United States Patent [19]

Hubing et al.

[11] **3,914,715**

[45] **Oct. 21, 1975**

[54] **COAXIAL RING ROTARY JOINT**

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[73] Assignee: **Texas Instruments Incorporated,** Dallas, Tex.

[22] Filed: **June 26, 1974**

[21] Appl. No.: **483,166**

[52] **U.S. Cl.** ..... **333/24 R;** 333/9; 333/84; 333/97 R; 333/98 TN

[51] **Int. Cl.²** **H01P 1/06;** H01P 3/08; H01P 5/12

[58] **Field of Search** ..... 333/24 R, 84 M, 24 C, 27, 333/84 R, 97 R, 97 S, 98 R, 98 TN, 6, 9; 343/741, 743, 757, 763, 764, 766, 869

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Primary Examiner—James W. Lawrence
Assistant Examiner—Marvin Nussbaum
Attorney, Agent, or Firm—Harold Levine; Rene Grossman; Alva H. Bandy

[57] **ABSTRACT**

A tuned split coaxial ring rotary joint for a single channel or multichannel RF transmission line is disclosed. The tuned split coaxial ring means has a stator half in operable association with a rotatable rotor half. Multiple channels are formed by securing two rotor sections together within two stator sections. By stacking this arrangement any even number of channels can be accommodated and a single arrangement can be added for an odd number of channels.

20 Claims, 11 Drawing Figures

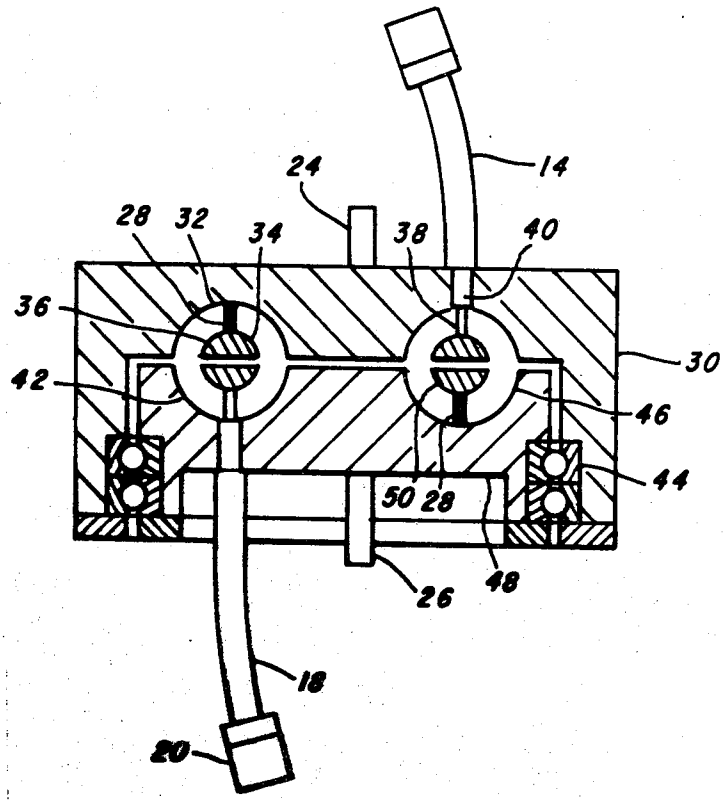


Fig. 1

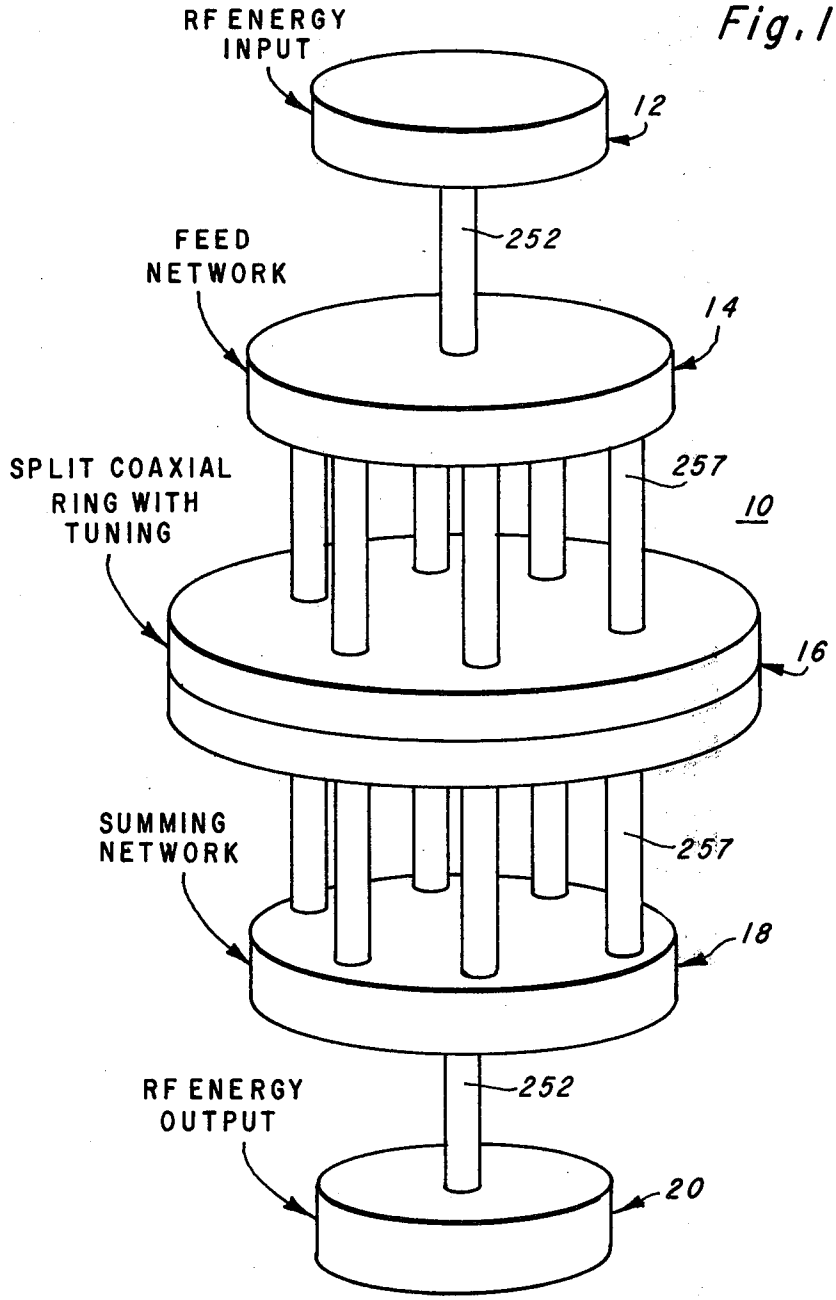
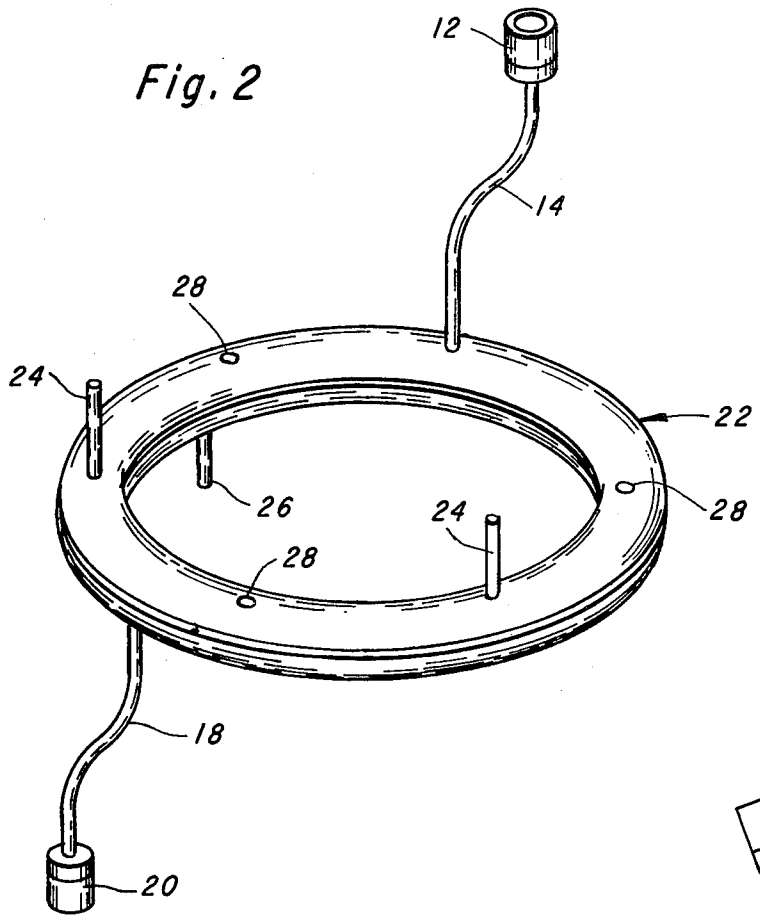

