Nov. 11, 1958 J. F. ZALESKI 2,860,309

BROADBAND WAVEGUIDE JUNCTION

Filed Nov. 17, 1953 2 Sheets-Sheet 1

FIG. 1

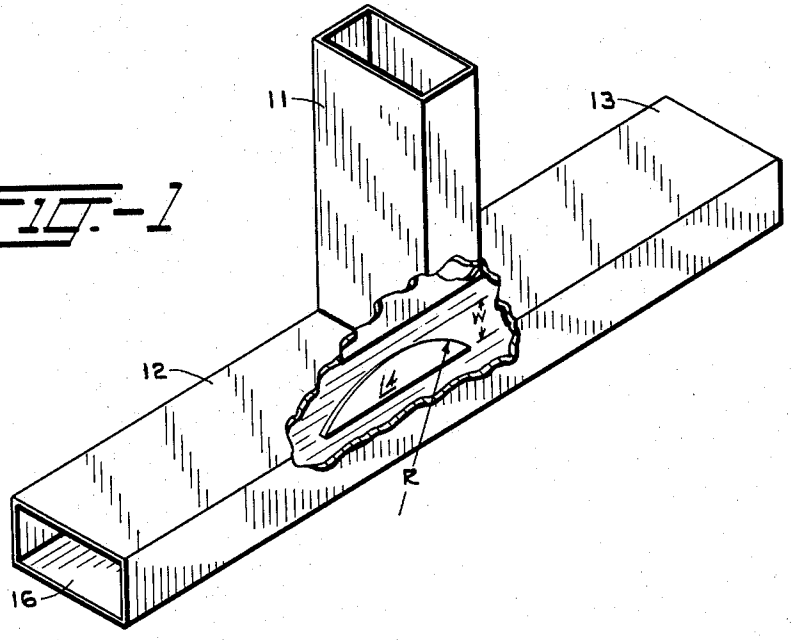
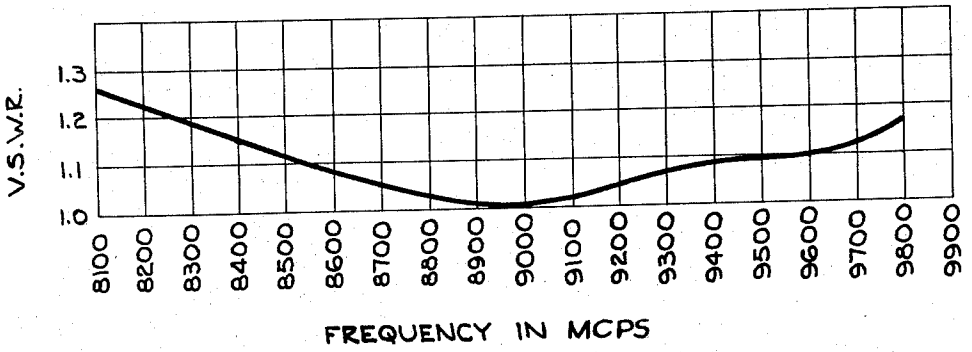


FIG. 2



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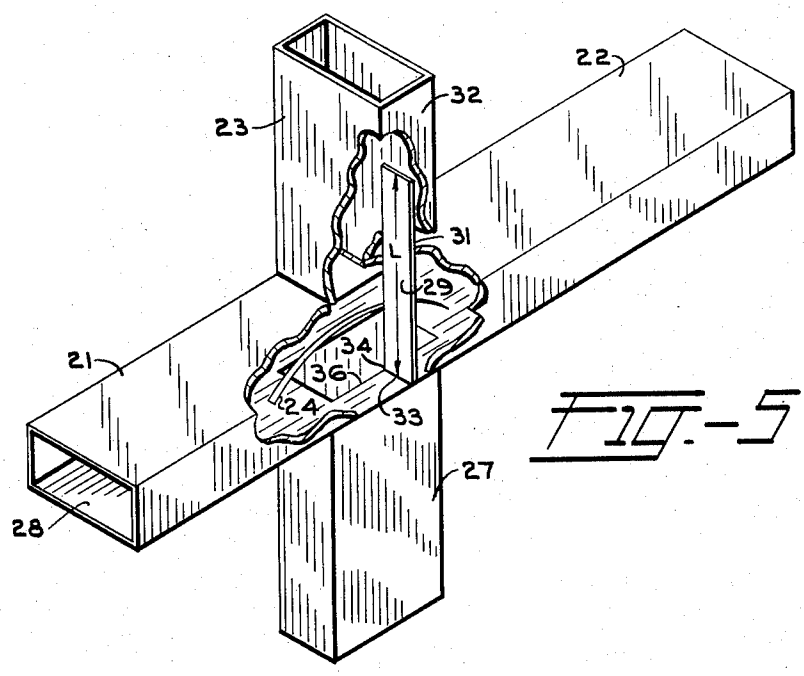


