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METHOD AND APPARATUS FOR MANUFACTURING TRAVELLING
WAVE ELECTRON DISCHARGE DEVICES
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Fig. 1

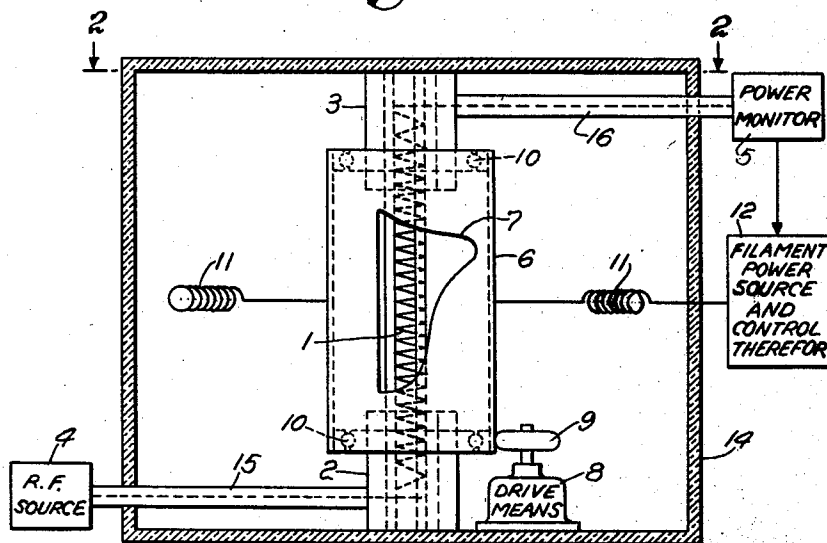
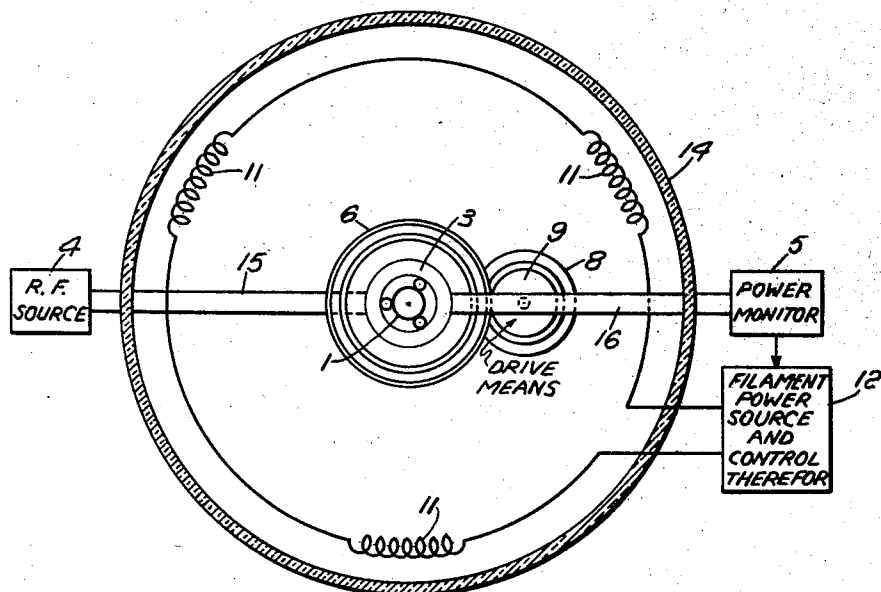


Fig. 2



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METHOD AND APPARATUS FOR MANUFACTURING TRAVELLING WAVE ELECTRON DISCHARGE DEVICES

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This invention relates to travelling wave electron discharge devices and more particularly to an improved means and method for applying attenuation to the radio frequency propagating structure in such devices to prevent undesirable oscillations.

The travelling wave type of electron discharge device or tube is particularly useful in wideband microwave systems since it is capable of amplifying radio frequency energy over a wide range of frequencies. The travelling wave tube includes a form of transmission line, usually a helix, for transmission of microwave energy therealong for interaction with an electron beam closely associated with the line.

The useful range of amplification of this type of 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 device 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 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 end must be attenuated if the tube is to remain stable.

