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MULTI-POSITION SWITCHING SYSTEMS

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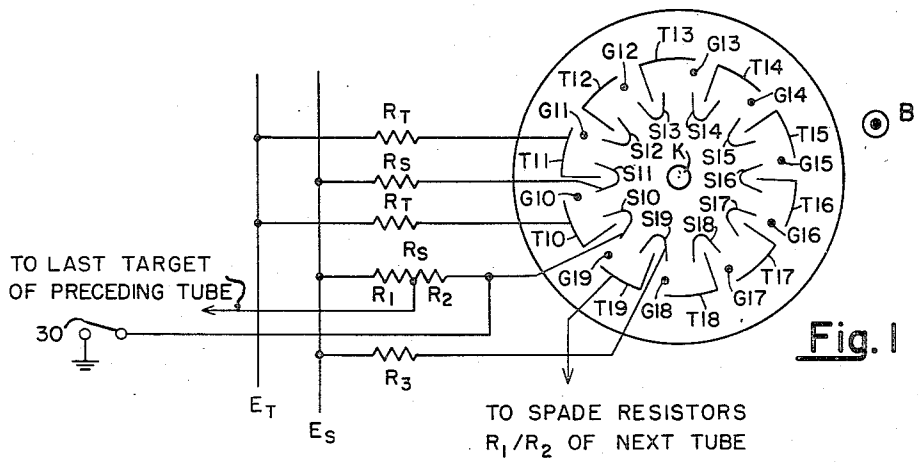


