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COAXIAL ROTARY JOINT WITH SPRING BIASED SLIDING CONTACT RING

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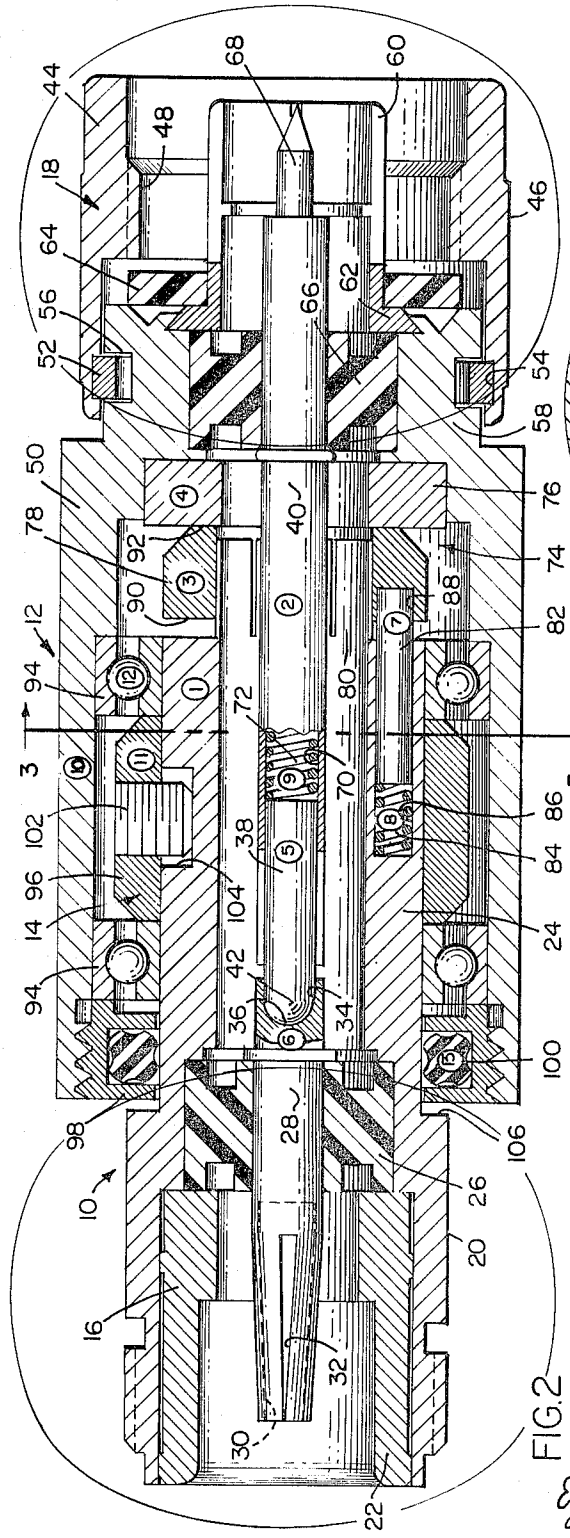


