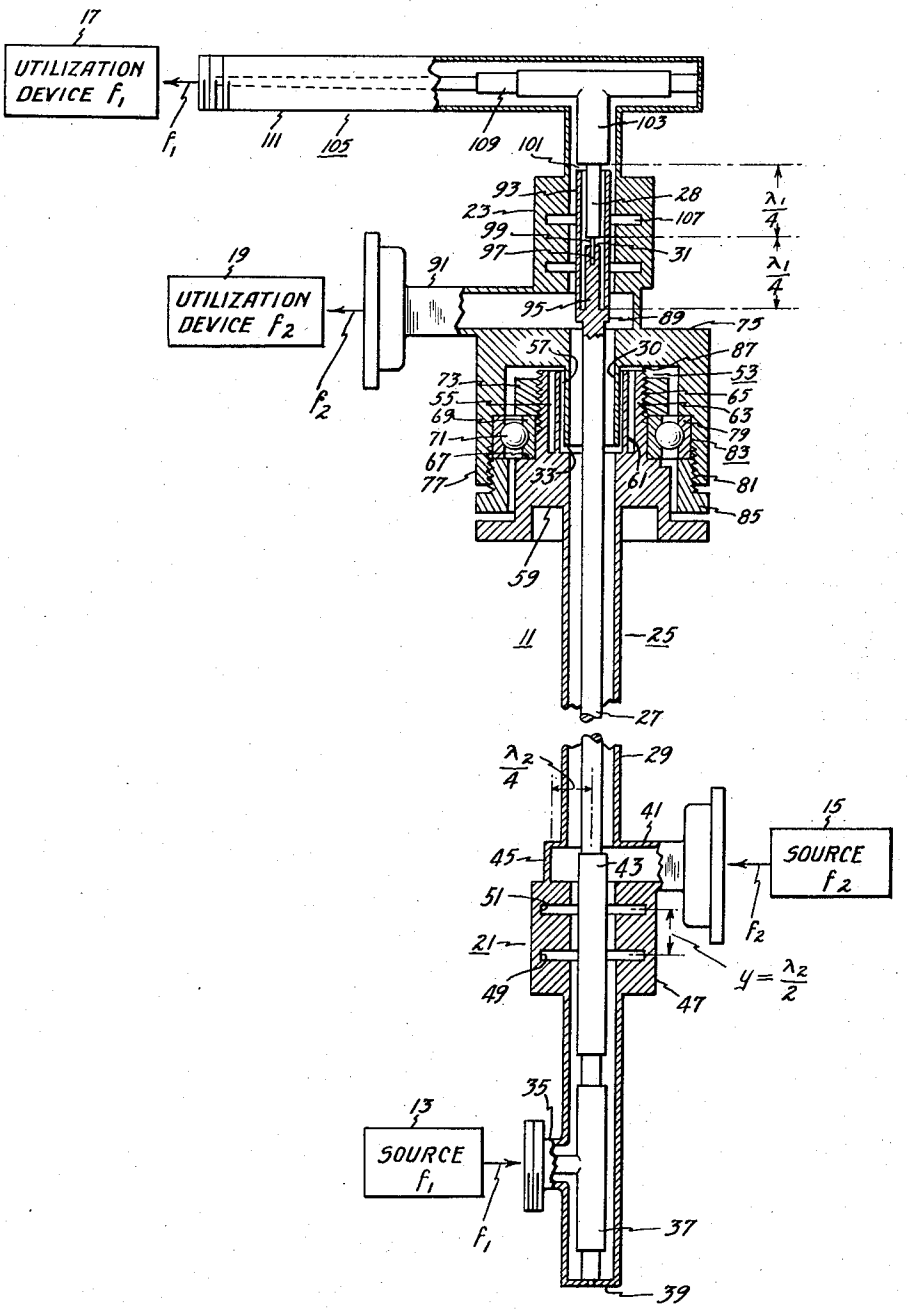
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DUAL FREQUENCY ROTATABLE JOINT

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DUAL FREQUENCY ROTATABLE JOINT

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The present invention relates to rotatable-joint structures for ultra-high-frequency wave energy and, more particularly, to such rotatable joints that are adapted for operation with waves of two different frequency values.