Fig. 1

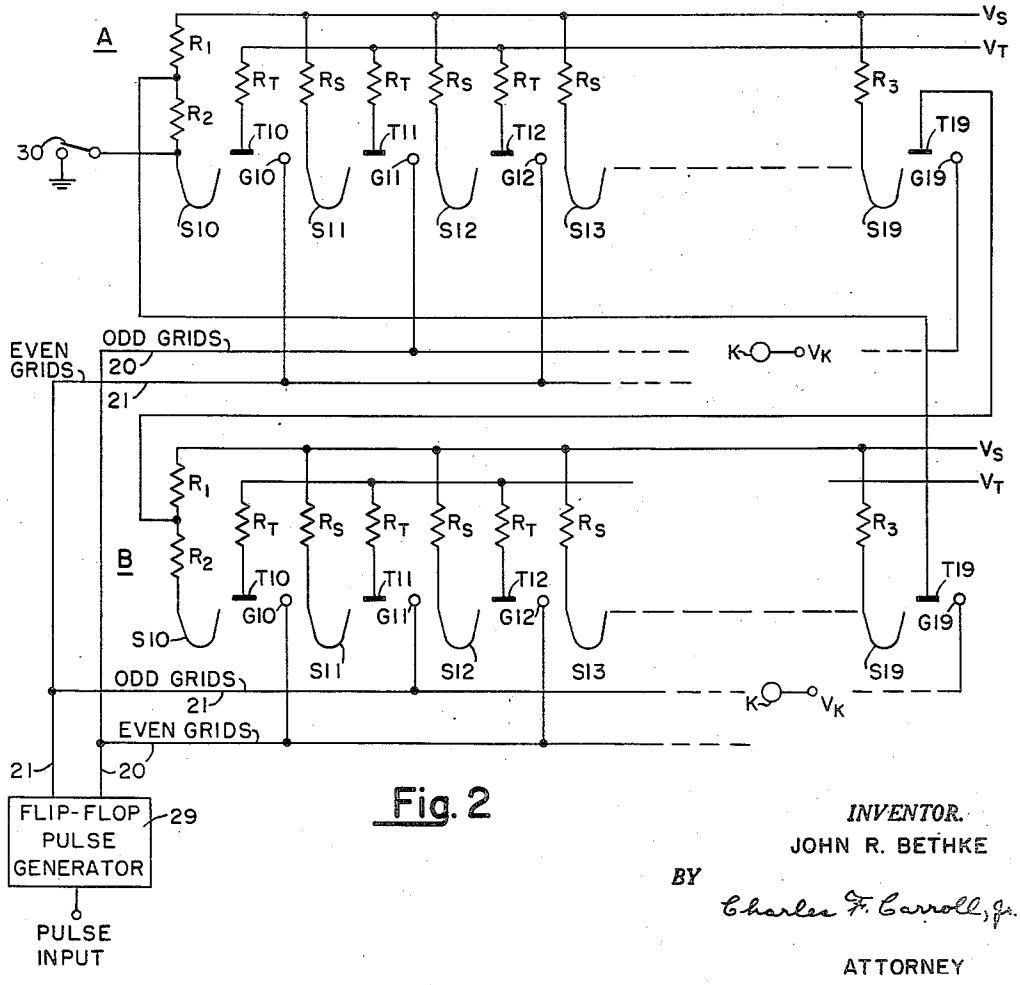


Fig. 2

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MULTI-POSITION SWITCHING SYSTEMS

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This invention relates to multi-position switching or distributor circuits using electron discharge devices of the magnetron beam switching type.

In the complex circuitry of missile guidance systems, telemetering links, computers, and coding equipment, the need for precise and rapid switching or signal distribution is serious. As circuits become more complex, the number of positions needed in various switches or distributors grows very rapidly. Magnetron beam switching tubes perform this precise and rapid switching very well. However, physical factors limit the maximum number of switching positions per tube to about ten. It becomes advantageous to connect magnetron beam tubes in cascade so that a switching sequence will advance through the separate positions of each tube in succession. Since the time relationship of contacts for sequential switching positions often is a critical factor, this switching transition must proceed between tubes as smoothly as it does between positions within a tube.

In the system embodying this invention the beam is scanned through the output positions of a first tube after which the beam is extinguished in this first tube and reformed in a succeeding tube where a subsequent scanning cycle takes place.

An object of this invention is to provide an improved multiple position electronic switching system using a plurality of beam switching tubes.

A further object of this invention is to utilize the number of output positions of each beam switching tube efficiently in a pulse distributor or switching circuit.

Another object of this invention is to produce a series of cascaded tubes with a plurality of sequential switching positions wherein the transition from one switching tube to the next is efficiently accomplished to afford stable switching.

An additional object of this invention is to produce an improved circuit for transferring a beam switching sequence from a selected position of a first beam switching tube to a selected position of a succeeding beam switching tube.

One type of discharge device which may be utilized in this invention is a magnetron beam switching tube shown and described in an article entitled "A New Beam Switching Tube," published in Electronic Design of January 1954. Such a tube also is the subject of U. S. Patent No. 2,721,955 entitled "Multi-Position Beam Tube" by S. P. Fan et al. This magnetron beam switching tube has an elongated axial cathode and several circular concentric arrays of other electrodes around it. On a first or smallest radius from the cathode is an array of evenly spaced spade electrodes. These spade electrodes are of approximately U-shaped cross-section with their convex surfaces facing the cathode. These spades serve to form a beam within the tube and to hold the beam in place so that it partly impinges on other electrodes. In line with one side of each spade and on a slightly larger radius is an array of switching electrodes.

These switching electrodes are elongated rods and are aligned parallel to the axial cathode. They serve to disturb the stable beam holding function of an associated spade and to cause the beam to switch over to the next position in which it can be stably held.

On the next larger or outside radius is an array of L-shaped target electrodes. One arm of each L is arcuate and positioned on the circumference in line with one of the open spaces btween two spades. The radial arm of each L extends inwardly toward a spade and may actually project slightly into the concave space or cavity of that spade. One of the switching electrodes is positioned between a spade on the other side of the space between spades and the end of the arcuate arm of the L-shaped target. Each space between spades is covered by a target electrode which provides a beam-receiving position or compartment. The spade adjacent the radial arm of the L-shaped target holds a beam on that target when the electrodes are connected to appropriate circuitry and voltages. The switching grid and spade on the other side of the space serve to move the beam toward them and into the next compartment to strike the next target.