FIG. 2

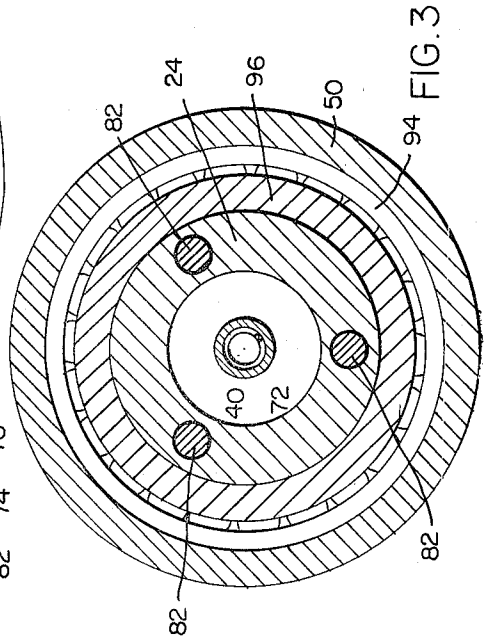


FIG. 3

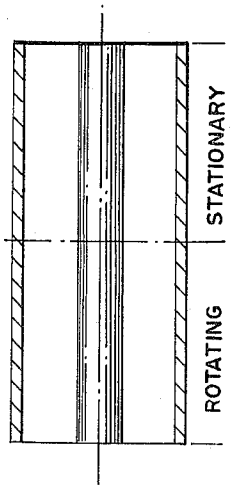


FIG. 1B

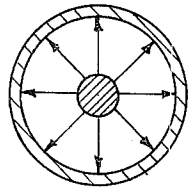


FIG. 1A

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COAXIAL ROTARY JOINT WITH SPRING BIASED SLIDING CONTACT RING

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This invention relates to a method of maintaining continuity between a fixed and rotating section in both a coaxial line operating in the dominant TEM mode and circular waveguide operating in the TMO1 mode. The method of maintaining continuity is not dependent upon the impedance of the transmission lines selected. The method described here enables extremely broad band coverage. In a coaxial line the method described here operates efficiently depending upon the connectors or RF ports which are associated with the coaxial line. In circular waveguide the method may be applied to practically any frequency which the circular waveguide is capable of transmitting. This method may also be applied to any physical size of coaxial line or circular waveguide. This particular method has been employed in coaxial lines ranging in size from Type "N" line up through 3⅛" standard EIA coaxial line sizes. It has also been applied to circular waveguide up through 3¾" in diameter. This does not preclude its use in larger size transmission lines. This method of maintaining continuity in a coaxial line has also been appleid to multi-channel rotary joints, that is where each succeeding channel runs coaxially with the preceding channel.

The objectives of this invention may be state as follows:

(1) Maintain continuity in a coaxial transmission line and/or circular waveguide transmission line between a fixed and stationary section while operating over a broad frequency range.

(2) Maintain continuity in the said transmission line while rotating one section relative to another section in excess of 1,000 r.p.m. for prolonged periods with no deterioration in the mechanical structure (in excess of 5×10^6 revolutions).

(3) Maintain essentially no discontinuities in the transmission line (less than 1.02:1) over a broad frequency range while stationary or rotating from 0 r.p.m. through to in excess of 1,000 r.p.m. for prolonged periods with no deterioration in the VSWR (in excess of 5×10^6 revolutions).

(4) Maintain essentially 0 insertion loss in the transmission line over a broad frequency range while stationary or rotating in accordance with object #2.

(5) Maintain essentially 0 WOW: that is less than 0.02 change in insertion loss while rotating through 360° of mechanical rotation at rotational speeds from 0 through in excess of 1,000 r.p.m. for prolonged periods per object #2.

(6) Maintain a change in VSWR of less than 0.02 through 360° of mechanical rotation at rotational speeds from 0 through in excess of 1,000 r.p.m. for prolonged periods per object #2.

(7) Maintain a minimum change in phase length while rotating through 360° at rotational speeds from 0 through in excess of 1,000 r.p.m. for prolonged periods per object #2. By minimum phase shift it is meant typically less than 0.1 electrical degrees at 14,000 mc. This is representative of the phase shift characteristics with rotation for any given frequency range.

(8) Sustain average power in a coaxial line equal to the power rating of the coaxial line while operating at an inner conductor temperature as high as 102° C.

(9) Achieve these objects in single channel or multi-channel rotating joints for the transmission of RF energy. When used in multi-channel rotating joints, the isolation between channels may be maintained at a minimum of 50 db.

Numerous other features, objects and advantages of the invention will become apparent from the following specification when read in connection with the accompanying drawing in which:

FIGS. 1A and 1B show diametric and longitudinal sectional views of an ideal coaxial line rotary joint;

FIG. 2 shows a longitudinal sectional view of a single channel coaxial line rotary joint embodying the principles of the invention; and

FIG. 3 is a view through section 3—3 of FIG. 2.

