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DIRECTIONAL COUPLERS FOR MICROWAVE TRANSMISSION SYSTEMS

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2 Sheets-Sheet 1

Fig. 1

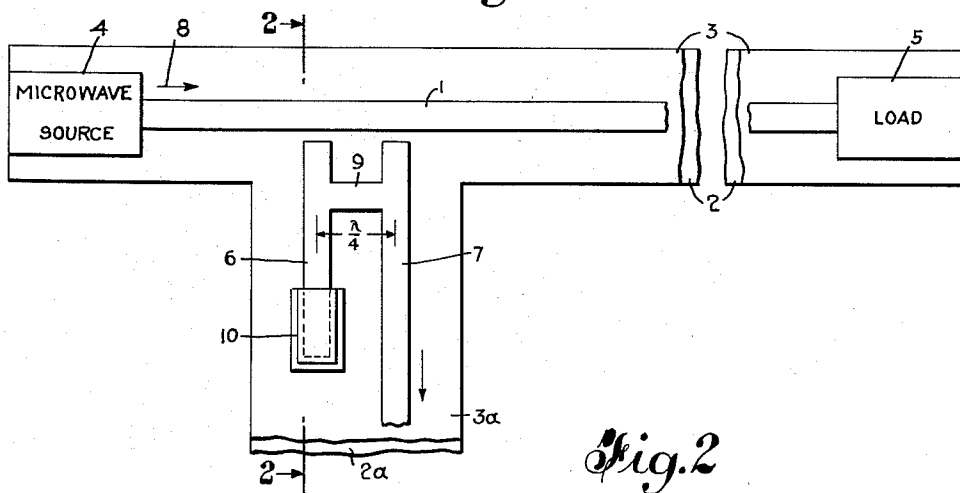


Fig. 2

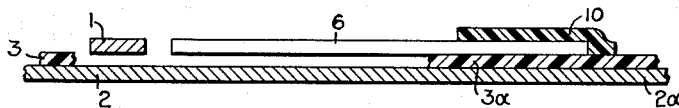


Fig. 3

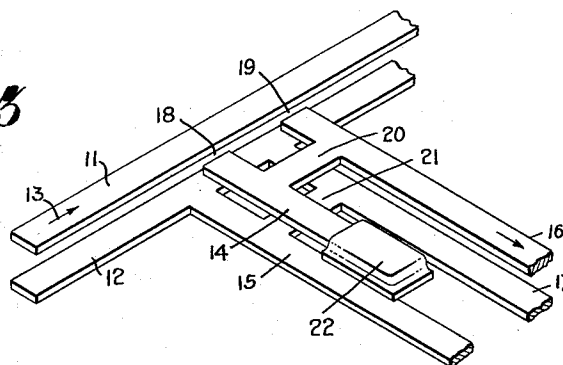
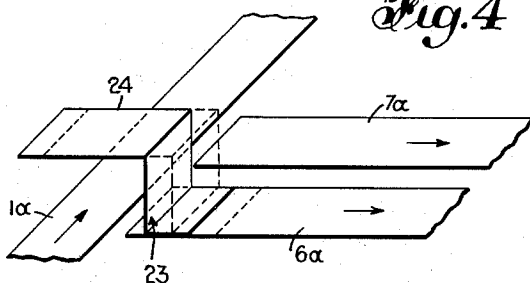


Fig. 4



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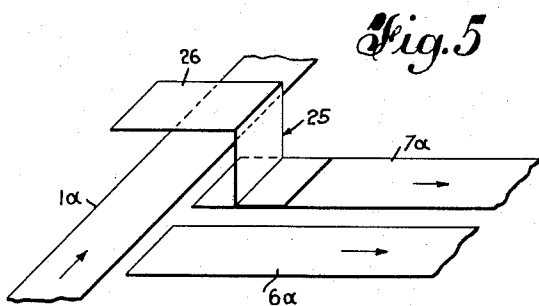
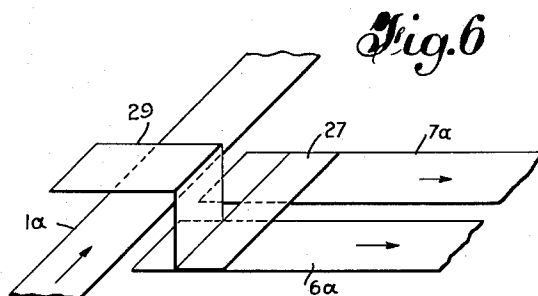
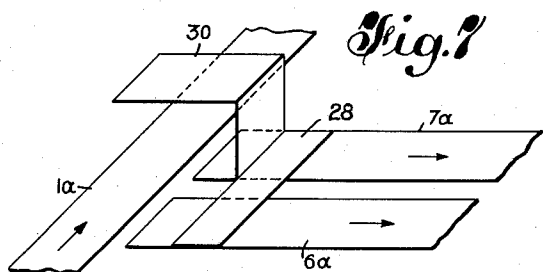
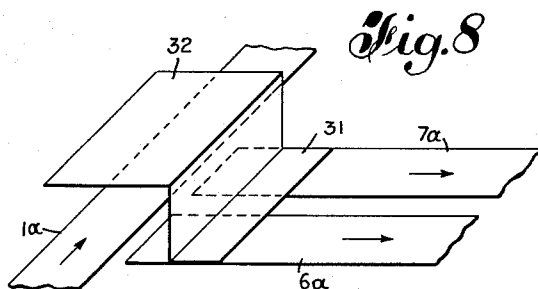
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DIRECTIONAL COUPLERS FOR MICROWAVE TRANSMISSION SYSTEMS

