May 15, 1956 O. DÖHLER ET AL 2,745,983

TRAVELING WAVE TUBE

Filed May 25, 1950 5 Sheets-Sheet 1

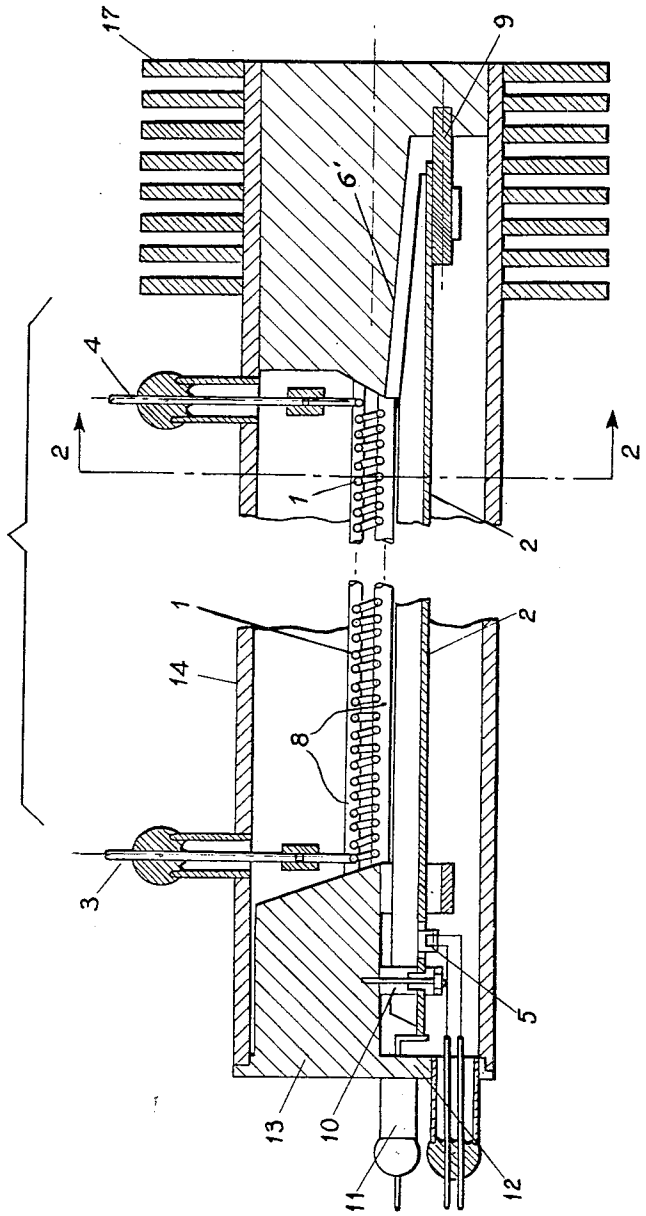


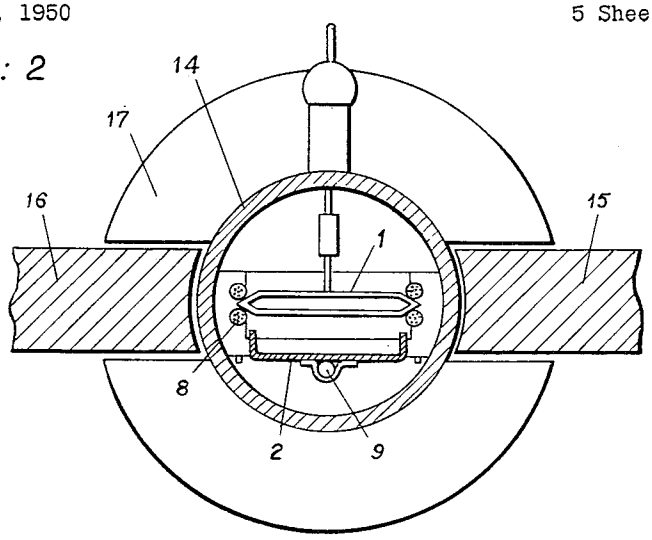
Fig. 1

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Fig: 2



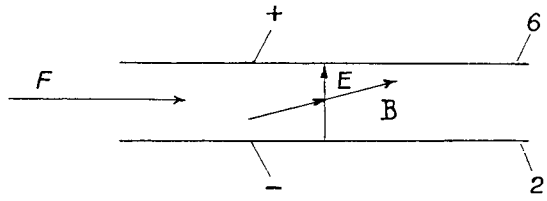


Fig: 3