RF ENERGY INPUT
12
252
FEED NETWORK
14
SPLIT COAXIAL RING WITH TUNING
257
10
16
SUMMING NETWORK
257
18
RF ENERGY OUTPUT
252
20

Fig. 2


12
14
28
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24
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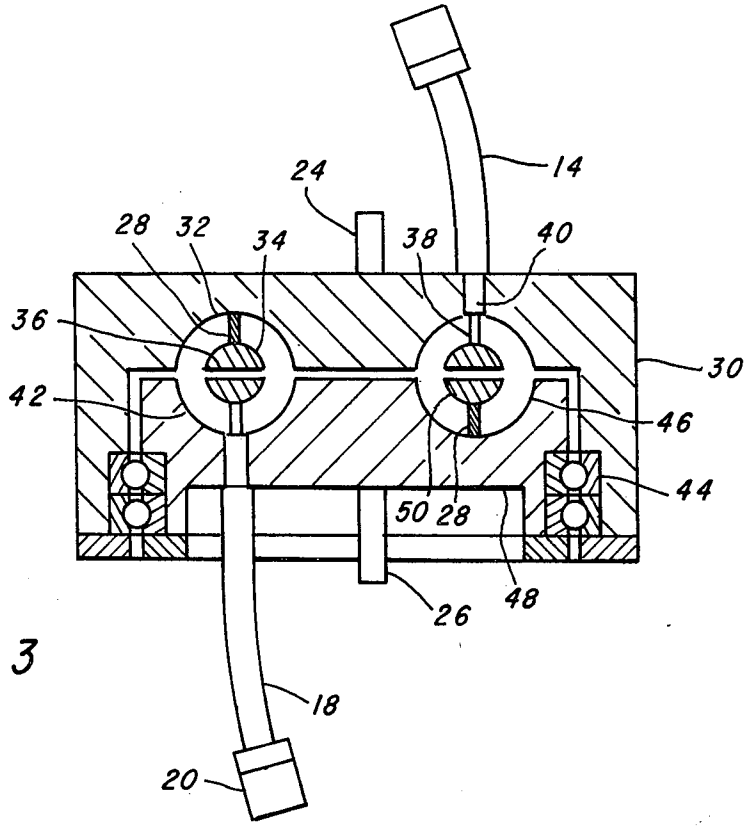

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Fig. 3

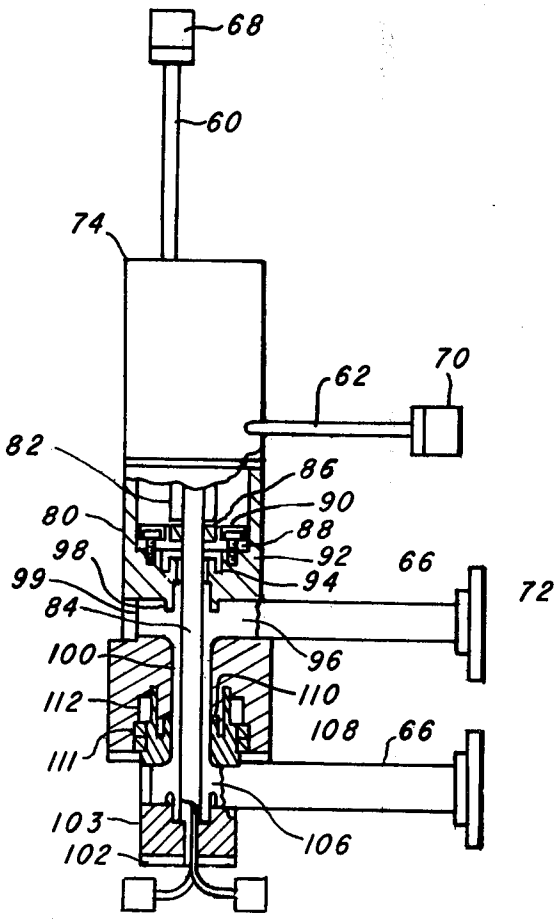


Fig. 4

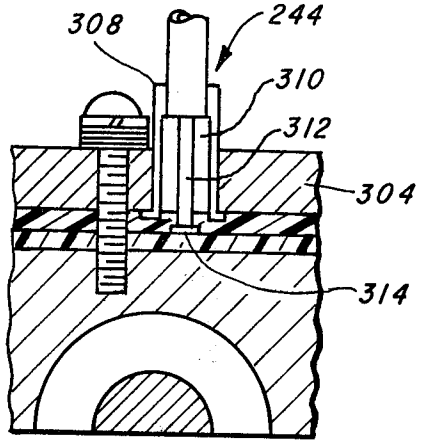


Fig. 8

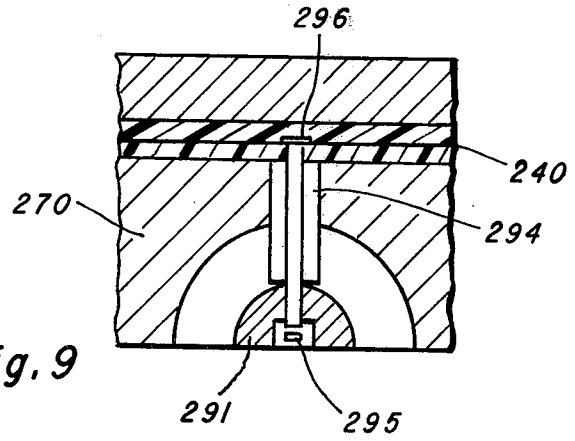
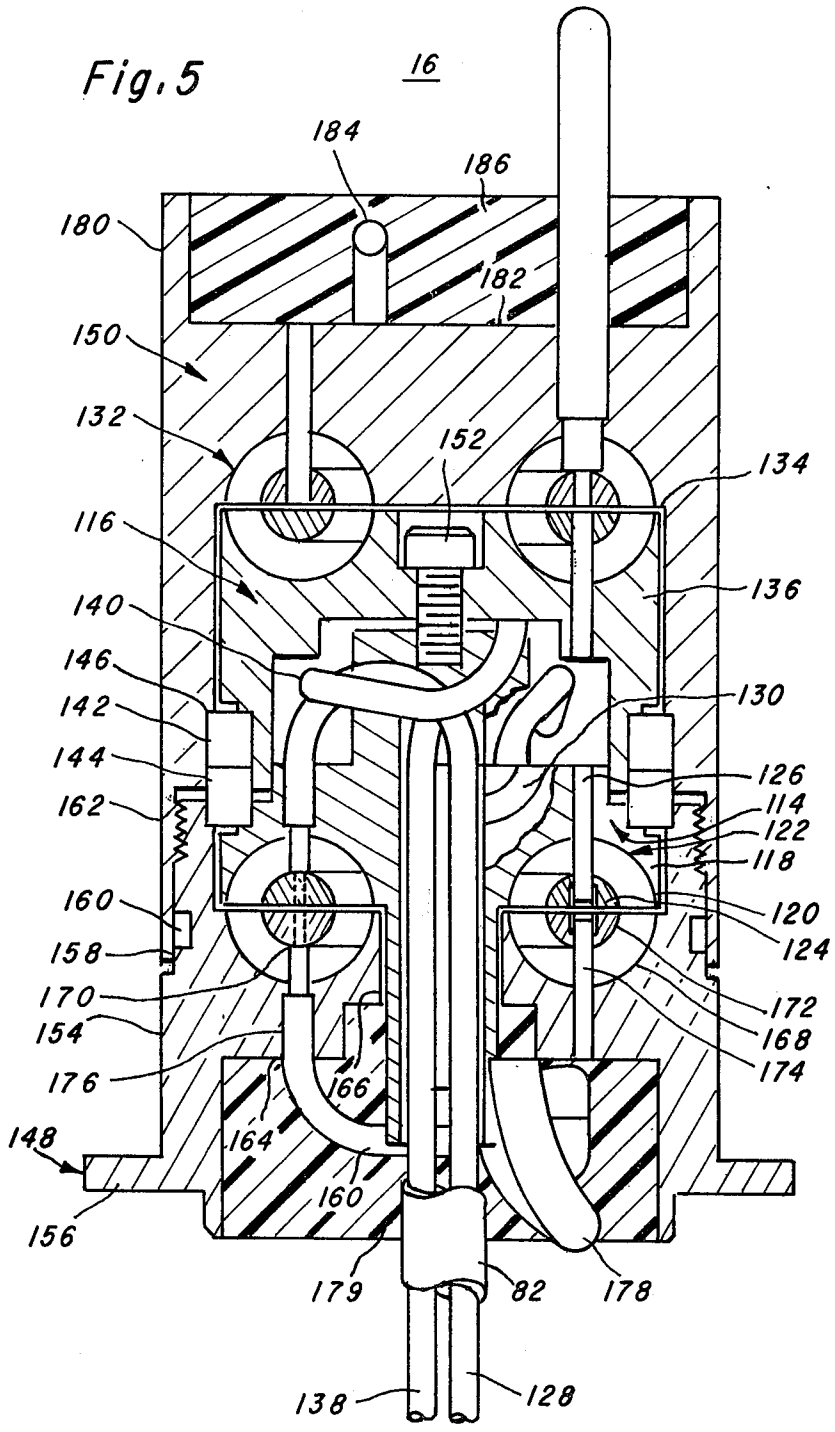


