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TRAVELING WAVE ELECTRON DISCHARGE DEVICE

Filed Oct. 25, 1954

2 Sheets-Sheet 1

Fig. 1

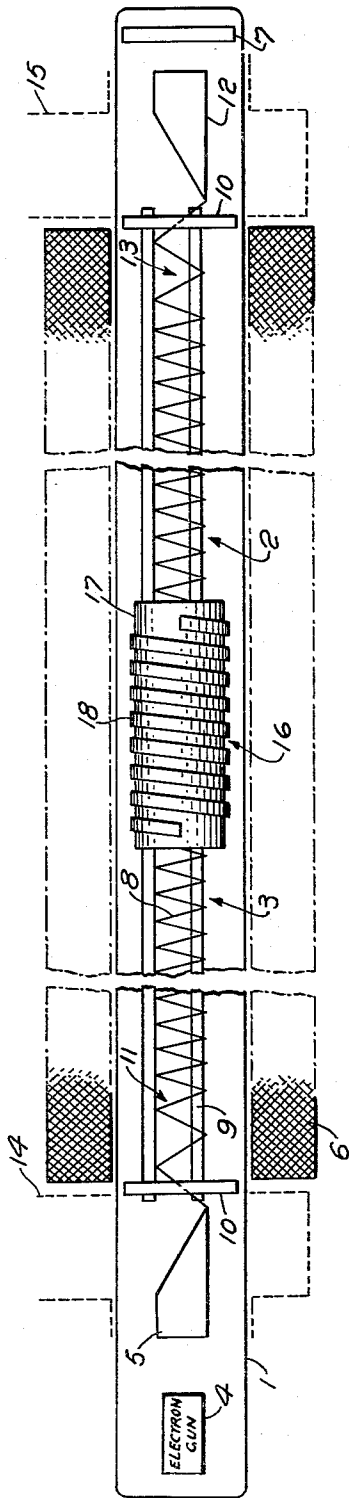


Fig. 2

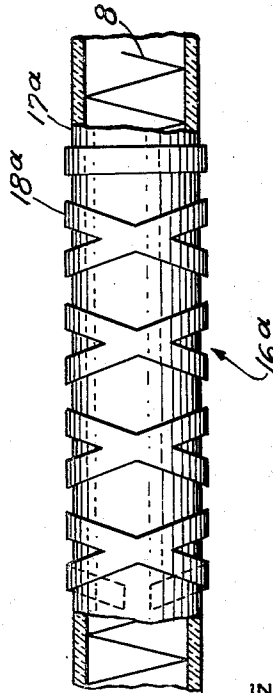
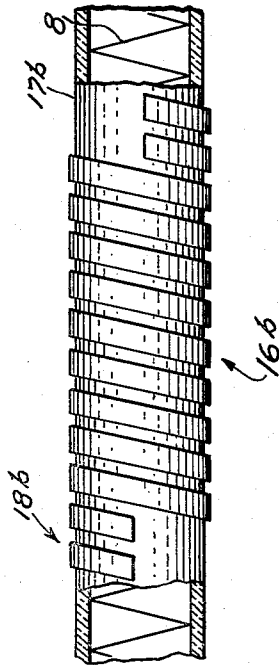