The tendency of generating self-sustaining oscillations in the past has been overcome by employing resistive or lossy material, such as aquadag, to attenuate the reflected waves. The lossy material may be distributed along the entire length of the helix or along a major portion thereof, or in a lumped form disposed in spaced relation to the helical conductor but in the electromagnetic field, or as a part of the helical conductor itself. The lossy or resistive material in the past has been applied to the helical conductor or propagating structure by spraying or otherwise painting this lossy material upon the propagating structure. It has been found that merely spraying or painting the attenuation upon the propagating structure does not enable a control of the position of the attenuation, the configuration of the attenuation which includes the distribution thereof and the density of the material per unit length, and the amount of signal attenuation presented by the applied attenuation. Accurate control of these parameters is necessary for reproducing the attenuating characteristic of the applied attenuation in the production of a plurality of identical propagating structures for travelling wave type of tubes.

Therefore, it is an object of the present invention to provide an improved method of applying attenuation to signal propagating structures enabling the reproduction of the attenuating characteristics thereof.

Another object of the present invention is to provide an improved method for reproducing the attenuating characteristics of an attenuation section disposed in the

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path of the radio frequency field adjacent to the signal propagating structure of a travelling wave tube so as to prevent self-sustaining oscillations therein and yet obtain high gain and maximum output power therefrom.

Another object of the present invention is to provide a means to carry out the method of this invention.

A feature of this invention is the provision of passing a signal of given power level and frequency through a propagating structure during the application of a layer of resistive material to at least a certain portion of the propagating structure and monitoring the signal output of the propagating structure to determine when a proper amount of resistive material has been applied thereto to decrease the signal output to a predetermined power level.

Another feature of this invention is the provision of evaporating resistive material for continual deposit thereof in the form of particles to build up a layer of resistive material on at least a certain portion of a radio frequency propagating structure and monitoring the attenuation of a radio frequency signal passed through the propagating structure during the deposit of the particles of resistive material until the level of attenuation is brought to a predetermined value at which time the evaporation of the resistive material is discontinued.

Still another feature of this invention is the provision of a vacuum enclosure surrounding a propagating structure and a mask disposed in coaxial relationship and having relative rotation therebetween, said mask including an aperture of given configuration. Radio frequency energy of given power level and frequency is passed through the propagating structure and filaments having a resistive material thereon are disposed within the vacuum closure in spaced relation with respect to the pattern mask. The filaments are heated from a controlled power source to evaporate the resistive material, the particles of which continually pass through the aperture of the mask which restricts the deposit of the particles of resistive material to a given location and density per unit length on the propagating structure. A power detector is provided to monitor the output energy of the propagating structure during the depositing of the resistive material. When the output energy is attenuated a given amount, the power detector operates on the filament power source to automatically disrupt the flow of filament power and thereby discontinue the evaporation of resistive material.

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 view in elevation, partially in section, of one form of apparatus which may be employed to carry out the method of this invention; and

Fig. 2 is a plan view of the structure of Fig. 1 with the top removed.

The accurate control of the characteristics of the applied attenuation, density per unit length over a fixed length, amount of attenuation and position along the propagating structure, is achieved by passing a signal of known power level and frequency, preferably the mid-band frequency of the desired operating frequency range, through the propagating structure from the input end thereof to the output end thereof and monitoring the power level of the signal at the output of the propagating structure while the signal attenuating or resistive material is sprayed, evaporated or otherwise deposited on the propagating structure. The position and density per unit length of the attenuation is determined by a mask having an aperture of predetermined configuration disposed coaxial of the propagating structure and a relative

rotation effected between the mask and the propagating structure. The amount of attenuation presented to the signal by the layer of resistive material restricted to at least a certain portion of the propagating structure by the mask aperture is determined by a reduction in the known power level of the signal passed through the structure as indicated by a power detector or monitoring device. The reduction of the known power level to a predetermined level signifies that the proper amount of resistive material has been applied and the application thereof should be discontinued. This control of the application of signal attenuating material enables a reproduction of attenuation impedance which is important in the production of travelling wave tube, and similar, propagating structures.

