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WAVEGUIDE HYBRID JUNCTIONS FOR MUTUALLY ORTHOGONAL WAVEGUIDE MODES

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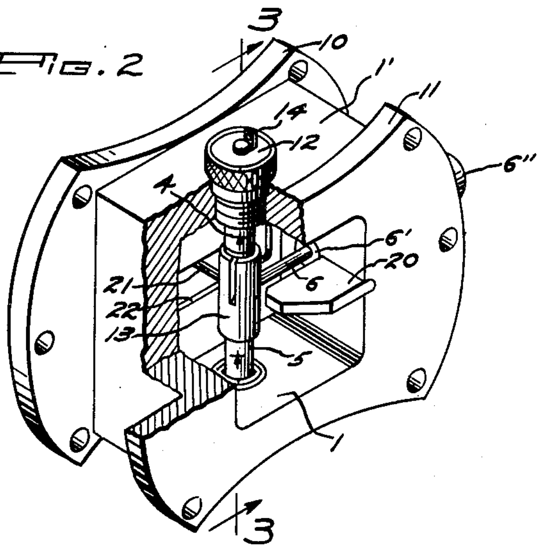

FIG. 2

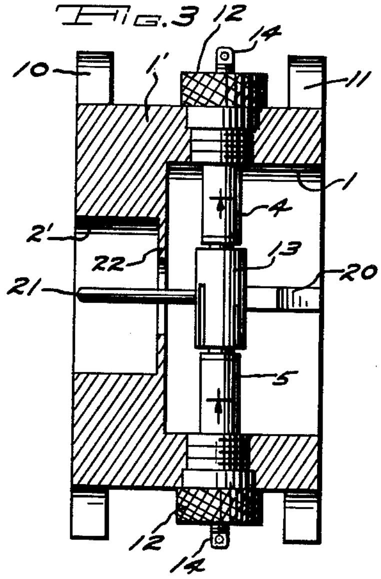

FIG. 3

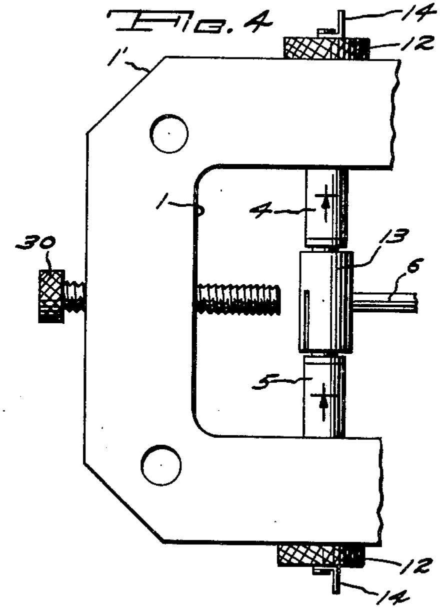

FIG. 4

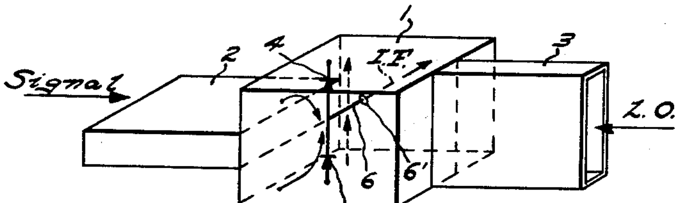

FIG. 1

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WAVEGUIDE HYBRID JUNCTIONS FOR MUTUALLY ORTHOGONAL WAVEGUIDE MODES

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The present invention relates in general to waveguide hybrid junctions embodied in such microwave components as power dividers, duplexers, mixers, modulators and parametric devices, and more particularly to novel waveguide hybrid junction structures presenting an improved impedance match to the connecting circuitry.