Fig. 3



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Fig. 4

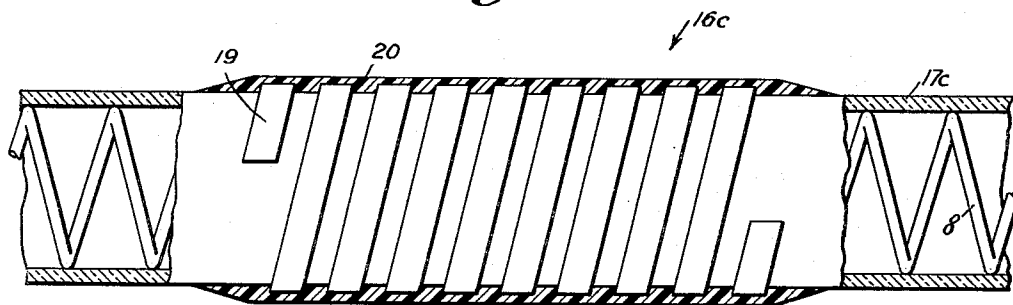


Fig. 5

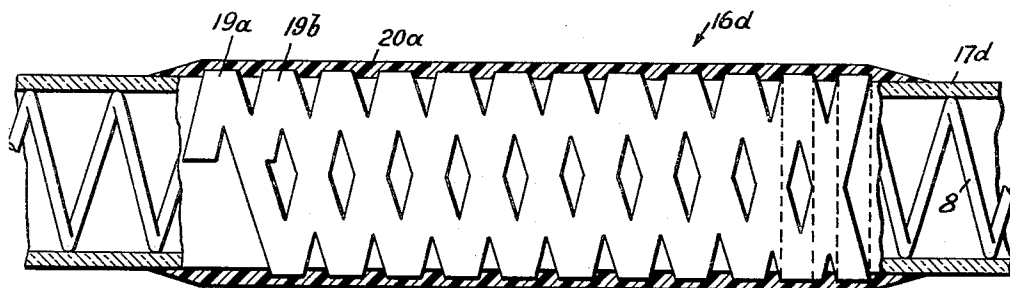
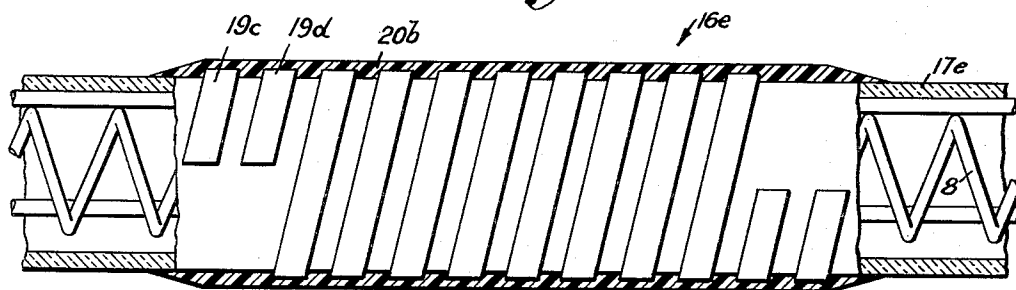


Fig. 6



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TRAVELING WAVE ELECTRON DISCHARGE
DEVICE

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11 Claims. (Cl. 315—3.5)

This invention relates to traveling wave electron discharge devices and more particularly to coupled helices and the method of fabricating the same for introducing a circuit loss along the path of the radio frequency field of a traveling wave in such devices to prevent both undesired oscillations and modes of propagation therein.

The general structure and theory of operation of a traveling wave type of electron discharge device or tube is well known in the art, a comprehensive treatment being given in the book published during 1950 by D. Van Ostrand Company, Inc., entitled "Traveling Wave Tubes," by J. R. Pierce.

It is recognized that the useful range of amplification of a traveling wave tube is limited by a tendency to generate self-sustaining oscillations as the amplification is increased. This effect is usually due to mismatch between the output circuit of the tube and the load circuit over all or part of the wide range of frequencies to be amplified. Due to such mismatch, energy of at least certain frequencies is reflected back toward the input end of the amplifying device. When the reflected wave is not attenuated in its travel along the helix, or other type propagating structure, in a direction opposite to the motion of the electron stream, some energy reaching the input end of the device is reflected therefrom causing the generation of self-sustaining oscillations. Thus, the energy reflected or transmitted back to the input must be attenuated if the tube is to remain stable.

Heretofore various means have been employed to overcome this tendency of generating self-sustaining oscillations. One such means employs a body of resistive material disposed on or adjacent to the propagating structure, either in a confined location thereabout or coextensive therewith to absorb the reflected energy. Another such means employs wire wound helices coaxial of the propagating structure and in coupled relation thereto for removal of reflected energy from the propagating structure for coupling to an appropriate termination thereof to overcome the tendency for self-sustaining oscillations.

These means for overcoming the tendency for self-sustaining oscillations have greatly improved the usefulness of the traveling wave tube at least for particular applications. However, in the search for high power and high gain, stability of the attenuation at high temperatures, broadband attenuation characteristics and reproducibility of electrical and mechanical properties of the attenuators, it has been found that the above-mentioned types of attenuators fail to meet one or more of the above major physical and electrical properties.

