

June 15, 1965

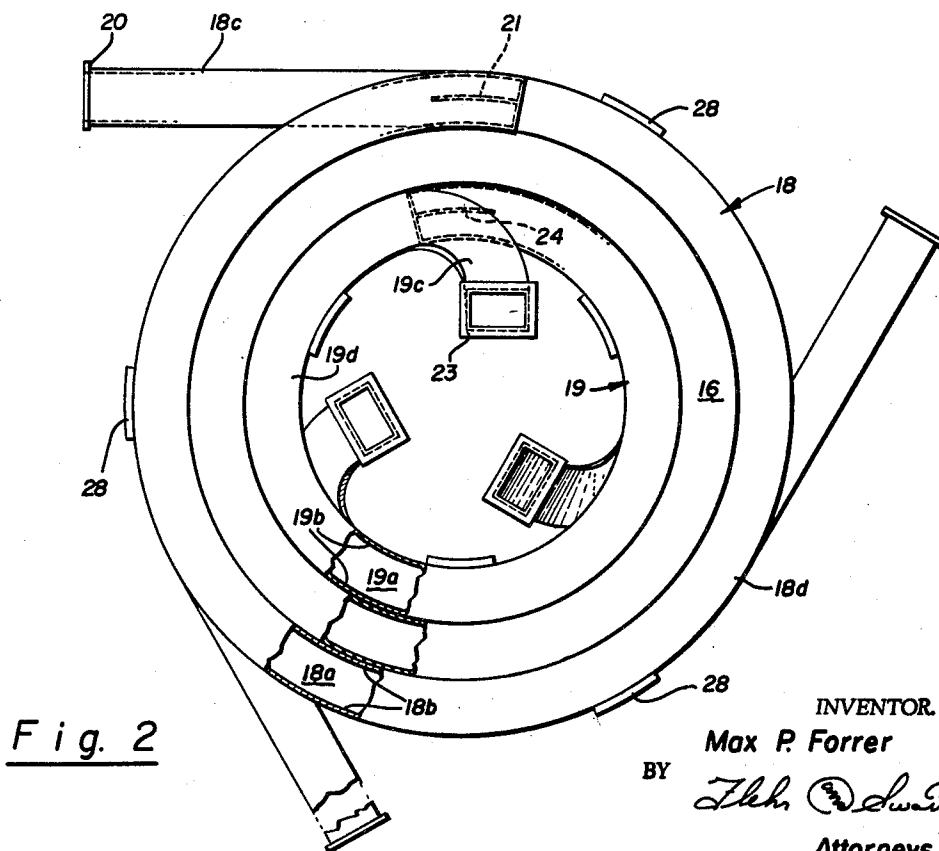
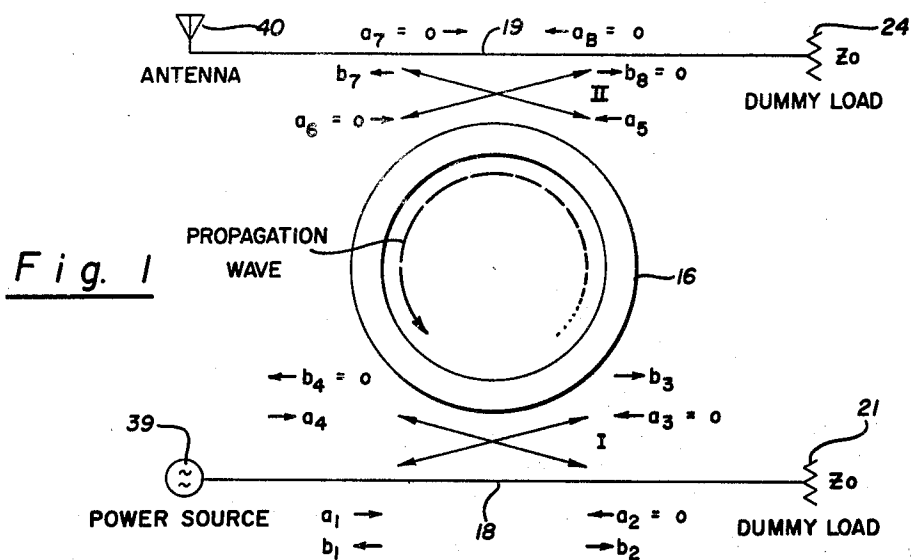
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3,189,855