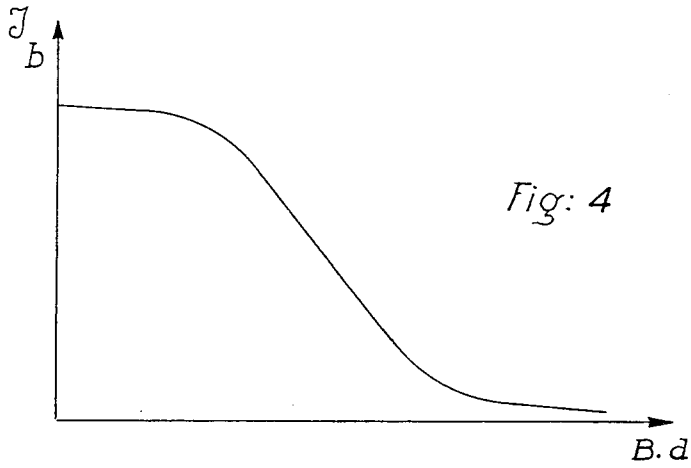


Fig: 4

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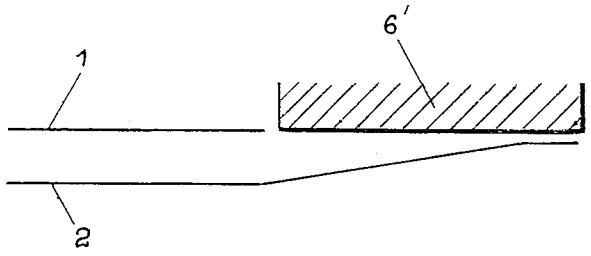


Fig: 5

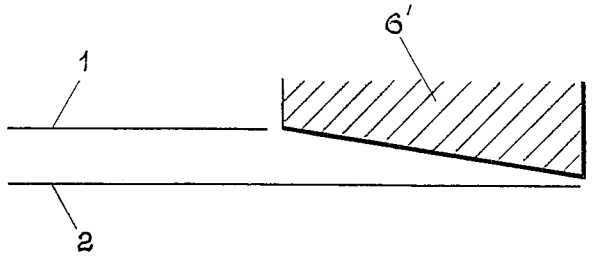


Fig: 6

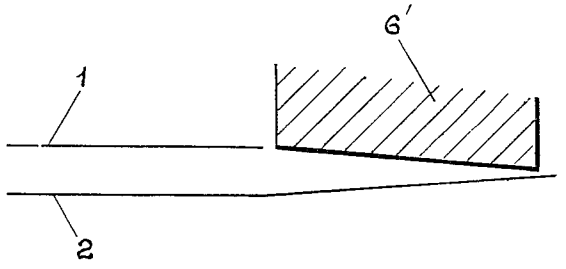


Fig: 7

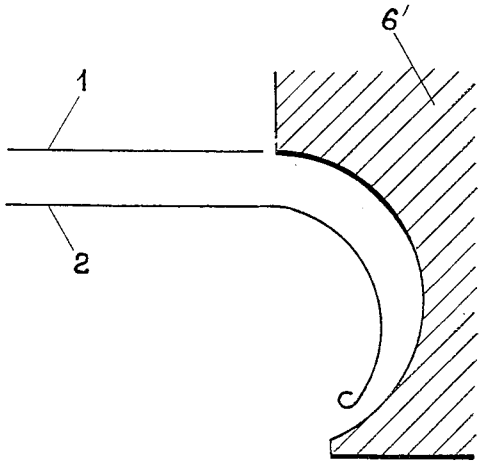
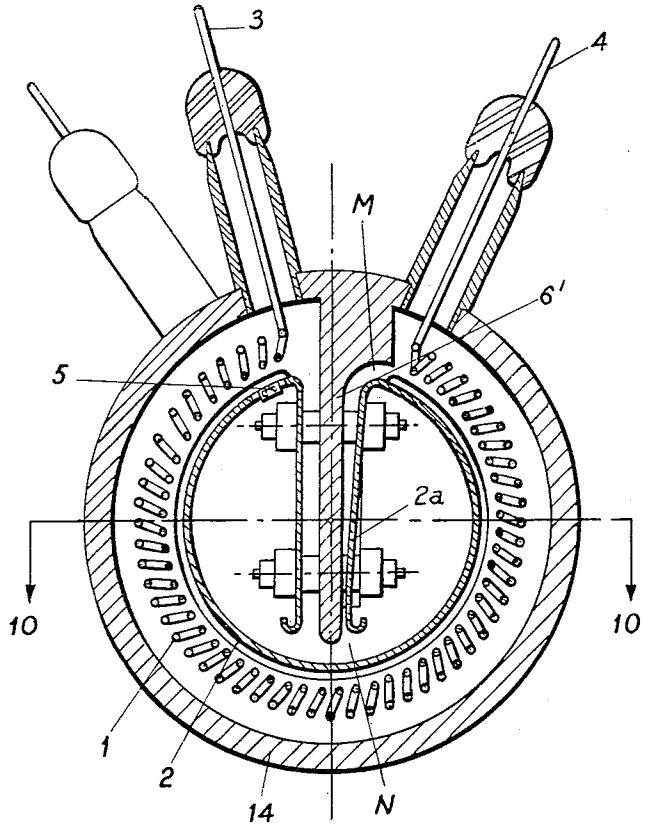


