Aug. 26, 1958 G. H. ROBERTSON 2,849,651

TRAVELING WAVE TUBES

Filed Aug. 23, 1952

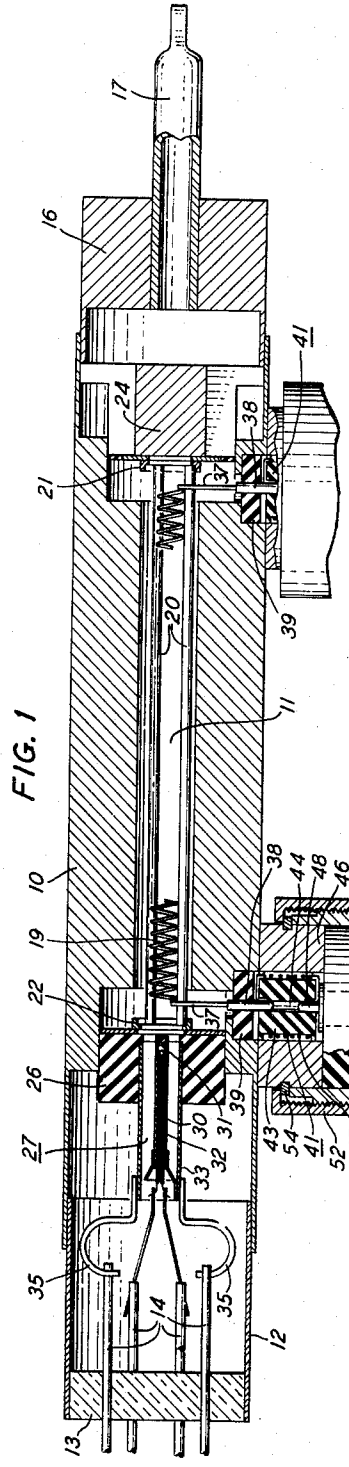


FIG. 1

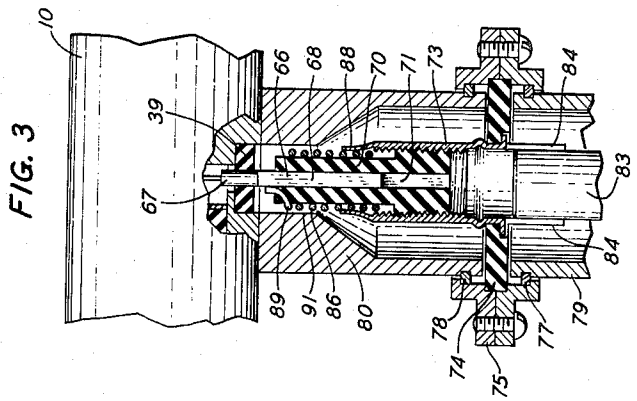


FIG. 3

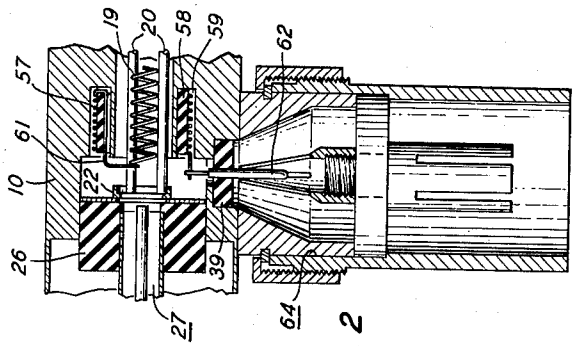


FIG. 2

INVENTOR
G. H. ROBERTSON
BY
ATTORNEY

United States Patent Office 2,849,651 Patented Aug. 26, 1958

2,849,651

TRAVELING WAVE TUBES

George H. Robertson, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 23, 1952, Serial No. 305,958

9 Claims. (Cl. 315—39.3)

This invention relates to traveling wave tubes and more particularly to the transfer of energy to and from the helix of such tubes.

The helix of a traveling wave tube defines a transmission line with a certain characteristic impedance. When a coaxial input or output line is connected to the helix, there is a junction of two transmission lines of unequal characteristic impedances. As is known, when a change in characteristic impedance occurs, a portion of the energy being transmitted along the first transmission line is not transferred over to the second transmission line but is reflected back along the first line. Thus, if a coaxial input line is connected directly to the helix of the traveling wave tube, a portion of the energy instead of being transferred to the helix is reflected back along the coaxial line. If there is a large change in characteristic impedance between the coaxial line and the helix, only a very small percentage of the energy in the coaxial line may be transferred to the helix.