WAVEGUIDE ROTARY JOINT UTILIZING ANNULAR RESONANT WAVEGUIDE

Filed May 17, 1962

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

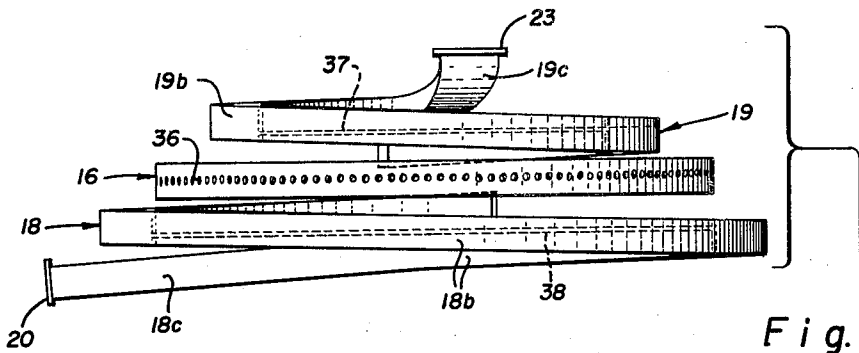


Fig. 3

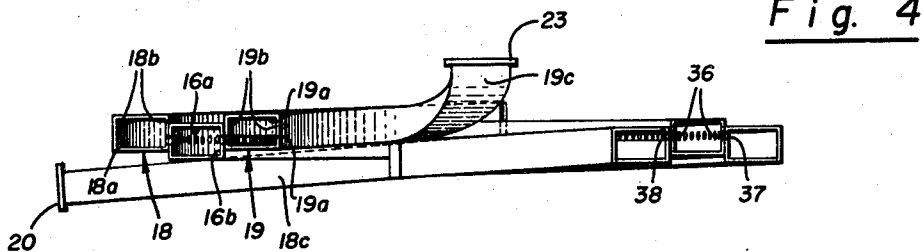


Fig. 4

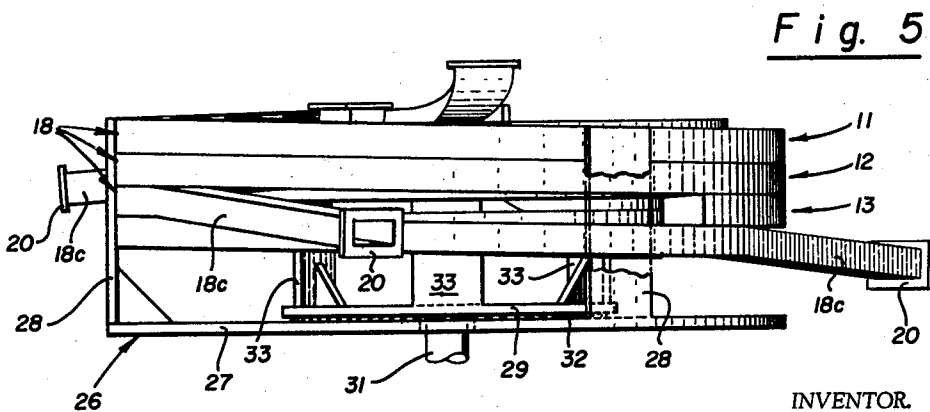


Fig. 5

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Fig. 6

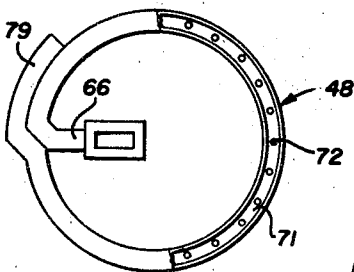
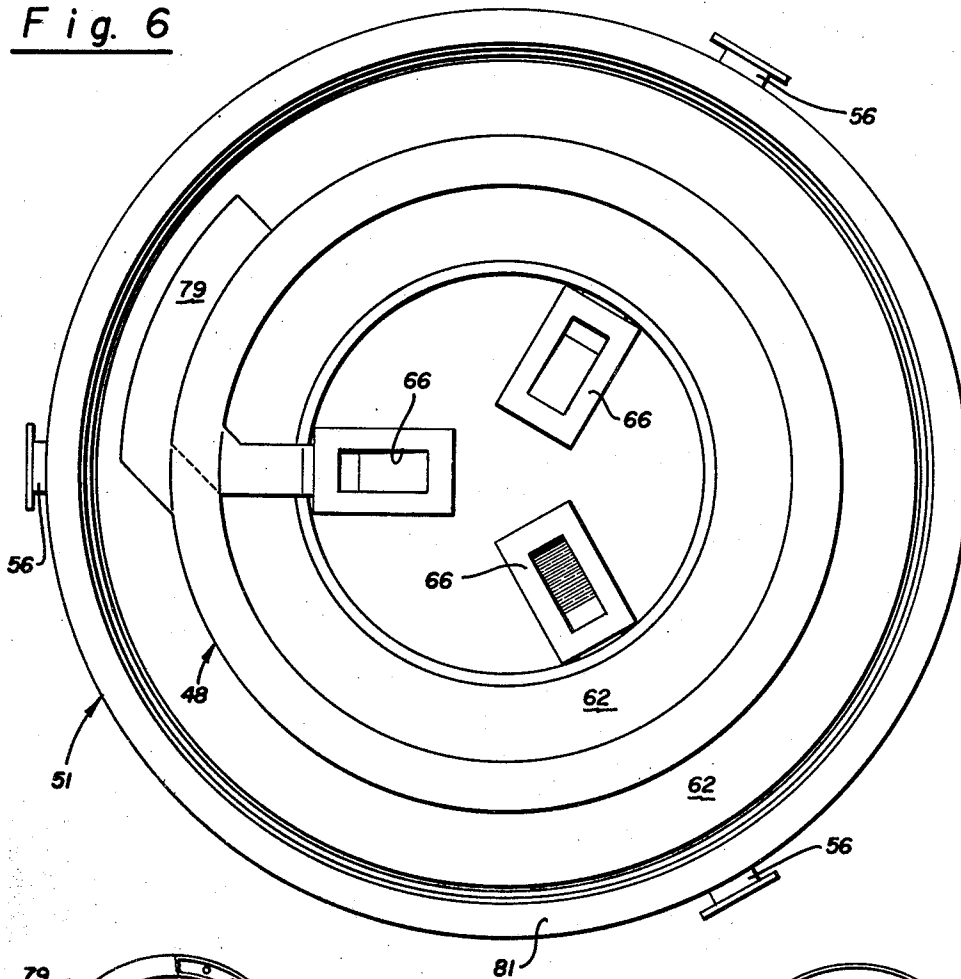