Fig: 8

Fig: 9



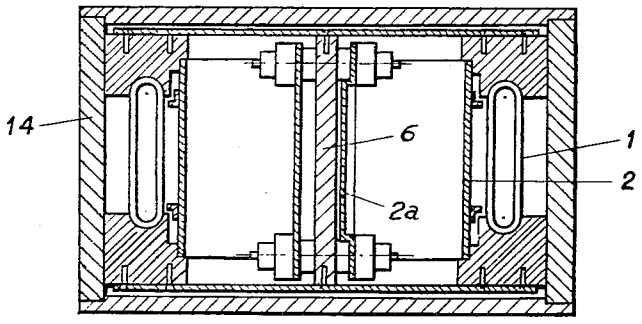


Fig: 10

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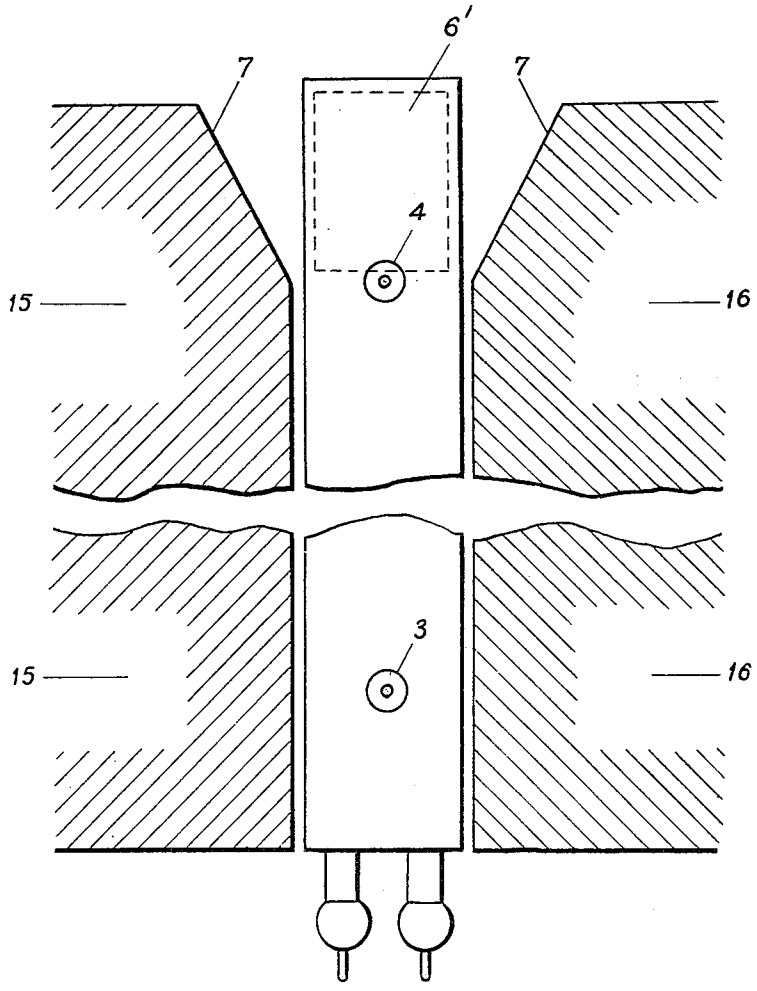


Fig: 11

United States Patent Office

2,745,983

Patented May 15, 1956

2,745,983

TRAVELING WAVE TUBE

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Application May 25, 1950, Serial No. 164,128

3 Claims. (Cl. 315—3.5)

The object of the present invention is to increase substantially the dissipation of a traveling tube operating with crossed electric and magnetic fields. It consists more especially in a form of the current collector by which the electrons are collected and in a predetermined dimensioning of the delay line and of the distribution of the magnetic field in the neighbourhood of the said collector and, if desired, of the distance between the said line and the said collector.

