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2,888,594

TRAVELING WAVE TUBE

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This invention relates to electron discharge devices and more particularly to such devices of the traveling wave tube type.

Traveling wave tubes, as is well known in the art, generally comprise a slow wave interaction circuit along which an electromagnetic wave is transmitted for interaction with an electron beam projected adjacent to the slow wave circuit. The most usual type of such slow wave circuit is defined by a helical wire, generally referred to simply as a helix and so designated herein. It is often desirable to be able to have a direct current connection to this helix both for fabrication purposes, such as outgassing of the helix, and to enable a direct current voltage bias to be applied to the helix during operation of the tube. A connection for a direct current voltage bias may be made by a separate terminal through the envelope of the tube in the vicinity of the helix, but this is disadvantageous in that it unduly complicates both the fabrication of the tube and the requisite magnetic circuit. It is, therefore, desirable to have all connections, except to the collector, made by means of terminals in the base of the tube.

This means that an electrical circuit must be provided from the tube base through the electron gun region to the helix. It is known in the art that such a circuit must not be utilized by any high frequency energy being launched on the helix directly adjacent the gun; accordingly, some provision should be taken to prevent leakage of electromagnetic or high frequency energy back from the helix to the electron gun along this path.

Priorly in traveling wave tubes wherein the external circuits to which the helix are coupled comprised wave guides, the leakage of high frequency energy back to the gun has been prevented by external quarter-wave chokes. When, however, the external circuit is a coaxial line rather than a wave guide, such a solution would require an excessive amount of space and might not be accommodated by the tube or magnetic circuit.

Accordingly, it is a general object of this invention to provide an improved traveling wave tube.

It is a further object of this invention to enable a direct current connection to be made through the electron gun region to the helix while at the same time preventing leakage of radio frequency power back from the helix to the gun along this path.

It is another feature of this invention to provide a simple and efficient means for blocking leakage of radio frequency power back to the gun from the helix of a traveling wave tube wherein the external connections to the helix are not of a type with which external quarter-wave chokes can be readily employed.

These and other objects of this invention are attained in one specific illustrative embodiment thereof wherein a traveling wave tube comprises an elongated glass envelope in which is located a wire helix and an electron gun. Encompassing each end of the helix for coupling energy between the helix and external coaxial lines are coaxial pillbox couplers of the type generally described

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by R. W. Peter in the R.C.A. Review, volume 13, page 359 (September, 1952). The electron gun in this specific embodiment incorporates the so-called "velocity-jump" principle, as described by D. A. Watkins in the Proceedings of the I.R.E., volume 40, page 65 (January, 1952), whereby the noise in the electron beam is reduced by an acceleration of the electron beam, the changes in beam velocity being produced at selected points along the beam path, as determined by the effective plasma frequency of the beam.

The electron gun includes a cathode, a first electrode located behind the cathode, a plurality of electrodes located in succession in front of the cathode and through which the beam is projected, and a long drift tube located after the last of these electrodes. The electrode behind the cathode is advantageously negative with respect to the cathode and those in front of the cathode positive with respect to the cathode and positioned from the cathode at distances to effect the desired changes in plasma frequency of the beam for noise reduction. The drift tube is connected to the helix, in a manner in accordance with this invention as described further below and is, therefore, at helix potential. Focusing of the electron beam in the gun, as well as in the helix, is attained by a magnetic field, both the gun and the helix being immersed in an axial or straight magnetic focusing field. Advantageously there is employed a magnetic circuit employing an ellipsoidally shaped magnet having an axial aperture axially therealong, in which aperture the traveling wave tube is located, as further disclosed in application Serial No. 543,235, filed October 27, 1955, of P. P. Cioffi, now Patent 2,871,395, issued January 27, 1959.

The helix of the tube is secured to an elongated cylindrical sleeve which is positioned adjacent to the drift tube of the electron gun. Ceramic support rods are positioned around the periphery of the helix and glazed thereto to support the helix, as is known in the art, the rods further extending through depressions in the cylindrical sleeve and glazed thereto. The rods are also secured to the outer periphery of the end of the drift tube.

In accordance with an aspect of our invention, electrical connection to the helix from the tube stem or base is made by a short wire which is secured to the electron gun end of the cylindrical sleeve, is wound around the outer surfaces of the helix support rods in grooves specially provided therefor, and is secured to the outer surface of the drift tube at a point remote from its end closest to the cylindrical sleeve. Further, in accordance with our invention, the cylindrical sleeve is dimensioned to be effectively a quarter-wave length long at the mid-band operating frequency of the tube, and the single wire providing the direct current connection between the drift tube and the cylindrical sleeve is similarly dimensioned to be effectively a quarter-wave length long at the mid-band operating frequency of the tube.

