June 8, 1965 M. R. BOYD 3,188,583

PARALLEL PLATE LINE TRANSITION SECTION BETWEEN A COAXIAL LINE AND A RIDGED WAVEGUIDE

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FIG. 1

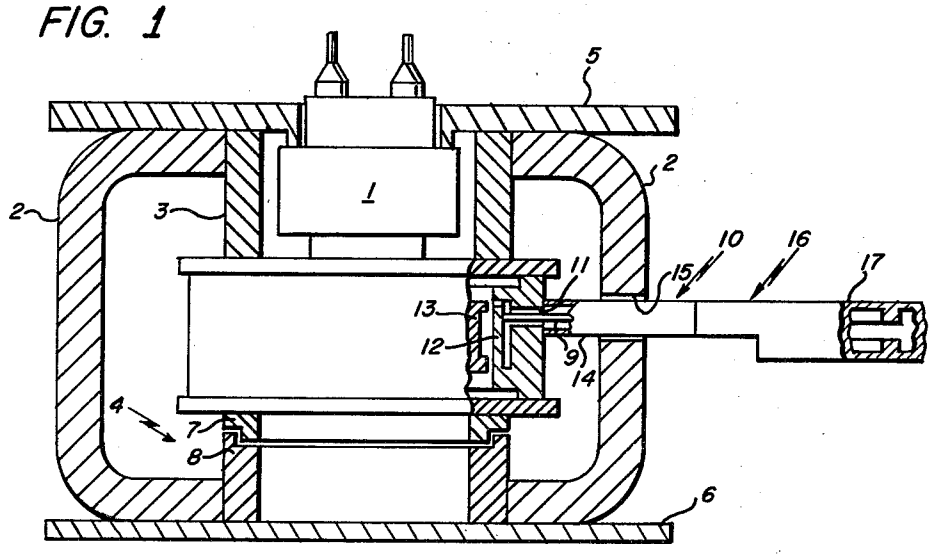
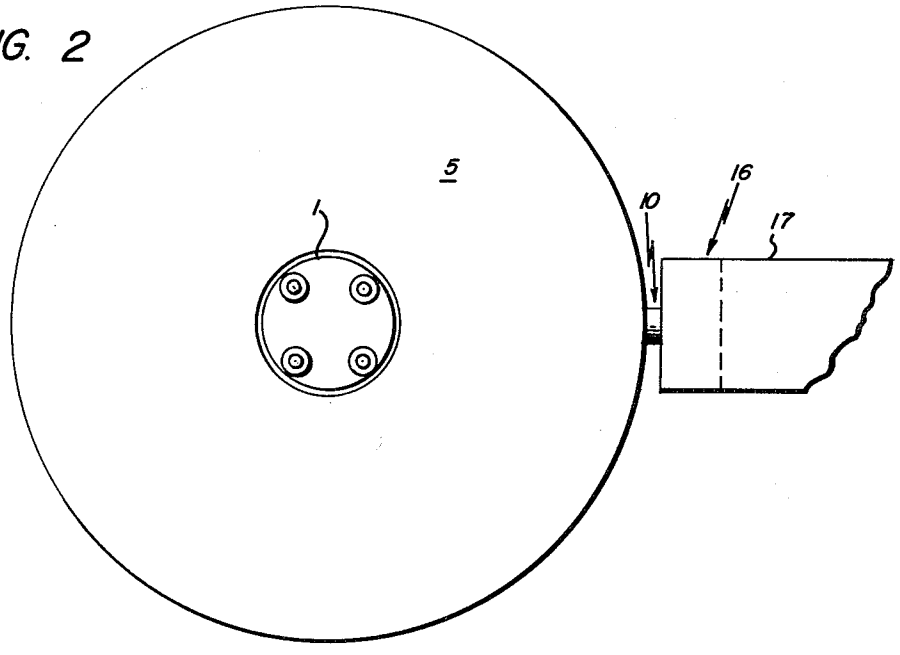


