

July 21, 1959

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2,896,117

LINEAR MAGNETRON TRAVELING WAVE TUBE

Filed Feb. 28, 1955

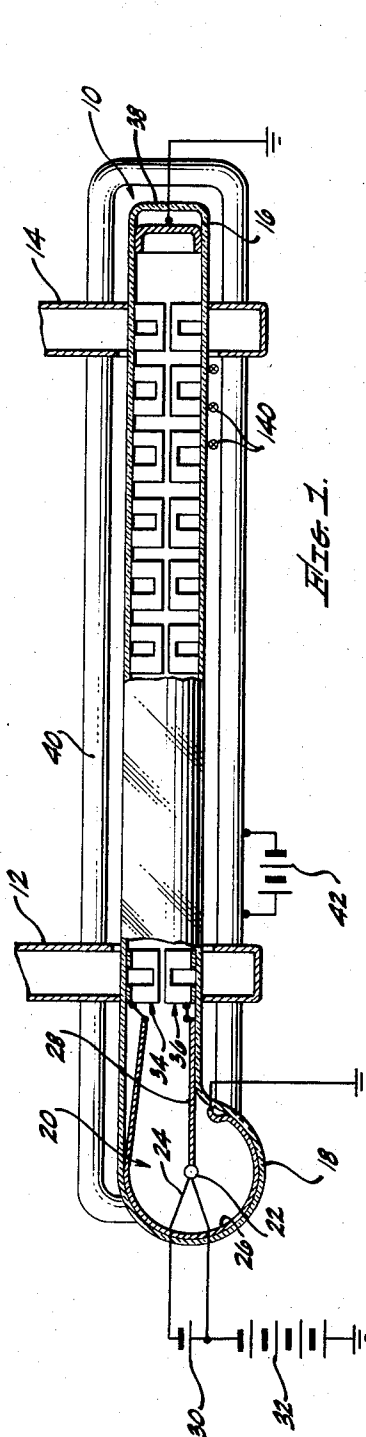


FIG. 1.

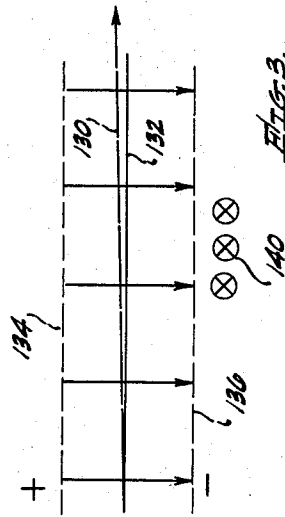


FIG. 3.

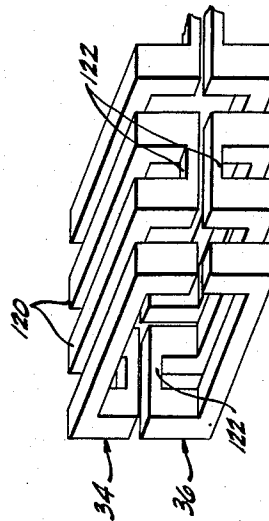


FIG. 2.

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LINEAR MAGNETRON TRAVELING WAVE TUBE

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Application February 28, 1955, Serial No. 490,953

3 Claims. (Cl. 315-39.3)

This invention relates to microwave tubes and more particularly to the slow-wave structure of a traveling-wave tube.

In traveling-wave tube amplifiers of the type called traveling-wave magnetrons an electron stream is projected between a conductive plate and a conductive slow-wave structure such as a conductive helix while the stream is subjected to a unidirectional transverse magnetic field. Such an amplifier is described in U.S. Patent Number 2,607,904 to Lerbs. The slow-wave structure of the amplifier therein described is maintained at a potential positive with respect to that of the conductive plate. The stream is introduced between the plate and the slow-wave structure at an appropriate distance from the plate and with a suitable axial velocity. The stream then follows a path which is inclined slightly toward the slow-wave structure. When an electromagnetic wave is launched along the slow-wave structure, the stream interacts with the wave to cause it to grow or be amplified. The stream thus loses axial momentum by giving up energy to the wave. The restraining force of the transverse magnetic field is decreased by the decrease in axial stream velocity and the transverse electrostatic field causes the stream to be directed slightly toward the slow-wave structure.

The gain and efficiency and the radio-frequency or RF power output of traveling-wave magnetrons employing conventional conductive helices are restricted because an electron stream is projected only near a portion of the outside of a conductive helix. The longitudinal field is shorted out at the conductive plate and greatly reduced due to the presence of the plate in the region between the helix or other slow-wave circuit and the plate. Hence, the average longitudinal field is seriously reduced and gain and efficiency of the tube is low.

