

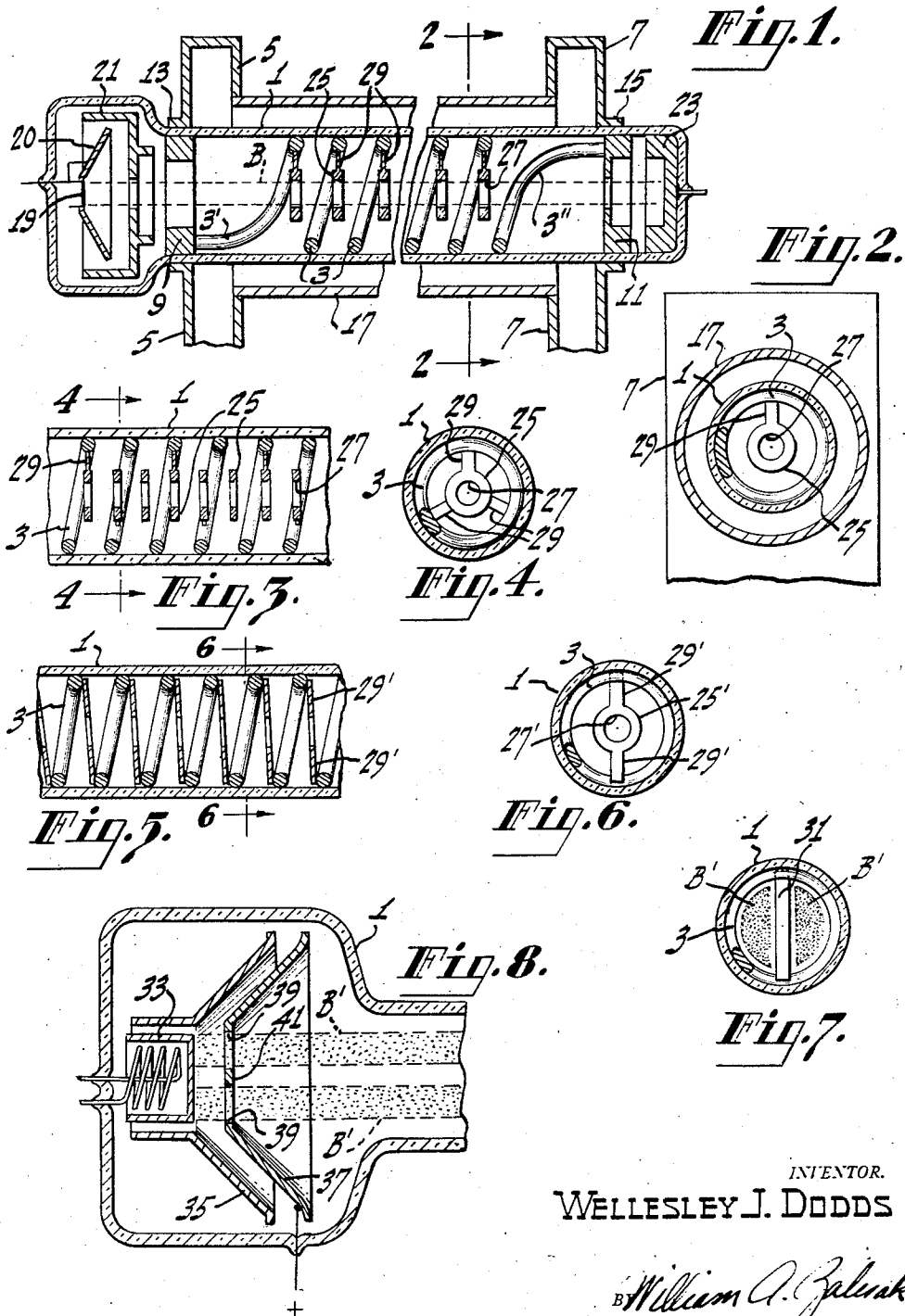
Aug. 6, 1957

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2,802,135

TRAVELING WAVE ELECTRON TUBE

Filed Aug. 22, 1952



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2,802,135

TRAVELING WAVE ELECTRON TUBE

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Application August 22, 1952, Serial No. 305,797

17 Claims. (Cl. 315—3.5)

This invention relates to improvements in electron tubes, and particularly to beam tubes of the traveling wave type.

