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HIGH-FREQUENCY AMPLIFYING DEVICE

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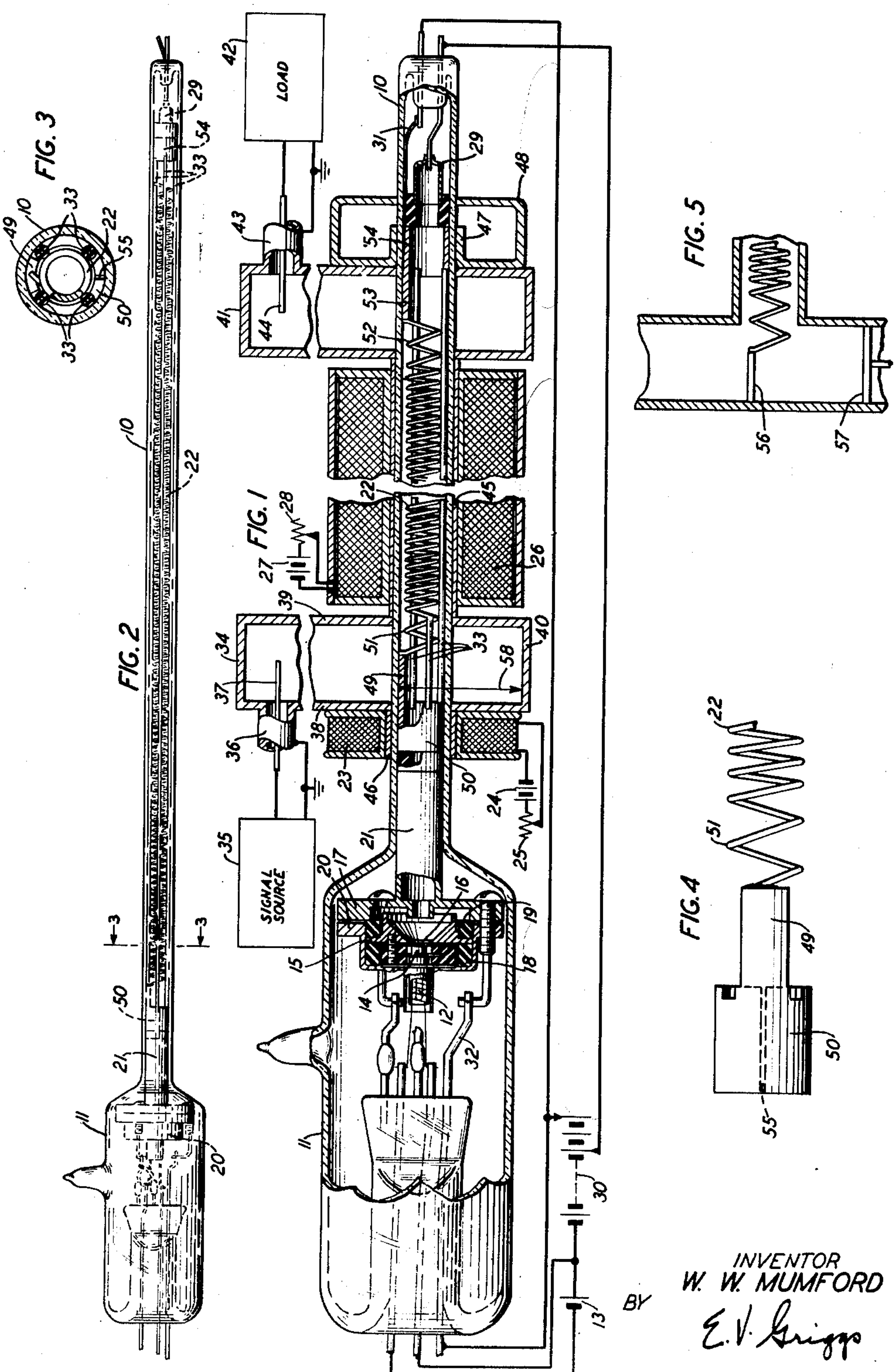

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HIGH-FREQUENCY AMPLIFYING DEVICE

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This invention relates to devices for amplifying high frequency electrical waves, particularly such device 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 coaxial line to wave guide transducers adapted for use over a wide band of frequencies.