These tubes require an axial magnetic field permeating them. For the beam to move in a clockwise direction the magnetic flux lines must flow toward the observer. This axial magnetic field usually is provided by a cylindrical permanent magnet but could be provided by an electromagnet or a combination of both type magnets. When a positive potential with respect to the cathode is applied to the spade electrodes and target electrodes, crossed-magnet electrical fields of a magnetron are provided. In this invention these fields are adjusted to place the tube well into the magnetron cut-off region, so no beam is formed and no current flows when the potential of all spades is positive. If the potential of one of the spades is lowered to near the cathode potential, this axially symmetrical field is changed and electrons will flow to the compartment adjacent this spade, forming a beam. Some electrons strike this spade and flow through one of the resistors which connect each spade to the positive potential. The resulting IR voltage drop developed by current flowing through the resistor enables that spade to hold the beam stably in that compartment, striking the target thereof. To switch this beam to the next compartment, the switching electrode in the compartment holding the beam is given a low potential. This alters the beam so that at least some of it moves toward this switching electrode and the spade electrode near it. When some of the beam's current flows through this next spade a voltage drop occurs due to this current flowing through a resistance connecting this second spade to its positive potential. This voltage change causes the beam to swing on into the next compartment and enables the next spade to hold the beam in position.

In accordance with the features of one embodiment of this invention, the target electrode of the last array in a first beam switching tube is connected to the voltage supply through a resistor which also connects the first spade electrode of the succeeding tube to this voltage supply. Impingement of the beam upon the target of the last array causes an electron current to flow through the resistor mutually connecting the first spade and last target to the voltage supply and this lowers the potential on the first spade electrode of the normally cut-off succeeding tube enough to form a beam at the first array thereof. In this manner, only one array or position of each tube is used as a control position for beam extinguishing and forming, and nine positions are available for useful output positions in each tube. The spade load

resistor for this control position is made too low in ohmic value to stably hold the beam when the beam is switched thereto. Accordingly when the control position is reached, the beam is cut off in each tube.

The various features of the invention will be more fully understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 is a circuit diagram including a plan view of the electrodes in a magnetron beam switching tube; and

Fig. 2 is a schematic diagram of multiposition switching circuit embodying the invention.

In Fig. 1, a plan view of the electrodes within a magnetron beam switching tube are shown. The central cathode K defines the axis of the tube, and the magnetic field B is established with lines through the tube parallel to the axis, with lines proceeding from the plane of the drawing to cause clockwise rotation of the beam during switching. The generally U-shaped spade electrodes S10 to S19 are arranged concentrically around the cathode with their convex surface facing the cathode. The rod-like switching grids G10 to G19 are positioned concentrically around cathode K, on a radius slightly larger than that for the spades, and each grid is radially aligned with one edge of a corresponding spade. The L-shaped target electrodes T10 to T19 are arranged with their circumferential portions on a radius slightly larger than that for the switching grids, and with radial surfaces extending into the concave portion of the associated spade. One set of electrodes, such as target T10, grid G10, and spade S10 are considered a group providing one output position. This particular group is designated as an initial position. Each of the spade electrodes is connected to a voltage E_S through a corresponding resistor R_S. To simplify the drawing, only representative connections are shown. Each of the targets except target T19 is connected to a voltage E_T through a corresponding resistor R_T. Target T19 is termed the last target since it is the last target to receive the beam before another cycle starts on target T10. Target 19 couples the tube to a following similar tube at the junction of resistors R_1 and R_2 used for connecting the initial spade S10 of the following tube to voltage E_S.