It is therefore an object of the invention to provide an improved slow-wave structure for a traveling-wave tube.

It is another object of the invention to provide means for increasing the efficiency and radio-frequency power output of traveling-wave magnetrons.

In accordance with the invention, a slow-wave structure which may be split along an axial plane is employed to provide the electrical equivalent of a contrawound conductive helix. Different potentials are applied between the separate halves of the slow-wave structure and an electron stream is projected between them. An electromagnetic wave is launched along the slow-wave structure, and the stream is permitted to interact with the wave. The amplification produced is thus increased over that produced in conventional traveling-wave magnetrons because interaction between the wave and the stream is possible in substantially all of the space occupied by the stream between the separate halves of the slow-wave structure.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and

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advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

Fig. 1 is a sectional view of a traveling-wave magnetron in which a slow-wave structure having the configuration of contrawound conductive helices is shown;

Fig. 2 is an isometric view of the slow-wave structure shown in Fig. 1 at the left end of the tube; and

Fig. 3 is the trajectory plot of an electron stream employed in the traveling-wave magnetron of Fig. 1.

Referring to the drawing, and particularly to Fig. 1 there is shown a traveling-wave magnetron 10 having a rectangular input waveguide 12 at its left end and a rectangular output waveguide 14 at its right end. The traveling-wave magnetron 10 comprises an evacuated envelope 16 which has an enlarged portion 18 at its left end for housing an electron gun 20. The gun 20 comprises a cathode 22 which is provided with a filament 24, a focusing electrode 26, and a combined cathode support and focusing electrode 28. The filament 24 is heated by means of a battery 30. Cathode 22 is maintained a few hundred volts negative with respect to ground by means of an accelerating source of potential 32. Focusing electrode 26 is maintained at ground potential whereas focusing electrode 28 is maintained at the cathode potential. The gun 20 is similar to one described in the Lerbs patent above referred to.

To the right of focusing electrodes 26 and 28, a slow-wave structure is shown inside the envelope 16 comprising two serpentine, conductive structures 34 and 36 which are similar to a slow-wave structure disclosed and claimed in a co-pending application, Serial No. 456,682, entitled Traveling-Wave Tube, filed September 17, 1954, by Charles K. Birdsall and Lester M. Field, now abandoned. A collector electrode 38 is disposed at the right end of the envelope 16 to intercept the stream electrons produced by the gun 20. Collector electrode 38 is for this purpose maintained at ground potential. A transverse magnetic field is produced along the path of the stream produced by the gun 20 by means of two magnetic solenoids 40, only one of which is shown in the sectional view of Fig. 1. The solenoid 40 shown is provided with a source of potential 42.

The slow-wave structure of the tube 10 in Fig. 1 is shown in a broken isometric view in Fig. 2. The serpentine structures 34 and 36 are transverse images, that is, they are identical except for the fact that the right-hand portion of one is mechanically equivalent to the left-hand portion of the other. Each serpentine structure 34 and 36 comprises a plurality of transversely extending conductive segments 120 which are connected by axially extending conductive segments 122. The conductive segments 120 may have semicircular shape although their specific rectangular shape shown may be found to be more efficient and convenient to use. Both of these shapes may be generically classified as arches. Alternate adjacent pairs of the arched, conductive segments 120 are connected alternately to diametrically opposed points by the axial segments 122. The axial segments 122 of each of the serpentine structures 34 and 36 are then disposed contiguous to one another whereby an electromagnetic coupling may be produced by the capacitance between the axial conductive segments 122 and the opposed ends of the arched conductive segments 120 respectively of each of the serpentine structures 34 and 36, which are disposed opposite one another.

As explained in the aforementioned Birdsall and Field

application, the slow-wave structure including the serpentine structures 34 and 36 appears to be a contrawound conductive helix electrically. This is true because the segments 122 in both of the serpentine structures 34 and 36 are connected for purposes of wave propagation along the serpentine structures 34 and 36. It is to be understood that the number of pairs of the serpentine structures 34 and 36 is only limited by their practical mechanical strength. More than two may be employed although two may be found to be most convenient. Such structures are further described in the aforementioned Birdsall and Field application.

