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TRAVELING WAVE TUBE

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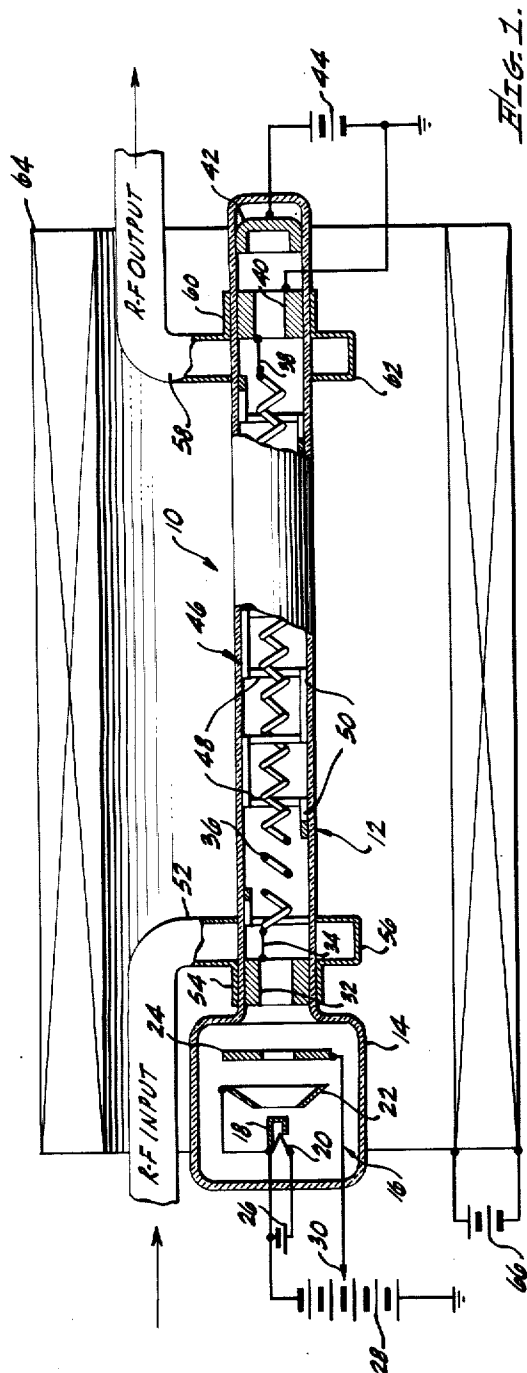


FIG. 1.

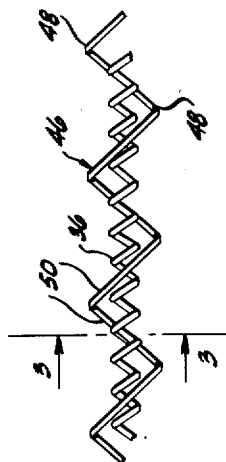


FIG. 2.

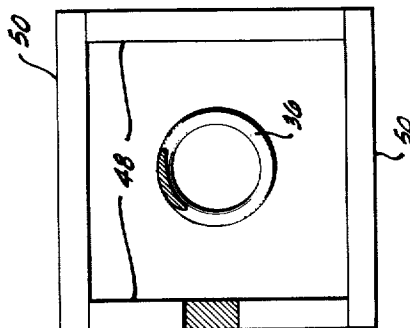


FIG. 3.

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1

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TRAVELING WAVE TUBE

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8 Claims. (Cl. 315—3.6)

This invention relates to microwave tubes and more particularly to a non-reciprocal attenuating structure suitable for use with the slow-wave structure of a traveling-wave tube.

In a traveling-wave tube, an electron stream is projected through a slow-wave structure to interact with a traveling wave propagated therealong whereby signal amplification may be produced. A longitudinal direct-current magnetic field is then used to focus or confine the stream.

