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WAVEGUIDE ROTARY JOINT

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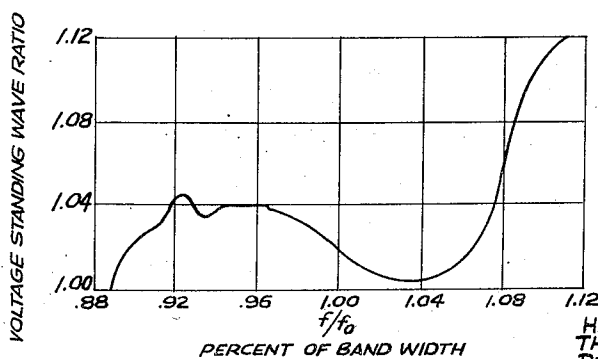
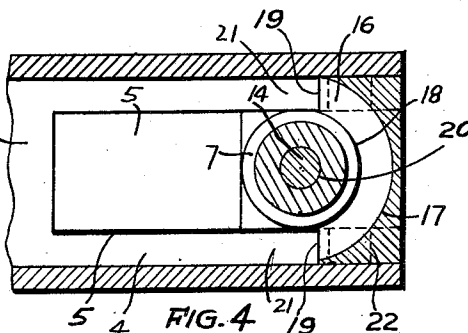
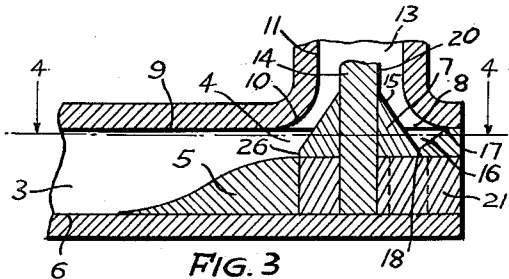
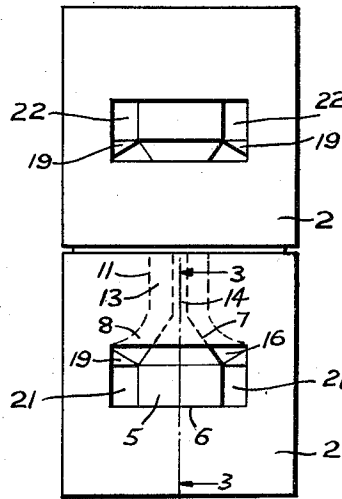
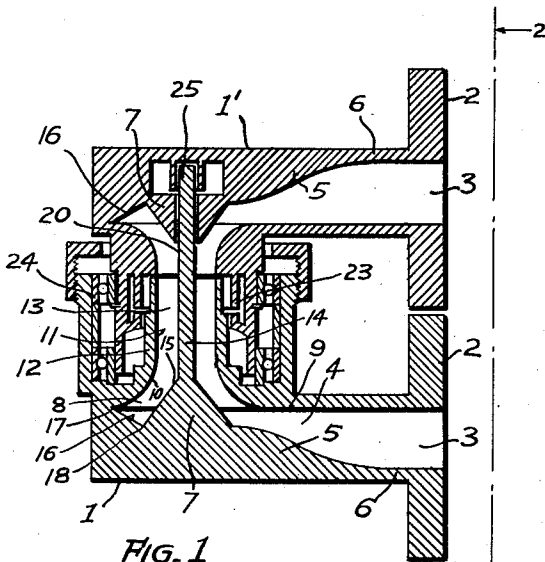


FIG. 5

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WAVEGUIDE ROTARY JOINT

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The present invention relates to waveguide rotary joints for the transmission of microwaves through a transmission system capable of angular adjustment. In particular, it relates to an improved transition from rectangular waveguide to coaxial line which is particularly suited for use in rotary joints.

The principal object of the present invention is to provide a waveguide rotary joint which operates over a wider band of frequencies with a lower voltage standing wave ratio than has been obtainable heretofore.

A further object of the present invention is to provide a waveguide rotary joint which may be used for high power transmission at conditions of low atmospheric pressure, as for example, in an airplane at high altitude.

Another object of the present invention is to provide a waveguide rotary joint in which the variations of the reflection coefficient and transmission coefficient as a function of the rotation of the rotary joint are negligible.

Other and further objects of the present invention will appear from the following description.

In general, the invention contemplates the provision of a rotary joint comprising a rectangular input waveguide, a mode transformer for converting a T. E. _{1,0} mode existing in the rectangular input waveguide to a symmetric T. E. M. mode existing in the coaxial line, thus permitting angular rotation, and then retransforming the T. E. M. mode to the rectangular T. E. _{1,0} mode in the output rectangular waveguide. This is done by a particular choice of guiding surfaces which permits the transition from the rectangular waveguide to the coaxial line to be made with a very low V. S. W. R. over a wide band of frequencies. It is this transition, then which is the content of the present invention.