The invention relates to a tube according to the application U. S. Serial No. 794,164, now U. S. Patent No. 2,511,407, filed on December 27, 1947 by the applicants, and the application U. S. Serial No. 102,896 filed on July 2, 1949, by R. Warnecke et al., now Patent No. 2,687,777. As is explained in detail in the said specifications the mechanism of the operation of this type of tube is based on the following phenomena. An electron beam passes through a space containing crossed electrostatic and magnetic fields, these fields being directed perpendicularly to the mean direction of movement of the electrons. A wave is guided in the direction of the beam in this space, by means of a line which at the same time has the property of very substantially reducing the speed of the wave so that equality is obtained between the speeds of the wave and of the electrons in the direction perpendicular to the crossed electric and magnetic fields. In this case, due to the interaction with the electron beam, the wave is amplified, that is to say, its amplitude and the power guided are higher at the output terminal of the tube than at the input terminal.

Figures 1 and 2 show by way of example, respectively in longitudinal section and in cross-section along the line 2—2 of Figure 1, a tube of linear form built up in accordance with the aforesaid principles. These figures serve to illustrate both the known construction and the improvement provided by the invention, as applied to a linear tube. Figures 3 and 4 and 5 to 8 show explanatory diagrams and characteristics. Figures 9 and 10 show the application of the invention to a tube of circular form. Finally, Figure 11 shows a variant of the means employed in accordance with the invention.

In Figures 1 and 2, the delay line comprises two conductors 1 and 2. Conductor 1 has the form of a flat helix for the purpose of reducing the speed of the travelling wave. Between conductors 1 and 2 is applied a transverse electric field, conductor 2 being at a negative potential with respect to conductor 1. The magnetic field provided by the poles 15 and 16 is perpendicular to the plane of the drawing. The signal is applied to the terminal 3, which has the form of a small coaxial line, the inner conductor of which is connected to the input end of the helix. The terminal 4, which is connected to the output end of the helix, serves to tap off the amplified power. The electron beam is generated by the cathode 5 and, being subjected to the forces of the crossed electric and magnetic fields, moves in the form of a somewhat undulatory sheet along the axis of the tube inside the

electron and wave interaction space between conductors 1 and 2.

The helix 1 is supported by insulating rods 8, and the conductor 2 is supported by the insulating elements 9 and 10 and is energized through the terminal 11. The whole assembly is mounted on a base 12 provided with a solid part 13 intended to absorb the electrons in the absence of the magnetic field, this base being connected to a metal envelope 14.

The dimensions of the tube and the operating conditions are so selected that, in the absence of an input signal, almost all the electrons are collected by a collector 6, which is situated at the rear of that extremity of the helix which is in the neighbourhood of the output terminal 4. The section of the beam which must pass through the interaction space is of the order of several tenths of a square centimetre. In practice, for example, the distance between conductors 1 and 2 is of the order of 0.3 cm. and the width of the beam is of the order of 1 cm., that is to say, the section of the beam is of the order of 0.3 square centimetre. This beam carries a power of the order of several hundred watts, the voltage of the collector being, for example, 3 kv., while the current is 200 ma. and consequently the continuous power is of the order of 600 w. If the beam, with the aforesaid section and continuous power, impinges upon the collector on a surface approximately equal to its initial section in the interaction space, the collector would have to dissipate for each square centimetre a power which, with the figures given by way of example, is of the order of 2 kw. per square centimetre. This means such high local heating of the collector that it is difficult or even impossible to dissipate the heat produced.

The present invention provides a structure of the tube and more especially of the collector, due to which the electrons do not impinge upon the collector over a surface of the order of the section of the beam, but are distributed over a considerably larger impact surface. Consequently, the specific dissipation per square centimetre of the collector is much lower, and there is no very high localized heating by electron bombardment, but heating occurs over a large surface at farily low temperature, whereby the dissipation of the continuous power carried by the electron beam is made substantially simpler.

According to the invention the product of the magnetic field and of the distance separating the electrodes of the delay line is varied along the path of the beam in the region in which the electrons travel along the impact surface of the collecting electrode.