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10 Claims. (Cl. 333—10)

This invention relates to microwave transmission systems and more particularly to directional coupling devices therefor.

In the patent to H. F. Engelmann, No. 2,654,842, dated October 6, 1953, a principle of microwave transmission is disclosed with which the coupling devices of this invention are particularly applicable. The new system employs, usually, two conductors, the first as a "line conductor" and the second as a "ground conductor" spaced close together in substantially parallel relation. The so-called "ground conductor" which may be at ground potential or some other given potential, is preferably wider than the line conductor so that the surface thereof provides in effect an image or mirror reflection of the line conductor, whereby the distribution of the electric and magnetic fields between the conductors is substantially the same as the distribution between one conductor and the neutral plane of a theoretically perfect, two-conductor parallel system. Microwaves can be propagated substantially in the TEM mode along this line-ground conductor system since the microwaves flow in the conductive skin of the opposed surfaces of the line and ground conductors between which the electronic field is most highly concentrated.

One of the objects of this invention is to provide coupling devices for such lines for directive transfer of microwave energy from such lines.

A feature of the invention is the two-point coupling characteristic of the coupling devices. The coupler, for example, includes two conductors disposed in parallel with their ends spaced slightly from the line conductor of the line-ground transmission system, the two conductors being spaced a quarter wavelength apart and provided, in some embodiments, with a cross connection whereby coupling from the transmission line is directive over one or the other of said conductors depending upon direction of energy flow along the transmission line. In this form of coupler more or less coupling may be had by having end extensions partially encircling the line. Also the ground conductor may be substantially identical in width to the line conductor for both the transmission line and the coupling lines, thereby presenting a parallel line system.

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 description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a plan view showing a transmission line-ground conductor system with one form of directional coupling device in accordance with the principles of this invention;

Fig. 2 is a cross-sectional view taken substantially along line 2—2 of Fig. 1;

Fig. 3 is a view in perspective with insulation removed of a directional coupler for parallel printed lines;

Figs. 4 and 5 are views in perspective of a directional coupler utilizing a conductor extension for increasing the coupling; and

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Figs. 6, 7 and 8 show perspective views of additional embodiments of the coupler.

Referring to Figs. 1 and 2 of the drawings, the microwave transmission system illustrated is of the printed circuit type comprising a first or line conductor 1 and a second or ground conductor 2 with a layer of insulating material 3 therebetween. The conductive material may be applied to the layer of insulation in the form of conductive paint or ink, or the conductive material may be chemically deposited, sprayed through a stencil or dusted onto selected surfaces of the insulation according to known circuit printed techniques. If desired, conductive strips may be cut and applied by a die-stamping operation. Also, the line conductor of desired configuration may be obtained by etching a thin conductive coating on one surface of the layer of insulation. Furthermore, conductive lines need not be applied to a layer of insulation but may be supported, if desired, in spaced relation with respect to a sheet of conductive material forming the ground conductor.

The conductor 2, may comprise one of the walls of a chassis or other part of the electric apparatus with which or in which the transmission system is used. The ground conductor 2 may extend a considerable distance laterally with respect to the line conductor but for practical purposes the width of the ground conductor is preferably two or three times the width of the line conductor, a width three times that of the conductor producing the effect of substantially a planar conductor of infinite width. This ratio of widths provides in effect an image reflection of the line conductor so that the distribution of the electric and magnetic fields between the conductors is similar to the distribution between one conductor and the neutral plane of a theoretically perfect two-conductor parallel system. By making the spacing between the two conductors small, for example, a small fraction of the wavelength of the microwave energy propagated, the electric flux distribution is concentrated almost entirely between the opposed surfaces of the two conductors.

Microwave energy may be launched onto the line-ground conductor system by any suitable means, such for example, as a coaxial line or other wave guide line with suitable transition means to minimize the effect of any physical discontinuity at such coupling, the characteristic impedance of the two lines, of course, being matched. Also, by making the spacing between the line-ground conductors a very small fraction of a quarter wavelength, any higher order modes than the TEM mode caused by any physical discontinuity along the line are quickly attenuated.