Well known backward-wave and reflected-wave self-oscillations are troublesome in traveling-wave tubes in that amplifier operation may be seriously hampered by them. It is thus desirable to employ a non-reciprocal attenuating structure in order to attenuate backward and reflected waves selectively without attenuating forward waves, i. e. waves propagated in the direction of flow of the electron stream. To this end, ceramic ferromagnetic ferrite materials, known simply as ferrites, are presently employed. It is necessary to employ a direct-current magnetic field with ferrites in order to obtain a non-reciprocal attenuation. As a result of the type of wave propagation along known slow-wave structures it is necessary to provide a direct-current component of magnetic field through a ferrite perpendicular to the focusing field of the electron stream in a traveling-wave tube. An auxiliary ferrite helix has been employed in the past to produce such a transverse component of magnetic field by diverting a portion of the focusing field through the relatively low reluctance helical path the ferrite helix provides.

There are two principal disadvantages attendant upon the employment of the ferrite helix. The first is characterized by the fact that a helical ferrite configuration is difficult to manufacture. In the second place, most non-reciprocal attenuation is encountered when a ferrite body is disposed in a plane substantially perpendicular to the longitudinal axis of the slow-wave structure. It is obvious that no section of a ferrite helix exists exactly in a plane perpendicular to the longitudinal axis of the slow-wave structure. The magnitude of the transverse component of the unidirectional axial magnetic field in the ferrite helix is diminished by a decrease in pitch of the ferrite helix, which would place sections of the ferrite helix more nearly in such a plane. Furthermore, after a predetermined axial magnetic field strength for focusing is reached, when the ferrite helix is constructed to have a minimum pitch, substantial increases in the strength of this field produce only minute increases in the transverse component of the field within the ferrite helix. In addition, as higher operating frequencies are demanded, it is necessary to increase the transverse component of magnetic field. For a given ferrite, it becomes impossible to obtain a sufficiently large transverse component of the magnetic field in the ferrite to obtain substantial non-reciprocal attenuation.

It is therefore an object of the invention to provide an improved non-reciprocal attenuating structure which may be easily manufactured.

2

It is another object of the invention to provide a non-reciprocal attenuating structure for producing substantially non-reciprocal attenuation at operating frequencies substantially higher than those to which similar current attenuating structures are restricted.

In accordance with the invention a plurality of ceramic ferrite bodies is disposed alternately between a plurality of ferromagnetic bodies such as iron bars in a helical fashion about a slow-wave structure. The separate segments of the ferrite bodies in the iron bars need not necessarily be arcuate or provide a perfect helix shape. A box-shaped helix may thus be employed to advantage. In this case the ferrite bodies may be disposed perfectly in planes transverse to the longitudinal axis of the slow-wave structure whereby maximum attenuation may be produced. In addition, the use of the iron bars increases the magnitude of the component of transverse magnetic field which may be diverted through the ferrite bodies over the transverse component which could be diverted through a ferrite 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 in which the non-reciprocal attenuating structure of the present invention is incorporated;

Fig. 2 is a plan view of the slow-wave and non-reciprocal attenuating structures shown in Fig. 1; and

Fig. 3 is a sectional view on a line 3—3 of the slow-wave and non-reciprocal attenuating structures shown in Fig. 2.

Referring to the drawing, there is shown in Fig. 1 a traveling-wave tube 10 comprising an evacuated envelope 12 having an enlarged portion 14 at its left end. Within the enlarged portion, electron gun 16 is shown comprising a cathode 18 which is provided with a filament 20, a focusing electrode 22 and an accelerating anode 24. A direct-current is maintained in the filament 20 by means of a filament source of potential 26 connected thereacross. Focusing electrode 22 is maintained at the same potential as cathode 18 by appropriate connection thereto. Cathode 18 is maintained at a voltage at a few thousand volts negative with respect to ground by means of an accelerating source of potential 28, the positive terminal of which is connected to ground. Accelerating anode 24 is maintained somewhat negative with respect to ground by means of a connection to a tap 30 on the accelerating source of potential 28. Focusing electrode 22, which is well-known in the art, has a frusto-conical configuration with an internal surface of revolution disposed 67½ degrees from its axis of symmetry.

In the direction of electron flow from the electron gun 16, there is shown disposed within the envelope 12 an input matching ferrule 32 connected over an antenna lead 34 to a conductive helix 36, which is in turn connected over an output antenna lead 38 to an output matching ferrule 40. Disposed at the right end of the envelope 12 is a collector electrode 42 which is maintained a few volts positive with respect to ground by means of a potential source 44 in order that secondary electrons emitted therefrom will not be collected by the helix 36 or the output matching ferrule 40. Other conventional helix-type slow-wave structures may be substituted for the helix 36.