Fig. 9

Fig. 5


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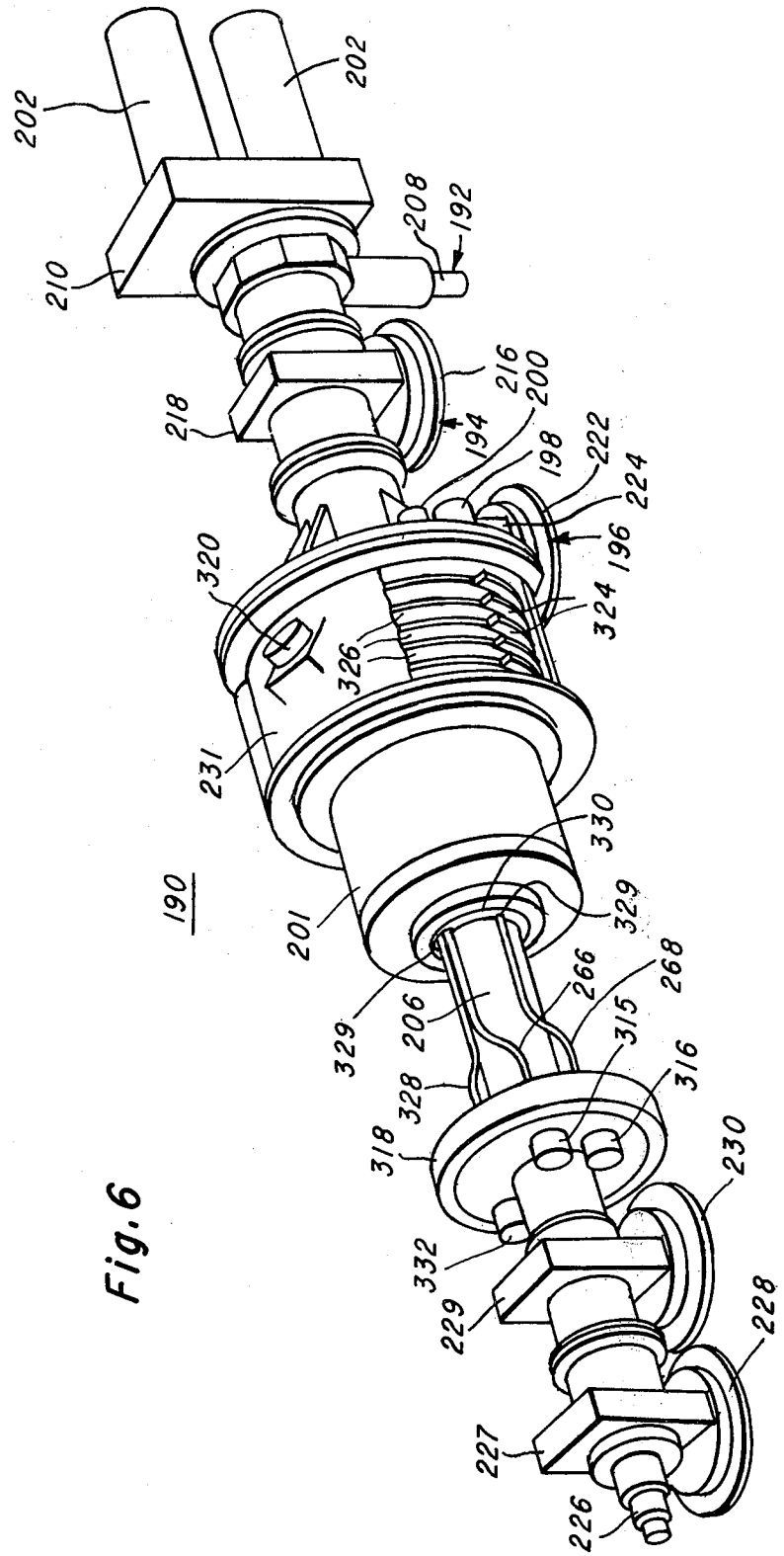