More specifically, a propagating structure which may be of the helical conductor type is disposed within a vacuum atmosphere and mounted in energy transition devices which provide a radio frequency impedance match between both the input and output of the propagating structure and a radio frequency signal source and load circuit, respectively, for transmission of a signal having a given power level and frequency through the propagating structure during the addition of the attenuation. Positioned coaxially of the longitudinal axis of the propagating structure is a mask having an aperture of apertures of given configuration and given longitudinal location with respect to the propagating structure. This mask may be in the form of a cylinder having a cutout or cutouts therethrough to provide a desired density per unit length and position for the attenuation section. The attenuation section may be distributed along the entire length of the propagating structure, a major portion thereof, or in a given restricted location. By employing interchangeable masks, the density per unit length of the attenuation and the position thereof along the propagating structure may be adjusted to satisfy requirements of various applications for the propagating structure.

In carrying out the method, the mask and propagating structure are caused to rotate relative to each other on their longitudinal axis. This may be accomplished by holding the mask stationary and rotating the propagating structure, or holding the propagating structure stationary and rotating the mask, or providing both the propagating structure and the mask with rotating motion with one of the elements rotating faster than the other to provide relative rotation therebetween.

A body of resistive material is disposed in spaced coaxial arrangement about the mask and in alignment with the aperture of the mask. The resistive material is evaporated. The evaporated resistive material in the form of particles continually passes through the mask aperture for deposit upon the propagating structure to build a layer of resistive material in the form of a film.

The relative rotation of the mask and propagating structure causes a relatively uniform circumferential deposit of the resistive material on the propagating structure. The body of resistive material can be filaments of refractory material carrying thereon a desirable resistive material, such as nickel, aluminum, tin, tungsten, iron, and various alloys thereof or a mixture thereof with a dielectric material, such as quartz. By applying an appropriate D.-C. potential to the filaments, the resistive material can be evaporated. As mentioned above, the evaporation deposition of the resistive material is carried out in a vacuum. If the vacuum is better than 5×10^{-4} mm. Hg. the evaporated material will travel in a relatively straight line from the source thereof to the propagating structure through the mask aperture.

The R.-F. power of given power level and frequency transmitted through the propagating structure is attenuated by the deposit of the resistive material. By monitoring or measuring the output power level, the depositing of the resistive material can be stopped when the

signal is attenuated a given amount. The control afforded by the relative rotation of the mask and the propagating structure, the longitudinal position and configuration of the mask aperture and the measuring of the signal power level loss during the depositing step enables a relatively accurate reproduction of the attenuation added to propagating structures.

It is to be understood that the transmission of signal through the propagating structure during the attenuating material application to enable a control of the amount of attenuation applied may be employed with other material application methods, such as spraying. However, applicants prefer to employ in conjunction with their power monitoring feature, the depositing of material by the evaporation process herein set forth.

The vacuum evaporation duplicates the environment of the attenuation section in a completed vacuum tube so that when the completed tube is baked out, very little change occurs in the magnitude of the attenuation produced by the evaporated resistive material. Care must be exercised in the storage of the propagating structure having attenuation applied by this method or contamination thereof will result. Satisfactory storage of these products have resulted without contamination by coating the structures with a lacquer or by maintaining the structures in a vacuum. The same degree of control can be achieved in this process of evaporation of resistive material in vacuum as is obtained in the field of depositing optical films.

It has been found that by employing the method of this invention, that the attenuating section added to radio frequency propagating structures in general and those employed in travelling wave tubes in particular can be reproduced with a relative amount of ease. The characteristics accurately controlled by this method are the position of the attenuation section along the longitudinal dimension of the propagating structure, the configuration or density per unit length of the attenuation section in the predetermined position, and the amount of radio frequency attenuation. The amount of signal attenuation and the configuration of the attenuation section provides a given pattern of loss or attenuation versus length over a fixed length of the propagating structure. These accurately controlled characteristics cooperate to provide an attenuating impedance which is reproducible. Further, it has been found that a wide range of impedances for the attenuation section is possible to meet the requirements of different devices utilizing the propagating structures modified by the addition of attenuation in accordance with the method of this invention. This wide range of impedances is accomplished by employing high resistive materials, such as nickel, aluminum, tin and tungsten, employing a mixture of metals and dielectrics, such as nickel and quartz, and employing magnetic materials, such as iron and various magnetic alloys thereof, as the constituents of different attenuation sections.