In a conventional traveling wave tube an elongated section of transmission line is mounted within a vacuum envelope with suitable input and output structures coupled through the envelope to the opposite ends of the section. The transmission line section is designed as a delay line along which electromagnetic waves are transmitted at a fraction of the velocity of light. Although other forms have been suggested, the form of delay line usually used in traveling wave tubes is a conducting helix, such as a helical metal wire coil. An electron beam is projected by suitable means along, and preferably coaxially of, the helix at a beam velocity substantially equal to the axial wave velocity along the helix. In operation of the tube as an amplifier, a signal wave traveling along the helix creates electromagnetic fields therealong which interact with the electrons in the beam to produce electron velocity modulation and consequent electron bunching. As the wave and beam travel synchronously along the helix the phenomena reverse and the bunched beam induces fields and currents along the helix. The amplitude of the wave increases exponentially along the helix, because the electron beam gives up more energy to the helix than it abstracts therefrom, thus producing an amplified signal at the output end of the tube.

In a copending application of Rolf W. Peter and myself, Serial No. 169,674, filed June 22, 1950, the amplification bandwidth of a helix-type traveling wave tube is limited by providing reactance elements uniformly distributed along the length of the helix. These elements may be primarily inductive, for example, in the form of tabs attached directly to the helix, or may be elements having both inductance and capacitance coupled to the helix at points uniformly spaced therealong.

The present invention relates to improvements for increasing the coupling between the electron beam and the helix of a traveling wave tube, and at the same time limiting the amplifying bandwidth of the helix in accordance with the principles disclosed in said copending application. In fact, as will be explained in more detail later, one of the embodiments of the present invention is disclosed but not claimed specifically in said copending application as an embodiment of the broad invention generically claimed therein. Therefore, the present application is a continuation-in-part of said copending application Serial No. 169,674.

Although the axial wave velocity along the helix of a conventional traveling wave tube is substantially independent of frequency, the coupling factor between the beam and the helix decreases rapidly as the operating frequency is increased. At these higher frequencies, the length of each turn of the helix becomes an appreciable fraction of a wavelength. Therefore, in order to keep the coupling factor high enough for adequate ampli-

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fication it is necessary to make the helix dimensions smaller as the desired operating frequency is increased. Because of this the helix is found to approach limiting conditions on wire size and pitch at the higher microwave frequencies, in the same way that triode amplifiers become difficult or impossible to design in the kilomegacycle range due to requirements for extremely close grid-cathode spacings and very fine, tightly-wound, grid wires. This is also true for the filter helix structures shown in the above-mentioned copending application, with the exception of the structure shown in Figs. 12 and 13 thereof.

For example, a power amplifier tube to operate at reasonably low beam voltages at 2,000 megacycles with a power output of several watts requires a helix of about 0.100 inch mean diameter, with 60 or more turns per inch of 0.008 inch wire. This helix must be placed so as to closely surround an electron beam carrying 20 to 50 watts of power. It can be seen that if any appreciable portion of the beam were to strike the helix enough damage could be done to the tube to make it inoperable. Further, in order to maintain the proper axial wave velocity on the helix the requisite fine pitch must be maintained accurately, which is very difficult in such a physically fragile structure.

As another example, a power amplifier tube for operation at 6500 megacycles with a power output of several watts at voltages below 1000 volts requires a helix having a mean diameter of approximately 0.040 inch and about 200 turns per inch of wire less than 0.005 inch in diameter. At this frequency, the mechanical and thermal difficulties mentioned above are considerably aggravated. At still higher frequencies the difficulties become much greater.

The principal object of the present invention is to provide traveling wave amplifier tubes with enhanced beam-to-helix coupling which utilizes, at any given operating frequency, much larger and more rugged helix structures than would be possible with existing tubes. Such large helix structures can be formed with high precision to retain their original dimensions under physical and thermal stresses encountered during operation and still produce an intense electric signal field in the region occupied by the electron beam.

In accordance with the invention, the helix of an otherwise conventional traveling wave tube is provided with tabs attached to (or forming an integral part of the wire of) the helix and extending inwardly from the helix at spaced points therealong to couple to the electron beam. These tabs are distributed along the entire length of the helix and, preferably, are attached to the helix at equal intervals therealong in order that they will also serve as bandwidth limiting discontinuities in the manner described in said copending application.

Other objects, features and advantages of the invention will be apparent to those skilled in the art from the following detailed description of the invention taken in connection with the annexed drawing, in which:

Fig. 1 is a longitudinal sectional view of a traveling wave tube embodying one form of the invention;

Fig. 2 is a transverse sectional view taken on line 2—2 of Fig. 1;

Fig. 3 is a fragmentary view showing a modification of the tube of Fig. 1;

Fig. 4 is a transverse sectional view taken on the line 4—4 of Fig. 3;

Fig. 5 is a fragmentary view of another modification of Fig. 1;

Fig. 6 is a transverse sectional view taken on the line 6—6 of Fig. 5;

Fig. 7 is a view similar to Fig. 6 of a modification thereof; and

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Fig. 8 is a longitudinal sectional view of a gun structure for producing the two beams shown in Fig. 7.