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Fig. 6

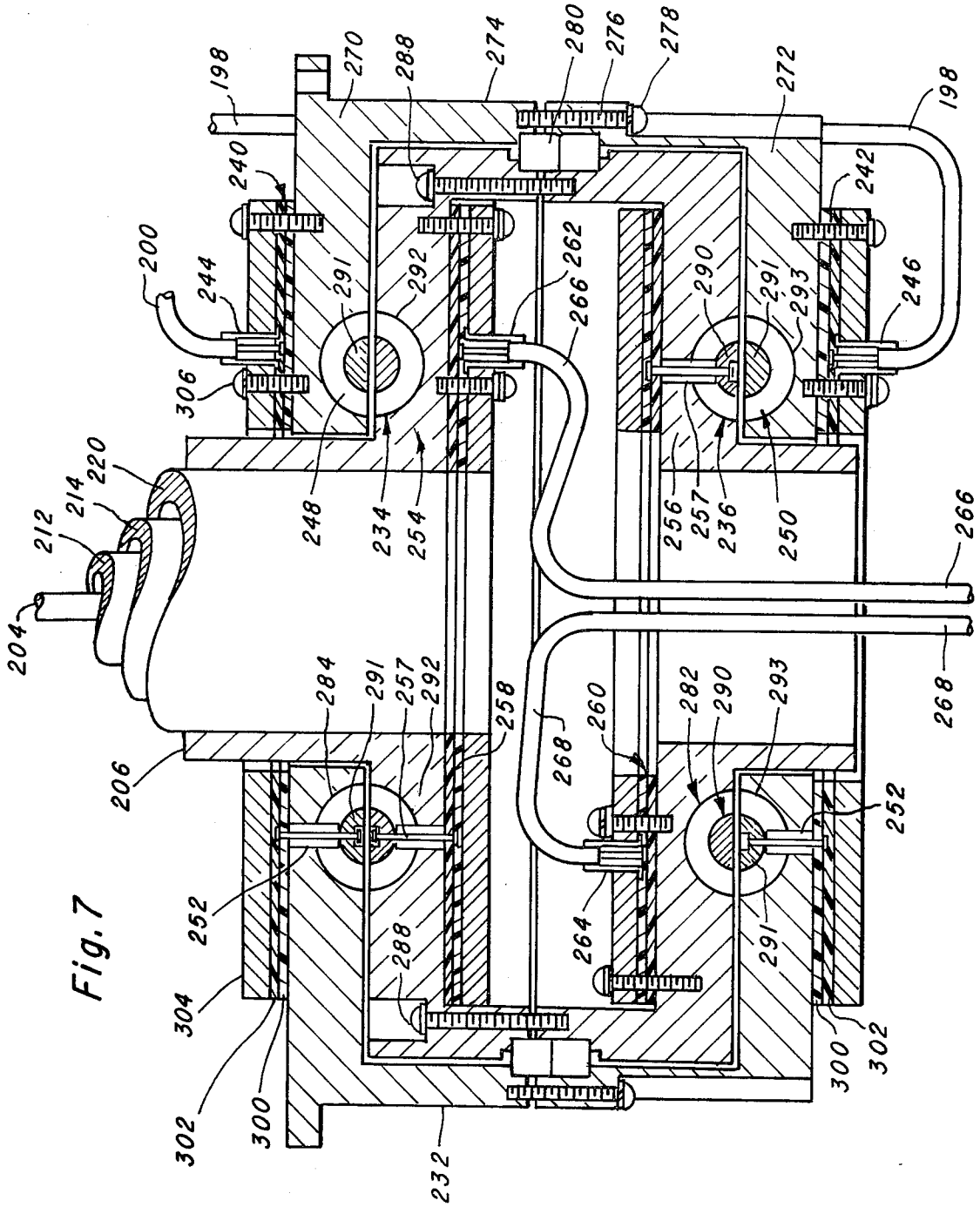

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Fig. 7

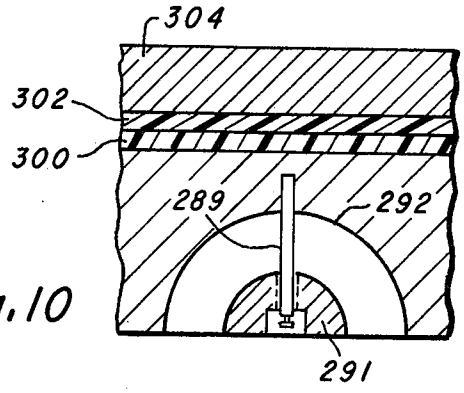


Fig. 10

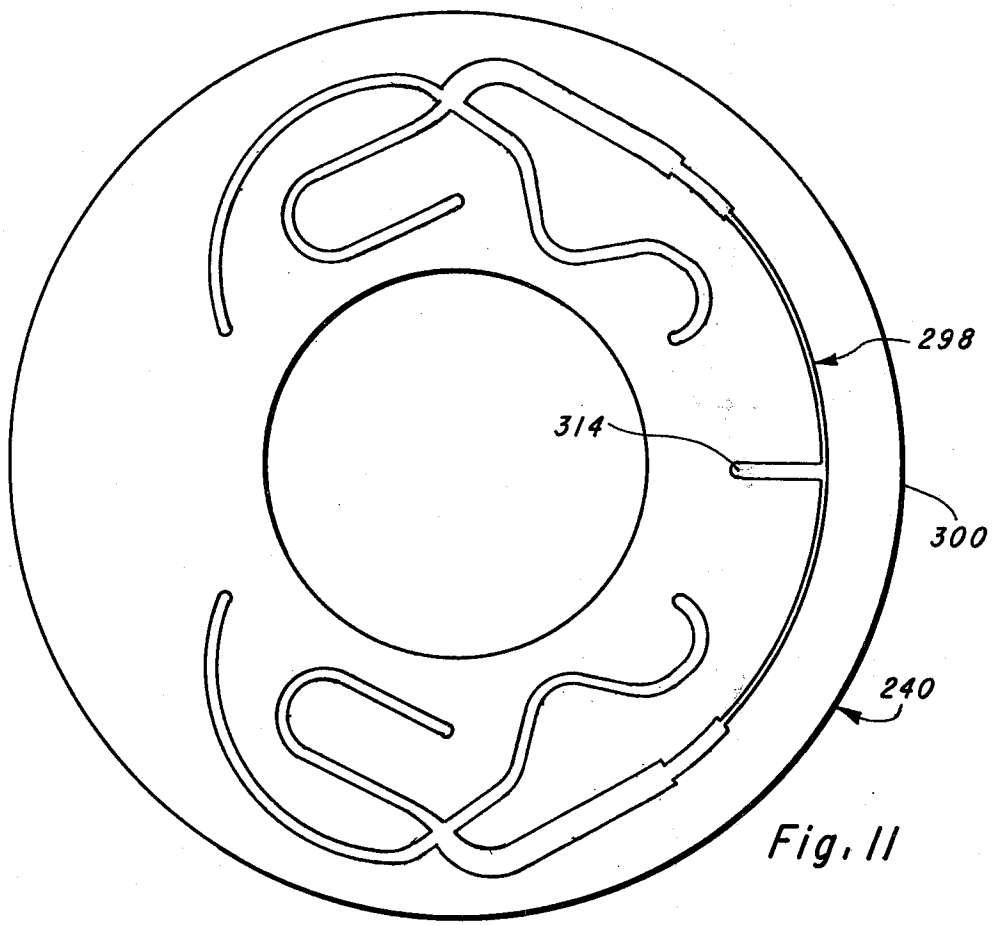


Fig. 11

COAXIAL RING ROTARY JOINT

This invention relates to radio frequency transmission lines, and more particularly to a rotary joint for feeding either a single or multiple channel rotating device such as an antenna.

A significant component of each radio frequency transmission line for a rotating multi-beam antenna is the rotary joint. The rotary joint is a device that is designed to provide radio frequency continuity to a continously rotating antenna system. The basic rotary joint is a coaxial-line configuration operation in the transverse electromagnetic (TEM) mode. To allow rotation, the transmission line is physically broken, and half-wavelength choke sections are employed to maintain RF continuity and prevent RF leakage. Morris Cohen in "A Six-Channel Vertically Stacked Coaxial Rotary Joint for the S-L and X-Band Region", *Microwave Journal*, Vol. 7, No. 11, November 1964, page 71, describes a rotary joint having a feed system in which energy is coupled to and from a coaxial line structure by voltage probes backed up by an effective length of shorted radial line. An impedance matching post is placed in the same plane as the voltage probe and directly opposite it. The dual rotary joint of coaxial configuration has the center conductor of the structure common to both rotary joints and is made hollow to allow passage of the cable going to the stator section of the upper rotary joint. Several rotary joints can be vertically stacked in this manner since each has a hollow center conductor. Nevertheless, the number of stacked joints is restricted by the allowable diameter of the center conductor and by the number and diameter of the stator cables which must pass through it.

To maintain a nominal characteristic impedance of from 40–60 ohms, the ratio of diameters of the inner and outer conductors of a coaxial cable for each structure must be in the order of 1.95 (for 40 ohms) to 2.72 (for 60 ohms). Therefore in the S through X band regions the mean diameters of the respective coaxial lines could permit the introduction of high order circumferential modes which effect the transmission characteristics of the rotary joints. The possibility of higher order circumferential mode interference together with the requirement for broad band frequency coverage requires a feed system capable of maintaining a constant transmission characteristic with rotation (power variation with joint rotation or WOW).

The choice of feed network depends on the composite system requirements in terms of allowable insertion loss, VSWR, frequency band of operation, bandwidth, the geometry and gain of the antenna, and the available space in its use environment such as, for example, an aircraft, or spacecraft. At frequencies above 3 gigahertz (GHz), half wavelength chokes provide a compact broadband and reliable means of insuring electrical continuity in the rotary joint, however, at lower frequencies the choke widths and lengths become prohibitive and lead to very bulky components. The half-wavelength choke section at one GHz, for example, is approximately 30 centimeters long. A multi-channel rotary joint at this frequency using chokes becomes expensive to manufacture, difficult to handle, and prohibitive in size.

An alternative solution to the need for electrical continuity has been the use of precious metal contacts at the cut surfaces of the inner and outer conductors of the coaxial cable. Advantages obtained by using a precious metal contact are that it reduces the space requirement and has very broad bandwidth characteristics; it disadvantage lies in the fact that the silver graphite material constituting the contact rubs on a hardened surface such as coin silver and wears out. As the graphite wears it creates loose graphite and silver particles that can damage bearings and contaminate the RF transmission line. Because of the materials involved, the assembly problems, and the limited life time, the precious metal contact turns out to be a very expensive item, particularly in multi-channel rotary joints.

As object of the present invention is to provide a durable compact rotary joint for use in RF transmission lines at frequencies, for example, below three gigahertz.

Another object of the present invention is to provide a radio frequency rotary joint which, at frequencies below three gigahertz, is more economical to manufacture than other known rotary joints designed to operate at these frequencies.

Still another object of the present invention is to provide a multichannel radio frequency rotary joint which is more reliable and which enjoys a longer operating life than a precious metal contact type rotary joint.

Yet another object of the invention is to provide a rotary joint for a radio frequency energy transmission line which operates with a VSWR of about 2 or less.

Still yet another object of the invention is to provide a rotary joint for a radio frequency energy transmission line which is adaptable to a plurality of configurations to provide system design flexibility.

Briefly stated, the rotary joint for radio frequency energy constituting the present invention comprises: either a power divider for a multiple feed system or a coaxial feed line for single lead feed system to supply radio frequency energy to a tuned split coaxial ring; and a summing network for collecting the RF energy from the split coaxial ring. The coaxial ring is a toroidally shaped ring of coaxial cable divided into two halves along the plane of the ring. One ring half forms a stator for the rotary joint; and RF energy from the multiple feed system is fed from the power divider, or for a single line feed system from the coaxial feed line, into the stator half of the split coaxial ring. Transition impedances are matched in the coaxial ring by at least one tuner which tunes the coaxial ring to a selected band of frequencies. The second half of the split coaxial ring forms a rotor supported for rotation by bearings. The ring halves are aligned and to prevent contact during rotation the ring halves are spaced or gapped. The gap is maintained small as compared to the coaxial dimensions. RF energy is collected from the rotor by a summing network which is similar to the construction of either the power divider or the coaxial feed line whichever is used. From the summing network, the power is fed to the power output connector.

The above objects and other objects and features of the invention will become more readily understood in the following detailed description taken in conjunction with the drawings in which:

FIG. 1 is a block diagram of an RF energy rotary joint utilizing the split coaxial ring rotary joint.

FIG. 2 is an isometric view of a split coaxial ring for use in the rotary joint of an RF energy transmission line.

FIG. 3 is a sectional view of a coaxial ring rotary joint using a single lead feed system.

FIG. 4 is a view of a multi-channel rotary joint arrangement depicting a two channel coaxial ring rotary joint atop a coaxial waveguide rotary joint; the housing for the rectangular waveguide partly broken away to show the coaxial waveguide rotary joint in section.

