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TRAVELING WAVE TUBE OF HIGH FORWARD WAVE IMPEDANCE

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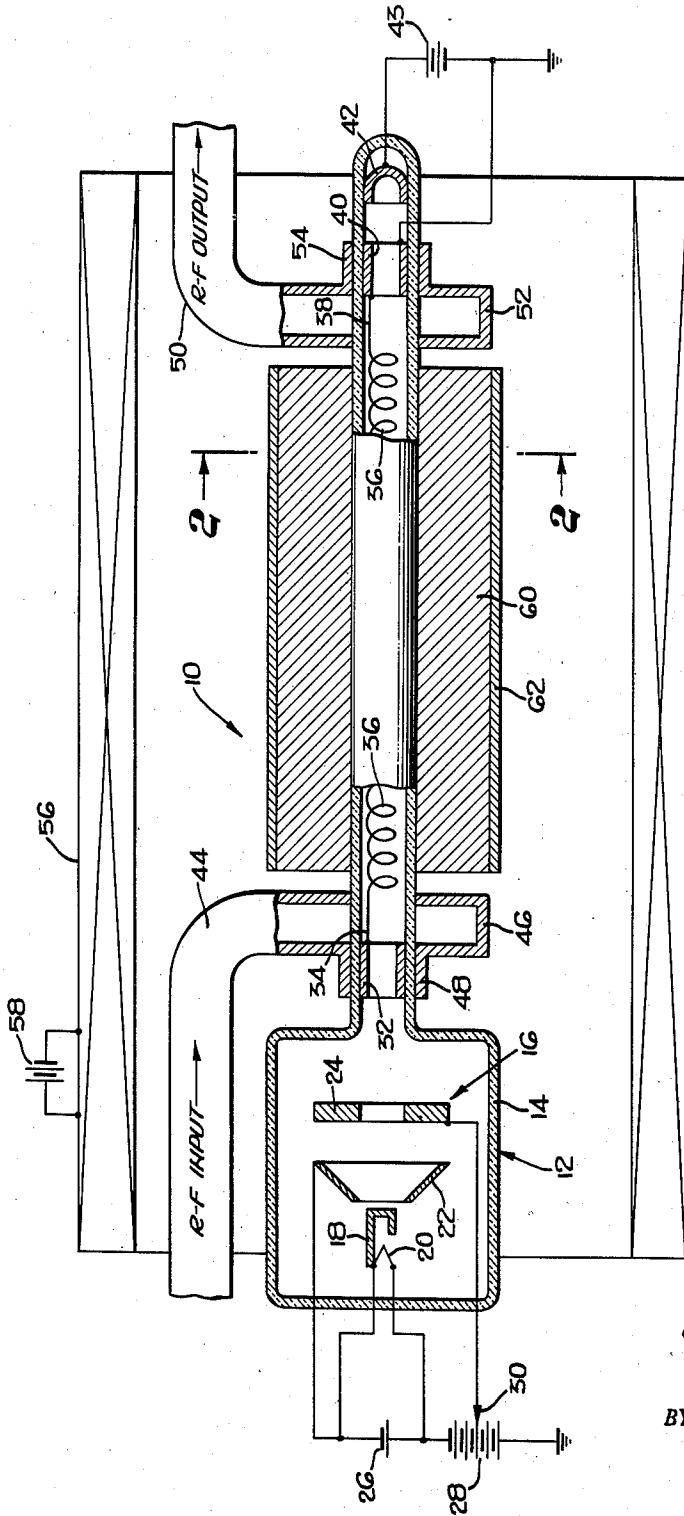


FIG. 1.

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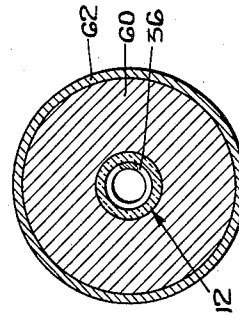


FIG. 2.

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TRAVELING WAVE TUBE OF HIGH FORWARD WAVE IMPEDANCE

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4 Claims. (Cl. 315—3.6)

This invention relates to microwave tubes and more particularly to means providing a relatively high-impedance slow-wave transmission path for a traveling-wave tube.

It is desirable to increase the forward wave impedance of the slow-wave structure such as a conductive helix of a traveling-wave tube in order to increase not only the power and efficiency of the tube but also to control its practical frequency range of operation. For higher operating frequencies, it becomes necessary to use helices of smaller diameters in order to avoid certain self-oscillations called backward wave self-oscillations which prevent the use of a traveling-wave tube as an amplifier about and above a certain limiting backward wave self-oscillation frequency. By increasing the ratio of the forward wave impedance to the backward wave impedance of a given slow-wave structure, the power output of a traveling-wave tube may be increased because a conductive helix of a larger diameter may be employed to accommodate a relatively large electron stream which is directed therethrough, whereby the tube power may be increased and, at the same time backward wave self-oscillations may be avoided.

