ABSTRACT: A microwave hybrid ring in modified coaxial line in which the inner conductor is the rim of a wheel mechanically fixedly mounted and electrically grounded at its geometrical center. The electrical grounding at the center may be at the design frequency through a choke.
MICROWAVE HYBRID WHEEL

BACKGROUND OF THE INVENTION

1. Field of the Invention
The present invention relates to circular microwave directional couplers and to the hybrid ring familiarly known as the "Rat Race." It is a further object of the invention to provide a hybrid ring in the form of a solid disk.

2. History of the Invention
The hybrid coupler is a four-terminal device in which a signal inserted at one terminal divides equally between two of the remaining terminals with essentially no reflection and no output at the fourth terminal. The conventional circular hybrid is the "hybrid ring" having an annular shape and a circumference of one and one-half wavelengths at the design frequency. Four terminals are usually connected to the ring spaced at one-fourth wavelength intervals about the circumference. Parameters of hybrid rings will be found in Microwave Engineering, Harvey, Academic Press, 1963, pp. 115-117. In all cases, a signal connected in at any one terminal will divide between terminals of the same characteristic impedance positioned at odd multiples of a quarter-wavelength away. There will be essentially no output at other terminals. While this is a very simple device, there are significant difficulties in assembly when the "ring" is the center conductor of a coaxial-type transmission line. The ring is conventionally connected inside a cavity, the walls of which provide the outer coaxial conductor. Preferably the ring is symmetrically located in the cavity with no contact other than to the terminals. Considering the small size of the rings, especially when charged to operate in the range of 5 gigahertz and above, connecting the ring for symmetrical support in the cavity is difficult. One common practice has been to add an outer ring concentric with the hybrid ring and fitting snugly into the cavity. Holes in the outer ring opposite the terminal connection points are insulated with polytetrafluorethylene insulators into which the transmission cables are secured. The central transmission leads extend to the hybrid ring where they are soldered or otherwise secured providing both electrical connection and support for the hybrid ring. The entire assembly can then be slipped into position in the cavity. It will be noted that the outer ring and insulators are additional parts required for assembly purposes only, and, if anything, deteriorate the performance. As the design frequency goes up the pieces become smaller and more difficult to handle. Symmetrical positioning in the cavity is next to impossible within any close tolerance and the stability against impact and vibration is poor. Overall, these various factors have made the conventional hybrid ring in coaxial line rather impractical at frequencies above 10 gigahertz.

SUMMARY OF THE INVENTION

In accordance with the present invention, the hybrid ring has been replaced with a wheel made either with spokes and hub or in the form of a solid disk. In either of these general embodiments, the wheel is anchored solidly at its center to the cavity wall. The center of a wheel, having a circumference of one and one-half wavelengths, is very nearly one-fourth wavelength from that circumference. A point of zero impedance one-fourth wavelength from the signal terminal looks like an insulator at the signal terminal as is well known. The central anchor point is extremely stable and by assembly even at frequencies extending above 10 gigahertz. The invention also provides for a further terminal connection at the center if desired. By using an insulating mounting the central point can be grounded through an RF choke such as a quarter wave section so as to permit a signal terminal connection at the central point which may be used for a different frequency.

This is an object of the invention to provide a novel hybrid ring directional coupler.

It is a further object of the invention to provide a hybrid ring in the form of a wheel having spokes and hub.

It is a further object of the invention to provide a hybrid ring in the form of a solid disk.

It is still a further object of the invention to provide a directional microwave coupler in the form of a circular element mounted at a central point of said element in a cavity. It is still a further object of the invention to provide a hybrid coupler in the form of a wheel adapted for central mounting and grounding.

Further objects and features of the invention will become apparent upon reading the following description taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a plan view of a prior art hybrid ring positioned in a cavity with cover removed.

FIG. 2 is a plan view in partial section of a circular coupler in the form of a spokeed wheel positioned in a cavity with cover removed.

FIG. 3 is a plan view in partial section of a circular coupler in the form of a solid disc positioned in a cavity with cover removed.

FIG. 4 is a cross section of elevation through 4-4 of FIG. 2 illustrating the mounting means for the wheel.

FIG. 5 is a cross section of elevation through 5-5 of FIG. 3 illustrating insulated mounting means for the wheel.

FIG. 6 is a diagrammatic illustration partly schematic showing the wheel of FIG. 3 connected as a balanced mixer.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 depicts the prior art hybrid ring. Ring 10 is an annular metal element having an outer circumference of one and one-half wavelengths at the design frequency. Ring 10 is suspended in a cavity 11 machined in block 12 which may be an aluminum block. RF cables 14, 15, 16, and 17 lie in grooves 18 in block 12. Outer ring 20 fits tightly against the wall 21 of cavity 11. Cables 14 through 17 are partially mechanically terminated by insulators 22 set in apertures 24 of outer ring 20. The signal lead of each of cables 14 through 17 extends through the respective insulators 24 to terminate at ring 10. The signal lead terminations are made at points on the circumference of ring 10 spaced at quarter-wavelength intervals. The terminations can be made by soldering the leads to ring 10 and the leads then support ring 10 in the cavity. A cover (not shown) is commonly secured to the top of the cavity 11.