With reference now to the drawing and more particularly FIG. 1 thereof, there is shown diametric and longitudinal sectional views of an ideal coaxial line rotary joint in which continuity is maintained between both inner and outer conductors. How the present invention nearly achieves this ideal condition will be better understood by considering an exemplary embodiment of the invention.

Referring to FIG. 2, there is shown a longitudinal sectional view of a single channel coaxial line rotating *r-f* joint according to the invention. The rotary joint consists basically of the coaxial line and the contacting junctions, the support members and the RF connectors. The RF connectors at either end of the rotary joint are encircled. These connectors may vary in size and shape depending on the coaxial line size and the requirements relating to frequency range and power. The basic parts of the contacting junctions as related to the coaxial line are as follows and identified in FIG. 2 by corresponding numbers encircled:

(1) Outer conductor.
(2) Inner conductor.
(3) Outer conductor contact A.
(4) Outer conductor contact B.
(5) Inner conductor contact A.
(6) Inner conductor contact B.
(7) Outer conductor contact alignment pin.
(8) Outer conductor contact spring.
(9) Inner conductor contact spring.
(10) Outer support housing.
(11) Bearing spacer.
(12) Bearings.
(13) Bearing retainer and seal.

The relationship and function of these parts will first be described somewhat generally. The outer conductor **1** and the inner conductor **2** are selected dimensionally to satisfy the coaxial line impedance for the application as required. The outer conductor **1** is so constructed as to contain at one end a series of spring fingers which are incorporated as an integral part of the outer conductor. The spring fingers are shown at the inner diameter of the outer conductor contact **3**. The thickness of the spring fingers is held to a minimum to assure that the coaxial line impedance will not be affected by the difference in diameters from the originally selected diameter. The outer conductor contact **3** fits over the spring fingers. The spring fingers are preformed so that when the outer conductor contact is placed over them, intimate contact is maintained at all times between the outer conductor and the outer conductor contact. The outer conductor contact **3** contact A makes contact with the outer conductor **4** contact B through the pressure exerted by a series of three springs and alignment pins **7** and **8**. The alignment pins fit into the outer conductor contact **3** and into the outer conductor **1** to restrain the outer conductor contact 3A from rotating relative to the outer conductor

1. The outer conductor contact springs assure a positive contact at all times between the outer conductor contact A3 and the outer conductor contact B. The center conductor 2 is fabricated to provide a hole at one end forming a wall thickness between the outer diameter and the hole of approximately five thousandths of an inch. The end of the center conductor around the periphery of the hole is slotted to form spring fingers. The inner conductor contact A5 fits into the inner conductor spring fingers. The inner conductor spring 9 forces the inner conductor contact A5 against the inner conductor contact 6 at all times. The friction caused by the spring fingers formed at one end of center conductor 2 prevents the inner conductor contact A5 from rotating relative to the inner conductor 2. The inner conductor 2 is supported by the dielectric beads or stub supports or any other convenient means. The outer conductor contact B4 is pressed into the outer support housing 10 and becomes essentially an integral part of it. The inner conductor contact B is soldered to the connector center conductor which is straight knurled, then pressed into the support bead. The outer conductor 1 is supported by a series of ball bearings 12. The ball bearings in turn fit into the outer housing 10. The ball bearings are separated by the spacer 11 and held fast to the outer housing by the bearing retainer 13.

The arrangement as described here related to the ball bearings assures a pre-loading which eliminates all of the axial and radial play. It should be noted that discontinuities in the coaxial line due to the difference in diameters between the spring fingers, which are part of the outer conductor 1 and the outer conductor contact A, is minute relative to the actual diameter of the coaxial line parameters. Therefore, the discontinuities are held to a minimum. Likewise, the discontinuities are held to a minimum relative to the center conductor because of the minute difference in diameters between the outside diameter of the inner conductor contact A5 and the inner conductor outer diameter 2. It should also be noted that because of the unique arrangement incorporating the contact springs 8 and 9, the contact pairs are always in intimate contact, thereby assuring complete continuity at all times and the positive elimination of radial cracks which would preclude the VSWR and insertion loss measurements.

