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RADIO FREQUENCY TRANSMISSION LINE TEE HYBRID

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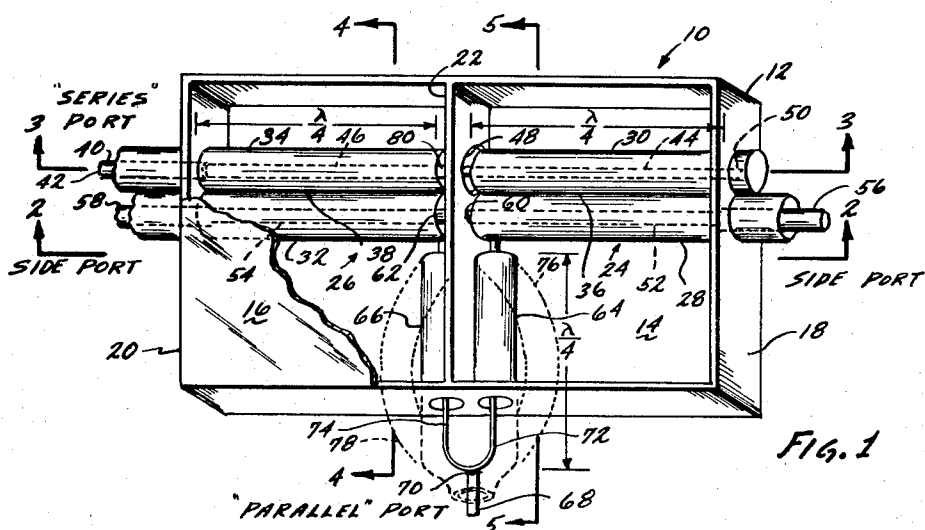
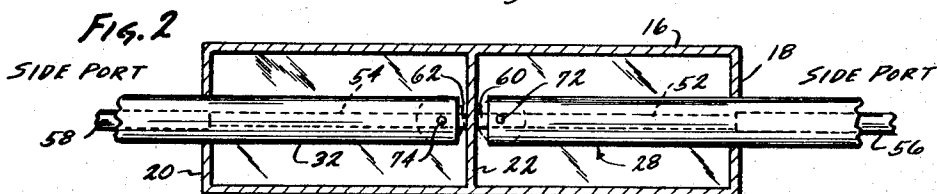
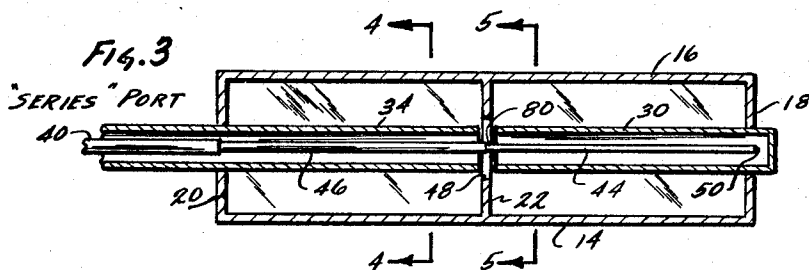
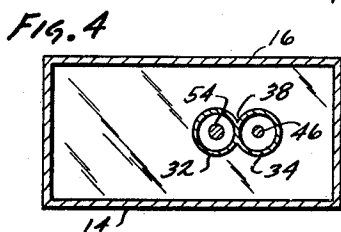
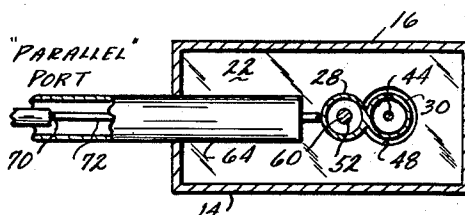
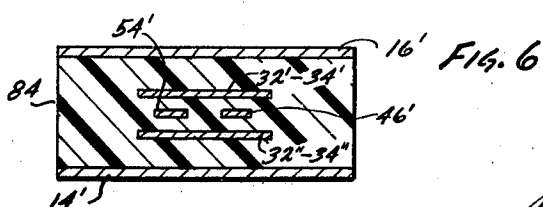