The principle of the present invention is explained by the characteristic curve plotted in Figure 4, which relates to a discharge system, shown diagrammatically in Figure 3. A beam is introduced between the two electrodes 6 and 2. Electrode 6 is positive with respect to electrode 2, so that an electric field exists between them with such a direction that the electric field E attracts the electrons towards electrode 6. This force exerted on the electrons is compensated for by the Lorentz force, generated by the magnetic field B perpendicular to the plane of the drawing.

In Figure 4 is plotted the curve $I_b=f(Bd)$, that is to say, the current collected by the electrode 6, as a function of the product Bd for a constant value of the potential difference between electrodes 6 and 2, d being the distance between 6 and 2, and B the strength of the magnetic field. For high values of Bd, all the current passes through the space and the current I collected by the electrode 6 is smaller as Bd is higher. This will readily be understood from the physical viewpoint: If B decreases with d=constant, the Lorentz force evB becomes smaller and the equilibrium between eE and evB

is disturbed (v=speed of the electrons), so that the movement of the electrons is directed towards electrode **6** and some of the electrons are collected thereby. This is also the case if d decreases, because E then increases and the strength of the magnetic field is no longer sufficient to prevent collection of electrons by the electrode **6**. Consequently, if, as is proposed in accordance with the invention, the product Bd decreases progressively along the direction of propagation of the beam, either by decrease of B for d=constant or by decrease of d for B=constant, it is possible to make the absorption of the electrons by the electrode **6** occur along a fairly long electron path. The length of the path along which the electrons are collected by the positive electrode may be selected at will by the rate of variation of d along the path of the electrons. From these explanations, it is obvious that the beam is prevented by this method from impinging upon the electrode **6** within the limits of a restricted surface and that the collection of the electrons, and therefore the resultant heating, can be distributed over a very large impact surface, which renders possible or simplifies the cooling of this surface.

The principle of the present invention is based on this phenomenon. If the electrode **6** in Figure 3 is replaced by the collector, this collector is given such a profile for B=constant that the transverse electric field between this collector and the negative electrode increases progressively in the direction of propagation of the beam, which is effected by the decreasing spacing between the collector and the negative electrode.

On the other hand, the same object can be achieved if, with a constant spacing between these electrodes, the transverse magnetic field is progressively decreased.

The construction of a collector according to the principle of the present invention is illustrated in Figure 1, in which electrode **6'** is the collector. The profile of the said collector is such that the electron impact surface extends substantially parallel to the path of the electrons. In addition, as indicated, the spacing between the negative electrode **2** and the collector **6'** varies continuously in the direction of propagation of the beam, as a result of which the absorption of electrons is distributed over the entire surface of the collector.

In Figures 1 and 2, the collector **6'** is provided with fins **17** cooled by a current of compressed air. The cooling may also be effected by heat transmission by conduction, or it may be improved by a current of water passing through the collector.

Figures 5 to 8 show diagrammatically different variants by which a continuous increase of the transverse electric field can be obtained by continuously varying the spacing between the electrode **2** and the collector **6'**. In Figure 5 the impact surface of the collector remains parallel to the conductor **1**, while the conductor **2** gradually approaches it. In Figure 6, it is the surface of the collector which is disposed obliquely and gradually approaches the conductor **2**. In Figure 7, the two preceding figures are combined. Finally, in Figure 3d the collector **6'** is curved, and the conductor **2** follows its curve while gradually approaching it.

Figures 9 and 10 show a cross section and an axial section on the line **10—10** respectively, through a tube in which the delay line is bent in the form of a circle, based on the principle of the invention. The reference numerals of these figures have the same signification as those of Figures 1 to 3. The collector **6'** of this tube serves simultaneously as a screen between the output terminal **4** and the input terminal **3**, whereby all harmful reaction is eliminated. The reciprocal arrangement of the collector and of the delay line is based on Figure 8. At the point M, the beam enters the space between the collector **6'** and the curved part **2***a* of the electrode **2**. The distance between conductors **1** and **2** is here so great that only a small part of the electrons is collected

in the neighbourhood of this point. The beam is propagated towards the point N, while the distance between **6'** and **2***a* decreases progressively, and consequently the electrons of the beams are collected by the collector over the entire surface of the latter between M and N.