It is a characteristic of such magnetron type tubes that, with the cathode-to-spade voltage and axial magnetic field adjusted beyond a critical ratio, no current will flow to the targets. If, however, the voltage on one of the spade electrodes is lowered, the circumferentially symmetric electrical field gradient within the tube is changed and electrons will move along equipotential lines, forming a radially extending beam. To initiate beam formation when the beam is cut off, the beam forming switch 30 may be actuated to lower the spade potential momentarily to ground potential. This beam will curve outward to graze the spade electrode having a lowered potential and strike the adjacent target electrode. With a resistor R_S of the proper value in series with each spade, the slight portion of the beam current which strikes the spade it grazes is caused to depress that spade's potential due to the beam current flowing through the resistor R_S. This effect enables a spade to hold the beam in a stable lock-in position once the beam has been formed on the associated array.

To switch a beam from one set of electrodes to another, switching grids G10 to G19 are provided in each tube. In one circuit connection, switching grids G10 to G19 are connected in common connections of alternate grids, i. e. all odd grids are connected together and all even grids are connected together. This connection as shown in Fig. 2 utilizes a sinusoidal signal or push pull signals where one set of grids are driven negatively as the other set of grids are driven positively. Thus, alternate sets of grids receive the successive negative pulses of a switching signal.

Consider the moment when a beam is formed on

target T10 and grid G10 of tube A is driven to a negative potential. Because of the change this introduces in the equipotential lines between spades S10 and S11, the beam moves toward spade S11 and a small amount of beam current strikes spade S11. The flow of this current through spade S11's resistor R_S lowers the potential of spade S11 producing additional change of the electrical field which causes the beam to switch to target T11. At this moment grid G11 is not negative and may even be at a positive potential when a sinusoidal switching signal is used. Thus, no further switching occurs at that moment. On the next half cycle of a sinusoidal switching signal or upon the next pulse from the flip-flop circuit or other source of push pull switching signals, grid G11 will be driven negative and another switching step occurs as for grid G10. The alternate connections limit the switching to a single step for each half cycle of the switching signal.

In Fig. 2, two, ten-array, magnetron beam switching tubes, A and B, are shown for clarity in a linearly disposed form. The tubes are coupled for stepping through eighteen successive positions. To simplify the presentation, representative connections are made in the drawings to indicate that the manner in which a number of elements may be similarly connected. Thus spades S11 to S18 are connected through separate resistors R_S to voltage V_S, and targets T10 to T18 are connected through resistors R_T to voltage V_T. Initial spade S10 of each tube has resistors R_1 and R_2, of total series resistance equal to R_S, connecting it to voltage V_S, and the last spade S19 of each tube has resistor R_3, of lower ohmic value than R_S connecting it to voltage V_S. Target T19 of each tube connects to the junction point between resistors R_1 and R_2 of the series connection to spade S10 of the following tube. Cathodes K are grounded or connected to a low, negative voltage V_K.

To start the pulse distribution, the potential on initial spade S10 of tube A is lowered to about ground potential. Switch 30 can be used, or an initiating negative trigger pulse could be provided at the same point. This lowered potential on spade S10 of tube A causes a beam to form to initial target T10. A small portion of this beam current strikes spade S10 and the voltage drop it produces in flowing through resistors R_1 and R_2 will enable spade S10 to hold the beam after switch 30 is opened. Switching grids G10 to G19 are connected in one common connection of all odd grids G11, G13 . . . G19, and another common connection of all even grids G10, G12 . . . G18. The odd grids connect to lead 20 and the even grids connect to lead 21 for tube A, and the odd grids of tube B connect to lead 21 and the even grid of tube B connect to lead 20. This transportation of connections will be explained in connection with the switching sequence through both tube A and tube B.

