

May 2, 1961

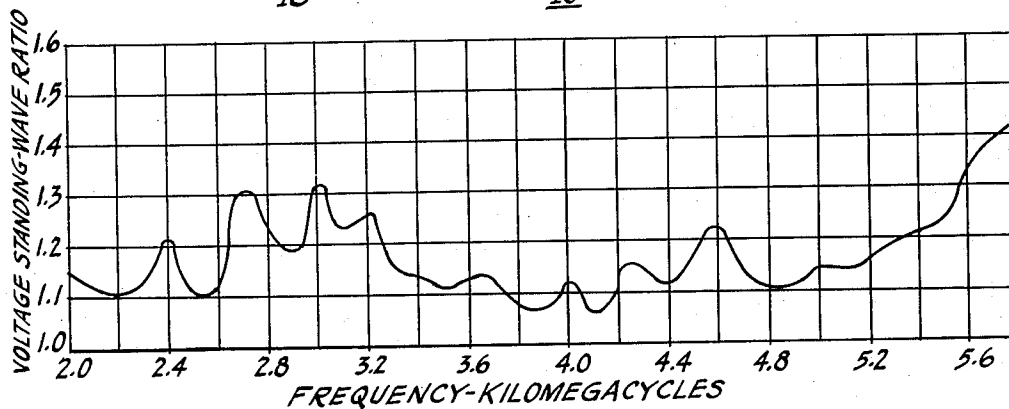
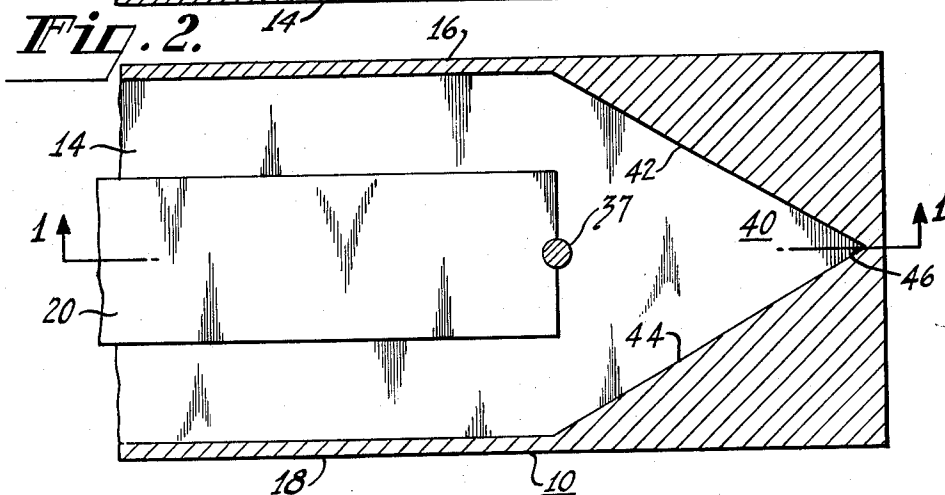
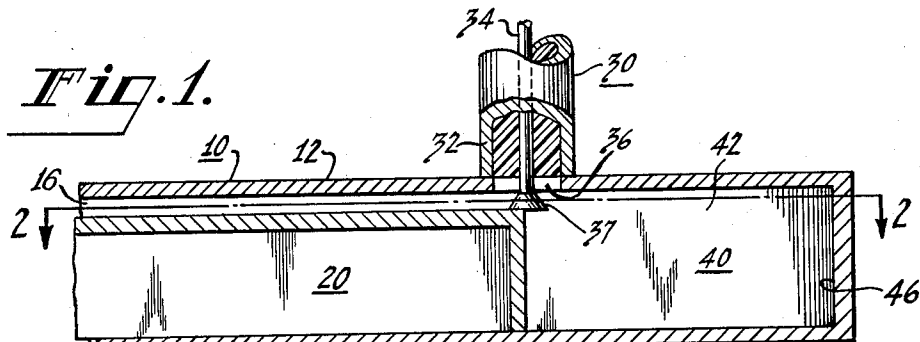
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2,982,927

TRANSITION DEVICE

Filed Jan. 6, 1958

2 Sheets-Sheet 1



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Fig. 3.