Fig. 5

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**RADIO FREQUENCY TRANSMISSION
LINE TEE HYBRID****Seymour B. Cohn, Tarzana, Calif., assignor to Emerson
Electric Company, St. Louis, Mo.****Filed Aug. 24, 1967, Ser. No. 663,137****Int. Cl. H01p 5/12****U.S. Cl. 333—11****10 Claims****ABSTRACT OF THE DISCLOSURE**

The application discloses a four port, microwave, coaxial, magic tee hybrid in which the outer conductors of the symmetrical side ports are connected to the inner conductor of the parallel port. The outer conductor of the parallel port is connected to a pair of outer conductive ground planes with respect to which the outer conductors of the side ports form a pair of symmetrically opposed, quarter wave stub conductors which may be excited symmetrically by the parallel port. The quarter wave stubs may also form a series circuit for out of phase excitation when excited by a series port whose two piece outer conductor is coupled one part to one of the side port outer conductors and the other part to the other side outer conductor. Reference should be had to the complete specification for details of structure and apparatus.

This invention relates generally to radio frequency networks and more particularly to improved, transmission line, four port magic tee type hybrid apparatus.

BACKGROUND OF THE INVENTION

Although the present invention finds particularly advantageous application in the field of coaxial microwave circuitry and although in the cause of brevity and clarity of presentation, much of the following discussion and description of examples of the invention relate particularly thereto, it is expressly to be understood that the advantages of the invention are equally well manifest in other applications such as, for example, microwave strip-line configurations or apparatus designated for operation of radio frequencies not necessarily denoted as microwave or the like.

An exceedingly useful tool and network component in modern microwave circuitry is the four port magic tee hybrid wherewith radio frequency signals may be combined or split in various ways, with various phasing results, and with highly desirably interport isolation and low VSWR. In addition, these results are obtained with relatively simple and passive apparatus.

This is particularly true in rectangular waveguide transmission embodiments; and, with respect to prior art approaches, has been less true as regards coaxial transmission line embodiments, the less perfect results being due to the complications of achieving the various couplings and symmetries with a two conductor transmission system.

Prior art approaches have typically suffered the disadvantages of narrow bandwidth interport isolation and VSWR at the various ports, typical band widths being of the order of five to ten percent. In addition, the coaxial hybrids heretofore available have been complex, bulky, and critical in their various manufacturing steps causing them to be excessively costly. The best prior art coaxial hybrid heretofore known which is designated for full octave operation exhibits VSWR of greater than 1.4 at its various ports causing it to be relatively poor in many applications where a coaxial tee hybrid would otherwise be highly desirable.

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SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide four port hybrid tee apparatus which is not subject to these and other limitations of the prior art.

It is another object to provide such apparatus which is truly compact, mechanically rugged and simple, and which is, consequently, low in manufacturing cost and long in reliable service lifetime.

It is another object to provide such apparatus which provides isolation between all ports of better than 53 db and exhibits VSWR at all port of less than 1.2 over a full octave bandwidth.

Briefly, these and other objects are achieved in an example of the invention which includes an outer pair of conductive ground planes across which are connected three substantially parallel transverse shorting planes, one at either end and one, as a plane of symmetry, across the mid portion of the assembly. A quarter wavelength intermediate conductor means is connected to each of the end plates and extends to a point contiguous to but not in contact with the mid conductive plane. Within the intermediate conductors a pair of inner conductors extend substantially collinearly for the length of the assembly. A first of the inner conductors passes through an aperture in the mid plane while the second terminates in a connection to either side of the mid plane. The latter forms a pair of symmetrically disposed side arm ports with coaxial terminals for the two electrode system consisting of the inner and intermediate conductors; and the former forms a two-quarter wavelength long series port with its "outer" conductor portions connected to or formed integrally with corresponding and coextensive ones of the "outer" conductor portions of the side arm ports. A coaxial "series" terminal is provided at either one of the outer ends of the series port.