A non-reciprocal attenuating structure 46 is shown disposed about the helix 36 which comprises a plurality of ferrite bars 48 which are disposed alternately on each side of the helix 36, and a plurality of ferromagnetic bars 50 which may be made of iron, or other material having a permeability substantially higher than that of the ferrite bodies or bars 48. Alternatively, the ferromagnetic bars 50 may be bar magnets poled in the same direction. In order to prevent the disturbance of the normal non-attenuating wave propagation properties of the conductive helix 36 which serves as a slow-wave structure, iron bars 50 may be plated with a highly conductive material such as silver in order that no loss will be produced by iron bars 50. Input ferrule 32 with antenna-leads 34 and 38, helix 36 and output ferrule 40 are all maintained at ground potential by an appropriate connection from output ferrule 40. A rectangular radio-frequency or RF input waveguide 52 is shown at the left end of the helix 36 disposed about the envelope 12. Input waveguide 52 is provided with a conductive shorting sleeve 54 which is disposed about the envelope 12 coextensive with input ferrule 32. Input waveguide 52 is also provided with a shorted termination 56. A rectangular output waveguide 58 is shown disposed about the envelope 12 at the right end of the helix 36 having a conductive shorting sleeve 60 disposed about the envelope 12 coextensive with output ferrule 40. Output waveguide 58 is similarly provided with a shorted termination 62.

A magnetic solenoid 64 is disposed concentrically about the envelope 12 in order to focus or confine the electron stream produced by electron gun 16. In order to energize the solenoid 64, a focusing source of potential 66 is connected to the solenoid 64 to provide a source of direct current.

The helix 36 and the non-reciprocal attenuating structure 46 are shown in a plan view in Fig. 2 with the envelope 12 broken away. The separate portions of the non-reciprocal attenuating structure 46 are indicated by the same reference characters. For example, the iron bars 50 are there shown, although the transverse ferrite bodies or ferrite bars 48 can only be seen in end view. Helix 36, ferrite bars 48 and the iron bars 50 are again shown in Fig. 3 in section. The iron bars 50 shown in Fig. 3 increase the component of the direct-current magnetic field transverse to the longitudinal axis of the helix 36. The ferrite bars 48 are appropriately positioned in planes transverse to the longitudinal axis of the helix 36. The iron bars 50 thus provide a low-reluctance path through which a substantial portion of the axial magnetic field provided by the solenoid 64 may be diverted. By using the bar type configuration for both the ferromagnetic bodies 50 and the ferrite bodies 48, the non-reciprocal attenuating structure 46 may be easily constructed.

What is claimed is:

1. In combination, in a traveling-wave tube, a slow-wave structure having a longitudinal axis, and a ferromagnetic attenuating structure disposed helically about said slow-wave structure, said attenuating structure comprising a plurality of elongated ceramic ferrite bodies disposed in planes perpendicular to said axis, and a plurality of elongated ferromagnetic bodies disposed parallel to said axis, said ceramic ferrite bodies being disposed alternately between said ferromagnetic bodies, said ferromagnetic bodies having a permeability substantially greater than that of said ceramic ferrite bodies.

2. In a traveling-wave tube, a slow-wave structure, and a ferromagnetic attenuating structure disposed about said slow-wave structure, said attenuating structure comprising a first set of elongated ceramic ferrite bodies disposed on one side of said slow-wave structure, a second set of elongated ceramic ferrite bodies disposed alternately between said first set of elongated ceramic ferrite bodies on the opposite side of said slow-wave structure, all of said ferrite bodies being disposed in planes transverse to the

longitudinal axis of said slow-wave structure, a first set of elongated ferromagnetic bodies, each being connected from one of said first set of ferrite bodies to the next succeeding one of said second set of ferrite bodies, and a second set of elongated ferromagnetic bodies, each being connected from the ends of one of said second set of ferrite bodies opposite the ends of said second set of ferrite bodies connected to said first set of elongated ferromagnetic bodies to the next succeeding one of said first set of ferrite bodies, said elongated ferromagnetic bodies having a permeability substantially higher than that of said ceramic ferrite bodies.