FIG. -5

FIG. -3

FIG. -6

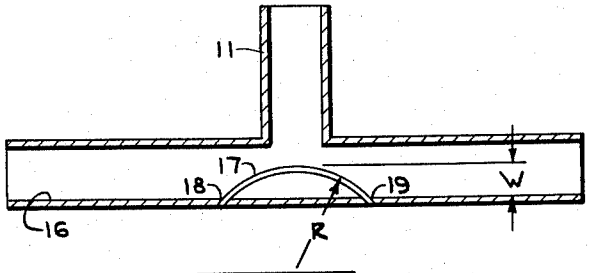
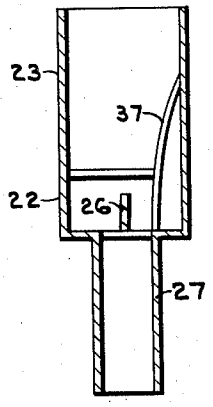
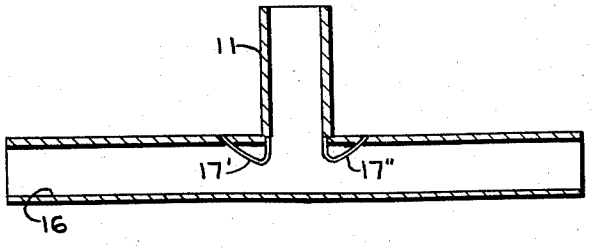


FIG. -4





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BROADBAND WAVEGUIDE JUNCTION

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Application November 17, 1953, Serial No. 392,643

18 Claims. (Cl. 333—11)

This invention relates to microwave hollow guide junctions employing discontinuity-preventing devices, and more specifically to such components incorporating an E-plane or series junction and having broadband frequency characteristics due to the nature of the matching devices incorporated in them.

In matching an E-plane or series side arm in a microwave rectangular hollow guide one early conventional means consisted of an iris plate partly closing the side arm near its junction with the collinear arms. Such a matching device is imperfect, and a minimum voltage standing wave ratio (VSWR) of the order of 1.1 exists in the side arm used as an input.

The present invention provides a matching device for such a series arm which permits no reflection whatever at the design center frequency, and with which but little reflection exists over a wide frequency band.

In one embodiment of this invention applied to a rectangular guide series tee, an elongated metallic fin or septum having tapered ends is secured to the inner surface of that broad face of the collinear arms which faces the side arm, the septum being symmetrical with the side arm. The width, length and shape of this fin are designed to eliminate reflection into the side arm when that arm is used as the input arm.

The discontinuity presented by a series tee to energy applied at the side arm is of two kinds, termed impedance discontinuity and geometrical discontinuity. The impedance discontinuity can be matched out by constricting the narrower cross-sectional dimension of the collinear arms at the junction so that the sum of the characteristic impedances of the collinear arms equals the characteristic impedance of the side arm. This is in effect accomplished by a fin disposed as described because the spaces beside the fin are below cutoff and cannot support a field. Therefore part of the width of the guide is denied by the fin to the field as though a solid platform extended across the greater cross-sectional dimension of the collinear arms. The fin, however, also has reactive properties, and therefore is capable of matching out or neutralizing the reactive geometrical junction discontinuity, which a platform cannot do.

The principal purpose of this invention is to provide a highly efficient, broadband and simple matching device for the series arm of a hollow waveguide junction.

Another purpose of this invention is to provide such a matching device for the side arm of a rectangular waveguide series tee.

Another purpose of this invention is to provide such a matching device for the series arm of a rectangular waveguide magic tee.

Another purpose of this invention is to provide such a matching device for the series arm of a rectangular waveguide magic tee having its series and shunt arm axes coincident.

Another purpose of this invention is to provide a

matching device comprising a conductive tapered fin for the series arm of a hollow waveguide component.

Another purpose of this invention is to provide a matching device comprising a curved conductive wire for the series arm of a hollow waveguide component.

Further understanding of this invention may be secured from the detailed description and the drawings, in which:

Figure 1 is a view of a series rectangular guide having a matching fin and having a portion cut away to illustrate the internal construction.

Figure 2 illustrates the VSWR/frequency characteristic of the tee depicted in Fig. 1.

Figure 3 is a longitudinal median sectional view of a series tee having as a matching element an arcuate wire.