The parallel port, with a coaxial terminal, is formed by spacing a conductor means on either side of the mid plane by an amount to give the desired characteristic impedance. Such may be accomplished by a single conductor or preferably by (1) an inner conductor means connected to each of the side arm "outer" conductors and (2) an outer conductor means which is connected in a symmetrical fashion to the transverse mid-plane.

In operation, a driving signal impressed on the parallel port excites the ends of the quarter wave stubs formed by the "outer" conductors of the side arm ports and launches a pair of waves outwardly from the mid plane along the inner conductors of equal amplitudes and phase.

On the other hand, a driving signal impressed on the series terminal launches a wave along the full length of the two-quarter wavelength along series port. This excites waves on the quarter wave stubs, consisting of the intermediate and the outer ground plane system, which are equal and opposite with respect to the mid-plane. Consequently, the resulting waves launched along the side port inner conductors are equal and opposite.

The substantially total symmetry and quarter wave design techniques embodied in the assembly provide exceedingly high levels of hybrid performance vis-a-vis interport isolation and desired signal phasing, power splitting and combining, and the like.

Further details of these and other novel features and their principles of operation as well as additional objects and advantages of the invention will become apparent and be best understood from a consideration of the following description when taken in connection with the accompanying drawing which is presented by way of illustrative example only and in which:

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a simplified, partially schematic in nature, upper perspective view, with the top cover plate shown partially broken away, of an example of coaxial four port tee hybrid apparatus constructed in accordance with the principles of the present invention;

FIGURE 2 is a longitudinal sectional view of the structure of FIGURE 1 taken along the sectional reference of lines 2—2 thereof;

FIGURE 3 is a longitudinal sectional view of the structure of FIGURE 1 taken along the sectional reference lines 3—3 thereof;

FIGURE 4 is a cross-sectional view of the structure of FIGURE 1 taken along the sectional reference lines 4—4 thereof;

FIGURE 5 is a cross-sectional view like FIGURE 4 taken along the sectional reference lines 5—5 of FIGURE 1; and

FIGURE 6 is a cross-sectional view analogous to that of FIGURE 4 illustrating a stripline alternative example of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With specific reference now to the figures in more detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and structural concepts of the invention. In this regard no attempt is made to show structural details of the apparatus in more detail than is necessary for a fundamental understanding of the invention. The description taken with the drawing will make it apparent to those skilled in the microwave arts how the several forms of the invention may be embodied in practice. Specifically, the detailed showing is not to be taken as a limitation upon the scope of the invention which is defined by the appended claims forming, along with the drawing, a part of this specification.

In FIGURE 1, the example of the invention shown includes a coaxial configuration of a four-port hybrid assembly 10 having a body 12 comprising a pair of spaced, parallel ground plate members 14, 16 with transverse, conductive end plate members 18, 20 connected therebetween. Midway between the end plate members, a conductive mid plate member 22 is disposed connectedly between the ground plate members 14, 16 and forms a plane of symmetry for the assembly.

A pair of quarter wavelength stub members 24, 26 are affixed electrically, and, in this example each is supported in cantilevered fashion to a respective one of the end plate members 18 and 20 and extend between the outer ground plate members 14, 16 to a point contiguous to, but not in contact with, the mid plate member 22. Each of the stub members 24, 26 includes, in this example, a pair of intermediate conductor tubular members 28, 30, 32 and 34, respectively, which are aligned parallel to and equidistant from the outer ground plate members 14, 16 and which are electrically continuously bonded to each other along their lines of tangency 36, 38. The tubular intermediate conductor members 30, 34 are substantially colinear as are the members 36, 38.

A "series" excitation inner electrode 40 having an enlarged terminal portion 42 and series halves 44, 46, half 46 being slightly larger than 44, extends coaxially from the terminal portion 42 through the intermediate tubular member 34, through a conductor aperture 48 in the mid plate member 22, through the tubular member 30 to an open circuited termination 50 contiguous to the plane of the end plate member 12. Similarly, side arm excitation inner conductor electrodes 52 and 54 extend from respective enlarged terminal portions 56, 58 through respective

tubular members 28, 32 to a termination point 60, 62, respectively, on opposite sides of the plate member 22.

