Nov. 10, 1953 S. B. COHN 2,659,055

DIELECTRIC WAVE GUIDE TO COAXIAL LINE JUNCTION

Filed May 24, 1946 2 Sheets-Sheet 1

FIG. 1

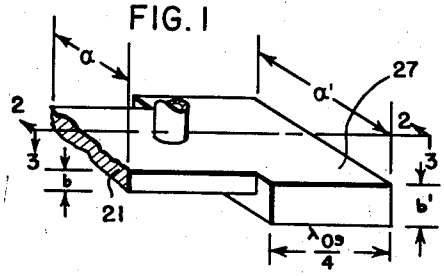


FIG. 2

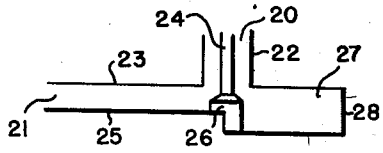


FIG. 3

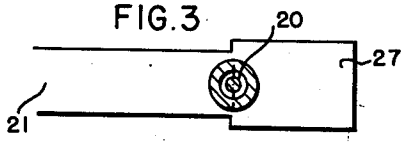


FIG. 4

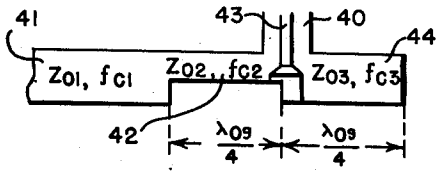


FIG. 5

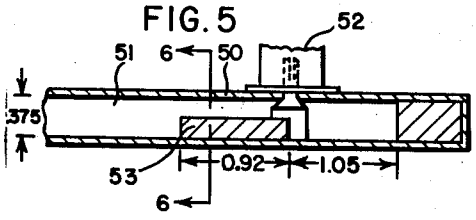


FIG. 6

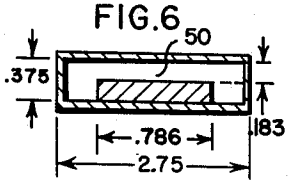


FIG. 7

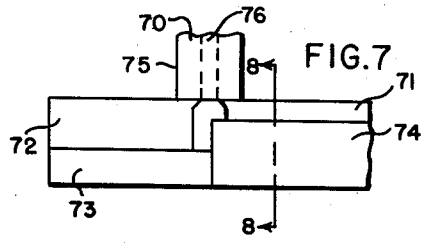


FIG. 8

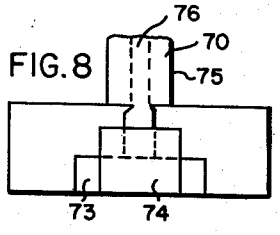


FIG. 9

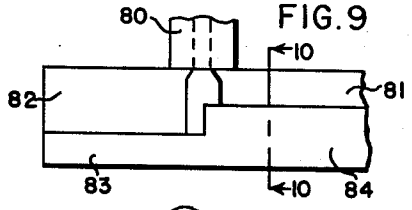
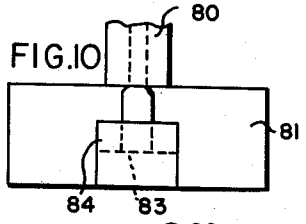


FIG. 10



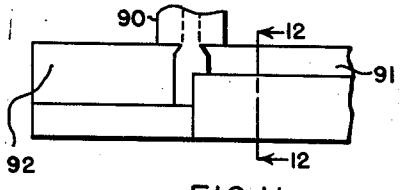
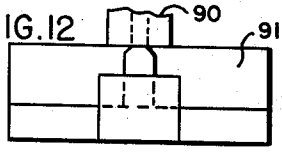


FIG. 11

FIG. 12



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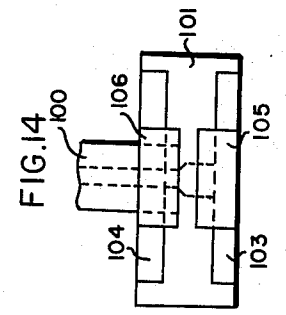