FIG. 2



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FIG. 3

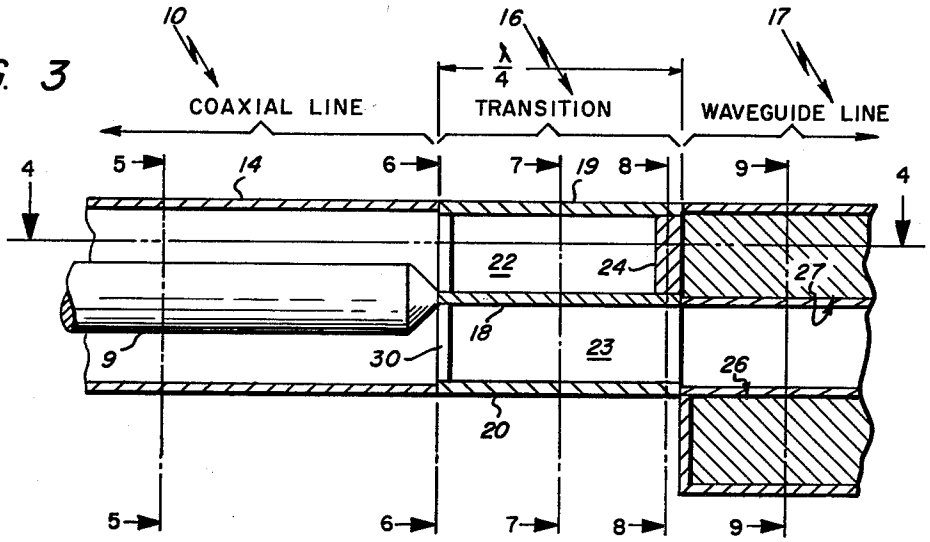
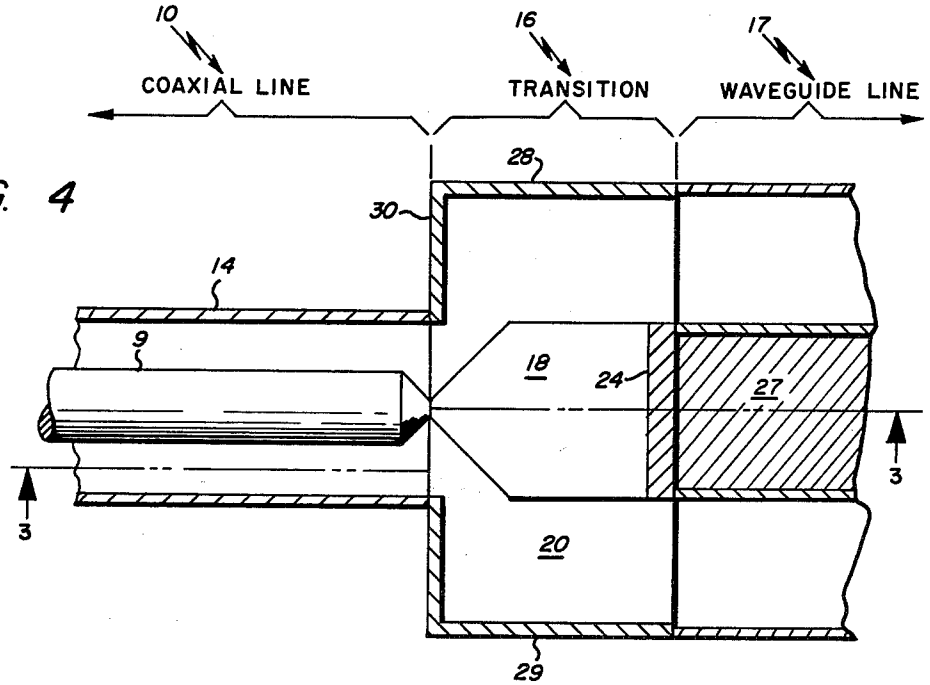