In a copending application of A. E. Smoll and D. L. Smith, Serial No. 287,128, now Patent No. 2,719,230 filed May 10, 1952, entitled "Dual Frequency Antenna," and assigned to the assignee of the present application, an ultra-high-frequency antenna is described and claimed, which is adapted to be operated with electromagnetic waves of two different ultra-high-frequency values having a frequency ratio of about 3:1. Such an antenna is suitable for and is therein disclosed in connection with a marine-navigation radar system. Accordingly, the antenna is ship-borne and mounted for continuous rotation about a predetermined axis and selectively operable at one or the other of the different frequencies according to the location of the ship on the open sea where operation at one frequency is advantageous, or in harbors and relatively narrow channels where operation at the other frequency is advantageous.

The rotatable joint of the present invention is especially well suited for transmitting waves of the widely differing frequencies between the rotatable antenna and the stationary transmitting and/or receiving apparatus of the radar referred to hereinabove. It will be understood, however, that other uses for the rotary joint of this invention will be apparent to those skilled in the art. Such uses can be found in multiple-receiver radar systems having separate antennas for the individual receiving systems, as for example, radar systems having associated interrogation equipment.

Heretofore, ultra-high-frequency rotary joints or couplings for multi-frequency operation have been proposed of which one known type employs a double-concentric line for isolation of the individual frequencies, while another uses cavity resonators at the opposite ends of a single coaxial line or waveguide to operate as filter elements for separating the individual frequencies. While the latter-mentioned type overcomes an inherent defect of the former type that resides in the fact that, for operation with more than two individual frequencies, the multiple coaxial construction is complicated and unwieldy, the cavity resonator type itself is relatively impractical because of the odd geometrical forms and shapes that the resonators must assume making it difficult to predict with certainty the operating mode. Also, since the power must traverse the resonators, the power-handling capacity is necessarily limited to avoid arcing and attendant loss of signal. Furthermore, the known types of rotary joints heretofore described are useful for operation with different frequencies where the individual frequencies lie within a relatively small band of frequency values, e. g., where the frequencies differ from each other only by as much as 10%.

An object of the invention is, therefore, to provide a novel and improved rotatable joint operable with electromagnetic waves of widely different frequency values, having a ratio of frequencies of the order of 3:1 or more.

Another object of the invention is the provision of an improved rotatable joint operable with waves of such widely different frequency values and which is so designed as to prevent waves of either frequency from being supplied from the source of one frequency to the source of the other frequency.

Another object of my invention is to provide a joint of the type mentioned having improved means to effect decoupling of the individual supply circuits, thereby to reduce dissipation of the energy.

Another object of the invention is the provision of an improved rotatable joint operable with waves of different frequency values and which is so designed as to prevent waves of either frequency from being supplied from a common source to the translation apparatus of the other frequency. More specifically, an object of my invention is to provide such a joint having means to effect decoupling of the two circuits connected to said joint for supplying to and receiving therefrom waves of ultra-high-frequency energy, thereby to reduce dissipation of the energy of either frequency in the circuit of the other frequency.

Briefly stated, in accordance to one aspect of my invention, the waves of one frequency are effectively isolated from the sources and/or the receivers of waves of the other frequency by means of a common coaxial-line transmission system having relatively rotatable parts capable of transmitting waves of both frequencies, to which system are connected a waveguide coupling for connecting the system to a source or receiver of one frequency and a coaxial coupling for connecting said system to a source or receiver of the other frequency, the couplings being spaced by transmission line filter sections adapted to pass one frequency and reject the other; the system further including an additional filter at the junction of the rotatable and stationary parts of the common coaxial system adapted to minimize radiation energy of either frequency through the junction.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, the single figure of which is a block diagram of a system incorporating novel features of the invention and including a longitudinal cross sectional view of a rotatable coupling arrangement constructed in accordance with the principles of my invention.

The drawing illustrates a rotatable coupling **11** that is capable of transmitting electromagnetic waves of two widely different frequency values between stationary sources **13** and **15** of wave energy frequencies f_1 and f_2, respectively, and respective relatively rotatable utilization devices **17** and **19** therefor. In one practical embodiment, the rotatable coupling of this invention, as noted hereinabove, and as described in the above-mentioned copending application, is employed in a marine-navigation radar in which the utilization devices **17** and **19** are in the form of a single antenna adapted to be energized by waves of the first frequency, f_1, which, for example, may be of the order of 3,000 megacycles per second, and also by waves of the second frequency, f_2, which may be of the order of 9,000 megacycles per second. For the purpose of this description, the use of the rotatable coupling in such a system will be taken as illustrative, it being clearly understood, however, that other uses are possible, as for example, in systems where the utilization devices **17** and **19** are separate antennas. It will be understood further, that although the invention is here described as applied to a transmitter unit, it can be used, with equal effect,

in connection with a receiver unit or with a transmit-receive unit, as desired.