Referring to Figs. 1 and 2, the embodiment shown therein comprises an elongated dielectric envelope 1 containing an elongated metal helix 3 in the form of a helical wire coil. The helix may be supported by the envelope wall as shown, or may be supported in spaced relation to the envelope by conventional insulating members. Any suitable means may be used to couple an input signal source and an output load to the ends of the helix 3. For example, an input waveguide 5 and output waveguide 7 are shown coupled to axial extensions 3' and 3'', respectively, of the helix 3. The tube extends transversely through the two waveguides with the helix extensions 3' and 3'' oriented parallel to the electric field within the waveguides. The two extensions are also connected to rings 9 and 11 which are capacitively coupled to flanges 13 and 15 of the two waveguides. Preferably, the two waveguides are connected by a tubular member 17 of non-magnetic metal which serves as an electrostatic shield around the tube. An enlarged cup-shaped envelope portion 12 contains a gun structure, which may comprise a cathode 19, a beam-forming electrode 20 and an accelerating electrode 21, for projecting an electron beam B along the axis of the helix 3 to a collector electrode 23. An axial focusing magnetic field may be provided, for example, by an electromagnet surrounding the tube.

In accordance with the invention, the helix is provided with means for greatly increasing the coupling between the beam and the helix, particularly where the helix has a large diameter and pitch. The helix 3, which would closely surround the beam in a conventional tube, has a diameter several times that of the beam B, and is coupled to the beam at spaced points throughout its length by coupling rings 25. Each ring 25 has an aperture 27 slightly larger than the beam diameter and a tab 29 by which it is supported by and electrically connected to the helix 3. Preferably, the coupling rings 25 are connected at least one to each turn of the helix 3, as shown in Fig. 1.

In the tube shown in Figs. 1 and 2, the beam B is coupled to the helix 3 substantially only by the rings 25 and tabs 29, there being very little if any direct coupling between the beam and the fields traveling along the helix itself. A combination of direct and indirect coupling between the beam and the helix of a conventional tube has been obtained by omitting the rings 25 and utilizing inwardly extending tabs 29 to greatly enhance the normal coupling between the helix and the beam. In this case, however, the ratio of the diameter of the helix to that of the beam must be made smaller than in Figs. 1 and 2 in order to obtain greater direct coupling, with a consequent loss in advantage of the invention in the design of traveling wave tubes for use at extremely high frequencies.

Very favorable results have been obtained with tubes utilizing the arrangement shown in Figs. 1 and 2. For comparison with other tube designs using plain helices, the aperture in the coupling rings was made about the same diameter as would be required of a plain helix to give essentially the same coupling factor. About one-third watt of high frequency power output was obtained at 3300 megacycles, with 17 db gain and about 15 percent efficiency, at 800 volts helix potential.

Figs. 3 and 4 show a modification in which the coupling rings 25 are connected to the helix 3 at points spaced 240° apart around the periphery of the helix instead of 360° as in Figs. 1 and 2. This arrangement produces greater coupling and also is more symmetrical than that of Figs. 1 and 2.

Particularly for tubes designed for operation at frequencies above 6000 megacycles, the arrangement shown in Figs. 5 and 6 has been found to be very satisfactory. In this embodiment of the invention, each coupling ring 25' is connected by two tabs 29' to two points spaced 180° apart on the periphery of the helix. With this arrange-

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ment it has been possible to make the diameter of the helix twice as great at a given frequency as in the arrangement shown in Figs. 1 and 2. The dimensions used at 2000 megacycles were: $1\frac{1}{16}$ inch diameter helix with 9 turns per inch of 0.040 inch diameter wire, with $\frac{1}{4}$ inch diameter apertures in the coupling rings. This is to be compared with the very small dimensions given above for a conventional 2000 megacycle power amplifier tube. The enlarged helix structure of Figs. 5 and 6 gives power output, gain and efficiency equal to experimentally-determined values for a helix smaller in diameter than the apertures in the coupling rings.

