

Nov. 20, 1951

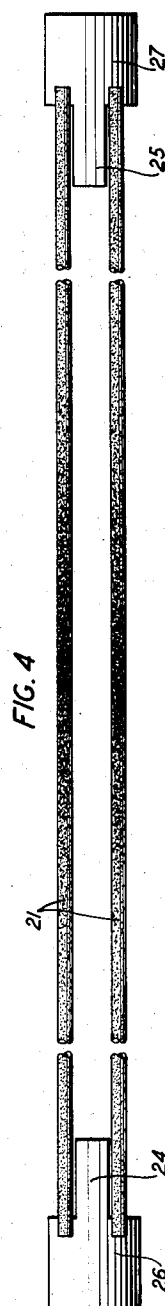
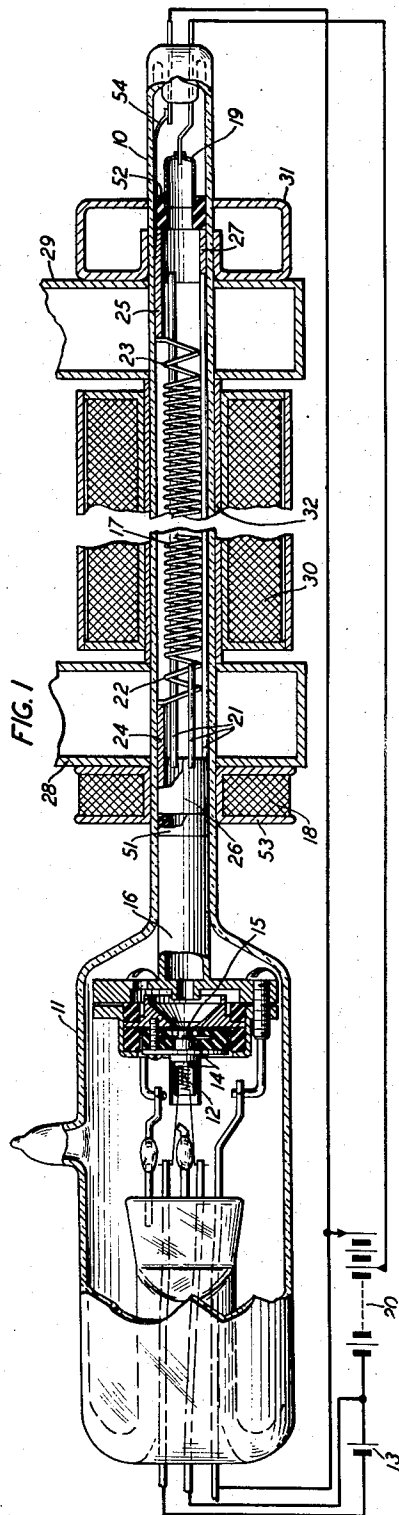
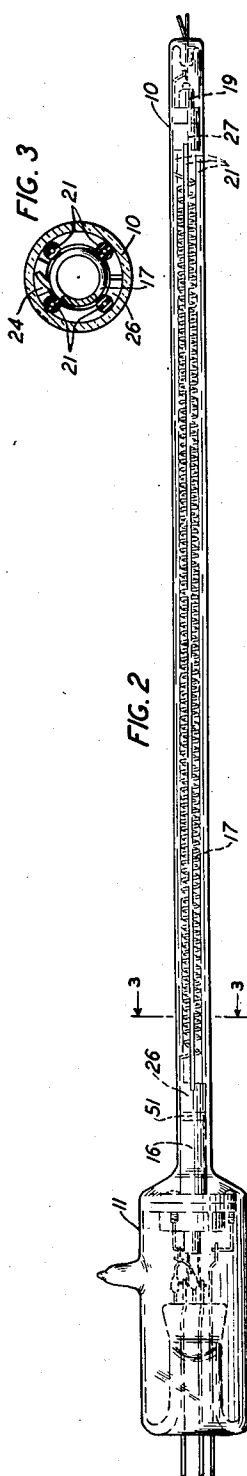
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2,575,383

