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TRAVELING WAVE TUBE ATTENUATOR

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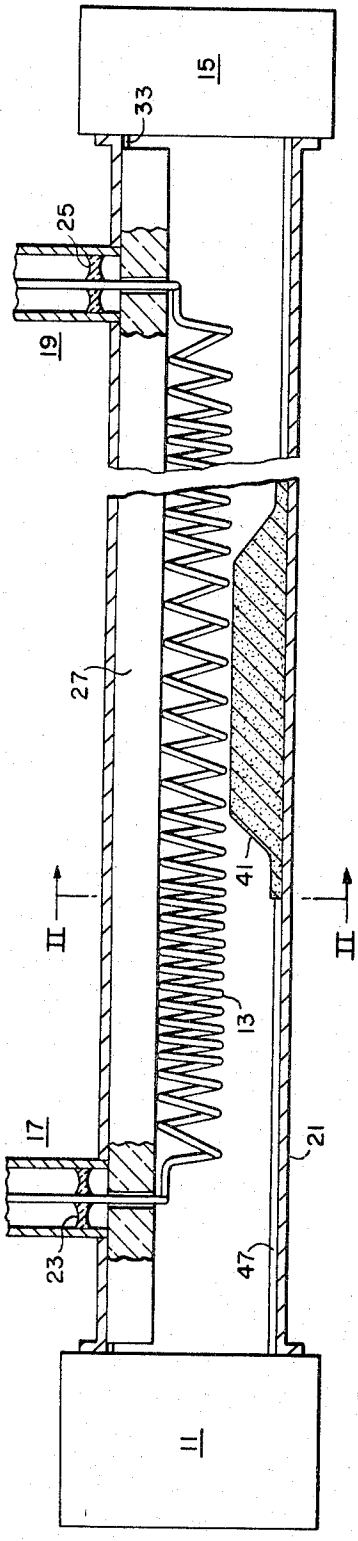


Fig. 1.

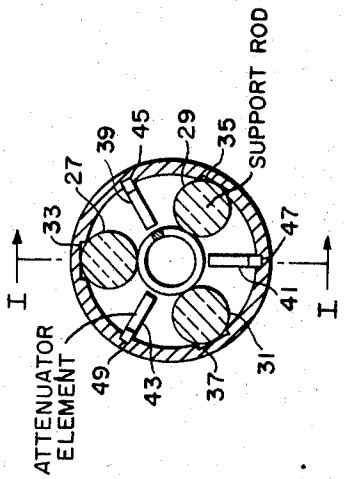


Fig. 2.

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TRAVELING WAVE TUBE ATTENUATOR

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ABSTRACT OF THE DISCLOSURE

The invention relates to a traveling wave tube in which the slow wave propagating member is supported within the envelope by a plurality of dielectric support members to provide support and cooling of the propagating member. Separate attenuator elements are also provided between the propagating member and the envelope and in the spaces between the support members for providing the necessary attenuation for the traveling wave tube.

The present invention relates to a traveling wave tube and more particularly to attenuators therefor.

Attenuators are necessary for stability in all but very low gain traveling wave tubes, but the use of attenuators poses several problems. At any position along the slow-wave structure of the tube the loss per unit length and also the total loss of the attenuator should be controlled so that they are within relatively narrow limits. Electromagnetic energy reflections from the attenuator should be minimized. The operating efficiency and stability of the traveling wave tube should not be reduced by the attenuator. Also, in a high power traveling wave tube the attenuator should not adversely affect cooling of the slow-wave structure. Moreover, the attenuator should not reduce the ease with which the traveling wave tube can be manufactured.

Traveling wave tube attenuators that meet some of the foregoing problems are known in the art. However, no attenuator that overcomes all or substantially all of these problems has been known heretofore. In the usual traveling wave tube the attenuator is a thin, resistive film on the helix support rods. Consequently, it is difficult to make. Moreover, it must go through the brazing furnace when the tube is manufactured.

Therefore, it is an object of the present invention to provide an improved traveling wave tube attenuator that overcomes substantially all of the foregoing problems.

Another object is to provide a traveling wave tube attenuator that is readily incorporated within the vacuum envelope for the tube without degrading the performance of the tube.

Still another object is to provide an attenuator for incorporation within the vacuum envelope of a traveling wave tube, the attenuator being readily optimized for performing its function without adversely affecting either the performance of other parts of the tube or the gain and efficiency of the tube.

A further object is to provide, in a high power traveling wave tube, an improved attenuator that does not adversely affect the cooling efficiency of the tube.