FIG. 5 is a sectional view of the two channel split coaxial ring rotary joint.

FIG. 6 is an isometric view of another multi-channel arrangement depicting a multi-channel split coaxial ring rotary joint in combination with a multi-channel coaxial waveguide rotary joint.

FIG. 7 is a cross-sectional view of the multiple feed multi-channel split coaxial ring rotary joint utilized in the rotary joint of FIG. 6.

FIG. 8 is a broken sectional view of the feed line connection of the source of RF energy to the power divider of FIG. 6.

FIG. 9 is a broken sectional view of the feed lines interconnecting the power divider and split coaxial ring of FIG. 6.

FIG. 10 is a broken sectional view of the tuner used in the split coaxial ring rotor joints of FIG. 6.

FIG. 11 is a plan view of a conductor pattern for a six feed line power divider for FIG. 6.

Referring to FIG. 1 in which there is shown a radio frequency (RF) split coaxial ring rotary joint **10** for coupling a stationary system (not shown) to a rotating system such as a rotating radar antenna (not shown). The RF feed line system comprises an input terminal **12** for receiving RF energy for a source thereof. Feed network **14** is coupled to the RF energy input **12** and to a stationary half (stator) of a split coaxial ring rotary joint **16** through one or more feedlines. An RF energy summing network **18** is connected to a rotating half (rotor) of the split coaxial ring rotary joint **16** to collect through one or more output lines the RF energy from the continuous path provided by the split coaxial rotary joint **16.** An RF energy output terminal **20** is coupled to the output of the summing network **18.**

Referring now to FIG. 2 in which there is shown a basic split coaxial ring **22** for a rotary joint **16.** The split coaxial ring may be constructed of any suitable conductor material such as, for example, aluminum. The length around the coaxial ring's center line is one-quarter wavelength or less. For split coaxial rings of one-quarter wavelength or less the feed network **14** and the summing network **18** consist of the feedlines and the output lines which are lengths of coaxial cables terminating, respectively, at the input and output connectors **12** and **20.** The feed netowrk **14** or cable is connected to the upper half or stator of the split coaxial ring **22** and the summing network **18** or cable is connecteed to the lower half or rotor of the split coaxial ring. To tune the coaxial ring **22** to the desired frequency, the stator and rotor of the split coaxial ring are provided with tuners **24** and **26.** Tuner **24,** connected to the stator of the coaxial ring **22,** is spaced 120° from the stator's feed network **14** input connection, and tuner **26,** connected to the rotor of the coaxial ring **22,** is spaced 120° from the rotor's summing metwork **18** output connection. The upper and lower halves of the inner conductor (not shown) of the coaxial ring **22** are supported on an axis common to the inner and outer conductors, each by three equally spaced nonconductive pins **28** having ends mounted in the outer conductor halves of the split coaxial ring **22.**

A rotary joint embodying the coaxial ring **22** of FIG. **2** is demonstrated in FIG. **3.** The stator **30** is an inverted cylindrical cup shaped member. The stator's half of the coaxial ring's outer conductor **32** is formed in the inner surface of the bottom of the cup and the stator's half of the inner conductor **34** is centrally disposed about an axis common to the inner and outer conductor halves and supported there by the nonconducting pins **28.** The flat surface **36** of the inner conductor is substantially coplanar with the inner surface of the stator **30.** RF energy is fed from a source thereof (not shown) to the stator **30** through a feed network **14** consisting of a single coaxial cable. The inner conductor **38** of the feed network's coaxial feed cable terminates in the stator's inner conductor half **34** of the coaxial ring; the outer conductor **40** of the feed network's coaxial cable terminates at the stator's half of the outer conductor **32** of the coaxial ring. The tuner **24** of the stator **30,** which may be, for example, a shorted section of the coaxial cable, is coupled to the stator's half of the split coaxial ring 120° from the feed line connection. The tuner is coupled to the stator's half of the coaxial ring as was the coaxial feed line and fine tunes the frequency of the stator.

The rotor **42** of the split coaxial ring rotary joint is also an inverted cylindrically cup shaped member rotatably mounted within the walls and spaced about 0.004 inch from the bottom of the inverted cylindrically cup shaped member of the stator by bearings **44.** The rotor's half of the outer conductor **46** of the split coaxial ring is formed in the outer surface of the bottom **48** of the rotor and the rotor's half of the split coaxial ring's inner conductor **50** is supported about an axis common to the inner and outer conductors by three nonconductive pins **28** having ends mounted in the outer conductor. The summing network **18** cable has the output connector **20** at one end, and its other end connected to the rotor's half of the split coaxial ring in a manner identical to that of stator's power divider feed network cable. A tuner **26,** which may be identical in construction to tuner **24** of the stator, is connected to the rotor's half of the split coaxial ring 120° from the summing networks connection thereto.

FIG. **4** shows a multichannel rotary joint consisting of a combination of two split coaxial ring rotaty joints and a coaxial waveguide rotary joint. The split coaxial ring rotary joints are for frequencies below 3 GHz, and the coaxial waveguide rotary joint is for frequencies above 3 GHz. It will be understood that the choice of the two configurations is determined by matters of economics. The coaxial waveguide rotary joint is cheaper to fabricate at frequencies above 3 GHz than is the split coaxial ring rotary joint. At frequencies below 3 GHz the choke structure of the coaxial waveguide becomes too large and heavy for easy handling and aircraft or spacecraft use; therefore, the coaxial ring is preferred. As the split coaxial ring rotary joint structure and the coaxial waveguide rotary joint are compatible, as will become more apparent as the description proceeds, they make an ideal combination for a multichannel rotary joint.

A combined multichannel rotary joint is shown in FIG. **4** in which two coaxial cables **60** and **62** are provided with connectors **68** and **70** for coupling to sources of RF energy at frequencies, for example, below 3 GHz. A rectangular waveguide **66** is provided

with a rectangular flange **72** for coupling to a source of RF energy at frequencies, for example, above 3 GHz.

The coaxial cable feed lines **60** and **62** are attached to two split coaxial ring rotary joints enclosed by housing **74.** The housing **74** is mounted atop housing **80** for a coaxial waveguide rotary joint. A drive tube **82** is connected to the rotors of the split coaxial ring rotary joints and has one end forming keyways for splines joining a tubular member **84.** Member **84** is mounted on bearings **86** which are retained in a bearing insert **88.** The bearing insert **88** is attached by screws **90** to stator **92** of the coaxial waveguide rotary joint. The tubular member **84** consistutes the inner conductor of the coaxial cable for the coaxial waveguide rotary joint. Stator **92** is shaped to form with the bearing insert **88,** a choke **94** for the inner conductor **84.** The rectangular waveguide **66** opens into the coaxial cable **96** below the choke **94,** and the choke acts to maintain electrical continuity between the stator **92** and the inner conductor **84** and to reduce loss of power. The RF energy in the rectangular waveguide **66** is conducted in the dominate mode (TE_{10}) and is converted to the dominant (TEM) mode in the coaxial cable by a crossed waveguide transition including a transformer **98** and a tuner **99** formed in the housing **80** opposite the opening for the rectangular waveguide **66.**

The stator **92** extends downwardly and inwardly from the housing rectangular waveguide opening to form the outer conductor **100** of the coaxial cable **96.** The bottom flange **102** of the bottom flanged tubular member **84** supports a rotor **103** which includes a transformer **104** adjacent to the rotor output **106** of the output section of the rectangular waveguide **66** and an outer conductor choke **110.** The transformer **104** converts the RF energy from the TEM mode back to the TE_{10} mode for the output section of the rectangular waveguide **66.** The rotor **103** is rotatably mounted in the lower end of stator **92** on bearings **108.** The outer conductor choke **110** prevents loss of RF energy through the pair of bearings **108,** which are retained between the rotor and stator by bearing nut **111.** The choke **110,** bearings **108** and bearing retaining nut **111** are in sealing engagement with a seal **112.**

Turning now to the multichannel split coaxial ring rotary joint **16** (FIG. **5**), the rotor **103** (FIG. **4**) of the coaxial waveguide rotary joint is connected to the rotors **114** and **116** (FIG. **5**) of the two channel split coaxial ring rotary joint **16** by the tubular member **84** splined to the drive tube **82** (FIG. **4**). The rotors **114** and **116** (FIG. **5**) are attached to the drive tube **82** for rotation. Rotor **114** is a cylindrically shaped block **118** of conductive material such as, for example, aluminum having a centrally disposed aperture with walls engaging the tubular drive **82** for rotation. The lower surface of block **118** is shaped to form the upperhalf **120** of the outer conductor of a split coaxial ring **122.** The upper half of an inner conductor **124** for the split coaxial ring is supported concentrically within the upper half **120** of the outer conductor by three nonconductive pins **126** spaced 120° one from another.