It has hitherto been known that two transmission lines of dissimilar characteristic impedances can be matched, i. e. can be joined so that substantially all the energy along the one line is transferred to the other, by the imposition between them of a third transmission line which is a quarter wavelength long at the frequency desired for optimum transfer of energy between the two lines and whose own characteristic impedance is given by the equation

$$Z_1=\frac{Z_3^2}{Z_2}$$

where Z_1 and Z_2 are the characteristic impedances of the two transmission lines it is desired to join and Z_3 is the characteristic impedance of the transmission line interposed between them. This interposed transmission line is referred to as a transformer section or as a quarter wavelength transformer. By making the length of this imposed transformer section a quarter wavelength long, the energy reflected back along it from the junction between the transformer section and the second transmission line, such as the helix, arrives at the junction between the transformer line and the first transmission line, such as the coaxial line, just out of phase with the energy being reflected back at that junction so as to cancel it out, provided the magnitude of the characteristic impedance of the transformer section is chosen according to the above equation.

A traveling wave tube can be a broad band device but the overall band width is limited by the band width of the junctions between the helix and the input and output transmission lines. This band width is generally measured by choosing a certain percentage of the incident energy that must be passed by the junction between the transmission lines. The range of frequencies at which at least that fraction of energy is transferred between the transmission lines determines the band, and those frequencies at which more than the predetermined amount of incident energy is reflected at the junction are outside

the band. It is therefore desirable to increase the band width of the junction between the transmission lines so as to be able to take advantage of the inherent broad band capabilities of the helix. Therefore, as the inherent band width of a traveling wave tube may be larger than that of any particular quarter wave transformer, in order to take fullest advantage of the properties of the traveling wave tube it is desirable to be able to vary the frequency at which there is a perfect match between the two transmission lines, i. e., the center frequency of the transmission band of the transformer section between the coaxial line and the helix.

It is one object of this invention to provide improved impedance matches for energy transfer to and from the helix of a traveling wave tube.

A further object of this invention is to provide an improved quarter wave transformer for imposition between the helix of a traveling wave tube and a coaxial input or output line.

A still further object of this invention is to enable the use of the inherent broad band properties of the traveling wave tube. Thus it is an object of this invention to increase the range of frequencies over which a particular traveling wave tube may be operated.

It is another object of this invention to facilitate the fabrication of traveling wave tubes by enabling a single basic tube design to be employed for various tubes operable over a wide range of center frequencies, the single design employing standard parts of the same dimensions.

It is still another object of this invention to provide an improved traveling wave tube.

These and other objects of this invention are attained in accordance with features of this invention by the employment of a separate quarter wavelength transformer which comprises, in certain specific embodiments, a coil of wire wound on an insulating center member and positioned closely adjacent a portion of the traveling wave tube envelope or other member defining ground, the impedance of the quarter wave transformer being determined by the wire diameter and spacing between the coil and the ground, and the mid-band frequency of the transformer being determined by the length of the wire of the coil. By employing a separate transformer, which is electrically connected between the helix and the center conductor of the coaxial line, no limitation as to wire size, pitch, or turn spacing is imposed on the helix of the traveling wave tube due to impedance matching or transformer consideration. Instead the separate transformer coil can be readily wound of whatever size and at whatever pitch is required for optimum conditions for impedance matching with no disturbance of the amplification or transmission properties of the traveling wave tube itself. Thus the helix's physical characteristics can be determined purely by considerations of its functioning in the traveling wave tube without concern for the impedance matching problems involved.

Further in accordance with a feature of this invention the quarter wave transformer may be mounted external to the envelope of the traveling wave tube so that various transformer sections, centered at different frequencies but all having the same characteristic impedance, can be employed with a single traveling wave tube whereby the inherently broad band properties of the tube can be better utilized. In another specific illustrative embodiment of this invention, a single transformer section may be employed with a traveling wave tube and mounted external to the envelope thereof, but its effective length varied as desired during the operation of the tube to change the center frequency of the frequency band of impedance matching.

In another specific illustrative embodiment of this in-

vention, the separate and distinct transformer section may be positioned within the envelope of the traveling wave tube. The helix, gun and other parts of the tube may be designed for a particular broad band of frequencies and various tubes fabricated employing the standard parts of the design but centered at different frequencies, depending on the center frequency of the particular transformer section employed, whereby the fabrication of various tubes of similar characteristics but different frequency bands is greatly facilitated.