Therefore, it is an object of this invention to provide an improved means for preventing self-sustaining oscillations in a traveling wave tube and a method of fabricating the improved means to satisfy the above-mentioned properties.

Another object of this invention is to provide an attenuator for the propagating structure of a traveling wave tube including a coating having a lossy characteristic disposed on a sleeve of dielectric material coaxially of the propagating structure and in the electromagnetic field thereof, said coating including at least in part a helical conductive form disposed in coupled relation with said electromagnetic field.

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A feature of this invention is the provision of a coupled-helix circuit loss for the propagating structure of a traveling wave tube comprising a metallic film of high conductivity material painted in helical form upon a dielectric sleeve disposed coaxially of the propagating structure and in coupling relation with the electromagnetic field existing thereabout and a lossy material deposited on said film and said sleeve whereby said high conductivity material and said lossy material are constituents of a coating for attenuating energy coupled from said electromagnetic field.

Another feature of this invention is the provision of a coupled-helix circuit loss for the propagating structure of a traveling wave tube comprising a predetermined mixture or solution of low conductivity material and high conductivity material which results in a controlled conductivity coating, said mixture or solution being painted in helical form upon a dielectric sleeve disposed coaxially of the propagating structure and in coupling relation with the electromagnetic field existing thereabout whereby said low conductivity material and said high conductivity material are constituents of a controlled conductivity coating for attenuating energy coupled from said electromagnetic field.

Still another feature of this invention is a method whereby the attenuating coating of at least two materials is applied to a dielectric sleeve for disposition coaxial of the propagating structure of a traveling wave tube by painting at least a constituent material of said coating on said sleeve in a helical conductive form and firing the sleeve and the painted coating at an elevated temperature in an atmosphere of air for a given time to provide an adherent, temperature stable, coupled-helix attenuator.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic illustration of a traveling wave tube incorporating one form of the coupled-helix attenuator of this invention;

FIGS. 2 and 3 are elevational views, partially in section, of other embodiments of this invention; and

FIGS. 4, 5, and 6 are sectional views, partially in elevation, of still other embodiments of this invention.

Referring to FIG. 1, there is shown an illustrative embodiment of a traveling wave tube adapted to be used as an amplifier at ultra-high frequencies. The arrangement shown comprises an electron beam tube including an evacuated envelope 1. The envelope 1 may be constituted of a low-loss insulating material, such as glass or quartz, or a non-magnetic type of metal. The shape of envelope 1 may have a uniform diameter as illustrated in FIG. 1 or may include an elongated portion coextensive with the interaction section 2 and in supporting relationship with the propagating structure 3 included therein. The envelope 1 is provided at one end with means, such as a known type of electron gun 4 for producing an electron beam or stream. The electron stream emerges from the electron gun 4 and travels along a path that is straight through an input coupler 5 and axially down the evacuated envelope 1. The electron stream is further concentrated and guided along this substantially axial path by a longitudinal magnetic field produced by magnet 6 which may be either an electromagnet or a permanent magnet. Electrode 7 serves to collect the electrons arriving at the end of envelope 1.

The propagating structure 3 which serves as a path along which the radio frequency wave may be propagated is illustrated as including a helix 8. Helix 8 is wound with several turns per wavelength along its axis, which may preferably be of a plurality of wavelengths of the frequency being amplified. The helix is illustrated as

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being supported by a series of non-conductive rods 9 equally spaced about the circumference thereof and supported in an axial relationship with respect to envelope 1 by discs 10. As is known in the art, helix 8 may be supported by means of a ceramic tubing or by so shaping envelope 1 to provide an elongated portion in contact with the helix 8 for support thereof.

The helix 8 is joined at the input coupler 5 by an input matching section 11 and the output coupler 12 by the output impedance matching section 13. These matching sections are simply extensions of the helix in which the spacing between turns is increased along the circumference of the helix and acts as tapered transmission lines to provide a wave transmission path of uniformly changing impedance from the relatively low impedance at the end of the couplers 5 and 12 to the relatively high impedance of the central portion of helix 8 with a minimum reflection of energy back to the signal source.

