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H. HUBER
TRAVELING-WAVE AMPLIFYING TUBE OF THE
TRANSVERSE MAGNETIC FIELD TYPE

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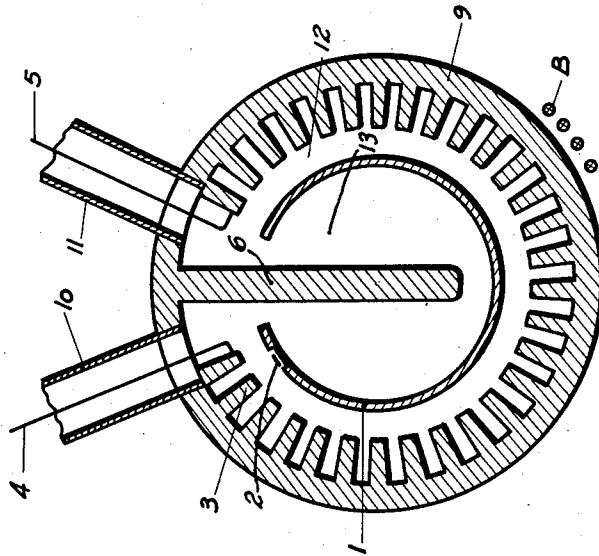


Fig. 5

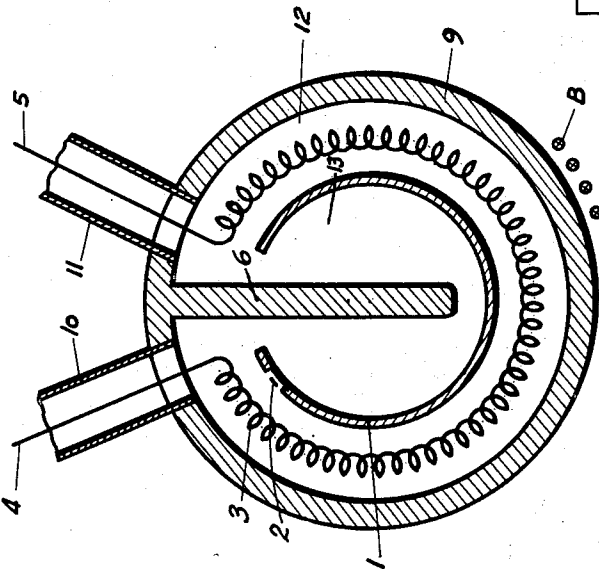


Fig. 4

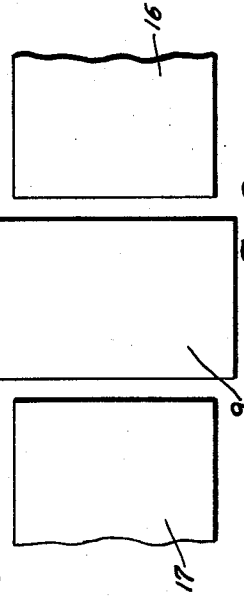


Fig. 3a

INVENTOR
HARRY HUBER
By: *Haseltine, Lake & Co.*
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TRAVELING-WAVE AMPLIFYING TUBE OF THE TRANSVERSE MAGNETIC FIELD TYPE

Harry Huber, Paris, France, assignor to Compagnie Generale de Telegraphie Sans Fil, a corporation of France

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6 Claims. (Cl. 315—3.6)

My invention relates to an improvement in tubes intended for ultra-short wave transmission, of the travelling-wave type with a transverse magnetic field of circular shape, described in my co-pending U. S. application Ser. No. 794,164 filed on December 27, 1949, now Patent 2,511,407 issued June 13, 1950.

It relates more particularly to an efficient device for decoupling the input from the output of said tube so as to eliminate self-oscillation.

In the accompanying drawings:

Figure 1 is a cross-section through a portion of a tube in accordance with the above-mentioned patent;

Figures 2, 3, 4 and 5 are views similar to Figure 1 through some embodiments of tubes in accordance with the present invention; and

Figure 3a is a side view of the tube of Figure 3.