Turning now to a more detailed description, the embodiment of this invention shown in the drawings includes in its general organization an inner housing assembly 10*a* and an outer housing assembly 12*a* supported for relative rotation coaxially with respect to one another by bearing assembly 14. The inner housing assembly 10*a* includes a coaxial coupling 16 at its left end as viewed in FIG. 2, and the outer housing assembly 12*a* includes a coaxial coupling 18 at its opposite end.

The housing assemblies 10*a* and 12*a* by means of their respective couplings are adapted to be separably connected to adjacent ends of two sections of a coaxial line, and the inner and outer housings together form a rotary joint for the sections while connecting them together electrically. The coupling 16 which forms part of the inner housing assembly includes an externally threaded collar 20 lined with a sleeve 22. The sleeve is rigidly connected to and in electrically conducting relationship with the collar. The collar 20 is formed as an integral part of the cylindrical body 24 of the inner housing assembly 10*a* and together they define part of the outer conductor for the coaxial line through the joint.

An insulating bushing 26 in the body 24 at the inner end of the collar 20 supports the inner conductor 28 of the inner housing assembly 10*a* in coaxial relationship with the body 24. The conductor 28 has a recess 30 extending inwardly from its outer end within the collar 20, and the walls of the conductor about the recess are split or slotted as shown at 32 to enable the walls to be crimped about the inner conductor of a coaxial line inserted in the recess.

The inner end of the conductor 28 has a shallow recess 34 provided with a spherical surface 36 at its inner end, and the recess 34 receives the contact 38 of the inner conductor 40 forming part of the outer housing assembly 12. The outer end 42 of the contact 38 is provided with a spherical tip of the same radius as the spherical surface 36 in the recess 34, and the two surfaces are in intimate contact with one another throughout their entire area. It will be apparent from the description below that the intimate engagement between the contact 38 and the recess 34 is not disturbed by relative rotation of the inner and outer housing assemblies.

The coaxial coupling 18 at the exposed end of the outer housing assembly 12*a* includes a collar 44 which may for convenience have an outer knurled surface 46, and the collar 44 is internally threaded as suggested at 48. The collar 44 is rotatably joined to the cylindrical body 50 of the outer housing assembly by a ring 52 positioned in a circular recess 54 on the inner surface of the collar and in a track 56 in boss 58 surrounded by the collar and formed as an integral part of the body 50. The rotatably supported collar 44 surrounds an inner sleeve 60 having an outwardly extending flange 62 at its inner end anchored in the end of the boss 58. An insulating ring 64 surrounds the inner end of the sleeve 60 adjacent the flange 62, and an insulating bushing 66 within the boss 58 supports inner conductor 40 coaxially with the sleeve 60. The bushing 66 electrically insulates the inner conductor 40 from the sleeve 60, and also cooperates with the ring 64 to retain the sleeve on the boss 58. While the sleeve 60 is insulated from the inner conductor 40 of the outer housing assembly 12, it is in electrical communication with the boss 58 which forms an integral part of the body 50 of the outer housing assembly and thus serves as the second part of the conducting path of the outer coaxial line through the joint.

The free end of the conductor 40 which forms part of the outer housing assembly 12*a* has a pin-type contact 68 adapted to electrically engage the inner conductor of a coaxial line connected to the coupling 18 of the outer housing assembly. It will be noted that the pin 68 could mate with a terminal identical to that at the free end of the inner conductor 28 forming part of the inner housing assembly. Similarly, the sleeve 60 forming the terminal of the outer conductor of the outer housing assembly could just fit within the sleeve 22 which lines the collar 20 of the coupling of the inner housing assembly. Thus, the coaxial rotary joint shown could be ganged with an identical rotary joint if for any reason this was desirable. It will of course be appreciated that the relationship of the couplings suggests that each is adapted to be connected to a coaxial line having a mating coupling part on its end identical to the other coupling of the joint.

