

March 10, 1959

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2,877,426

MICROWAVE TRANSMISSION LINES

Filed Feb. 2, 1953

2 Sheets-Sheet 1

Fig. 1

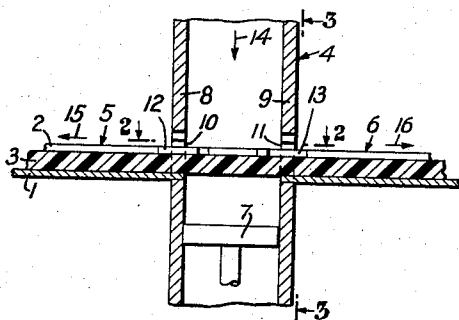


Fig. 3

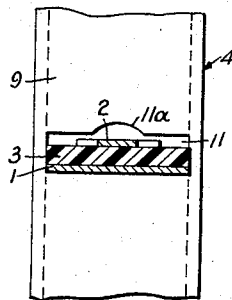


Fig. 2

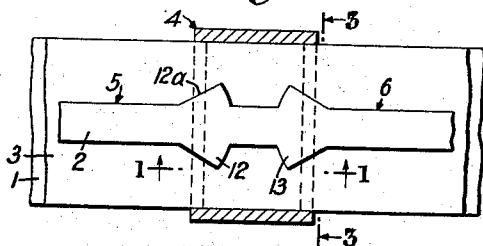


Fig. 6

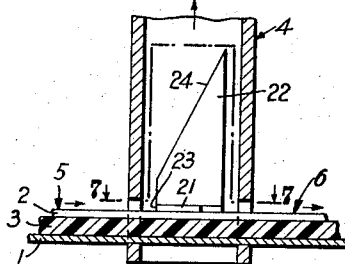


Fig. 4

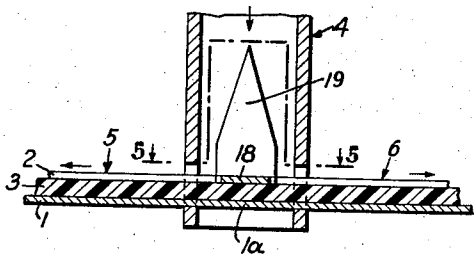


Fig. 7

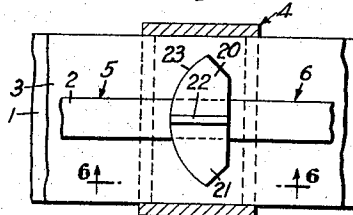
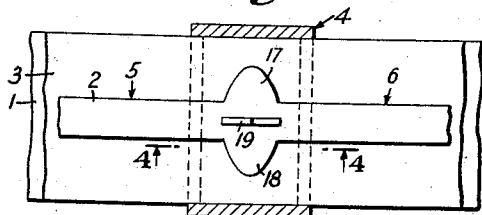


Fig. 5



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Fig. 8

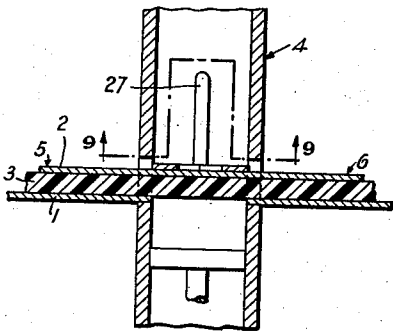


Fig. 9

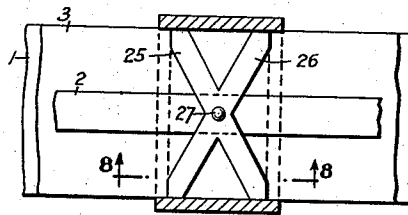


Fig. 10

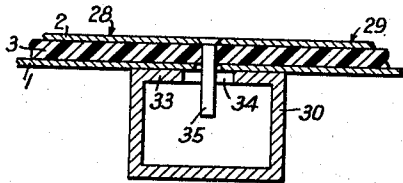


Fig. 11

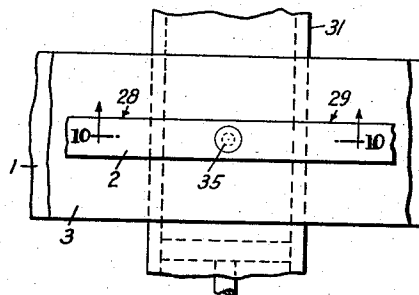


Fig. 12

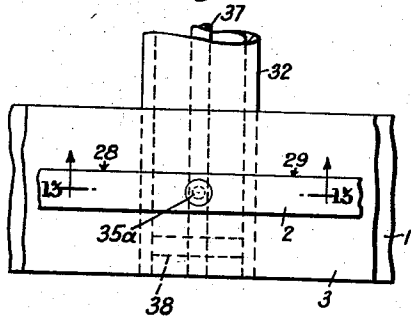
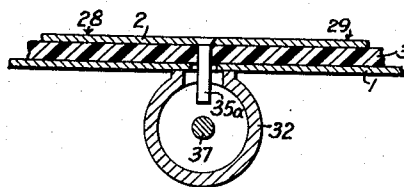