The "parallel" port of the hybrid assembly 10 comprises, in this example, a symmetrical pair of tubular members 64, 66, each connected, at least at their inner ends, to the mid plate member 22 in a manner to provide electromagnetic shielding between the ground planes and a symmetrically bifurcated "parallel" excitation inner conductor having a terminal portion 68, a juncture 70, and a pair of branches 72, 74 each connected to a respective one of the intermediate conductor tubular members 28, 32.

The lengths of the stub members 24, 26 extending into the inter electrode space between the outer ground plate members 14, 16 from their respective end plate members 18, 20 is quarter wavelength at a predetermined selected mid band frequency. The gaps between their ends and the mid plate member 22 as well as the thickness of the mid plate member may be quite short so that the overall lengths of the assembly 10 between the end plate members 18, 20 may be approximately half wavelength.

Similarly, the effective electrical length of each branch of the bifurcated parallel excitation inner conductor between the juncture 70 and the connection of each branch with the respective tubular conductor member 28, 32 is approximately quarter wavelength. As indicated by the dotted lines 76, 78, the width of the assembly 10 may be made considerably more compact, particularly at lower frequencies by warping or bending the members 64, 66 outwardly as indicated so long as they are electrically connected to the mid plate member 22 at their inner ends. In this manner, the effective electrical length of each branch of the parallel port transmission line may be quarter wavelength while not requiring that the assembly be inherently quarter wavelength or more in overall width.

Referring to FIGURE 2, the longitudinal sectional view illustrates the quarter wavelength relation of the intermediate tubular members 28, 32 within and with respect to the outer conductor ground plate members 14, 16 and the end plate members 18, 20. Also illustrated are the side port terminals portions 56, 58 and the connection 60, 62 of their inner conductors 52, 54 with the mid plate member 22. Also illustrated in FIGURE 2 are the terminations of the branches 72, 74 on the side walls of the tubular members 28, 32 and the relation of the "parallel" tubular members 64, 66 with respect to the mid plate member 22.

Similarly to FIGURE 2, the longitudinal sectional view of FIGURE 3 illustrates the cantilevered quarter wavelength stub relation of the "series" intermediate conductor tubular members 30, 34 with respect to the outer ground plate members 14, 16 and the end plate members 18, 20. Also emphasized in this view is the series nature of the inner conductor extending from the series port terminal portion 42 through the plane of the end plate member 20 and collinear with the portions 46, 44, which are, respectively, axially substantially coextensive with the tubular members 34, 30 and which are connected by a portion 80 passing through the connector aperture 48 in the mid plate member 22. The right hand end, as viewed in the drawing, of this series inner conductor is terminated in open circuit fashion at the point 50 contiguous to the plane of the end plate member 18.

Referring to FIGURE 4, the cross sectional view illustrates the coaxial relation of the inner conductor portions 46, 54 with respect to their respective tubular intermediate conductor members 32, 34 which electromagnetically shield the inner conductors from the outer conductor plate members 14, 16. Also indicated is the soldered connection 38 between the members 32, 34 along the line of their tangency. In practice, however, some models of the invention are constructed with the tubular members 32, 34 formed integrally from a single piece of brass stock having two parallel bores formed therethrough for receiving the inner conductors 46, 54.

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In FIGURE 5, the mid-plate member 22 is shown in elevation with the connector aperture 48 formed there-through coaxially with the "series" center conductor portion 44 and the intermediate conductor tubular member 30. Similarly the side port inner conductor 52 is shown disposed concentrically within the intermediate electrode tubular member 28 and terminated at the point 60 on the mid-plate element 22. In addition, the inner conductor branch 72 of the parallel port is shown terminated at a connection with the wall of the tubular member 28. The juncture 70 constitutes the opposite end of the quarter wave branch 72 and is connected to the terminal portion 68 of the parallel port.