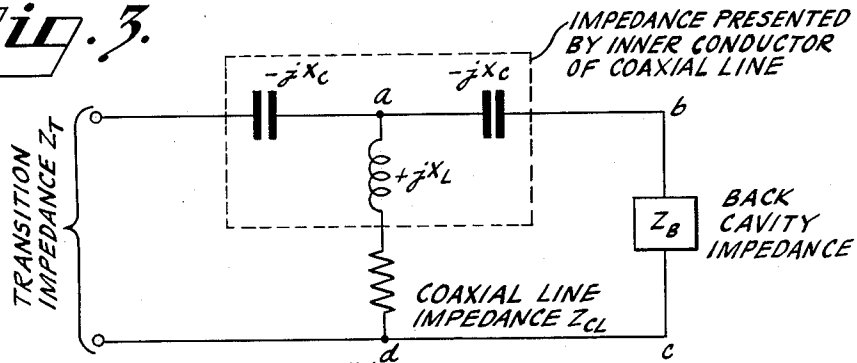
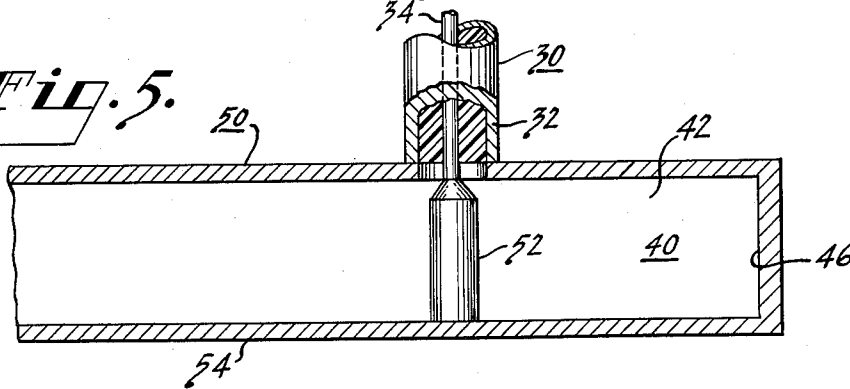


Fig. 5.



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TRANSITION DEVICE

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7 Claims. (Cl. 333—34)

The invention relates to a transition device, and particularly to a transition device for coupling radio frequency energy between a coaxial transmission line and a waveguide.

An object of the invention is to provide an improved transition device for coupling radio frequency energy between a coaxial transmission line and a waveguide.

Another object of the invention is to provide an improved transition device that couples radio frequency energy between a coaxial transmission line and a waveguide, and that has a low voltage standing-wave ratio over a wide band of frequencies.

The transition device is intended to couple radio frequency energy between a coaxial transmission line and a rigid waveguide, although the device can be used equally well with a conventional completely hollow rectangular waveguide. The coaxial transmission line is coupled to one end of the waveguide with the outer conductor of the transmission line coupled to a wall of the waveguide and with the inner conductor of the transmission line extending into the interior of the waveguide so as to couple energy to or from the waveguide. A V-shaped back cavity is joined to the same end of the waveguide so that the vertex of the back cavity is remote from the waveguide. The back cavity has a cross-sectional configuration at the end which is joined to the waveguide that is substantially the same as the inner contour of the waveguide would be without a ridge. The back cavity tapers to a smaller configuration at the vertex, this smaller configuration substantially preventing the radio frequency energy in the waveguide from propagating to the vertex. An effective waveguide-beyond-cutoff is thus provided by the back cavity which presents a high shunt impedance over a wide band of frequencies at the junction of the coaxial cable with the waveguide. This high shunt impedance enables the transition device to have a low voltage standing-wave ratio over this wide band of frequencies.

The invention is explained in detail in connection with the accompanying drawing in which:

Figures 1 and 2 show side and top longitudinal sectional views respectively of a ridged waveguide utilizing the transition device, Figure 1 being taken along the lines 1—1 in Figure 2, and Figure 2 being taken along the lines 2—2 in Figure 1;

Figure 3 shows an equivalent circuit diagram of the transition device shown in Figures 1 and 2;

Figure 4 shows a curve illustrating the low voltage standing-wave ratio provided by the transition device shown in Figures 1 and 2;

Figure 5 shows a side longitudinal sectional view of a conventional rectangular waveguide utilizing the transition device.