A principal object of the invention is to extend the band width of effective transmission in high frequency devices of the type which utilize the interaction of an electron stream and the high frequency field of waves traveling along a common path.

An object of the invention is to overcome the effects of impedance mismatch between a device of the character described and the transmission circuits associated therewith.

A further object of the invention is to provide an electric wave transducer suitable for impedance matching between a wave guide and a coaxial transmission line of the type having a helical inner conductor over a wide band of frequencies.

Copending application Serial No. 704,858, filed October 22, 1946, by J. R. Pierce, now United States Patent 2,602,148, granted July 1, 1952, 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 traveling in the same direction as the electron stream.

A wave amplifying device of the character described is essentially of a non-resonant nature, that is, it does not depend for amplification upon resonance effects within the tube structure as has been necessary in devices previously utilized at the very high frequency portion of the spectrum. The device is, therefore, very well adapted for use in applications wherein it is necessary to amplify signals which cover a wide band of frequencies, for example of the order of several hundred megacycles at wavelengths of the order of three to ten centimeters.

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The usefulness of the device in the amplification of such wide band signals has, however, been limited by the nature of the input and output coupling devices which have heretofore been known. While the wave guide structures used for conducting the signal to be amplified to the device, and the amplified output signal to the load circuit are by their nature adapted for use with broad band signals, still the transducers used to couple the wave guides to the transmission path within the device have a relatively sharp frequency-versus-impedance characteristic and hence are not well adapted to the transmission of broad band signals.

A preferred structure for the amplifying device described in the J. R. Pierce application, to which reference has been made, utilizes a wave transmission path in the form of a concentric transmission line in which the central conductor is an elongated helix. Wave guides are utilized for the transmission of signals to and from the device and coupling strips in the order of one-fifth of a wavelength of the signals to be amplified in length in the field within the wave guide serve to impart the signal to be amplified to the helix and the amplified signal from the helix to the output wave guide. Since the tip of the coupling strip is a relatively high impedance point while the natural impedance of the helical conductor is relatively low, there is an impedance discontinuity which in the operation of the device would have the effect of reflecting a portion of the impinging waves. While the discontinuity may be eliminated by the proper positioning of the coupling strip, the resultant impedance-versus-frequency characteristic of the system is relatively narrow and not adequate to utilize the full capabilities of the amplifying device.

The present invention contemplates a coupling from the wave guide to helix in which the natural impedance at the tip of the coupling strip is matched to that of the helix by the use of a structure which has a smoothly varying or "tapered" impedance characteristic between the coupling strip and the helix. Such a characteristic is obtained by varying the spacing between the turns of a section of the helix, preferably in accordance with an exponential function. It is also an important feature of the invention that the coupling strip be positioned a distance in the order of a fifth of the length of the waves to be amplified from a closed off end of the wave guide. There is thus provided a reactance characteristic which varies in a manner opposite in direction to that of the coupling strip as the frequency is varied so as to provide a very broad impedance versus frequency characteristic.

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 drawing, 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 an enlarged view of the coupling section showing the coupling probe, support cylinder and the impedance transforming section; and

Fig. 5 is an illustrative view of a wave guide to concentric transmission line transducer utilizing the impedance transformer of the invention.

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 quartz or glass.

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 a metallic disk **15** having an aperture **16** for confining the electrons emitted from the cathode to a concentrated stream. An annular ring **17** held in spaced non-conductive relation to the disk **15** by ceramic insulating rings **18** and **19** and a flange **20** supports a cylinder **21** having a configuration which will provide field patterns suitable to accelerate and focus the electron stream when the cylinder is biased to a suitable potential. The electron stream is further concentrated and guided along an axial path within the space surrounded by a helix **22** by a magnetic focussing coil **23** energized by a battery **24** through a rheostat **25** and by cylindrical coil **26** energized by a battery **27** through a rheostat **28**. The strong magnetic field formed by the coil **26** serves also to prevent the deviation of the electron stream from the desired path by an outside magnetic influence. Anode **29** serves to collect the electrons arriving at the end of the envelope.

