps through which radially extending electron beams may pass. Rings 111 also serve to reduce cross-talk between any single output ring 105 and those adjacent thereto.

The broken-line rectangle 117, drawn to enclose a length of the tube 17 substantially corresponding to the active portion of the cathode, designates any suitable conventional apparatus for providing a rotating magnetic field, which field is preferably directed radially of and perpendicularly to the axis of tube 17, and adapted to rotate about an axis colinear with the tube axis. A suitable apparatus for generating such a rotating magnetic field is the stator of a three-phase motor connected to be driven from the three-phase generator 91.

The following description of the operation of our switching tube is made with reference to a transducer having 48 elements, such as are in common use in scanning sonar systems. It should be understood distinctly, however, that the selection of a sonar system and/or the selection of the specified number of transducer elements are merely exemplary, and are not to be construed as limitations of scope.

In operation with such a 48-element transducer, it is generally desirable that the switching device simultaneously control 18 of the 48 elements. That is to say, as the switching operation proceeds, it is desired that circuits in-

cluding 18 of the transducer elements be made and the circuits including 18 elements be broken all within a given time interval. Such operation is accomplished in the tube 17, by rotating a plurality of radially extending beams of electron that are formed from a rotating electron sheath or lamina, which, in turn, is derived by the joint action, on the electron cloud from cathode 43 of the rotating magnetic field generated by the apparatus 117 and the rotating bias on the beam suppressing grid assembly 60. The steps in the formation of the plural radial beams are now to be considered.

The electrons from the cathode 43 are emitted substantially uniformly along the length of the cathode and around the periphery thereof, forming a substantially cylindrical electron cloud. The cloud is transformed into a sheet-like or laminar distribution of electrons by the action of the radial magnetic field in accordance with well known theories of electron ballistics. The lamina of electrons is normally planar and extends diametrically across the tube 17 with the plane of the lamina including the axis of the tube. The lamina, of course, is caused to rotate about the axis of the tube by and in accordance with rotation of the radial magnetic field.

In the form of the invention illustrated in Fig. 3, characterized by the fact that the signal grid wires 95 are arranged parallel to the axis of the tube 17, to accomplish sequential switching, it is necessary that the plane of the rotating lamina be skewed at a pitch such that, for a given orientation of the lamina, it is modulated by signal from a predetermined number, which in the assumed example is 18, consecutive transducer elements. Such a skewed lamina is shown at 11 in Fig. 5, and is derived by skewing the winding slots and the windings of the polyphase motor stator 117.

As described above, the suppressor grid assembly 60 (Fig. 3) is energized from the same polyphase generator 91 as is the magnetic-field producing apparatus 117. Accordingly, it will be seen that the alternating potential on the segments 63, 65 and 67 of the suppressor grid is polyphase and varies at the same frequency as the rate of rotation of the magnetic field produced by apparatus 117. Thus the half of the electronic lamina 119 (in Fig. 5) that is directed toward the negatively energized segments of the suppressor grid is effectively suppressed, while the half 118 directed away from the negatively energized segments is radially accelerated and rotated by the rotating field.

To ensure smooth and continuous rotation of the non-suppressed half of the lamina 118, the adjustable phase-control device 89 (Fig. 3) is desirably inserted in the lines from the generator 91 to the suppressor grid 60 to adjust and control the relative phases of the polyphase energy used to produce the rotating field and that used to energize the grid 60. The relative phases are adjusted so that peak voltages are developed on the grid segments slightly in advance of the voltage peaks developed in the magnetic apparatus whereby the arrival of the rotating lamina occurs slightly after peak positive voltage is developed at the corresponding grid segment.

The rotating lamina interacts with the signal grid wires 95, of which there are 48 in the illustrative example herein assumed, each of which receives a signal voltage from a corresponding transducer element 13 and modulates the lamina therewith. The signal-modulated lamina

reupon transformed into radial beams 121 (Fig. 5) by the shielding rings 111. The beams pass through the annular gaps between the grids 111 and impinge on the 18 anode rings 105, hence output signals corresponding to the modulation signal of the beams are delivered to the ray network 19.

As above described, the network 19 combines signals interposing therebetween suitable amounts of delay, and thus causes a sharp sensitivity maximum to be defined, of which the position of maximum sensitivity is indicated by the reference of direction 16 (Fig. 1).