As this particular multichannel rotary joint arrangement permits the coaxial rings to be ¼λ or less in length, and as a single feedline provides adequate performance neither a power divider nor a summer is required. Thus, rotor **114** requires only one summing or output feedline. Summing line **128** is a coaxial line having its inner conductor connected to the inner conductor of the split coaxial ring **122** and its outer conductor connected to the outer conductor of the split coaxial ring **122.** The summing line **128** is fed through the tubular drive member **82** and bottom flanged tubular member **84** to its output terminal. A tuner **130,** which may be a short piece of coaxial cable having one end selectively short circuited is attached to the rotor as part of the tuning system in the split coaxial ring. The tuner is located, when looking at the split side of the ring, 120° measured clockwise from the summing line connection to the split coaxial ring.

The rotor **116** for the second channel has the lower half or output half of the split coaxial ring **132** formed in the outer surface **134** of the cross member of a cylindrically cup shaped member **136.** As the construction of the rotor half of the split coaxial ring **132** is substantially identical to that of the rotor for the split coaxial ring **122,** it is not described. The difference is that its summing line **138** connection is spaced from the summing line **128** connection of rotor **114,** and the tuner **140** when observed from the split side, is 120° measured counterclockwise from the summing line **138.** The cylindrical sides of rotors **114** and **116,** respectively, have recesses in which bearings **142** and **144** are mounted; shims **146** may be used to adjust the bearings within the recesses. A screw **152** locks together the rotors **114** and **116** to load bearings **142** and **144** to gap the rotors **114** and **116** from stators **148** and **150.**

The stator **148** comprises an inverted cylindrically cup shaped member **154** having: at its lower end an outwardly extending flange member **156,** adapted to receive the housing **74** and to rest upon the housing **80** of the choke type rotary joint (FIG. **4**); and at its upper end a recess **158** with an O-ring **160** (FIG. **5**). The recess and O-ring receive and seal a narrow flanged end **162** of stator **150.** The bottom or cross-member **164** of the cup shaped member **154** has a centrally disposed aperture **166** through which the drive tube **82** extends. The outer conductor **168** forming the lower half of the split coaxial ring **122** is formed in the upper surface of the cross-member **164.** The inner conductor **172** of the split coaxial ring is concentrically mounted in the outer conductor by nonconductive pins **174** spaced 120° one from another. As no power divider is required for this arrangement, the coaxial feedline **60** has its inner conductor **170** attached to the inner conductor **172** of the lower half of the split coaxial ring, and its outer conductor **176** attached to the outer conductor **168** of the split coaxial ring for transferring the RF energy from the feedline **60** to the lower half of the split coaxial ring **122** in the primary TEM mode. A tuner **178** identical in construction to tuner **130** is attached to the lower half of the split coaxial ring **122** to complete the tuning in the split coaxial ring. The cup cavity **179** is filled with a suitable potting compound such as, for example, a silicon rubber sold under the trade mark 3144 RTV by Dow Corning Corporation to support the tuner **178** and feedline **60.**

The stator **150** comprises a cylindrically cup shaped member having a flange **180** extending upwardly from the cross-member **182** and a cylindrical side terminating in a downwardly extending narrow flange **162.** As the upper half of the split coaxial ring **132** is identical in construction to that of the above described lower half formed in stator **148,** it will not be described. It is to be observed that as no power divider is required for this arrangment, the coaxial feedline **62** is attached di-

rectly to the upper half of the split coaxial ring **132** and the tuner **184** is spaced 120° from the feedline **62.** The cup cavity **186** between flange **180** is potted with a potting compound such as, for example, an epoxy sealer sold under the trademark Devcon F–2 by Devcon Corporation to support the tuner **184** and feedline **62.**

Referring now to FIG. **6** in which there is shown another combination arrangement for a multichannel rotary joint **190.** In this arrangment three high frequency channels such as, for example, "S" band channels **192,** 194, and **196** are combined with two low frequency channels **198** and **200** such as, for example, "L" band channels. The "L" band channels are positioned between the "S" band channel inputs and outputs. The arrangment of FIG. **4,** that is, where the low frequency channels are positioned at the end of the high frequency channel would be an objectional arrangment for the combination of FIG. **6** as a substantial length (about 4 feet) of coaxial cable of the "L" band channels would have to pass through the length of the coaxial waveguide channels. Incorporating the length of the coaxial cable for the "L" bands through the center of the coaxial waveguide channels would make the "S" band coaxial tubes substantially difficult to work with while maintaining the desired TEM mode. To reduce the number of coaxial cables the two split coaxial ring joints for the "L" band channels are centrally positioned in housing **201** (FIG. **6**) with their output feedlines taken outside the 3 S-band channels.

The arrangment of the multichannel split coaxial rings in combination with multichannel choke type rotary joints (FIG. **6**) includes at the input end azimuth position indicators (APG) **202** which may be, for example, shaft encoders as sold by Litton Industries. The APG **202** are servo type instruments driven by a rod **204** (FIG. **7**) centrally disposed in drive tube **220** and connecting the drive shaft of the APG to the rotating antenna (not shown). The first "S" band channel **192** (FIG. **6**) has a coaxial cable connector (Type N) **208** which connects to a source (not shown) of RF energy at, for example, "S" band frequencies. The RF energy entering the connector is transmitted into the inner coaxial waveguide rotary joint via a right angle stub **210** surrounding the APG drive rod **204.** The rotary joint may be a choke type rotary joint such as that described in conjunction with FIG. **4.** The coaxial cable of the inner rotary joint has its inner conductor (FIG. **7**) formed by the APG drive rod **204,** and its outer conductor **212** held in spaced relationship about the inner conductor **204.**

The second "S" band channel **194** (FIG. **6**) has a rectangular waveguide flange **216** for connecting a rectangular waveguide feedline from a source of RF energy (not shown). The RF energy is fed from the flange **216** into a door knob type rotary joint **218** utilizing a "door knob" transition structure such as that disclosed by George L. Ragan, "Microwave Transmission Circuits," p. 454, McGraw-Hill Book Company, Inc. 1948. The rotary joint utilizes the outer conductor **212** of the channel **1** coaxial cable as its inner conductor and has an outer conductor **214** spaced therefrom (FIG. **7**).

The third "S" band channel **196** (FIG. **6**) has a rectangular waveguide flange **222** for connecting to a rectangular waveguide feedline from a source of RF energy (not shown). The rotary joint **224** utilizes a cross waveguide transition disclosed at p. 239 and 240 of Ragan's "Microwave Transmission Circuits" textbook cited above. The third coaxial waveguide channel utilizes the outer conductor **214** of the second rotating coaxial cable as its inner conductor and utiliizes the drive tube **220** as its outer conductor (FIG. **7**).

RF energy for channel **1** (FIG. **6**) passes through the coaxial connector **208** in the TEM mode through the right angle stub **210** and is conducted by the center rotating coaxial cable formed about drive rod **204** to the coaxial cable outlet connector **226** which is, for example, a type N connector. RF energy for channel **2** enters rectangular waveguide flange **216** in the TE_{10} mode and passes through the door knob type rotary joint **218** for transition from the TE_{10} mode to the TEM mode and is conducted by the second or middle rotating coaxial cable to rectangular waveguide takeout **227** where it is reconverted to the TE_{10} mode and conducted through output flange **228.** RF energy for channel **3** enters rectangular waveguide flange **222** in the TE_{10} mode and passes through a crossed waveguide transition **224** for conversion from the TE_{10} to the TEM mode for conduction by the third or outer rotating coaxial cable rectangular waveguide takeout **229** where the TEM mode is converted back to the TE_{10} mode and collected at rectangular waveguide flange **230.**

The two "L" band channels **198** and **200** pass through the center housing **231** to housing **201** in which is mounted the dual split coaxial ring rotary joint **232** (FIG. **7**). As the split coaxial ring rotary joint surrounds the three coaxial waveguide "S" band channels, the circumferences of the split coaxial rings **234** and **236** at "L" band, for example, are more than ¼λ; thus, more than one feedline (FIG. **1**) is required to feed each of the split coaxial rings. By feeding these large tuned split coaxial rings with suitable power dividers at 60 electrical degree intervals, a voltage standing wave ratio (VSWR) of less than 1.2 and a WOW (VSWR variation with joint rotation of less than 0.05 can be maintained. The rotary joint input feed lines **198** and **200** feed RF energy to power dividers **240** and **242** (FIG. **7**) (hereinafter described) through connections **244** and **246,** and through a plurality of feedlines **252** (hereinafter described) to the stator halves **248** and **250** of split coaxial rings **234** and **236.** The RF energy is collected from halves of the split coaxial rings **234** and **236** formed in rotors **254** and **256** through a corresponding plurality of power output leads **257,** which are identical in construction to the input feedlines **252.** The feedlines **257** feed the RF energy to summing networks **258** and **260.** Summing networks **258** and **260** are identical in construction to power dividers **240** and **242.** Connectors **262** and **264,** which are identical in construction to connectors **244** and **246,** connect the RF energy output to the output coaxial feedlines **266** and **268.**

The stator halves **248** and **250** of the split coaxial rings **234** and **236** are formed in flanged annular rings **270** and **272.** A duplex pair of bearings **280** is seated in recesses of the inner edges of the flanges and the bearings rotatably support flanged rotors **254** and **256.** The flange of stator **270** is provided with a plurality of threaded passages **274** in its depending edge which mate with passages **276** in stator **272** through which screws **278** are passed to join the stators **270** and **272** together and to hold the bearings **280.** The rotor halves **282** and **284** of the split coaxial rings **234** and **236** are formed in rotors **254** and **256.** The rotors **254** and **256** have flanges with outer recesses adjacent the ends of

the flange to support races of the bearings **280.** The rotors **254** and **256** are held together by a plurality of screws **288.** The arrangment of the bearings **280** and the stator and rotor screws **278** and **288** maintain a gap between the rotor and stator halves of the split coaxial rings **234** and **236** at about, for example, 0.005 inch.