It is therefore an object of the invention to provide means whereby the impedance of the slow-wave structure of a traveling-wave tube may be increased.

It is another object of the invention to provide means whereby the forward wave impedance of a conductive helix may be increased.

In accordance with the invention, a dielectric cylinder having a relatively high dielectric constant is disposed contiguously about the slow-wave structure or conductive helix of a traveling-wave tube. A conductive cylinder is then disposed contiguously about the dielectric cylinder. Such a structure will increase the forward wave impedance of the conductive helix.

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 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 tube illustrating one embodiment of the wave transmission structure of the present invention; and

Fig. 2 is a section along line 2—2 of the traveling-wave tube of Fig. 1.

Referring to the drawing, a traveling-wave tube 10 is shown in Fig. 1 having an evacuated envelope 12 having an enlarged portion 14 at its left extremity. An electron gun 16 is disposed in the enlarged portion 14 of the envelope 12 for producing an electron stream along the longitudinal axis of the envelope 12. Electron gun 16 comprises a cathode 18 which is provided with a filament 20, a focusing electrode 22, and an accelerating anode 24. Filament 20 is supplied with direct current by means of a filament source of potential 26, the negative terminal of which is connected to both cathode 18 and focusing electrode 22.

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Cathode 18 is maintained at, for example, 1000 volts negative with respect to ground by means of an accelerating source of potential 28, the negative terminal of which is connected to the positive terminal of potential source 26 and the positive terminal of which is connected to ground. Focusing electrode 22 may have a frusto-conical configuration with an internal surface of revolution disposed at an angle of 67½ degrees from its axis of symmetry. Anode 24 is maintained at a few hundred volts positive with respect to ground by means of a connection to a tap 30 at accelerating source of potential 28.

Proceeding in the direction of electron flow from electron gun 16, there is shown disposed concentrically within the elongated portion of the envelope 12 an input matching ferrule 32 which is connected over a lead 34 to a slow-wave structure shown for purpose of illustration as a conductive helix 36 which is, in turn, connected over a lead 38 to an output matching ferrule 40. A collector electrode 42 is disposed at the right end of the envelope 12, as viewed in Fig. 1, for intercepting the stream electrons.

Helix 36 is maintained at ground potential by a connection from output ferrule 40 to ground and collector electrode 42 is maintained at a potential of a few hundred volts positive with respect to the potential of output ferrule 40 by a battery 43 in order to prevent the collection of secondary electrons emitted from the collector 42 at output ferrule 40.

A radio-frequency or RF rectangular input waveguide 44 is shown disposed about the left end of the elongated portion of the envelope 12 having a shorted termination 46 and a conductive sleeve 48 disposed contiguous to the envelope 12 coextensive with ferrule 32. A virtual shorting plane is thus simulated at the left internal surface of input waveguide 44. An RF rectangular output waveguide 50 having a shorted termination 52 and a conductive sleeve 54 is similarly positioned about the right end of the envelope 12.

A focusing solenoid 56 is disposed concentrically about the envelope 12 in order to provide an axial magnetic field throughout the entire length of the envelope 12 whereby the electron stream produced by the electron gun 16 may be constrained or focused. To this end, solenoid 56 is connected to a direct-current source of potential 58.

Means which are provided for increasing the forward wave impedance of the conductive helix 36 are shown disposed contiguously about the elongated portion of the envelope 12 coextensive with the helix 36. This means includes a dielectric cylinder 60 which is disposed contiguously about the envelope 12 coextensive with the helix 36 and a conductive cylinder 62 which is disposed contiguously about the external surface of the dielectric cylinder 60. A cross sectional view of the helix 36, the envelope 12, dielectric cylinder 60 and conductive cylinder 62 is shown in Fig. 2. For optimum operating conditions, the radial thickness of dielectric cylinder 60 should be equal to or less than

$$\frac{\lambda_g}{4}$$

where

$$\lambda_g$$

is the wavelength for radial propagation in the dielectric at the mid-frequency of the operating band of the traveling-wave tube 10. A virtual shorting plane is thus desirably not presented to helix 36 at or between adjacent turns of the helix 36. The dielectric cylinder 60 should consist of a relatively high dielectric constant material such as, for example, a titanate, some of which have a

relative dielectric constant as high as 300. Alternatively, the cylinder 60 may be made of a material having a relatively high permeability such as ferromagnetic ferrites.