Fig. 6 diagrammatically represents the spatial orientation of the signal grids 95 and anode rings 105 in relation to the skewed electron lamina 118 and beams 121. As shown, the rings 105 and grids 95 form a substantially rectangular lattice that is intersected by the beams 121 and lamina 118 of electrons in a region here shown the dotted lines 123 oriented skew-wise thereto. The dotted lines 125 represent the intersection of the lamina and beams after rotation thereof through an angle of $7\frac{1}{2}$ degrees. It will be noted that in the position of the beams and lamina at 123, signals from 18 grid wires designated serially *c* through *t* modulate the beams 121, and the beams, so modulated, impinge on the anode rings 105. After rotation of the beams through $7\frac{1}{2}$ degrees, signals from grids *b* through *s* modulate the beams and the latter, as *v* modulated, impinge on the anode rings 105. It will be seen that, as the lamina 118 and electron beams 121 rotate through the predetermined angle, in the illustration herein assumed, equal to $7\frac{1}{2}$ degrees, signals from successive arrays of 18 consecutive elements are used to modulate the beams, the modulated beams impinge on respective anodes 105, and the output circuits 109 connected to the anodes 105 receive and carry signals characteristic of arrays of elements successively spaced $7\frac{1}{2}$ degrees from preceding arrays. Thus, as the lamina 118 and beams 121 continue in rotation, the sensitivity maximum 21 is formed from signals successively different arrays of elements and, accordingly, progresses around the transducer 11.

To ensure proper synchronization of the voltages applied to the segments 63, 65 and 67 and the rotary movement of the skewed beams 121, the arrangement of the segments may also be skewed at substantially the same pitch as the skewing of the beams. However, even without skewed arrangement of the segments 63, 65 and 67, deviation from perfect synchronism is not so marked as to interfere with satisfactory functioning of the tube.

Fig. 7 illustrates an alternative construction of signal grids that may be employed in the switching tube. As shown, wires 127, forming the signal grid, are disposed in substantially helical fashion. With the grid wires so arranged, an electron lamina 129 and beams 131 are formed and disposed in a vertical plane parallel to the axis of the tube, thus obviating the necessity of providing the winding slots and windings of the magnetic-field producing apparatus 117. The pitch of the grid wires is adjusted, as was the pitch of the beam in the embodiment of Figs. 1, so that for a given angular position of the lamina, the latter is modulated by the signals from a predetermined number of consecutive transducer elements.

In all other respects, a tube constructed with a signal grid and beam arranged in accordance

with the illustration of Fig. 7 is substantially similar in structure and in operation to that described hereinabove.

There has thus been described a scanning sonar system embodying an electron discharge tube that is constructed to perform the necessary switching operations to supply proper signal combinations from an array of pressure-responsive elements to a stationary beam-forming network.

It will be seen, that the tube is, in effect, an electrical analogue of a mechanical commutator with multiple slip rings and brush connectors. By the presently described device, the rotating mass of a mechanical commutator is advantageously replaced with a plurality of rotating beams of electrons thereby rendering this commutator susceptible to operation at considerably greater rotative speeds, and hence higher rates of scanning without being subject to the manifold mechanical design problems of high-speed commutators. Furthermore, the frequency of rotation of the beams, and hence the switching rate, may readily be adjusted as by varying the frequency of the polyphase energy from source 91, so that variable scanning speeds are thus provided.

While the switching or commutator tube has hereinabove been described as embodied in a sonar system, it will be understood that it is readily adapted for use in many other systems such as, for example, in radar, radio-direction finding, instrument landing and other high-speed scanning systems. It will be noted further, that any desired number of circuits, other than the herein specified number, may conveniently be serially switched.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

We claim:

1. Switching apparatus comprising an envelope, means within said envelope for providing a supply of electrons, means for forming said electrons into a lamina and for rotating said lamina, a plurality of circuits to be switched, grid means in the path of said rotating lamina and adapted for energization by electric signals from said plurality of circuits to modulate the rotating lamina, and a plurality of anodes spaced from said grids and arranged selectively to receive portions of said rotating electronic lamina after modulation thereof, whereby signals from individual circuits appear in succession on individual anodes.

2. Switching apparatus comprising an evacuated envelope, means within said envelope for generating a supply of electrons, means for forming said electrons into a lamina and for rotating said lamina about an axis extending through said envelope, a plurality of grids in the path of said rotating lamina and adapted to be energized by electric signals from a like plurality of circuits to be switched, said grids being angularly disposed relative to said lamina thereby to modu-

late the rotating lamina with signals from individual circuits in succession, and a plurality of anodes spaced from said grids and arranged selectively to receive portions of said rotating electronic lamina after modulation thereof by the energized grids, whereby signals from individual circuits appear in succession on individual anodes.