In order to utilize the device in an operable system, there is provided an incoming wave path represented by the dotted input waveguide 14 into which there is introduced the input wave signal to be amplified. An output wave path, shown as the output waveguide 15, serves to transfer the amplified output wave to a load circuit. As the electron beam and the radio frequency wave travel axially of the helix at substantially the same linear velocity, an interaction takes place whereby energy is transferred from the beam to the wave thereby greatly amplifying the wave. As the amplified wave reaches the output end of the helix 8, it is transferred to the output waveguide 15 by means of output coupler 12. As the amplified wave reaches the impedance matching section 13, even with an extremely favorable termination, at a given band of frequencies, there will still exist reflected waves at frequencies both inside and outside the given band at the output end of the helix. This reflected wave is very little affected by the electron stream and hence will propagate back along the helix 8 toward the input end with attenuation. The reflected wave will reach the input end of the helix 8 with attenuation equal to the circuit attenuation and will in turn be reflected back toward the output end of the helix. It is obvious that there will be some reflected energy which will result in self-sustaining oscillations, provided there is not enough circuit attenuation to dampen the reflected energy. It will thus be seen that the deliberate introduction of an artificial loss within the electromagnetic field of the helix so as to provide a dissipation or removal of the reflected wave will serve to greatly increase the range of useful amplification which can be achieved with a device of this type.

In accordance with the principles of this invention, the artificial loss or circuit attenuation is introduced along the portion of the helix by a coupled-helix attenuator 16 appropriately disposed longitudinally along the helix 8 and in coupled relation with respect to the electromagnetic field existing about the helix.

The coupled-helix attenuator 16 of FIG. 1 is shown to include a thin walled quartz cylinder or sleeve 17 having disposed thereon a coating 18 in a helical conductive form. In this instance, the coating 18 is a low conductivity metal film painted upon cylinder 18 in the form of a single filar, single direction helix. It has been found that satisfactory attenuation was obtainable with a mixture or solution of two parts platinum metal paint, which is essentially an organic solution of metal resins containing 3.2 percent gold and 4.2 percent platinum plus less than 1 percent base metals, such as bismuth, and more than 91 percent of organic resins and solvents, and one part gold metal paint, which is essentially an organic solution of metal resins containing 12 percent gold, less than 1 percent base metals, such as bismuth, and more than 87 percent organic resins and solvents. An optimum value of conductivity for maximum attenuation is obtained by adjusting the amount of each material used in the coating. It was further found that a satisfactory

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amount of attenuation was obtained when the length of the coupling helix corresponds to about two coupling wavelengths. By coupling wavelength is meant the axial length of lossless coupling helix required to transfer all the energy on the main helix to the lossless coupling helix.

It will be noted that sleeve 17 is disposed about the rods 9 employed to support the helix 8 but close enough thereto to place coating 18 in a coupling relation with the electromagnetic field of helix 8. It will, of course, be recognized that the extra sleeve is not necessary in all configurations of traveling wave tubes nor is the coating applied to sleeve 17 limited to a single filar, single direction wound helix.

Referring to FIGS. 2 and 3, variations of the coupled-helix attenuator 16 of FIG. 1 are illustrated at 16a and 16b. Constituent materials of coating 18a may be substantially the same and may be in substantially the same proportion as the painting mixture of the coupled-helix attenuator of FIG. 1. The constituent materials for the coating are not limited to the above-mentioned materials and any solution of other low conductivity and high conductivity metals to give a resultant low conductivity characteristic may be successfully substituted therefor. With reference to FIG. 2 the coating 18a is illustrated as being applied to a thin walled dielectric sleeve 17a in the form of a single wire counterwound type helical form. In FIG. 3, the coating 18b is depicted as being applied to sleeve 17b in the form of a bifilar, single direction wound helix. By painting the coupled-helix attenuator of this type in the form of a multifilar helix as illustrated in FIG. 3 and single wire counterwound helices as illustrated in FIG. 2, it is found that greater attenuation and bandwidth are obtainable.