As shown, the coupling **11** is comprised of relatively stationary and rotatable parts **21** and **23**, respectively, which are interconnected by a section of coaxial transmission line **25** of any suitable length and having coaxially disposed inner and outer conductive members **27** and **29**, respectively. The conductors **27** and **29** may be of circular cross section having respective diameters which are dimensioned to support the principal TEM mode for the frequencies f_1 and f_2.

The coaxial line **25** is divided, as by a pair of axially spaced junctions or gaps of which a first junction or gap **31** spaces the fixed inner conductor **27** from a relatively movable inner conductor **28**, and a second junction or gap **33** spaces the fixed outer conductor **29** from a relatively movable outer conductor **30**. It will be understood that the upper part **23** is capable of rotation relative to the lower part **21** by the operation of any suitable driving means (not shown) well known to those skilled in the art. The lower part **21** may be relatively fixedly supported by any suitable means (not shown). For reasons that will become more apparent as the description proceeds, the vertical spacing of the junctions **31** and **33**, is a singularly advantageous feature of the invention inasmuch as the usual problems associated with the design and construction of suitable filter elements are thereby minimized.

The stationary part **21** of the coaxial line **25** is preferably coupled to the source **13** of the wave energy of frequency f_1 by means of a stub-supported coaxial T-joint comprising a short section of coaxial line **35** that is coupled to the part **21** through a suitable opening in the outer conductor **29**. The required impedance match for the source **13** of the frequency f_1 may be provided by a conventional stub support **37** short-circuited at one end as by a conductive plate member **39** and having a suitable length, as measured from the junction of the T-joint to the shorting plate **39** that can be determined in accordance with well-known principles, to provide a desirable voltage-standing-wave ratio.

The coupling of the source **15** of the wave energy of the frequency f_2 is preferably effected by means of a section of rectangular waveguide **41**, which, as shown, is coupled to the coaxial line **25** by means of a conventional waveguide-to-coaxial transition. Such a transition commonly includes an enlarged-inner-conductor portion **43** extending transversely through the wave guide and a quarter-wavelength short-circuited section **45** of waveguide which cooperate in a well-known manner to improve the impedance match. The waveguide **41** is desirably dimensioned below cutoff for waves of the frequency f_1 while passing freely waves of the frequency f_2.

To isolate the source **13** from wave energy of the frequency f_2 originating at source **15**, I provide a filter section **47** between the T-joint **35** and the coaxial-to-waveguide transition **43, 45**. The filter **47** is designed to pass waves of the frequency f_1 and to reject waves of the frequency f_2, and to that end, it is formed of a pair of radial transmission lines **49** and **51** in the form of annular grooves each having a depth substantially equal to one quarter wavelength at the frequency f_2, the centers of the grooves being spaced a distance of about one-half wavelength at the same frequency. The distance from the groove **51** to the waveguide **41** is desirably adjusted in the assembling of the coupling so as to provide suitably matched impedances between the filter and the waveguide. Also, the width of the grooves **49, 51** is made sufficiently large to minimize the danger of electrical breakdown.

Filter sections of the type here described are well known and operate as band-rejection filters; the filter **47** tending to reject a band of frequencies peaked at the frequency f_2 and to pass other frequencies including the frequency f_1. It will thus be seen that wave energy at the frequency f_1, applied from source **13** to T-junction **35** traverses the filter **43** and is rejected by the waveguide **41**, which, as noted above, is dimensioned below cutoff for waves of frequency f_1. Accordingly, waves of frequency f_1 are propagated by the coaxial section **25** toward the junctions **31** and **33**, without loss to the source **15**. Also, wave energy at the frequency f_2 is coupled into the coaxial section **25** from the waveguide **41** and source **15**, and, being rejected by the filter **47**, is propagated toward the junctions **31** and **33** of coaxial section **25**, without loss to the source **13**.

At the junction **33** between the stationary and rotary parts of the joint **11**, I provide a filter **53** that is adapted to pass wave energy of both frequencies f_1 and f_2 axially across the junction gap **33** while minimizing the passage of energy of either frequency radially through the gap. As shown, the filter **53** is comprised of a tandem connection of a short-circuited quarter-wavelength transmission-line section **55** and an open-circuited quarter-wavelength transmission-line section **57**, the latter being folded back along the former to provide a compact non-contacting high-frequency short circuit at the peripherally extending gap defined by the adjacent ends of the outer conductors **29** and **30** of the coaxial transmission line **25**.