Fig. 8

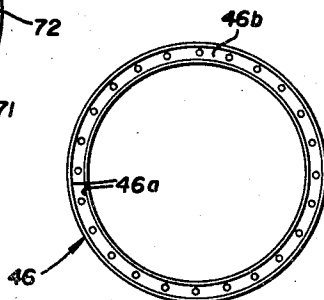


Fig. 9

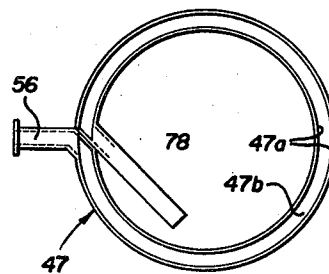


Fig. 10

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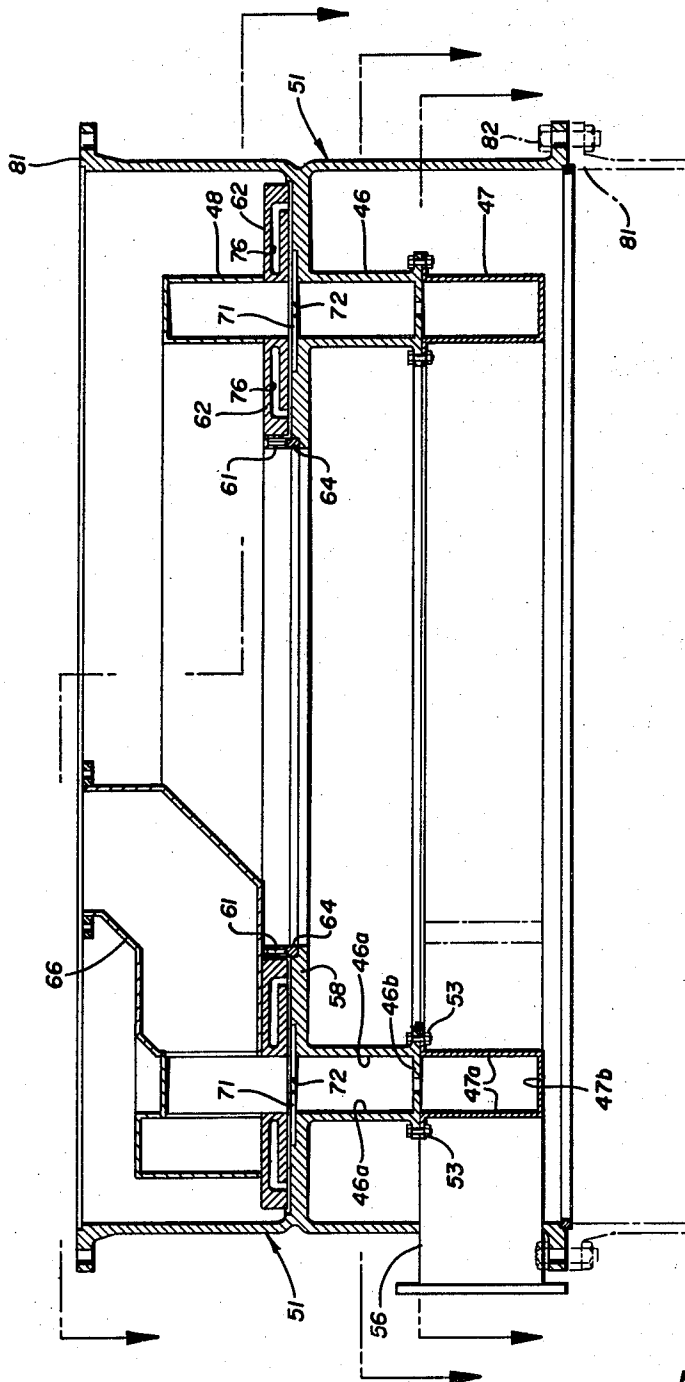


Fig. 7

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WAVEGUIDE ROTARY JOINT UTILIZING ANNULAR RESONANT WAVEGUIDE

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Filed May 17, 1962, Ser. No. 195,507

9 Claims. (Cl. 333-98)

This invention relates to a waveguide rotary joint and more particularly to a multi-channel waveguide rotary joint assembly suitable for high power applications.

Conventional multi-channel rotary joints of the coaxial type making use of a series of concentrically mounted coaxial line sections in which the outer tubing of one line forms the center conductor of the outside line cannot be used to provide many concentric high power transmission circuits because of the large spacings required to prevent breakdown particularly in the innermost channels which, in turn, creates higher order mode problems for the outermost channels. These limitations are sufficiently severe so as to exclude multiple coaxial lines for high power applications. Rotary joints which make use of circularly symmetric modes in cylindrical waveguides possibly may be suitable for high power applications but their geometry is such as to not allow multi-channel operation because of inability to stack on a common axis. Considering these limitations, the only feasible approach to a rotary joint suitable for use in multi-channel operation for high power application is a ring-type circuit in which the rings can be stacked on a common axis in accordance with the number of channels desired. The input then may be connected from the outside, whereas the output can be connected from the inside. Thus, the only factor limiting the number of channels is the inside ring opening. A waveguide rotary joint of such a type is discussed in an article entitled "A New Annular Waveguide Rotary Joint" by Kiyo Tomiyasu, published in the "Proceedings of the IRE," volume 44, 1956, on pages 548-553. The rotary joint proposed by Tomiyasu is generally comprised of a pair of annular coupled waveguides in which the outer ring is the input coupling ring and the inner ring is the output coupling ring. However, as pointed out by Tomiyasu, in such a rotary joint pseudo-resonant conditions occur at various frequencies which could not be avoided. As also disclosed in the article by Tomiyasu, such a rotary joint has dead angles, that is, there are rotational positions in the resonant ring where power is not transmitted but is actually reflected back into the transmitter. In view of these very serious limitations in the waveguide rotary joint proposed by Tomiyasu, there is a requirement for a new and improved waveguide rotary joint which is particularly adapted for use in multi-channel assemblies suitable for operation at high power.