FIG. 4



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FIG. 5

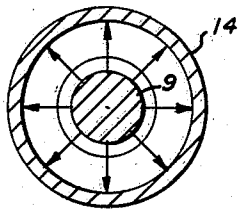


FIG. 6

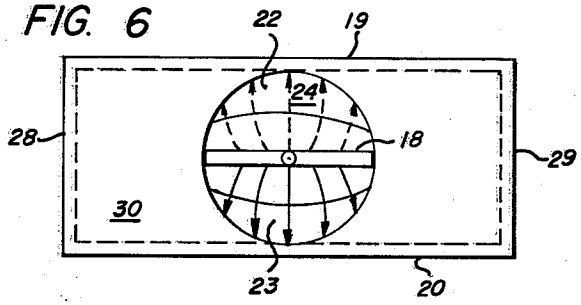


FIG. 7

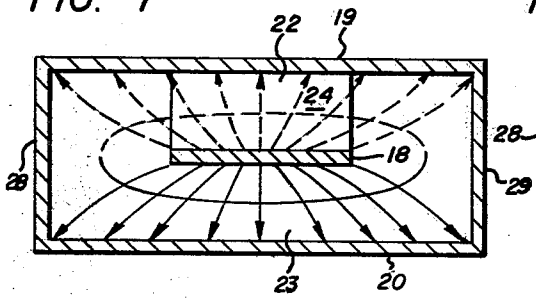


FIG. 8

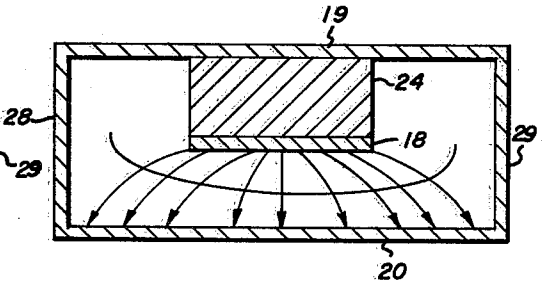
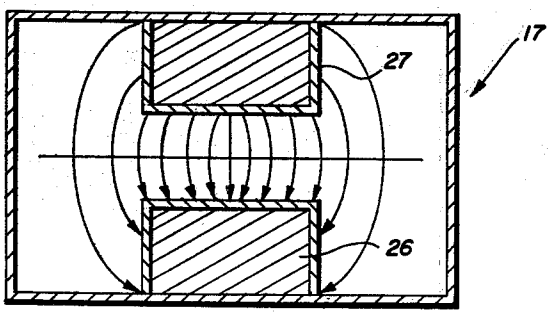


FIG 9



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PARALLEL PLATE LINE TRANSITION SECTION BETWEEN A COAXIAL LINE AND A RIDGED WAVEGUIDE

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Filed Oct. 12, 1961, Ser. No. 144,614
5 Claims. (Cl. 333—26)

This invention relates to traveling wave tube transmission lines and more particularly to a transition section for coupling the relatively low impedance coaxial output from the tube to a relatively high impedance ridged waveguide without creating excessive reflections.

A balanced transmission line, such as a waveguide, generally consists of a plurality of conductors in the presence of ground capable of being operated in such a way that when the voltage of the two conductors at all planes transverse to the direction of transmission are of equal magnitude and opposite in polarity with respect to ground, the currents in the two conductors are equal in magnitude and are opposite in direction. In an unbalanced line, such as a coaxial line, on the other hand, the currents in the two conductors are not equal in magnitude and opposite in direction. As a rule, propagation in an unbalanced transmission line assumes the dominant TEM mode, whereas propagation in a balanced line assumes a TE or TM mode. When radio frequency waves propagate in a TEM mode, the electric and magnetic vectors of the wave are at all times perpendicular to each other and to the direction of flow of energy. However, when waves propagate in a TE mode, only the electric vector of the wave is perpendicular to the direction of propagation and flow of energy. To distinguish between these modes in another way, all wave magnetic lines in TEM propagation encircle a conductor, whereas in TE mode propagation none of the wave magnetic lines encircle a conductor; they only encircle the electric lines. With these differences between the TEM mode and TE mode propagation in mind, it becomes quite clear that transition from, for example, TEM mode to the TE mode is not readily accomplished.