To form the transmission-line sections **55** and **57** of the filter **53**, the end of the outer conductor **29** adjacent the junction **33** is provided with a radially-extending flange member **59**, which carries on the upper edge thereof an inner sleeve **61** and a coaxially disposed outer sleeve **63**, each said sleeve being substantially one-quarter wavelength long at the frequency f_1, the sleeve **63** being externally threaded, as at **65**, over a portion of its length. The sleeve **61** extends in spaced parallel nesting relation to the rotatable outer conductor **30** and the sleeve **63** is so disposed on the upper edge of the flange **59** as to define therewith a peripherally extending shoulder **67** adapted to seat the inner, relatively stationary race **69** of a suitable conventional ball-bearing assembly **71**. The race **69** can be securely fastened in position as by an internally-threaded nut **73** in engagement with the threaded portion **65** of the sleeve **63**.

A radially extending flange **75**, formed on the rotatable outer conductor **30** and spaced from the gap **33** a distance substantially one-quarter wavelength at the frequency f_1, is provided at the periphery thereof with a downwardly projecting cup-shaped member **77** of which the inner surface is recessed as at **79** and threaded as at **81**. The surfaces of the recess **79** provide a shoulder on which the movable race **83** of the bearing assembly **71** is seated and secured as by an externally-threaded nut **85**. The nesting relation of the relatively stationary and rotatable parts is such that the inner surface of the flange **75** and the upper edge of the sleeves **61** and **63** are spaced to define a gap **87**.

It will thus be seen that the portion of the rotatable outer conductor **30** depending from the flange **75** and the sleeve **61** cooperate to provide the open-circuited quarter-wavelength transmission-line section **57**, and the sleeves **61** and **63** cooperate to define the short-circuited quarter-wavelength transmission-line section **55** connected in tandem to the section **57** through the gap **87**.

In accordance with the well-known transmission-line theory, and recalling that the frequency values f_1 and f_2 related in accordance with $f_2=3f_1$, so that the lengths of the sections **55** and **57** are three-quarters of a wavelength at the frequency f_2, a minimal impedance for wave energy of both frequencies f_1 and f_2 is presented at the gap **33**, the current across the gap being a maximum, while the impedance at the gap **87** is maximized for both frequencies. This desirable result makes possible relatively lossless transfer of energy of either or both frequencies from the stationary to the rotational parts of the outer conductor coupling.

As noted above, the rotating joint for the inner conductor **27** of the coaxial line is preferably axially spaced

from the rotating joint for the outer conductor **29**, thereby to overcome the problem of spacing relatively large numbers of machined parts in a relatively small space, which is encountered where the respective inner and outer rotating joints are located at the same vertical position. It will also be apparent from the following description that the inner conductor rotating joint beyond the output coupling to the utilization device **19**, the inner conductor rotating joint is called upon to operate only for one frequency, namely the frequency f_1.

To form the inner conductor rotating joint, the stationary inner conductor **27** is provided with an enlarged diameter portion **89** starting at a point within the output coupling to the utilization device, which, as will be explained hereinbelow, is preferably a below-cutoff waveguide section **91** adapted to transmit freely waves of frequency f_2 and to reject waves of frequency f_1.

The inner-conductor portion **89** is formed as an open-ended hollow cylinder **93** of a length substantially equal to one-half wavelength at the frequency f_1. A reentrant stub **95** is coaxially disposed within the cylinder **93** and projects upwardly for a distance slightly less than one-quarter wavelength at the frequency f_1. An axial well **97** is formed in the upper part of the stub **95** to receive a bearing pin **99** secured to the bottom end of the rotating inner conductor **28**. If desired or required, lubrication of the pin bearing may be had by coating the pin **99** with a suitable lubricant such as graphite powder.

The operation of the inner-conductor rotating joint assembly just described follows from well-known transmission-line theory. The sleeves **93** and the stub **95** and inner conductor **28** assembly cooperate to define a cascade connection of two quarter-wavelength sections of transmission line, one section being short-circuited by the closed end of the sleeve **93**, the other section being open-circuited. Since the bearing is at the junction **31** of the quarter-wavelength sections, an open circuit appears thereat, which open circuit is transformed by the upper quarter-wavelength section to a short circuit at the gap **101** between the open end of the sleeve **93** and the adjacent end of an enlarged-diameter extension **103** of the rotatable inner conductor **28**. It will thus be clear that energy at the frequency f_1 rejected by the waveguide **91** and traversing the coaxial portion extending thereabove is substantially completely passed through the coaxial output coupling **105** to the utilization device **17** with practically no loss of said energy through the bearing gap **31**.