Still another object is to provide an attenuator which is easily optimized to perform a precise attenuation function, which is readily incorporated into the vacuum envelope of a traveling wave tube, and which does not need to go through the brazing furnace during tube assembly.

The foregoing objects as well as other objects and advantages of the present invention are achieved by providing a slow wave propogating helix that is surrounded by a vacuum envelope and by providing a plurality of dielectric rods and attenuator elements that extend axially along the helix while engaging both the helix and the envelope. The attenuator elements, which preferably are made from a material that is lossy in its bulk properties, are separate from the dielectric rods. A plurality of longitudinally extending slots are provided in the inner wall of the vacuum envelope for positioning, respectively, the dielectric rods and the attenuator elements around the helix. The pitch of the helix is tapered in the vicinity of the attenuator elements to preserve the phase velocity of electromagnetic energy carried by the helix.

The details of the present invention will become more apparent from the following description of the accompanying drawing wherein:

FIG. 1 is a longitudinal sectional view, partly schematic and taken from line I—I of FIG. 2 of a traveling wave tube amplifier which includes an attenuator that is provided in accordance with the present invention; and

FIG. 2 is a cross sectional view taken from the line II—II in FIG. 1.

Referring to the drawing, there is illustrated a traveling wave tube amplifier that comprises an electron gun **11**, a helix **13**, and an electron collector **15**. The electron gun produces a stream of electrons that passes coaxially through the helix to the collector.

In a high power tube the gun **11** produces an electron stream that converges to a minimum diameter before the stream enters the helix **13**. A conventional magnetic focusing system, not shown, is employed to maintain the diameter of the electron stream constant as the stream passes through the helix. Suitable means, not shown, may be used to cool the collector **15**.

The helix **13** is a slow wave propagating structure which is adapted to guide traveling electromagnetic energy in the microwave range of frequencies. One end of the helix is connected directly to the inner conductor of an input coaxial line **17**. The other end of the helix is connected directly to the inner conductor of an output coaxial line **19**. The impedances of the helix and the coaxial lines are matched over the frequency range of the energy to be amplified. The outer conductors of the coaxial lines **17** and **19** are connected to a cylindrical conductor **21** that forms a vacuum envelope for the tube. Suitable means, not shown, are employed to cool the envelope.

The inner conductors of the coaxial lines **17** and **19** pass into the vacuum envelope **21** through dielectric beads **23** and **25**, respectively. These beads support the ends of the inner conductors in vacuum-sealed relationship with the outer conductors of the coaxial lines.

The helix **13** is supported coaxially within the surrounding vacuum envelope **21** by three dielectric rods **27**, **29** and **31**. These rods have a circular cross section. However, the rods may have other cross sections suited to the design. The rods extend longitudinally along the helix while engaging both the helix and the envelope. Preferably the rods extend past the coaxial lines as is illustrated in FIG. 1. Three longitudinally extending slots **33**, **35** and **37** are provided in the inner wall of the envelope **21** for respectively positioning the three dielectric rods around the helix **13** in equally spaced relationship.

In a high power tube the dielectric rods **27**, **29** and **31** preferably are made from an insulating material that can withstand high temperatures. This material should be a relatively good heat conductor for transferring heat from the helix to the vacuum envelope **21**. Thus, the rods **27**, **29** and **31** both support the helix and help to keep

the helix cool. The rods must be in good heat transfer relationship with the helix **13** and the envelope **21**.

In accordance with an important aspect of this invention, three attenuator elements **39**, **41** and **43** extend longitudinally along an intermediate portion of the helix **13** while engaging both the helix and the vacuum envelope **21**. These elements have a rectangular cross section, but other cross sections may be suitable. Regardless of the cross section, these elements should be thin to minimize dielectric loading. Preferably, the attenuator elements are made from slabs of a material that is lossy in its bulk properties, i.e., a homegeneous material that is a mixture of insulating material and conducting material that has been thoroughly mixed and fired to produce a synthesized material having a suitable high resistance. Tungsten carbide and alumina may be selected for the constituent materials, for example. In some cases the attenuator elements, which are separate from the dielectric support rods **27**, **29** and **31**, are made from dielectric slabs that are coated with a resistive film.

Three longitudinally extending slots **45**, **47** and **49** are provided in the inner wall of the envelope **21** for respectively positioning the three attenuator elements around the helix. The attenuator elements form a Y-like configuration having legs which are spaced equally and which extend radially inward to the helix **13** from the inner wall of the vacuum envelope **21**. It is not necessary that the attenuator elements contact the helix **13**. A spacing of about 5 mils may be provided. Each of the dielectric support rods **27**, **29** and **31** is located in the middle of a space between two legs of the Y-like configuration.

