April 23, 1957 J. A. KOSTRIZA 2,790,148

MICROWAVE COUPLING ARRANGEMENTS

Filed Feb. 4, 1952 2 Sheets-Sheet 1

Fig. 1

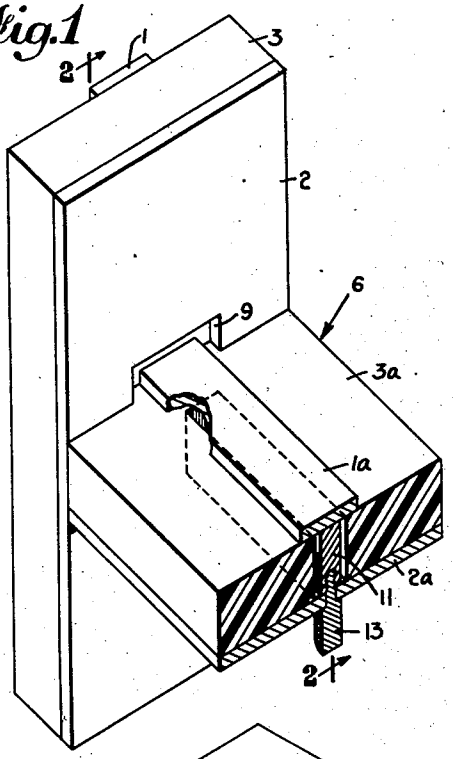


Fig. 2

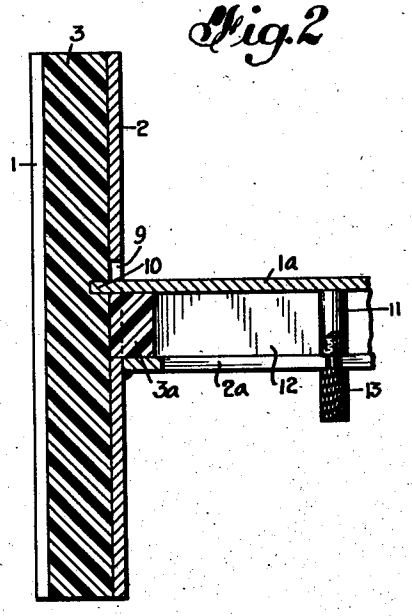


Fig. 6

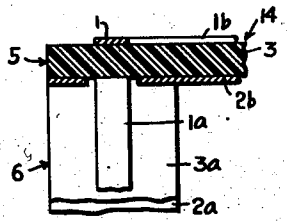


Fig. 5

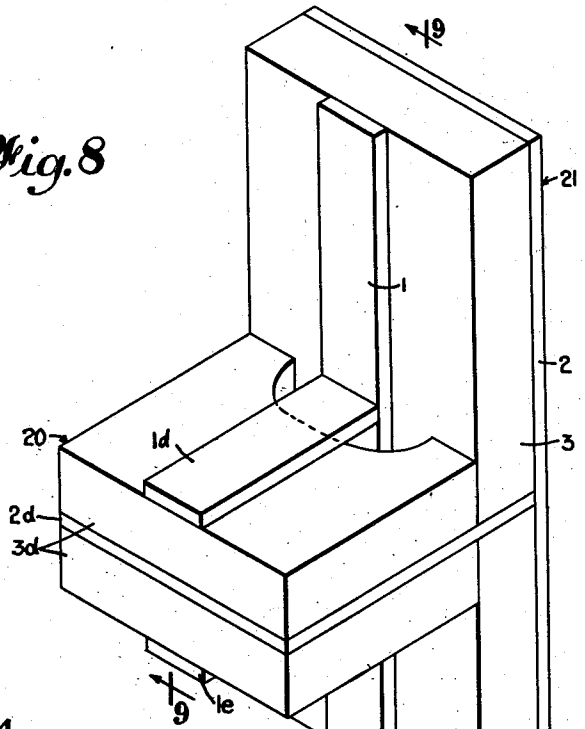
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April 23, 1957 J. A. KOSTRIZA 2,790,148

