Dec. 2, 1958 M. ARDITI 2,863,093

TRAVELING WAVE ELECTRON DISCHARGE DEVICES

Filed Sept. 4, 1953

Fig. 1

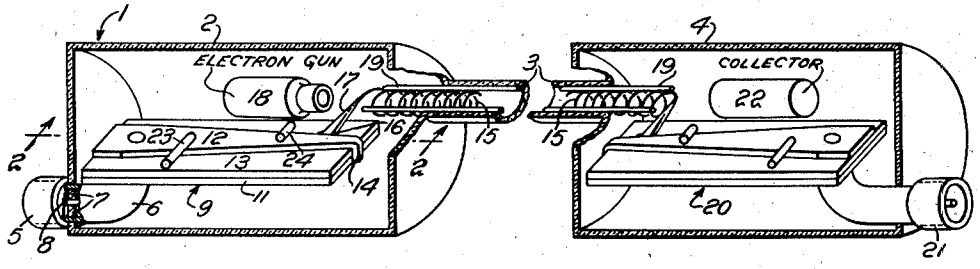


Fig. 2

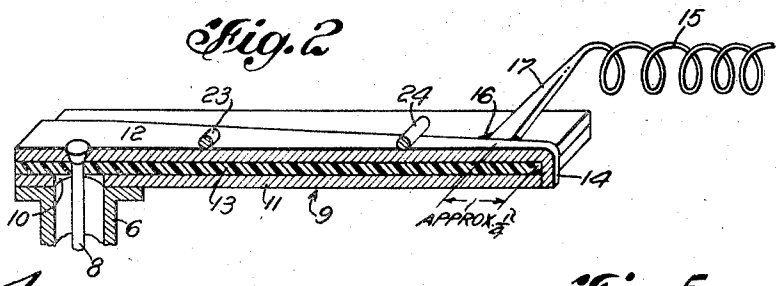


Fig. 4

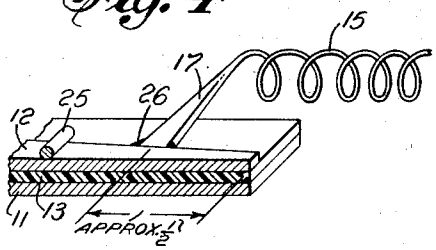
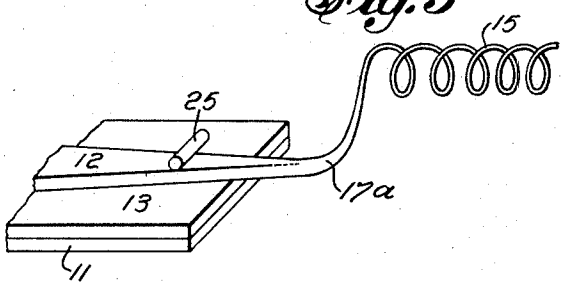


Fig. 5



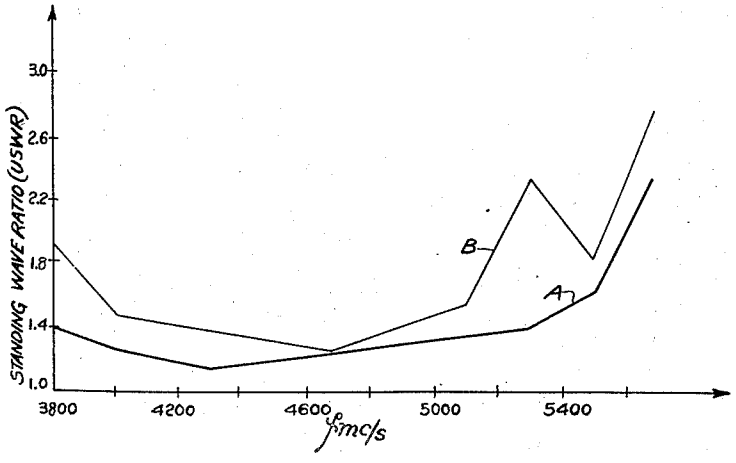


Fig. 3

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TRAVELING WAVE ELECTRON DISCHARGE DEVICES

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18 Claims. (Cl. 315—39.3)

This invention relates to traveling wave electron discharge devices and more particularly to transducer or transition arrangements for matching a low impedance radio frequency line to a relatively high impedance helical line of the type usually employed in such devices. This is a continuation-in-part of my copending application Serial No. 314,381, filed October 11, 1952, now abandoned.

In traveling wave tubes or devices particularly where a high impedance helical line is employed, it is often difficult to properly match the radio frequency input and output terminal connections of the tube to the helical line, particularly where wide band operation is required.

