July 7, 1959 D. A. LANCIANI 2,894,218

TRANSITION FOR WAVEGUIDE

Filed Jan. 3, 1955

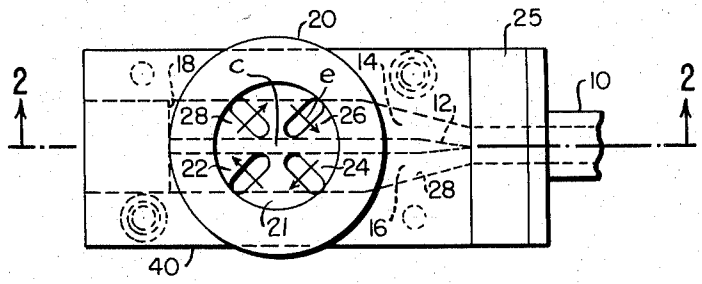


Fig. 1

Fig. 2

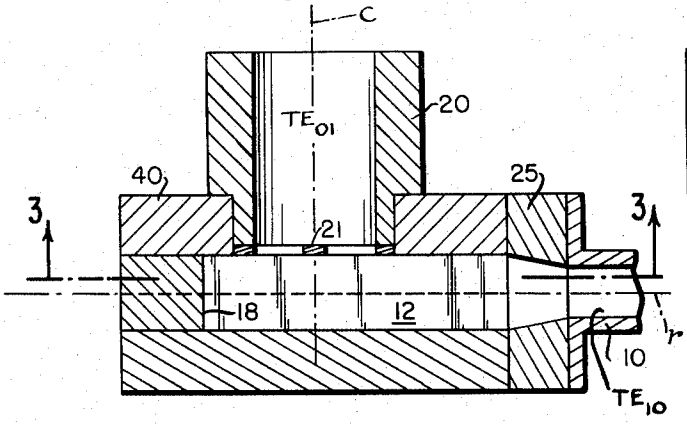
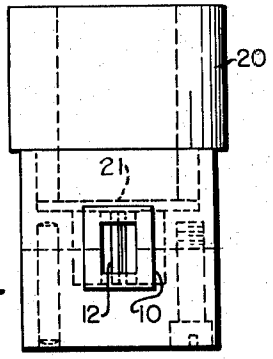


Fig. 4



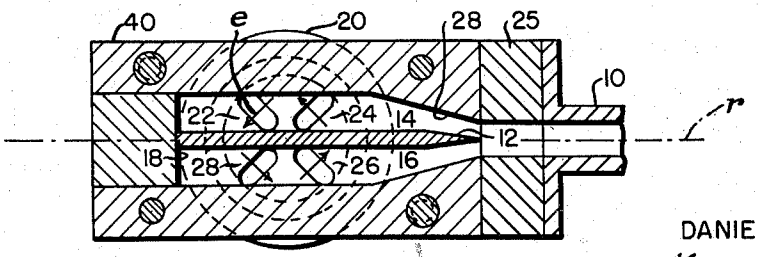


Fig. 3

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United States Patent Office 2,894,218 Patented July 7, 1959

2,894,218

TRANSITION FOR WAVEGUIDE

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Application January 3, 1955, Serial No. 479,285

9 Claims. (Cl. 333—21)

This invention relates to a parallelepipedal to cylindrical waveguide transition and in particular to an end-feed transition for circular waveguides propagating the TE_{01} mode.

Various methods have been proposed for establishing the TE_{01} mode in a circular waveguide. Generally these methods have contemplated the insertion of power in a number of points in a circular waveguide, and where a circular waveguide is being fed from a rectangular guide, it is conventional to divide the power into a series of separate waveguide structures which in turn feed the circular waveguide. The feed into the circular waveguide has been in the form of slots, either parallel to the axis of the circular waveguide or radial to the end plate. However, in all of these cases the division of power into a plurality of separate waveguide structures has required bulky and expensive waveguide plumbing. Not only has the structure been awkward but it has very often resulted in the propagation of undesired modes, particularly the TE_{21} mode, which can propagate in a smaller size circular waveguide than the TE_{01} mode. Also such structures have usually exhibited relatively narrow band widths.

It is the object of this invention to provide a relatively simple and compact apparatus for launching the TE_{01} mode in a round waveguide.

A further object of this invention is to provide greatly simplified coupling between a circular waveguide and a rectangular waveguide which will have a relatively wide band width and a high degree of mode purity.

It is a feature of this invention that it achieves the necessary power division and phase relationships by way of resonant slots feeding the end of the circular waveguide without the use of cumbersome separate waveguide structures for each feed.