Fig. 13



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MICROWAVE TRANSMISSION LINES

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Application February 2, 1953, Serial No. 334,486

8 Claims. (Cl. 333—9)

This invention relates to power splitting junctions and more particularly to transducer arrangements for splitting microwave energy between two different types of waveguides.

In the copending applications of D. D. Grieg and H. F. Engelmann, Serial No. 227,896, filed May 23, 1951, now abandoned, and Serial No. 234,503, filed June 30, 1951, now Patent No. 2,721,312, granted October 18, 1955, and M. Arditì and P. Parzen, Serial No. 286,764, filed May 8, 1952, now Patent No. 2,774,046, granted December 11, 1956, microwave waveguides comprising generally a "line-above-ground" type of transmission line, over which microwave energy may be propagated in a mode simulating a TEM mode are shown. In this type of transmission line, a planar conductor is employed as a "ground" conductor with a line conductor disposed in spaced parallel relation thereto by means of a strip or layer of dielectric material. The line and planar conductors are preferably of different widths, that is, the planar conductor is made wider than the line conductor so that it appears as an infinite conducting surface to the line conductor, thereby insuring an electric field distribution characterized generally by the TEM mode. For example, the field distribution is believed to be similar to that which occurs between one of the conductors of a truly parallel conductor system and the neutral plane between such conductors. The important parameters of this type of transmission line are the width of the line conductor and the dielectric spacing between the line conductor and the planar conductor.

One of the objects of this invention is to provide power splitting transducer junctions for splitting microwave energy between branch waveguides wherein one or more of the branches comprises a "line-above-ground" type of waveguide.

Another object is to provide a transducer arrangement to effect energy coupling between a "line-above-ground" type of waveguide and another type of waveguide or cavity resonator.

One of the features of this invention is the provision of a "line-above-ground" type of waveguide in coupling relation to another type of waveguide such as the rectangular waveguide or coaxial waveguide or with a cavity resonator. The line-above-ground type of waveguide is employed as two branches in coupled relation to a different type of waveguide or resonator and is provided with transducer structures for effecting transfer of microwave energy between the line-above-ground type of waveguide and the other type of waveguide or resonator. The transducer structures may comprise various conductor shapes associated with the line conductor of the line-above-ground waveguide including conductor portions in the plane of the line conductor or in the form of posts or vanes at an angle to the plane of the line conductor.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following

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description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a longitudinal sectional view of an energy splitting junction according to the principles of this invention; the sectional view being taken along line 1—1 of Fig. 2;

Fig. 2 is a sectional view showing the line-above-ground waveguide of Fig. 1 in plan view, the section being taken along line 2—2 of Fig. 1;

Fig. 3 is a cross-sectional view taken along lines 3—3 of Figs. 1 and 2;

Fig. 4 is a longitudinal sectional view of another power splitting transducer junction according to this invention, the view being taken along line 4—4 of Fig. 5;

Fig. 5 is a sectional view taken along line 5—5 of Fig. 4;

Figs. 6 and 7 show a further embodiment of the invention, Fig. 6 being a longitudinal sectional view taken along line 6—6 of Fig. 7, and Fig. 7 being a cross-sectional view taken along line 7—7 of Fig. 6;

Figs. 8 and 9 are views of still another embodiment of an energy splitting transducer, Fig. 8 being taken along line 8—8 of Fig. 9 and Fig. 9 being taken along line 9—9 of Fig. 8;

Fig. 10 is a cross-sectional view of a transducer junction in which one of the branches comprises a cavity resonator;

Fig. 11 is a plan view of a three-branch junction similar to the junction shown in Fig. 10, wherein a rectangular waveguide is substituted for the resonator; and

Figs. 12 and 13 show a further embodiment of the invention wherein one of the branches is a coaxial waveguide, Fig. 12 being a plan view and Fig. 13 being a sectional view taken along line 13—13 of Fig. 12.