HIGH-FREQUENCY AMPLIFYING DEVICE

Filed Oct. 22, 1946

2 SHEETS--SHEET 1



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2 SHEETS—SHEET 2

FIG. 5

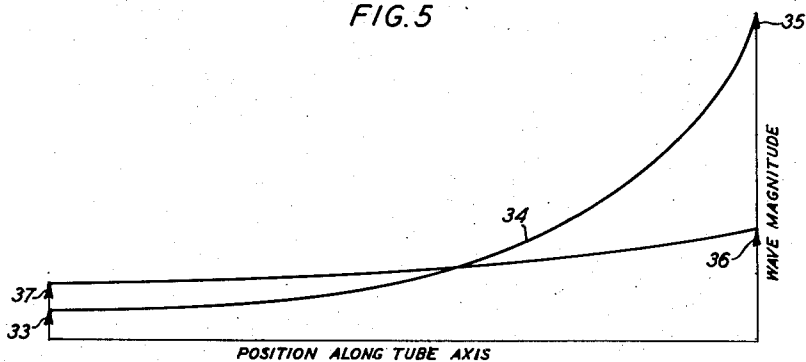


FIG. 6

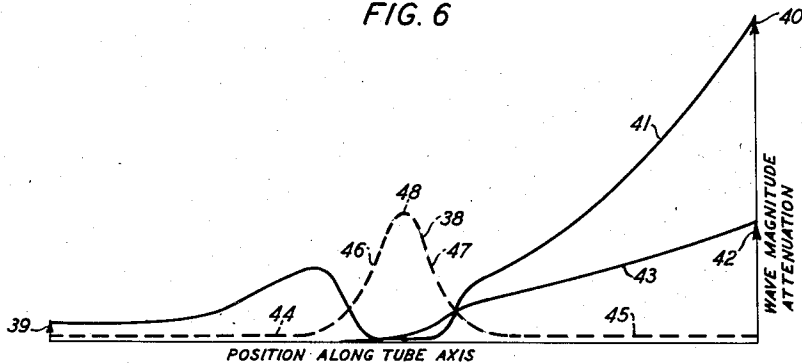
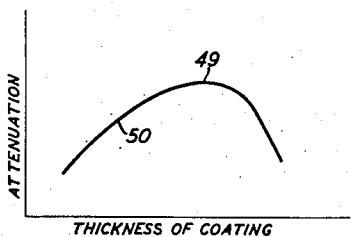


FIG. 7



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2,575,383

HIGH-FREQUENCY AMPLIFYING DEVICE

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Application October 22, 1946, Serial No. 704,918

20 Claims. (Cl. 315—39)

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This invention relates to devices for amplifying high frequency electric waves, and particularly to such devices in which amplification is had through interaction between an electron stream and a high frequency electric field associated with the waves to be amplified over an extended distance such as a distance of more than a wavelength along the transmission path of the wave. It relates also particularly to devices for introducing a loss along the path of the high frequency field and the electron stream so as to prevent self-oscillation.

A principal object of the invention is to minimize tendencies toward self-oscillation in high frequency devices of the type which utilize the interaction of an electron stream and the high frequency field of waves the stream and waves traveling along a common path.

An object of the invention is to provide means for introducing a loss along the path of the field of the traveling wave in a device of the character described.

A further object of the invention is to overcome the effects of impedance mismatch between the output circuit of the amplifying device and the transmission circuit associated therewith.

Another object of the invention is to extend the band width over which the amplifying device is capable of providing effective transmission.

A still further object of the invention is to prevent the accumulation of non-uniform static charges on the supporting structure along the path of the beam in a device of the character described.

Copending application Serial No. 704,858, filed October 22, 1946, by J. R. Pierce, describes an electronic amplifying apparatus for high frequencies in which the transmission path of the wave to be amplified is incorporated into the amplifying apparatus. The traveling wave follows a path such that the associated electric field may be traversed by an electron stream having a velocity of the same order of magnitude as that at which the traveling wave moves through the amplifying apparatus. Under such conditions the electron stream reacts on the electric field and the electric field reacts on the electron stream in such a manner that the wave traveling along the path in the same direction as the electron stream increases in amplitude with distance while a wave traveling against the stream is little affected by the presence of the electrons. Thus, the device acts as an amplifier for waves

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traveling in the same direction as the electron stream.