It has priorly been suggested that the quarter wave transformer section be provided by a ring, a quarter wavelength long, positioned intimately adjacent the helix. However, at low frequencies employable with coaxial input and output lines this requires the ring to be adjacent a large number of turns of helix, which is itself of small diameter and employs small diameter wire. In such constructions, which are disclosed in J. R. Pierce Patent 2,761,915, issued September 4, 1956, and C. F. Quate Patent 2,708,727, issued May 17, 1955, this length of helix adjacent the transformer ring is thus unsupported and is subject to physical movement, the helix exhibiting a high degree of flexibility and springiness. Further the transformer section includes a portion of the helix itself, thereby imposing further design characteristics onto the helix which are not necessarily compatible with the required transmission characteristics of the helix. Also the transformer section is necessarily within the traveling wave tube envelope, and thus is not capable of either change or constant variation during the life of the tube.

It is therefore a feature of this invention that a quarter wave transformer be a coil of wire wound on an insulating member separate and distinct from the helix of the traveling wave tube and mounted intimately adjacent a metallic member or a portion of the traveling wave tube defining ground. By separately winding the transformer section on an insulator member, the transformer section is facilely fabricated and each of its turns is firmly supported at all times. Further by employing a distinct transformer section separate from the helix the helix is not a portion of the transformer section and thus is also fully supported at all times. Further, the helix can be designed and fabricated without concern for impedance matching characteristics.

It is a further feature of this invention that the quarter wave transformer coil may be mounted external to the envelope of the traveling wave tube whereby various transformers may be employed with a single traveling wave tube to vary the band of frequencies of the energy transferred from or to the coaxial input or output line to or from the helix of the traveling wave tube with the desired minimum of reflection.

It is a further feature of this invention that a single quarter wavelength transformer itself may be varied during the operation of the traveling wave tube so as to vary the effective length of the transformer and thus to change the center frequency of the band at which substantially no reflection occurs.

It is a further feature of this invention that various different transformers may be mounted in different traveling wave tubes of the same design and dimensions whereby tubes of different frequency characteristics are facilely fabricated.

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

Fig. 1 is a sectional view of a traveling wave tube in accordance with one specific illustrative embodiment of this invention wherein separate and distinct quarter wavelength transformer coils are mounted external to the envelope of the tube between the helix thereof and both the coaxial input and output lines;

Fig. 2 is a partial sectional view of another specific illustrative embodiment of this invention showing particularly a quarter wave transformer section mounted within the traveling wave tube between a coaxial input and the helix thereof; and

Fig. 3 is a sectional view of a terminal for a traveling wave tube in accordance with still another specific embodiment of this invention wherein the quarter wavelength transformer is mounted external to the envelope of the tube and the effective length of the transformer is variable during the life of the tube.

Referring now to the drawing, the specific illustrative embodiment depicted in Fig. 1 comprises a housing member **10** having a central bore **11** therein, a cathode base member **12** having a vitreous member **13** sealed across it and through which a plurality of terminal pins **14** extend, and a collector base member **16** having an exhaust tubulation **17** sealed therein. Situated within the central bore **11** is a helix **19** supported by a plurality, such as three, support rods **20** advantageously glazed thereto. The support rods are positioned by a pair of ring like members **21** and **22**, member **21** being supported by the collector block **24** positioned in the collector base member **16** and ring member **22** being supported from an insulating member **26** which encompasses the cathode assembly **27** in the cathode base member **12**. The cathode assembly advantageously comprises a cathode tube **30** having a small emitter disc **31** at its end, a heater element **32** within the tube **30**, and a heat shield **33** encompassing the tube **30** and connected thereto at their base. Leads **35** secured to the shield **33** and to certain of the pins **14** advantageously spring bias the heat shield **33** against the insulating member **26**.

Each end of the helix **19** is connected, as by a lead **37**, to a pin **38** extending through an insulating or vitreous ring **39**, which ring is hermetically sealed to the pin and to the encompassing portion of the housing member **10** and thus defines the hermetic envelope of the tube. Directly adjacent the envelope thus defined but external thereto is a quarter wave transformer **41** which comprises an insulator core member **43** having a central aperture **44** therethrough, a winding **45** thereon, and an encompassing metallic member **46** secured to the housing **10**. The pin **38** advantageously fits into the aperture **44** of the core member **43** and is connected to one end of the winding **45**. A pin **48** of the coaxial terminal **50** advantageously fits into the other end of the aperture **44** and is connected to the other end of the winding **45**. Advantageously, the two ends of the winding **45** are positioned in slight grooves in the aperture **44** so that connection to the pins **38** and **48** may be made by merely inserting the pins into the aperture **44**. Thus a different transformer core and winding may facilely be substituted by merely removing the pins **38** and **48** from the aperture **44**. The transformer is advantageously secured in place by some locking means, as by a nut **52** threadedly engaged to the outer conductor **53** of the coaxial terminal **50** and a ring member **54** extending from the metallic ground member **46**.