In the copending U.S. patent application of Richard M. Whitehorn, Serial No. 862,356, filed December 28, 1959, now U.S. Patent No. 3,066,290, there is disclosed and claimed a class of extremely compact and lightweight balanced hybrid junctions comprising a section of hollow waveguide (for example, rectangular or circular) capable of supporting two axially propagating orthogonal waveguide modes established by the waves propagated through two of the junction connections, said waveguide section being provided with a structure which perturbs one of said modes so that the two modes are in-phase in the third junction connection and out-of-phase in the fourth junction connection thereby providing a broadband balanced coupling to said third and fourth connections. It has been found that the perturbing structure in such a junction presents a substantial impedance mismatch to the connecting circuit which propagates the perturbed wave. In a microwave mixer, for example, in which a local oscillator is the source of the perturbed wave, this mismatch is disadvantageous in applications where it is desired to conserve local oscillator power, or where it is desired to obtain phase comparison information from the local oscillator wave.

Accordingly, it is the principal object of the present invention to improve the impedance match for the perturbed wave in an orthogonal mode waveguide hybrid junction.

One feature of the present invention is the provision of a projecting structure lying substantially in the plane of polarization of the perturbed wave in an orthogonal mode junction whereby the coupling of said wave to the balanced connections of said junction is enhanced without substantially affecting the unperturbed wave.

Another feature of the present invention is the provision of a ridge structure projecting from the wall of an orthogonal mode waveguide junction, the cross-section at one end of said ridge matching the waveguide supporting the perturbed wave to said junction, and the cross-section at the other end of said ridge matching said perturbed wave to the balanced connections of said junction.

Another feature of the present invention is the provision of a probe extending from the balanced junctions into the waveguide supporting the unperturbed wave of an orthogonal mode hybrid junction thereby presenting a resonant structure to the perturbed wave which enhances the coupling between said perturbed wave and the balanced connections of said junction.

A still further feature of the present invention is the provision of a probe extending inwardly from the wall of an orthogonal mode hybrid junction to enhance the coupling between the perturbed wave and the balanced connections of said junction.

These and other features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in connection with the drawings wherein:

FIG. 1 is a schematic diagram illustrating the operation of an orthogonal mode hybrid mixer,

FIG. 2 is an isometric view, partially broken away, of a microwave mixer in accordance with the present invention,

FIG. 3 is a cross-sectional view taken along line 3—3 in FIG. 2, and

FIG. 4 is another embodiment of a microwave mixer in accordance with the present invention.

The present invention will be described by reference to the microwave mixer schematically illustrated in FIG. 1. A square waveguide section **1** is energized in two orthogonal modes by a vertically polarized signal wave propagated through a horizontally disposed rectangular waveguide **2** at the left wall thereof, and by a horizontally polarized local oscillator wave propagated through a vertically disposed rectangular wave guide **3** at the right wall thereof, one mode corresponding to each input wave. Positioned inside the waveguide section **1** is a pair of collinear crystal diode rectifiers **4** and **5** contacted at the oppositely poled inwardly extending terminals thereof by a horizontal output post **6**. The electric field of the signal wave is unperturbed by the post **6** and couples into each of the crystal rectifiers **4** and **5** in the same direction as indicated by the dotted arrows. The local oscillator wave, however, is perturbed by the post **6** in such a manner that the electric field thereof couples into each crystal rectifier in an opposite direction as indicated by the solid arrows. The difference between the currents in the separate rectifiers flows along the conductor **6** through a low-pass insulating choke **6'** in the rear waveguide wall to the inner coaxial conductor of a balanced I.F. beat frequency output, the current components in the separate crystal rectifiers due to local oscillator noise canceling each other at the junction of post **6**.