This invention may be more readily understood by reference to the drawings in which

Fig. 1 is a view along the axis of the circular guide toward the junction;

Fig. 2 is a sectional side view of the apparatus according to Fig. 1 along the line **2**—**2** of Fig. 1; and

Fig. 3 is a section taken along the line **3**—**3** of Fig. 2 looking toward the slots leading to the circular guide and showing the internal relationship of the slots in the end of the circular waveguide and the E plane power divider in the rectangular waveguide.

Fig. 4 is an end elevation of Fig. 1.

Referring to the figures it will be seen that this invention contemplates the use of a cylindrical, here circular waveguide **20** for propagating the TE_{01} mode coupled by means of the transition **40** to the parallelepipedal, here rectangular waveguide structure **10** in which the TE_{10} mode is being propagated. As shown in Figs. 1 and 3, the preferred embodiment of the transition which achieves this coupling is formed of two chambers **14** and **16** separated by an E plane dividing partition, septum, or power divider **12**. This partition is in the plane of intersection of the axes of the two waveguides and parallel to the

long sides of both the rectangular guide and the two transition chambers. The axes of the circular and rectangular guides are indicated at *c* and *r*, respectively. The two chambers **14** and **16** terminate in a conducting end plate **18** which is so located as to appropriately tune the two chambers to give optimum radio frequency matching between the rectangular waveguide and the slot array at the transition design center frequency.

The chambers are preferably coupled to the circular waveguide by means of four slots, **22**, **24**, **26** and **28** in the end plate **21** of the circular guide **20**. In order for these slots to meet the requirements for TE_{10} mode propagation in the rectangular guides and still satisfy the TE_{01} mode propagation in the circular guide, the following conditions must be satisfied: The slots should be mounted radially in the circular waveguide end plate **21** so that they intercept the maximum end plate current for the TE_{01} mode of the circular waveguide. In addition, with the present circular guide the slots are slanted 45 degrees with respect to a line parallel to the rectangular waveguide axis *r* and are with the midpoints of the pair of slots on each side of the rectangular waveguide axis spaced either a single one-half guide wavelength at the design center frequency of the chambers apart or an odd multiple of that half guide wavelengths apart along the rectangular waveguide axis. In other words in the preferred embodiment the axes of the slots intersect in, and are inclined 45° to a plane through the intersecting axes of both waveguides, and the distances between the midpoints of pairs of adjacent slots are an odd multiple half guide wavelength at the center frequency for which the chambers are designed. It will be evident that the midpoint of any radial slot is spaced one-half of an odd multiple half guide wavelength from the plane through the circular guide axis, at right angles to the rectangular guide axis. As indicated by the solid arrows *e* in Figs. 1 and 3 showing the electric field vectors in the E plane, this half wavelength spacing and 45 degree slanting provide the necessary phase reversal and field orientation which are needed to establish the circular electrical field in the cylindrical waveguide.

The end plate **18** which tunes the two resonant chambers is also appropriately located with respect to the centers of the slots. However, if this shorting plate is as close as one-quarter guide wavelength from the nearest pairs of slots **22** and **28** this proximity will tend to cause local field interference and for practical purposes, the shorting plate is therefore located at least three-quarter guide wavelengths from the centers of the nearest slot pair. Since the two slots in each resonant chamber are separated by a half guide wavelength in most instances, the shorting plate will then be approximately one guide wavelength from the axis *c* of the circular guide, which is midway between the slots. Slots **22** and **28** will be approximately ¾ guide wavelengths from the shorting plate at the center frequency of the transition and slots **24** and **26** will be approximately one and one-quarter guide wavelengths from the shorting plate. It would be possible to move the shorting plate a much greater distance from the slots, but the tendency in this event would be to decrease the band width because of the increased frequency sensitivity of a longer line length.

The cross section of the two chambers **14** and **16** is dependent on the center frequency of operation of the transition since a number of transitions would be necessary to cover the entire band width which may be transmitted through a single size of standard rectangular waveguide. Assuming that the H-plane dimensions of the chambers **14**, **16** differ from that of the waveguide **10** with which the transition is to be used, it is necessary first to employ an H-plane transformer **25** as shown in Figs. 2 and 3 in order to match the standard rectangular

waveguide to the transition. Such a transformer is simply a tapered section which decreases, or as the case may be, increases the H-plane dimension of the guide as clearly shown in Fig. 2.

Since the transition utilizes an E-plane power divider it will be necessary in all cases to utilize an E-plane tapered section or stepped transformer **28** which, together with the power dividing partition **12**, will transfer power from the TE_{10} mode in the rectangular guide to the same mode in each of the two chambers of the transition. To avoid the formation of unwanted reflections, is is desirable that this transformer section be at least one guide wavelength long and that the power divider be similarly tapered as shown in Fig. 3 to form a sharp edge projecting into the rectangular waveguide. The distance from the edge of the E-plane power divider which forms the beginning of the tapered or stepped transformer section to its intersection with the axis *c* of the circular waveguide will therefore be on the order of two and one-quarter free space wavelengths, assuming that the chamber should have at least one wavelength between the end of the transformer section and the intersection with the axis *c* of the circular guide.