The split coaxial rings **234** and **236** each have split inner conductors **290–291,** which may be, for example, an aluminum ring split in half along the plane of the ring, and two tuners **289** (FIG. **10**) positioned 180° apart and midway between adjacent feedpoints in either the rotors or stators. The halves of the inner conductor (FIG. **7**) are concentrically positioned within the outer conductors **292–293** so that their axes are common to those of the outer conductors and each half is supported therein by the feedlines **252.** As the tuners **289** (FIG. **10**) are identical only one is described. Each tuner **289** is, for example, a metal rod or tube mounted in the split coaxial ring to d.c. short the inner and outer conductors **291** and **292** of the coaxial rings.

The split coaxial rings **234** and **236,** as previously mentioned, have a plurality of input feedlines and collector lines **252** (FIGS. **1, 7** and **9**) spaced 60 electrical degrees one from the other. As each input feedline and collector line is identical in construction only one is described. Each input feedline or output feedline (FIG. **9**) includes an insulated feed pin **294** having one end **295** connected to a half of the split inner conductor **291,** its insulated body passing from the inner conductor **291** through stator **270** or **272** or a rotor **282** or **284** as the case may be to a takeoff **296** of the power divider **240** for the feedline or the summer for the collector output line. The power dividers **240** and **242** (FIGS. **7** and **11**) and summing networks **258** and **260** are identical in construction, thus, only the power divider **240** is described in detail. The power divider, for example, is a six-way stripline power divider having a conductor pattern **298** (FIG. **11**) for producing equal amplitude and equal phase outputs. The pattern is formed on the dielectric **300** (FIG. **7**). A patternless printed circuit board **302** is positioned to form a dielectric over the patterned board **298;** and an aluminum plate **304,** which is secured to the stator **270** by screws **306,** forms an upper ground plane for the power divider. The upper surface of the stator **270** forms a lower ground plane.

RF energy at frequencies below 3 GHz is fed the power dividers **240** and **242** and taken from the summing networks **258** and **260** through right angle launch mechanisms **244, 246** and **262, 264.** As each launch mechanism is identical in construction only one is described. The launch mechanism **244** (FIG. **8**) comprises an energy launch member **308,** a dielectric insert **310,** and center contact **312.** The launch member **308** has one end connected to the outer conductor of the coaxial feed cable **200,** a body portion which passes through the ground plane **304,** and another end forming an outwardly extending flange to secure the launch member to the ground plane **304.** The dielectric insert **310** separates the launch member **308** from the center contact **312.** The center contact **312** is the inner conductor of the coaxial feedline or an extension thereof which is in contact with the input point **314** (FIG. **11**) of the conductor pattern **298.**

In operation of the two split ring rotary joint channels, RF energy at, for example, "L" band frequencies is fed through the coaxial feedlines **200** and **198** (FIG. **7**) to connectors **244** and **246** connecting the feed lines to the power dividers **240** and **242.** The conductor pattern **298** (FIG. **11**) of each power divider divides the RF energy equally amongst six feed lines **252** (FIG. **7**), which feed the RF energy to the stator halves of the split coaxial rings **234** and **236** at six different points spaced 60 electrical degrees apart. Tuners **289** (FIG. **10**) tune the VSWR and WOW of the coaxial rings **234** and **236,** and this tuned RF energy is collected from the rotor halves by six collector lines **257** corresponding to the feed lines **252** (FIG. **7**) The collector lines **257** couple the RF energy to the summing networks **258** and **260,** which are identical in construction to the power divider **240** (FIG. **11**). Coaxial type output feed lines **266** and **268** are coupled to the summing network output points for conducting the collected RF energy to output terminals.

From the summing network, the output feed lines **266** and **268** exit housing **201** (FIG. **6**) adjacent the drive tube **206** and terminate at connectors **315** and **316** coupled to a support plate **318** (FIG. **6**).

A slip ring arrangement for coupling electrical current to ancillary equipment is provided the rotary joint **190** through receptacle **320** (FIG. **6**) mounted in housing **231.** The housing **231** supports brushings **324** for a plurality of annularly shaped slip rings **326** which include conductors mounted on the faces of an insulated support ring. The slip rings **326** are mounted for rotation with the drive member **206.** Leads **328** from the slip rings pass along the drive member **206** through the housing **201** and exit housing **201** in passages **329** formed in rotating member **330** of the housing **201.** The slip ring leads terminate in plug **332** mounted in support member **318.**

Although preferred embodiments of the present invention have been described in detail, it is to be understood that various changes, substitutions, and alterations can be made therein and more specifically any number of split coaxial rings may be joined for the rotary joint without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

1. A rotary joint for supplying RF energy through a system having a stationary member and a rotating member comprising:

a. an RF energy input feed line means coupled to a source of RF energy;

b. a rotary joint means, said rotary joint means including a split coaxial, ring-shaped cable means having a stator half electrically coupled to the stationary member through the input feed line means, and a rotor half electrically coupled to the rotating member; and

c. an RF energy output collecting means operatively coupled to the rotor half for collecting the RF energy passing through the split coaxial, ring-shaped cable means.

2. A rotary joint for an RF transmission line comprising:

a. an RF energy coaxial feed line means coupled to an RF energy source, said coaxial feed line means having an outer conductor and an inner conductor;

b. a rotary joint means including an RF energy coaxial, ring-shaped line having its outer and inner conductors split to provide a stator portion and rotor portion, said outer and inner conductors of the stator portion connected, respectively, to the outer

and inner conductors of the RF energy input coaxial feed line; and

c. an RF energy coaxial, collector line means, said coaxial, collector line means having outer and inner conductors coupled, respectively, to the outer and inner conductors of the rotor portion of the split coaxial, ring- shaped line to collect the RF energy, said collector means including an output terminal for coupling the RF energy to a rotating member.

3. A rotary joint for an RF transmission line according to claim **2,** wherein said RF energy coaxial feed line means includes a power divider for selectively feeding RF energy to the stator half of the split coaxial ring.

4. A rotary joint for an RF transmission line according to claim **2,** wherein said split RF energy coaxial, ring shaped line includes an outer conductor means formed in a stator and an outer conductor means formed in a rotor, said outer conductor means supporting, respectively, first and second inner conductor means of the split coaxial ring means.

5. A rotary joint for an RF transmission line according to claim **2,** wherein said RF energy coaxial collector line means includes a summing network for collecting the RF energy output of the split RF energy coaxial, ring shaped line rotor half into a single RF energy output.

6. A rotary joint for an RF transmission line according to claim **2** wherein said RF energy coaxial, ring shaped collector line means comprises a first dielectric, a conductor pattern supported by said first dielectric, a second dielectric covering the conductor pattern, and a ground plane member covering the second dielectric, said ground plane, first and second dielectrics, and conductor pattern attached to a rotor member of the split coaxial ring, said rotor member acting as a second ground plane for the collector means, a plurality of coaxial feed lines coupled to the rotor half of the split coaxial ring for collecting RF energy for the conductor pattern of the collector means, and an RF energy output line coupled to the output terminal of the conductor pattern for providing a combined RF energy output.

7. A rotary joint for an RF transmission line according to claim **3** wherein said power divider is a strip line having a conductive pattern for dividing an input of RF energy into a plurality of RF energy outputs to a corresponding plurality of feed lines, said plurality of feed lines coupled to the split coaxial ring for feeding RF energy at selected electrical degree intervals to the split coaxial ring.