In embodiments of our invention we have been able to obtain optimum transfer of power from the coaxial line through the pillbox to the helix, the helix end of the cylindrical sleeve appearing as a short circuit to this power. At the same time, the other or electron gun end of the sleeve appears as a very high impedance so that any power leakage that does occur through the sleeve is reflected back to the helix. Further, by winding the connecting wire between the sleeve and the drift tube around the outside of the helix support rods, and specifically in grooves in these rods, the physical length of wire requisite for the desired electrical length may be readily accommodated while at the same time assuring that the connecting wire is remote from the electron stream; this prevents any unwanted coupling or interaction between the connecting wire and the stream. It should further

be noted that, in accordance with our invention, the wire is connected to the drift tube remote from its end adjacent the sleeve; we have found this arrangement to prevent most effectively any power leakage back to the gun.

It is a feature of this invention that a single conducting wire be connected between a cylindrical sleeve, to which the helix of a traveling wave tube is connected, and a drift tube, the wire defining a portion of the direct current connection between the helix and the base of the tube.

It is another feature of this invention that the wire be connected to the drift tube at a point on the outer surface of the drift tube remote from the end of the drift tube adjacent the cylindrical sleeve.

Further features of this invention include dimensioning the single conducting wire and the cylindrical sleeve to be each effectively a quarter-wave length long at the mid-band operating frequency of the tube; winding the single connecting wire between the drift tube and the cylindrical sleeve around the outer periphery of the insulating helix support rods so as to be remote from the electron stream, thereby preventing interaction therebetween; and positioning the wire in grooves placed in each of the insulating helix support rods encompassing the drift tube.

A complete understanding of this invention and of these and other features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a side view of a traveling wave tube illustrative of one specific embodiment of this invention and depicting the positioning on the tube of the coaxial pillbox connectors;

Fig. 2 is an enlarged sectional view of the electron gun end of the traveling wave tube of Fig. 1 showing particularly the single connecting wire between the drift tube and the cylindrical sleeve, in accordance with one specific illustrative embodiment of our invention;

Fig. 3 is a further enlarged view of the connecting wire of this specific embodiment;

Fig. 4 is a plan view taken along the line 4—4 of Fig. 3; and

Fig. 5 is a plan view taken along the line 5—5 of Fig. 3.

Turning now to the drawing, the specific illustrative embodiment of our invention therein depicted comprises an elongated glass envelope 10 in which are positioned the helix 11, electron gun 12, and electron collector 13. The envelope 10 is secured to a base member 14 through which terminals 15 extend. Interior leads 16, of which only two are depicted, are connected between the terminals 15 and the various electrodes of the electron gun.

As best seen in Fig. 2, the electron gun 12 comprises a cathode element 19 which extends through an aperture in a first electrode 21, the electrode 21 being maintained negative with respect to the cathode 19. A heater 20, of a type known in the art, is positioned behind and within the cathode element 19. Positioned in front of the cathode 19 are electrodes 22, 23, and 24, advantageously maintained positive with respect to the cathode and positioned so as to reduce noise waves on the electron beam, in accordance with the velocity-jump principles discussed above. An elongated drift tube is positioned adjacent the last of these electrodes. All of the elements of the gun 12 are advantageously mounted by a plurality of ceramic rods 26.

Positioned directly adjacent the end of the drift tube 25 but spaced therefrom is a cylindrical sleeve 30 having an enlarged aperture at the end remote from the gun, in which end is secured the end of the helix 11. Ceramic helix support rods 31 support the helix, as by being glazed thereto, and are also secured to the sleeve 30, as best seen in Fig. 5, and the outer periphery of the drift tube 25, as best seen in Fig. 4. The helix 11 advantageously

has a turn 32 of enlarged pitch to facilitate coupling of radio frequency energy, as is known in the art.

Positioned around the envelope 10 of the tube at the ends of the helix 11 are pillbox couplers 33 which serve to couple the radio frequency energy between the helix and the external coaxial lines, comprising inner conductors 34 and outer conductors 35. As best seen in Fig. 2, the pillbox coupler 33 comprises an inner cylindrical sleeve 36 to which the inner conductor 34 of the coaxial line is connected and which has a gap 37 therein specifically positioned adjacent the end of the helix 11 and of the cylindrical sleeve 30, as shown, and an outer sleeve 38 to which the outer conductor 35 is connected. The inner and outer sleeves 36 and 38 are joined by end plates 40.

Coupling between the cavity 33 and the tapered helix matching section, defined by turn 32, occurs by means of electric fields. A wave propagated along a helix possesses a predominant axial electric field. The pillbox cavity 33 may be considered as a section of coaxial line with the gap 37 in the inner conductor, defined by sleeve 36. Within the pillbox 33 the electric field will be radial from the inner conducting sleeve 36 to the outer conducting sleeve 38 except at the gap 37 where the field fringes out and has axial components. Coupling, therefore, occurs between the axial field of the helix 11 that is exposed to the gap and the fringing field within the pillbox at the gap.