In the employment of this device, the useful range of amplification which can be utilized is limited by a tendency to generate self-sustaining oscillations as the amplification is increased. This effect appears to be caused by the impossibility of attaining a perfect impedance match between the output circuit of the device and the load circuit, over all of the wide range of frequencies over which a wave traveling along the helix in the direction of electron flow is caused to increase by interaction with the electron stream. As a result of the mismatch or improper termination of the transmission path within the device at some frequencies a portion of the energy is reflected back toward the input end of the amplifying device in accordance with the well-known behavior of transmission lines. If the reflected wave is little attenuated by travel along the helix in a direction opposite to the motion of the electron stream, sufficient energy will reach the input end of the device so that the portion of this energy which is reflected from the input end will cause the generation of self-sustaining oscillations.

The amplifying device disclosed and claimed in the J. R. Pierce application to which reference has been made utilizes a series of rods of electrically non-conductive ceramic material of low dielectric constant for supporting the helical wave transmission conductor. It has been found that the rods and the inner walls of the evacuated envelope tend to accumulate high static charges with subsequent random discharges and arcing. This phenomenon is particularly troublesome in that the rods are not uniformly exposed to the electron stream and the variations in potential distribution along the helix lead to generally unstable and unsatisfactory operation.

In accordance with the present invention these difficulties may be remedied by coating the ceramic supporting rods of the helical wave transmission conductor with a highly resistive material such as colloidal graphite and with a particular thickness distribution along the rods. A light coating of extremely high resistance is applied along the greater portion of the rods to provide a conductive path for incident electrons and hence prevent the accumulation of an excessive static electric charge. At the center of the rod, however, the conductivity of the path is greatly increased by increasing the thickness of the coating. Such a thickness distribution results in the concentration of the greater portion

of the attenuation in the central region and the reflected wave energy is dissipated with a minimum of reduction in the amplitude of the wave traveling in the direction of the electron stream.

It is an important feature of the present invention that the conductive coating may be readily applied to the helix support rods during the construction of the device. Furthermore, the thickness of the coating may be more readily controlled to achieve the desired conductivity magnitude and distribution characteristics than in structures utilizing other methods of obtaining an energy dissipative characteristic along the length of the helical transmission path.

The features of this invention are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may be better understood by reference to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 shows a wave amplifying device of the type to which the present invention pertains with parts broken away and other parts in section;

Fig. 2 shows an external view of the wave amplifying device;

Fig. 3 is an enlarged cross-sectional view of the wave amplifying device taken along the line 3—3 of Fig. 2 which illustrates the manner in which the ceramic support rods are disposed between the helix and the envelope;

Fig. 4 is a view of the support rod assembly which shows the distribution of the dissipative coating along the rods;

Fig. 5 is a qualitative graph of wave amplitudes in an amplifying device in which there is no dissipative material;

Fig. 6 is a qualitative graph of wave amplitudes in an amplifying device to which the present invention has been applied; and

Fig. 7 is a representation of the manner in which the effective wave attenuation varies with a variation in the thickness of the coating of the dissipative material.

Referring now particularly to Fig. 1, there is shown an illustrative embodiment of a discharge device adapted to be used as an amplifier for ultra-high frequencies. The arrangement shown comprises an electron beam tube including an evacuated envelope having an elongated portion 10. This portion, which is of uniform diameter along its length, connects with an enlarged electrode containing portion 11. The envelope is constituted of a low loss insulating material such as glass or quartz.

The tubular envelope portion 10 is provided at one end with a means such as a known type of electron gun for producing an electron beam. The combination shown comprises a heater 12 which is supplied with energy by a source 13, a cathode 14, and an aperture 15 for confining the electrons emitted from the cathode to a concentrated stream. One side of heater 12 is connected to cathode 14. A metallic cylinder 16 having a configuration which will provide suitable electric field patterns is biased to a positive potential in order to accelerate and focus the electron stream. The electron stream is further concentrated and guided along an axial path within the space surrounded by a helix 17 by a magnetic focussing coil 18 and a cylindrical coil 30. The strong magnetic field formed by the coil 30 serves also to prevent the deviation of the electron stream from the desired path by outside magnetic

influences. Anode 19 serves to collect the electrons arriving at the end of the envelope.