Where rectangular waveguides are employed these input and output connections are rather critical requiring tuning shorts to effect an impedance match. Such tuning shorts, however, are frequency sensitive and restrict the bandwidth. Where coaxial lines are used for radio frequency input and output connections to obtain wider bandwidth operation, the construction of the tube becomes more difficult and requires a high degree of care in the accuracy of the assembly.

It is one of the objects of this invention to provide relatively simple, inexpensive wideband, impedance matching transition arrangements for the R.-F. input and output couplings to helical or other R.-F. propagating lines of relatively high impedance. Another object is to provide a new improved transition arrangement between the R.-F. input and output terminals and the helical line of a traveling wave discharge device.

One of the features of the invention is the employment of a relatively simple, inexpensive microwave printed circuit for the transition sections between high and low impedance lines. To obtain good impedance match the transition arrangement of this invention includes a printed transmission line principle disclosed in my joint copending application with P. Parzen, Serial No. 286,764, filed May 8, 1952, now Patent No. 2,774,046. A typical printed R.-F. line as disclosed in this copending application comprises a pair of strip conductors wherein the first conductor is in the form of a strip having a planar surface over which a second conductor is disposed in closely spaced, substantially parallel relation. The second conductor is preferably of strip form but usually narrower than the first or ground conductor. In the present invention the second conductor is tapered and in one embodiment thereof the small end of the tapered section is connected to the first or ground conductor to establish a radio frequency voltage null. The coupling of the low impedance line to the section is made at or adjacent the large end of the tapered portion while the high impedance line or helix is coupled to a high voltage point approximately one quarter of a wavelength of the mid-operating frequency of the device from end where the voltage null point is established. In another embodiment, the small tapered end may be left "open" in which case the high impedance line is coupled to the transition section approximately one-half a wavelength from the open end. In

still another embodiment the small end of the tapered section may be tapered directly into the size of the conductor of the high impedance line to which it is connected, the tapered portion in conjunction with the "open" termination of the first or ground conductor functioning as a launching or receiving section, as the case may be.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a fragmentary view in longitudinal section of a traveling wave electron discharge device incorporating transition sections at the ends of the helical line in accordance with the principles of this invention;

Fig. 2 is a longitudinal section taken along line 2—2 of Fig. 1;

Fig. 3 is a graph showing voltage standing wave ratios of the transition section disclosed in Figs. 1 and 2;

Fig. 4 is a fragmentary longitudinal section of the transition section, similar to the section shown in Fig. 2, showing a second embodiment of the invention; and

Fig. 5 is a view in perspective of a fragmentary portion of a transition section similar to those shown in Figs. 2 and 4 illustrating still another embodiment of the invention.

Referring more particularly to Figs. 1 and 2 of the drawing, the traveling wave electron discharge device or tube therein shown comprises a glass envelope **1** having a first or input section **2**, a helical line section **3**, and an output section **4**. The sections **2** and **4** in the drawing are enlarged to better illustrate the R.-F. coupling transition sections of the invention. It will be understood, however, that these end sections are of sufficiently small diameter as to permit reception of a solenoid thereabout for the establishment of a magnetic field axially of the helical line section.

As shown in Figs. 1 and 2, the R.-F. input terminal comprises a coaxial line **5** which extends through the envelope, the envelope being sealed to the outer conductor **6** while a glass or other ceramic seal **7** is provided within the coaxial line between the outer conductor **6** and the inner conductor **8**. The coaxial line is coupled to the printed line section **9** by a direct connection between the outer conductor **6** and the first conductor **11**, the inner conductor **8** being extended through an opening **10** in the first conductor **11** for connection to the second strip conductor **12**. This coupling is made at the large end of the strip section. Interposed between the two strip conductors is a layer of dielectric material **13**, which may comprise glass, fiber glass, or any other suitable dielectric material permissible in the particular application. The strip **12** is tapered from a point adjacent the coupling to the coaxial line to the point **14** where the conductor **12** is connected to the conductor **11** to establish a radio frequency voltage null. The end of the high impedance helical line **15** is connected to the conductor **12** through a lateral extension **17** at a point **16** approximately one quarter of a wavelength or an odd multiple thereof, of the operating mid-frequency of the device from the null point **14**. The extension **17** is preferably tapered, that is, enlarged from the diameter of the helical conductor to substantially the width of the line **12** at the point of connection thereto so as to make gradual the transition from the strip **12** to the conductor size of the helical line. The extension **17** extends from the point **16** parallel to the planar surface of conductor **11** and beyond the lateral edge thereof to the helical line **15**. While this extension constitutes in effect a right angle bend with respect to conductor **12**, it does not present any appreciable reflections or loss due to radiation, probably because of its parallel relation with respect to conductor **11** and its taper from the point of its connection

with conductor **12**. The electric field of the propagated signal energy is the same along extension **17** as along conductor **12** until the extension strip **17** leaves the edge of the planar conductor **11** where it changes in mode to that of a single conductor waveguide.