In the operation of the device the focussing cylinder **21** and the helix **22** are maintained at a potential of the order of fifteen hundred to two thousand volts above that of the cathode by a potential source conventionally represented as a battery **30**. A conductor **31** within the envelope **10** serves to impart the high potential to the helix **22**, while conductor **32** serves similarly to impart the high potential to the focussing cylinder **21**. The collector **29** 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 transfer the amplified waves to the output circuits associated with the device. 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 **22** serves as a path along which the waves to be amplified are propagated in order that they may react with the electron stream flowing therethrough. In order to perform this function, the dimensions of the helix must be such that the linear velocity at which a wave traveling along the circumference of the helix advances along the axis is of some value to which the electron stream may be accelerated by the use of moderate voltages. For accelerating voltages in the order of fifteen hundred to two thousand volts, the helix may be wound with several turns per wavelength along the axis which may in turn have a length of the order of thirty or forty wavelengths of the wave to be amplified.

The helix is supported by a series of electrically non-conducting ceramic rods **33** which are disposed between the helix **22** and the envelope **10**. This preferred structure is better illustrated by Fig. 2 which is an external view in section and with parts broken away of the device shown 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 **33** act to hold the helix **22** firmly in a position concentric with the tubular envelope **10**.

There are provided wave guide paths external to the amplifying device for conducting to the device the waves to be amplified and the amplified waves to a transmission or load circuit. At the input end of the helix **22** a wave guide **34** of rectangular cross-section and preferably of dimensions such that the waves to be amplified will be propagated through the interior of the guide in a TE_{10} mode, is coupled to an input signal source **35** of the waves to be amplified. The coupling is represented conventionally as a coaxial transmission line **36** and a probe **37** but should be of a design suitable for the transmission of wide band signals as is described in application Serial No. 585,096 filed March 27, 1945 by W. W. Mumford (issued as United States Patent 2,527,146 on October 24, 1950) or in United States Patent No. 2,408,032, issued September 24, 1946, to A. C. Beck. The amplifying device is inserted transversely through the wave guide so that the axis of the helix **22** passes perpendicularly through the center of side walls **38** and **39** and the distance from the inner side of end wall **40** to the coupling strip **49**, as indicated by arrow **58**, is about one-fifth of the length of the wavelength of the waves to be amplified. At the output end of the helix **22** the amplifying device is similarly positioned through an output wave guide **41** which is coupled to a load **42** by means of a transmission line **43** and a probe **44**.

The input wave guide **34** is joined with the output wave guide 41 by a metallic cylinder 45 of non-magnetic material surrounding the envelope 10. This cylinder cooperates with the helix 22 to form a concentric transmission line and serves also to prevent outside electric fields from influencing the path of the electron stream through the helix without affecting the action of the solenoid 26. A cylindrical section of non-magnetic conducting material 46 is attached to the input wave guide 34 and the metallic wall 47 of a wave resonator 48 is electrically connected to the output wave guide 41 to effectively extend the length of the outer conductor of the transmission line. While this outer conductor may not form a concentric transmission line in the conventional sense in view of the high frequency wave propagation characteristics in the wavelength range at which the device is intended to operate, such nomenclature will be used for convenience of discussion and description with no intent to limit the functioning of the amplifier.

The wave resonator 48 is coupled to the helix high voltage supply lead 31 and functions as a high frequency choke to prevent the radiation of high frequency energy imparted to the lead by the helix 22. The resonator is adjusted to some frequency near the center of the band of frequencies to be amplified and its action is adequate to fulfill the intended purpose over the entire band.