In the present invention, a coaxial transmission line is coupled to the slow wave structure of a backward wave oscillator tube and extends therefrom through an opening in the tube magnet. The impedance of the coaxial line preferably matches the impedance of the slow wave structure which is relatively low. Accordingly, the transverse dimensions of the coaxial line are relatively small, and this is convenient because the opening in the tube magnet can be small. In many applications the tube output must be fed to a waveguide of relatively large impedance and a transition section coupling the unbalanced coaxial line to the balanced waveguide must be provided. Such transitions are sometimes referred to as "balun circuits."

It is well known that such a "balun circuit" transition can be formed by a structure which gradually alters the electric field of wave energy propagating in a TEM mode so that all of the field lines are in the same direction and substantially parallel to each other in a plane transverse to the direction of propagation (as in a TE mode). Heretofore, this transition has been accomplished by, for example, gradually increasing the gap in one direction between two elements which support the TEM mode so that the electric field in that direction gradually diminishes in intensity, and, as a result, the relative intensity of electric field in the opposite direction between the two elements increases in strength. More particularly, in the past the "balun circuit" transition of this type has included a center conductor in a waveguide which progressively is spaced closer to one wall of the guide and farther from the opposite wall. The length of such a transition is usually large in order to achieve a smooth transition with minimum reflection. It is an object of the present invention to provide a smooth transition from unbalanced to balanced line, while at the same time avoiding the above-mentioned disadvantage of prior devices.

In accordance with the present invention, the unbalanced coaxial line is coupled to a balanced ridged waveguide by a transition section comprised of a section of three-element strip transmission line, one pair of elements coupling waves from the coaxial line to the waveguide and another pair of elements being terminated to form a radio wave choke. In a preferred embodiment of the invention, the three-element strip line is modified so that the two outer elements are connected together completely enclosing the center conductor. This modification, however, does not alter the mode of propagation of waves therethrough. Other objects and features of the invention will be more apparent from the following specific description taken in conjunction with the drawings in which:

FIGS. 1 and 2 illustrate side and plan views of a backward wave oscillator having its coaxial line output coupled to a ridged waveguide by a transition section;

FIG. 3 is a side sectional view of the transition joining the coaxial line output to the waveguide;

FIG. 4 is a plan sectional view of the transition and lines;

FIGS. 5–9 illustrate sectional views taken transverse to the axis of the transition and lines to show the electric field configuration of waves propagating therethrough.

FIGS. 1 and 2 illustrate a typical backward wave oscillator tube of the type having a circular interaction space and including a "balun circuit" transition section coupling the oscillator to a waveguide in accordance with the invention. The oscillator tube is preferably constructed with a circular interaction space as described in copending United States application Serial No. 126,936 for a Temperature Compensated Traveling Wave Tube filed July 26, 1961 by Peter Janis, which includes an interdigital type slow wave structure with a digit thereof connected to the outer conductor of the coaxial line.

FIG. 1 illustrates a side sectional view of the tube showing the assembled parts thereof. These parts consist of a center envelope 1 (partly in section) disposed within the magnet 2 between cylindrical pole pieces 3 and 4. The assembly is mounted between support plates 5 and 6. Pole piece 4 is in two parts 7 and 8 separated from each other by an air gap. This construction, as described in the above-mentioned application, serves to compensate the magnetic field in the envelope 1 for variations due to thermal expansion of the structure. As shown in FIG. 1, the center conductor 9 of coaxial line 10 extends through an opening 11 in the envelope and conects to finger 12 of the interdigital line 13. The outer conductor 14 of line 10 is attached to the outside of the envelope which is at anode or ground potential. A relatively small diameter opening 15 in magnet 2 permits coaxial line 13 to extend therethrough to the "balun circuit" transition 16 which couples coaxial line 10 to double ridged waveguide 17 (shown broken to reveal the ridges).