In the operation of the device the focussing cylinder 16 and the helix 17 are maintained at a potential of the order of fifteen hundred to two thousand volts above that of the cathode 14 by a potential source conventionally represented by a battery 20. A conductor 54 serves to impart the high potential to the helix 17. The collector 19 is maintained at a somewhat lower potential by a tap on the same potential source for the purpose of decelerating the electron stream before it strikes the collector. This is by no means essential to the operation of the device and the collector may be maintained at a potential higher than that of the helix.

The portions of the device just described are related only to the generation of a stream of electrons and guiding them through the envelope. The electrodes which make up the high frequency system of the device serve to introduce the high frequency waves to be amplified into the envelope, provide a path along which the waves may travel to interact with the electron stream, and to couple the path of the waves to the electron stream. The device is normally intended for the uniform amplification of a wide band of high frequency waves at wavelengths in the order of three to ten centimeters and the high frequency portions of the device must necessarily have dimensions suitable for use at the particular wavelength to be amplified. Since the band width of the waves to be amplified may well be of the order of several hundred megacycles, the expression "wavelength to be amplified" will be understood to denote the wavelength of the frequency at the center of the band.

The helix 17, which serves as the path along which the waves may be propagated, is wound with several turns per wavelength along its axis which may preferably be of a length of thirty to forty of the wavelengths to be amplified. The helix is supported by a series of non-conductive ceramic rods 21 which are disposed between the helix and the envelope. This preferred structure is better illustrated by Fig. 2 which is an external view of the device shown in section in Fig. 1, and by the section taken along the line 3—3 in Fig. 2 and shown in Fig. 3. As shown in Fig. 3, the support rods act to hold the helix firmly in a position concentric with the tubular envelope.

There is provided at the input end of the helix a hollow cylindrical metallic section 26 which supports the input coupling strip 24 and at the output end of the helix a similar cylindrical section 27 which supports the output coupling strip 25. The input coupling strip support section 26 and the output coupling strip support section 27 are positioned in spaced relation to the cylinder 16 and the anode 19 by the ceramic spacer 51, the helix support rods 21, and the ceramic spacer 52. The coupling strips 24 and 25 and support sections 26 and 27 are each in the order of one-eighth of the length of the wavelength to be amplified. They are illustrated in greater detail in Fig. 4, in which the identification numbers correspond with those of Fig. 1.

The helix 17 is joined to the input coupling strip 24 by the input impedance matching section 22 and to the output coupling strip 25 by the output impedance matching section 23. These matching sections are simply extensions of the helix in which the spacing between turns is increased along the circumference of the helix

and serve to provide a wave transmission path of uniformly changing impedance from the relatively high impedance at the end of the coupling strip to the relatively low impedance of the central portion of the helix. An amplifying device employing impedance matching sections of this type is disclosed and claimed in application Serial No. 705,181, filed October 23, 1946, by W. W. Mumford.

In order to utilize the device in an operable system, there is provided an incoming wave path conventionally represented by the input wave guide 28 into which there is introduced the input wave signal to be amplified. An output wave path shown as the output wave guide 29 serves to transfer the amplified output wave to the load circuit. The wave resonator 31 is coupled to the conductor 54 in order to prevent the radiation of high frequency energy imparted to the conductor by the helix 17. The action of the resonator is adequate to fulfill its intended purpose over the entire band of frequencies to be amplified even though the resonator is resonant to some frequency near the center of the band. The input and output wave guides are joined by the metallic cylinder 32 and further connected electrically to the metallic shell 53 of the focussing coil 18 and the wave resonator 31 to provide, in effect, the outer conductor of a concentric transmission line. The input coupling strip support section 25 in conjunction with the metallic shell 53 of the focussing coil 18 and the wall of the wave guide 28 form an open-circuited transmission line which is electrically one-quarter the length of the wavelength to be amplified. It thus acts as a low impedance path across the opening in the wall of the wave guide through which the envelope 10 is inserted and as a low impedance support point for the coupling strip 24. The output coupling strip support section cooperates with the walls of the wave resonator 31 and the output wave guide 29 in a similar manner to provide a low impedance support point for the output coupling strip 25.