8. A rotary joint for an RF transmission line according to claim **3** wherein said power divider comprises a first dielectric, a conductor pattern supported by said first dielectric, a second dielectric covering the conductor pattern, and a ground plane member covering the second dielectric, said ground plane member, first and second dielectrics, and conductor pattern attached to a stator member of the split coaxial ring, said stator member acting as a second ground plane for the power divider, an RF energy feed line operatively coupled to the conductor pattern for supplying the RF energy to the power divider, and a plurality of coaxial feed lines coupled to a corresponding plurality of output terminals of the conductor pattern for coupling RF energy to the stator half of the split coaxial ring.

9. A rotary joint for an RF transmission line according to claim **4** wherein said split RF energy coaxial, ring shaped line comprises an outer conductor ring, a tuner means and an inner conductor ring, said outer and inner conductor rings having a common axis and split in half along the plane of the ring to form a stator half for receiving RF energy from a stationary member, and a rotor half for transferring RF energy from the split coaxial ring for a rotating member, and said tuner means operatively coupled to the split coaxial ring for tuning the RF energy to a desired frequency band.

10. A rotary joint for an RF transmission line according to claim **9,** wherein said inner conductor halves of the split, ring shaped coaxial line are supported concentrically within the outer conductors by a plurality of nonconductive pins.

11. A rotary joint for an RF transmission line according to claim **9,** wherein said inner conductive halves of the split, ring shaped coaxial line are supported by the feed lines.

12. A rotary joint for an RF transmission line according to claim **9,** wherein said inner conductor of the stator half is supporte in spaced relationship to the outer conductor of the split coaxial ring, said outer conductor formed in a cylindrically cup shaped stator member, and said inner conductor of the rotor half of the split coaxial ring supported in spaced relationship to the outer conductor of a cup shaped cylindrical rotor member, said rotor member rotatably supported by the stator member with the stator and rotor halves of the split coaxial ring aligned to form the split, ring shaped coaxial line.

13. A rotary joint according to claim **12** wherein said multichannel rotary joint means comprising a plurality of split, ring shaped coaxial line rotary joints further comprises a plurality of coaxial waveguide rotary joints having spaced input and output terminals, said plurality of coaxial waveguide rotary joints having concentric inner conductors, the inner conductor of each successive coaxial cable forming the outer conductor of each preceding coaxial cable, and said inner and outer conductors coupled together to form a rotating drive member for the rotors of the plurality of split, ring shaped coaxial line rotary joints, said plurality of split, ring shaped coaxial line rotary joints mounted concentrically about the coaxial waveguide rotary joints intermediate their input and output terminals, and having their rotors attached to the rotating drive member for rotation therewith.

14. A rotary joint for an RF transmission line comprising:

a. an RF energy feed line means coupled to an RF energy source;

b. a rotary joint means including a split coaxial cable means having a ring shape and including a stator portion, a rotor portion, and a tuning system, said stator portion operatively connected to the RF energy feed line means for receiving RF energy into the split coaxial cable means having a ring shape, said tuning system having a post for tuning the RF energy in the split coaxial cable means having a ring shape to a desired frequency band, and said rotor portion coupled in rotatable association with said stator portion for coupling the RF energy to a collector means; and

c. a collector means having output feed line means coupled to the rotor portion of the split coaxial cable means having a ring shape to collect the RF energy, said collector means including an output

terminal for coupling the RF energy to a rotating member.

15. A rotary joint for a multichannel transmission line comprising:

a. an RF energy feed line means coupled to RF energy sources:

b. a multichannel rotary joint means, said multichannel rotary joint comprising a plurality of tuned split, ring shaped coaxial lines forming a plurality of stator halves and a corresponding plurality of rotor halves, said plurality of rotor halves mechanically connected one to another and each of said plurality of rotors electrically coupled to a collector means, and said plurality of stator halves mechanically connected one to another and each of said plurality of stators electrically coupled to the RF energy feed line means and rotatably supporting the rotor halves with the split, ring shaped coaxial line halves of the rotors and stators forming a plurality of split, ring shaped coaxial lines for a corresponding plurality of RF energy channels; and

c. collector means for collecting RF energy from the rotor halves of the split, ring shaped coaxial lines of the multichannels.

16. A rotary joint for a multichannel transmission line according to claim **15** wherein said multichannel rotary joint comprising a plurality of tuned split, ring shaped coaxial line rotary joints is mounted adjacent to a second rotary joint having one or more coaxial waveguide transfer means, said coaxial waveguide transfer means having a tubular inner conductor operatively connected to the rotors of the split, ring shaped coaxial lines for rotating the rotors and providing a passage for the rotor's output feed lines of the plurality of split coaxial ring rotary joints.

17. A rotary joint for an RF transmission line comprising:

a. an RF energy feed line means coupled to an RF energy source;

b. a rotary joint means including a split coaxial ring having a stator half, and a rotor half, said stator half operatively connected to the RF energy feed line means for receiving RF energy into the split coaxial ring means, and said rotor half coupled in rotatable association with said stator half for coupling the RF energy to a collector means; and

c. a collector means having output feed line means coupled to the rotor half of the split coaxial ring to collect the RF energy, said collector means including an output terminal for coupling the RF energy to a rotating member, wherein said RF energy collector means comprises: a first dielectric, a conductor pattern supported by said first dielectric, a second dielectric covering the conductor pattern, and a ground plane member covering the second dielectric, said ground plane, first and second dielectrics, and conductor pattern attached to a rotor member of the split coaxial ring, said rotor member acting as a second ground plane for the collector means, a plurality of coaxial feed lines coupled to the rotor half of the split coaxial ring for collecting RF energy for the conductor pattern of the collector means, and an RF energy output line coupled to the output terminal of the conductor pattern for providing a combined RF energy output.

18. A rotary joint for an RF transmission line comprising:

a. an RF energy feed line means coupled to an RF energy source, wherein said RF energy feed line means includes a power divider for selectively feeding RF energy to the stator half of the split coaxial ring, wherein said power divider is a strip line having a conductive pattern for dividing an input of RF energy into a plurality of RF energy outputs to a corresponding plurality of feed lines, said plurality of feed lines coupled to the split coaxial ring for feeding RF energy at selected electrical degree intervals to the split coaxial ring;

b. a rotary joint means including a split coaxial ring having a stator half; and a rotor half, said stator half operatively connected to the RF energy feed line means for receiving RF energy into the split coaxial ring means, and said rotor half coupled in rotatable association with said stator half for coupling the RF energy to a collector means; and

c. a collector means having output feed line means coupled to the rotor half of the split coaxial ring to collect the RF energy, said collector means including an output terminal for coupling the RF energy to a rotating member.

19. A rotary joint for an RF transmission line comprising:

a. an RF energy feed line means coupled to an RF energy source wherein said RF energy feed line means includes a power divider for selectively feeding RF energy to the stator half of the split coaxial ring, wherein said power divider comprises a first dielectric, a conductor pattern supported by said first dielectric, a second dielectric covering the conductor pattern, and a ground plane member covering the second dielectric, said ground plane member, first and second dielectrics, and conductor pattern attached to a stator member of the split coaxial ring, said stator member acting as a second ground plane for the power divider, an RF energy feed line operatively coupled to the conductor pattern for supplying the RF energy to the power divider, and a plurality of coaxial feed lines coupled to a corresponding plurality of output terminals of the conductor pattern for coupling RF energy to the stator half of the split coaxial ring;

b. a rotary joint means including a split coaxial ring having a stator half, and a rotor half, said stator half operatively connected to the RF energy feed line means for receiving RF energy into the split coaxial ring means, and said rotor half coupled in rotatable association with said stator half for coupling the RF energy to a collector means; and

c. a collector means having output feed line means coupled to the rotor half of the split coaxial ring to collect the RF energy, said collector means including an output terminal for coupling the RF energy to a rotating member.

20. A rotary joint for an RF transmission line comprising:

a. an RF energy feed line means coupled to an RF energy source,

b. a rotary joint means including a split coaxial ring wherein said split coaxial ring includes an outer conductor means formed in a stator and an outer conductor means formed in a rotor, said outer conductor means supporting, respectively, first and second inner conductor means of the split coaxial ring means, wherein said split coaxial ring com-

prises an outer conductor ring, and an inner conductor ring, said outer and inner conductor rings having a common axis and split in half along the plane of the ring to form a stator half for receiving RF energy from a stationary member, and a rotor half for transferring RF energy from the split coaxial ring for a rotating member, and said tuner means operatively coupled to the split coaxial ring for tuning the RF energy to a desired frequency band, wherein said inner conductor of the stator half is supported in spaced relationship to the outer conductor of the split coaxial ring, said outer conductor formed in a cylindrically cup shaped stator member, and said inner conductor of the rotor half of the split coaxial ring supported in spaced relationship to the outer conductor of a cup shaped cylindrical rotor member, said rotor member rotatably supported by the stator member with the stator and rotor halves of the split coaxial ring aligned to form the split coaxial ring; and

c. a collector means having output feed line means coupled to the rotor half of the split coaxial ring to collect the RF energy, said collector means including an output terminal for coupling the RF energy to a rotating member.

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