FIG. 14

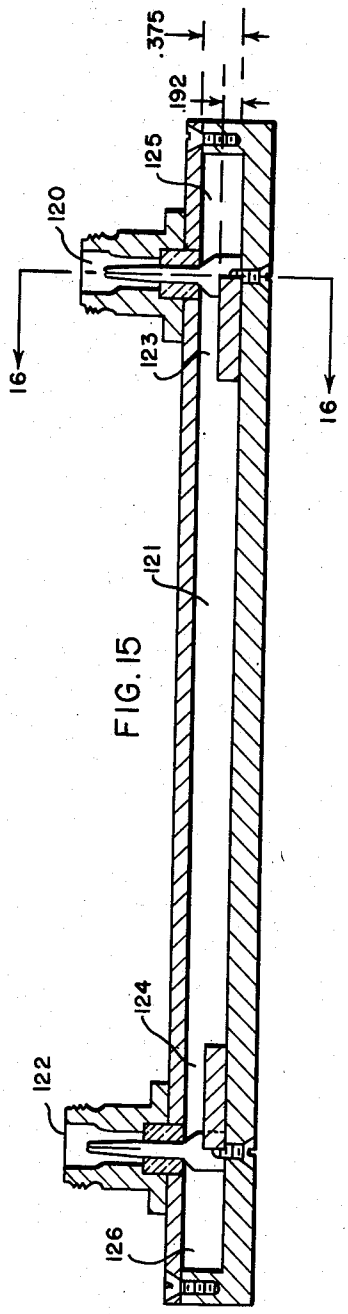


FIG. 15

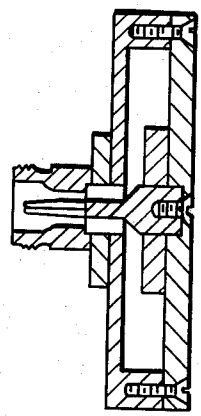


FIG. 16

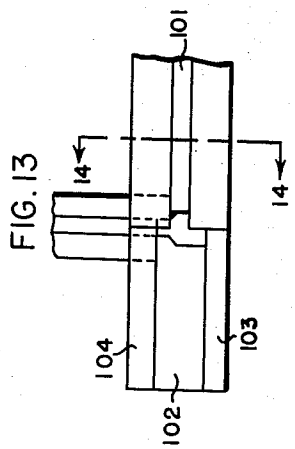


FIG. 13

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DIELECTRIC WAVE GUIDE TO COAXIAL LINE JUNCTION

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Application May 24, 1946, Serial No. 672,017

9 Claims. (Cl. 333—35)

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My invention relates to electrical apparatus and more particularly to electromagnetic energy transference structures having junctions between coaxial transmission lines and wave guide transmission lines.

It is frequently desirable in the electrical art to transfer electromagnetic energy of high or ultra-high frequency between coaxial lines and wave guides. For example, the energy generated by many ultra-high frequency oscillators is most readily transmitted therefrom by a probe means which is usually extended to form the inner conductor of a coaxial line. A like adaptation is often utilized in coupling energy from or to resonant cavity structures. Coaxial transmission lines for systems of this nature employing frequencies in a relatively high range, prove comparatively inefficient for carrying the energy over any extended distance. Furthermore, it is frequently desirable in such systems to employ wave guide transmission lines of various kinds to make available in the system advantages which inhere in certain wave guide transmission modes. One of the difficulties encountered in prior art junctions between a coaxial transmission line and a wave guide transmission line is the limited frequency band through which the junction may be used without excessive losses being introduced. These losses have occurred not only at frequencies displaced from the contemplated operating frequency but sometimes even at the contemplated operating frequency. Various expedients have been proposed heretofore to minimize the undesirable effects of a restricted frequency band of operation and to increase the effective frequency band of operation, with more or less success.