Referring to FIGURE 6, a stripline configuration of the invention is illustrated which is analogous in essential respects to the apparatus of the previous figures. The cross-sectional view is taken at the analogously same location as indicated for the view of FIGURE 4 and illustrates a pair of parallel, strip inner conductors 46', 54', disposed equidistantly between a pair of intermediate electrode conductive plate members 32'-34' and 32''-34''. These intermediate conductor strip electrode members are in turn, disposed symmetrically between a pair of outer conductor ground plate members 14', 16'. The various strip-line type electrodes of the assembly may be supported and electrically separated as desired by solid dielectric material as indicated at 84.

In operation a signal impressed upon the parallel port, is by symmetry divided into equal portions arriving in phase at the ends of the quarter wave stub assemblies 24, 26. The resultant excitation of the stubs, with respect to the outer ground planes, launches equal waves along the inner-intermediate conductor systems and out the side port terminals. Such in phase excitation of the stubs does not launch waves along the "series" inner conductor system because any such tendency causes a cancellation at the portion 80 of the equal but oppositely directed signals along the same continuous conductor formed by its series portions 44, 80, 46. Hence, with the signal impressed at the parallel port 68, the energy is divided equally into in-phase portions at the side port terminals 56, 58; while the series port terminal 42 remains effectively isolated. Furthermore, in exactly the same, but reciprocal manner, in-phase equal amplitude signals impressed on the hybrid at the side ports combine constructively at the parallel port with substantially total isolation of the series port.

Conversely when the input signal is impressed upon the series port terminal 42, the series arrangement of the intermediate conductor tubular members 30, 34 causes the launching of a wave along the portions 46, 80, 44 which is all continuous or unilateral therealong, for example to the right in the FIGURE 1. The same excitation, of course, exists with respect to the portions 28, 32 of the quarter wave stub assembly so that, as seen by the side port coaxial systems with respect to plane of symmetry 22, the side are excited by equal and oppositely phased signals.

This series excitation of the quarter wave stub assembly is transmitted along the inner conductor branches 72, 74 to the juncture 70 where substantially complete cancellation occurs thereby effectively isolating the "parallel" port. Similarly and reciprocally, equal amplitude, opposite phase excitation at the side ports as input terminals to the hybrid results in a constructive combination thereof along the series port line and the launching of an output wave at the terminal 42.

It should be noted, as indicated briefly earlier, that in addition to the symmetry of the bifurcated parallel port system, effective length thereof from their end terminations at the intermediate conductor tubular members 38, 30 to their juncture 70 is preferably quarter wavelength. For "parallel" drive, this relation provides the desirable impedance transformation from the quarter wave stub lines to the parallel terminal; while for "series" drive, it provides the pure 90 degree reactance for the balance line configuration formed by the hybrid assembly.

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In practical embodiments of the hybrid constructed along the lines indicated by the schematic view of FIGURE 1, a VSWR of less than 1.2 in a 2 to 1 frequency band is exhibited at each port and isolation between the series port and the parallel port is greater than 53 db.

In a typical example, the characteristic impedances obtained through the proper sizing of the terminals and conductors as shown and above briefly described is:

(1) Between intermediate conductors 32, 34 together and the outer plate members 14, 16 at ground potential, (Z01) 100 ohms.

(2) Between inner conductor 46 and the inner wall of intermediate conductor 34 (Z02), 67.5 ohms.

(3) Between the inner conductor 74 and the inner wall of the intermediate conductor 66 and between the inner conductor 72 and the inner wall of the intermediate conductor 64, (Z03) each 67.5 ohms.

(4) Between the inner conductor 44 and the inner wall of the intermediate conductor 30 (Z04) 122 ohms.

(5) Between the inner conductors 52 and 54 and the inner walls of the intermediate conductors 32 and 28, respectively Z05, each 50 ohms.

There have thus been disclosed and described various details of structure and operation of examples of novel four port radio frequency hybrid tee apparatus which achieve the objects and exhibit the advantages set forth hereinabove.