MICROWAVE COUPLING ARRANGEMENTS

Filed Feb. 4, 1952 2 Sheets-Sheet 2

Fig. 8



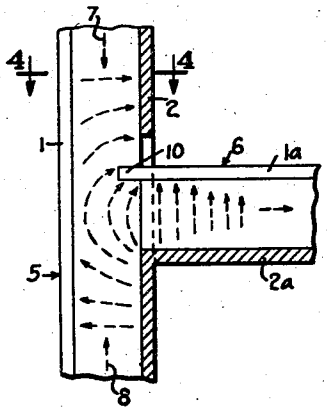


Fig. 5

Fig. 9

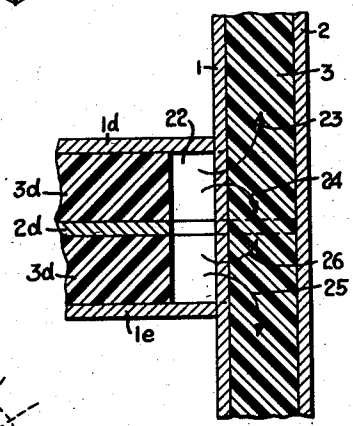
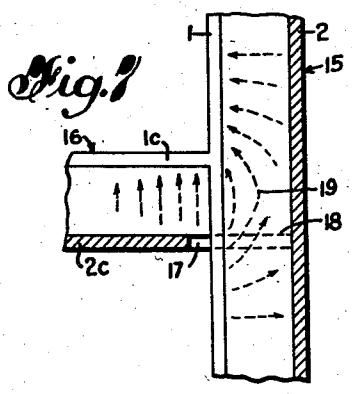


Fig. 7



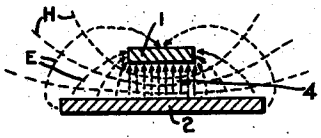


Fig. 4

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MICROWAVE COUPLING ARRANGEMENTS

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Application February 4, 1952, Serial No. 269,717

2 Claims. (Cl. 333—11)

This invention relates to microwave transmission systems and more particularly to coupling arrangements for a new type of microwave transmission system.

In the copending applications of D. D. Grieg and H. F. Englemann, Serial No. 234,503, filed June 30, 1951, now Patent No. 2,721,312, a new principle of microwave transmission is disclosed, comprising in its simplest form two conductors, one as a "ground conductor" and the other as a "line 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 considerably wider than the line conductor so that the surface thereof provides in effect an image 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. Small variations in size and shape of the line conductor may produce variations in the characteristic impedance of the system but the field distribution with respect to the ground conductor is not materially disturbed. Likewise, certain variations in the surface of the ground conductor do not materially disturb the field distribution with respect to the surface thereof since such variations either neutralize each other or do not adversely affect the field distribution between the two conductors. By this system, microwaves can be propagated by a mode closely approximating the TEM mode along the line-ground conductor system.

One of the objects of this invention is to provide coupling arrangements, such as "T-junctions," tuning stubs and combination "E" and "H" junctions, for transmission systems of the character referred to above.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a view in perspective of one form of T-junction in accordance with the principles of this invention;

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

Fig. 3 is a cross-sectional view similar to Fig. 2 with the insulation omitted to indicate the lines of electric intensity;

Fig. 4 is a cross-sectional view taken along line 4—4 of Fig. 3 to show the distribution of the electric field between the line and ground conductors of the transmission line;

Fig. 5 is a view in perspective of a combination "E" and "H" junction;

Fig. 6 is a cross-sectional view taken substantially along line 6—6 of Fig. 5;

Fig. 7 is a cross-sectional view of another form of T-junction showing the distribution of the lines of electrical force;

Fig. 8 is a view in perspective of a T-junction similar to the one shown in Fig. 7 except that one of the branches comprises a double line; and

Fig. 9 is a cross-sectional view taken along line 9—9 of Fig. 8.

