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MICROWAVE POWER DIVIDERS

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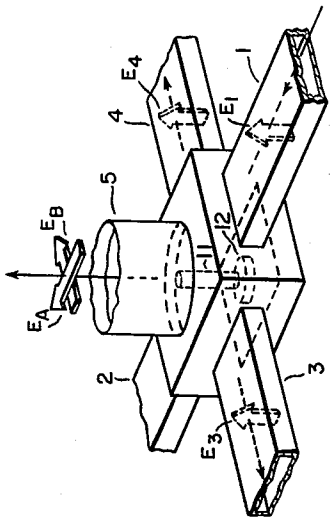


FIG. 1

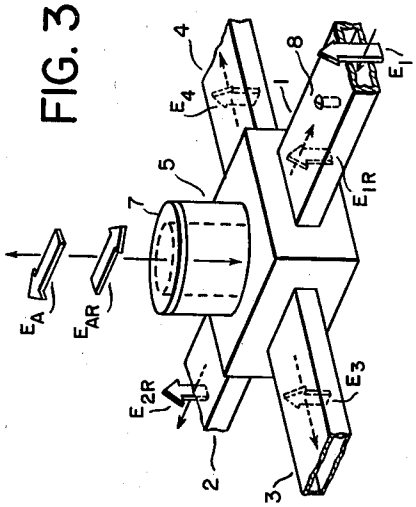


FIG. 3

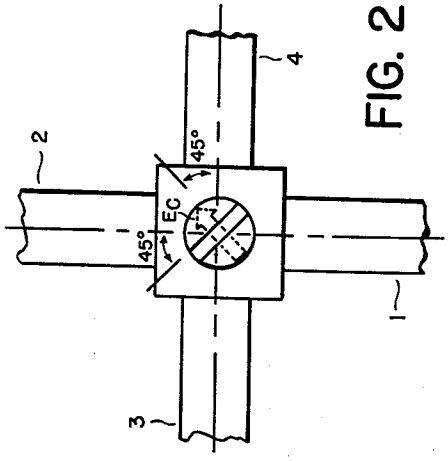


FIG. 2B

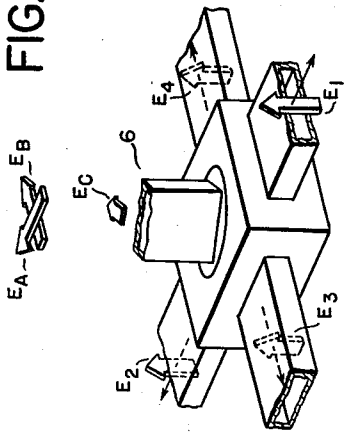


FIG. 2A

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MICROWAVE POWER DIVIDERS

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The present invention relates in general to microwave power dividers and in particular to apparatus, which includes a turnstile junction, for effecting the division of substantially equal amounts of microwave power into three or four channels. An example of a need for such power division is described in the copending application of Maurice A. Meyer, entitled Doppler Radar System, Serial No. 610,444, filed September 10, 1956.

The theory of the turnstile junction, which is a well established microwave component, is reviewed in a paper by Maurice A. Meyer and Harold B. Goldberg entitled Applications of the Turnstile Junction published in the "IRE Transactions on Microwave Theory and Techniques," volume MTT–3, Number 6, December 1955, and references cited therein.

It is an object of the present invention to provide means for supplying from a single source of microwave energy equal amounts of microwave power to more than two output channels.

Another object of the invention is to effect power division according to the preceding object with substantially no power loss between the source and output channels.

Still another object of the invention is the attainment of power division according to the above objects with compact lightweight microwave components which are easily adjusted and remain properly adjusted for equal power division over extended periods of use.

In a broad aspect of the invention, a matched turnstile junction, having four rectangular openings and a circular opening, with the planes of the rectangular openings orthogonal to the plane of the circular opening and spaced by 90° about its axis, is energized with microwave energy at one of the openings whereby substantially equal amounts of energy emerge from more than two of the other openings.

For four way power division, the circular opening is energized with microwave energy polarized with the electric vector oriented at an angle of substantially 45° relative to a line perpendicular to the plane of a rectangular opening and equal amounts of power emerge from the rectangular openings. In a specific embodiment, the input microwave energy is coupled to the circular opening by a rectangular waveguide oriented such that the sides of its rectangular cross-section are at an angle of substantially 45° relative to said perpendicular line.

For three way power division, energy is applied to a first of the rectangular openings with its electric vector oriented so that half the input energy divides equally between adjacent rectangular openings and emanates therefrom, while the other half emerges from the circular opening but is reflected back into the junction to divide equally between the first rectangular opening and the remaining rectangular opening opposite the first opening. Means are provided for reflecting energy emerging from the first opening back into the junction. The latter means may be an iris, post or other microwave impedance element which may be in an input waveguide coupled to the first rectangular opening and arranged so that the standing

wave ratio at the input to the input waveguide is substantially unity.