In Figures 1 and 2, the transition device couples a ridged rectangular waveguide 10 to a coaxial transmission line 30. A rigid waveguide is preferred over the conventional waveguide because it can be operated over a wider band of frequencies. The waveguide 10 is rec-

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tangular in cross section, and comprises two wide walls 12, 14 and two narrow walls 16, 18 which are joined together to form the waveguide 10. A ridge 20 extends longitudinally along the length of the waveguide 10 in the interior thereof, and is fastened to one of the walls of the waveguide 10. In Figures 1 and 2, the ridge 20 is fastened to the interior of the wide wall 14 midway between the narrow walls 16, 18. The coaxial transmission line 30 is coupled to the waveguide 10 at one side. The outer conductor 32 of the coaxial line 30 is fastened to the wide wall 12 opposite the ridge 20, and the inner conductor 34 of the coaxial line 30 extends through an opening 36 in the wide wall 12 into the interior of the waveguide 10. The inner conductor 34 is coupled to the ridge 20 through a matching post 37. The post 37 has a diameter greater than the diameter of the inner conductor 34 of the coaxial line 30 for a reason that will be explained. The transition between the two diameters may be gradually tapered to minimize discontinuity. Radio frequency energy is thus coupled between the waveguide 10 and the coaxial transmission line 30.

While presently known transition devices satisfactorily couple radio frequency energy between the waveguide 10 and the coaxial line 30, as described, such devices have a limited passband of frequencies at an acceptable voltage standing-wave ratio because of the manner in which the waveguide is terminated. For example, the device taught by Cohn in Patent No. 2,633,493 utilizes a quarter-wave terminating cavity to terminate the waveguide. Such a transition device is frequency sensitive, and as a result, high voltage standing-wave ratios are present over its desired frequency passband. The present invention provides an improved transition device which has a lower voltage standing-wave ratio over the desired band of frequencies. The transition device of the invention comprises a V-shaped cavity 40 which is coupled to the one end of the waveguide 10 so as to produce, in effect, a waveguide beyond cutoff that is less frequency sensitive than a quarter-wave termination. The shape of the V-shaped back cavity 40 is shown clearly in Figure 2. The cavity 40 comprises first and second plane walls 42, 44 which are fastened to the narrow walls 16, 18 of the waveguide 10, and which extend away from the waveguide 10 at the base end of the cavity 40 to a point or vertex 46 where they are joined together to form the V-shaped configuration. The back cavity 40 is enclosed by third and fourth walls which may be extensions of the wide walls 12, 14 of the waveguide 10. The converging plane walls 42, 44 may be made of a plane conductive sheet or plate of metallic material, or may be formed from a solid block of conductive material as shown in Figure 2. The ridge 20 does not extend into the cavity 40.

The V-shaped back cavity 40 forms, in effect, a waveguide beyond cutoff for substantially the entire band of frequencies which the ridged waveguide 10 is capable of passing. Thus, a high shunt impedance is presented at the junction of the coaxial line 30 with the waveguide 10 over substantially the entire band of frequencies passed by the waveguide 10. And, this high shunt impedance enables the transition to present a relatively low voltage standing-wave ratio over the band of frequencies.

An equivalent electrical circuit for the transition device of Figures 1 and 2 is shown in Figure 3. The impedance presented by the transition device is designated Z_T , and this impedance should match the impedance Z_W of the waveguide to which the transition device is coupled. The transition device impedance comprises the series capacity reactance $-jX_C$ and the shunt inductive reactance $+jX_L$ presented by the inner conductor of the coaxial line, the coaxial line impedance Z_{CL} which is in series with the inductive reactance $+jX_L$, and the shunt impedance

Z_B presented by the back cavity of the invention. If, in Figure 3, it is assumed that the impedance of path $abcd$ is very high in comparison to that of path ad , then the high impedance path $abcd$ may be ignored. And, if it is assumed that X_C is equal to X_L , then the transition device can be properly matched to a waveguide by making the coaxial line impedance Z_{CL} equal to the waveguide impedance Z_W or vice versa. The path $abcd$ can be made to have a high impedance by making the impedance of the back cavity Z_B high. One way of accomplishing this has been to use a short-circuited quarter wavelength of ridged waveguide as the back cavity, the impedance of this quarter wavelength section being high with respect to the impedance of the transition device and the waveguide. Such a quarter wavelength section is taught by Cohn in the patent previously mentioned. While such a quarter wavelength section does present a high impedance over a certain band of frequencies, it is frequency sensitive over a very high, wide band of frequencies. The present invention includes a tapered back cavity which provides a waveguide beyond cutoff over a wider band of frequencies. As previously explained in connection with Figures 1 and 2, this waveguide beyond cutoff is made by gradually decreasing the width of the waveguide and eliminating the ridge. Such a structure will provide a waveguide beyond cutoff for the entire range of frequencies which the ridged waveguide must carry.