It is, therefore, an object of my present invention to provide an improved junction between a coaxial transmission line and a wave guide transmission line.

It is a further object of my invention to provide such a junction which affords an increased frequency band of efficient operation.

It is another object of my invention to provide a junction which will operate in a satisfactory manner at frequencies of operation in the near neighborhood of the cutoff frequency of the wave guide.

It is another object of my invention to provide a junction between a coaxial transmission line and a rectangular cross-sectional wave guide.

Another object of my invention is to provide a junction between a coaxial transmission line and a ridge wave guide.

Still another object of my invention is to provide a junction between a coaxial transmission line and a double ridge wave guide.

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A further object of this invention is to provide a high pass filter which will have a sharp cut-off frequency characteristic.

Still another object is to provide a wave guide section interposed in a coaxial transmission line to serve as a high pass filter.

Other and further objects, advantages, and novel features of my invention will become apparent herein from the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a perspective view of one illustrative embodiment of the present invention showing a junction between a coaxial transmission line and a rectangular cross-sectional wave guide.

Fig. 2 is a schematic line drawing of a section taken through the line 2—2 of Fig. 1.

Fig. 3 is a top view of the embodiment of Fig. 1;

Fig. 4 is a schematic line drawing of an illustrative embodiment of my present invention showing the junction between a coaxial transmission line and a rectangular wave guide utilizing a rectangular wave guide transformer section;

Fig. 5 is a cross-sectional view of another illustrative embodiment of the present invention utilizing a ridge wave guide transformer section;

Fig. 6 is a cross-sectional view along the line 6—6 of Fig. 5;

Fig. 7 is a schematic line drawing of another embodiment of my invention illustrating a junction between a coaxial transmission line and a ridge wave guide;

Fig. 8 is another line drawing of the embodiment illustrated by Fig. 7 viewed along the line 8—8 thereof looking in the direction of the arrows;

Fig. 9 is a schematic line drawing of yet another illustrative embodiment of the present invention illustrating a junction between a coaxial transmission line and a ridge wave guide;

Fig. 10 is a view of the embodiment of Fig. 9 along the line 10—10 thereof;

Fig. 11 is a schematic line drawing of still another illustrative embodiment of the present invention, again illustrating a junction between a coaxial transmission line and a ridge wave guide;

Fig. 12 illustrates a view through the line 12—12 of Fig. 11;

Fig. 13 is a schematic line drawing of another illustrative embodiment of the present invention illustrating a junction between a coaxial transmission line and a double ridge wave guide;

Fig. 14 is a view of the embodiment of Fig. 13 taken along line 14—14 thereof;

Fig. 15 is a cross-sectional view of yet another embodiment of the invention comprising a high pass filter; and

Fig. 16 is a cross-sectional view of the embodiment of Fig. 15 along the line 16—16.

In brief, my invention contemplates a coaxial line-wave guide junction, wherein one or more sections of wave guide adjacent to and communicating with the junction have a different cross section from the wave guide to be matched. These sections are proportional so as to improve the impedance match and the response characteristics of the junction.

Referring now more particularly to Figs. 1, 2 and 3 wherein like numbers refer to like parts, there is illustrated a junction between a coaxial transmission line **20** and a wave guide **21**. Coaxial transmission line **20** has an outer conductor **22** connected to one broad wall **23** of wave guide **21** and an inner conductor **24** which extends to the other broad wall **25** of wave guide **21** and which has a portion **26** of enlarged diameter within the junction, as shown. A wave guide section **27** is provided which communicates directly with the junction and has its axis directly under the axis of wave guide **21** extended through the junction. Wall **23** is extended to form the top wall of section **27**. It will be assumed in this description, as well as those which follow, that the coaxial transmission line extends into the top wall of the wave guide, as shown for example in the view of Fig. 2, to afford convenient reference to top and bottom walls of the guide. Section **27** has a width a', the distance between its narrow walls, which is greater than the corresponding dimension a between the narrow walls of wave guide **21**. Also, wave guide section **27** has a greater depth b' between its broad walls than the corresponding dimension b between broad walls **23** and **25** of wave guide **21**. Wave guide section **27** is "shorted" or closed by an end portion **28** at its far end from the junction. Consequently, section **27** may be considered as a chamber communicating with the junction.