In general, it is an object of the present invention to provide a waveguide rotary joint and assembly which can be utilized for high power.

Another object of the invention is to provide a rotary joint of the above character which is particularly adapted for use in an assembly for multi-channel operation.

Another object of the invention is to provide a rotary joint of the above character which has high performance.

Another object of the invention is to provide a rotary joint of the above character in which there is a full power transfer.

Another object of the invention is to provide a rotary joint of the above character in which negligible power is reflected back into the power source.

Another object of the invention is to provide a rotary joint in which a separate resonant ring is utilized.

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Another object of the invention is to provide a rotary joint of the above character in which the input and output coupling to and from the resonant ring is uniformly distributed around the circumference of the resonant ring.

Another object of the invention is to provide a rotary joint of the above character in which the transmission characteristics are independent of the rotational angle of the rotary joint.

Another object of the invention is to provide a rotary joint of the above character which provides high power transfer independent of the relative angle of rotation of the rotary joint.

Another object of the invention is to provide a rotary joint of the above character which is capable of handling essentially the full rated waveguide power.

Another object of the invention is to provide a rotary joint of the above character in which there is an absence of cross-talk.

Another object of the invention is to provide a rotary joint of the above character in which there is symmetry among all the channels.

Another object of the invention is to provide a rotary joint of the above character which can be readily fabricated.

Additional objects and features of the invention will appear from the following description in which the preferred embodiments are set forth in detail in conjunction with the accompanying drawings.

Referring to the drawings:

FIGURE 1 is a schematic illustration, somewhat simplified, of a rotary joint showing the initial and reflected waves.

FIGURE 2 is a top plan view with certain portions broken away of a multi-channel rotary assembly joint incorporating my invention.

FIGURE 3 is an exploded side elevational view of one of the rotary joints shown in FIGURE 2.

FIGURE 4 is a cross-sectional view of one of the rotary joints shown in FIGURE 2.

FIGURE 5 is a side elevational view with certain portions broken away of the multi-channel rotary joint assembly shown in FIGURE 2.

FIGURE 6 is a top plan view of another multiple channel rotary joint assembly incorporating my invention.

FIGURE 7 is a cross-sectional view taken along the line 7-7 of FIGURE 6 but only showing the top channel of the multiple channel rotary joint assembly shown in FIGURE 6.

FIGURES 8, 9 and 10 are cross-sectional views taken along the lines 8-8, 9-9 and 10-10, respectively, of FIGURE 7.

In general, my waveguide rotary joint consists of an annular resonant waveguide, which also may be called a first waveguide, forming a transmission-type cavity. A pair of additional waveguides, which may be called second and third waveguides, are provided, each of which has a ring-like configuration. Means is provided for forming an input directional coupling arrangement between one of the additional waveguides and the annular waveguide. Means is also provided for forming an output directional coupling arrangement between the other additional waveguide and the annular waveguide. Means is provided for forming an output connection with said one additional waveguide and means is provided for forming an input connection to said other additional waveguide. Means is provided for mounting the annular resonant waveguide and the additional waveguides to permit rotation of one of the additional waveguides relative to the other additional waveguide. The rotary joint is constructed in such a manner that it can be stacked one above

another on a common axis to provide an assembly suitable for multi-channel operation.

In FIGURE 5, I have shown a multi-channel waveguide rotary joint assembly which is suitable for high power applications. In this embodiment, I have shown three rotary joints 11, 12 and 13 which provide three separate power transfer channels. It is readily apparent that, if desired, a fewer or greater number of rotary joints can be provided in order to obtain the necessary number of channels.

Each of the rotary joints consists of a first annular waveguide 16 which is in the form of a continuous ring. The waveguide is rectangular in cross-section and is of a type well known to those skilled in the art. The waveguide is provided with parallel spaced wide side walls 16a and parallel spaced narrow side walls 16b (see FIGURE 4). As hereinafter described, the waveguide 16 is dimensioned so that it forms a travelling wave resonator which also may be called a resonant ring for the frequency for which it is designed.

Directional coupling means is provided for coupling power into and out of the resonant ring 16 and consists of a pair of waveguides 18 and 19 which also may be called second and third waveguides. As can be seen, particularly from FIGURES 2 and 3, the waveguides 18 and 19 have a ring-like or annular configuration. However, unlike the waveguide 16, the waveguides 18 and 19 are not continuous.