The problem of particular concern in the present invention is that of providing maximum coupling between both the local oscillator and signal modes and the balanced crystal rectifier connections. Considering first the signal wave, an optimum match between the signal waveguide **2** and the crystal rectifiers **4** and **5** is obtained by placing the crystal rectifiers closely adjacent the step transition between the rectangular waveguide **2** and an approximately square rectangular waveguide section **1**, there being a region of high electric field at that position which is strongly coupled to the crystal rectifiers since the fractional wavelength distance between the rectifiers and the right wall of the waveguide **1** which appears as a shorting plane to the vertically polarized signal wave, is sufficient to provide a heavy loading of the signal wave. Having so optimized the coupling to the signal wave, there exists a substantial mismatch between the local oscillator waveguide **3** and the rectifiers **4** and **5** due to: (1) the discontinuity presented by the step transition between rectangular waveguide **3** and square waveguide **1**, (2) the discontinuity presented by the perturbing output post **6**, and (3) the inadequate loading of the local oscillator waves by the crystals **4** and **5** due to the short distance between the left wall of waveguide **1**, which appears as a shorting plane to the horizontally polarized local oscillator waves, and the crystal rectifiers.

Referring now to FIGS. 2 and 3, there is shown a microwave mixer in accordance with the present invention in which the above-described local oscillator mismatch is effectively minimized. The square waveguide section **1** is recessed through the right surface of a metallic block **1'** provided with a flange **10** for mating to a vertically polarizing signal waveguide and a flange **11** for mating to a horizontally polarizing local oscillator waveguide. The crystal rectifiers **4** and **5** are seated in removable caps **12** threaded through the top and bottom walls, and are held in contacting relation under tension at the inner terminals thereof by a split cylindrical sleeve **13**. The output I.F. post **6** is attached to the sleeve **13**, and extends through the insulating low-pass choke **6'** in the waveguide wall to form the inner conductor of the output coaxial I.F. connector **6''**. Each cap **12** is provided with a filter network bypassing the A.C. crystal current components to the grounded waveguide block **1'**, so that the D.C. current levels in the crystal rectifier may be monitored at the lugs **14** without producing undesirable leakage fields.

Impedance matching to the local oscillator waveguide is effected by means of: (1) a ridge **20** projecting from the right wall of the waveguide **1** and extending between the exterior surface of the flange **11** to a position closely adjacent the I.F. output post **6**, and (2) a probe **21** axially extending from the crystal terminal contacting sleeve **13** into an extension **2'** of the rectangular signal waveguide which is recessed into the left end of the block **1'** in order to protect the probe **21** against damage. The portion of the ridge **20** adjacent the flange **11** matches the input local oscillator wave to the waveguide section **1**; and the portion of the ridge **20** adjacent the I.F. output post **6** matches the perturbed local oscillator waveguide mode to the crystal rectifiers **4** and **5**. The ridge may be beveled at the right end thereof to optimize the transition from the local oscillator waveguide, and beveled at the left end thereof to optimize the coupling to the rectifiers **4** and **5**. The probe **21** presents a resonant TEM structure to the local oscillator wave thereby moving the effective shorting plane back into the signal waveguide and enhancing the loading of this wave by the crystal rectifiers **4** and **5**. In an illustrative mixer constructed according to FIGS. 2 and 3, the local oscillator VSWR was found to remain less than 2:1, without adjustment, over the frequency range from 4.9 to 5.9 kmc. Since the matching structures **20** and **21** lie substantially within a horizontal plane through the center of the square waveguide section **1**, which plane is a neutral septum to vertically polarized waves, these matching structures do not affect the signal wave mode.

It should be further noted that the step transition between the rectangular signal waveguide portion **2'** and the square waveguide section **1** is provided with an inwardly directed shoulder **22** providing an iris coupling thereat. This iris coupling permits the size of the square waveguide to be adjusted, for example, to accommodate matched crystal rectifiers of standard size terminal tips, such as type 1N415 rectifiers. This arrangement is much more economical than one requiring the use of specially shortened crystals. In addition the longer supporting area of these tips permits the use of a simple and inexpensive split cylindrical contacting sleeve, which requires substantial length for effective spring action.

In a modified mixer in which the local oscillator junction input was by a coaxial probe through the front wall of the waveguide **1**, a probe **21** extending into the signal waveguide was found effective in enhancing the coupling of the local oscillator wave to the crystal rectifiers.