This transition consists first of smooth, specially shaped taper from the rectangular waveguide having a nominal impedance of about 400Ω to a section of ridged waveguide with a nominal impedance of about 65Ω, and then a novel transition from the ridged waveguide to a coaxial line having a characteristic impedance of 50Ω.

By examining a large number of ridged waveguide to coaxial line transitions, we have discovered that a right circular cone terminating in a cylinder having substantially the same diameter at its base as the width of the ridge and attached thereto and tapering at its apex to the diameter of the inner conductor of the coaxial line and attached thereto to form a continuation of the inner conductor if projected sufficiently into a bell mouthed opening provided in the outer conductor of the coaxial line, will result in a transition having very low V. S. W. R.'s over broad bands of frequency if the ridged waveguide is terminated suitably. We have found that a suitable reactive termination consists of a portion of an inverted, right circular conical funnel-shaped surface, having at its base substantially the diameter of the base of the pyramidal cone which forms an extension of the inner conductor and at its apex substantially the diameter of the outer edge of the bell mouthed opening of the outer conductor

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of the coaxial line. This funnel shaped termination is a portion of a right circular inverted cone. It is placed so that its base and apex are in contact with the corresponding portion of the pyramidal cone and bell mouthed opening which define its dimensions. This funnel-shaped surface extends part way around the coaxial line until its extremities lie in and are part of that plane which is substantially tangent to the inner conductor of the coaxial line and is perpendicular to the axis of the waveguide and further from its mouth. The shape of the bell-mouthed opening is obtained by rotating a quadrant of a circle about the axis of the coaxial line. This circle is tangent to the upper wall of the rectangular waveguide at its widest point, and also tangent to the inner surface of the outer conductor of the coaxial line.

We have found after many experiments that the optimum angle for the surface of the circular cone is in the neighborhood of 53½°, while the angle of the inverted conical funnel-shaped surface is 35½°. Although the precise reasons for the surprising performance of this rotary joint is unknown to us, it is worthy of note that in the coaxial region between the pyramidal cone and the bell-mouth opening to the coaxial line, the diameters are such that in the frequency band of operation of the device, it is possible for the T. E. _{2,0} mode for coaxial line to propagate as well as the T. E. M. mode. For example, in our preferred model the diameter of the outer conductor of the coaxial line is 1.122", while the diameter of the pyramidal cone at the corresponding position is .500". Thus the mean diameter is .811". This corresponds to a cut-off wavelength of 6.5 cms. Since the operating band of this rotary joint falls between 3 and 3.7 cms., it is clear that this mode can propagate a substantial distance into the bell-mouthed transition of the coaxial line.

A more comprehensive understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawings and those features of the invention which are believed to be novel and patentable will be pointed out in the claims appended thereto.

In the accompanying drawings, which form part of this specification and which are to be read in conjunction therewith, and in which like reference numerals are used to indicate like parts in the various views:

Figure 1 is a sectional elevation of a waveguide rotary joint showing one embodiment of our invention.

Figure 2 is a plan view viewed along the line 2—2 of Figure 1.

Figure 3 is a sectional view showing in greater detail the transition from waveguide to coaxial line along the line 3—3 of Figure 2.

Figure 4 is a sectional view showing in greater detail the transition from waveguide to coaxial line along the line 4—4 of Figure 2.

Figure 5 is a graph giving V. S. W. R.'s obtainable with our invention over a band of frequencies.

More particularly now referring to Figures 1—4 the present invention comprises a lower transition 1 made of a metallic alloy possibly aluminum and an essentially similar upper transition 1'. Flanges 2 are provided for connecting the rotary joint to input waveguides. The lower duct 3 is rectangular in cross section and enters into a section of ridged waveguide 4 which is U-shaped in cross section. This is accomplished by a ridge 5 which gradually rises from the lower wall 6 of the rectangular waveguide. This U-shaped duct comprises a section of ridged waveguide. From the top of ridge 5 projects a metallic cone 7 which passes through a bell mouthed opening 8 provided in the upper wall 9 of the section of ridged waveguide 4. This opening 8 is bounded by a surface of revolution generated by a quadrant of a circle 10 to form

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a bell mouthed continuation of the inner surface 11 of the outer conductor 12 of a coaxial line 13. The inner conductor 14 of the coaxial line 13 is attached to the upper portion 15 of the cone 7. The ridged guide 4 beyond the cone 7 terminates in a curved metallic short circuit 16 which is bounded by a portion of an inverted conical funnel-shaped surface which at its upper outer circular edge 17 approximately touches the outermost edge of the bell mouthed opening 8, and at its lower inner circular edge 18 approximately touches the lower edge of the cone 7. This metallic short 16 proceeds substantially symmetrically around the coaxial line 13 until its two extremities 19 lie in a plane which is substantially tangent to the rear-most edge 20 of the inner conductor 14 of the coaxial line 13. The portion 21 of the ridge guide 4 below the short 16 is terminated with metallic plugs 22 which fill the space below the short 16, but may be displaced backward slightly from its extremities 19 away from the coaxial line 13 as shown in Figure 4.