Section **27** may have a dimension a' equal to, greater than, or less than the dimension a. I prefer to provide the end section **27** with a dimension b' greater than dimension b of wave guide **21**, so that the end section has a greater characteristic impedance than that possessed by prior art conventional end sections which have the same inside dimensions as the wave guide to which the junction is made.

By increasing the characteristic impedance of shorted section **27**, its reactance may be maintained at a comparatively high value over a relatively wide frequency range in comparison with the impedance of the wave guide to which a junction is effected. I prefer to construct section **27** to be substantially one-quarter wave guide wavelength long measured from the axis of the coaxial line termination to the closed end at about the center frequency of the operating range. I prefer to calculate the dimensions of the various parts to provide a substantially zero standing wave ratio at this frequency. In other words, the dimensions are calculated to give a perfect match at some chosen frequency.

Referring now more particularly to Fig. 4 illustrating another preferred embodiment of my invention, there is shown a junction between a coaxial transmission line **40** and a rectangular wave guide **41**. A transformer section of wave guide **42** is inserted at the junction of the line **40** with the wave guide structure. Wave guide section **42** has a smaller characteristic impedance than the impedance of wave guide **41**. I prefer to design the junction to provide an approximate impedance match at some intermediate operating frequency designated as f_0 which may not be exactly at the center of the contemplated operating range of the junction. As shown, the outer conductor of the coaxial line **40** terminates on the upper surface of the guide **41** and the center conductor is extended to terminate on the lower surface thereof. I have determined that good results may be obtained by increasing the diameter of the center conductor **43** by means of a taper where it enters the wave guide to a diameter approximately 0.15 times the width of the guide. In addition I provide a back cavity, or shorted section **44** having the same cross-sectional dimensions as main wave guide **41**. In one operative model constructed in accordance with the illustration of Fig. 4 I provide a junction between a coaxial line **40** having a characteristic impedance of 50 ohms, and a wave guide having cross-sectional dimensions of 2¾ inches in width by ⅜ inch in height. The length of section **42** is chosen to be substantially one-quarter guide wavelength ($\lambda og/4$) at frequency f_0, as shown, and a terminating shorted section **44** also of length $\lambda og/4$ is provided, extending from the junction oppositely from wave guide **41**, as shown. Terminating section **44** has the same cross-sectional dimensions as wave guide **41**. A quarter guide wavelength at a center frequency f_0 of 3200 megacycles was calculated to be about 1.22 inches. At this center frequency a very good match is provided by choosing the height of section **42** to be .234 inch.

Better operation near the cutoff frequency of wave guide **41** may be obtained by reducing the cutoff frequency of transformer section **42**. This may be accomplished by widening this portion of the wave guide to be greater than the 2¾ inches width of wave guide **41**, or by utilizing a ridge wave guide or a double ridge wave guide for the transformer section **42**.

Referring now to Figs. 5 and 6, there is illusterated a practical embodiment employing a ridge wave guide transformer section **50** to form a junction between wave guide **51** and coaxial line **52**. Section **50** of the ridge wave guide has the same width as the main wave guide **51** and a longitudinal ridge insertion **53** of length 0.92 inch, height .192 inch and width .786 inch. The ridge commences at the axis of the junction of the coaxial line, as shown in Fig. 5, which is located 1.05 inches from the shorted end of wave guide **51**. Each of the dimensions 0.92 and 1.05 are equal to $\lambda og/4$ at the operating frequency, the difference in dimensions being due to the fact that the velocity of electromagnetic energy in the ridge section is less than the velocity of electromagnetic energy in the shorted section. I find it generally preferable in such embodiments as that of Fig. 5 to use a ridge which is between ⅓ and ⅔ of the width of the guide. The ridge section shape should be chosen so that it has a cutoff frequency about $\frac{8}{10}$ of the main wave guide cutoff frequency. The main wave guide **51** has cross-sectional dimensions of 2¾ by ⅜ inches.