Referring to Figs. 1 to 4 of the drawings, one form of T-junction is shown comprising transmission lines of the "line-above-ground" type. Preferably the microwave transmission line is of the printed circuit type comprising a first or "line" conductor 1 and a second or "ground" conductor 2 with a layer 3 of insulating material therebetween. The conductive material may be applied to the layer of insulation, such as polystyrene, polyethylene, polytetrafluoroethylene ("Teflon"), or other flexible insulation of high dielectric quality, in the form of conductive paint or ink, or the conductive material may be chemically deposited, sprayed through a stencil or dusted onto selected prepared surfaces of the insulation according to known printed circuit techniques. For relatively short lengths of lines the conductive strips may be cut and applied by a die-stamping operation. In some cable manufacturing processes, the insulation may be extruded and simultaneously or later coated on the two sides thereof with conductive material of the desired thickness and widths. Where the widths of the two coatings are the same and it is desired to reduce the width of one of the coatings, the portions of the two coatings that are to be retained may be coated with a chemically inert material exposing the parts to be removed, and thereafter passed through an etching bath, whereupon the exposed portions of the conductive coatings are removed. While the two conductive coatings 1 and 2 are shown in cross-section to be substantially rectangular, they may comprise different shapes so long as the ground conductor 2 presents a wide extended surface with respect to the line conductor. Preferably, the ground conductor should be from two to three times the width of the line conductor 1, although wider dimensions give still lower loss. The electric field concentrated for a ratio of widths of line to ground conductors of 1 to 3 is found to range from about 95 percent to approximately 99 percent. From the foregoing it is clear that a narrow ground conductor may be used without much radiation loss, and where it can be three or more times the width of the line conductor, an exceptionally low loss transmission line is assured. For further information on various "line-above-ground" cable constructions, reference may be had to the aforementioned copending application, Serial No. 234,503, now Patent No. 2,721,312.

From the foregoing description of a line-above-ground transmission system, it will be clear that such a conductor arrangement is similar to a rectangular waveguide especially where the line conductor is of flat strip form. Whether or not the line conductor is round, oval or flat, wave propagation is predominantly of one polarization, that is, the concentration of lines of electrical force 4 are substantially perpendicular to the opposed surfaces of the line and ground conductors (see Fig. 4). It will be understood from this that the spacing of the two conductors comprises a very small fraction of a wavelength of the microwave propagated therealong and that this spacing is usually less than the diameter or width of the line conductor 1.

Referring more particularly to Figs. 1, 2, and 3, a straight piece of transmission line 5 is shown to which, at right angles, another similar transmission line has been joined in the electric or "E" plane, that is the plane parallel to the densest group of electric lines of force. In Fig. 1 the perpendicular branch line is shown in the form of a tuning stub 6 and comprises a line conductor 1*a* and a ground conductor 2*a*. This right angle line need not be a stub tuner but may comprise a branch line for coupling

purposes. Assuming this to be the case, and that the coupled lines are properly matched, the lines of the electric field intensity may be represented as indicated in Fig. 3. Assuming that two waves are propagated along the two branches of section **5** as indicated by the arrows **7** and **8**, 180° out of phase a maximum transmission to the right angle line **6** will result. Likewise, if a wave is received over branch line **6**, it would tend to divide equally between the other two branches. If the waves propagated along the two branches as indicated by **7** and **8** were in phase and of equal magnitude, then the power transfer to the third branch **6** would be equally divided and 180° out of phase, thereby resulting in zero power transmission along branch **6**.

In this respect the T-junction is similar to an E-plane T-junction of the rectangular waveguide form. It should be noted, however, that the method of joining the branch **6** to the transmission line section **5** is such that the ground conductor **2***a* is directly connected to the ground conductor **2** and the line conductor **1***a* is terminated, in an opening **9** cut through conductor **2**. The size of the opening about the conductor **1***a* as well as the point of termination **10** of the conductor **1***a* will play a part in the matching of the junction. The location of the perpendicular branch **6** in a transmission line may or may not receive power depending upon the voltage maximum of the standing wave along the transmission line. Should the junction be at the voltage maximum, then no power will be received; but should it be located at a voltage minimum, then maximum power would be received.

The particular form of branch **6** shown in Figs. 1 and 2 includes an adjustable conductor **11** for shorting the line **1***a* to the ground conductor **2***a*. The insulation **3***a* is provided with a slot **12** whereby the short **11** can be moved lengthwise of the line thereby determining the length of the stub. The short is provided with a knob **13** for manipulation. By adjusting the short **11**, the length of the stub for reflection of wave energy may be determined as desired, whereby the apparent impedance for waves traveling along line **5** may be varied.