The helical configuration may be painted on a quartz cylinder in the desirable helical conductive form by rotating the sleeve in a lathe and employing a lettering pen attached to the screw-thread mechanism of the lathe which is caused to travel longitudinally at a given rate as the sleeve is rotated at a given rate. The proper selection of the pen size as determined by the consistency of the solution and the winding condition in conjunction with the variables of the machine lathe provide a method whereby the uniformity of turns per inch of the coupled helices and the mechanical reproducibility of these coupled-helix attenuators are obtainable. The coupled helical form painted on the sleeve is fired at an elevated temperature in the region of 650° C. to 700° C. in an atmosphere of air for about 10 minutes. This heat treatment provides a very adherent, temperature stable, film or coating to the extent that no changes have been noted in the electrical and physical properties of these attenuators during either the exhaust process or the actual operation of the tubes. An estimate of the power handling capabilities of these attenuators in vacuum is about 1 watt of average power. In air, 6 watts average or 4 kw. of peak power have not been found excessive for these attenuators. The platinum-gold solution, or equivalent solution, is adjusted in composition and thickness so as to optimize the level of attenuation obtained with this coupled-helix attenuator.

The sleeves 17a and 17b of FIGS. 2 and 3 are shown in a supporting relation with the helix 8. These sleeves may be the dielectric tubing supporting the helical structure axially of the traveling wave tube or may be the elongated portion of the vacuum envelope of a traveling wave tube utilized to support the helix as well as provide the desired vacuum closure. In the latter case, the coupled-helix attenuator will be deposited on the atmosphere side of the vacuum envelope which enables repair to the helix attenuator or replacement thereof without disturbing the rather delicate structure of the traveling wave tube included within the vacuum closure.

Referring to FIGS. 4, 5 and 6, further components of the coupled-helix attenuators of this invention are illustrated. In each instance, a thin walled support cylinder 17c, 17d, and 17e are provided and are substantially

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identical to the support sleeve of FIGS. 1, 2 and 3. As illustrated in these figures, the support sleeve may support the main helix 8 as well as the coupled-helix attenuator or may be disposed about the rod type support structure for the main helix. Sleeve 17c and 17b may, of course, constitute a portion of the vacuum envelope and has the same advantages of placing the coupled-helix configuration outside the vacuum portion of the traveling wave tube as disclosed in connection with FIGS. 2 and 3.

The coupled-helix attenuator 16c of FIG. 4 includes a coating having a lossy characteristic disposed on cylinder 17c with the constituent materials thereof comprising a high conductivity metal film such as gold or silver, painted on sleeve 17c in the form of a single direction wound helix as indicated at 19 which has sprayed thereon a resistive or lossy material 20 such as aquadag. The high conductivity film forming the helical conductive portion 19 of coating 16c may be provided by a silver metal paint, which is essentially a suspension of finely divided silver particles and base metal compounds in an organic vehicle containing approximately 48 percent silver, 2.5 percent base metals, such as bismuth and lead, and more than 47 percent organic resins and solvents, applied to the sleeve as in the previous embodiments by cooperation between a machine lathe and a lettering pen. This painted helical portion of coating 16c is then fired at a temperature in the range of 650° C. to 700° C. in an air oven for about 10 minutes. This step in the process provides a very adherent, high conductivity and temperature stable film deposited on sleeve 17c. A resistive or lossy material 20 is then sprayed on the helical conductive form and quartz sleeve in a coaxial configuration. Rather than spraying the lossy material as above, the lossy material could be deposited by a dipping process. This assembly is again fired at about 200° C. to assure that the aquadag or resistive material will adhere to the painted helix and the sleeve 17c to provide a coating 16c having a lossy characteristic or attenuation of sufficient value to attenuate reflected energy in the electromagnetic field about helix 8. By changing the form of the lossy material and the amount used, a varying level of attenuation may be obtained.

FIGS. 5 and 6 illustrate further embodiments of the coupled-helix attenuators of this invention. In FIG. 5 the high conductivity material of the coating 16d is applied to the sleeve 17d in the form of a bifilar counterwound type helical configuration. The filars of this counterwound arrangement are indicated at 19a and 19b and as before have deposited thereon a lossy material as indicated at 20a to provide as before a coating having a lossy characteristic and including therein two constituents, one of which is provided to have a helical conductivity form. FIG. 6 illustrates a coating 16e having a bifilar single direction wound configuration for the high conductivity material. The filars 19c and 19d have deposited thereon a lossy material to provide a coating having sufficient attenuation characteristics to stabilize the device.