In order to enable the invention to be understood more clearly, the principle of the tube according to my aforesaid co-pending application will be described with reference to Figure 1, wherein the cathode 1 contains an electron-emitting portion 2. The delay line 3, in most cases of the shape of a flat helix or of a zig-zag wire, also acts as an anode and sustains a travelling wave adapted to pass from the input terminal 4 to the output terminal 5. At 6 is located a screen that stops the electrons which have followed the trajectory between the terminals 4 and 5. The movement of the electrons takes place under the influence of an electric field between the electrode 1 and the electrode 3 and of a magnetic field B at right angles to the plane of the drawing, and the exchange of energy between the electrons and the wave passing through the delay line takes place if the velocity of movement of the electrons is approximately equal to the phase velocity of the wave. Under these conditions the power collected at the output end 5 is greater than the power which was applied to the input end 4; the tube can therefore be used as an amplifier.

For such a tube to operate in a satisfactory manner as an amplifier, it is necessary to prevent any feed-back by coupling between the ends 4 and 5 of the delay line that may cause self-oscillation of the tube. Outside the tube a screening between 4 and 5 can easily be provided, but inside the tube, the necessity of separating the cathode 1 from the high tension applied to the delay line 3 is troublesome. The screen 6 of Fig. 1, that terminates the travel of the electrons according to the aforesaid patent, does not form an efficient screening between the ends 4 and 5 of the delay line because it is necessarily raised to a positive potential for collecting the electrons, and the space 8 that exists between its inner edge 7 and the cathode 1 always allows a certain portion of the radio-frequency energy amplified at the output end 5 to pass, i. e. a portion of the radio-frequency power from the output can reach the input end 4 and thereby produce a feed-back and the danger of self-oscillation. Since the ends 4 and 5 are necessarily very close together in the circular shape of tube, it has already been proposed in co-pending patent application Serial No. 102,896 filed by Warnecke et al. on July 2, 1949, for "Thermionic Tube for Ultra-Short Waves" to construct according to the same principle a tube of straight shape in which the ends of the delay line are spaced as far apart as possible. However, this shape only solves the problem by abandoning the compact shape of the circular tube which is a great advantage as compared with the straight tube.

My invention enables this feed-back difficulty to be overcome in the tube of the type considered and makes

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it possible to use it as an amplifier while retaining its circular shape. Considering first of all the case in which the delay line is formed by a flat helix or a zig-zag wire, both shapes being included in the word "helix," I place the helix, which has been curved into the shape of a circle, in a cylindrical metal box provided with a wide screen that divides the box throughout its length into two portions. The cathode of the tube is shaped in such a manner that it forms, together with the walls of the box and the screen, a bent waveguide of such a cross-section that the critical wavelength is below the wavelength used for all the possible modes. In this case the wave can only be propagated periodically along the wire of the helix and can only be propagated in the waveguide in an aperiodic form both in the left-hand direction and in the right-hand direction, i. e. the radio-frequency field through the waveguide is so attenuated that the radio-frequency field from the output end cannot reach the input end of the tube.

Figs. 2, 3, 4 and 5 show transverse sections of four non-limitative embodiments of the invention, while Figure 3a shows a side view of Figure 3.

In Fig. 2, the helix 3 with its input end 4 and its output end 5 is curved into the shape of a circle and is placed in a metal box 9 which is provided with a screen 6 and into which penetrate the pipe sections 10 and 11 that act with the wires 4 and 5 as a coaxial line. The cathode electrode 1 together with the emitting portion 2 is of the shape of a cylinder provided with a wide and deep radial slot in the direction of its axis. This electrode 1 defines, together with the inner wall of the metal box 9, a waveguide 12 of rectangular cross-section curved into the shape of a circle and containing the helix 3. The cathode electrode 1 defines, together with the walls of the screen 6, another waveguide 13 which is bent to U-shape and which connects the ends of the waveguide 12 to one another. The cathode 1 is thus separated from the box 9 and the screen 6 as regards the D. C. high tension, and at the same time the input and output ends of the delay line can be completely decoupled in respect of the radio-frequency.