From the explanations given, it is obvious that the stream of electrons impinging upon the collector is distributed over a surface which is larger as the variation of the distance between the collector and the negative electrode is smaller. The collector will be longer and the variation of the distance between the electrodes smaller as the power to be dissipated on the collector is greater. In addition, it is possible to obtain a very uniform absorption of electrons over the entire surface of the collector by curving either the said collector or that part of the negative electrode which lies opposite thereto, that is to say, it may be advantageous not to vary the distance in question linearly along the path of the electrons.

It has been mentioned above that a progressive reduction of the magnetic field in the space in which the collector is situated has the same effect as a reduction of the spacing. This reduction of B may be effected with a suitable form of the pole pieces of the magnet. Figure 11 shows a fundamental structure, taking for example the tube of Figure 1 shown in plan. Only the form of the collector of Figure 1 will be modified, and in this case its surface will not be disposed obliquely, but the form will again be adopted in which the spacing between the collector and the negative electrode is constant, that is to say, equal to the distance between the two conductors **1** and **2** of the delay line. In Figure 11, the magnetic field is constant and homogeneous in the interaction space in which the helix is situated, which is necessary for the high-frequency operation of the tube. On the other hand, in the zone of the collector **6'**, the pole pieces **15** and **16** of the magnet are of such form at **7** that B decreases progressively in the direction of the beam. In Figure 11, this effect is obtained, by way of example, by progressively increasing the distance between the poles of the magnet.

The invention is not limited to this method of varying the magnetic field, but covers any method in which, by varying the magnetic field, it is possible to distribute the collection of electrons of the electron beam fairly uniformly over a surface of the collector which is larger than the transverse section of the beam.

A progressive reduction of the space and of the magnetic field along the conductor may also be combined.

In addition, the invention is not limited to a tube containing a helix, but covers any tube operating with a travelling wave and crossed magnetic and electric fields regardless of the form of the conductors of the delay line, the arrangements described being applicable to all these cases without departing from the spirit of the invention.

We claim:

1. Travelling wave tube comprising a transmission line comprising two substantially parallel spaced conductors, at least one of which comprises wave delay elements and input and output terminals for the circulation of ultra-high frequency energy therethrough, means for applying different potentials to the conductors of the line thereby to establish therebetween an electrostatic field having mean lines of force oriented substantially perpendicular to the axes of the conductors, means for establishing a substantially time-constant magnetic field in the space between the conductors having lines of force substantially perpendicular both to the mean lines of force of the electrostatic field and to the axes of the conductors, means comprising an electron gun positioned adjacent to the input terminal of the line for emitting an electron beam along a mean direction substantially parallel to the axes of the conductors and in the space therebetween, and an electron collector positioned in the vicinity of the output terminal and having an electron-receiving surface facing one of the

conductors slightly inclined relatively to the direction of impact of the beam and progressively approaching the one conductor in the direction of travel of the electrons.

2. Travelling wave tube comprising a transmission line comprising two substantially parallel spaced conductors, at least one of which comprises wave delay elements and input and output terminals for the circulation of ultra-high frequency energy therethrough, means for applying different potentials to the conductors of the line thereby to establish therebetween an electrostatic field having mean lines of force oriented substantially perpendicular to the axes of the conductors, means for establishing a substantially time-constant magnetic field in the space between the conductors having lines of force substantially perpendicular both to the mean lines of force of the electrostatic field and to the axes of the conductors, means comprising an electron gun positioned adjacent to the input terminal of the line for emitting an electron beam along a mean direction substantially parallel to the axes of the conductors and in the space therebetween, and an electron collector positioned in the vicinity of the output terminal and having an electron-receiving surface facing one of the conductors substantially parallel to the mean direction of the beam, the intensity of the magnetic field decreasing along the surface of the collector in the direction of travel of the electrons.

3. Travelling wave tube comprising a transmission line comprising two substantially parallel spaced conductors, at least one of which comprises wave delay elements and input and output terminals for the circulation of ultra-high frequency energy therethrough, means for applying different potentials to the conductors of the line thereby to establish therebetween an electrostatic field having

mean lines of force oriented substantially perpendicular to the axes of the conductors, means for establishing a substantially time-constant magnetic field in the space between the conductors having lines of force substantially perpendicular both to the mean lines of force of the electrostatic field and to the axes of the conductors, means comprising an electron gun positioned adjacent to the input terminal of the line for emitting an electron beam along a mean direction substantially parallel to the axes of the conductors and in the space therebetween, and an electron collector positioned in the vicinity of the output terminal and having an electron-receiving surface facing one of the conductors, the product of said magnetic field intensity and the distance between said electron receiving surface and the said facing conductor decreasing progressively in the direction of travel of the electrons.

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