In FIG. 4 there is shown an embodiment of a microwave mixer in accordance with the present invention in which the local oscillator matching structure comprises a screw probe **30** variably inserted through the left waveguide wall coaxially with the axis of the output post **6**. The penetration of the screw **30** is adjusted to a position (about $\lambda/8$) at which maximum crystal current is measured at the monitoring terminals **14**. With the probe at this position it is found that the local oscillator wave is well matched (VSWR of less than about 1.3) although over a rather narrow frequency band (about 1%). The apparent reason for this match is that the I.F. post **6** presents a highly inductive discontinuity to the local oscillator wave which is tuned out by the capacitive reactance of the probe thereby producing a resonant condition at the crystal rectifiers **4** and **5**. Again the signal mode is unperturbed by this matching structure since it lies within a neutral septum plane. In an illustrative embodiment constructed according to FIG. 4, the mixer could be tuned by screw **30** over a frequency band of 20% with a VSWR of less than 2.0. In another embodiment the screw **30** was used in addition to the matching structures **20** and **21** of FIGS. 2 and 3 to provide additional enhancement of the coupling of the local oscillator mode into the crystal rectifiers without degradation of the available bandwidth.

In view of the uniformly low VSWR presented to both input waveguides, it is possible to completely reverse the signal and local oscillator connections. Also it should be noted that a junction configuration similar to that illustrated may be operated, for example, as a modulator by using the perturbing post as an input terminal for the modulating frequency and the opposite waveguide arms as a carrier frequency input and a modulated output, respectively; or as a parametric amplifier by using voltage controlled diode capacitors instead of dissipative diode rectifiers.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A waveguide hybrid junction comprising: a hollow waveguide section capable of supporting a pair of axially propagating orthogonal waveguide modes established by first and second waves propagating, respectively, through a pair of junction connections adjoining said section; means for perturbing the mode established by said second wave so that the electric field thereof in one waveguide region extends in the same direction as the electric field of the mode established by said first wave and in another waveguide region extends in a direction opposite to said last-named field; and projecting structure means directed midway of said waveguide regions in said waveguide section for matching said waveguide regions to the junction connection propagating said second wave.

2. A waveguide hybrid junction according to claim 1 wherein said matching means comprises a probe extending inwardly from the wall of said waveguide section toward said waveguide regions.

3. A waveguide hybrid junction according to claim 1 wherein said matching means comprises a ridge projecting from the wall of said waveguide section and extending between the junction connection propagating said second wave and said waveguide regions.

4. A waveguide hybrid junction according to claim 1 wherein said matching means comprises a probe extending from said waveguide region toward the junction connection propagating said first wave.

5. A waveguide hybrid junction according to claim 1 wherein said junction connections comprise a pair of waveguides at opposite ends of said waveguide section, the first and second waves supported by said pair of waveguides being polarized in mutually perpendicular directions.

6. A waveguide hybrid junction according to claim 5 further including means collinearly extending from opposed portions of the wall of said waveguide toward the axis thereof in the polarization direction of said first wave for directionally responding to the fields in said waveguide, said mode perturbing means comprising a metallic projection extending from the wall of said waveguide toward said axis in the polarization direction of said second wave whereby said field responsive means are responsive to the fields in said two waveguide regions.

7. A microwave mixer comprising: a section of hollow waveguide for orthogonally supporting a first axially propagating wave received through a waveguide adjoining one end thereof and a second axially propagating wave

received through a waveguide adjoining the opposite end thereof, said first and second waves being polarized in mutually perpendicular directions; a pair of collinearly disposed crystal rectifiers extending inwardly from opposed portions of the wall of said waveguide section in the polarization direction of said first wave, the inwardly extending terminals of the separate crystals being of opposite polarity; a conducting post contacting said inwardly extending terminals and insulatedly extending through an adjacent wall portion of said waveguide section along the perpendicular bisector of the axis of said crystal rectifiers to provide a balanced beat frequency terminal; and projecting structure means extending midway of said crystal rectifiers and disposed substantially in a neutral septum plane to said first wave for matching said crystal rectifiers to the waveguide propagating said second wave.