Figures 1 and 2 illustrate one form of apparatus which may be utilized to carry out the method of this invention. Propagating structure 1 is mounted in support members 2 and 3 which provide a physical support for structure 1 and further provides transition sections therein for a radio frequency impedance match between structure 1 and source 4 and structure 1 and power monitor 5. Coaxial of structure 1 is disposed a mask 6 in a form of a cylinder having an aperture 7 therein of given configuration and longitudinal position on mask 6 relative to a given longitudinal position on structure 1. The relative rotation between structure 1 and mask 6 is provided by means of driving source 8, such as a motor, a friction drive means 9 in driving relation to the outer surface of mask 6, and the bearings 10 disposed between the inner surface of mask 6 and the outer surface of supports 2 and 3. Encircling mask 6 and spaced therefrom in alignment with aperture 7 are disposed filaments 11 in a series

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relation with a filament power source 12 including therein a control circuit, such as a relay, to enable the automatic disabling of the output of source 12. It is to be understood, however, that the control circuit can be manual, such as a single pole, single throw switch. Filaments 11 are composed of a refractory material having a substantial quantity of resistive material thereon, such as nickel. The structure 1, mask 6, members 2 and 3 and filaments 11 are enclosed in housing 14 which is evacuated in a known manner (not shown) to provide a vacuum atmosphere for the evaporation process.

The signal of source 4 having a predetermined power level and frequency, preferably at the midband of the desired operating frequency range of structure 1, is coupled by transmission line 15 through the wall of housing 14 to support member 2. The signal is coupled by the transition section of member 2 to structure 1 and hence from structure 1 to support member 3 for transfer to transmission line 16 for coupling to monitor 5 through the wall of housing 14. The signal measured by monitor 5 will have a power level equal to the predetermined power level output of source 4 minus the loss experienced in traversing the circuit path from source 4 to monitor 5.

The source 12 is made operative by the control circuit therein and the mask 6 is rotated. The resistive material is evaporated from filaments 11. The evaporated particles travel through the revolving aperture 7 for a restricted deposit in the form of a film or structure 1 in a position thereon and having a density determined by the relative position and configuration of aperture 7. As the resistive material is deposited on structure 1, the signal passing therethrough encounters an ever increasing resistance or attenuation resulting in a decrease of power level. This power level decrease is observed at monitor 5. When the power level reaches a predetermined value, the monitor 5 causes the control circuit of source 12 to stop the flow of power therefrom and the evaporation of resistive material is discontinued. This arrangement of one form of apparatus to carry out the method of this invention enables a relatively accurate reproduction of the density per unit length, the position along structure 1, and the amount of signal attenuation of the attenuation section added to a propagating structure.

With the control circuit of source 12 responsive to the predetermined power level, as detected in monitor 5 to discontinue the material evaporation automatically, it is possible to have one person load and unload a plurality of devices, such as shown in Figs. 1 and 2, to provide a substantially automatic production of propagating structures where the attenuating characteristics of each of the produced structures are substantially identical.

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. A method of adding signal attenuation material to a signal propagating structure of elongated configuration to establish the electrical conductivity thereof at a predetermined value comprising the steps of passing a signal of given power level and frequency lengthwise through said propagating structure, detecting the power level of the signal output of said propagating structure, and applying resistive material to the circumference of and for at least a certain length of said propagating structure until the detected signal output decreases to a predetermined power level.

2. A method of adding signal attenuation material to a signal propagating structure of elongated configuration to establish the electrical conductivity thereof at a predetermined value comprising the steps of passing a signal of given power level and frequency lengthwise through said propagating structure, detecting the power level of

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the signal output of said propagating structure, and applying continually particles of resistive material to the circumference of and for at least a certain length of said propagating structure to deposit thereon a resistive layer until the detected signal output decreases to a predetermined power level.

3. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said propagating structure, evaporating a resistive material for deposit on the circumference of said propagating structure, restricting the deposit of said resistive material to a predetermined density per unit length over at least a certain length of said propagating structure, detecting the attenuation imposed on said transmitted signal by said resistive material during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

4. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said propagating structure, evaporating a high resistance metal for deposit on the circumference of said propagating structure, restricting the deposit of said metal to a predetermined density per unit length over a given length of said propagating structure, detecting the attenuation imposed on said transmitted signal by said metal during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

5. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said propagating structure, evaporating a mixture of high resistance metal and dielectric material for deposit on the circumference of said propagating structure, restricting the deposit of said mixture to a predetermined density per unit length over a given length of said propagating structure, detecting the attenuation imposed on said transmitted signal by said mixture during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

6. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said propagating structure, evaporating a magnetic material for deposit on the circumference of said propagating structure, restricting the deposit of said magnetic material to a predetermined density per unit length over a given length of said propagating structure, detecting the attenuation imposed on said transmitted signal by said magnetic material during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

7. A method of adding signal attenuation material to an elongated helical signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said helical propagating structure, evaporating a resistive material for deposit on the turns of said helical propagating structure, masking said helical propagating

structure to restrict the deposit of said resistive material to at least a certain number of turns of said helical propagating structure, detecting the attenuation imposed on said transmitted signal by said resistive material during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

8. A method of adding signal attenuation material to an elongated helical signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of transmitting a signal of predetermined power level and frequency lengthwise through said propagating structure, evaporating a resistive material for deposit on the turns of said helical propagating structure, masking said helical propagating structure to restrict the deposit of said resistive material to at least a certain number of turns of said helical propagating structure, effecting relative rotation between said helical propagating structure and the means masking said helical propagating structure to distribute the deposit of said resistive material in circumferential uniformity about said certain number of turns and in a predetermined density per unit length over said certain number of turns, detecting the attenuation imposed on said transmitted signal by said resistive material during the depositing thereof, and automatically discontinuing said depositing in response to attenuation detecting when the attenuation of said transmitted signal reaches a given value.

9. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of applying continually particles of resistive material to the circumference of said propagating structure to deposit thereon a resistive layer and restricting the deposit of said layer to a predetermined density per unit length over at least a certain length of said propagating structure.

10. A method of adding signal attenuation material to an elongated signal propagating structure to establish the electrical conductivity thereof at a predetermined value comprising the steps of applying continually particles of resistive material to the circumference of said propagating structure to deposit thereon a resistive layer, masking said propagating structure to restrict the deposit of said layer to at least a certain length of said propagating structure and effecting relative rotation between said propagating structure and the means masking said propagating structure to distribute the deposit of said resistive material in circumferential uniformity about said certain length and in a predetermined density per unit length over said certain length.

11. Apparatus for applying attenuation to a signal propagating structure comprising means to transmit a signal of given power level and frequency through said propagating structure, means disposed in spaced relation to said propagating structure to apply a resistive material thereon, and monitor means to measure the power level of the output signal of said propagating structure during the application of said resistive material to determine when a sufficient amount of said resistive material has been applied to attenuate the output signal a given amount.

12. Apparatus for applying attenuation to a signal propagating structure comprising means to transmit a signal of given power level and frequency through said propagating structure, means disposed in spaced relation to said propagating structure to apply a resistive material thereon, monitor means to detect the power level of the output signal of said propagating structure during the application of said resistive material to indicate when a sufficient amount of said resistive material has been applied to reduce the power of the output signal to a given power level, and control means coupled between said monitor means and said means to apply resistive material,

said control means rendering said means to apply resistive material inoperative when said monitor means detects said given power level.

13. Apparatus for applying attenuation to a signal propagating structure comprising a source of signal having a given power level and frequency, means to couple the signal of said source to said propagating structure for transmission therethrough, means disposed in spaced relation to said propagating structure to apply a resistive material thereon, a mask disposed intermediate said last mentioned means and said propagating structure and coaxially of said propagating structure, said mask having an aperture of given configuration, means to effect relative rotation between said mask and said propagating structure, said means to rotate and the configuration of the aperture of said mask cooperating to restrict the deposit of said resistive material to a given density per unit length along at least a certain length of said propagating structure, and means monitoring the power level of the signal output of said propagating structure during the application of said resistive material to determine when a sufficient amount of said resistive material has been applied to attenuate the signal of said source a given amount.

14. Apparatus for applying attenuation to a signal propagating structure comprising a source of signal having a given power level and frequency, means to couple the signal of said source to said propagating structure for transmission therethrough, means disposed in spaced relation to said propagating structure to apply a resistive material thereon, a mask disposed intermediate said last mentioned means and said propagating structure and coaxially of said propagating structure, said mask having an aperture of given configuration, means to effect relative rotation between said mask and said propagating structure, said means to rotate and the configuration of the aperture of said mask cooperating to restrict the deposit of said resistive material to a given density per unit length along at least a certain length of said propagating structure, monitor means to detect the power level of the output signal of said propagating structure during the application of said resistive material to indicate when a sufficient amount of said resistive material has been applied to reduce the power of the output signal to a given power level, and control means coupled between said monitor means and said means to apply resistive material, said control means rendering said means to apply resistive material inoperative when said monitor means detects said given power level.