Direct current voltage is applied to the helix 11 from a terminal 15 through a conducting path, including a lead 16 connected to the drift tube 25, the cylindrical sleeve 30, and a single conducting wire 42. Wire 42, as seen in Figs. 2, 3 and 4, is connected to the end of the sleeve 30 facing the electron gun, is positioned outside the ceramic support rods 31, and is wound around the rods 31 in grooves 43 in their outer surfaces. The other end of the wire 42 is secured to the outer surface of the drift tube 25, at a point or region 44 remote from the end of the drift tube adjacent the cylindrical sleeve 30; as seen in Figs. 3 and 4, the drift tube in the region of the support rods 31 is entirely within the periphery of the support rods.

In accordance with aspects of our invention, leakage of any of the radio frequency energy being coupled from the pillbox 33 to the helix 11 back through the cylindrical sleeve 30 and thence to the electron gun is effectively prevented while at the same time allowing a direct current voltage connection to be made from the electron gun to the helix. Specifically, in accordance with this embodiment of our invention, the cylindrical sleeve 30 and the wire 42 are each effectively a quarter-wave length long, or odd multiples thereof, at the mid-band operating frequency of the tube. In order to prevent leakage of energy back through the axial aperture in the sleeve 30, the end surface of the sleeve 30 at the helix should appear as a short circuit. Accordingly, the electron gun end of the sleeve 30 appears as a high impedance a quarter-wave length away. Further, because of the presence of this high impedance, any radio frequency energy that might leak through the sleeve 30 is reflected at this end of the sleeve back to the helix.

The connection of the wire 42 to the other surface of the drift tube 25, as at the point 44 best seen in Fig. 3, is a low impedance connection so that the juncture of the wire 42 and the gun end of the sleeve 30 appears as a high impedance. Further, the relative impedances of the transmission paths defined by the sleeve 30 and wire 42 are such that, considering these two elements as conductors of a transmission line, the sleeve portion is of a relatively low characteristic impedance and the wire portion is a relatively high characteristic impedance so that at the junction between these two portions of the line there is an impedance discontinuity, which is such, because of the electrical lengths of the two portions, to assure that the gun end of the sleeve 30 is a high impedance point and

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the helix end of the sleeve is a low impedance point. In this regard, it may be noted that in one specific illustrative embodiment of our invention the sleeve 30 was of molybdenum approximately a half inch long and having a central aperture approximately a twentieth of an inch in diameter at the gun end, while the connecting wire 42 was of .010 inch molybdenum wire and approximately $\frac{1}{32}$ of an inch long. This specific illustrative embodiment operated over a frequency band of 700 megacycles centered near 3100 megacycles.

Further, it should be noted that advantageously the wire 42 is not connected to the drift tube 25 directly at the end of the tube 25 but rather at a point removed from the end adjacent the sleeve 30. Accordingly, the wire 42, together with the portion of the tube 25, between point 44 and the end of the tube 25 adjacent the sleeve 30, may be considered together to define a quarter-wave choke for preventing passage of radio frequency energy therealong. The sleeve 30, accordingly, may be considered to define a quarter-wave transformer to transform the high impedance appearing at the gun end of sleeve 30, due to this quarter-wave choke, to the desired low impedance at the helix end of the sleeve 30. It is to be understood, however, that the meritorious advantages of our invention and the results attainable thereby are not to be considered as dependent on any one or more analyses of the functioning of the various elements in the attainment of a direct current path to the helix from the electron gun region while at the same time preventing passage of radio frequency energy back from the helix to the gun region of the tube.

As clearly seen in Fig. 3, in accordance with an aspect of our invention, the wire 42 is wound around the outside of the helix support rods 31 and is positioned in grooves 43 in the rods 31 specifically provided for this purpose. This enables the attainment of a number of desirable ends. It enables the length of connecting wire 42 required for electrical purposes, as described further above, to be accommodated in a short axial length, thereby not enlarging the spacing between the drift tube 25 and the cylindrical sleeve 30. Also, it enables the wire 42 to be accommodated without enlarging the diameter of tube envelope 10 in this region. Further, it assures that the wire is remote from the electron stream so that interaction between the electromagnetic fields of the electron stream and any energy on the wire 42 is substantially prevented.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A traveling wave tube comprising an electron gun, including an elongated tube member, a wire helix, a cylindrical sleeve connected to said helix and adjacent said tube member, and a single conducting wire connected to said sleeve and said tube member and defining a direct current connection therebetween, the electrical lengths of said sleeve and said wire both being effectively substantially one quarter-wave length at the mid-band operating frequency of the tube.