The microwave energy propagated from source 4 along the line-ground conductor system 1, 2 may be applied to a utilization device 5 which may include a transmitter, receiver or other circuitry. It is often desirable to couple a circuit to a transmission line of such a system for directional branching of energy to determine the flow of energy to a load. As shown in Figs. 1 and 2, the directional coupling device includes a lateral extension 2a of the ground conductor 2 together with a pair of parallel conductors 6 and 7 supported by a layer of dielectric 3a, and disposed at an angle to the first conductor 1. The ends of the conductors 6 and 7 are closely spaced with respect to the conductor 1, as indicated by distance a, and are in addition coupled together by a conductor 9 a distance b from the conductor 1. The conductors 6 and 7 are spaced apart by a distance equal substantially to a quarter wavelength of the transmission system. The branch conductor 6 is terminated in conjunction with an attenuator pad 10 of suitable lossy material to provide a matched termination for the branch. The other branch 7 may be continued to a utilization device such as

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a meter or other circuitry to which energy is desired from the source of propagation.

In operation the two conductor branches of the directional two-point coupler is preferably arranged so that the space dimension therebetween equals approximately a quarter wavelength or an odd multiple thereof. The dimensions a and b may be varied depending upon the degree of coupling desired, the distance a preferably being a very small fraction of a wavelength, while the dimension b may be considerably varied depending on the structure of the circuitry involved. The degree of coupling between the conductors 6 and 7 and the line conductor 1 is determined by the spacing between the ends of the conductors 6, 7 and conductor 1, the closer the spacing the greater the coupling. This spacing preferably is a small fraction of a quarter wavelength. In Figs. 4 to 8, one or both of the conductors 6 and 7 may be provided with an extension which partly surrounds the line conductor 1 in order to provide for more coupling. This may constitute an overlapping of conductors with dielectric material disposed therebetween as in printed circuit technique.

For directive coupling of energy from source 5, the two-point coupler together with the cross connection 9 provides for energy pick-up by the two branches 6 and 7. If the coupling is such as to provide balanced currents in the two branches 6 and 7, the currents will be in phase at the junction of branch 7 and cross connection 9 and out of phase at the junction of branch 6 and cross connection 9. For any reflections from load 4 the phase relation of the coupled energy is opposite to that just described for energy from source 5 so that energy coupled in phase by branches 6 and 7 is attenuated in the attenuator pad 10 on branch 6, thereby providing true directive coupling over the output of branch 7. This phase relationship is made possible by making the distance between conductors 6 and 7 substantially a quarter wavelength or an odd multiple thereof.

In Fig. 3 the same type of coupling as shown in Figs. 1 and 2 is illustrated, wherein the transmission line represents a parallel line system. The main line comprises conductors 11 and 12 over which energy is propagated as indicated by the arrow 13. The two-point coupler comprises two parallel lines 14, 15 and 16, 17. The lower conductors 15 and 17 of the two pairs are connected directly to the second conductor 12 of the main line. The other two conductors 14 and 16 are coupled to the line 11 at right angles thereto through gaps 18 and 19, similarly as shown in the case of the branch line 6 and 7 of Fig. 1. The coupled lines are connected together by cross connections 20 and 21 for directive coupling in accordance with the phase relationship of the coupled energy. The branch line 14, 15 is provided with an attenuator pad 22 for absorption of unwanted energy. It will be clear that the parallel wire system of Fig. 3 provides for directive coupling in a manner similar to that of the strip line illustrated in Figs. 1 and 2.

Figs. 4 and 5 show diagrammatically a strip line coupling similar to Fig. 1 with the ground conductor and dielectric sheet omitted for simplicity of illustration. These two figures, however, show the main line conductor 1a and the two branch conductors 6a and 7a. In Fig. 4, the branch conductor 6a is provided with a conductive extension 23 which has a portion 24 which overlaps in spaced relation the conductor 1a thereby increasing the capacitive coupling of branch 6a with respect to line conductor 1a. In tests, this type of increased coupling provided the branch 6a with a slightly greater flow than that along branch 7a for energy flowing in the direction indicated. In Fig. 5, the branch 7a is provided with an extension 25 having an overlapping portion 26 to increase the coupling for branch 7a over that of branch 6a. This additional coupling for branch 7a was found to provide a much greater coupling for branch 7a than for branch 6a in the form shown in Fig. 4 for the same direction of energy

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flow along 1a. The form shown in Fig. 4, however, tested fairly uniform for ratio of currents in 7a and 6a over frequencies 4500 to 5000 mc. per second while tests for the form shown in Fig. 5 for the same frequencies the ratio changed rapidly, the highest ratio of currents (7a/6a) being at the lower of the frequencies tested.