It is well known that a plurality of identical slots spaced one half guide wavelength along the edge of a waveguide section will each couple out an equal amount of energy from the chamber. In the above described construction the power in the rectangular waveguide **10** is divided equally between the two chambers **14** and **16** by means of the power divider **12**, and because there are two slots in each chamber spaced one half guide wavelength apart, one fourth of the total power in the original rectangular waveguide will be coupled through each slot to the circular waveguide which projects at right angles from the transition. In addition, as mentioned above, the odd multiple of half guide-wavelengths spacing between the two slots in each chamber results in the necessary phase reversal in order to couple the energy to the TE_{01} mode in the circular guide.

The shape and size of these slots is important in determining the band width and characteristic of the coupling. For example, in order to minimize the problem of breakdown across the resonant slot and increase the power handling capacity it is desirable to shape the slot so as to lengthen the radio frequency breakdown path. This can be done by increasing the width of the slot in the center where the maximum energy is transmitted.

The fact that the slots are mounted radially in the end plate **21** tends to reduce coupling to the undesired TE_{21} mode in the circular waveguide. Increasing the thickness of the end plate also has this effect; however, this thickness cannot be made very large without upsetting the slot coupling to the desired TE_{01} mode.

The width and length of the slot also require a compromise between power handling capacity and mode purity. Increasing the width and at the same time maintaining a resonant condition by adjusting the slot length is feasible so long as the width does not approach a point at which the TE_{21} mode becomes excited in the circular waveguide. A slot width slightly less than one-quarter wavelength and a slot length slightly greater than one-half wavelength has proven optimum.

The transition slot structure described permits direct coupling between the TE_{10} mode in the rectangular waveguide chambers and the TE_{01} mode in the circular waveguide. If no slots were present in the resonant chambers the TE_{10} electric field vectors would be parallel with the shorting end plate, but the presence of the resonant slots distorts the field so that the vector of maximum electric field lies directly across the narrow width of the slot. As a result, coupling through any slot radial to the circular guide in the narrow side of these chambers will tend to be parallel with the circular electric field of the TE_{01} mode in the circular guide. This four slot arrangement radiating equal energy, as described, provides excellent performance in a very simple construction.

In the apparatus as shown in Figs. 1 and 3 the two resonant chambers side by side have a total width of somewhat less than the diameter of the circular waveguide and, in fact, tend to cover portions of the outer edges of each slot. This effect is in some instances desirable. For some wavelengths it may be desirable to separate the chambers, the method of feed being still through a tapered or stepped transformer.

The use of the E-plane power dividing partition **12** is essential for satisfactory mode purity and band width but not necessarily for the physical operation of this device at frequencies where the two chambers can be adjacent. If this power divider **12** is eliminated coupling will still take place through the radial slots to the circular waveguide. Unfortunately, the single cavity will then have an oversized E plane dimension and a result will be the excitation of higher order modes in the rectangular waveguide section, which in turn will give rise to unwated TE_{11} and possibly TE_{21} modes in the circular waveguide. The band width will also tend to be decreased if the power divider is not used. In general, these effects will appear whenever the E-plane dimension in the resonant chamber becomes larger than the H-plane dimension, and of course for lower frequencies a separation of the chambers may be essential.

The method of feeding the circular waveguide from two small chambers through a slotted end plate effectively rejects the lower undesired modes, particularly the TE_{21} mode, as well as certain of the higher modes. The suppression of higher modes may be aided by the use of a circular waveguide which is too small to permit the higher modes such as the TE_{41} and TE_{31} to be successfully propagated. Where this technique results in an initial circular waveguide section which is not sufficiently large to utilize the low loss properties of an oversize TE_{01} mode circular waveguide, low loss transmission is obtained by tapering to a larger diameter beyond the transition section. It has been found that for a transition of this configuration the band width for a maximum VSWR of 1.2 to 1 is approximately 7% and the mode purity over this range exceeds 15 db or 97%. The total insertion loss of this transition is less than ¼ db over the same band width.

While this invention has been described in respect to a single embodiment, it is obvious that the basic concepts can be implemented in a number of configurations without departing from the spirit of the invention which is encompassed in the following claims.