The series reactance X_C can be made approximately equal to the shunt reactance X_L over the desired band of frequencies if the diameter of the matching post 37 is between 15 and 20% of the width of the waveguide at the location of the matching post 37. Further design information for this feature is explained on pages 257-266 of the "Waveguide Handbook," volume 10, M.I.T. Radiation Laboratories Series, McGraw-Hill Book Co., 1951, and on pages 717-718 of "Very High Frequency Techniques," volume II, Harvard University Radio Research Staff, McGraw-Hill, 1947. Under these conditions X_C and X_L will be very small, or approximately one-tenth of the waveguide characteristic impedance. For most waveguide widths or dimensions, a diameter for the matching post which is 15 to 20% of the waveguide width will have to be obtained by tapering or enlarging the inner conductor of the coaxial line.

With the transition device constructed so that the series reactance X_C is equal to the shunt reactance X_L , and with the back cavity constructed in accordance with the invention to present a high impedance, the only impedance which effectively remains is the coaxial line impedance Z_{CL} . This impedance Z_{CL} can be matched to the waveguide impedance Z_W by properly choosing the coaxial cable dimensions. However, since most frequently the coaxial cable impedance is fixed by commercial practice, it is the usual practice to match Z_W to Z_{CL} . In ridged waveguides, this can be done by tapering the height of the ridge. Further information on the impedance of ridged waveguides is given by Samuel Hopfer in an article entitled "The Design of Ridged Waveguides," beginning at page 20 of IRE Transactions, Microwave Theory and Techniques, October 1955.

In one embodiment of the invention actually constructed, a nominal one inch by two inch ridged waveguide was used. This ridged waveguide had narrow walls whose inside width was 0.872 inch and wide walls whose inside width was 1.872 inches. The ridge had a width of 0.625 inch and a height of 0.775 inch high at its point of contact with the matching post, and tapered to a height of 0.742 inch at a point 2.214 inches back along the ridge so as to match the waveguide and the coaxial cable impedances. A tapered or V-shaped back cavity was fastened to the end of the waveguide to which the coaxial line was fastened, the back cavity having a length of 2.163 inches between its point of attachment to the waveguide and its vertex. When the ridged waveguide

was excited by a 50 ohm coaxial cable, the voltage standing-wave ratio shown in Figure 4 was obtained over a band of frequencies between 2.0 and 5.6 kilomegacycles. In Figure 4, it will be seen that the voltage standing-wave ratio exceeds 1.35 only above 5.6 kilomegacycles and is below 1.2 over most of the passband. While the degree of taper for the back cavity is not critical, it can be expected that a relatively long back cavity will be more suitable for transitions intended for lower frequency operation and that a relatively short back cavity will be more suitable for high-frequency transitions. However, in either case the use of the tapered back cavity provides a marked improvement over the presently known quarter-wave terminations.

Figure 5 shows a side longitudinal sectional view of a conventional rectangular waveguide 50 using the V-shaped back cavity 40 shown in Figure 2 and described previously. The transition device in Figure 5 is substantially similar in all respects to that shown in Figures 1 and 2, and operates in the same manner. However, since there is no ridge in the waveguide, the matching post 52 connected to the inner conductor 34 extends all the way across the waveguide 50 and is connected to the opposite wide wall 54. Such posts are also described in the "Waveguide Handbook" previously mentioned. Although not shown, the matching post 52 in Figure 5 could be replaced by a probe of the same diameter as the inner conductor of the coaxial line. Such a probe would not extend to the opposite wall 54, but would end at some point between the wide walls as in a conventional transition between a waveguide and a coaxial line. The probe might present impedances which would result in an equivalent electrical circuit different from Figure 3, but the back cavity of the invention would furnish the necessary high impedance over a wide band of frequencies.

The back cavity of the invention could also be used with a bolometer to provide a termination that presents a high impedance over a wide band of frequencies. For example, the back cavity could be used in place of the quarter wavelength stub shown in Figure 16.11 on page 603 of "Microwave Antenna Theory and Design," vol. 12, M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., Inc. 1949.

The invention claimed is:

1. A transition for coupling radio frequency energy between a coaxial transmission line and a waveguide, comprising a waveguide having an outer wall, a coaxial transmission line coupled to said waveguide at one end thereof with the outer conductor of said coaxial transmission line coupled to said outer wall and with the inner conductor of said transmission line extending into the interior of said waveguide, and a back cavity having one end thereof joined to said one end of said back waveguide, said cavity having a cross-sectional configuration at said one end that is substantially the same as that of said outer wall of said waveguide and that tapers along converging planes to a smaller configuration in a direction away from said one end of said waveguide so that said cavity presents a high impedance to said waveguide over a wide band of frequencies.