The mid-band frequency of the transformer **41**, and thus of the impedance match between the coaxial line secured to terminal **50** and the helix **19**, is determined by the length of the coil or winding **45** while the impedance of the transformer **41** is determined by the diameter of the wire of the coil and the distance between the wires and the enclosed ground as defined by the inner surface of the enclosing member **46**. As can be readily seen by employing a separate transformer section **41** in accordance with my invention the transformer section can be changed during the life of the tube as may be desired to follow changes in the mid-band frequency of the energy being transmitted to the tube by the coaxial input line.

Referring now to Fig. 2 in the specific illustrative embodiment of this invention there depicted the quarter wave transformer comprises a coil **57** wound on an insulator cylinder **58** and positioned in a circular groove **59** in the housing **10**. One end of the helix **19** is connected to the inner end of the coil **57**, as by a wire **61**

extending through an aperture in the insulator cylinder **58**, and the other end of the coil **57** is connected to a terminal pin **62** extending through the insulator seal member **39** and connected to the inner conductor of a coaxial terminal **64**.

In the specific illustrative embodiment depicted in Fig. 3 the transformer section is again external to the envelope of the tube and its length can be varied during the operation of the tube. As there seen the end of the helix is connected to a shaft member **66** which has a round section **67** extending through the sealing member 39 and sealed thereto and a rectangular section **68**. The insulator core **70** of the transformer has a mating rectangular aperture **71** which fits onto the rectangular section **68** of the shaft **66**. The upper end of the core **70** is threaded and is engaged by an encompassing threaded nut **73** fixedly secured by an insulating ring **74** to a rotatable member **75**. Rotatable member **75** is secured, as by two rotating joints **77** and **78**, to the outer conductor **79** of a coaxial terminal and to the ground defining member **80** mounted on the housing **10**. The inner conductor **83** of the coaxial terminal slidingly fits into fingers **84** secured to the threaded nut **73** whereby rotation of the nut **73** does not impart motion to the center conductor **83**.

The winding **86** of the transformer encompasses the lower portion of the insulator core **70**. Electrical connection is made to one end of the winding by spring fingers **88** on the threaded nut **73**. The other end of the winding extends through an aperture **89** in the core member **70** and fits slidingly against the shaft **66**.

The effective length of the winding **86** which defines the mid-band frequency of the impedance match pass band, at which frequency there is substantially no reflection of energy between the coaxial line and the helix, is determined by the length of the coil **86** directly adjacent the portion **91** of the encompassing ground defining member **80**. By turning the rotatable member **75** which is in threaded engagement with the insulator core **70** translation of the core is effected as the rectangular bore **71** and rectangular shaft **68** prevent rotation, thereby inserting a longer length of the coil **86** into the transformer section defined by the ground portion **91** or withdrawing a portion of the coil **86** from that transformer section. If desired a calibration scale can be placed on or adjacent the rotatable member **75** to indicate the particular frequency setting of the transformer section.

The impedance of the transformer section, being determined by the size of wire employed for the coil **86** and the distance between the coil and the adjacent ground defining portion **91**, does not vary as the coil is moved into or out of this ground defining portion. As the impedance of a coaxial line and the impedance of a helix can be both considered substantially independent of frequency, the required relationship between the characteristic impedances of the coaxial line, the helix, and the quarter wave transformer to obtain perfect impedance matching at the mid-band frequency can be met.

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 a conductive wire helix, means for projecting a stream of electrons along said helix, a coaxial terminal, and means for transferring electromagnetic signal waves between said helix and said terminal, said last-mentioned means comprising a solid insulator core member, a conductive wire coil of constant pitch wound on said core member and electrically connected between said helix and the inner conductor of said coaxial terminal, and a metallic member encompassing said coil, closely spaced therefrom, and connected to the outer conductor of said coaxial terminal, the length of said coil being a quarter wave long at a particular frequency of said signal waves and the impedance of the transmission line defined by said coil and said metallic member being constant and being such as to match the impedances of said helix and said coaxial terminal whereby substantially no reflection of said signal waves occurs at said frequency.

2. A traveling wave tube comprising an envelope, a conductive wire helix within said envelope, a coaxial line external to said envelope, and means for transferring electromagnetic wave energy between said helix and said coaxial line, said means comprising a coil of conductive wire of constant pitch connected between the inner conductor of said line and said helix and a metallic member closely adjacent said coil and connected to the outer conductor of said coaxial line, the diameter of said wire and the spacing between said coil and said metallic member being such that the impedance of the transformer section transmission line defined thereby is constant and matches the impedances of said helix and said line and the length of said coil being a quarter wave long at a particular frequency of said electromagnetic wave energy whereby said energy is transferred at said frequency with substantially no reflection.