In accordance with the present invention there is provided a device for the transfer of high frequency wave energy between the wave transmission paths external to the amplifying device and the wave transmission path within the amplifying device which will act as an impedance matching connection over a wide band of frequencies. The wave energy is thus transferred between the external transmission systems and the input and output portions of the amplifier over an electrically "smooth" path and reflection effects are avoided. This is an important advantage inasmuch as the presence of reflected waves along the transmission path within the device may cause the formation of self-sustaining oscillations.

At the input end of the helix 22 an input coupling strip 49 is disposed within the envelope 10 in a direction parallel to the electric field lines of the high frequency waves propagated through the wave guide 34 so that a corresponding electric potential is built up along the length of the coupling strip. The coupling strip is supported by a hollow metallic cylinder 50 which fits closely within the envelope 10 and cooperates with the metallic cylinder 46 outside the envelope 10 to form a transmission line having an electrical length of one-quarter of the wavelength of the waves to be amplified. Since the input impedance of an open-circuited quarter wavelength transmission line is very low, the coupling strip support point is a low impedance point electrically. The high frequency waves induced along the coupling strip are imparted to the helix through an impedance transforming section 51 which provides a smoothly varying impedance characteristic from the high impedance at the tip of the coupling strip 49 to the relatively low impedance of the helix 22 so that the wave encounters no impedance discontinuity in traveling from the probe to the helix. At the output end of the helix, the amplified wave similarly traverses an impedance matching section 52 to an output coupling strip 53 which is supported by a metallic cylinder 54 also of one-quarter wave-

length electrically and associated with the surrounding metallic wall 47 to provide a low impedance support point in the same manner as does the corresponding element at the input terminal of the helix 22, so as to induce corresponding high frequency waves in the output wave guide 41. An impedance match is thus provided in the same manner as at the input terminal of the helix 22.

There is shown in Fig. 4 an enlarged view of a coupling assembly comprising the coupling strip 49, the support cylinder 50, and the impedance matching section 51. The coupling strip may have a length in the order of one-eighth of the wavelength of the waves to be amplified so that in conjunction with the dielectric effect of the envelope 10 surrounding the strip it will have an effective electrical length in the order of one-fifth of a wavelength. Similarly the coupling strip support cylinder 50 is in the order of one-eighth of a wavelength of the waves to be amplified in length, but in this case the more intimate disposition of the envelope between the support cylinder 50 and the external cylinder 46 produces an equivalent electrical length of one-quarter of the wavelength of the waves to be amplified. As is shown in end view in Fig. 3 and illustrated in dotted lines in Fig. 4, the support cylinder may preferably be provided with a narrow slot 55 opposite the pick-up probe. This slot will allow a certain amount of mechanical resilience so that the cylinder will be firmly positioned within the envelope 10. The capacitance across the gap is of such a value that the gap will have no effect upon the proper functioning of the cylinder for its intended purpose.

In order to obtain the optimum band-pass characteristic between the wave guide 34 and the helix 22 it is desirable that the coupling strip 49 be positioned within the wave guide at a distance from the inner side of the end wall 40 closing the wave guide 34 which is equivalent to the electrical length of the coupling strip. Since the section of the wave guide between the coupling strip and the end wall of the wave guide acts as a short-circuited transmission line while the coupling strip acts as an open-circuited line the reactance components of impedance of each will vary in opposite directions with change in frequency so that the optimum conditions for impedance matching will be relatively independent of frequency.

The impedance matching section 51 is an extension of the helix 22 in which the spacing between turns is increased uniformly from that of the main portion of the helix to a maximum value at the tip of the coupling strip 49. While the exact spacing to be used must be determined experimentally in any given structure, it appears that the spacing between turns should preferably vary in accordance with a logarithmic curve as might be expected from a consideration of the theory of transmission lines. In a typical amplifier designed for operation at wavelengths in the order of eight centimeters the helix was wound of .027 inch diameter wire spaced 20 turns per inch measured along the longitudinal axis and with an inside diameter of .167 inch. Optimum band-pass characteristics were obtained with an impedance matching section in which the spacing of the first turn was .140 inch and the amount of spacing between turns reduced to that of the helix over a distance of five turns.