Referring to Figs. 1, 2 and 3 of the drawings, the line-above-ground type of waveguide is shown to comprise a first conductor 1, a second conductor 2 spaced apart by a thin strip or layer of dielectric material 3. The two conductors 1 and 2 are preferably of flat strip form, the first conductor being wider than the second conductor so that propagation of microwave energy therealong is in an approximate TEM mode as hereinbefore explained. The dielectric material may be polyethylene, polystyrene, Teflon, Fiberglas or laminated Fiberglas impregnated with Teflon, quartz, or other suitable material of high dielectric quality. The conductors 1 and 2 are preferably formed on the dielectric strip by any of the known printed circuit techniques, the one preferred being an electrolytic etching process.

As shown more clearly in Fig. 1, the junction comprises three branches 4, 5 and 6. The branches 5 and 6 comprise the line-above-ground type of waveguide, the two branches being interconnected so that the second conductor 2 thereof comprises a continuous line. The branch 4 in this embodiment comprises a rectangular waveguide, the terminating end of which is provided with an adjustable short 7 rearwardly of the conductor 2 of branches 5 and 6. The two opposed walls 8 and 9 of the rectangular waveguide are provided with aligned openings 10 and 11 through which the conductor 2 of the branches 5 and 6 extend. The conductors 1 of the two branches 5 and 6 are terminated at the walls 8 and 9 to which they are electrically connected.

To enhance wave energy coupling between the branches the second conductor 2 is provided with laterally extended portions 12 and 13 partly disposed within the hollow structure of the rectangular waveguide. These lateral extensions are preferably integral with the conductor 2 and are carried by the dielectric strip 3 in the plane of the conductor 2. While the shaping of these laterally extended portions may follow various forms, one preferred form is provided with a taper, as indicated at

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12a in the direction of the slots longitudinally of the conductor 2. The slots 10 and 11, as more clearly shown in Fig. 3, are of such size as to provide proper dielectric spacing with respect to the conductor 2, one side of the slot being enlarged as indicated at 11a so that the wall containing the slot does not interfere with the electrical lines of force between the conductors 1 and 2.

Assuming a source of microwave energy connected to the branch 4, the wave energy propagated along branch 4, as indicated at 14, is split substantially equally between the branches 5 and 6, as indicated at 15 and 16. By properly adjusting the short 7, an impedance match between the branches is readily obtainable. Assuming that the source of wave energy is coupled to branch 5, the propagation therealong is split between branches 4 and 6, the division ratio being dependent upon the size and location of the transducer sections 12 and 13. If desired, section 13 may be omitted when the power source is coupled to branch 5, and when coupled to branch 6 the section 12 may be omitted.

Referring to Figs. 4 and 5, another embodiment of the invention is shown, wherein the transducer arrangement differs from that shown in Figs. 1 to 3 and wherein the first conductor 1 of branches 5 and 6 forms the end termination of the rectangular waveguide of branch 4. The first conductor 1 is electrically connected to the four walls of the waveguide forming branch 4 thus establishing a terminating wall 1a for the branch 4. The transducer structure includes two lateral extensions 17 and 18 which lie in the plane of the conductor 2 and are contained within the rectangular waveguide. These two sections 17 and 18 taken together form substantially an elliptical area. The sections 17 and 18 may be triangular but preferably the sides thereof are curved substantially as indicated in Fig. 5. The transducer includes a third vane-like section 19 disposed at right angles to the plane of the conductor 2 and extends longitudinally of the rectangular waveguide of branch 4. This section 19 is shown to taper in the direction of the branch 4 so as to provide a gradual transition from the conductor 2 into the passage of the waveguide. In the form illustrated in Figs. 4 and 5, power propagated along branch 4 is equally divided between the branches 5 and 6. Likewise, power propagated along one of the branches such as branch 5, for example, may be equally divided or divided according to a desired ratio between the branches 4 and 6 dependent upon the structural proportions of the transducer.

Figs. 6 and 7 show a junction similar to that shown in Figs. 4 and 5 except that the transducer is different. In this embodiment the transducer is made up as a separate unit which is soldered or otherwise secured in place on the conductor 2 of branches 5 and 6, the transducer having a base composed of two identical sections 20 and 21 and a third vane-like section 22 disposed at right angles thereto. This transducer is particularly constructed to divide equally the wave energy propagated along branch 5 between the branches 4 and 6. The front portions of the sections 20 and 21 are curved as indicated at 23, and the front edge of the vane section 22 is inclined so as to provide improved transition from the line-above-ground waveguide to the rectangular waveguide. For energy propagated over branch 6, the ratio of division is such that a smaller portion of power is diverted over branch 4 than in the case where the source of energy is applied to branch 5. By making transducer sections symmetrical substantially as illustrated in Figs. 4 and 5, with proper dimensions, an equal division may be had regardless which branch is connected to the source of power. While sections 20 and 21 are shown separate from conductor 2, it should be understood that they may be made integral therewith and in the same plane. It will also be understood that the transducers of Figs. 1-3 and 4-5 may be made separate from conductor 2 if desired.