FIG. 2 illustrates a plan view of the tube showing the coaxial line extending therefrom to the transition section and waveguide. Details of structure and operation of the transition section and waveguide are shown in FIGS. 3–8 and described below.

FIGS. 3 and 4 illustrate side and plan sectional views, respectively, of the transition 16 coupling coaxial line 10 to the symmetrical ridged waveguide 17. FIG. 3 illustrates a section taken through the axes of the coaxial line and waveguide, and FIG. 4 illustrates a section taken as shown in FIG. 3. As illustrated, the end of coaxial

line 10 comprised of center and outer conductors 9 and 14 is coupled to the ridged waveguide 17 by transition section 16 which may be described as a modified parallel plate line or a modified three-element strip transmission line. The center conductor or tongue 18 of this modified strip line is attached to the center conductor of the coaxial line, while the outer conductors 19 and 20 are connected to the outer conductor 14 of the coaxial line. Conductor 18 is shown in plan view in FIG. 4 to illustrate one suitable shape for this conductor. As shown in FIG. 4, the end of conductor 18 that is attached to center conductor 9 is preferably tapered to reduce the possibility of electrical breakdown between conductor 9 and the outer conductor 14 of the coaxial line.

As already mentioned, the transition section may be considered as a modified parallel plate line or a modified three-element strip line. In any event, wave propagation through this section is in the TEM mode which is not altered by the fact that the upper and lower plates 19 and 20 form a continuous surface enclosing the center conductor or tongue 18. If the transition section is considered as two parallel plate lines sharing a common conductor (tongue 18) then it is apparent the transition consists of two parallel plate transmission lines, an upper one 22 and a lower one 23.

The upper parallel plate line 22 is formed by conductors 19 and 18, and the lower parallel plate line 23 is formed by conductors 18 and 20. These parallel plate lines 22 and 23 in combination match the impedance of the coaxial line 10, and parallel plate line 23 alone matches the impedance of the ridged waveguide 17. The transition section 16 is matched to the coaxial line by making parallel plate line 22 appear to half of the coax as an open circuit (or at least a relatively large impedance) and by shaping center conductor 18 as necessary to match the impedance of the other half of the coaxial line. Parallel plate line 22 appears as an open circuit because it is approximately a quarter wave length long and terminated by conductive block 24. The length of parallel plate line 23 is also an important factor in accomplishing the match, and it has been found effective to make line 23 slightly longer than a quarter wave length. As a result, propagation in the coaxial line 10 which is in a TEM mode continues in the TEM mode in the transition section 16. However, only the lower part of the transition section formed by parallel plate line 23 conducts energy to the waveguide 17.

The transition section 16 is connected as shown in FIGS. 3 and 4. Briefly, conductor 19 of the transition section is connected to the upper wall of waveguide 17 while the lower conductor 20 of the transition section is connected to the end of the lower ridge 26 of the waveguide. The center conductor or tongue 18 of the transition section is connected to the end of the upper ridge 27 of the waveguide. Accordingly, RF energy is coupled from the coaxial line 10 to parallel plate line 23 of the transition section and from there to the ridges of the waveguide where the energy continues to propagate in a TE mode.

FIGS. 5–9 illustrate sectional views of the structure taken as shown in FIG. 3 to more completely describe the structure and to illustrate the general shapes of the radio wave electric fields throughout the device. For example, FIG. 5 illustrates a sectional view showing the outer conductor 14 and center conductor 9 of the coaxial line 10. The electric field of the radio frequency wave is represented by heavy line arrows, and the magnetic field of the wave is indicated by the light lines. FIG. 6 illustrates a view taken at one end of the transition section 16 showing the upper and lower conductors 19 and 20 of the transition with side walls 28 and 29 and end cover plate 30 connected therebetween so as to enclose the center conductor or tongue 18. As shown, conductors 18 and 19 together form parallel plate line 22, and conductors 18 and 20 together form parallel plate line 23, the opposite end of line 22 being terminated by shorting bar 24. Since the two parallel plate lines 22 and 23 are in shunt, line 22 being very high impedance and line 23 being relatively low, it is quite apparent that substantially all power will be conducted by line 23 and substantially none by line 22.