Other features, objects and advantages will become apparent from the following specification when read in connection with the accompanying drawing in which:

Fig. 1 illustrates a basic turnstile junction;

Fig. 2A is an illustration of a turnstile junction arranged for four-way power division;

Fig. 2B is a top view of the apparatus of Fig. 2A; and

Fig. 3 illustrates a turnstile junction arranged for three-way power division.

Referring now to the drawing and more particularly Fig. 1 thereof, the turnstile junction is illustrated with four rectangular waveguide sections and a circular waveguide section extending therefrom. The circular section 5 is seen to meet the junction at a circular opening while the four coplanar rectangular arms 1, 2, 3 and 4 meet the junction at respective rectangular openings whose planes are orthogonal to the plane of the circular opening and disposed at 90° intervals about the axis of the latter.

The network thus formed is termed a six-terminal pair unit with two of the terminal pairs being attributed to the two polarizations in the circular guide represented by the orthogonal electric vectors E_A and E_B parallel to the plane of the circular opening. The other terminal pairs are the four rectangular arms. The matching of the junction is accomplished by adjustments of concentric pins, 11 and 12, both in diameter and in length. The necessary and sufficient condition for match of the junction is that the impedance looking into any of the arms (including circular) shall be matched when matched loads are put on the other four arms.

Under the condition of a matched junction, the following condition of power split exists. If power is fed into any of the rectangular arms, such as arm 1, with its electric vector oriented as indicated by vector E_1 and arms 2, 3, 4, and circular arm 5 terminated in a match, one half of the incident power will be transmitted up circular arm 5 with a polarization indicated by electric vector E_A. The remaining fifty percent of the incident power will divide equally between arms 3 and 4 with respective electric vectors E_3 and E_4 oriented as indicated with no power entering arm 2. If instead energy were applied at the input of arm 3 of polarization indicated by electric vector E_3, one half of the incident power would be transmitted up circular arm 5 with a polarization indicated by vector E_B, the remaining power dividing equally between arms 1 and 2 with no power entering arm 4.

The geometry of the junction results in the existence of even symmetry between each rectangular arm and its two adjacent rectangular arms, and odd symmetry between any two opposite rectangular arms and the circular arms. If energy is applied to the circular arm with its electric vector oriented along E_A, the power will divide equally between arms 1 and 2. Should its electric vector be oriented along E_B, the power will divide equally between arms 3 and 4. If instead the circular opening is energized with energy having its electric vector oriented along E_C which is at a 45° angle relative to E_A and E_B, the input power will divide substantially equally among the four rectangular arms. This result is better understood when it is realized that the vector E_C may be resolved into two equal amplitude orthogonal components respectively aligned along E_A and E_B. By superposing the power dividing effects of the respective orthogonal components, it is seen that equal four-way power division is obtained.

With reference to Fig. 2A, there is illustrated the means for energizing the circular opening of the turnstile junction to effect four-way power division. The reference numerals of Fig. 1 identify corresponding elements in Fig. 2. Observe that the circular arm 5 of Fig. 1 has been replaced by a rectangular arm 6 with the sides of the

latter cross-section oriented to form an angle of substantially 45° with the planes defined by the axes of the circular and rectangular openings. The orientation of the latter cross-section is better understood from the top view of the apparatus of Fig. 2A shown in Fig. 2B. The equality of division is a function of the accuracy of orientation of the rectangular feed coupled to the circular opening and the impedances on the rectangular arms. In practice, deviations from equality of less than 0.2 decibels is readily attained.

Referring now to Fig. 3, there is illustrated novel means for effecting three-way power division. The reference numerals of Figs. 1 and 2 identify corresponding elements in Fig. 3. The structure is seen to differ from that of Fig. 1 in that circular arm **5** is terminated in a short circuit **7**, and a matching post **8** resides within arm **1**, the latter being energized with input power of polarization as indicated by electric vector E_1. The matching post **8** is arranged so that a standing wave ratio of substantially unity is measured at the input to arm **1**. Other microwave impedance elements which effect substantially the same standing wave ratio may be substituted therefor. Stated in other words, the impedance element coacts with the junction to effectively provide selective transmission means which allows power applied to the input of arm **1** to enter the junction, but reflected power emerging from the rectangular opening of the junction to which arm **1** is coupled, is reflected back into the junction by the impedance element.

The mode of operation by which three-way power division is obtained will be better understood from the following discussion of a complete cycle of power flow, which includes one reflection from short circuiting plate **7**. Electric vectors associated with power reflected therefrom are designated by the letter R appearing in the subscripts.

Energy is applied at the input of arm **1** with polarization as indicated by vector E_1. One half of the incident power enters circular arm **5** through the circular opening of the junction with its electric vector oriented along E_A; and the remaining fifty percent of the incident power divides equally between arms **3** and **4** with electric vectors oriented along E_3 and E_4 respectively. At this time, no power enters arm **2**.