A choke assembly 23 is provided in the outer conductor 12 of the coaxial line 13 which permits rotation of the outer conductor portion of the rotary joint without introducing any serious mismatch. The details of this choke assembly will not be described in detail, because it is well known to the art. Also shown is a bearing and housing assembly 24 which mechanically supports the two portions of the rotary joint and permits rotation of one portion with respect to the other. The details of this assembly form no part of the present invention and are well known to the art. The free rotation of the inner conductor portion of the two halves of the rotary joint is made possible by the choke 23 which is well known to the art. The details of the upper portion of the rotary joint are identical with those of the lower portion except possibly for the choke assembly 23.

The performance of the present rotary joint is remarkable in that very low V. S. W. R.'s are obtained over a wide band of frequencies. This has been achieved after extensive experimental effort and can be duplicated only if the dimensions of the components are held to close tolerances. Accordingly the precise dimensions employed or rather their relative magnitudes is an essential part of our invention. Our experimental measurements were made with a unit in which the rectangular waveguide 3 had the dimension of 1.122" x .497". The centrally located ridge had a width of .688" and tapered over a length of 1.167" with an S-shaped curve from zero height to a thickness of .344". The cone 7 had an outer diameter of .688" and an angle of 53½° measured from the surface of the ridge. The height of cone 7 was .328" and it tapered to a diameter of .218" which is also the diameter of the inner conductor 14. The cone 7 also had a short vertical cylindrical section 26 which was approximately .050" high. The angle of the surface of the funnel shaped short 16 was 35½° measured from the surface of the ridge. The radius of the circle which defined the bell mouthed opening was .312" with the inner part of the bell mouthed opening tangent to the inner surface of the outer conductor 12 of the coaxial line and tangent at its outer opening to the upper wall 9 of the rectangular waveguide 3. The diameter of the outer conductor of the coaxial line was .500", while the diameter of the inner conductor of the coaxial line was .218". The actual length of the coaxial line was found to be non critical so long as it exceeded a minimum length of about 1".

We have accomplished the objective of my invention, as will be seen from the performance (shown in Figure 5) for a rotary joint constructed in accordance with our invention. When the spacing between the center lines of the two rectangular waveguides was 3.5" no variation in the electrical performance of the rotary joint could be observed over the frequency band shown.

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It will be found that the relative magnitudes as given in the values above should be preserved, that is, for instance, where larger waveguides are used the remaining dimensions should be increased preserving in general the same angles for the elements as herein set forth.

Having now described our invention, we claim:

1. A microwave transmission system comprising, a conductively terminated hollow rectangular waveguide section, a coaxial line section having inner and outer cylindrical conductors perpendicularly extending outwardly from a broad wall of said waveguide section in the region of said conductive termination, a conductive tapered ridge disposed centrally on the broad wall of said waveguide opposite said coaxial line section and extending from a point within said waveguide to said conductive termination, said outer cylindrical conductor of said coaxial line being formed with a bell-mouthed section opening into said waveguide opposite said ridge, a conductive conical member based upon said ridge and converging into said coaxial line inner conductor within the region of said bell-mouthed opening, said waveguide termination being formed with an arcuate conical conductive surface inverted with reference to, and partly encircling the base of, said conical member.

2. A microwave transmission system as in claim 1 and arranged whereby for normal operating frequencies the coaxial region defined between said conical member and said bell-mouthed opening are dimensionally capable of supporting microwave propagation in both T. E. M. and T. E._{2,0} modes.

3. A microwave transmission system as in claim 2 wherein the width and height of said tapered ridge are 61% and 69% of the width and height respectively of said rectangular waveguide.

4. A microwave transmission system as in claim 2 wherein the base diameter of said conical member is substantially equal to the width of said tapered ridge.

5. A microwave transmission system as in claim 2 wherein the height of said conical member measured from said tapered ridge to the juncture with said coaxial line section inner conductor is substantially 96% of the height of said tapered ridge, and further wherein said conical member projects for substantially half its height into said bell-mouthed opening.

6. A microwave transmission system as in claim 2 wherein said arcuate conical conductive surface terminates at one end at the base of said conical member and at the other end thereof at the outer edge of said bell-mouthed opening, the extremities of said conical surface falling in a plane perpendicular to the axis of said waveguide and tangent to the edge of said inner conductor nearest said conductive termination.

7. A microwave transmission system as in claim 1 wherein said coaxial line section is formed with a rotary choke joint in a region of said inner and outer conductors displaced axially from said bell-mouthed opening and said conical member.

8. Apparatus permitting angular adjustment between rectangular waveguide components comprising, first and second substantially like transmission systems each as defined in claim 1, the respective coaxial line sections of said first and second transmission systems being coupled by a rotary choke joint.

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