In the operation of the amplifying device in its intended fashion, the input signal from the signal source 35 sets up a wave which is propagated through the wave guide 34 in a mode such that there is an electric field vector parallel to the input coupling strip 49. A corresponding wave is thus generated in the input coupling strip which is imparted to the helix 22 through the input impedance matching section 51. 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 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 somewhat slower than the electrons forming the modulated 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 output impedance matching section 52 to the output coupling strip 53 and induces a corresponding wave in the output wave guide 41.

While the general considerations in the design of the coupling devices have been pointed out, it will be realized that extremely small variations in dimensions or even the nature of the conducting surfaces greatly affect the performance of any given unit. For example it has been found that variations in the spot weld at the junction of the pick-up probe and the first turn of the impedance matching section may cause a great variation in the band-pass characteristics of a unit. For this reason it is preferable that each assembly comprising the helix, the input and output impedance matching sections, the input and output probes and supporting cylinders be individually adjusted by standing wave ratio tests in order to obtain the optimum impedance versus frequency characteristic curve before the assembly is incorporated into an amplifier.

The coupling between the amplifying device and the associated wave guides must, in general, be adjusted to obtain the optimum band-pass characteristics for the particular operating condition. Generally speaking, the impedance magnitudes, that is, the magnitude of the impedance of the wave guide at the point where the amplifier is inserted through the guide and the magnitude of the impedance of the helix as it appears at the coupling strip may be matched by adjusting the position of the probe laterally across the wave guide, for example, at the input terminal of the helix 22 between the walls 38 and 39 while the corresponding reactances may be matched by the angular adjustment of the probe position about the longitudinal axis of the amplifying device. The angular adjustment is important primarily from the standpoint of varying the distance from the probe to the end of the wave guide and hence to obtain a desirable reactance versus frequency characteristic as has previously been explained. While the adjustments are not completely independent, they are very nearly so and the optimum coupling may be obtained with very little difficulty. It has been found possible to adjust an amplifier of the type previously described so as to have a standing wave ratio of two decibels over a band width of 900 megacycles.

While the invention has been described in connection with a specific application it will be realized that the principle is capable of more general application. There is shown in Fig. 5, by way of illustration, a wide band transducer suited for coupling a hollow wave guide to a concentric transmission line having a helical inner conductor. This transducer functions in accordance with the general description given in connection with the wave amplifying device with the exception that since the coupling strip 56 is fixed, the reactance adjustments for the desired band-pass characteristics of an individual structure may be adjusted by the tuning piston 57.

What is claimed is:

1. An amplifying space discharge device which comprises an electromagnetic signal wave transmission line, means to direct a stream of electrons lengthwise of and through the field region of said line, input coupling means to supply signal wave energy to one end of said line, impedance transforming means coupled to said input coupling means comprising an end section of said line the impedance of which changes progressively with distance along its length as said input coupling means is approached, output coupling means to withdraw amplified signal wave energy from the other end of said line, and impedance transforming means coupled to said output coupling means comprising an end section of said line the impedance of which changes progressively with distance along its length as said output coupling means is approached.

2. An amplifying space discharge device which comprises a signal wave transmission circuit in the form of an elongated conductive helix, means to direct a stream of electrons lengthwise of and through the field region of said helix, input coupling means to supply signal wave energy to one end of said helix, impedance transforming means coupled between said helix and said input coupling means comprising a continuation of said helix having a ratio of average distance between turns to circumference per turn which varies continuously along its length to change its impedance progressively in successive turns to that of said input coupling means as said input coupling means is approached, output coupling means to withdraw amplified signal wave energy from the other end of said helix, and impedance transforming means coupled between said path and said output coupling means comprising a continuation of said helix having a ratio of average distance between turns to circumference per turn which varies continuously along its length to change its impedance progressively in successive turns to that of said output coupling means as said output coupling means is approached.