To direct the energy of frequency f_2 to the utilization device **19** therefor, an output coupling is provided in the form of a waveguide **91** dimensioned below cutoff for frequency f_1 and a coaxial-to-waveguide transition generally similar to the corresponding elements described hereinabove in connection with the waveguide **41**. The transition and the waveguide **91** operate in the manner described above so that the energy of frequency f_2 is freely propagated through the waveguide **91**, energy of frequency f_1 being rejected thereby.

The energy of frequency f_1, rejected by the waveguide **91** is passed by a filter **107** of substantially the same type as described above in connection with the filter **47** on the stationary part **21**. The filter **107**, it will be understood, operates to reject wave energy of frequency f_2, and as a result of the operation of the below-cutoff waveguide **89** and the filter **93**, isolation of the utilization devices **17** and **19** with respect to the frequencies f_2 and f_1, respectively, is effected.

The output coupling **105** can be in the form of any suitable conventional coaxial-line section having a tapered inner-conductor **109** coaxially supported within a cylindrical outer conductor **111** for efficiently conducting the energy of frequency f_1 to the utilization device **17**.

An important advantage of my invention is that a single coaxial-line rotatable transmission joint can be employed to conduct waves of two or more widely different ultra-high-frequency values under relatively high-power conditions. Furthermore, the design of the filters is considerably simplified inasmuch as certain ones need be designed for operation with but one of the two different frequencies.

While I have shown and described certain preferred embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention. I therefore aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A rotatable coupling for a coaxial transmission line, comprising a stationary coaxial line section and a relatively rotatable coaxial line section, each having respective outer conductors and coaxially disposed inner conductors dimensioned to transmit ultra-high-frequency waves of two integrally related frequency values, adjacent ends of said outer conductors being supported in spaced relation to define an outer-conductor junction, adjacent ends of said inner conductors being supported in spaced relation to define an inner-conductor junction, said inner conductor junction being axially spaced from said outer-conductor junction, means connected to said stationary line section coupling thereto wave energy of said two frequency values, a first output coupling connected to said rotatable line section and disposed between said outer-conductor junction and said inner-conductor junction for waves of one said frequency value, a second output coupling connected to said rotatable line section at a point thereon opposite said inner-conductor junction relative to said outer-conductor junction, and filter means at each said junction adapted selectively to pass waves of predetermined ones of said frequency values and to minimize loss of said waves through said junctions.

2. An ultra-high-frequency wave transmission system comprising a first source of ultra-high-frequency wave energy having a predetermined frequency, a second source of ultra-high-frequency wave energy having a predetermined frequency harmonically related to the frequency of said first source, utilization means adapted for operation with wave energy of either of said frequencies, said utilization means being supported for rotary movement relative to said first and said second sources, and coaxial transmission-line means interconnecting said sources and said utilization means, said transmission-line means including rotary coupling means having unitary filter means associated therewith, said filter means comprising a coaxial transmission-line section an effective length corresponding to one-quarter wavelength at one said frequency and three-quarters wavelength at the other said frequency, whereby waves of both said frequencies are transmitted thereby with substantially no attenuation.

3. An ultra-high-frequency wave transmission system comprising a first source of ultra-high-frequency wave energy having a predetermined frequency, a second source of ultra-high-frequency wave energy having a predetermined frequency related to the frequency of said first source according to the ratio 3:1, utilization means adapted for operation with wave energy of both said frequencies, said utilization means being supported for rotary movement relative to said first and said second sources, and coaxial transmission-line means connecting said sources and said utilization means, said transmision-line means including rotary coupling means defining axially-spaced junctions between relatively rotatable inner and outer conductors, respectively, filter means associated with one said junction adapted to pass freely energy of both said frequencies and filter means associated with the other said junction adapted to pass waves of a predetermined one of said frequencies, and output coupling means connected to said transmission-line means to opposite sides of said last-named filter means for conducting

energy of respective ones of said frequencies to said utilization means.