In Figs. 5 and 6 a transmission line coupling is shown wherein a transmission line section has one branch line series "E" coupled thereto and another branch line parallel "H" coupled thereto. The series coupling is similar to the one described in connection with Figs. 1 to 4. The same reference characters are used for corresponding parts in Fig. 5. The additional branch which is parallel coupled to the line **5** is shown as branch line **14**. The line conductor **1***b* thereof is directly connected to the line conductor **1** at right angles as indicated in Fig. 6. The straight line **5** functions as the 'through arms" of the junction, branch **6** functions as a series or E-arm and branch **14** functions as a parallel or H-arm.

In Fig. 7 another form of T-junction is shown comprising a section **15** of a conductor-above-ground transmission line similarly as described in connection with Figs. 1 to 4, to which is joined, at right angles, a branch line **16**. The branch line, however, is joined to the side of the line **15** on which the line conductor **1** is disposed. The line conductor **1***c* of section **16** is directly connected to the line conductor **1** and the ground conductor **2***c* is provided with a cut-out **17** to provide spaced relation about the conductor **1**, the ground conductor **2***c* being joined at lateral points **18** to the ground conductor **2**. This manner of connecting the two sections of line conductor-above-ground transmission lines provides for a similar field distribution as indicated for the form illustrated in Figs. 1 to 4. Assuming that a wave is propagated over branch line **16** toward the junction, the electric field distribution is believed to follow substantially the lines of force indicated at **19** dividing the energy substantially equally between the two branches of the line **15**. The energy division in opposite directions assumes 180° phase relation substantially as indicated. The converse is also true as described in connection with the junction of Figs. 1 to 4. Where two waves are received in opposite directions over the section **15**, the energy transfer to the branch line **16** will depend upon the point of coupling, that is whether the coupling is at a maximum voltage point or a minimum voltage point.

The form shown in Figs. 8 and 9 is substantially identical to the form shown in Fig. 7 with the exception that the right angle branch **20** is provided with a parallel or double conductor-above-ground transmission line. The branch **20** for example comprises a ground conductor **1***d* which is joined directly with the ground conductor **2** of transmission line section **21** and two line conductors **1***d* and **1***e* separated from the ground conductor **1***d* by layers of insulation **3***d*. The ground conductor **1***d* as well as the layers of insulation **3***d* are provided with cut-out portions as indicated at **22** to accommodate in spaced relation the line conductor **1**.

The double branch line properly matched provides for directive coupling as suggested by arrows **23**, **24** and **25**, **26**, Fig. 9. The opposed arrows **24** and **26** tend to cancel, especially when the waves are of equal magnitude and phase. If not equal, either in magnitude or phase an unbalanced distribution results.

While I have described above the principles of my 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 my invention, as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A transmission line coupler having a plurality of branch lines each comprising a first conductor, a second conductor and means to dispose said conductors in substantially parallel dielectrically spaced relation, said second conductor being substantially flat with the width thereof greater than the width of said first conductor to present thereto a planar surface, said first conductor being centrally located with respect to said second conductor, two of said branches being coupled in end-to-end relationship, a third branch being coupled perpendicularly to the said two branches at the junction thereof in "E" series relation, said second conductors of said two branch lines and said third branch line being in substantial width alignment, the second conductor of said third branch being coupled electrically to the second conductors of said two branches and the first conductor of said third branch being coupled electrically to the first conductors of said two branches in the electric field thereof, a fourth branch coupled to said two branches in "H" parallel relation at right angles to said third branch, the second conductor of said fourth branch being coupled to the second conductors of said two branches and lying in the plane thereof.

2. A transmission line coupler having a plurality of branch lines, each comprising a first conductor, a second conductor and a layer of dielectric material separating the conductors in substantially parallel relation, said second conductor being substantially flat with the width thereof greater than the width of said first conductor, said first conductor being centrally located with respect to said second conductor, two of said branches being coupled in substantially aligned end-to-end relationship with a third branch coupled perpendicularly to the junction of said two branches such that the plane of said third branch is perpendicular to the longitudinal axes of said two branches, the second conductor of said third branch being directly connected to the said second conductors of said two branches, the said second conductors of said two branches being provided with a cutout so that the first conductor of said third branch can pass through said cutout thereby electrically coupling the third branch with said two branches at the said junction thereof, and a fourth branch directly connected at right angles to said

two branches at the junction thereof, said fourth branch being in the same plane as said two branches.

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