Ring 20 and insulators 22 are required only for support purposes and can be omitted if ring 10 can be otherwise supported.

FIG. 2 depicts a ring 30 supported centrally by six shorted quarter-wave stubs 31. The center of a ring 1½ wavelengths in circumference is 0.239 wavelengths from the circumference. This is close enough to one-fourth wavelength to be operative, however for a given size ring the performance curves move up slightly in frequency relative to the ring of FIG. 1. The stubs 31 connect centrally to a hub 32 which provides a shorting termination by being screwed, pinned, clamped or otherwise directly metallically connected to block 12 at the center of cavity 11. Stubs 31, having the appearance of spokes of a wheel, are evenly positioned around ring 30 and ring 30 is positioned in cavity 11 so that four of stubs 31 line up with cables 14 through 17.

Central conductors 34 of cables 14, 15, 16 and 17 are depicted as soldered to rim 35 of ring 30. No special insulated supports are required as in FIG. 1 since conductors 34 carry no load. Instead of being directly soldered to rim 35, conductors 34 may be connected by an RF choke as will be described in relation to the embodiment of FIG. 3. RF choke coupling prevents direct current flow.

The embodiment of FIG. 3 uses solid disk 36 instead of a spokeed wheel. FIG. 3 further depicts the present hybrid wheel specifically arranged for use as a balanced mixer. In FIG. 3, cavity 11 containing disc 36 is machined in a rectangular...
block 37 which is suitably aluminum. Cables 15 and 17 have been replaced with microwave diodes 38 and 40 mounted in holes 41 and 42 respectively. Diodes 38 and 40 are held in position conventionally by springs 44 and 45 secured by threaded caps 46 and 47. The mounting grounds one electrode of each of diodes 38 and 40 while the other electrode of each diode 38 and 40 bears against rim 48 of disc 36 making electrical connection therewith. The other two terminal connections for Fig. 3 are by two coaxial connectors 50 and 51 mounted to block 37. Center conductors 52 and 54 are connected to the central terminals of connectors 50 and 51 respectively and extend through channels 55 and 56 in block 37 to quarter wave choke couplings 57 and 58 in disc 36. Center conductors 52 and 54 are centrally supported in channels 55 and 56 by insulators 60 and 61. By drilling cylindrical channels 62 and 64 in disc 36, conductors 52 and 54 can be extended nearly to the center of disc 36 and surrounded with dielectric so as to form quarter wave section choke couplings. Disc 36 is mounted at hub 65 as will be described with respect to Fig. 5.

An exemplary mounting of wheel 30 is depicted in cross section by Fig. 4. In Fig. 4, wheel 30 is mounted centrally in cavity 11 by machine screw 70 entering cavity 11 through an aperture in block 12. Screw 70 is threaded into hub 32 securing wheel 30 to the bottom of cavity 11. Cap 71 closes cavity 11 and is held in place by second machine screw 72 threaded into the top of hub 32. The relative dimensions of disc 30 and the spacings of the cavity walls has been ignored in the drawing. Example dimensions will be given hereinafter.

Fig. 5 is a cross section through 5—5 of Fig. 3. In Fig. 5, hub 65 of disk 36 has central pins 75 and 76 extending into bottom 77 of block 37 and into cover 78 of cavity 11 respectively. Insulators 80 and 81 fitted into bottom 77 and cover 78 respectively have central channels for receiving pins 75 and 76. Insulators 80 and 81 and pins 75 and 76 are dimensioned to function as quarter wave section RF chokes. Pin 76 is exposed at its outer end to permit electrical connection. It could equally be pin 75 exposed for electrical connection.

The quarter wave sections operate as an RF ground at hub 65 for the design frequency of the coupler. The output connection at pin 76 is useful for a difference frequency “if” output when the input terminals provide a local oscillator (L.O.) input and an incoming signal both within the design frequency spectrum of the coupler. Where there is no interest in a connection for a frequency outside the design spectrum of the coupler, direct metallic connection can be made as in Fig. 4.