The short circuiting plate **7** reflects the energy which entered circular arm **5**, back into the junction with its electric vector oriented along E_{AR}. The reflected energy divides equally between arms **1** and **2** with a polarization as indicated by electric vectors E_{1R} and E_{2R}, respectively. At this point, it is appropriate to note that ¼ of the incident power has been transmitted to each of arms **2**, **3** and **4**. If it were not for matching post **8**, the remaining ¼ would be returned to the source which originally energized arm **1**. However, matching post **8** serves to reflect this power back into the junction where the cycle previously described is repeated. Thus, ⅛ of the incident power is divided equally between arms **3** and **4** and ⅛ enters circular arm **5** to be reflected by short circuiting plate **7** with 1/16 of the reflected power entering arm **2** and 1/16 entering arm **1** for reflection back into the junction by matching post **8**. The above sequence of multiple reflections continues until substantially equal amounts of the input power energize arms **2**, **3** and **4**.

The fractional amount F of input power applied to each arm is the sum of the fractional amounts of input power upon each cycle. This is seen to be

$$F=\frac{1}{4}+\frac{1}{16}+\frac{1}{64}+\frac{1}{256}+\ldots+\frac{1}{4^n}$$

or

$$\sum_{n=1}^{n=\infty}(\tfrac{1}{4})^n=-1+\sum_{n=0}^{n=\infty}(\tfrac{1}{4})^n$$

Note that the latter sum is a geometric series of the type

$$\sum_{n=0}^{n=\infty} r^n$$

where $|r|<1$. Hence, the sum S_n is given by the equation

$$S_n=\frac{1}{1-r}=\frac{1}{1-\frac{1}{4}}=\frac{4}{3}$$

$$F=-1+\tfrac{4}{3}=\tfrac{1}{3}$$

Thus, it is seen that ⅓ of the input power enters each of the arms **2**, **3** and **4**.

Post **8** is preferably spaced half-way between the narrow sides of arm **1**. Its distance from the rectangular opening of the junction and depth within the waveguide may be determined by first measuring the impedance at the latter rectangular opening with arms **2**, **3** and **4** terminated in their respective wave impedances while short circuiting plate **7** terminates circular arm **5** in a short circuit. With the aid of a Smith chart, or other means well known in the microwave art, the distance to the junction and depth within the waveguide of post **7** may be determined such that the standing wave ratio at the input of arm **1** is substantially unity. Other microwave impedance elements, such as irises may be substituted for post **7**. Those skilled in the art may also use combinations of microwave impedance elements to obtain the desired unity standing wave ratio.

The novel power dividers are seen to provide equal three or four-way power division with substantially zero insertion loss. Another advantage is the compact arrangement effected by using a turnstile junction. For example, a representative turnstile junction at X band has the dimensions 1¼ inches by 1¼ inches by 1 inch. Still another feature is the convenient arrangement of input and output guides whereby adjacent waveguides are orthogonal, thereby enabling associated microwave components to be conveniently located in a compact system.

Those skilled in the microwave art may make numerous modifications of and departures from the specific embodiments described herein without departing from the disclosed inventive concepts. Consequently, the invention is to be construed as limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A microwave power divider comprising, a matched turnstile junction formed with four rectangular openings and a circular opening with the planes of the rectangular openings orthogonal to the plane of the circular opening and spaced by 90° about its axis, means for energizing said junction through only a first of said rectangular openings with microwave energy, a portion of said energy leaving said junction through said circular opening means for reflecting all energy emerging from said junction through said circular opening back therethrough into said junction, a portion of the energy thus reflected leaving said junction through said first rectangular opening, and means for reflecting all energy emerging from said junction through said first rectangular opening back therethrough into said junction.

2. A microwave power divider comprising, a matched turnstile junction formed with four rectangular openings and a circular opening with the planes of the rectangular openings orthogonal to the plane of the circular opening and spaced by 90° about its axis, three output rectangular waveguides coupled to said junction at respective rectangular openings, means for energizing said junction at the remaining rectangular opening with microwave energy through means which reflect energy emerging from said junction and which pass energy arriving from said energizing means, and means for reflecting all energy which emerges from said junction through said circular opening back therethrough into said junction thereby energizing said three output waveguides with substantially equal amounts of energy.

3. A microwave power divider comprising, a matched turnstile junction formed with four rectangular openings and a circular opening with the planes of the rectangular openings orthogonal to the plane of the circular opening and spaced by 90° about its axis, three output rectangular waveguides coupled to said junction at respective rectangular openings, an input rectangular waveguide coupled to said junction at the remaining rectangular opening, means for energizing said input waveguide with microwave energy, means for reflecting energy which emerges from said junction through said circular opening back therethrough into said junction, and means including a microwave impedance element arranged within said input waveguide to effect a standing wave ratio of substantially unity at the input thereof.

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