3. The invention as defined in claim 2 wherein said elongated ferromagnetic bodies are plated with a material which is highly conductive with respect to said ferromagnetic bodies.

4. In combination, in a traveling-wave tube, a slow-wave structure, and a ferromagnetic attenuating structure disposed about said slow-wave structure, said attenuating structure comprising a first set of elongated ceramic ferrite bodies disposed in a first axial plane on one side of said slow-wave structure, a second set of elongated ceramic ferrite bodies disposed in a plane parallel to said first plane adjacent said slow-wave structure on the side of said slow-wave structure opposite said first plane, each one of said second set of elongated ceramic ferrite bodies being disposed alternately between two adjacent ones of said first set of elongated ceramic ferrite bodies, all of said ferrite bodies being disposed in planes transverse to the longitudinal axis of said slow-wave structure, a first set of elongated ferromagnetic bodies, each being connected from one of said first set of elongated ceramic ferrite bodies to the next succeeding one of said second set of elongated ceramic ferrite bodies, and a second set of elongated ferromagnetic bodies, each being connected from the ends of one of said second set of said elongated ceramic ferrite bodies opposite the ends of said second set of elongated ceramic ferrite bodies connected to said first set of elongated ferromagnetic bodies to the next succeeding one of said first set of elongated ceramic ferrite bodies, all of said elongated ferromagnetic bodies having a permeability substantially higher than that of said ceramic ferrite bodies.

5. The invention as defined in claim 4, wherein said elongated ferromagnetic bodies are iron bars, said iron bars being plated with a material which is highly conductive with respect to iron.

6. The invention as defined in claim 4, wherein said elongated ferromagnetic bodies are bar magnets, said bar magnets disposed on one side of said slow-wave structure being poled in the same direction and said bar magnets on the opposite side of said slow-wave structure being poled in the same direction.

7. In a traveling-wave tube, a slow-wave structure, and a ferromagnetic attenuating structure disposed about said slow-wave structure, said attenuating structure comprising a first set of elongated ceramic ferrite bodies disposed on one side of said slow-wave structure, a second set of elongated ceramic ferrite bodies disposed alternately between said first set of elongated ceramic ferrite bodies on the opposite side of said slow-wave structure, all of said ferrite bodies being disposed in planes transverse to the longitudinal axis of said slow-wave structure, a first set of elongated ferromagnetic bodies, each being connected from one of said first set of ferrite bodies to the next succeeding one of said second set of ferrite bodies, a second set of elongated ferromagnetic bodies, each being connected from the ends of one of said second set of ferrite bodies opposite the ends of said second set of ferrite bodies connected to said first set of elongated ferromagnetic bodies to the next succeeding one of said first set of ferrite bodies, said elongated ferromagnetic bodies having a permeability substantially higher than that of said ceramic ferrite bodies, and means for maintaining an

5

axial magnetic field through said ferromagnetic attenuating structure.

8. In a traveling-wave tube, a slow-wave structure, and a ferromagnetic attenuating structure disposed about said slow-wave structure, said attenuating structure comprising a first set of elongated ceramic ferrite bodies disposed in a first axial plane on one side of said slow-wave structure, a second set of elongated ceramic ferrite bodies disposed in a plane parallel to said first plane adjacent said slow-wave structure on the side of said slow-wave structure opposite said first plane, each one of said second set of elongated ceramic ferrite bodies being disposed alternately between two adjacent ones of said first set of elongated ceramic ferrite bodies, all of said ferrite bodies being disposed in planes transverse to the longitudinal axis of said slow-wave structure, a first set of elongated ferromagnetic bodies, each being connected from one of said first set of elongated ceramic ferrite bodies to the next succeeding one of said second set of elongated ceramic ferrite bodies, a second set of elongated ferromagnetic bodies, each being connected from the ends of one

6

of said second set of said elongated ceramic ferrite bodies opposite the ends of said second set of elongated ceramic ferrite bodies connected to said first set of elongated ferromagnetic bodies to the next succeeding one of said first set of said elongated ceramic ferrite bodies, all of said elongated ferromagnetic bodies having a permeability substantially higher than that of said ceramic ferrite bodies, and means for maintaining an axial magnetic field through said ferromagnetic attenuating structure.

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