Figure 4 is a longitudinal median sectional view of a series tee with the matching element attached to the same side of the collinear arms that carries the series side arm.

Figures 5 and 6 depict cruciform magic tees embodying the series matching element of the invention and illustrating devices for coupling the shunt side arm in combination with the series side arm matching element.

Referring now to Fig. 1, a series or E-plane microwave tee junction made of rectangular hollow guide is depicted, having an internal cross section of 0.4 x 0.9 inch. In such a tee the microwave energy is frequently applied to the side arm **11**, with loads connected to the collinear arms **12** and **13**, each load being matched in impedance to the characteristic guide impedance, and therefore causing no reflection. The junction matching element consists of a conductive metallic fin or septum **14** having the shape of a segment of a circular disc. When the design center is 9000 mc. p. s. the radius of the segment R is $\frac{25}{32}$ inch and its width W is .227 inch. The fin should be as thin as possible consistent with strength, $\frac{1}{32}$ inch thickness being suitable. The fin is secured along the longitudinal center line of the broad side of the collinear arms opposite to the side arm, extending perpendicularly into the guide. The fin is positioned symmetrically relative to the side arm.

The characteristic curve of the specifically desecribed matched tee is depicted in Fig. 2. The abscissae represent frequencies of microwave energy applied to the side arm **11** and dissipated in matched loads connected to arms **12** and **13**. The ordinates represent the corresponding voltage standing wave ratios set up in arm **11** by the discontinuities of the tee. The VSWR is zero at the design center frequency of 9000 mc. p. s. and is less than 1.1 over a band of 8550 to 9580 mc. p. s., or over more than 11% of the design center frequency. This is several times better than has been attained with previously available forms of matching elements such as the widely used iris.

The fin illustrated in Fig. 1 may be skeletonized to the form illustrated in Fig. 3 without loss of effectiveness. The arcuate conductive wire **17** is in the position of the edge of the fin **14**, Fig. 1 and for a design center frequency of 9000 mc. p. s. and employing .9" x .4" guide the dimension W is .227 inch and the radius R of the periphery of the wire is $\frac{25}{32}$ inch. The wire is positioned symmetrically relative to the series side arm **11** and is conductively and mechanically secured at its ends **18** and **19** to the broad side **16** of the collinear arm portion of the tee. The cross section of the wire may have any desired form and thickness. For example, a round wire having a thickness of $\frac{1}{32}$ inch has been found to be electrically satisfactory. A rectangular cross section having an axial dimension of $\frac{1}{32}$ inch and a radial dimension of $\frac{1}{16}$ inch has, however, been found to be stiffer and therefore mechanically preferable while being electrically as satisfactory as the fin or the $\frac{1}{32}$ inch round wire.

Such an arcuate wire performs the matching function as satisfactorily as the fin, and it can be shown experimentally that there is no electromagnetic field inside the area enclosed by the wire and the guide wall.

The matching arcuate wire of Fig. 3 and the matching fin shown in Fig. 1 can alternatively be placed on the broad side of the collinear arms opposite that shown and described. In that case, however, a gap must be made in the wire or fin to permit passage of energy in the series side arm. This form employing wire is illustrated in Fig. 4, in which the sections of wire 17′ and 17″ together perform the function of the wire 17, Fig. 3.

In place of employing a conductive fin or wire to match the series arm discontinuity, a fin or wire made of low loss dielectric material, such as tetrafluoroethylene, may be employed.

A combination of either the fin or wire form of series tee matching element with a shunt arm coaxial with the series arm is particularly appropriate because the disposition of the series tee matching element does not mechanically interfere with the shunt arm matching element.

Such a device forms a magic tee of a particular species, as illustrated in Figs. 5 and 6, having two pairs of coaxial arms. This is constructionally a very useful form of magic tee because it lends itself to easy incorporation into microwave systems. The arms **21** and **22** are coaxial in the sense of having coinciding axes and are also collinear, each being an exact prolongation of the other. These arms together with the series side arm **23** are similar to the series tee of Figs. 1 and 3. The series arm **23**, Fig. 5 is matched by a wire **24** as previously described in connection with Fig. 3, and the series arm **23**, Fig. 6, is matched by a fin **26** as previously described in connection with Fig. 1.

The shunt arm **27**, Figs. 5 and 6, is positioned in the longitudinal center line of the broad side **28** of the collinear arms **21**, **22**, and is coaxial but not collinear with the series arm **23**. As so far described the shunt arm, being symmetrically positioned relative to the collinear arm axis, has no coupling to these arms and no energy can enter or leave the shunt arm. An element is provided, however, which twists the field so that it can enter or leave the shunt arm and at the same time acts to match the shunt arm discontinuity.