One advantage in employing a ridge wave guide with ridge dimensions in the region hereinbefore indicated, is that the next dominant mode of the ridge section will be equal to or greater than the next dominant mode of the wave guide without the ridge. Hence, if operation at frequencies near the cutoff frequency of the next dominant mode is desired, it is advantageous thus to choose

the width of the ridge to inhibit higher mode excitation. The ridge wave guide section, hereinbefore described connecting the 2¾ by ⅜ inches wave guide to a 50 ohm characteristic impedance coaxial transmission line, is designed for a center frequency f_0 of 3530 megacycles. The ridge section has a lower cutoff frequency than that of the main wave guide. There is a great improvement in the low frequency response near the cutoff frequency of the main wave guide. An overall band width of 2400 to 5300 megacycles with a standing wave ratio of less than 2.0 results. Other useful variations of this embodiment will suggest themselves; for example, it may be advisable to use two transformer sections which are substantially one-quarter wavelength, in terms of guide wavelengths, at two different frequencies in order to level the response characteristics.

It may, under some circumstances, be desirable to build a junction which is mismatched at the chosen intermediate frequency in order to afford a wider operating frequency band wherein the resulting standing wave ratio remains below some predetermined figure.

Figs. 7 to 14 illustrate modifications of the embodiment shown in Figs. 5 and 6, which are identical therewith except as hereinafter set forth.

Referring now to Figs. 7 and 8 wherein like reference numerals refer to like parts, a junction is illustrated between a coaxial transmission line **70** and a ridge wave guide **71**. A back cavity **72** is formed on an opposite side of the junction of wave guide **71** which comprises a "shorted" or closed section of ridge wave guide. Ridge **73** in section **72** extends to the junction and has different dimensions from ridge **74** which extends in the main wave guide **71**. The other internal dimensions of wave guides **71** and **72** may be the same. As before, the outer conductor **75** of coaxial line **70** terminates on the top broad wall of the wave guide junction and inner conductor **76** is extended into the junction to make contact with the ridges which extend symmetrically along the lower broad wall. The diameter of inner conductor **76** may be enlarged, as shown, where it enters the junction, to provide a more perfect impedance match. This feature may be included in the other embodiments herein disclosed.

Referring now to Figs. 9 and 10, there is illustrated a junction between a coaxial transmission line **80** and a ridge wave guide **81**. This embodiment is similar to the embodiment illustrated by Figs. 7 and 8 except that the shorted back cavity **82** is a section of ridge wave guide wherein the rectangular ridge **83** has the same width as ridge **84** in main wave guide **81** but has a different height.

Referring now to Figs. 11 and 12 there is illustrated still another embodiment of the present invention showing a junction between a coaxial transmission line **90** and a ridge wave guide **91**. In this embodiment back cavity **92** is formed of a conventional section of wave guide having a smaller depth than the depth of ridge wave guide **91** with the ridge absent, but having its upper internal wall formed as an extension of the upper internal wall of wave guide **91**.

Referring now to Figs. 13 and 14, there is illustrated still another illustrative embodiment of the present invention wherein a junction is provided between a coaxial transmission line **100** and a section of double ridge wave guide **101**. The back cavity is formed of a section of double ridge wave guide **102** wherein the two symmetrical rectangular ridges **103** and **104** extending from the broad walls have different dimensions from the symmetrical ridges **105** and **106** of main wave guide **101**. The ridges **103** and **104** of the back cavity **102** are not so deep and are broader than those of main wave guide **101**.