The embodiments hereinabove described in conjunction with proper construction techniques will provide a long-life and rugged type of attenuator for use in traveling wave tubes. This type of attenuator provides in summary the following advantages:

(1) The coupled-helix attenuator need not be located in intimate contact with the main helix of the traveling wave tube and, therefore, reduces the possibility of mismatch on the main helix due to the attenuation.

(2) The coupled-helix attenuator may be located either inside or outside of the vacuum envelope.

(3) The coupled-helix attenuator of this invention has the ability of being adjusted along the length of the main helix of the traveling wave tube to enable the efficiency and power output characteristics of the tube to be optimized.

(4) Simple fabrication techniques with high quality

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vacuum material can be employed with this type of attenuator.

(5) Because of the employment of pure metal films, the amount of attenuation can be made to remain constant over a varied temperature range.

(6) The reproducibility of the level of attenuation with these attenuators can be obtained within close tolerances.

(7) The power handling capabilities of this type of attenuator, particularly when located outside of the vacuum envelope, can be greatly improved by forced-air, oil, or water-cooling techniques.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. In traveling wave electron discharge devices having a propagating structure for the propagation of radio frequency energy therealong and a means of projecting a beam of electrons parallel to the axis of said propagating structure for interaction with the electromagnetic field of said energy; an attenuator for said propagating structure comprising a sleeve of dielectric material disposed coaxially of said propagating structure and in said electromagnetic field and a coating of controlled conductivity having a lossy characteristic disposed on said sleeve, said coating including at least in part a helical conductive form disposed in coupled relation with said electromagnetic field.

2. A device according to claim 1, wherein said coating includes a film of high conductivity metal and a film of lossy material, said film of high conductivity metal being disposed in a helical conductive form.

3. A device according to claim 2, wherein said film of high conductivity metal includes metallic paint disposed on said sleeve in a single direction wound helical conductive form.

4. A device according to claim 2, wherein said film of high conductivity metal includes a metallic paint disposed on said sleeve in a counterwound helical conductive form.

5. A device according to claim 1, wherein said coating includes a low conductivity film disposed in a helical conductive form, said film including a mixture of low conductivity metal and high conductivity metal.

6. A device according to claim 5, wherein said film includes a mixture of two parts of low conductivity metal to one part of high conductivity metal.

7. A device according to claim 5, wherein said film includes a mixture of two parts of platinum metal paint to one part of gold metal paint, said mixture being disposed on said sleeve in a single direction wound helical conductive form.

8. A device according to claim 5, wherein said film includes a mixture of two parts of platinum metal paint to one part of gold metal paint, said mixture being disposed on said sleeve in a counterwound helical conductive form.

9. In traveling wave electron discharge devices having a propagating structure for the propagation of radio frequency energy therealong and a means of projecting a beam of electrons parallel to the axis of said propagating structure for interaction with the electromagnetic field of said energy; an attenuator for said propagating structure comprising a ribbon having a lossy characteristic disposed coaxially of said propagating structure and in said electromagnetic field, said ribbon having a helical form and in coupling relation with said electromagnetic field.

10. In traveling wave electron discharge devices having an envelope, a conductor in the form of a helix for propagation of radio frequency energy therealong disposed in axial coincidence with said envelope, an elongated dielectric tubing in supporting relationship with said helix, and a means of projecting a beam of electrons axially of said helix for interaction with the electromagnetic field

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of said energy, said electromagnetic field including a reflected component therein; an attenuator for said helix comprising a coating having a lossy characteristic of at least two materials disposed on said tubing, said coating including at least in part a helical conductive form disposed in coupled relation with said electromagnetic field for removal of said reflected component therefrom.

11. In a traveling wave electron discharge device having an envelope of dielectric material including an elongated portion, a conductor in the form of a helix for propagation of radio frequency energy therealong disposed in axial coincidence with and in supporting relationship with the elongated portion of said envelope, and a means of projecting a beam of electrons axially of said helix for interaction with the electromagnetic field of said energy, said electromagnetic field including a reflected com-

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ponent therein; an attenuator for said helix comprising a coating having a lossy characteristic of at least two materials disposed on the elongated portion of said envelope, said coating including at least in part a helical conductive form disposed in coupled relation with said electromagnetic field for removal of said reflected component therefrom.

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