The inner conductor 40 of the outer housing assembly is provided at its inner end with a recess 70 which slidably carries the contact 38. A spring 72 in the recess behind the contact 38 acts in compression to urge the contact into firm electrical engagement with the mating recess 34 in the inner conductor 28 of the inner housing assembly. The recess 70 is designed to form a spring finger arrangement which clamps the contact 38 with sufficient force to prevent relative rotation between the two, yet allow the contact 38 to move axially.

While the inner conductors of the inner and outer housing assemblies are electrically joined by the contact 38 and its mating recess 34, the contact assembly 74 serves to electrically connect the bodies 24 and 50 of the inner and outer housing assemblies which comprise the outer coaxial line through the joint. The contact assembly 74 includes a ring contact 76 permanently seated on the shoulder at the inner end of the boss 58 of the body 50 of outer housing assembly 12. The contact 76 is securely fixed in place and is in good electrical contact with

the boss 50. A second ring contact 78 made of a highly conductive material such as silver impregnated carbon graphite is slidably mounted on the axially extending flange 80 of the body 24 of the inner housing assembly 10 so that it can move toward and away from the fixed ring contact 76. As is evident in FIGS. 2 and 3, the slidable ring contact 78 is urged toward the ring contact 76 by means of three independent actuators. Each actuator includes a dowel pin 82 and a spring 84 mounted in cylindrical recesses 86 extending axially in the body 24 of the housing and disposed radially beyond the flange 80. The pins 82 also extend into recesses 88 provided in the end face 90 of the ring contact 78 to lock the ring contact 78 in a fixed angular position with respect to the body 24. Because the pins 82 are disposed in cylindrical recesses in the body 24 and extend into the recesses 88 in the ring contact 78, the body and contact cannot turn angularly with respect to each other but rather are locked together and turn together under the influence of an angularly directed force. The springs 84 acting upon the inner ends of the pins 82 force the pins to the right as viewed in FIG. 2, which in turn urge the ring contact 78 against the end face 92 of the fixed ring contact 76.

As suggested above, the inner and outer housing assemblies 10*a* and 12*a* are separated by bearing assembly 14. The bearing assembly includes a pair of bearing races 94 separated by spacer 96. The bearing assembly is retained within the annular space between the inner and outer housings by the locking nut 98 having a recessed packing gland 100 which seals the space between the housings closed. It will be noted in FIG. 2 that the spacer 96 is retained in place against rotation with respect to the inner housing body 24 by set screw 102 which extends into a recess 104 in the outer surface of the body. The recess 104 is axially wider than the diameter of the set screw 102 so that limited movement in an axial direction is permitted the body 24 with respect to the bearing assembly and the outer housing body. Limited clearance also exists between the locking nut 98 and the shoulder 106 at the rear or inner end of the collar 20 of the coaxial coupling 16. Thus, by exerting pressure to the right as viewed in FIG. 2, the inner housing assembly 10*a* and its associated parts may be moved to the right, which will cause the springs 84 as well as the spring 72 to compress. This action will only serve to make more firm the electrical connection between the inner coaxial conductors 28 and 40 and the outer coaxial conductors as joined by the ring contacts 76 and 78. It is of course recognized that the ring contact 78 is in electrical contact with the body 24 of the inner housing assembly by virtue of its sliding engagement with the flange 80 and its constant engagement by the pins 82.

In use the coupling 16 is connected to one end of a coaxial line and the coupling 18 is connected to the end of the second coaxial line which is to be connected to the first by the rotary joint. As is evident from the foregoing description, the conductor 28 of the coupling 16 is connected to the inner conductor of the first coaxial line and the pin 68 of the coupling 18 is connected to the inner conductor of the second line. The outer conductor of the first line is placed in electrical contact with the sleeve 22 in the coupling 16, and the outer conductor of the other line is placed in electrical contact with the sleeve 60 of the coupling 18. When the lines are thus connected the joint serves to electrically connect their inner and outer conductors, and the two lines may be positioned in any relative angular position without disturbing the electrical connections. The inner housing 10*a* and the coaxial line connected to it may be rotated with respect to the outer housing assembly 12*a* and its coaxial line, and the conductor 28 and contact 38 will maintain the electrical connection between the inner conductors of the two lines while the ring contacts 76 and 78 will maintain the outer conductors in electrical engagement. The springs 72 and 84 assure continued electrical contact of the two lines so that the combined line is capable of carrying very appreciable loads.