Consider the moment when a beam is formed on target T10 of tube A and grid G10 of tube A is driven to a low potential through a negative going pulse on lead 21. Because of the change this introduces in the equipotential lines within tube A, the beam will switch over spade S11 to strike target T11. Since no signal, or an opposite positive signal, has been applied to grid G11 at this moment the beam will not progress any further. On the next half cycle of the switching signal a negative pulse is applied on lead 20 and grid G11 does go negative causing the beam to advance over spade 12 to strike target T12 as described before. This switching sequence continues with each half cycle of the switching signal through the positions of tube A until the beam reaches the last target T19. Here the flow of beam current from target T19 goes through resistor R1 of the next tube B lowering the potential of initial spade S10, thereby causing a beam to form in tube B. At the same time, only the small fraction of the beam current striking spade S19 flows through resistor R3. However, resistor R3

is of too low an ohmic value to enable spade S19's potential to lower enough due to the IR voltage drop caused by the flowing through resistor R3, to enable spade S19 to hold the beam stably on target T19. Accordingly, the beam in tube A is extinguished shortly after it reaches the electrode group comprising target T19 and spade S19. Where useful values for R_S are in the order of 100,000 ohms, the useful values for R_3 have been found to be in the order of 40,000 ohms.

With an odd number of useful output positions per tube (positions 0 to 8), grid connections in the next tube B must be transposed in order to maintain an uninterrupted switching sequence. Consider tube A to be the first tube and tube B to be the second, etc. Accordingly, the push-pull output of the flip-flop pulse generator 29 shown in Fig. 2 has the odd grids of all odd tubes and the even grids of all even tubes coupled to one output connector 21, and the even grids of all odd tubes and the odd grids of all even tubes coupled to the other output connector 20. The need for this will be evident from the following description.

If the switching sequence and transfer from one tube to the other is considered in connection with Fig. 2, it will be seen that the above explained pattern of grid connections is required. When the beam reaches target T18, a pulse on the even grids of the odd tubes will be applied to grid G18 causing the beam to switch to target T19. Spade S19 is connected to voltage V_s through resistor R_3 which is of too low an ohmic value to enable spade S19 to hold the beam, so tube A is cut off. However, for the short period when the beam is on target T19, beam current flows through resistor R_1 of tube B and lowers the potential on spade S10 of tube B. This forms a new beam on target T10 of tube B. Now, the next pulse must be applied to the even grids of the even tubes B etc. in order to switch the beam in tube B from target T10 to target T11. The other grids of both tubes must be connected to maintain the alternate relationship that has been described.

As the switching beam progresses through tube B, it reaches target T18 thereof, and the next switching signal moves the beam to target T19. In the same manner described for tube A, the connection of spade S19 through resistor R_3 renders spade S19 of tube B incapable of holding the beam stably on target T19 so tube B cuts off when this electrode group is reached. The electron current flow to target T19 of tube B is conducted through resistor R1 to voltage source V_S. This current flow causes a negative pulse on spade S10 of tube A, forming a new beam in tube A before tube B cuts off. It is within the scope of this invention to make the connections from tube B to another succeeding tube instead of returning the sequence to tube A or to allow it to expire until a further cycle is initiated by switch 30. The succession can be extended to a large number, N, of ten position tubes, providing 9N output positions for each sequential tube connection.

In all the tubes, targets T10 to T18 inclusive are the switching positions connected to output circuitry. Switching signals advance the beam to these targets in succession and from tube to tube. Instead of common connections of alternate grids utilizing push-pull switching signals, all grids can be coupled in one common connection. The switching signals therefor would be pulses of such timed duration and amplitude that only one step of the beam's advance is possible during each pulse.

Switching achieved through potential gradient changes produced by voltages applied to the switching grids is not the only method by which the beam can be switched in a beam switching tube. Alternate methods are known, such as depressing the potential of the cathode so that the spade-to-cathode potential is increased, or increasing the potential simultaneously on all the spades to achieve the same effect. When such alternate switching methods are employed, tubes without switching grids may

be utilized or switching grids may be biased to some neutral potential which permits the tube to function.

If a repetitive cycle is not desired, as mentioned hereinbefore, then the last target 29 of the last tube in a succession of tubes would be connected through a resistor R_T to voltage supply V_T as are all other targets, and there would be no connection to the initial spade S10 of the first tube. Thus, with low ohmic resistor R3 in series with spade S19 of this last position, the beam could not be held on target 29 and the last tube would be cut off. Switch 30 would then be actuated to start another cycle.