3. Electronic switching apparatus, comprising an evacuated envelope, cathode means axially mounted within said envelope and adapted to provide a substantially cylindrical cloud of electrons, means for forming said electron cloud into a lamina and for rotating said lamina at a predetermined speed, means for transforming the peripheral part of said lamina into a plurality of radial beams, a plurality of grid elements in the path of said rotating lamina and adapted for energization by electric signals from a like plurality of circuits to be switched to modulate said radial beams, and a plurality of anodes spaced from said grids and arranged selectively to receive said radial beams after modulation thereof by the energized grids, whereby signals from individual circuits appear in succession on individual anodes.

4. Electron-discharge tube apparatus, comprising means providing a cloud of electrons, means for forming said electron cloud into skewed electronic lamina having radially extending beam portions and for rotating said lamina and said beam portions about an axis in said tube, grid means axially disposed in the path of said rotating lamina and adapted, upon energization thereof by electric signals from a plurality of circuits to be switched, to modulate the rotating beam portions, a plurality of anodes spaced from said grids and adapted selectively to receive said beam portions after modulation thereof by the energized grids, and means interposed between said grid means and said anodes for minimizing cross-talk between adjacent anodes.

5. An electron discharge tube, comprising means for producing supply of electrons, means for forming said electrons into a plurality of beams mutually spaced along a common axis in the tube, said beams extending along substantially parallel planes, magnetic-field-producing means for simultaneously rotating said beams about said axis a plurality of signal grids in the path of said rotating beams, each said grid bearing an electric signal characteristic of a condition and adapted to modulate the beams thereby, a plurality of anodes surrounding said grids, individual ones of said anodes being adapted to receive a respective one of said beams, and means controlling the rotative motion of said beams, whereby said individual anodes successively receive signals from respective grids.

6. The electron discharge tube defined in claim 5 wherein said signal grids are disposed in skew-wise relation with respect to the axis of the tube, and the beams are coplanarly arranged.

7. The electron discharge tube defined in claim 5 wherein said signal grids are filamentary and disposed parallel to each other and to the axis of the tube and the beams are skewed.

8. An electron discharge tube, comprising means for producing a plurality of electron beams mutually spaced along a common axis in the tube, said beams extending radially of the tube and in substantially parallel planes, means for simultaneously rotating said beams about said axis, grid means in the path of said rotating beams, and a plurality of anodes surrounding

said grid means with at least one grid for each anode, individual ones of said anodes being aligned with individual ones of said beams defining there with a plurality of conductive paths in the tube

9. The electron discharge tube as in claim further characterized by signal input terminal connected to individual grids and individual output terminals connected to said anodes, whereby electric signals from said grids are successively conducted to said anodes.

10. An electron discharge tube, comprising means for producing a supply of electrons, means for forming said electrons into a plurality of beams mutually spaced along a common axis in said tube, said beams extending in substantially a single direction, and means for rotating said beams about said axis simultaneously.

11. An electronic distributor comprising an envelope, a cathode axially located therein means for forming electrons from said cathode into a radial beam, modulation electrode means comprising a plurality of filamentary conductors arranged parallel to each other and to the axis and in the path of said beam, and a plurality of anodes surrounding said modulation-electrode means.

12. Electron discharge apparatus comprising an envelope, means within said envelope for providing supply of electrons, means for forming said electrons into a lamina and for rotating said lamina, grid means in the path of said rotating lamina and adapted to modulate the rotating lamina, and a plurality of annular anodes spaced from said grid means and arranged in space concentric alignment selectively to receive portions of said rotating lamina after modulation thereof.

13. The apparatus as in claim 12 wherein said grid means comprises a cylindrical array of conductors, the individual conductors being parallel to each other and inclined to the axis of said envelope.

14. The apparatus as in claim 12 wherein said grid means comprises a plurality of conductors disposed in cylindrical array and in the path of said beams, said conductors being mutually insulated from each other and adapted to be individually energized by signals from individual ones of a plurality of circuits.

15. The apparatus as in claim 12 further comprising a plurality of shielding rings, individual ones of said rings being interposed between adjacent pairs of said anodes and in partly overlapping relation therewith.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,603,283	Hubbard	Oct. 19, 1926
1,893,741	Hecht et al.	Jan. 10, 1932
1,977,974	Rudolph	Oct. 23, 1933
2,197,042	Gray	Apr. 16, 1944
2,217,774	Skellett	May 27, 1945
2,221,743	Wagner	Nov. 12, 1945
2,266,671	Wolf	Dec. 16, 1946
2,269,688	Rath	Jan. 13, 1947
2,293,368	Stuart, Jr.	Aug. 18, 1947
2,358,542	Thompson	Sept. 19, 1949
2,395,299	Skellett	Feb. 19, 1949
2,474,960	Skellett	July 5, 1949
2,494,670	Rajchman	Jan. 17, 1950
2,533,401	Schramm	Dec. 12, 1951