The basic contact materials in pairs, as described, are silver impregnated carbon and coined silver. One contact is silver impregnated carbon and the mating contact is coined silver. The silver impregnated carbon used in the contacting surfaces consists of carbon graphite in solid form, the pores of which have been impregnated with molten silver. Its self-lubricating properties depend on the combined graphite and metallic nature of the structure. The material increases its strength rapidly, removes the heat generated at the contact surfaces and thereby materially reduces the wear. The best results are obtained when the silver impregnated carbon surfaces have been ground to a fine finish with a mating surface hardness of 30 to 50 Rockwell C with a finish of 4 micro inches. Aside from its excellent electrical properties this particular material is actually used as self-lubricating bearing material, thrust washers, friction discs and seals. It is particularly useful where lubricants cannot be used. The materials used here are also very well suited for outer space applications where the environment is essentially a complete vacuum. That is the material used in the contacts described here may be used in environments where the pressure is 10^{-8} millimeters of mercury with substantially no transformation of the basic characteristics of the material. The mechanical properties of the contact materials used are as follows:

(1) One contact is pure ½ hard coin silver.

(2) One contact is silver impregnated carbon with the following properties:

(a) Silver content	48% ±8.
(b) Max. temperature range	650° F.
(c) Coefficient of linear thermal expansion	2.5×10^{-8} in./in./° F.
(d) Coefficient friction running on well-polished mating surface	0.1.
(e) Tensile strength	Approx. 7000 p.s.i.
(f) Compressive strength	Approxi. 25,000 p.s.i.
(g) A.D. range	2.90±.4 gms./c.c.
(h) Average D.C. resistance at 20° C.	.00005 ohms/in.

It should also be realized that a number of other materials may be used for the contacting surfaces in construction of this type. Another material which has been used successfully is a Leach Garner #226.

A number of rotary joints of the type described have been in operation for many months. Numerous mechanical and electrical measurements confirm that the invention achieves the objectives set forth above. It is evident that those skilled in the art may now make numerous modifications of, departures from and uses of the specific embodiment described herein without departing from the inventive concepts. Consequently, the invention is to be construed as limited solely by the spirit and scope of the appended claims.

What is claimed is:

1. A coaxial rotary joint comprising

an inner housing having a coupling at one end,

an outer housing coaxial with and surrounding the inner housing and having a coupling at its end remote from the coupling of the inner housing,

bearings mounted on the inner housing and supporting the outer housing for rotation thereon,

a ring contact carried by the outer housing adjacent the other end of the inner housing,

a mating ring contact slidably carried on said other end of the inner housing,

a plurality of pins axially symmetrical on the inner housing and engaging the mating ring contact,

biasing means mounted on the inner housing and engaging the pins urging the pins to hold the mating ring contact against the outer ring contact for contact between opposed faces orthogonal to the axis of said coaxial rotary joint,

and a locking means carried on one of the housings and preventing the inner housing from being withdrawn from the outer housing.