I claim:

1. Radio frequency transmission line hybrid tee apparatus comprising:

outer conductor ground plate means including spaced conductive portions;

first and second spaced transverse end conductive plate means disposed connectively between said spaced portions of said outer conductor ground plate means; transverse, conductive mid-plate means disposed connectively between said spaced portions of said conductor ground plate means between said first and second transverse end plate means, said mid-plate means being formed to provide an aperture there-through;

first inner conductor means extending through said first end plate means and terminating at said mid-plate means;

second inner conductor means extending through said second end plate means and terminating at said mid-plate means;

third inner conductor means extending through said first end plate means, through said aperture of said mid-plate means, and through substantially the inner plate distance between said mid-plate means and said second end plate means;

first intermediate conductor means connected to said first end plate means and extending between said spaced portions of said conductor ground plate means to a point contiguous to said mid-plate means and disposed to form electromagnetic shielding between said spaced portions of said conductor ground plate means and said first conductor means and that first portion of said third inner conductor means extending from said first end plate means to adjacent said mid-plate means;

second intermediate conductor means connected to said second end plate means and extending between said spaced portions of said conductor ground plate means to a point contiguous to said mid-plate means and disposed to form electromagnetic shielding between said spaced portions of said outer conductor plate means and said second conductor means and substantially that second portion of said third inner conductor means extending between said mid-plate means and said second end plate means; said first and second intermediate conductor means having a length which is approximately one quarter wave-

length at a predetermined mid-band frequency of operation;

symmetrically bifurcated inner conductor means having a first branch connected to said first intermediate conductor means and a second branch connected to said second intermediate conductor means;

shielding conductor means connected to said mid-plate means and disposed to provide electromagnetic shielding between said bifurcated inner conductor and said spaced portions of said outer ground plate means.

2. The invention according to claim 1 in which said shielding conductor means is substantially symmetrical and comprises a pair of hollow cylindrical body members connected to said mid plate means and each disposed coaxially about a respective one of said branches of said bifurcated inner conductor means.

3. The invention according to claim 1 in which said outer conductor means comprises a pair of conductive plate members disposed substantially parallel to and spaced substantially equally from said first and second inner conductor means.

4. The invention according to claim 3 in which said first and second inner conductor means are substantially collinear.

5. The invention according to claim 3 in which said first conductor means and said first portion of said third inner conductor means and said second conductor means and said second portion of said third inner conductor means comprise, respectively, a pair of parallel juxtaposed stripline elements defining a center plane and said intermediate conductor means comprises a pair of stripline elements whose width is wide compared to that of said inner conductor stripline elements which are disposed parallel to said center plane disposed equidistantly therefrom in electromagnetic shielding relation between ones of said juxtaposed pairs of said inner conductor stripline elements and said outer conductor plate members.

6. The invention according to claim 3 in which said first and second intermediate conductor means each comprises an elongated tubular conductor disposed about and substantially parallel to respective ones of said first, second, and third inner conductor means.

7. The invention according to claim 6 in which each said elongate tubular conductor is formed to provide a cylindrical bore coaxially disposed about each respective

one of said first, second and third inner conductor means.

8. A hybrid tee comprising:

first and second side by side substantially parallel coaxial conductor means orthogonally disposed symmetrically on each side of a conductive mid-plate means and extending in opposite directions from said mid-plate means for a distance of approximately one-quarter wavelength, said wavelength being at a predetermined mid-band frequency of operation;

conductive means interconnecting the outer conductors of said first and second coaxial conductor means;

means connecting the inner conductor of said first coaxial conductor means to said mid-plate means; and

third coaxial conductor means having its inner conductor connected to the outer conductor of said first coaxial conductor means and its outer conductor connected to said mid plate means.

9. A hybrid tee as defined in claim 8 wherein the inner conductor of said third coaxial conductor means is connected to the outer conductor of said first coaxial conductor means by a pair of conductors spaced one on each side of said mid-plate means.

10. A hybrid tee as defined in claim 8 wherein said third coaxial conductor means is a pair of coaxial conductors of approximately one-quarter wavelength at said predetermined mid-band frequency and having their outer conductors connected to said mid-plate means and their inner conductors symmetrically spaced one on each side of said mid-plate means and connected together at their terminal end opposite the connection to said first coaxial conductor means.

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