Referring to Figs. 8 and 9 still another embodiment of the invention is shown wherein the difference from the

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embodiment shown in Figs. 1 to 3 is also in the transducer structure. In this form the transducer comprises two cross-conductors disposed diagonally crosswise of the rectangular waveguide of branch 4 as indicated at 25 and 26. The ends of the conductors 25 and 26 may be electrically connected to the walls of the waveguide and disposed in contact, or integral if desired, with the conductor 2 of branches 5 and 6. The transducer arrangement of conductors 25 and 26 provide for equal division of energy regardless to which branch the source is applied. To further enhance this division the transducer may include a conductive probe 27 disposed axially of the waveguide branch 4.

Figs. 10, 11, 12 and 13 show another junction arrangement wherein two branches 28 and 29 comprise a line-above-ground type of waveguide consisting of first and second conductors 1 and 2 spaced apart by a strip of dielectric 3 the same as hereinbefore described. In these figures the line-above-ground waveguide does not pass through the other branch but is disposed adjacent the waveguide of the other branch which may be a resonator chamber 30 as indicated in Fig. 10, a rectangular waveguide 31 as indicated in Fig. 11, or a coaxial waveguide 32, as indicated in Figs. 12 and 13. In Fig. 10, for example, one wall 33 of the chamber 30 is provided with an opening 34 over which the line-above-ground waveguide is disposed. The conductor 1 and the dielectric 3 are provided with an opening which is in alignment with the opening 34 and through which a conductive probe 35 extends from the line conductor 2. Such arrangement provides for communication between the conductors 1 and 2 and the chamber 30, the probe 35 functioning as a transducer to enhance the coupling.

The junction shown in Fig. 11 shows an identical coupling arrangement between branches 28 and 29 and a rectangular type of waveguide 31, the section shown in Fig. 10 being representative of a section taken along line 10-10 of Fig. 11. The waveguide 31 is terminated at one side of the junction by an adjustable shorting device 36.

The coupling shown in Figs. 12 and 13 for the junction of the branches 28 and 29 with respect to the coaxial branch 32 is identical to that illustrated in Figs. 10 and 11 in that the line conductor 2 is provided with a probe 35a which extends through an opening of the conductor 1 and the outer conductor of the coaxial waveguide to a short distance from the inner conductor 37. The coaxial branch 32 is terminated at one side of the junction by an adjustable short as indicated at 38. The degree of coupling between the line-above-ground branches and the hollow waveguide or resonator structures of Figs. 10 to 13 is dependent upon the opening in the conductor 1 and the distance the probe extends into the hollow waveguide or resonator structure.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention, as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A waveguide junction having three branches, at least one of said branches consisting of a hollow structure and the other of said branches consisting of a type of waveguide which comprises a first conductor, a second conductor and means to maintain said conductors in dielectrically spaced substantially parallel relation, said first conductor being wider than said second conductor so that said first conductor presents substantially a planar surface with respect to said second conductor, a transducer carried by said second conductor with at least a part thereof disposed within said hollow structure to enhance the coupling of wave energy from one to the other of said branches, the longitudinal axis of said hollow structure lying in a plane parallel to said first and second con-

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ductors and said hollow structure is provided with an opening in a wall thereof, said first conductor being disposed in overlying relationship to said wall and provided with an opening therethrough in alignment with the opening in said wall, and a conducting probe extends from said second conductor through said openings into said hollow structure.

2. A waveguide junction according to claim 1, wherein said hollow structure is a rectangular waveguide.

3. A waveguide junction according to claim 1, wherein said hollow structure is a coaxial waveguide, and said probe is spaced from the center conductor of said coaxial waveguide.

4. A waveguide junction according to claim 1, wherein said hollow structure is a resonator.

5. In combination, a transmission line having first and second strip-like conductors and a layer of dielectric material separating said conductors in spaced substantially parallel relation, said second conductor being wider than said first conductor to provide a substantially planar conducting surface in close spaced relation to said first conductor, a hollow structure, the longitudinal axis of said hollow structure lying in a plane parallel to said first and

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second conductors a wall of said hollow structure having an opening therethrough and said transmission line being disposed with said second conductor in conductive relation to said wall with the space between said first and second conductors in communication with said opening, and a conducting probe extending from said second conductor through said opening into said hollow structure.

6. The combination according to claim 5, wherein said hollow structure is a rectangular waveguide.

7. The combination according to claim 5, wherein said hollow structure is a coaxial waveguide, and said probe is spaced from the center conductor of said coaxial waveguide.

8. The combination according to claim 5, wherein said hollow structure is a cavity resonator.

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