In addition to the R.-F. coupling transition the input section **2** also includes an electron gun **18** adapted to provide a beam of electrons for flow axially of the helical line **15**. The helical line may be supported by rods **19** at spaced points about the periphery thereof, the rods extending parallel to the axis of the helix and received in the glass envelope section **3**. In the place of rods, a special glass tubing may be provided receivable in the section **3** or the envelope itself may be provided with internal spaced ribs for engagement with the helical line.

The output section **4** of the tube is provided with a transition section **20** which may be substantially identical to the section **9** of the input section, the section **20** being coupled through a coaxial line terminal **21** to the outside of the envelope. The section **4** also includes an electron collector **22** disposed in alignment with the beam path from gun **18**.

In providing a transition section as illustrated at **9** and **20**, there may still be a slight mismatch between the low impedance line and transition section and/or between the transition section and the helical line. To tune out this slight mismatch and thus obtain optimum match, I provide small conducting pieces as indicated at **23** and **24** located approximately one quarter wavelength from the adjacent point of coupling and so positioned in contact with the strip conductor **12** as to present the necessary susceptance required to tune out the slight mismatch. For additional disclosure of ways and means of tuning out mismatch at couplings, reference may be had to my copending application with George A. Deschamps and Jack Elefant, Serial No. 286,762, filed May 8, 1952, now U. S. Patent 2,794,174.

In a reduction to practice model of the transition arrangement illustrated in Figs. 1 and 2, a section of printed line 170 millimeters long was employed. The length of the section between the shorted end **14** and the point of coupling **16** was 7.5 millimeters. The taper extended approximately 150 millimeters from the shorted end **14**. The degree of the taper and the length thereof are not critical, the taper being selected to obtain a gradual transition in contrast to a relatively abrupt transition. The impedance of the coaxial line **5** was 50 ohms, while the impedance of the helical line **15** was between 300 and 400 ohms. The helix employed had 113 turns per inch and the conductor size of the helix had a diameter of 0.045 inch.

In Fig. 3 are shown two curves A and B which indicate the standing wave ratio of the transition section over a frequency range of 3800 to 5400 megacycles per second. Curve A is the input VSWR for a junction coaxial line—to printed line terminated in a matched load. Curve B shows the input VSWR for a junction coaxial line—to printed line—to helical line terminated in a matched load. From these two curves it can be readily seen that the quality of the impedance match of the transition section of my invention is good over the 1500 megacycle bandwidth tested. It was also obvious that even wider bandwidth could be obtained by more carefully adjusting the positions of conductor pieces **23** and **24**.

In Fig. 4 I have shown a slight variation from the transition coupling arrangement illustrated in Figs. 1 and 2. In this embodiment, as well as others described hereinafter, corresponding elements are identified with the same reference characters used in Figs. 1 and 2. In this embodiment, the small end **25** of the strip **12** is left "open" and the extension **17** connected to the helical line **15** is coupled to the strip **12** at a point **26** approximately a half wavelength from the open end **25**. This insures a high voltage point for coupling to the helical line, as will be clear to those skilled in the art.

In Fig. 5 the strip **12** is also "open" except that the same tapered end is tapered directly as shown by extension **17***a*, into the size of the conductor of the helical line **15**. The first conductor **11**, however, is terminated as in Fig. 4. The tapered portions **12** and **17***a* provide for a gradual transition of the impedance of the section from a low impedance at the coupling to the coaxial line **5** to the high impedance of the helical line **15**. To tune out any slight mismatch at the junctions of strip **12**, susceptance elements, as hereinbefore indicated at **23** and **24**, may be applied to the strip **12**.

While I have described above the principles of my invention in connection with specific apparatus such as a traveling wave tube, it is to be clearly understood that this description is made only by way of example since obviously it may be applied in various apparatus wherever a transition is required between high and low impedance lines. The present description and illustrations are therefore to be regarded as examples only and not as a limitation to the scope of my invention, as set forth in the objects thereof and in the accompanying claims.

I claim:

1. In a traveling wave electron discharge device having a helical line of relatively high characteristic impedance and a radio frequency line of relatively low characteristic impedance, a transition section coupling said low impedance line to said helical line, comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion to increase the impedance of said section from a low impedance at one end thereof to a high impedance at the other end thereof, means coupling said helical line to said second conductor at an impedance point matching substantially the impedance of the helical line, means coupling said low impedance line to said transition section at an impedance point matching substantially the impedance of said low impedance line, and susceptance means disposed on said second conductor and extending beyond a peripheral edge thereof a given distance from each of said coupling means to tune out any mismatch that may be present in each of said coupling means.

2. In a traveling wave electron discharge device according to claim 1, wherein the small end of said second conductor is coupled to said first conductor to establish a radio frequency voltage null and the means for coupling said helical line to said second conductor is arranged to couple the helical line thereto at a point spaced from said null a distance equal to approximately one quarter of a wavelength or an odd multiple thereof of the operating frequency of said device.