A flexible electronic switching system thus has been provided, capable of utilizing all but one position of each beam switching tube for useful output positions and equally capable of being connected for fewer positions or of being connected back to an initial position for repetitive cycles through the succession of beam tubes.

What is claimed is:

1. An electron beam switching system comprising a succession of magnetron beam switching tubes including at least an initial and a last tube in said succession of tubes each tube having a cathode and a multiplicity of spade electrodes, switching grid electrodes, and target electrodes arranged in a succession of electrode groups of one of each said electrodes per group, with one group starting said succession of groups and designated the initial group and another group at the other end of the succession designated the last group, circuit means for connecting said magnetron beam switching tubes to a voltage supply and including first resistance means connecting each target electrode except the last target electrode of each tube to a voltage supply to receive electron beam current and second resistance means connecting each spade electrode except the last spade electrode of each tube to a voltage supply to pass enough beam current to hold a beam in place when it reaches the respective electrode group thereof, starting means to lower the potential on the initial spade electrode of the initial tube to form a beam to the initial electrode group, coupling means connecting the last target electrode of each tube with the initial spade electrode of the following tube to lower the potential of said initial spade when an electron beam strikes said last target thereby to form a beam in said following tube, third resistance means for connecting the last spade of each tube to a voltage supply enabling said last spade to cut off a beam when the beam is switched to said last group, and switching means connected to said switching grid electrodes to advance a beam to each electrode group of a tube in succession and from tube to tube in said succession of tubes.

2. A pulse distributor comprising a plurality of normally cut-off magnetron beam switching tubes each having a plurality of beam forming and holding electrodes, switching grids, and output electrodes arranged in successive electrode groups, starting means connected to a spade electrode for forming a beam in one of said plurality of tubes, circuit means connecting a target electrode of each tube with a spade electrode of a following tube of said plurality and responsive to a beam striking said target electrode to form a beam in said following tube of said plurality of tubes, and switching means connected to said switching grids and responsive to switching signals to advance a beam successively to the electrode groups of each tube and from tube to tube in succession.

3. In an electronic switching system a succession of multiple output beam switching tubes each being normally cut-off and having a plurality of beam receiving compartments each comprising a spade electrode, a grid electrode, and a target electrode, circuit means interconnecting a target electrode of each tube with a spade electrode of a following tube resistive means in said circuit means responsive to a beam striking said target electrode of the transferor tube to cause the potential of said spade electrode to decrease and a beam to form to

the compartment of the transferee tube having said spade electrode, and circuit means coupled to each tube to extinguish the beam of each tube shortly after it reaches a compartment which includes said interconnected target electrode.

4. In an electronic switching system a succession of multiple output beam switching tubes each having a plurality of beam receiving compartments each comprising a spade electrode, a grid electrode, and a target electrode, circuit means interconnecting a target electrode of each tube with a spade electrode of a following tube, a resistor commonly connected with the interconnected spade and target responsive to a beam striking said target electrode of the transferor tube to cause the potential of said spade electrode to drop and a beam to form to the compartment of the transferee tube having said spade electrode, and circuit means coupled to the spade electrode of the compartment of each tube having said interconnected target electrode to extinguish the beam of each tube when the beam reaches said compartment.

5. In an electronic beam switching system a succession of magnetron beam switching positions having a plurality of arrays for successively receiving the beam and each array having at least a spade electrode and a target electrode, circuit means coupling the target electrode of a predetermined array with the spade electrode of a further successive array to form a beam at said successive array, and current responsive means connected for applying potential to an electrode of said predetermined array so that it will cut off the beam shortly after said beam reaches said predetermined array.

6. A circuit as defined in claim 5 wherein said current responsive means is in the beam current path of said predetermined array and will cut off the beam shortly after said beam reaches said predetermined array.