As a further illustration of the advantages to be gained in using the structure of Figs. 5 and 6, the data below compare two sets of design figures for a 6450 megacycle power amplifier requirement of about two watts of output power from a 20 watt electron beam, based on theory only:

	Plain Helix	Helix of Figs. 5, 6
Helix diameter.....	0.055 inch.....	0.225 inch.
Helix pitch.....	0.010 inch.....	0.050 inch.
Helix wire.....	0.005 inch.....	0.025 inch.
Operating volts.....	1,250 approx.....	900-1,000.

It can be seen that the dimensions of the helix of the Fig. 5 arrangement are approximately five times greater than for a plain helix.

Fig. 7 shows a modification of Figs. 5 and 6, in which the coupling rings are eliminated and the coupling means comprises a series of straight tabs 31 bridging the turns of the helix, in the same manner as in Fig. 5, with two parallel electron beams B' projected along opposite sides of the tabs. This embodiment has the advantage, over the ring embodiments shown in the other figures, that the direct coupling between the beams and the helix contributes appreciably to the total coupling, even with relatively large helix dimensions.

Fig. 8 shows a double-beam gun structure that may be used in place of the single-beam gun structure of Fig. 1 to project the two beams B' shown in Fig. 7. This gun structure comprises a circular cathode 33, a beam-focusing electrode 35 and an accelerating and beam-splitting electrode 37. The electrode 37 has a pair of apertures 39 separated by a web portion 41 of the electrode 37 which splits the original beam into two spaced parallel beams B'. Preferably, the apertures 39 are part-circle as indicated by the cross-section of the beams B' in Fig. 7.

In all of the embodiments shown, the tabs function not only as means for coupling the beam to the helix but also as inductive reactance elements which load the helix and thereby limit the amplification bandwidth of the tube in the manner explained in said copending application. The tube shown in Figs. 1 and 2 is substantially the same as that shown in Figs. 12 and 13 of said copending application.

What is claimed is:

1. An electron tube of the traveling wave type comprising an elongated conductive helix, means adjacent to one end of said helix for projecting at least one beam of electrons through the interior of said helix, and conductive means located between said helix and said beam and connected to said helix at spaced points only for coupling said beam to said helix along substantially the entire length thereof.

2. An electron tube as in claim 1, wherein said helix is a wire coil and said coupling means comprises a series of tabs connected to said coil at points equally spaced therealong.

3. An electron tube as in claim 2, wherein there is at least one of said tabs connected to each turn of said coil.

4. An electron tube as in claim 3, wherein said tabs are connected to said coil at two points on each turn.

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5. An electron tube as in claim 4, wherein each tab is connected to opposite sides of each turn.

6. An electron tube of the traveling wave type comprising means for projecting an electron beam of given diameter along an extended path, an elongated conductive helix of diameter several times that of said beam surrounding said beam path, and conductive means interposed between said beam and said helix and connected to the latter at spaced points only for coupling said beam to said helix along substantially the entire length thereof.

7. An electron tube as in claim 6, wherein said coupling means comprises a series of conductive rings closely surrounding the path of said beam and connected to said helix at points equally spaced therealong.

8. An electron tube as in claim 7, wherein said rings are connected to said helix at points spaced 240° apart on the periphery thereof.

9. An electron tube as in claim 7, wherein there is one of said rings connected to each turn of said helix.

10. An electron tube as in claim 9, wherein each ring is connected by a tab to one point only on said turn.

11. An electron tube as in claim 9, wherein each ring is connected by two oppositely-extending tabs to opposite sides of each turn.

12. An electron tube of the traveling wave type comprising an elongated conductive helix, means adjacent one end of said helix for projecting two parallel beams of electrons through the interior of said helix parallel to the axis thereof, and conductive means located within said helix between said beams and connected to said helix at spaced points only for coupling said beams to said helix along substantially the entire length thereof.

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13. An electron tube as in claim 12, wherein said conductive means comprises a series of tabs extending across and connected to opposite sides of each turn of said helix.

14. An electron tube of the traveling wave type comprising an elongated conductive helix, means adjacent to one end of said helix for projecting at least one beam of electrons through the interior of said helix, and conductive means located within said helix and connected thereto at spaced points only for coupling said beam to said helix along substantially the entire length thereof.

15. A traveling wave tube comprising means for projecting an electron beam along an extended path, an elongated wire coil surrounding said beam path along substantially the entire length thereof, and means for coupling said beam to said coil comprising a series of conductive tabs within said coil and in contact with the turns thereof at points equally spaced along substantially the entire length thereof.

16. A traveling wave tube as in claim 15, wherein said series includes at least one tab contacting each turn of said coil.

17. A traveling wave tube as in claim 16, wherein each tab is in contact with opposite sides of each turn.

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