In the operation of the device the input wave guide 28 is coupled to a source of signal energy so as to produce a mode of wave propagation having an electric field vector parallel to the coupling strip 24. A corresponding wave is thus generated along the coupling strip and imparted to the helix through the impedance matching section 22. This matching section acts as a tapered transmission line and transfers the wave from the relatively high impedance at the end of the coupling strip to the relatively low impedance of the helix with a minimum reflection of energy back to the signal source. The wave then travels along the circumference of the helix at a speed approximating that of light, but at a linear velocity along the axis of the tube which is smaller in proportion to the ratio of the distance between turns to the circumference per turn. The initial interaction between the traveling wave and the electron stream is very slight, the wave serving initially only to produce waves of charge density and velocity in the electron stream. However, as the wave and the electron stream travel along the axis of the helix and a wave is established in the electron stream, a condition is established in which the wave travels a little slower than the electrons forming the modulated electron stream and the electrons impart energy to the wave in a manner which increases the amplitude of the wave at a rapidly increasing rate. As the amplified wave reaches

the output end of the helix, it traverses the second impedance matching section 23 and is transferred to the output wave guide 29 by means of the coupling strip 25.

In Fig. 5 there is shown a qualitative representation of the wave amplitude relationships within the device. Assuming an input wave to the helix of a magnitude represented by ordinate 33 as the wave travels along the helix, it is reinforced by the interaction of the field of the wave with the moving electron stream and increases in accordance with the curve 34 to reach the amplitude represented by ordinate 35 at the output end of the helix. It is to be noted that the amplitude grows slowly at first, but at an increasing rate, so that a major portion of the amplification is achieved along the last third of the path traveled. This effect is an important consideration in the present invention.

Now, considering the action as the amplified wave reaches the impedance matching section 23 at the output end of the helix 17, it is desirable to point out that the impedance match achieved by the tapered line of the type shown provides a standing wave ratio in the order of two decibels over a frequency range of several hundred megacycles. While this is an extremely favorable termination over such a band width by the present standards of the art, there will still exist a reflected wave at the output end of the helix whose amplitude may be represented at 36. This wave is very little affected by the electron stream and hence will propagate back along the helix with very little attenuation. The wave will reach the input end of the helix with an amplitude which may be represented at 37 and will, in turn, be reflected back toward the output end of the helix. While the phase relationship of the waves is not shown in this diagram, it will be realized that with the random frequency and phase distribution of a wide band of frequencies always present as random fluctuations, there will be some reflected wave having a component in phase with an input wave so that there will result a self-sustaining oscillation. While this effect will not manifest itself at levels of amplification such that the wave reflected from the output end will be largely dissipated before reaching the input end of the helix, such a manner of operation would not begin to utilize the full capabilities of the device as a high frequency amplifier.

It will be seen that the deliberate introduction of an artificial loss along the helix so as to provide a dissipation of the reflected wave will serve to greatly increase the range of useful amplification which can be achieved with a device of this type. There is shown in Fig. 6 a qualitative representation of the wave amplitude relationships in a device of the character described in which the attenuation along the helix is represented by the broken line 38. In such a device the input wave having an amplitude represented by the ordinate 39 increases slowly in amplitude, drops rapidly through the region of high attenuation, and then rapidly increases to the amplitude 40 at the output end of the helix in the manner shown by the curve 41. The apparent amplification is thus reduced only slightly, due to the cumulative effect of the density variations of the electron stream previously described. The reflected wave represented at 42 is, however, reduced to a very low value, as shown by curve 43, thus permitting a large increase in level of amplification to be achieved in practice. The greater attenuation of the reflected wave will serve also

to extend the band width over which the device may be used as an amplifier since the limitations due to the requirements of good impedance match over the band of frequencies are effectively reduced.

In accordance with the principles of the present invention the artificial attenuation may be most advantageously introduced along the length of the helix by coating the helix support rods 21 with a suitable dissipative material. The dissipative coating easily may be applied during the process of manufacture; the thickness distribution easily may be controlled to provide any desired type of attenuation characteristic; and the coating also serves in the operation of the device to prevent the accumulation of static charges due to the incidence of electrons upon the non-conductive support rods 21 and upon the inner walls of the envelope 10.