The length of the attenuator elements is chosen to achieve a desired total attenuation of electromagnetic energy. The total attenuation and the loss per unit length is easily controlled to be within relatively narrow limits. Both ends of the attenuator elements are tapered to reduce reflections of microwave energy. Another function of the tapering of the slabs is to vary the attenuation per unit length as a function of distance without requiring a variation of the material from which a slab is made.

Separation of the attenuator elements from the dielectric support rods ensures that the attenuator elements will not affect the function of the dielectric rods in cooling the helix. Also, by keeping the attenuator elements and support rods separate, both the attenuator and helix support can be easily made to achieve their separate functions with optimum results. This adds considerably to the quality and manufacturing ease of the tube.

The attenuator elements are readily inserted into the tube after the tube envelope and the dielectric rod support assembly have been made. This is an advantage because it may be desirable to put the dielectric rod assembly through a brazing furnace. If the attenuator elements were to go through this furnace, serious changes might occur in the attenuator.

The attenuator elements **39**, **41** and **43** may be in close proximity to the helix **13** and add to the dielectric loading of the helix. This slows down the traveling wave carried by the helix. However, the attenuator elements are located at an axial position along the tube where, if the velocity of the traveling wave carried by the helix is disturbed at all, it should be speeded up rather than be slowed down. Therefore, the pitch of the helix along the attenuator elements is increased to maintain the value of phase velocity along the helix at least equal to or higher than the value of phase velocity that occurs along the helix beyond the ends of the attenuator elements.

The operation of the tube is conventional. Microwave energy from a suitable source, not shown, is supplied to the input coaxial line **17**. The energy travels along the helix **13** and interacts with the stream of electrons passing through the helix. This interaction produces amplification of the microwave energy in accordance with well-known principles. The amplified energy is delivered to a suitable load, now shown, by the output coaxial line **19**.

The attenuator elements **39**, **41** and **43** are employed to prevent undesirable oscillations from being produced in the traveling wave tube.

In some cases it may be desirable to support the helix with four or more rods. The number of attenuator elements could also be increased to four. It is feasible to use a number of attenuator elements that is different from the number of support rods. Also, other modifications might be made without departing from the true scope and spirit of the invention, which is limited solely by the accompanying claims.

I claim as my invention:

1. A traveling wave tube comprising a slow wave propagating structure for guiding electromagnetic energy for interaction with an electron beam, a vacuum envelope, a plurality of dielectric elements for supporting said propagating structure within said envelope and providing thermal transfer from said helix to said envelope, and a plurality of separate attenuator elements positioned between said slow wave propagating structure and said envelope and in the spaces provided between said dielectric elements.

2. A traveling wave tube comprising a slow wave propagating structure for guiding electromagnetic energy for interaction with an electron beam, a vacuum envelope, a plurality of dielectric elements for supporting and providing thermal transfer of energy from said helix to said envelope and a plurality of separate attenuator elements of a material that is lossy in its bulk properties positioned between said slow wave propagating structure and said envelope in the spaces between said dielectric elements.

3. A traveling wave tube comprising a propagating structure for guiding electromagnetic energy for interaction with an electron beam, a vacuum envelope, a plurality of dielectric elements in the form of rods which extend axially along the propagating structure while engaging both the propagating structure and the envelope to enhance cooling of the slow wave propagating structure and a plurality of separate attenuator elements positioned between said slow wave propagating structure and said envelope in the spaces between said dielectric elements.

4. A traveling wave tube comprising a slow wave propagating structure for guiding electromagnetic energy for interaction with an electron beam, a vacuum envelope a plurality of dielectric elements for supporting said propagating structure within said envelope, said dielectric elements in the form of elongated rods which extend axially along the propagating structure while engaging both the propagating structure and the envelope to enhance cooling of said propagating structure and a plurality of attenuator elements in the form of slabs and made from a material that is lossy in its bulk property positioned between said propagating structure and said envelope in the spaces between said dielectric elements.

5. A traveling wave tube comprising a slow wave propagating structure for guiding electromagnetic energy for interaction with an electron beam, a vacuum envelope, a plurality of dielectric elements for supporting said propagating structure within said envelope, said dielectric elements in the form of rods which extend axially along the propagating structure while engaging both the propagating structure and the envelope to provide transfer of heat from said helix to said envelope and a plurality of separate attenuator elements in the form of elongated slabs of a material that is lossy in its bulk properties positioned between said slow wave propagating structure and said envelope in the spaces between said dielectric elements and in contact with said envelope and said propagating structure.