4. A dual-channel high-frequency rotatable joint, comprising a transmission line section having relatively rotatable parts, axially-spaced means on one said part coupling energy sources of different frequency values to said transmission line, axially-spaced means on the other part coupling said transmission line to utilization means operable at said different frequencies, wave-filter means on each said part and positioned between the spaced coupling means thereon, said filter means being adapted to selectively pass only one of said frequencies, thereby effectively isolating the coupling means on each part with respect to the energy of said one of said frequencies, and additional filter means at the junction between said relatively movable parts, adapted to pass both said frequencies, thereby to minimize losses through said junction.

5. In multiple channel transmission apparatus, means defining a path for the transmission of wave energy, a first filter means obstructing the passage of wave energy at a first predetermined range of frequencies in a first region of said path, a second filter means obstructing the passage of wave energy at said first predetermined range of frequencies in a second region of said path spaced from said first region, first and second energy transfer devices connected with said path respectively on either side of the region embraced by said first and second filter means, and third and fourth energy transfer devices connected in energy exchanging relationship with said path within the region defined by said first and second filter means, said third and fourth energy transfer devices having the property of effectively transferring only wave energy characterized by a frequency exceeding a predetermined value, said predetermined value being less than that of the lowest frequency in said first predetermined range.

6. The combination according to claim 5, in which said path is defined by a pair of substantially coaxially disposed conductive members.

7. The combination according to claim 5, in which the members defining different portions of said path are relatively rotatable.

8. In a multiple channel device for transferring electromagnetic energy, means defining a path for the transmission of wave energy characterized by a first mode of energy propagation, a first filter means obstructing the passage of wave energy at a first predetermined range of frequencies disposed in a first region of said path, a second filter means obstructing the passage of wave energy at said first predetermined range of frequencies in a second region of said path spaced from said first region, first and second energy transfer devices connected with said path respectively on either side of the region embraced by said first and second filter means, and third and fourth mode transducing energy transfer devices connected in energy exchanging relationship with said path within the region defined by said first and second filter means, said mode transducing devices translating the propagation mode of wave energy between said first mode and a second mode characterized by a predetermined minimum propagation frequency, said minimum propagation frequency being less than the lowest frequency in said first predetermined range.

9. The combination according to claim 8 in which the members defining different portions of said path are relatively rotatable.

10. In multiple channel transmission apparatus, a transmission line comprising an inner conductor and an outer conductor embracing said inner conductor, first and second resonator chambers interposed in said outer conductor at spaced regions along the length of said line, said resonators presenting an impedance maximum at a predetermined frequency in the sheath constituted by said outer conductor, first and second transmission line to wave guide couplers whose low frequency cut-off is less than said predetermined frequency connected with said line at spaced points within the region defined by said resonator chambers, and third and fourth energy transfer devices connected with said transmission line respectively at regions outside the region bounded by said resonators.

11. The combination according to claim 10, in which said transmission line to wave guide couplers are rigidly attached to said outer conductor and are relatively rotatable about a common axis contained within said outer conductor.

12. The combination according to claim 10, in which said resonators are quarter wave resonant at said predetermined frequency.

13. In dual channel transmission apparatus, a transmission line comprising coaxially disposed jointed inner and outer conductors, a first pair of resonator chambers spaced by one-half wavelength on said transmission line at a predetermined frequency interposed in said outer conductor, a second pair of resonator chambers spaced by one-half wavelength on said transmission line at said predetermined frequency interposed in said outer conductor at a distance from said first pair, said resonator chambers being quarter wave resonant to wave energy at said predetermined frequency, first and second transmission line to wave guide couplers whose low frequency cut-off is less than said predetermined frequency connected with said line at spaced points within the region defined by said resonator chamber pairs, and means for making electrical connection with said transmission line at locations disposed on either side of the region bounded by said resonator chamber pairs, the sections of said line on either side of the joints being relatively rotatable about the axis of said line.

References Cited in the file of this patent

UNITED STATES PATENTS

1,934,602	Gilman	Nov. 7, 1933
2,128,400	Carter	Aug. 30, 1938
2,421,033	Mason	May 27, 1947
2,426,633	Mason	Sept. 2, 1947
2,434,509	Okress	Jan. 13, 1948
2,465,922	Peterson	Mar. 29, 1949
2,484,798	Bradley	Oct. 11, 1949
2,523,348	White et al.	Sept. 26, 1950
2,580,389	Anderson	Jan. 1, 1952
2,713,151	Farr	July 12, 1955