7. An electron beam switching system comprising a succession of magnetron beam switching tubes, with each tube including a plurality of electrode groups for successively receiving a beam, and each group having a spade electrode and a target electrode and defining a beam-receiving position, starting means connected to the spade electrode of the first group of the first tube of said succession to form a beam directed into said first group, impedance means to connect each spade electrode and target electrode except those of the last group of each tube to a voltage source to hold the electron beam of their respective tubes on their respective group when the beam is switched thereto, current responsive means connected to the last group of each tube to couple the target electrode of said last group to the spade electrode of the following tube to form a beam in said following tube and to control the potential of the spade electrode of said last group to cut off the beam in each tube when the beam is switched to said last group of each tube, and an input circuit connected to electrodes of said tubes and responsive to switching signals to cause a beam to advance to successive groups and to successive tubes in smooth transition.

8. An electron beam switching system comprising a plurality of cutoff magnetron beam switching tubes with each tube having at least a cathode, N spade electrodes and N output electrodes, said spade electrodes and output electrodes being arranged in groups of one of each type electrode per group to provide N electrode groups, coupling circuit means between successive tubes interconnecting an output group of each tube with an input group of a following tube, current responsive circuit means connected to each output group to extinguish a beam when it reaches said output group, means for starting a beam in a tube of said plurality of tubes, and means for successively stepping the beam to deliver continuous useful output indications at N-1 electrode groups in each tube in response to the beams' stepping succession.

9. A multistable position magnetron beam tube switching system comprising a succession of electrode groups each comprising a spade electrode for forming a beam and holding a beam in stable position when receiving beam current, means for deflecting a beam from one stable position to the next, and a target electrode for receiving beam current for operating load circuits, with one group starting said succession of groups and designated the initial group and another group at the other end of the succession and designated the last group, circuit means for connecting the magnetron beam tube to a voltage supply and including first-resistance means connecting each target electrode except the last target electrode to a voltage supply to receive electron beam current and second resistance means connecting each spade electrode except the last spade electrode to a voltage supply to pass enough beam current to hold a beam in place when it reaches the respective electrode group thereof, means for operating the electrode groups in magnetron cut off conditions, starting means to lower the potential on a spade electrode to form a beam in the corresponding electrode group, coupling means for connecting a beam receiving the electrode in the last electrode group with a spade electrode in an initial group to lower the potential of said spade electrode of the initial group when an electron beam strikes the last target thereby to form a beam at the respective electrode group, third resistance means for connecting the spade of the last group to a voltage supply enabling said last spade to cut off a beam shortly after the beam is switched to said last group, and switching signal means connected to the means for deflecting a beam from one stable position to the next, to advance a beam from one electrode group to another along said succession of groups.

10. An electron beam switching system comprising a succession of magnetron beam switching tubes including at least an initial and a last tube, each tube having a cathode, a multiplicity of spade electrodes for forming and holding a beam, switching grid electrodes and target electrodes arranged in a succession of electrode groups of one of each said electrodes per group, with one group starting said succession of groups and designated the initial group, the intermediate groups numbered successively, and another group at the other end of the succession designated the last group, circuit means for connecting said magnetron beam switching tubes to a voltage supply and including first resistance means connecting each target electrode except the last target electrode of each tube to a voltage supply to receive electron beam current and second resistance means connecting each spade electrode except the last spade electrode of each tube to a voltage supply to pass enough beam current to hold a beam in place when it reaches the respective electrode group thereof, starting means to lower the potential on a spade electrode of the initial tube to form a beam, coupling means connecting the last target electrode of each tube with an electrode group of the following tube to thereby lower the potential of the initial spade when an electron beam strikes said last target, and switching means having two leads at which push-pull signals are developed respectively connected to sets of alternately disposed switching electrodes in each tube comprising odd numbered and even numbered switching electrodes, the sets of even numbered electrodes of each tube being connected to the same switching means lead with the sets of odd numbered electrodes of adjacent switching tubes in said succession.

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