2. A traveling wave tube comprising an electron gun, including an elongated tube member, a wire helix, a cylindrical sleeve connected to said helix and adjacent said tube member, and a single conducting wire connected to the end of said sleeve adjacent said tube member and to said tube member remote from its end adjacent said sleeve, said wire defining a direct current connection between said tube member and said sleeve and being effectively substantially one quarter-wave length long at the mid-band operating frequency of the tube.

3. A traveling wave tube comprising an electron gun, including an elongated drift tube, a wire helix, a cylindrical sleeve connected to said helix and adjacent said tube, and a single conducting member connected to the end of said sleeve adjacent said tube and to the outer

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surface of said tube member at a point remote from its end adjacent said sleeve, said conducting member defining a direct current connection between said tube and said sleeve, being remote from the electron stream of said gun, and being substantially one quarter-wave length long at the mid-band operating frequency of the tube.

4. A traveling wave tube comprising an electron gun including an elongated tube member, a wire helix, a cylindrical sleeve connected to said helix adjacent said tube member, a plurality of insulating rods secured to said helix, sleeve, and tube member, and a single conducting wire connected to said sleeve at its end adjacent said tube member and to the outer surface of said tube member at a point remote from its end adjacent said sleeve, said wire extending around the outer surfaces of said rods and being effectively substantially one quarter-wave length long at the mid-band operating frequency of the tube.

5. A traveling wave tube comprising an electron gun including an elongated tube member, a wire helix, a cylindrical sleeve connected to said helix adjacent said tube member, a plurality of insulating rods secured to said helix, sleeve, and tube member, and a single conducting wire connected to said sleeve and said tube member, said wire extending around the outer surfaces of said rods and said wire and said sleeve each being effectively one quarter-wave length long at the mid-band operating frequency of the tube.

6. A traveling wave tube in accordance with claim 4, wherein each of said rods has a groove in its outer surface adjacent said tube member and said wire is positioned in said grooves.

7. A traveling wave tube in accordance with claim 6, further comprising means including said tube member, said wire, and said sleeve, for applying a direct current voltage to said helix.

8. A traveling wave tube comprising an elongated vitreous envelope, an electron gun at one end of said envelope, an electron collector at the other end of said envelope, an elongated drift tube adjacent said electron gun, a plurality of insulating support rods extending along said envelope between said tube and said collector, said rods being secured to said tube, a cylindrical sleeve mounted by said rods adjacent said tube but spaced therefrom, and a single conducting wire connected between said sleeve and said tube and extending around said rods remote from the path of the electron stream from said electron gun, the electrical length of said wire and said sleeve each being effectively substantially one quarter-wave length at the mid-band operating frequency of said tube.

9. A traveling wave tube in accordance with claim 8, wherein said wire is connected to said sleeve at its end adjacent said tube but is connected to the outer surface of said tube at a point remote from its end adjacent said sleeve.

10. A traveling wave tube comprising an evacuated envelope, an electron gun at one end of said envelope, an elongated tube member adjacent said electron gun, a plurality of insulating rods extending along said envelope and secured to said tube, a cylindrical sleeve mounted by said rods adjacent said tube, a wire helix supported by said rods and connected to said sleeve, and a single conducting wire connected between said sleeve and said tube and defining a direct current path therebetween, said sleeve being effectively one quarter-wave length long at the mid-band operating frequency of the tube and said wire being connected to said tube at a point remote from the end of said tube adjacent said sleeve.

11. A traveling wave tube comprising an elongated evacuated envelope, a wire helix extending in said envelope, an electron gun at one end of said envelope and including a tubular member, and means providing a direct current connection between said tubular member and said helix, said means including a conducting element

connected to said member remote from its end adjacent said helix and defining with said member a quarter-wave choke and a cylindrical sleeve between said conducting element and said helix and defining a quarter-wave transformer.

12. A traveling wave tube comprising an elongated evacuated envelope, a wire helix extending in said envelope, an electron gun at one end of said envelope for projecting a stream of electrons along said helix and including a drift tube, and direct current connecting means between said tube and said helix for preventing leakage of high frequency energy back from said helix to said gun, said means including a conducting element connected to said tube at a point remote from its end facing said helix and defining with said portion of said tube between said point and said end a quarter-wave choke section and a cylindrical sleeve connected to said conducting element and said helix and defining a quarter-wave transformer whereby a high impedance to high frequency energy

appears at the gun end of said sleeve and a low impedance to high frequency energy at the helix end of said sleeve.

13. A traveling wave tube in accordance with claim 12, wherein said conducting element is a single wire.

14. A traveling wave tube in accordance with claim 13, wherein said wire extends around the outer surfaces of said tube and is secured to the outer surface of said tube.

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