3. In a traveling wave electron discharge device according to claim 1, wherein said first and second conductors are open at the end of the said tapered portion of said second conductor and the means for coupling said helical line is arranged to couple the helical line to said second conductor at a point spaced from said open end a distance equal to approximately a half wavelength or multiple thereof of the operating frequency of said device.

4. In a traveling wave electron discharge device according to claim 1, wherein the means for coupling said helical line includes a part of said second conductor tapered down to the size of said helical conductor to which it is connected said part being disposed substantially parallel to said first conductor for at least part of the length thereof.

5. In a traveling wave electron discharge device according to claim 1, wherein the low impedance line is a

coaxial line fed through the envelope of said device with the outer conductor thereof coupled to said first conductor and the inner conductor thereof coupled to said second conductor.

6. A transition coupler for use between a low impedance line and a high impedance line comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion with the small end thereof connected to said first conductor to establish a radio frequency voltage null, means coupling said low impedance line to the low impedance end of said section and means for coupling the high impedance line to said second conductor at a point spaced from said null point a distance equal to approximately a quarter wavelength or odd multiple thereof of the operating frequency of said transition.

7. A transition coupler according to claim 6, wherein said high impedance line is a helical line and the means for coupling said helical line comprises a tapered conductor the larger end of which is coupled to said second conductor.

8. A transition coupler according to claim 6, wherein said second conductor is provided with susceptance means disposed thereon and extending beyond a peripheral edge thereof a given distance from each of the points of coupling and having a value to obtain an optimum impedance match at said points of coupling.

9. A transition coupler according to claim 6, wherein said high impedance line is a helical line and the means for coupling said helical line comprises a conductor disposed at an angle to said second conductor and extending for at least part of its length in closely spaced parallel relation to said first conductor.

10. A transition coupler for use between a low impedance line and a high impedance line comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced, substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion with the small end thereof open with respect to said first conductor, means coupling said low impedance line to the low impedance end of said coupler and means for coupling the high impedance line to said second conductor at a point spaced from said open end a distance equal to approximately a half wavelength of the mid-operating frequency.

11. A transition coupler according to claim 10, wherein said high impedance line is a helical line and the means for coupling said helical line comprises a tapered conductor the larger end of which is coupled to said second conductor.

12. A transition coupler according to claim 10, wherein said high impedance line is a helical line and the means for coupling said helical line comprises a conductor disposed at an angle to said second conductor and extending for at least part of its length in closely spaced parallel relation to said first conductor.

13. A transition coupler according to claim 10, wherein said second conductor is provided with means for introducing a susceptance therein of a value to obtain optimum impedance match at the points of coupling.

14. A transition coupler for use between a low impedance line and a high impedance line comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion, said first conductor being terminated as an open conductor adjacent the small tapered portion of said second conductor, means coupling said low impedance line to the low impedance end of said coupler and means for coupling the high impedance line to said second conductor as a part of said second conductor, said part being disposed for at least part of its length parallel to said first conductor.

15. A transition coupler according to claim 14, wherein said high impedance line is a helical line and the means for coupling said helical line comprises an extension of the taper of said second conductor beyond the open end of said first conductor down to the size of the conductor of said helical line.

16. A transition coupler according to claim 14, wherein said second conductor is provided with means for introducing a susceptance therein of a value to obtain optimum impedance match at the points of coupling.

17. In a traveling wave electron discharge device having a helical line of relatively high characteristic impedance and a radio frequency line of relatively low characteristic impedance, a transition section coupling said low impedance line to said helical line, comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion to increase the impedance of said section from a low impedance at one end thereof to a high impedance at the other end thereof, said helical line being terminated adjacent the lateral edge of said first conductor, and a third conductor connecting the terminated end of said helical line to said second conductor at a point therealong matching substantially the high impedance of said helical line, said third conductor being disposed at an angle to said second conductor with at least a portion of said third conductor in closely spaced parallel relation to said first conductor.

18. A transition coupler for use between a low impedance line and a high impedance line comprising first and second conductors, a layer of dielectric material disposed therebetween to maintain said conductors in closely spaced substantially parallel relation, said first conductor having a planar surface over which said second conductor extends, said second conductor having a tapered portion to increase the impedance of said coupler from a low impedance at one end thereof to a high impedance at the other end thereof, means coupling said high impedance line to said second conductor at an impedance point matching substantially the impedance of said high impedance line, means coupling said low impedance line to said transition section at an impedance point matching substantially the impedance of said low impedance line, and susceptance means disposed on said second conductor and extending beyond a peripheral edge thereof a given distance from each of said coupling means to tune out any mismatch that may be present in each of said coupling means.

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