In the operation of the traveling-wave magnetron 10 in Fig. 1, a relatively thin electron sheet beam is projected through the serpentine structures 34 and 36 by means of the electron gun 20. The transverse magnetic field produced by the solenoid 40 prevents electrons from traveling beyond a predetermined distance towards the serpentine structure 34 which is maintained at the same potential as focusing electrode 26, that is ground, whereas the serpentine structure 36 is maintained at the potential of the focusing electrode 28, which is the cathode potential, by an appropriate connection thereto. Serpentine structure 34 is thus maintained at a potential positive with respect to that of the serpentine structure 36. If the sheet beam produced by the gun 20 is introduced at a proper distance between the serpentine structures 34 and 36 it will travel along a substantially linear path as indicated by an arrow 130 in Fig. 3, where the line 132 represents the symmetrical axis of the slow-wave structure comprising the serpentine structures 34 and 36. The dashed lines 134 and 136 represent the transverse portions of the serpentine structures 34 and 36, serpentine structure 34 being maintained at a potential positive with respect to that of serpentine structure 36 as indicated by the + and - signs. As the beam moves along the path indicated by the arrow 130, the beam will give up energy to the wave propagated along the serpentine structures 34 and 36 launched therealong at the input end of the tube by the excitation of the input waveguide 12 of the tube 10. As interaction takes place, the stream electrons moving along the path 130 will lose axial velocity or momentum. Hence, the transverse electrostatic field existing between the serpentine structures 34 and 36 will pull the electrons towards the serpentine structure 34. The magnetic field produced by the solenoid 40 will not prevent this movement because the axial velocity of electrons moving along the path 130 will be reduced and hence will reduce the magnetic force thereon restraining their movement towards the serpentine structure 34. A transverse magnetic field is indicated in both Fig. 3 and Fig. 1 by the crosses 140, the magnetic field being taken as having a direction into the paper of the drawing.

A traveling-wave magnetron of increased power and efficiency may thus be constructed by practicing the present invention in that interaction between the electron stream and the traveling-wave may be increased.

What is claimed is:

1. A slow-wave structure for use in a linear magnetron type traveling-wave tube comprising a plurality of arched conductive segments axially aligned with each other about a predetermined path; a plurality of axial conductors, individual ones thereof being connected between adjacent segments, said axial conductors alternating between opposite sides of said path, whereby said arched segments and said axial conductors define a serpentine shaped element; said structure defining an opposed pair of said elements, said opposed pair of elements being

separated in a direction perpendicular to said path and each element being the mirror image of the other, said elements being electromagnetically coupled together as a radio frequency unitary structure due to the close spacing between said elements; means for maintaining said elements at different direct current potentials and means for providing a magnetic field in the region of said slow-wave structure parallel to the plane of separation.

2. A slow-wave structure for use in a linear magnetron type of travelling-wave tube comprising a series of arched conductive segments axially aligned along the axis of the tube; a plurality of substantially straight axial segments disposed in an axial plane interconnecting adjacent arched segments, said axial segments alternating between opposite sides of said arched segments along the length of the tube, whereby said arched segments and said axial segments define a serpentine element; said slow-wave structure defining an opposed pair of said elements, said elements being separated in a direction perpendicular to said axial plane and each element being a direct current isolated mirror image of the other, means for maintaining said elements at different direct-current potentials, whereby an electrical field is caused to exist perpendicularly to said axial plane; and means for maintaining a magnetic field in the region of said tube parallel to said axial plane and transverse to the axis of said tube, said slow-wave structure being, as regards radio frequency energy, a unitary contrawound slow-wave structure.

3. A linear magnetron traveling-wave tube comprising a slow-wave structure having a first set of arched conductors disposed in the same position sequentially along a predetermined axis; a second set of arched conductors disposed sequentially along said axis and having their extremities disposed in an opposed adjacent position to the extremities of said first set of arched conductors; a first set of straight axial segments interconnecting adjacent arched conductors of said first set of conductors, said first set of axial segments alternating between opposite extremities of said first set of conductors; a second set of straight axial segments disposed adjacent to said first set of straight axial segments and interconnecting adjacent arched conductors of said second set of conductors, said second set of axial conductors alternating between opposite extremities of said second set of conductors, whereby said first set of arched conductors and axial segments defines a first serpentine shaped element and said second set of arched conductors and axial segments defines a second serpentine shaped element which is a mirror image of said first element, said first and second elements being direct current mutually insulated but radio frequency capacitively coupled, whereby the electrical equivalent of a contrawound helix is simulated, being made up of two continuous serpentine elements lying adjacent to each other and having axial plane of symmetry; means for maintaining said serpentine elements at different direct current potentials to provide an electric field perpendicular to said plane of symmetry and means for providing a magnetic field along said plane of symmetry in the region of said slow-wave structure transversely to the axis of said structure.

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