3. An amplifying space discharge device which comprises an electromagnetic signal wave transmission line, input coupling means to supply signal wave energy to one end of said line, output coupling means to withdraw amplified signal wave energy from the other end of said line, impedance transforming means coupled to at least one of said coupling means comprising an end section of said line the impedance of which changes progressively with distance along its length from that of said line to that of the coupling means as the coupling means is approached, and means to direct a stream of electrons lengthwise of and successively through the field regions of said line and said impedance transforming means.

4. An amplifying space discharge device which comprises a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, means to direct a stream of electrons lengthwise of and through the field region of said helix, input coupling means to supply signal wave energy to one end of said helix, output coupling means to withdraw amplified signal wave energy from the other end of said helix, and impedance transforming means coupled between said helix and at least one of said coupling means comprising a continuation of said helix having a ratio of average distance between turns to circumference per turn which varies continuously along its length to change its impedance progressively in successive turns to that of the respective coupling means as the coupling means is approached.

5. An amplifying space discharge device which comprises an electromagnetic signal wave transmission line having a substantially constant linear velocity of wave propagation throughout its length, an external signal wave transmission circuit, coupling means between said external circuit and said line comprising an end section of said line the linear velocity of wave propagation of which changes progressively with distance along its length in the direction toward said external circuit, and means to direct a stream of electrons lengthwise of and successively through the field regions of said line and said coupling means.

6. An amplifying space discharge device which comprises a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit, and coupling means between said external circuit and said helix comprising a continuation of said helix in which the pitch changes progressively in successive turns in the direction toward said external circuit.

7. An amplifying space discharge device which comprises a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit, and coupling means between said external circuit and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn progressively changes in successive turns in the direction toward said external circuit.

8. An amplifying space discharge device which comprises a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit, and coupling means between said external circuit and said helix comprising a continuation of said helix in which the center-to-center spacing between adjacent turns progressively changes in successive turns in the direction toward said external circuit.

9. In a wave translating device, a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, an external signal wave transmission circuit, and coupling means

between said external circuit and said helix comprising a continuation of said helix in which the pitch changes progressively in successive turns in the direction toward said external circuit.

10. In a wave translating device, a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, an external signal wave transmission circuit, and coupling means between said external circuit and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn progressively changes in successive turns in the direction toward said external circuit.

11. In a wave translating device, a signal wave transmission circuit in the form of an elongated conductive helix having a substantially uniform pitch throughout its length, an external signal wave transmission circuit, and coupling means between said external circuit and said helix comprising a continuation of said helix in which the center-to-center spacing between adjacent turns progressively changes in successive turns in the direction toward said external circuit.

12. A wave amplifying device which comprises a signal wave transmission circuit in the form of an elongated conductive helix, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit in the form of a hollow wave guide, and coupling means between said wave guide and said helix which includes a continuation of said helix extending into the interior of said wave guide and having dimensions which vary continuously with distance along its length to change its impedance progressively in successive turns.

13. A wave amplifying device in accordance with claim 12 in which said helical conductor extends through an aperture in the wall of said wave guide transversely of the direction of energy propagation of said wave guide.

14. A wave amplifying device which comprises a signal wave transmission circuit in the form of an elongated conductive helix, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit in the form of a hollow wave guide, coupling means in the form of a conductor within said wave guide extending from the wall of said wave guide transversely of the direction of energy propagation of said wave guide, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn progressively increases in successive turns in the direction toward said coupling means.

15. A wave amplifying device in accordance with claim 14 in which the length of the conductor comprising said coupling means is substantially one-fifth of the wavelength to be amplified.

16. A wave amplifying device which comprises a signal wave transmission circuit in the form of an elongated conductive helix, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit in the form of a hollow wave guide closed at one end, coupling means in the form of a conductor within said wave guide extending from the wall of said wave guide transversely of the direction of energy propagation of said wave guide, said conductor having a length

substantially one-fifth of the wavelength to be amplified and being positioned a distance of substantially one-fifth of the wavelength to be amplified from the closed end of said wave guide, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn progressively increases in successive turns in the direction toward said coupling means.