The waveguide 18 is also of a rectangular configuration and is formed by a pair of spaced parallel wide walls 18a and a pair of spaced parallel narrow walls 18b. The waveguide 18 is provided with a flanged arm or connector 20 which is connected to a portion 18c of the waveguide 18 which extends outwardly tangentially of the main ring-like portion 18d. The waveguide 18 is terminated in a dummy load 21 as shown. It will be noted that the waveguide 18 is formed in such a manner that it completely encircles the resonant ring 16 for a purpose hereinafter described. It also will be noted, particularly from FIGURES 3 and 4, that the waveguide 18 is formed into a helix so as to accommodate the dummy load 21 and still permit physical contact between the waveguides 18 and 16 at all angles. The resonant ring 16 and the waveguide 18 are arranged in such a manner that their narrow walls 16b and 18b, respectively, are parallel to the axis of rotation for the rotary joint as hereinafter described.

The waveguide 19 is formed in a manner similar to the waveguide 18 and is of a rectangular configuration with spaced parallel wide walls 19a and spaced parallel narrow walls 19b in which the narrow walls 19b are parallel to the axis of rotation for the rotary joint. The waveguide 19 is provided with a flanged arm or connector 23 which is connected to a portion 19c of the waveguide 19 which extends upwardly and inwardly from the main ring-like portion 19d of the waveguide, as shown in FIGURES 2, 3 and 4. The waveguide 19 terminates in a dummy load 24 of the same type as dummy load 21. The waveguide 19 is also formed in a helix to accommodate the dummy load 24 and so that portions of its outer narrow wall 19b are in engagement with portions of the inner narrow wall of the resonant ring 16 at all angles.

Means is provided between the waveguides 16 and 18 for forming a directional coupling between the same. Similar means is also provided for forming a directional coupling between the waveguides 16 and 19. Means is also provided for permitting rotation of one of the waveguides 18 and 19 with respect to the other and in the arrangement shown consists of means which permits rotation of the inner waveguide 19 relative to the outer waveguide 18. Such an arrangement is preferable in most situations because in a primary application of my rotary joint, the rotary joint is utilized for supplying power to an antenna. Since the antenna normally rotates, it is desirable to connect the antenna to the waveguide which has

the least mass on the smallest radius which, in this case, is the inner waveguide 19.

A framework 26 permits rotation in this manner and consists of an outer stationary platform 27 which is provided with a plurality of upstanding brackets 28 that are affixed to the outer waveguides 18 of each of the rotary joints 11, 12 and 13 to hold them stationary. A platform 29 is rotatably mounted on the platform 26 and is connected to a rotating shaft 31. Suitable means to reduce friction such as ball bearings 32 can be provided between the rotating platform 29 and the stationary platform 27. Spaced upstanding brackets 33 are secured to the platform 29 and have affixed thereto the inner waveguides 18 of the rotary joints 11, 12 and 13. The resonant ring 16 is affixed to the outer waveguide 18 by suitable means such as tack welding so that the inner waveguide 19 will rotate relative to the resonant ring 16. However, it is readily apparent that, if desired, the resonant ring could be affixed to the inner waveguide 19 and that relative rotation could occur between the resonant ring 16 and the outer waveguide 18.

In the multi-channel rotary joint assembly shown in FIGURES 2-5, it can be seen that the rotary joints are stacked on a common axis and that the inner waveguides can be rotated in unison with respect to the outer waveguides without difficulty.

Means is provided for coupling power between the waveguides 18 and the resonant ring 16 and also for coupling power between the resonant ring 16 and the waveguide 19. As hereinbefore explained, either of the waveguides 18 or 19 can be used as an input waveguide. However, in the arrangement shown, the outer waveguide 19 is utilized as an input waveguide to directionally couple energy into the resonant ring 16. Similarly, the waveguide 18 is utilized to directly couple energy from the resonant ring 16. Thus, in effect, the waveguides 18 and 19 serve as directional couplers for the resonant ring 16.

The coupling means can take any suitable form. For example, as shown in FIGURES 3 and 4 of the drawings, the coupling means can be in the form of coupling apertures which can be either continuous or discontinuous. Thus, the resonant ring 16 has been provided with a plurality of small, closely spaced holes 36 provided in both of its narrow walls 16b and spaced equi-distant from the wider walls 16a of the resonant ring. The holes 36, therefore, form an annular discontinuous aperture which forms a part of the coupling means. The holes 36 can have any desired size and spacing. However, it is preferable that the holes be spaced as closely as possible to obtain as uniform coupling as possible while at the same time retaining the desired strength in the resonant ring 16.

In order to permit energy to be coupled through the holes 36, the waveguides 18 and 19 are provided with annular continuous slots 37 and 38, respectively. These slots 37 and 38 lie in a plane parallel to the wide walls 16a of the resonant ring 16 and are immediately opposite their respective holes 36 provided in the inner and outer walls 16b of the resonant ring 16. In view of the fact that the ring-like waveguides 18 and 19 are in the form of helices, it is apparent that the slots 37 and 38 will be at different heights or positions on the narrow walls 18b and 19b of the waveguides so that the holes 36 in the resonant ring 16 will always be in communication with the waveguides 18 and 19 through the slots 37 and 38. Thus, it can be seen that even though the inner waveguide 19 is rotated relative to the resonant ring 16, all of the holes 36 in the inner wall 16b will be in continuous communication with the cavity provided by the waveguide 19.

The fact that the coupling slot 38 provided in the waveguide 19 is at different elevations in the wall of the waveguide 19 will not affect the coupling because, as is well known to those skilled in the art, waveguide electromagnetic fields do not vary with height and, therefore, the

coupling will remain constant, at least to a first order approximation.

Since relative motion must occur between the resonant ring 16 and one of the waveguides, it may be desirable to provide means to prevent arcing and R-F leakage at the point of relative movement. Such means is not shown in FIGURES 2-5 but may take the form of a choke joint hereinafter described with the embodiment shown in FIGURES 6-10.