15. Apparatus for applying attenuation to a signal propagating structure comprising means to support said propagating structure, a source of signal having a given power level and frequency, means coupling the signal of said source to said propagating structure for transmission therethrough, a body of resistive material disposed in spaced relation to said propagating structure, a mask disposed intermediate said body and said propagating structure and coaxially of said propagating structure, said mask having an aperture of given configuration, a first rotational bearing member integral with said support means, a second rotational bearing member integral with said mask, means in driving relation with at least one of said bearing members to effect relative rotation between said mask and said propagating structure, means connected to said body to evaporate the resistive material for deposit on said propagating structure, the relative rotation between said mask and said propagating structure and the aperture of said mask cooperating to restrict the deposit of said resistive material to a given density per unit length along at least a certain length of said propagating structure, and detector means coupled to the output of said propagating structure to indicate when a sufficient amount of said resistive material has been deposited on said propagating structure to reduce the signal of said source to a given power level.

16. Apparatus for applying attenuation to a signal

propagating structure comprising means to support said propagating structure, a source of signal having a given power level and frequency, means coupling the signal of said source to said propagating structure for transmission therethrough, a body of resistive material disposed in spaced relation to said propagating structure, a mask disposed intermediate said body and said propagating structure and coaxially of said propagating structure, said mask having an aperture of given configuration, a first rotational bearing member integral with said support means, a second rotational bearing member integral with said mask, means in driving relation with at least one of said bearing members to effect relative rotation between said mask and said propagating structure, means connected to said body to evaporate the resistive material for deposit on said propagating structure, the relative rotation between said mask and said propagating structure and the aperture of said mask cooperating to restrict the deposit of said resistive material to a given density per unit length along at least a certain length of said propagating structure, detector means coupled to the output of said propagating structure to indicate when a sufficient amount of said resistive material has been deposited on said propagating structure to reduce the signal of said source to a given power level, and control means coupled to said means to evaporate to render said means to evaporate inoperative when said detector means detects said given power level.

17. Apparatus for applying attenuation to a signal propagating structure comprising a vacuum enclosure, a first means to support said propagating structure within said enclosure engaging one end of said propagating structure, a second means to support said propagating structure within said enclosure engaging the other end of said propagating structure, each of said support means including an energy transition means, a source of radio frequency signal having a given power level and frequency disposed external of said enclosure, a power detector disposed external of said enclosure, transmission line means to couple the signal of said source through the wall of said enclosure to the transition means of said first support means for transmission through said propagating structure, transmission line means to couple the output signal of said propagating structure from the transition means of said second support means through the wall of said enclosure to said power detector, a plurality of series connected refractory filaments disposed within said en-

closure in spaced, coaxial arrangement with respect to said propagating structure, resistive material carried by each of said filaments, a cylinder disposed intermediate said filaments and said propagating structure and coaxially of said propagating structure, said cylinder having an aperture therethrough of given configuration; first bearing members integral with each of said support members, second bearing members integral with each end of said cylinder and in rotational engagement with said first bearing members, means in driving relation with said cylinder to effect rotation of said cylinder about said propagating structure, a direct current power source connected in series with said filaments for evaporation of said resistive material for deposit on said propagating structure, the rotation of said cylinder and the aperture of said cylinder cooperating to restrict the deposit of said resistive material to a given density per unit length along at least a certain length of said propagating structure, said power detector indicating when a sufficient amount of said resistive material has been deposited on said propagating structure to reduce the signal of said source to a given power level, and control means connected to said direct current power source to disconnect said direct current power source from said filaments to discontinue the deposit of said resistive material when said given power level is detected.

18. Apparatus according to claim 17, wherein said control means is connected between said power detector and said direct current power source, said control means to automatically disconnect said direct current power source from said filaments when said given power level is detected.

19. Apparatus according to claim 17, wherein said resistive material is a high resistance metal.

20. Apparatus according to claim 17, wherein said resistive material is a given mixture of high resistance metal and dielectric material.

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