This element is illustrated in Fig. 5 as a conductive rectangular septum or fin **29** with one edge **31** secured to the narrow side **32** of side arm **23** along its longitudinal center line. One end **33** of fin **29** is secured to the broad side **28** of the collinear arms. The dimensions of fin **29** are such as to perform the described functions. For example, the corner **34** may be positioned at the edge **36** joining the shunt side arm **27** to the collinear arms. The length L of the fin **29** should be sufficient to extend well into the series side arm **23**.

The shunt arm matching element may differ from the rectangular shape depicted in Fig. 5 and also it may consist of a fin skeletonized to a wire occupying the position of the edge of the fin, as was described in connection with the series tee matching element. In Fig. 6 the shunt arm matching element consists of a skeletonized fin or wire **37**, and also is shaped in the form of an arc positioned where the edge of a fin would be placed if used.

In the operation of the magic tees of Figs. 5 and 6, energy introduced at the series arm **23** is not affected by the presence of the fin **29** or wire **37** if thin, and the energy is divided and all of it passes out the collinear arms **21** and **22**. Energy introduced at the shunt arm **27** is not affected by the presence of the fin **26** or wire **24**, if thin, and all of it passes out the collinear arms **21** and **22**.

It is, of course, obvious that since, in a round guide transmitting microwave energy in the $TE_{1,1}$ mode, field patterns obtain similar to those in rectangular guide transmitting the $TE_{1,0}$ mode, all of the arrangements described may be applied without any substantial change

to round guide components and to components containing both round guide arms and rectangular guide arms.

What is claimed is:

1. A microwave hollow guide junction comprising, a pair of collinear arms, an E-plane side arm connected thereto, and a discontinuity matching device consisting of a thin arcuate member secured to the interior surface of one broad side of said pair of collinear arms, said member being symmetrically positioned relative to the longitudinal axis of said E-plane side arm and lying wholly in the median E-plane of said three arms.

2. A microwave hollow guide junction comprising, a pair of collinear guide arms, an E-plane side arm perpendicular to said pair of collinear guide arms and forming a microwave E-plane junction therewith, and a device for matching the side arm junction discontinuity offered to microwave energy applied to the side arm consisting of a thin circularly arcuate member positioned within said collinear arms and secured to the interior surface thereof, said member being symmetrically positioned relative to the longitudinal axis of said E-plane arm and lying wholly in the common median E-plane of said collinear arms and E-plane side arm.

3. A microwave rectangular hollow guide junction comprising, a pair of collinear rectangular hollow guide arms, a rectangular hollow guide joined thereto to form an E-plane side arm, and a thin member of arcuate form secured to the interior surface of one broad side of said pair of collinear arms, said member being symmetrically positioned relative to the longitudinal axis of said E-plane side arm and lying wholly in the common median E-plane of said collinear arms and of said E-plane side arm.

4. A microwave rectangular hollow guide junction comprising, a pair of collinear rectangular guide arms, a rectangular guide orthogonally joined thereto as a series side arm to form an E-plane junction therewith, and means for matching the side arm junction discontinuity offered to microwave energy applied to the side arm consisting of a thin circularly arcuate member positioned within said collinear arms secured to the interior surface thereof, said member being symmetrically positioned relative to the longitudinal axis of said series side arm and lying wholly in the common median E-plane of said collinear arms and of said series side arm.

5. A microwave rectangular hollow guide junction comprising, a pair of collinear rectangular guide arms, a rectangular guide orthogonally joined thereto as a series side arm to form an E-plane junction therewith, and means for matching the side arm junction discontinuity offered to microwave energy applied to the side arm consisting of a thin flat sheet in the form of a segment of a circle within said collinear arms symmetrically positioned relative to the longitudinal axis of said series side arm, said segmental sheet being secured by its straight edge to the interior surface of one broad side of said collinear guide arms and lying in the common median E-plane of said collinear arms and said series side arm.

6. A microwave rectangular hollow guide junction in accordance with claim 5 in which said thin flat sheet is made of a highly conductive material.

7. A microwave rectangular hollow guide junction in accordance with claim 5 in which said thin flat sheet is made of a low-loss dielectric material.

8. A microwave rectangular hollow guide junction in accordance with claim 5 in which said broad side of the collinear guide arms is opposite to the broad side joined to said series side arm.

9. A microwave rectangular hollow guide junction in accordance with claim 5 in which said broad side of the collinear guide arms is the broad side joined to said series side arm, and in which said segmental sheet contains a gap at said series side arm equalling in extent the smaller guide cross sectional dimension.