The dissipative coating may be formed of any material which may be readily applied to the surface of the rod and which will provide the proper values of resistance. In practice it has been found that a colloidal graphite commercially known as "Aquadag" is particularly effective both as to ease of application and for obtaining the proper orders of resistance. The graphite may be made into a solution with alcohol and applied by spraying with nitrogen gas in order to avoid the contamination which might be introduced by the use of oxygen. Alcohol is particularly desirable as a solvent since the coating will dry sufficiently rapidly to allow the application of successive coats without running. It is desirable that all of the rods for a given structure be processed as a group so that they will have exactly the same resistance characteristics. It has been found impractical to process the rods separately and then attempt to select units which have identical resistance characteristics for use in the same device.

The use of this and other coating materials in the practice of the invention may be guided by a consideration of the resistance values which have been found to be preferable. Referring again to the attenuation curve 38 of Fig. 6, the resistance per unit length along the end portions of the helix support rods represented at 44 and 45 may have a value in the order of one to five megohms per inch. In the region where the resistance per unit length is rapidly decreasing, represented at 46 and 47 along curve 38, the resistance per unit length may be in the order of 7,000 to 15,000 ohms per inch, while in the region of minimum resistance per unit length, represented at 48, a desirable value is in the order of 600 ohms per inch. It is desirable to point out in this connection that the resistance characteristic along the rod must vary smoothly. Any abrupt change in resistance value will have the effect of a discontinuity in a transmission line so that spurious oscillations may be formed in the regions between the point of reflection and the input or output end of the helix.

By way of illustration, there is shown in Fig. 4 an enlarged view of the helix support rods 21, in which the surface shading represents the coating thickness along the length of the rod.

Since the coated rod is in intimate contact with the outer surface of the turns of the helix, it is necessary that the conductivity along the rod not be increased beyond that of the indicated preferable minimum value of resistance per unit length. This will be apparent from a con-

sideration of the fact that the loss of energy is caused by the electric field vector of the traveling wave cutting the conductive coating in such a manner as to induce eddy currents which are in turn dissipated in the coating. It has been found that if the conductivity of the coating along the rod is made too high the mode in which the high frequency wave is propagated along the helix is changed to such an extent that the desired dissipative effect is substantially reduced. The graph of Fig. 7 shows in a qualitative way the relationship between the thickness of the coating of dissipative material and the effective attenuation which may be attained in the operation of the device. The maximum point 49 of the curve 50 represents an attenuation in the order of 20 decibels per inch.

In the operation of a device of the character described, it has been found that when the conductive coating of the present invention is not incorporated in the structure of the device, the incidence of electrons upon the ceramic supporting rods and upon the inner wall of the envelope tends to cause the formation of large static charges on the surfaces of these members. Since the metallic turns of the helix shield portions of these surfaces, the charging effect is non-uniform, so that the potential distribution along the path of the traveling waves and the electron stream will depart materially from that produced by the high frequency electrodes. Furthermore, the charges may accumulate to such an extent that energy redistribution may take place between the regions of differing potential level through random arcing and discharge phenomena. It will be seen that this phenomenon is particularly objectionable since it leads to erratic and unstable operation and may even prevent the operation of the device in its intended manner.

The present invention remedies the aforementioned difficulty by providing a conductive coating along the ceramic support rods and in contact with the inner walls of the envelope. This conductive coating prevents the accumulation of charges of varying magnitudes in separate regions of the structure by providing a path along which the electrons may flow. It will be apparent that while the total accumulated charge may vary from time to time, the charge will be uniformly distributed and hence have no effect upon the operation of the device.

While the invention has been described and illustrated in connection with a preferred structural embodiment, it will be realized that other forms of application are contemplated. For example, it is by no means necessary to combine the charge reducing function with that of the wave dissipating function in a single structure, since either function of the invention may be utilized independently in conjunction with other means of accomplishing the function of the other.

What is claimed is:

1. In a wave amplifying device, an evacuated container, a transmission path capable of guiding high frequency electrical waves, said transmission path comprising a conductor in the form of an elongated helix, means to impress waves to be amplified upon an input end of said transmission path to permit travel of the waves along said path, electrode means to direct an electron stream through the field region of said transmission path in the direction of wave travel, means to abstract amplified waves from an out-

put end of said transmission path, and supporting means for said helix comprising a plurality of members extending along the surface of said helix and disposed between said helix and said container, said members being of an electrically resistive material for introducing a high frequency loss into said transmission path.