6. A traveling wave tube comprising a conductive helix for propagating electromagnetic energy, a cylindrical conductor that forms a portion of a vacuum envelope, a plurality of dielectric rods for supporting said helix within said cylindrical conductor, said rods extending axially along said helix while engaging both said helix and said

conductor for enhancing cooling of said helix, and a plurality of attenuator members positioned within said cylindrical conductor in the spaces between said dielectric rods, said attenuator elements being made from a material that is lossy in its bulk properties.

7. A traveling wave tube comprising a conductive helix for propagating electromagnetic energy, a cylindrical conductor that forms a vacuum envelope, a plurality of dielectric rods for supporting said helix within said cylindrical conductor, said rods extending axially along said helix while engaging both said helix and said conductor for enhancing cooling of said helix, and a plurality of attenuator slabs positioned within said cylindrical conductor in the spaces between said dielectric rods, said attenuator slabs being made from a material that is lossy in its bulk properties, said envelope including a plurality of slots that extend longitudinally along the inner wall of said cylindrical conductor for positioning said dielectric rods in said attenuator slabs.

8. A traveling wave tube comprising a conductive helix for propagating electromagnetic energy, a cylindrical conductor that forms a vacuum envelope, a plurality of dielectric rods for supporting said helix within said cylindrical conductor, said rods extending axially along said helix while engaging both said helix and said conductor for enhancing cooling of said helix, and a plurality of attenuator slabs positioned within said cylindrical conductor in the spaces between said dielectric rods and spaced from the helix, said attenuator slabs being made from a material that is lossy in its bulk properties, the pitch of said helix being tapered in the vicinity of said attenuator slabs to compensate for extra dielectric loading.

9. In a traveling wave tube the combination of a vacuum envelope, a helix, a plurality of dielectric elements for supporting said helix within said envelope, a plurality of attenuator elements that are separate from said dielectric elements, and means including a plurality of longitudinally extending slots in the walls of said envelope for positioning said attenuator elements within said envelope for positioning said attenuator elements within said envelope in the spaces between said dielectric elements.

10. In a traveling wave tube the combination of a vacuum envelope, a helix, a plurality of dielectric elements for supporting said helix within said envelope, a plurality of attenuator elements that are separate from said dielectric elements that are in the form of slabs and made from a material that is lossy in its bulk properties and means including a plurality of longitudinally extending slots in the wall of said envelope for positioning said attenuator elements within said envelope in the spaces between said dielectric elements.

11. In a traveling wave tube the combination of a vacuum envelope, a helix, a plurality of dielectric elements for supporting said helix within said envelope, a plurality of attenuator elements that are separate from said dielectric elements and means including a plurality of longitudinally extending slots in the wall of said envelope for positioning said attenuator elements within said envelope

in the spaces between said dielectric elements, said rods engaging both said helix and the inner wall of said envelope and wherein said slabs extend radially inward from said envelope for said helix.

12. A traveling wave tube comprising a tubular vacuum envelope that is made from metal, a slow wave propagating helix, a plurality of dielectric rods for supporting said helix within said envelope, said rods extending longitudinally along said helix while engaging both said helix and said envelope, a first group of slots that extend longitudinally along the inner wall of said envelope for positioning said rods about said helix, a plurality of elongated attenuator elements which are made from a material that is lossy in its bulk properties, said attenuator elements extending longitudinally along said helix while engaging said envelope and a second group of slots that extend longitudinally along the inner wall of said envelope for positioning said attenuator elements around said helix.

13. A traveling wave tube comprising a tubular vacuum envelope that is made from metal, a slow wave propagating helix, a plurality of dielectric rods circular in cross section for supporting said helix within said envelope, said rods extending longitudinally along said helix while engaging both said helix and said envelope, a first group of slots that extend longitudinally along the inner wall of said envelope for positioning said rods, respectively, around said helix, a plurality of elongated attenuator elements being rectangular in cross section and made from a material that is lossy in its bulk properties, said attenuator elements extending longitudinally along said helix and forming a Y-like configuration having legs that extend radially inward to said helix from the inner wall of said vacuum envelope, said dielectric rods being located respectively in the spaces between the legs of the Y-like configuration of attenuator elements.

14. A traveling wave tube comprising a tubular vacuum envelope, an electromagnetic wave propagating structure positioned centrally within said tubular portion, a plurality of dielectric rods supporting said propagating structure within said envelope, said rods extending longitudinally along said propagating structure while engaging both said propagating structure and said envelope, a plurality of attenuator elements positioned between said envelope and said propagating structure and between said dielectric members, said attenuating elements having tapered end portions and said helix having a varied pitch in the vicinity of said attenuator elements to compensate for changes in phase velocity of the electromagnetic energy passing along said propagating structure due to said attenuator elements.

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