10. A microwave rectangular hollow guide junction comprising, a pair of collinear rectangular guide arms, a

rectangular guide orthogonally joined thereto as a series side arm to form an E-plane junction therewith, and means for matching the side arm junction discontinuity offered to microwave energy applied to the side arm consisting of a conductive filament having a circularly arcuate form within said pair of collinear rectangular guide arms symmetrically positioned relative to the longitudinal axis of said series side arm, said conductive filament being secured at its two ends to the interior surface of one broad side of said collinear guide arms and lying in the common median E-plane of said collinear arms and said series side arm.

11. A microwave rectangular hollow guide junction in accordance with claim 10 in which said broad side of the collinear guide arms is opposite to the broad side joined to said series side arm.

12. A microwave rectangular hollow guide junction in accordance with claim 10 in which said broad side of the collinear guide arms is the broad side joined to said series side arm and in which said conductive filament contains a gap at said series side arm equalling in extent the smaller guide cross sectional dimension.

13. A microwave hollow guide cruciform magic tee comprising, a pair of collinear hollow guide arms, an E-plane side arm, an H-plane side arm, the axes of said E-plane and H-plane side arms coinciding, all of said arms forming a four-arm junction with the axes of the four arms meeting at a point, a series discontinuity matching device consisting of a thin arcuate member secured to the interior broad surface of said pair of collinear arms and symmetrical relative to the longitudinal axis of said E-plane side arm, said series discontinuity matching device lying in the common median E-plane of said collinear arms and said E-plane side arm, and a shunt matching device consisting of a member lying in a plane normal to the common collinear arm longitudinal axis, said plane including the common axis of said E-plane and H-plane arms, said shunt matching device being secured to one side of said E-plane side arm.

14. A microwave rectangular hollow guide cruciform magic tee comprising, a pair of collinear rectangular hollow guide arms, a third rectangular hollow guide arm orthogonally joined to one common broad side of said pair of arms to form an E-plane junction, a fourth rectangular hollow guide arm orthogonally joined to the other common broad side of said pair of arms along its median center line to form a junction, the longitudinal axes of said third and fourth arms being coincident, a series discontinuity matching device consisting of a thin circular arcuate member secured to the interior surface of one broad side of said pair of collinear arms, said circularly arcuate member being symmetrically positioned relative to the longitudinal axis of said third-rectangular hollow guide arm and lying in the common median E-plane of said pair of collinear arms and of said third rectangular hollow guide arm, and a shunt discontinuity matching device consisting of a member lying in a plane normal to the common collinear arm longitudinal axis, said plane including the common axis of said third and fourth rectangular hollow guide arms, said shunt discontinuity matching device being secured to the longitudinal median line of one narrow side of said third rectangular hollow guide arm and to one narrow side of said pair of collinear rectangular hollow guide arms.

15. A microwave rectangular hollow guide cruciform magic tee in accordance with claim 14 in which said circularly arcuate member is conductive.

16. A microwave rectangular hollow guide cruciform magic tee in accordance with claim 14 in which said circularly arcuate member is made of a low-loss dielectric material.

17. A microwave rectangular hollow guide cruciform magic tee in accordance with claim 14 in which said circularly arcuate member is a conducting filament secured at its two ends.

18. A microwave rectangular hollow guide cruciform magic tee comprising, a pair of collinear rectangular hollow guide arms, a third rectangular hollow guide arm orthogonally joined to one common broad side of said pair of collinear arms to form an E-plane junction therewith, a fourth rectangular hollow guide arm orthogonally joined to the other common broad side of said pair of collinear arms to form a junction, the longer cross-sectional center line of the joined end of said fourth rectangular hollow guide arm being coincident with the longitudinal center line of said other common broad side of said pair of collinear arms, the longitudinal axes of said third and fourth rectangular hollow guide arms being coincident, means for matching the discontinuity of the junction of said third rectangular hollow guide arm and said pair of collinear rectangular hollow guide arms offered to energy applied to the third arm consisting of a thin flat sheet in the form of a segment of a circle within said pair of collinear arms symmetrically positioned relative to the longitudinal axis of said third rectangular hollow guide arm, said segmental sheet being secured by its straight edge to the interior surface of one broad side of said collinear guide arms and lying in the common median E-plane of said collinear arms and said third arm, and a shunt discontinuity matching flat sheet lying in a plane normal to the common collinear arm longitudinal axis, said plane including the common axis of said third and fourth rectangular hollow guide arms, said flat sheet being secured to one narrow side of said third rectangular hollow guide arm along its longitudinal median line and to one narrow side of said pair of collinear rectangular hollow guide arms.

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