June 9, 1953 S. SENSIPER 2,641,648

DIRECTIONAL COUPLER

Filed Jan. 25, 1949

Fig. 1A.

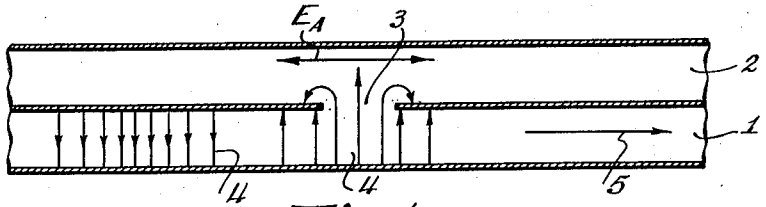


Fig. 1B.

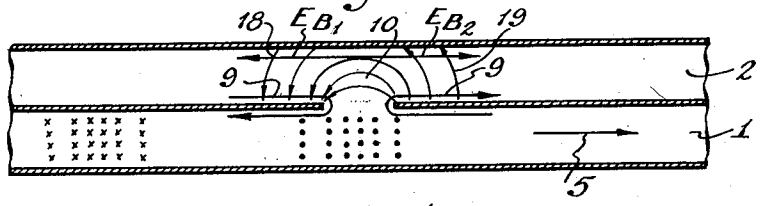


Fig. 1C.

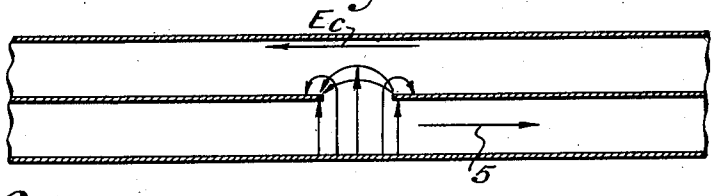


Fig. 2A.

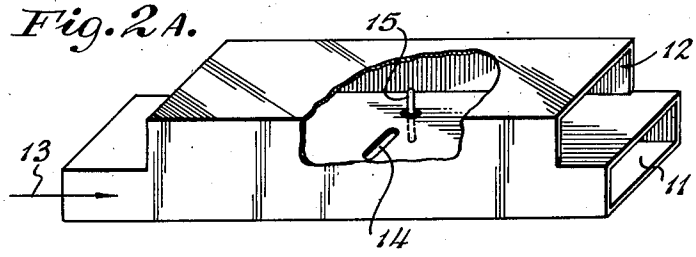


Fig. 2B.

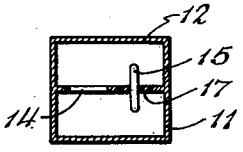


Fig. 2C.

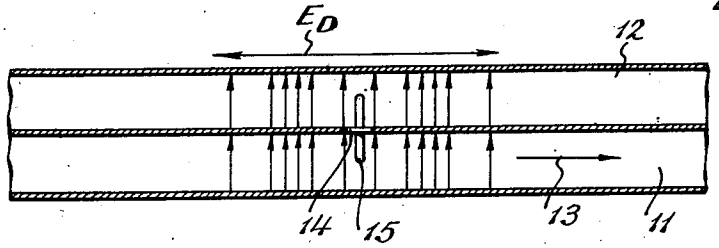
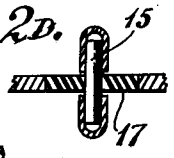


Fig. 2D.



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DIRECTIONAL COUPLER

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The present invention relates to electromagnetic energy couplers between ultra high frequency energy transmission lines, such as wave guides, coaxial lines, or the like, and in particular relates to directional couplers between two such ultra high frequency transmission lines.

In order to connect measuring apparatus to an ultra high frequency energy transmission system, some means of radio frequency energy coupling must be provided. Such coupling means operate independently of the standing waves which may exist in the transmission line, and the amount of power which is extracted from the transmission line should preferably be a definite fraction of the power which is to be transmitted along the main transmission line. To obtain these advantageous conditions, it is highly desirable that the coupler operate in such a manner that an electromagnetic wave travelling in a single direction along the main line induce a wave travelling in a single direction along the coupling line. Likewise, a wave travelling in the opposite direction in the main line should induce a wave travelling in the opposite direction in the coupling line. A coupler which has these properties is known as a "directional coupler."