Referring now to Figs. 15 and 16 wherein are illustrated two cross-sectional views of a high-pass filter structure, coaxial transmission line **120** is connected by a junction, which may be of the type previously disclosed herein, to one end of a length of wave guide **121**. A section junction, which may be similar to the first junction, affords a connection between the other end of wave guide **121** and a second coaxial transmission line **122**. The junction includes transformer sections **123** and **124** respectively composed of short sections of ridge wave guides which communicate directly with the conventional rectangular wave guide **121**. The junctions also include back cavities or sections **125** and **126**, respectively.

In the design of this filter the matching transformer sections and cavities are proportioned to give a match in impedance between the guide and the coaxial lines at frequencies well above the desired cutoff frequency. The dimensions shown provide a high-pass filter which will permit the transfer of frequencies from one coaxial line to the other (each having a characteristic impedance of 50 ohms) with practically no loss above a frequency of 2700 megacycles and up to about 7000 megacycles. Below 2700 megacycles the attenuation increases with great rapidity, for example, being 14 decibels down at 2500 megacycles.

It will be apparent from the foregoing description, to those skilled in the art, that my invention is susceptible of many variations. Therefore, it is not desired to restrict the invention to the precise embodiments herein disclosed, but I desire by the accompanying claims to include all such variations as fall within the scope and spirit of the invention.

What I claim as my invention and desire to secure by Letters Patent is:

1. An ultra-high frequency coupling device comprising: a wave guide including a rectangular first section having a length of substantially one-quarter wavelength at the operating frequency and having one end thereof closed, said first section having a given internal cross-section, and a rectangular second section having a length of greater than one-quarter wavelength at the operating frequency, and having one end thereof joined to the other end of said first section, at least a portion of said second section having an internal cross-section which is appreciably less than said given cross-section, said portion being adjacent to said first section and having at least a predetermined length, said predetermined length being substantially one-quarter wavelength at the operating frequency; a coaxial line coupled to said wave guide at the junction of said first and second sections, with the inner and outer conductors respectively of said line connected to the opposite wide walls of said first and second sections.

2. A coupling device as defined in claim 1, wherein the entire second section has an internal cross-section which is appreciably less than said given cross-section, both the wide and narrow walls of said first section being respectively larger than the wide and narrow walls of said second section.

3. A coupling device as defined in claim 1,

wherein said predetermined length is substantially one-quarter wavelength at the operating frequency; further comprising a rectangular third section of said wave guide having a length of substantially one-quarter wave length at the operating frequency and having one end thereof closed, said third section having said given internal cross-section, said second section having a length which is greater than one-half wavelength at the operating frequency and having its other end joined to the other end of said third section, said second section having a second portion having a cross-section and a length equal to said first-mentioned portion, said second portion being adjacent to said third section; and a second coaxial line coupled to said wave guide at the junction of said second and third sections, with the inner and outer conductors respectively of said second line connected to the opposite wide walls of said second and third sections.

4. A coupling device as defined in claim 1, wherein the portion of said inner conductor within said wave guide has a diameter greater than one-tenth the width of the smallest wide walls of the wave guide.

5. A coupling device as defined in claim 1 wherein said entire wave guide is a single wave guide element, and said portion is formed by a ridge extending longitudinally along the inner surface of one wide wall of the wave guide element.

6. A coupling device as defined in claim 1

wherein said portion is said predetermined length and differs in cross-section from the remainder of said second section so that it has a lower cut-off frequency than said remainder of said second section.

7. A coupling device as defined in claim 1, including a ridge extending from said inner conductor to said closed end of said first section along the inner surface of one wide wall of said first section.

8. A coupling device as defined in claim 7, wherein said portion includes a ridge extending longitudinally throughout said portion along the inner surface of one wide wall of said portion.

9. A coupling device as defined in claim 1, including a ridge extending longitudinally along the inner surface of each wide wall of said portion throughout said portion.

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