3. A traveling wave tube comprising an envelope, a conductive wire helix within said envelope, a coaxial line external to said envelope, means for transferring electromagnetic wave energy between said helix and said line, said means comprising a terminal pin extending through said envelope and sealed therein, means within said envelope connecting said terminal pin to said helix, an insulator core having an aperture therein, said terminal pin extending into said aperture external to said envelope, a conductive wire coil wound on said core, one end of said coil extending into said aperture and in contact with said pin, a metallic member encompassing said coil and closely spaced therefrom, said metallic member being connected to the outer conductor of said coaxial line and means connecting the other end of said coil to the inner conductor of said coaxial line, the spacing between said coil and said encompassing metallic member and the diameter of the wire of said coil being such that the impedance of the transmission line defined by said coil and said metallic member is constant and matches the impedances of said helix and said coaxial line and the length of said coil being a quarter wave long at a particular frequency of said wave energy whereby substantially no reflection of said wave energy occurs at said frequency.

4. A traveling wave tube in accordance with claim 2 wherein said envelope includes a metallic housing member having a bore therethrough and a cylindrical groove at one end coaxial with said bore, said conductive wire helix being positioned in said bore, said coil of conductive wire being in said groove and closely spaced from one wall of said groove, and said metallic housing member being connected to the outer conductor of said coaxial line.

5. A traveling wave tube in accordance with claim 4 further comprising an insulator cylinder in said groove, said coil being wound on said insulator cylinder.

6. A traveling wave tube comprising a conductive wire helix, electron gun means for projecting a stream of electrons along said helix, a coaxial terminal, and means for transferring electromagnetic signal waves between said terminal and said helix, said last-mentioned means comprising a coil of conductive wire, said coil being electrically connected between said helix and the inner conductor of said terminal, a metallic member closely adjacent said coil and connected to the outer conductor of said terminal, the impedance of the transmission line defined by said coil and said metallic member being constant and being such as to match the impedances of said helix and said coaxial terminal, and means for vary-

ing the effective length of said coil to vary the frequency at which said coil is a quarter wavelength long at which frequency said energy is transferred between said helix and said coaxial terminal with substantially no reflection.

7. A traveling wave tube comprising a conductive wire helix, means for projecting a stream of electrons along said helix, a coaxial terminal, and means for transferring electromagnetic signal waves between said terminal and said helix, said last-mentioned means comprising an insulator core, a coil of conductive wire wound on said core and electrically connected between said helix and the inner conductor of said terminal, a metallic member encompassing said coil and connected to the outer conductor of said terminal, said metallic member having a portion closely adjacent said coil, and means for axially moving said core to vary the length of coil in said metallic member portion closely adjacent thereto, the impedance of the transmission line defined by said coil and said portion closely adjacent thereto being constant and being such as to match the impedances of said helix and said terminal.

8. A traveling wave tube comprising an envelope, a conductive wire helix within said envelope, a coaxial line external to said envelope, and means for transferring electromagnetic signal waves between said helix and said line, said means comprising a terminal pin extending through said envelope and sealed therein, said terminal pin being connected to said helix within said envelope and having a rectangular cross section external to said envelope, an insulator core having a rectangular aperture therethrough, said terminal pin extending into said core, a coil of conductive wire wound on said core, one end of said coil extending into said aperture in said core and being slidingly in contact with said terminal pin, a metallic member having a portion closely encompassing said coil and defining a transformer section transmission line therewith, said metallic member being electrically connected to the outer conductor of said coaxial line, means for axially moving said core to vary the length of said coil adjacent said closely encompassing portion, and means connecting the other end of said coil to the inner conductor of said coaxial line, the impedance of said transformer section transmission line thus defined being constant and being such as to match the impedances of said helix and said coaxial line.

9. A traveling wave tube in accordance with claim 8 wherein said means for axially moving said core comprises a member in threaded engagement with the end of said core removed from said terminal pin and means for rotating said member, said member having a first set of spring fingers slidingly engaging the other end of said coil and a second set of spring fingers slidingly engaging the inner conductor of said coaxial line.

References Cited in the file of this patent

UNITED STATES PATENTS

1,965,202	Roys	July 3, 1934
2,516,944	Barnett	Aug. 1, 1950
2,535,317	Pierce	Dec. 26, 1950
2,578,434	Lindenblad	Dec. 11, 1951
2,697,799	Svensson	Dec. 21, 1954