2. In a wave amplifying device, an evacuated container, a transmission path capable of guiding high frequency electrical waves, said transmission path comprising a conductor in the form of an elongated helix, means to impress waves to be amplified upon an input end of said transmission path to permit travel of the waves along said path, electrode means to direct an electron stream through the field region of said transmission path in the direction of wave travel, means to abstract amplified waves from an output end of said transmission path, supporting means for said helix comprising a plurality of non-conductive members extending along the surface of said helix and disposed between said helix and said container, and means for incorporating into said wave transmission path a high frequency loss, said means comprising a coating of electrically resistive material on the surface of said supporting members.

3. In a wave amplifying device, an evacuated container, a transmission path capable of guiding high frequency electrical waves, said transmission path comprising a conductor in the form of an elongated helix, means to impress waves to be amplified upon an input end of said transmission path to permit travel of the waves along said path, electrode means to direct an electron stream through the field region of said transmission path in the direction of wave travel, means to abstract amplified waves from an output end of said transmission path, a plurality of non-conductive members extending along said helix, and means for incorporating into said wave transmission path a high frequency loss, said means comprising a coating of electrically resistive material on the surface of said non-conductive members, said coating being non-uniformly distributed to prevent self-oscillation with a minimum of loss.

4. In accordance with claim 2, said high-frequency loss means comprising a layer of colloidal graphite.

5. A wave amplifying device in accordance with claim 2, said high-frequency loss means being non-uniformly distributed along the surface of said supporting members to provide a relatively high loss in one region along the length of the helix while providing relatively low loss along the remaining regions.

6. A wave amplifying device in accordance with claim 2, said high-frequency loss means comprising a layer of colloidal graphite of such a thickness distribution that the resistance of the coating on each member varies from the order of megohms per inch at the ends of the said supporting members to the order of 600 ohms per inch at the center of said supporting members.

7. A wave amplifying device comprising a transmission line having an input end and an output end, one side of said transmission line comprising a conductor in the form of an elongated helix in an evacuated enclosure, means to direct a beam of electrons lengthwise of and within said enclosure, coupling means within said enclosure to supply signal waves to be amplified to said input end, a second coupling means within said enclosure to abstract amplified signal waves

from said output end, supporting means for said helix comprising a multiplicity of non-conductive members extending longitudinally between said two coupling means and disposed in contact with said helix at circumferentially spaced points to support it, and wave dissipative means distributed along and carried by said supporting members.

8. A wave amplifying device in accordance with claim 7, said wave dissipative means comprising a layer of colloidal graphite on the surface of said members.

9. A wave amplifying device in accordance with claim 7, said wave dissipative means being non-uniformly distributed along the surface of said supporting members to provide a relatively high loss in one region along the length of the helix while providing relatively low loss along the remaining regions.

10. A discharge device comprising an elongated envelope, wave-conducting means comprising a conductor in the form of an elongated helix within said envelope, means within said envelope to direct an electron stream axially of said helix, means to impress waves to be amplified upon an input end of said wave-conducting means to permit said waves to travel along said conducting means and interact with said electron stream, means to abstract amplified waves from an output end of said wave-conducting means, non-conductive supporting members for said helix disposed between and in contact with said helix and said envelope at discrete circumferentially spaced points, and a superficial coating over said supporting members effective to lessen the charging tendencies of said supporting members due to the incidence of electrons from said electron stream and comprising a layer of partially conducting material.

11. A discharge device in accordance with claim 10, said coating comprising a layer of colloidal graphite.

12. A discharge device comprising an elongated envelope, wave-conducting means comprising a conductor in the form of an elongated helix within said envelope, means within the envelope for producing an electron stream axially of said helix, means to impress waves to be amplified upon an input end of said wave-conducting means to permit said waves to travel along said conducting means and interact with said electron stream, non-conductive supporting members for said helix disposed between said helix and said envelope, and a superficial coating over said supporting members effective to lessen the charging tendencies of said supporting members due to the incidence of electrons from said electron stream and comprising a layer of partially conducting material, said supporting members being elongated rods and said coating comprising a layer of colloidal carbon of such a thickness distribution that the resistance of the coating on each member varies from the order of one megohm per inch at the ends of said supporting member to the order of 600 ohms per inch at the center of said supporting member.