Figs. 6 and 7 are diagrammatical illustrations of similar couplings with the branch lines 6a and 7a interconnected by a cross strip conductor 27 for Fig. 6 and 28 for Fig. 7. The cross strip conductor 27 is provided with an extension 29 in line with branch 6a to overlie and increase the coupling with respect to the main line 1a. In Fig. 7 the extension 30 of the strip 28 is disposed in line with branch 7a and overlie main conductor 1a for increased coupling. In comparing the directive coupling obtained by branches 6a and 7a, it was noted that the increased coupling obtained by extension 29 increased many times the ratio of currents (7a/6a) as compared to the ratios obtained in like tests of the embodiment shown in Fig. 7.

In Fig. 8 the cross strip 30 was provided with an extension 31 of the same width, that is, a width sufficient to overlie both branch conductors 6a and 7a. This form tested with current ratios (7a/6a) high similarly to those obtained in like tests of the embodiment shown in Fig. 6. Tests of forms in Figs. 4 to 8 included different degrees of coupling for the extensions overlying conductor 1a as indicated by broken lines in Fig. 4.

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 by way of example only 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 coupling device comprising a microwave transmission line having first and second conductors spaced close together in substantially parallel relation, third and fourth conductors disposed in parallel relation to each other substantially one quarter of a wavelength apart, means disposing said third and fourth conductors substantially in a given plane containing said first conductor with said third and fourth conductors at an angle to but in spaced relation with said first conductor, and said second conductor having portions disposed laterally in substantially a second plane parallel to said given plane with said portions in close spaced relation to said third and fourth conductors, at least one of said third and fourth conductors including a portion extending out of said given plane to partially encircle said first conductor.

2. A coupling device according to claim 1, wherein the third conductor includes said portion.

3. A coupling device according to claim 1, wherein the fourth conductor includes said portion.

4. A coupling device according to claim 1, wherein both said third and fourth conductors include a portion partially encircling said first conductor.

5. A coupling device according to claim 1, further including a cross conductor substantially parallel to said first conductor electrically connecting said third and fourth conductors together at points spaced from the ends thereof nearest said first conductor.

6. A coupling device according to claim 5, wherein said cross-conductor includes said portion which partially encircles said first conductor.

7. A coupling device according to claim 1, wherein one of said third and fourth conductors includes termination means to absorb energy flowing therein.

8. A coupling device for microwave transmission systems comprising a layer of dielectric material, a first conductor on one side of said layer, a second conductor on the other side of said layer in close spaced substantially parallel relation to said first conductor, the second conductor being wider than said first conductor thereby presenting a planar surface opposite the first conductor,

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whereby the electromagnetic field is distributed between opposed surfaces of said first and second conductors substantially the same as between the conductor and the neutral plane of a two-conductor parallel system, third and fourth conductors disposed on said one side of said layer in parallel relation to each other substantially one quarter of a wavelength apart, said third and fourth conductors being disposed at an angle to but in spaced relation with said first conductor, said second conductor having an extension disposed in parallel relation to said third and fourth conductors, and a cross conductor substantially a quarter wavelength long electrically connecting together said third and fourth conductors a distance from said first conductor to insure directivity of energy flow along one of said third and fourth conductors depending upon the direction of energy flow along said first and second conductors, said cross conductor including a portion which partially encircles said first conductor.

9. A coupling device for microwave transmission systems comprising a planar sheet of solid dielectrical material, a first planar conductor lying flat against and attached to one face of said sheet, a second planar conductor lying flat against and attached to the opposite face of said sheet, said conductors extending parallel to each other, said sheet spacing said conductors a fraction of a wavelength apart, said second conductor being at least twice as wide as said first conductor with the main portion of an electric field of a wave propagated along said first and second conductors being distributed between the opposed surfaces thereof, third and fourth planar conductors lying flat against said one face of said sheet in parallel overlying relation to said second conductor but at an angle to said first conductor, said third and fourth conductors

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being spaced apart between the center lines thereof by an electrical length substantially equal to a quarter of a wavelength or an odd multiple thereof at the mid-frequency of microwave energy propagated along said first and second conductors, a cross conductor electrically connecting together said third and fourth conductors a distance from said first conductor to insure directivity of energy flow along one of said third and fourth conductors depending upon the direction of energy flow along said first and second conductors, the end portions of said third and fourth conductors between said cross conductor and said first conductor being spaced in close interacting relation to said first conductor but outside said main field and at least one of said third and fourth conductors including a portion extending out of the plane containing said third and fourth conductors to partially encircle a portion of said first conductor.

10. A coupling device according to claim 9 wherein one of said third and fourth conductors includes termination means to absorb energy flowing therein.

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