In order that the waveguides 18 and 19 can function properly as input and output directional couplers, it is important that the phase velocities in both of the waveguides be equal. As is well known to those skilled in the art, the influence of the differing radii of the ring-like waveguides upon the phase velocity may be compensated for by the adjustment of the waveguide width.

In the drawings shown in FIGURE 1, a power source 39 and an antenna 40 are shown. The power source 39 is connected to the input of the ring-like waveguide 18 which is indicated as a line and as terminating in the dummy load 21. The output of ring-like waveguide 19 which is connected to the antenna 40 is shown as a line terminating in the dummy load 24. The resonant ring 16 is indicated between the directional couplers 18 and 19. The diagonal arms or arrows shown in FIGURE 1 between the input waveguide or directional coupler 18 and the resonant ring 16 and between the resonant ring 16 and the output waveguide or directional coupler 19 indicate the initial and reflected or incident waves. The four terminals of the waveguide or directional coupler 18 have been numbered 1-4, whereas the four terminals for the directional coupler or waveguide 19 have been numbered 5-8. The letter *a* indicates wave amplitudes emerging from the directional coupler, whereas the letter *b* indicates wave amplitudes incident upon the directional coupler. Thus, the designation *a*₁ indicates the wave amplitude delivered from the power source into the system or waveguide 18, whereas the designation *b*₁ indicates the power or wave amplitude which is reflected back into the power source. Thus, also *b*₃ indicates the wave amplitude delivered from the directional coupler into the resonant ring 16, whereas the designation *a*₃ indicates the wave reflected back into the directional coupler. In the same manner, the designation *b*₂ indicates the wave amplitude delivered to the dummy load and *a*₂ represents the wave reflected by the dummy load into the waveguide 18.

In considering the operation of the rotary joint assembly shown in FIGURES 2-5, it can be shown mathematically that the resonant ring 16 connected as a transmission-type cavity in each rotary joint is capable of providing a full power transfer from an input directional coupler to an output directional coupler, or, in other words, from a power source such as a transmitter to a suitable load such as an antenna with negligible power dissipation in the dummy loads 21 and 24 and negligible reflection of power back into the power source.

This can be established with relatively simple mathematics after making some idealized assumptions. For example, let it be assumed that the input and output directional couplers 18 and 19 are concentrated in a single plane or cross-section rather than distributed around the circumference. With this assumption and utilizing a conventional scattering matrix theory to calculate the power relationships, the following can be stated.

The scattering matrix of the directional coupler 18 (also called directional coupler I) is

$$S = \begin{bmatrix} 0 & k_1 & jk_2 & 0 \\ k_1 & 0 & 0 & jk_2 \\ jk_2 & 0 & 0 & k_1 \\ 0 & jk_2 & k_1 & 0 \end{bmatrix}$$

Where *k*₁ is the voltage coupling coefficient between diagonal arms (for example, 1-3) and *k*₂ is the voltage coupling coefficient between co-linear arms (for example, 1-2).

The coefficients *k*₁, *k*₂ are related through the following equation.

$$k_1 = \sqrt{1 - k_2^2}$$

The scattering matrix for the directional coupler 19 (also called coupler II) is identical. By appropriate combination of matrices and by taking into account the line length of the resonant ring 16, the various amplitudes of interest can be determined. It should be pointed out that the assumption of perfect coupler directivity and ideally matched loads render several amplitudes equal to zero as indicated in FIGURE 1. Thus, one obtains

$$b_3 = a_1 \frac{jk_2}{1 - k_1^2 e^{-\gamma L}}$$

Where *b*₃ is the wave amplitude launched into the resonant ring 16 and

Where *L* is the total line length of the resonant ring.

The amplitude delivered to the antenna is specified by the following equation.

$$b_7 = -a_1 \frac{k_2^2 e^{-\gamma l_1}}{1 - k_1^2 e^{-\gamma L}}$$

Where *l*₁ is the line length between terminals 3 and 5.

If the resonant ring is lossless ($e^{-\gamma L} = e^{-j\beta L}$), and tuned to the operating frequency ($e^{-j\beta L} = 1$), one has

$$b_7 = -a_1 e^{-j\beta l_1} \text{ or } \left| \frac{b_7}{a_1} \right| = 1$$

Thus, it can be seen that a full power transfer is achieved. The wave incident upon the primary dummy load 21 is

$$b_2 = a_1 k_1 \frac{1 - e^{-\gamma L}}{1 - k_1^2 e^{-\gamma L}}$$

which for a tuned ring becomes

$$b_2 = a_1 k_1 \frac{1 - e^{-\alpha L}}{1 - k_1^2 e^{-\alpha L}}$$

In the case of zero ring loss ($e^{-\alpha L} = 1$), *b*₂ obviously vanishes.

With 0.2 db loss in the resonant ring and with 3 db directional couplers, the above formulas show a total insertion loss of the resonant ring of

$$\left| \frac{b_7}{a_1} \right| \cong 0.3 \text{ db}$$

and a transmission loss to the primary dummy load of

$$\left| \frac{a_1}{b_2} \right| \cong 35 \text{ db}$$

As pointed out above, in making this mathematical analysis, certain assumptions were made. An extension of this analysis to a true rotary joint circuit with distributed directional couplers requires a considerably more complicated mathematical treatment.