2. A transition for coupling radio frequency energy between a coaxial transmission line and a waveguide, comprising a rectangular waveguide having outer walls, a coaxial transmission line coupled to said waveguide at one end thereof with the outer conductor of said coaxial line coupled to one of the walls of said waveguide and with the inner conductor of said coaxial line positioned in the interior of said waveguide, and a tapered cavity having plane walls with one end thereof joined to said one end of said waveguide, said one end of said cavity walls forming a cross-sectional configuration that is substantially the same as that of said outer walls of said waveguide, and said cavity tapering along two of said cavity walls from said cross-sectional configuration to a

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vertex at a point remote from said one end of said cavity walls so that said cavity presents a high impedance to said waveguide over a wide band of frequencies.

3. A transition for coupling radio frequency energy between a coaxial transmission line and a waveguide, comprising a rectangular waveguide having alternate wide and narrow walls, a coaxial transmission line coupled to said waveguide at one end thereof with the outer conductor of said coaxial line coupled to one of said walls of said waveguide and with the inner conductor of said coaxial line extending into said waveguide, and a tapered back cavity coupled to said one end of said waveguide, said back cavity being in effect a waveguide beyond cut-off that presents a high impedance to said first mentioned waveguide over a wide band of frequencies.

4. A transition for coupling radio frequency energy between a coaxial transmission line and a waveguide, comprising a rectangular waveguide having alternate wide and narrow walls, a first one of said walls having a ridge on the interior of said waveguide, a coaxial transmission line coupled to said waveguide at one end thereof with the outer conductor of said coaxial line coupled to a second of said walls opposite said first one of said walls and with the inner conductor of said coaxial line extending into said waveguide and coupled to said ridge, and a tapered back cavity coupled to said one end of said waveguide, said back cavity comprising first and second plane walls which are respectively fastened at one end thereof to the other two walls of said waveguide between said first and second walls of said waveguide, said first and second plane walls of said cavity being joined together at the other end thereof to form a V-shaped cavity, and said cavity comprising two substantially parallel walls fastened between said first and second walls of said cavity to form a cavity which in effect is a waveguide beyond cut-off that presents a high impedance to said first-mentioned waveguide over a wide band of frequencies.

5. In apparatus for transferring radio frequency energy, a waveguide having an outer wall, a transmission line having inner and outer members, a conductive connection between the outer member of said transmission line and the outer wall of said waveguide, a coupling between the inner member of said transmission line and the space enclosed within said outer wall, and a back cavity conductively connected to one end of said waveguide, said back cavity being in effect a waveguide beyond cut-off that presents a high impedance to said first-mentioned waveguide over a wide band of radio frequencies.

6. In apparatus for transferring a relatively wide band of high frequency wave energy, a waveguide having an outer wall, said waveguide comprising in effect two sec-

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tions the second section of which is an extension of the first section and decreases in width to converge and close the end of said second section of said waveguide remote from said first section of said waveguide, a transmission line having inner and outer members, a conductive connection between the outer member of said transmission line and said outer wall of said waveguide substantially at the junction point between said two waveguide sections, and a coupling between the inner member of said transmission line and the space enclosed within said waveguide, said coupling being formed by extending said inner member into the interior of said waveguide substantially at the said junction point between said two waveguide sections, said second section forming a back cavity which is in effect a waveguide beyond cut-off frequency and presents a high terminating impedance to said first-mentioned waveguide over a relatively wide band of said high frequency wave energy.

7. In apparatus for transferring a relatively wide band of high frequency wave energy, a ridged waveguide having an outer wall, said waveguide comprising in effect two sections the second section of which is an extension of the first section and decreases in width to converge and close the end of said second section of said waveguide remote from said first section of said waveguide, a ridge in said waveguide facing said outer wall and terminating substantially at the junction point of said two sections, a transmission line having inner and outer members, a conductive connection between the outer member of said transmission line and said outer wall of said waveguide substantially at the junction point between said two waveguide sections, and a coupling between the inner member of said transmission line and said waveguide, said coupling being formed by extending said inner member into the interior of said waveguide substantially at the termination of said ridge and substantially at the said junction point between said two waveguide sections, said second section forming a back cavity which is in effect a waveguide beyond cutoff frequency and presents a high terminating impedance to said first-mentioned waveguide over a relatively wide band of said high frequency wave energy.

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