In order to prevent any wave from being able to be propagated along the waveguide 13, it is necessary for its width a in the direction at right angles to the drawing and its height b to be smaller than

$$\frac{\lambda}{2}$$

in which λ is the wavelength in free space of the wave to be amplified. In this case no mode of this wave can be propagated periodically in the waveguide. Assuming for example that $\lambda=20$ cm., it is necessary to choose the distances between opposite walls of the waveguide smaller than 10 cm., which can be easily done and which is amply sufficient for enabling a delay line to be inserted therein. The more the transverse dimensions of the waveguide decrease and the more its length increases, the more the radio-frequency field is damped. It is therefore possible to endeavor to increase the radio-frequency cut-off properties of the waveguide by decreasing its dimensions a and b down to values which are compatible with the high tension and by increasing its length; this is shown in Fig. 3. In this case, only the dimension b of the waveguide which is bent round the screen is decreased and its length is increased by giving to the screen a cruciform cross-section. But any other shape that increases the length can also be used. It is thus possible to increase the length of the waveguide to a greater value than that of the helix itself for example, thereby eliminating the drawback of circular tubes as compared with straight tubes.

It is not necessary for the cross-section of the waveguide to remain constant, since a variation of said cross-section along the waveguide does not appreciably affect the damping effect on the radio-frequency field if the critical wavelength is always lower than that of the amplified wave.

As shown in Fig. 4, this enables the construction of the cathode to be simplified by replacing the solid shape of Figs. 2 and 3 by a mere hollow cylinder with thin walls. The decoupling device according to the invention can

also be applied to the case in which the delay line of the tube is formed by a system of slots and blades, called a "fin line," or by a series of circuits distributed along the line. Fig. 5, which is provided with the same reference numerals as Figs. 2 to 4, shows the application of a fin system, as in Fig. 1 of the aforesaid patent, but with a decoupling device according to Fig. 4 of the present application.

In the cases in which the wavelength used is not much higher than the critical wavelength, the radio-frequency field penetrates fairly deeply into the waveguide. In order that the value of the radio-frequency field at the input end, which reaches it from the output end through the waveguide, may be lower than the critical value that determines self-oscillation, the device may be completed by an attenuating layer on the walls bounding the waveguide. In Figs. 2 to 5 said layer would be placed on the inner wall of the metal box 9, on the outer and inner surfaces of the cathode 1, and on the screen 6. By way of a non-limitative example, layers of carbon or graphite may be used. But it is also possible to use layers which at the same time form a good getter, such as zirconium, thorium or cerium, these latter materials being particularly efficient as a getter on the walls of the screen, which is highly heated by the bombardment of the electrons, since it is known that the getter properties of these materials become more efficient at high temperatures.

In the embodiment illustrated in Figure 3, the wire 4 and pipe 10 are connected to the two sides of a source of potential 14 thereby establishing an electric field between the cathode 1 and the line 3 which are electrically connected respectively to the pipe 10 and the wire 4. The screen 6 and cathode 1 are provided at 15 with an attenuating layer on both sides of the separating gap between these elements.

In Figure 3a, there are shown the poles 16 and 17 of a magnet for establishing the field B directed along the axis of the tube.

What I claim is:

1. A travelling wave tube comprising a cylindrical envelope, means for producing a magnetic field having its lines of force directed along the axis of said envelope, said envelope being located in said field, a pair of spaced electrodes positioned concentrically about said axis inside said envelope, one of said electrodes being a cathodic electrode and at least one of said electrodes having the properties of a delay line for ultra-high frequency energy

and having input and output ends, means for applying potentials to said electrodes thereby to create an electrical field therebetween and to impart to said electrodes the respective characteristics of an anode and of a cathode, means for introducing a beam of electrons into the space between said electrodes, means for supplying an ultra-high frequency electromagnetic wave to said input end, means for collecting amplified electromagnetic wave energy at said output end, and decoupling means between said input and output ends comprising a screen connected to said envelope and a recess in said cathode electrode, said screen being positioned in said recess and defining therewith a bent wave guide of predetermined width, height and length having a cut-off wave-length lower than that of said delay line.

2. Tube according to claim 1, wherein the cathode electrode is a solid cylinder provided with a slot that leaves a constant distance between the wall of the recess and the screen.

3. Tube according to claim 1, wherein walls are attached to the screen transversely thereto, the recess of the cathode electrode being provided with corresponding slots.

4. Tube according to claim 1, wherein the screen and the recess of the cathode electrode are of cruciform cross-section.

5. Tube according to claim 1, wherein the screen and the wall of the recess of the cathode electrode are covered with a layer of wave attenuating substance.

6. Tube according to claim 1, wherein the screen and the wall of the recess of the cathode electrode are covered with a layer of wave attenuating substance that has the properties of a getter.

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