Diode 40 in Fig. 5 is not shown in section since the internal details of the diode have no significance to the invention. Fig. 6 shows in schematic and block diagram form, the electrical connections for use of the coupler of Fig. 3 as a balanced mixer. For ease of comparison, the same drawing item numbers as in Fig. 3 are used in Fig. 6. Thus rim 48 is shown as rim 48 in Fig. 6 and one-fourth wave RF choke couplings 57 and 58 are depicted by center conductors 52 and 54 extending through rim 48 without direct connection. Diodes 38 and 40 have cathode and anode respectively connected to rim 48. Signal source 85 and L.O. 86 are connected into the coupler at terminals positioned at 0° and 120° mechanically about rim 48. Diodes 38 and 40 are positioned at 60° and 180° mechanically about rim 48. These positions can be rearranged remembering that the signal source and L.O. must terminate 120° mechanically about rim 48 (one-half wavelength) from each other. The “if” signal is connected out at hub 65 to amplifier 87. Series choke 88 and shunt capacitor 90 block other frequencies from amplifier 87.

Following are specific examples of embodiments which have been tested.

An example in accordance with Prior Art Fig. 1 under the same conditions is given as a “control.” In each example the terminals are designated A, B, C, and D positioned at 0°, 60°, 120°, and 180° respectively. In each case signal input is at A and each terminal is terminated with its characteristic impedance.

Directivity (power out at D minus power out at C) exceeds 20 db. from 4.78 to 6.02 gigahertz. Peak of 30 db. at 5.5 gigahertz. Balance (power out at D—out at B) less than 1 db. from 4.78 to 6.02 gigahertz.

Example II

Directivity (D—C) exceeds 20 db. from 5.72 to 6.92 gigahertz. Peak of 34 db. at 6.4 gigahertz. Balance (D—B) less than 0.9 db. from 5.72 to 6.92 gigahertz.

Example III

Directivity (D—C) exceeds 20 db. from 5.1 to 6.02 gigahertz. Peak of 39 db. at 5.6 gigahertz. Balance (D—B) less than 0.7 db. from 5.1 to 6.02 gigahertz.

Example IV

Directivity (D—C) exceeds 20 db. from 6.0 to 7.2 gigahertz. Directivity peak 35 db. at 6.6 gigahertz. Balance (D—B) less than 0.65 db. from 6.0 to 7.2 gigahertz.

While the invention has been described with respect to specific embodiments, obvious variations are contemplated as within the invention. Capacitive buttons can be added to the wheel for better matching or to shift the spectrum slightly. Cavity 11 is depicted as an airspace but other dielectrics can be used and the wheel or disk can be embedded in a solid dielectric.

Accordingly it is intended to claim the invention broadly within the spirit and scope of the appended claims.

1 claim:
1. A hybrid ring directional coupler in modified coaxial line comprising:
   a. A metal housing structure containing a cylindrical cavity and forming the walls thereof;
   b. a circular conductive element positioned concentrically in said cavity having a rim substantially one and one-half wavelengths long at the design frequency of said coupler, said rim acting as the center conductor of said line;
   c. means to mount said element to said housing at the geometrical center of said element providing both mechanical and electrical connection;
   d. four coaxial terminal connections mounted in said housing with their center terminal leads electrically connected to said rim at 60° intervals around said rim and their outer conductors electrically continuous with said walls whereby said geometrical center is approximately one-fourth wavelength from each terminal connection at said rim and appears as an electrical insulator at said each terminal connection.

2. A hybrid ring according to claim 1 wherein said element is in the form of a fixed wheel having a rim, spokes positioned at 60° intervals matching at least said each terminal connection and a hub, said means to mount comprising said hub and fastening means for securing said hub rigidly to said housing at least the bottom of said cavity.

3. A hybrid ring according to claim 1 wherein said element is a solid disk connected to said housing at its center and spaced from said housing at all other points.

4. A hybrid ring according to claim 1 wherein said means to mount comprises electrical insulating material and said electrical connection is through a quarter wave section RF choke whereby said element is centrally grounded only at the design frequency band of said coupler.

5. A hybrid ring according to claim 4 wherein said coupler is connected as a balanced mixer with the if signal terminal connected at said RF choke.

6. A hybrid ring according to claim 1 wherein said center terminal leads are directly conductively connected to said rim.

7. A hybrid ring according to claim 1 wherein said electrical connection is a direct conductive connection.

8. A hybrid ring according to claim 1 wherein said means to mount comprises conductive cover means for said cavity and means to secure said element both at the bottom of said cavity and at said cover means.

9. A hybrid ring according to claim 1 further comprising quarter wave RF choke coupling of said center terminal leads to said rim.

10. A hybrid ring coupler operational over a broad spectrum centered at a predetermined design frequency comprising:
    a. A circular electrically conductive element having a circumference substantially equal to one and one-half wavelengths at the design frequency;
    b. An electrical conductor concentric about said element and separated therefrom by an electrically insulating medium;
    c. connection means at the geometrical center of said element providing direct mechanical and electrical connection to said conductor; and,
    d. means to provide terminal connections to said element at four 60° intervals about its perimeter.

11. A hybrid ring coupler according to claim 10 wherein said electrical conductor is a housing structure forming a cylindrical cavity, said element is positioned centrally in said cavity and said connection means is hub mounting means mounting said element to top and bottom walls of said structure.

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