The performance of a directional coupler may be described in terms of three quantities:

(1) *Attenuation*

The attenuation of a coupler is the strength of the travelling wave in the main line relative to the strength of the travelling wave which it induces in the auxiliary or coupling line. This is a power ratio, usually expressed in decibels.

(2) *Directivity*

Only in the ideal coupler does a single wave travelling in the main line induce a wave travelling in a single direction in the second line. In a practical coupler, two waves travelling in opposite directions are induced in the auxiliary line. The induced waves are normally greatly unequal in strength. Their relative strength is the directivity of the coupler, also expressed in decibels.

(3) *Bandwidth*

The bandwidth over which the coupler provides maximum directivity with minimum attenuation is important in many installations. It is particularly desirable to provide a wide bandwidth of operation to extend the useful operating range of the coupler so that one coupler can do the same job that a number of different couplers formerly did.

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Typical directional couplers of the prior art for coaxial lines and wave guides are shown by Terman in Radio Engineering, published 1947, by McGraw-Hill, pages 112 to 141. One type of these couplings comprises a pair of parallel wave guides having two coupling holes spaced one-quarter wavelength apart. In the secondary wave guide, propagation is reenforced in a desired direction and cancelled in the opposite direction due to the half wavelength difference in path of travel. The disadvantages of this type coupler is that it is frequency sensitive, and has a narrow useful bandwidth due to the quarter wavelength limitation.

Another typical prior art coupler shown in the Terman reference is the single hole, or Bethe hole, coupler in which both electrical and magnetic coupling takes place through the same opening. In this type coupling the electric field produces energy flow in both directions in the secondary line, where the waves in the secondary line travelling away from the coupling point are essentially in phase at the coupling point; the magnetic field produces energy flow in both directions in the secondary line, but the waves in the secondary line travelling away from the coupling point are essentially 180° out of phase at the coupling point. The magnetic coupling is proportional to the cosine of the angle at which the primary and secondary guides cross, whereas the electrostatic coupling is independent of this angle. Therefore the ratio of the couplings may be controlled so that they reenforce each other in one direction and cancel each other in the opposite direction by adjusting the angle between the primary and secondary guides. Good directivity in the secondary guide is obtained at an angle of approximately 63 degrees. This single hole coupler has the disadvantage of having a bulky and inconveneint wave guide joint due to the required large angle between the guides. The coupler is merely a single hole and there are no parameters to adjust.

Accordingly, the principal object of the invention is to provide an improved wide band directional coupler for ultra high frequency transmission lines.

Another object of the invention is to provide an improved directional coupler which is not frequency sensitive.

Another object of the invention is to provide a directional coupler having substantially independent magnetic and electric coupling.

Another object of the invention is to pro-

vide a directional coupler having independently variable electric and magnetic coupling.

Another object of the present invention is to provide a directional coupler in which the magnetic coupling may be varied without changing the angle between the transmission lines.

Another object of the present invention is to provide a directional coupler having additional substantially independent parameters for design purposes.

The present invention provides a directional coupler having substantially independent electric field and magnetic field coupling means. The electric coupling is accomplished by a probe and the magnetic coupling by a slot opening. Both of these couplings are in the same transverse plane of the guides, and they are substantially independent of each other. Thus, the frequency sensitive space factor of a multi-hole coupler is eliminated. In the present invention no frequency sensitivity results from space separation.

The fact that the electric and magnetic couplings are substantially independent provides parameters for adjustment for frequency insensitivity.

The single hole, or Bethe directional coupler is well known in the art, and is analyzed in the "Principles of Radar," by the M. I. T. Radar School Staff, published by McGraw-Hill, chapter 10, page 33, but it will be briefly reviewed here for the purpose of explaining the present invention.

Figs. 1A–1C illustrate a conventional single hole or Bethe directional coupler, Fig. 1A being the side view showing the main and auxiliary wave guides 1 and 2 which are joined together along their wide side, and the single coupling hole 3. The electric field is illustrated by the electric vectors 4 and the direction of energy flow in the main guide 1 shown by the arrow 5. The electric vectors 4 fringe through the hole 3 and excite the auxiliary guide 2 in both directions as shown by the arrow E_A.