From the above, it can be seen that a full power transfer is achieved with a very low insertion loss and a very low transmission loss to the primary dummy load independent of the angle of rotation of the rotary joint. In other words, there is no dead angles. The arrangement is also such as to permit low VSWR independent of the angle of rotation. There is also an absence of cross-talk and there is symmetry in all of the channels. It is possible to accomplish these results, i.e., transmission characteristics independent of rotational angle, because the input and output coupling to the resonant ring are uniformly distributed about the inner and outer circumferences of the resonant ring so that the entire rotary joint is circularly symmetrical.

Because of the substantial one-hundred percent power transfer in the directional couplers, energy will not recirculate repeatedly in the resonant ring, and for that reason the resonant ring gain will be equal to, or only slightly greater than, unity. Thus, the field intensity within the

resonant ring does not exceed the values present in the input and output directional couplers. For that reason and because the ring is heavily loaded, no breakdown problems are present in the ring proper. Because of the tight couplings with the transmission cavity, operating bands in the order of ten to twenty percent are possible.

Another embodiment of my waveguide rotary joint is shown in FIGURES 6 through 10. This embodiment is very similar to the embodiment which is shown in FIGURES 2 through 5 in that it includes an annular waveguide 46 in the form of a resonant ring and in which waveguides 47 and 48 are provided for coupling energy into and out of the resonant ring 46. In the embodiment shown in FIGURES 2 through 5, the waveguides 16, 18 and 19 are arranged with their narrow walls parallel to the vertical axis of the rotation, whereas in the embodiment shown in FIGURES 7 through 10, it can be seen that the waveguides 46, 47 and 48 are arranged so that their wider sides are parallel to the rotational axis.

From the arrangement shown in FIGURES 2 through 5, it can be seen that there is provided a multi-channel rotary joint assembly which has a relatively small height but which has a large diameter. On the other hand, the multi-channel rotary joint assembly shown in FIGURES 6 through 10 has a smaller diameter but has greater height. However, the primary disadvantage of the embodiment shown in FIGURE 1 is the formation of the waveguides 18 and 19 into helices. Since doing this precisely is relatively expensive, the embodiment shown in FIGURES 6 through 10 is disclosed in which it is unnecessary to form the outer and inner waveguides 47 and 48 into helices. Rather, they can take the form of annuli or rings.

In the embodiment shown in FIGURES 6 through 10, the wide walls 46a and one of the narrow walls 46b of the resonant ring 46 are formed as an integral part of an annular frame 51 as shown particularly in FIGURE 7. The input directional coupler waveguide 47 is substantially U-shaped in cross-section as shown in FIGURE 7 and is secured to the depending walls 46a so that its open end faces the integral wall 46b by suitable means such as bolts 53 extending through flanges provided on the respective members. The waveguide 47 is provided with a flanged input arm 56. The output directional coupler or waveguide 48 is also substantially U-shaped as can be seen from FIGURE 7 and is rotatably mounted upon an inwardly extending flange 58 formed as a part of the annular frame 51. Suitable means is provided for permitting rotational movement of the output waveguide 48 relative to the resonant ring 46 and consists of a plurality of support rollers 61 which are rotatably mounted upon a choke plate 62. The rollers 61 ride upon the concentric guide rail 64 provided on the flange 58 as shown particularly in FIGURE 7. The waveguide 48 is provided with a flanged output arm 66 which extends inwardly and outwardly from the waveguide 48.

The means for coupling energy from the input waveguide 47 into the resonant ring 46 consists of a coupling iris formed by the narrow wall 46b of the resonant ring 46. As can be seen from FIGURE 9, this wall is provided with a plurality of uniformly spaced apertures extending around the wall 46b. Similar means is provided for coupling the energy from the resonant ring 46 in the output waveguide 48 and consists of an iris coupling plate 71 which is mounted in the flange 58 and serves to separate the cavities formed by waveguides 46 and 48. The plate 71 is provided with a plurality of uniformly spaced coupling holes 72. No breakdown will result from the coupling means provided between the three ring waveguides 46, 47 and 48 because the apertures are in the narrow walls for reasons well known to those skilled in the art.

In order to minimize the possibility of any serious R-F leakage and electrical arcing or breakdown which

may be caused by relative movement between the output waveguide 48 and the resonant ring 46, a single choke is provided on each side. If desired, double chokes can be provided on each side if they are necessary. As is well known to those skilled in the art, the choke consists of an annular groove 76 which has a length or depth so that it has an electrical length of a quarter-wave. As is also well known to those skilled in the art, the impedance at the terminus of the groove looking out from the waveguides is the impedance of the groove in series with the impedance of the gap between the choke plate 62 and the flange 58. Since the groove 76 is a quarter-wave line terminated in a short, its impedance is infinite. Therefore, the total impedance at the terminus of the groove is always infinite for reasonable separation between the choke plate and the flange. Since the mouth of the groove is a quarter-wave length from the inner wall of the waveguides 46 and 48, the impedance at the junction of the waveguide and the choke is that of a quarter-wave line section terminated by an open circuit and this is zero. The waveguides 46 and 48, therefore, appear as continuous walls as long as the choke plate 62 and the flange 58 are not separated by more than one quarter-wave length.

Both of the input waveguide 47 and the output waveguide 48 are provided with dummy loads. Thus, as can be seen from FIGURE 10, the waveguide 47 is provided with a dummy load 78 which extends inwardly as is shown particularly in FIGURE 10, whereas the waveguide 48 is provided with a dummy load 79 which extends outwardly as shown particularly in FIGURE 8.