13. A wave amplifying device comprising an evacuated container, means for producing a beam of electrons therein, a wave transmission conductor disposed along the path of the beam for the propagation of high frequency electrical waves in the direction of said beam and at the same order of velocity as said beam, and means for introducing effective dissipation in the electromagnetic field of the waves propagated along

said conductor comprising a non-conductive member having a coating of a conductive material supported and extending in a direction generally parallel to said beam within said field.

14. A traveling wave electronic amplifier comprising an evacuated container, means for propagating a beam of electrons over an extended path therein, means for causing a traveling electromagnetic field of energy which is to be amplified to be propagated in the same direction as the beam and at the same order of propagation velocity, and energy dissipative means comprising a non-conductive rod extending parallel to said beam and having a coating of conductive material distributed therealong to introduce substantial loss for electromagnetic waves propagated in a direction opposite to that of said beam.

15. In a wave amplifying device, an evacuated container, a transmission path capable of guiding high frequency electrical waves, said transmission path comprising a conductor in the form of an elongated helix, means to impress waves to be amplified upon an input end of said transmission path to permit travel of the waves along said path, electrode means for projecting an electron stream through the field region of said transmission path in the direction of wave travel, means to abstract amplified waves from an output end of said transmission path, supporting means for said helix comprising a plurality of substantially parallel non-conductive rod-like members extending along the surface of said helix and disposed between said helix and said container, and means tending to electrically isolate said input circuit from waves derived from said output circuits, said means comprising a coating of electrically resistive material on the surface of said supporting members.

16. A wave amplifying device comprising a transmission line having an input end and an output end, one side of said transmission line comprising a conductor in the form of an elongated helix in an evacuated enclosure, means to direct a beam of electrons lengthwise of and within said enclosure, coupling means within said enclosure to connect a source of input waves to be amplified to said input end, impedance transforming means connected between said coupling means and said helix, a second coupling means within said enclosure to connect a load circuit to said output end, impedance transforming means connected between said helix and said second coupling means, at least one of said impedance transforming means comprising a section of transmission line having a continuously varying linear velocity of wave transmission along its length, supporting means for said helix comprising a plurality of electrically non-conductive rod-like members extending longitudinally along said helix substantially from one of said coupling means to the other, and wave dissipative means distributed along and carried by said supporting members.

17. A wave amplifying device in accordance with claim 16, at least one of said impedance transforming means comprising a section of elongated helix having varying pitch in successive turns.

18. A discharge device comprising an elongated envelope, wave-conducting means comprising a conductor in the form of an elongated helix

within said envelope, means within the envelope for producing an electron stream axially of said helix, means to impress waves to be amplified upon an input end of said wave-conducting means to permit said waves to travel along said conducting means and interact with said electron stream, a plurality of non-conductive supporting members for said helix disposed between said helix and said envelope at circumferentially spaced points, and a superficial coating over said supporting members effective to lessen the charging tendencies of said supporting members due to the incidence of electrons from said electron stream and comprising a layer of partially conducting material, said superficial coating being also in intimate contact with the inner wall of said envelope.

19. In a wave amplifying device, an evacuated container, a transmission path capable of guiding high frequency electrical waves, said transmission path comprising a conductor in the form of an elongated helix, means to impress waves to be amplified upon an input end of said transmission path to permit travel of the waves along said path, electrode means to direct an electron stream along said path through the field region of said helix in the direction of wave travel, means to abstract amplified waves from an output end of said transmission path, supporting means for said helix comprising a plurality of substantially parallel rod-like members extending along the surface of said helix, and means for incorporating into said wave transmission path a high frequency loss, said means comprising wave dissipative means distributed along and carried by said supporting members.

20. A discharge device comprising an elongated envelope, wave-conducting means comprising a conductor in the form of an elongated helix within said envelope, means within said envelope to direct an electron stream axially of said helix, means to impress waves to be amplified upon an input end of said wave-conducting means to permit said wave to travel along said conducting means and interact with said electron stream, means to abstract amplified waves from an output end of said wave-conducting means, non-conductive supporting members for said helix and a superficial coating over said members effective to lessen the charging tendencies of said members due to the incidence of electrons from said electron stream and comprising a layer of electrically resistive material.

LESTER M. FIELD.

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