2. A coaxial rotary joint comprising

inner and outer generally cylindrical coaxial housings,

a coupling connected to one end of one housing and the opposite end of the other housing,

a conductor having a recess provided therein and connected to the coupling of one of the housings and constituting the inner conductor for that housing,

a contact slidably mounted in the recess,

a fixed contact forming part of the inner conductor of the other housing and connected to its coupling,

a spring disposed in the sleeve behind the sliding contact urging the sliding contact into engagement with the fixed contact,

a fixed ring contact carried by one of the housings and electrically connected to its housing, said fixed ring contact being electrically insulated from the inner conductor of that housing,

an axially slidable ring contact carried by the other housing, said slidable ring contact being electrically insulated from the inner conductor of its housing,

spring biasing means carried by said other housing and engaging the axially slidable ring contact at a plurality of points urging that contact into electrical engagement with the fixed ring contact while maintaining said other housing and said axially slidable ring contact in relatively fixed angular relationship about the axis of said rotary joint for contact between opposed faces orthogonal to the axis of said coaxial rotary joint,

and means supporting the two housings for axial rotation with respect to each other.

3. A coaxial rotary joint as defined in claim 2 further characterized by,

the slidable contact and the axially slidable ring contact being carried by separate housings.

4. A coaxial contacting rotary joint comprising,

first and second inner conductors,

a first outer conductor coaxial about and stationary relative to said first inner conductor,

a second outer conductor coaxial about and stationary relative to said second inner conductor,

means for supporting said first inner conductor and said first outer conductor for relative angular movement about an axis common with said second inner conductor and said second outer conductor,

first and second annular conducting rings respectively connected to said first outer conductor and said second outer conductor,

means for supporting said first and second conducting rings for sliding contact along opposed annular contacting faces which faces are orthogonal to said axis,

and spring biasing means for both establishing electrical contact between one of said first and second conducting rings and a respective outer conductor at a plurality of points about said axis and for applying forces on said one ring in a direction generally parallel to said axis to maintain contact between said faces at all times and thereby establish a direct electrical connection between said first outer conductor and said second outer conductor while maintaining said respective outer conductor and said one ring in relatively fixed angular relationship about said axis.

5. A coaxial contacting rotary joint in accordance with claim 4 wherein said biasing means comprises,

at least three recesses formed in one of said outer conductors equidistant from and equiangular about said axis,

a conducting spring and a conducting pin in each of said recesses,

said conducting pins being between and in contact with said one conducting ring and a respective conducting spring for establishing electrical contact between said one outer conductor and said one conducting ring and applying generally axial forces to said one conducting ring to urge said one conducting ring against the other of said conducting rings.

6. A coaxial contacting rotary joint in accordance with claim 5 and further comprising a first inner conductor recess formed in one of said inner conductors,

an inner conducting spring and an inner conducting pin in said first inner conductor recess,

a second inner conductor recess formed in the other of said inner conductors,

said inner conducting pin being between and in contact with said inner conducting spring and the surface of said other inner conductor around said second inner conductor recess for establishing electrical contact between said first and second inner conductors.

7. A coaxial contacting rotary joint in accordance with claim 5 wherein one of said conducting rings is made of silver impregnated carbon and the other of said conducting rings is made of coined silver.

8. A coaxial contacting rotary joint in accordance with claim 6 wherein one of said conducting rings is made of silver impregnated carbon and the other of said conducting rings is made of coined silver,

one of said inner conducting pin and said surface is made of silver impregnated carbon and the other of said inner conducting pin and said surface is made of coined silver.

References Cited by the Examiner

UNITED STATES PATENTS

2,231,366	2/1941	Mehr	339—8
2,387,015	10/1945	Gilbertson	339—8
2,459,032	1/1949	Korth	339—8
2,520,945	9/1950	Marindin	333—97 X
2,545,939	3/1951	Brietenstein	174—21
2,634,358	4/1953	Duckstein	339—5
2,763,844	9/1956	Kruger	339—97

OTHER REFERENCES

Ragan, Microwave Transmission Circuits, McGraw-Hill Book Co., Inc., copyright 1948.

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Disclaimer

3,229,234.—*Ernest W. Lattanzi*, Melrose, Mass. COAXIAL ROTARY JOINT WITH SPRING BIASED SLIDING CONTACT RING. Patent dated Jan. 11, 1965. Disclaimer filed July 3, 1967, by the assignee, *Sage Laboratories, Inc.*

Hereby enters this disclaimer to the entire patent.

[*Official Gazette September 26, 1967.*]