In making the connections to the waveguides 47 and 48 for the input and output arms and the dummy loads, it will be noted that in order to obtain a configuration for the waveguides 47 and 48 which has portions in contact with portions of the resonant ring 46 at all angles, it has been unnecessary to place relatively sharp bends in the waveguide or corners as shown in the drawing. The bends or corners are minimized as much as possible by dividing the angle between the connection to the dummy load and to the input or output arm so that angles of approximately 45° are formed in the waveguide. Although this arrangement may produce slight discontinuities within the waveguide, the simplicity of this design still makes it a desirable embodiment.

In order to facilitate stacking of the separate rotary joints upon one another to provide a multi-channel rotary joint assembly, the annular frame 51 is provided with stacking flanges 81 which receive bolts 82 to fix the rotary joints one above the other and stacked on a common axis. The multi-channel rotary joint assembly can then be mounted in a suitable location and the input arms 56 connected to suitable sources of high frequency power and the output arms 66 connected antennas. The antennas together with the output waveguides 48 can then be rotated in unison without any difficulty relative to the resonant rings 46 and the input waveguides 47, while at the same time obtaining a power transfer from the transmitters to the antenna with a very low insertion loss and with a very small amount of power dissipated in the dummy load. In addition, the input VSWR, assuming a matched antenna, is very low. As in the previous embodiment, all of these features are characteristic of my rotary joint in any rotational position of the joint. Absorptive material (not shown) can be provided inside the frame if it is necessary to hold the cross-talk between the stacked channels to a minimum.

It is apparent from the foregoing that I have provided a new and improved rotary joint which gives a full power transfer or an energy transfer as well as other desirable features which is independent of the relative angle of rotation of the rotary joint.

It is also apparent from the foregoing that I have provided a rotary joint which can be readily constructed and economically manufactured.

I claim:

1. In a waveguide rotary joint, an annular resonant waveguide forming a transmission-type cavity, a pair of additional waveguides, each of said additional waveguides having a substantially annular portion, means forming an input directional coupling arrangement extending through substantially 360° between the annular portion of one of the additional waveguides and the annular waveguide, means forming an output directional coupling arrangement extending through substantially 360° between the annular portion of the other additional waveguide and the annular waveguide, and means for mounting the annular waveguide and the additional waveguides to permit rotation of one of the additional waveguides relative to the other of the additional waveguides.

2. A rotary joint as in claim 1 wherein the means for forming an output directional coupling arrangement is formed to provide a coupling which is uniformly distributed around the circumference of the annular resonant waveguide and wherein the means for forming an input directional coupling arrangement is formed to provide a coupling which is uniformly distributed around the circumference of the annular waveguide.

3. A rotary joint as in claim 1 wherein all of said waveguides are rectangular in cross-section and have spaced parallel wide and narrow walls and wherein the waveguides are stacked one above the other so that the narrow walls are parallel to the axis of rotation of said one additional waveguide.

4. A rotary joint as in claim 1 wherein all of said waveguides are rectangular in cross-section and have spaced parallel narrow and wide walls and wherein the waveguides are stacked one above the other with the wide walls of the waveguides parallel to the axis of rotation of the said one additional waveguide.

5. In a waveguide rotary joint, first, second and third rectangular waveguides, the first waveguide being annular in form and being dimensioned to provide a resonant transmission type cavity, said second and third waveguides each having a substantially annular portion in substantial engagement with walls of the first waveguide, said second and third waveguides also having a helical-like configuration to permit contact between the annular portions of the second and third waveguides and the first waveguide at all angles, wall means separating the first waveguide from the second waveguide, additional wall means separating the first waveguide from the third waveguide, means provided in the wall means separating the first waveguide in the annular portion of the second waveguide to form an input directional coupling arrangement, means provided in the wall means between the first waveguide and the annular portion of the third waveguide to

form an output directional coupling arrangement, and means for mounting said first, second and third waveguides to permit relative rotation of one of said second and third waveguides to the other of said second and third waveguides.

6. A rotary joint as in claim 5 wherein said wall means between the second and first waveguides is a common wall having aperture-like means extending over substantially 360° and wherein the wall means between the third and first waveguides is a common wall having an aperture-like means extending over substantially 360°.

7. A rotary joint as in claim 5 wherein the wall means between the second and first waveguides consists of pairs of parallel vertical walls having aperture-like means therein extending over substantially 360° and wherein the wall means between the third and first waveguides consists of substantially parallel vertical walls having aperture-like means therein extending over substantially 360°.

8. A rotary joint as in claim 6 wherein the wall means between the second and first waveguides consists of a common wall lying in a horizontal plane and having aperture-like means extending over substantially 360° and wherein the wall means between the third and first waveguides consists of a common wall lying in a horizontal plane and having aperture-like means extending through substantially 360°.

9. In a waveguide rotary joint, first, second and third waveguides, the first waveguide being annular in form and dimensioned to form a transmission-type resonant cavity, the second and third waveguides having a ring-like configuration, means forming an input directional coupling arrangement between said second waveguide and said first waveguide, means forming an output directional coupling arrangement between said third waveguide and said first waveguide, and means for mounting said first, second and third waveguides to permit relative rotation of one of said second and third waveguides to the other of said second and third waveguides, said first, second and third waveguides being stacked upon each other so that the narrow walls are parallel to the axis of rotation of the said one waveguide and wherein said second and third waveguides have a helical-like configuration to permit contact between the second and third waveguides and the first waveguides at all angles.

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