Fig. 1B is the same side view of the guides showing the portion of the magnetic field, illustrated by the dots and crosses, which is transverse to the longitudinal axis of the guides 1 and 2. This magnetic field creates an electric field 10 across the coupling hole 3 due to the charge currents 9 caused by the magnetic fields which flow along the walls of the guides. This excitation results in waves travelling in both directions as shown by arrow E_{B1} and E_{B2} but the phase of the electric fields is opposite as shown by the electric vectors 18 and 19.

Fig. 1C shows the two coupled electric fields of Figs. 1A and 1B superimposed, and illustrates that they reenforce each other to the left, and tend to cancel each other to the right, thereby producing the desired directional wave E_C. As previously mentioned the two fields do not completely cancel and it is necessary to skew the longitudinal axes of the guides to thereby vary the magnetic coupling for complete cancellation. The present invention obtains this cancellation without skewing the guides.

Fig. 2A illustrates the directional coupler of the present invention which operates similarly to the conventional single hole coupler of Figs. 1A–1C. It comprises main and auxiliary wave guides 11 and 12, direction of power flow being shown by the arrow 13, a slot 14 and a probe 15 coupling the two guides and being in the same transverse plane relative to the guides. Fig. 2B is the cross-section of Fig. 2A showing how probe 15 is mounted. Probe 15 is preferably insulated as by washer 17.

Fig. 2C shows the action of the probe 15 coupling the electric vector into the auxiliary guide 12. The probe 15 acts very much like an antenna exciting waves in the auxiliary guide 12 in both directions as shown by arrows E_D. The slot 14 couples the magnetic field into the auxiliary guide 12 in the same manner as the single hole coupler of Figs. 1A–1C. However, the fringing of the electric fields is minimized due to the narrowness of the slot.

Therefore the present invention acts similarly to the single hole coupler but has the advantages of the additional probe which provides extra parameters such as size of probe and slot and their spacing for choosing of the relative magnitudes of the coupled fields. By properly choosing the size of the slot 14, probe 15, the cancellation of the fields in the auxiliary guide and therefore directivity may be obtained without skewing the wave guides to an inconvenient angle, such as is required in the conventional single hole coupler. The probe may be made adjustable by making it of telescoping portions as shown in Fig. 2D.

The advantage is that the magnetic and electric coupling adjustments have been separated. This invention avoids frequency sensitivity resulting from separation. The invention is not limited to wave guides but may also be used with coaxial lines.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A wide band directional coupler including a pair of hollow tube wave guides, said wave guides extending in parallel adjacent relationship with a common side between, and a probe extending through the common side and projecting partly into the interior of each of the wave guides for coupling the electric fields, the common side having a longitudinal slot therethrough coupling the magnetic fields, the maximum dimension of the slot being perpendicular to the longitudinal axis of each of the wave guides, the slot and probe being positioned adjacent each other and centered in the same transverse plane relative to the longitudinal axes of the wave guides.

2. A wide band directional coupler comprising a pair of rectangular hollow wave guides extending in parallel relationship with a common broad wall therebetween, said common broad wall having first and second separate openings therein centered along a line extending in a direction perpendicular to the longitudinal axis of each of said wave guides, the second opening being an elongated slot having its longitudinal axis aligned with the center of said first opening, and a conductive probe element extending through said first opening and projecting an appreciable distance into the interior of each of said wave guides, the ends of said probe element being spaced from the walls of the respective wave guides, the probe element being supported by and insulated from said common broad wall.

3. A wide band directional coupler comprising

a pair of rectangular hollow pipe wave guides, said wave guides extending in parallel adjacent relationship with a common broad wall section therebetween, said common broad wall section having a straight narrow slit opening therein having its maximum dimension in a plane perpendicular to the longitudinal axis of each of said wave guides, and a conductive probe element insulatingly supported by said common broad wall section, said conductive probe element being centered in said perpendicular plane and projecting part-way across the interior of each said wave guides.

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