In order to better illustrate the reason for choosing a dielectric material having a relatively high dielectric constant or a high permeability, it is necessary to review one of the principles on which the calculation of the forward wave impedance of slow-wave structures or conductive helices are based. Forward wave impedance with no loading is equal to the reciprocal of the shunt admittance of the conductive helix 36. When additional structures are provided outside of the helix 36, such as, for example, the dielectric cylinder 60 plus the conductive cylinder 62, the forward wave impedance of the composite structure becomes approximately equal to the reciprocal of the sum of the shunt admittance of conductive helix 36 and the shunt admittance of dielectric cylinder 60 and conductive cylinder 62. Normally dielectric structures when disposed about a helix will tend to reduce rather than increase the forward wave impedance of the wave transmission path. However, it is possible to make the admittance of the dielectric cylinder 60 plus that of the conductive cylinder 62 negative with respect to that of the conductive helix 36 whereby the forward wave impedance of the composite structure may be substantially increased. The way in which the admittance of the dielectric 60 plus that of conductive cylinder 62 is changed from positive to negative with respect to the admittance of helix 36 is by making the dielectric cylinder 60 to have a large relative dielectric constant or high relative permeability constant such that electromagnetic energy will propagate radially through it. The wavelength of waves propagated radially through a dielectric cylinder 60 is given by the following approximate expression:

$$\lambda_g \approx \frac{\lambda_0}{\left(\mu_r \epsilon_r - \left[\frac{c}{u_0} \right]^2 \right)^{1/2}} \quad (1)$$

where λ_0 may be the free space wavelength of the mid-frequency of the operating band of the tube 10; ϵ_r is the relative dielectric constant of the material employed in the dielectric cylinder 60; μ_r is the relative permeability constant of dielectric cylinder 60; c is the velocity of light in free space; and u_0 is the velocity of the stream electrons traveling through the conductive helix 36. It is seen from Equation 1 that wave energy will propagate radially only when $\mu_r \epsilon_r$ is larger than

$$\left[\frac{c}{u_0} \right]^2$$

for only then will λ_g be a real number. The product of the relative dielectric constant and the relative permeability constant of the material of which the dielectric cylinder 60 consists should thus be larger than

$$\left[\frac{c}{u_0} \right]^2$$

What is claimed is:

1. A traveling-wave tube comprising an elongated glass envelope, an electron gun disposed at one end of said envelope for producing an electron stream, a conductive helix disposed adjacent said electron gun within said envelope for propagating electromagnetic waves, means for directing said stream through said helix at a velocity u_0 , a cylinder composed of dielectric material disposed about and contiguously to said envelope coextensive with said conductive helix, the product of the relative dielectric constant and relative permeability constant of said dielectric material being larger than

$$\left(\frac{c}{u_0} \right)^2$$

where c is the velocity of light, and a conductive cylinder

disposed adjacent to and contiguously about said dielectric cylinder.

2. A traveling-wave tube comprising an elongated glass envelope, an electron gun disposed at one end of said envelope for producing an electron stream, a conductive helix disposed adjacent said electron gun within said envelope for propagating electromagnetic waves, means for directing said stream through said helix at a velocity u_0 , a cylinder composed of dielectric material disposed about and contiguously to said envelope coextensive with said conductive helix, said dielectric cylinder having a thickness approximately equal to

$$\frac{\lambda_g}{4}$$

where λ_g is the waveguide wavelength of the mid-frequency of the operating band of said tube, the product of the relative dielectric constant and relative permeability constant of said dielectric material being larger than

$$\left(\frac{c}{u_0} \right)^2$$

where c is the velocity of light, and a conductive cylinder disposed contiguously about said dielectric cylinder.

3. A traveling-wave tube comprising an elongated glass envelope, an electron gun disposed at one end of said envelope for producing an electron stream, a slow-wave structure disposed adjacent said electron gun within said envelope for propagating electromagnetic waves, means for directing said stream through said slow-wave structure at a velocity u_0 , a cylinder composed of dielectric material disposed about and contiguously to said envelope coextensive with said slow-wave structure, the product of the relative dielectric constant and relative permeability constant of said dielectric material being larger than

$$\left(\frac{c}{u_0} \right)^2$$

where c is the velocity of light, and a conductive cylinder disposed adjacent to and contiguously about said dielectric cylinder.

4. A traveling-wave tube comprising an elongated glass envelope, an electron gun disposed at one end of said envelope for producing an electron stream, a slow-wave structure disposed adjacent said electron gun within said envelope for propagating electromagnetic waves, means for directing said stream through said slow-wave structure at a velocity u_0 , a cylinder composed of dielectric material disposed about and contiguously to said envelope coextensive with said slow-wave structure, said dielectric cylinder having a thickness approximately equal to

$$\frac{\lambda_g}{4}$$

where λ_g is the waveguide wavelength of the mid-frequency of the operating band of said tube, the product of the relative dielectric constant and relative permeability constant of said dielectric material being larger than

$$\left(\frac{c}{u_0} \right)^2$$

where c is the velocity of light, and a conductive cylinder disposed contiguously about said dielectric cylinder.

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