A cross section view of transition 16 is shown in FIG. 7 to illustrate the electric field therein. Substantially the same shape electric field extends from conductor 18 into lines 22 and 23. However, the field in line 22 is represented by broken lines because this parallel plate line carries little or no power between the coaxial line and waveguide. Substantially all power is conducted by parallel plate line 23. Accordingly, while propagation through the transition section is in a TEM mode, energy propagates through this section in a mode which is equivalent to a TE mode.

FIG. 8 illustrates the structure and field at the end of transition section 16 in a sectional view through the shorting block 24. At this point, all propagation in the transition section is in a mode which is substantially a TE mode, and the impedance at this end is substantially equal to the impedance of the ridged waveguide 17. FIG. 9 illustrates a sectional view through the waveguide 17 showing a typical symmetrical ridged waveguide and the general shape of the electric field of a wave propagating in a TE mode.

While there is described herein a specific embodiment of the invention showing a coaxial line and a waveguide coupled by a transition section which is formed by an open circuit or radio frequency choke coupled to one-half of the coaxial line and a modified parallel plate line coupling the other half of the coaxial line to the waveguide, it is to be clearly understood that these are made only by way of example and do not limit the spirit and scope of the invention as set forth in the accompanying claims.

What is claimed is:

1. A radio wave transmission line comprising a section of coaxial line, a section of ridged guide, a section of three-element parallel plate strip transmission line coupled between said coaxial and waveguide sections with the intermediate element of said parallel line being connected to the center conductor of said coaxial line, means shorting the intermediate and one of the outer elements of said strip transmission line to define a radio wave choke to waves propagated in one half of said coaxial line.

2. A radio wave transmission line comprising a section of coaxial line, a section of waveguide, a section of parallel plate lines coupled between said coaxial and waveguide sections comprising two outer ground plane conductors and an intermediate conductor therebetween, said intermediate parallel plate line conductor being connected to the center conductor of said coaxial line, one of said outer ground plane conductors defining with said intermediate conductor a radio wave choke to one half of said coaxial line and the other of said ground plane conductors defining with said intermediate conductor an open transmission line for the propagation of energy from the remaining half of said coaxial line.

3. A radio wave transmission line comprising a section of coaxial line, a section of ridged waveguide, a section of parallel plate lines coupled between said coaxial and ridged waveguide sections comprising two outer ground plane conductors and an intermediate conductor therebetween, said intermediate conductor being connected to the center conductor of said coaxial line, one of said outer ground plane conductors being shorted to said intermediate conductor to define a radio wave choke to one half of said coaxial line and the other of said ground plane conductors being connected to said waveguide ridge.

4. A radio wave transmission line comprising a section of coaxial line, a section of symmetrical ridged wave-

guide, a section of parallel plate lines coupled between said coaxial and ridged waveguide sections comprising two outer ground plane conductors and an intermediate conductor therebetween, said intermediate conductor being connected to the center conductor of said coaxial line, one of said outer ground plane conductors being shorted to said intermediate conductor to define a radio wave choke to one half of said coaxial line and the other of said ground plane conductors defining with said intermediate conductor means for coupling waves from the remaining half of said coaxial line to said ridges.

5. A transition section for coupling a coaxial transmission line to a symmetrical ridged waveguide comprising a third section of transmission line including a plurality of elements for propagating said waves in a balanced TEM mode, means coupling one end of one pair of said elements across one part of said coaxial line and the other end of said one pair across the ridges of said waveguide, means coupling one end of another pair of said

elements across another part of said coaxial line, and means shorting the other end of said other pair to provide a radio wave choke, the complete structure being such that energy propagating in said coaxial line is conducted therefrom by said one pair of elements to the ridges of said waveguide.

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