17. A wave amplifying device in accordance with claim 16 in which the pitch of said helix is substantially uniform along its length and in which the pitch of said helix continuation increases progressively in successive turns in the direction toward said coupling means.

18. A wave amplifying device which comprises a signal wave transmission circuit in the form of an elongated conductive helix, means to direct a stream of electrons lengthwise of and through the field region of said helix, an external signal wave transmission circuit in the form of a hollow wave guide, said wave guide having a pair of aligned apertures in opposite walls, a hollow conducting cylinder having a length substantially one-quarter of the wavelength to be amplified and extending through one of the apertures in said wave guide, coupling means within said wave guide in the form of a conductor having a length substantially one-fifth of the wavelength to be amplified and extending from said cylinder transversely of the direction of energy propagation of said wave guide, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix extending through the other aperture in said wave guide and having a pitch which increases progressively in successive turns in the direction toward said coupling means.

19. A wave amplifying device in accordance with claim 18 in which said wave guide is closed at one end and in which said coupling means is positioned a distance of substantially one-fifth of the wavelength to be amplified from the closed end of said wave guide, whereby the reactance of said coupling means and that of the section of said wave guide between said coupling means and the closed end vary in opposite directions with change in frequency to give broad band coupling.

20. In a wave amplifying device, a signal wave transmission circuit in the form of an elongated conductive helix, an external signal wave transmission circuit in the form of a hollow wave guide, and coupling means between said wave guide and said helix which includes a continuation of said helix extending into the interior of said wave guide and having dimensions which vary continuously with distance along its length to change its impedance progressively in successive turns.

21. In a wave amplifying device, a signal wave transmission circuit in the form of an elongated conductive helix, an external signal wave transmission circuit in the form of a hollow wave guide, coupling means in the form of a conductor within said wave guide extending from the wall of said wave guide transversely of the direction of energy propagation of said wave guide, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn progressively increases in successive turns in the direction toward said coupling means.

22. In a wave amplifying device, a signal wave transmission circuit in the form of an elongated conductive helix, an external signal wave transmission circuit in the form of a hollow wave guide closed at one end, coupling means in the form of a conductor within said wave guide extending from the wall of said wave guide transversely of the direction of energy propagation of said wave guide, said conductor having a length substantially one fifth of the wavelength to be amplified and being positioned a distance of substantially one fifth of the wavelength to be amplified from the closed end of said wave guide, whereby the reactance of said coupling means and that of the section of said wave guide between said coupling means and the closed end vary in opposite directions with change in frequency to give broad-band coupling, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix in which the ratio of the average distance between turns to the circumference per turn increases in successive turns in the direction toward said coupling means.

23. In a wave translating device, a signal wave transmission circuit in the form of an elongated conductive helix, an external signal wave transmission circuit in the form of a hollow wave guide, said wave guide having a pair of aligned apertures in opposite walls, a hollow conducting cylinder having a length substantially one quarter of the wavelength to be amplified and extending through one of the apertures in said wave guide, coupling means within said wave guide in the form of a conductor having a length substantially one fifth of the wavelength to be amplified and extending from said cylinder transversely of the direction of energy propagation of said wave guide, and impedance transforming means between said coupling means and said helix comprising a continuation of said helix extending through the other aperture in said wave guide and having a pitch which increases progressively in successive turns in the direction toward said coupling means.

24. A combination in accordance with claim 23 in which said wave guide is closed at one end and in which said coupling means is positioned a distance of substantially one fifth of the wavelength to be amplified from the closed end of said wave guide, whereby the reactance of said coupling means and that of the section of said wave guide between said coupling means and the closed end vary in opposite directions with change in frequency to give broad-band coupling.

WILLIAM W. MUMFORD.

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