I claim:

1. A microwave transition for coupling parallelepipedal and cylindrical waveguides, which comprises: a parallelepipedal waveguide; at the end of said parallelepipedal guide a power dividing partition parallel to a pair of walls of the guide, for establishing two resonant chambers; a cylindrical waveguide ending at a wall common to both chambers, with the longitudinal axis of the cylindrical guide in the plane of said partition and at right angles to the longitudinal axis of the parallelepipedal guide; and a plurality of slots in said common wall, said slots being radially inclined substantially 45° to the plane through said guide axes, and with the midpoints of pairs of adjacent slots spaced an odd multiple half guide wavelength at the design center frequency of said chambers, for directly coupling the ending of the cylindrical guide to the chambers.

2. Waveguide apparatus for coupling a rectangular waveguide and a circular waveguide, which comprises: a rectangular waveguide; two adjacent resonant chambers at the end of the rectangular guide; a tuned shorting plate for each of said chambers; a circular waveguide mounted on said chambers with its axis perpendicular to the axis of the rectangular guide; an end plate separating the circular guide and the chambers; and in said end plate a

plurality of radial slots inclined substantially 45° to the plane through said guide axes, and with the midpoints of pairs of adjacent slots spaced an odd multiple half guide wavelength at the design center frequency of said chambers, for directly coupling the circular and rectangular guides.

3. Waveguide apparatus for coupling the TE_{10} mode in a rectangular waveguide to the TE_{01} mode in a circular waveguide, which comprises: a rectangular waveguide; a partition including the axis of the rectangular waveguide for dividing its end into two parallel rectangular chambers; a circular waveguide mounted with its axis in the plane of said partition and joining at said partition a common wall of said chambers perpendicular to the axis of the rectangular guide; four resonant slots in said wall which separates the circular and rectangular guides, said slots being radially inclined substantially 45° to the plane through said guide axes, and with the midpoints of pairs of adjacent slots spaced an odd multiple half guide wavelength at the design center frequency of said chambers; and a conductive plate at the end of each chamber at an odd multiple of one quarter guide wavelengths from the midpoint of the nearest resonant slot.

4. A microwave transition for coupling a rectangular and a circular waveguide, which comprises: a rectangular waveguide; a plurality of parallel resonant chambers at the end of said rectangular guide placed with their longitudinal axes parallel to the axis of the rectangular guide and having a common wall that is parallel to said axes; a circular waveguide placed at said wall with its axis at right angles to the axes of the chambers; at least one slot radial to the axis of the circular waveguide in the wall of each chamber separating the chamber from the end of the circular waveguide, the slot inclination to the plane through said waveguide axes being substantially 45°, with the slot midpoint spaced from the plane through the circular waveguide axis at right angles to the rectangular waveguide axis one half of an odd multiple half guide-wavelength at the design center frequency of said chambers, such that the direction of the electrical field across the slot is substantially in registration with the electrical field of the TE_{01} mode in the circular guide; and coupling means for propagating a proportion of the energy in the rectangular guide from the end of the guide into the end of each chamber.

5. A microwave transition as in claim 4 wherein the power division between said parallel resonant chambers is such that each slot radiates an equal amount of energy into the circular guide.

6. A microwave transition for coupling a rectangular to a circular waveguide, comprising: rectangular wave guide means; at least one resonant rectangular chamber means opening into and fed by said guide means and having straight surfaces that are throughout substantially parallel to the surfaces of said rectangular guide means; a circular waveguide means extending with an end perpendicular to a wall in the E plane of said chamber means and having a diameter substantially on the order of the width of said wall of the chamber means such as to reject selected modes higher than the TE_{01} mode; and a plurality of slots in said wall of the chamber means leading to said circular guide means, said slots being substantially radial to the axis of the circular guide means, being inclined substantially 45° to the plane through the axes of said rectangular and circular guide means respectively, and being with the midpoints of pairs of adjacent slots spaced approximately an odd multiple half guide wavelength at the design center frequency of said chamber means.

7. Transition according to claim 6 wherein the E plane dimension of the chamber means is greater than that of the rectangular guide means, further comprising a transformer means leading from the rectangular guide means to the chamber means.

8. Transition according to claim 6 wherein the H plane dimension of the chamber means is greater than that of the rectangular guide means, further comprising a transformer means leading from the rectangular guide means to the chamber means.

9. A microwave transition for coupling a rectangular to a circular waveguide, comprising: a rectangular waveguide; a pair of rectangular chambers opening into and fed by said guide, said chambers having straight surfaces and axes that are throughout substantially parallel to the axis and the surfaces of said rectangular guide, and being tuned to a chosen center frequency; a circular waveguide at right angles to said chambers and having a diameter substantially on the order of the width of the wall in the E plane of said chambers such as to reject selected modes higher than the TE_{01} mode; an end plate for said circular guide forming a portion of one side of each chamber; and two pairs of slots in said end plate one pair leading to each chamber, the slots in each chamber being radially inclined substantially 45° to a plane through the axes of both waveguides, and with their midpoints approximately spaced an odd multiple half guide-wavelength at said center frequency.

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