8. A microwave mixer according to claim 7 wherein said matching means comprises a probe extending inwardly from the wall portion of said waveguide section opposite the wall portion through which said terminal post extends.

9. A microwave mixer according to claim 7 wherein said matching means comprises a ridge projecting from an adjacent wall portion of said waveguide section and extending between said crystal rectifiers and the position at which said waveguide section adjoins the waveguide which propagates said second wave.

10. A microwave mixer according to claim 9 wherein the cross section of said ridge at said adjoining position matches said adjoining waveguide to said waveguide section, and the cross section of said ridge adjacent said crystal rectifiers matches said waveguide section to said crystal rectifier.

11. A microwave mixer according to claim 7 wherein said matching means comprises a probe extending axially from the connected inward terminals of said crystal rectifiers toward the end of said waveguide section adjoining the waveguide which propagates said first wave.

12. A microwave mixer comprising: a rectangular orthogonal mode waveguide section adapted to receive a first wave through a first rectangular single mode waveguide secured to one end thereof and a second wave through a second rectangular single mode waveguide at the opposite end thereof, the broad walls of said first waveguide being perpendicular to the broad walls of said second waveguide so that said first and second waves are polarized in mutually perpendicular directions; a pair of collinearly disposed crystal rectifiers extending inwardly from opposed side walls of said waveguide section in the polarization direction of said first wave at a position closely adjacent the step transition between said first rectangular waveguide and said waveguide section, the inwardly extending terminals of the separate crystals being of opposite polarity; a conducting post contacting said inwardly extending terminals and insulatedly extending through an adjacent wall of said waveguide section along the perpendicular bisector of the axis of said crystal rectifiers to provide a balanced beat frequency output terminal; a ridge projecting from an adjacent side wall parallel to said terminal post and extending from the step transition between said second rectangular waveguide and said waveguide section; and a probe extending axially from the connected inward terminals of said crystal rectifiers toward the end of said waveguide section securing said first rectangular waveguide.

13. A microwave mixer according to claim 12 further including a second probe extending inwardly from the wall of said waveguide section opposite the wall from which said ridge projects, said second probe being collinear with said terminal post.

14. A microwave mixer according to claim 12 wherein the end of said waveguide section securing said first rectangular waveguide is provided with a step transition rectangular waveguide extension of said first waveguide, said probe extending into said waveguide extension.

15. A microwave mixer according to claim 14 further including an inwardly projecting shoulder about said step transition to provide an iris coupling between said first rectangular waveguide and said waveguide section.

16. A microwave mixer according to claim 15 further including a slotted cylindrical sleeve fitted over the inwardly extending terminals of said crystal rectifiers for holding the same in contacting relation under tension, the outside surface of said sleeve being contacted by said terminal post.

17. A microwave mixer comprising: a hollow waveguide section capable of axially propagating in two orthogonal modes established by oppositely polarized signal and local oscillator waves propagated, respectively, through a pair of junction connections; a pair of crystal rectifiers disposed within said waveguide section; means for perturbing said modes so that the field of said modes couple in-phase to one crystal rectifier and out-of-phase to the other crystal rectifier; means combining the signal in said crystal rectifiers for providing a balanced beat frequency output; and probe means extending from said crystal rectifier toward the junction connection propagating said first wave, said probe enhancing the loading of the mode established by said second wave by said crystal rectifiers.

References Cited in the file of this patent

UNITED STATES PATENTS

2,679,582	Edwards	May 25, 1954
2,761,061	Mattern	Aug. 28, 1956
2,810,904	Blitz	Oct. 22, 1957
2,813,972	Anderson et al.	Nov. 19, 1957
2,854,637	Zaleski	Sept. 30, 1958
2,943,192	Liss	June 28, 1960