# United States Patent [19]

**Beguin et al.**

[11] **3,758,879**

[45] **Sept. 11, 1973**

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[54] **VARIABLE DIRECTIONAL COUPLER**

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[73] Assignee: **International Standard Electric Corporation**, New York, N.Y.

[22] Filed: **Aug. 30, 1972**

[21] Appl. No.: **284,821**

[30] **Foreign Application Priority Data**

Aug. 31, 1971 France .............................. 7131466

[52] **U.S. Cl.** ..................... **333/10,** 333/11, 333/98 R

[51] **Int. Cl.** ........................... **H01p 5/12,** H01p 5/14

[58] **Field of Search** ........................ 333/10, 11, 98 R

[56] **References Cited**

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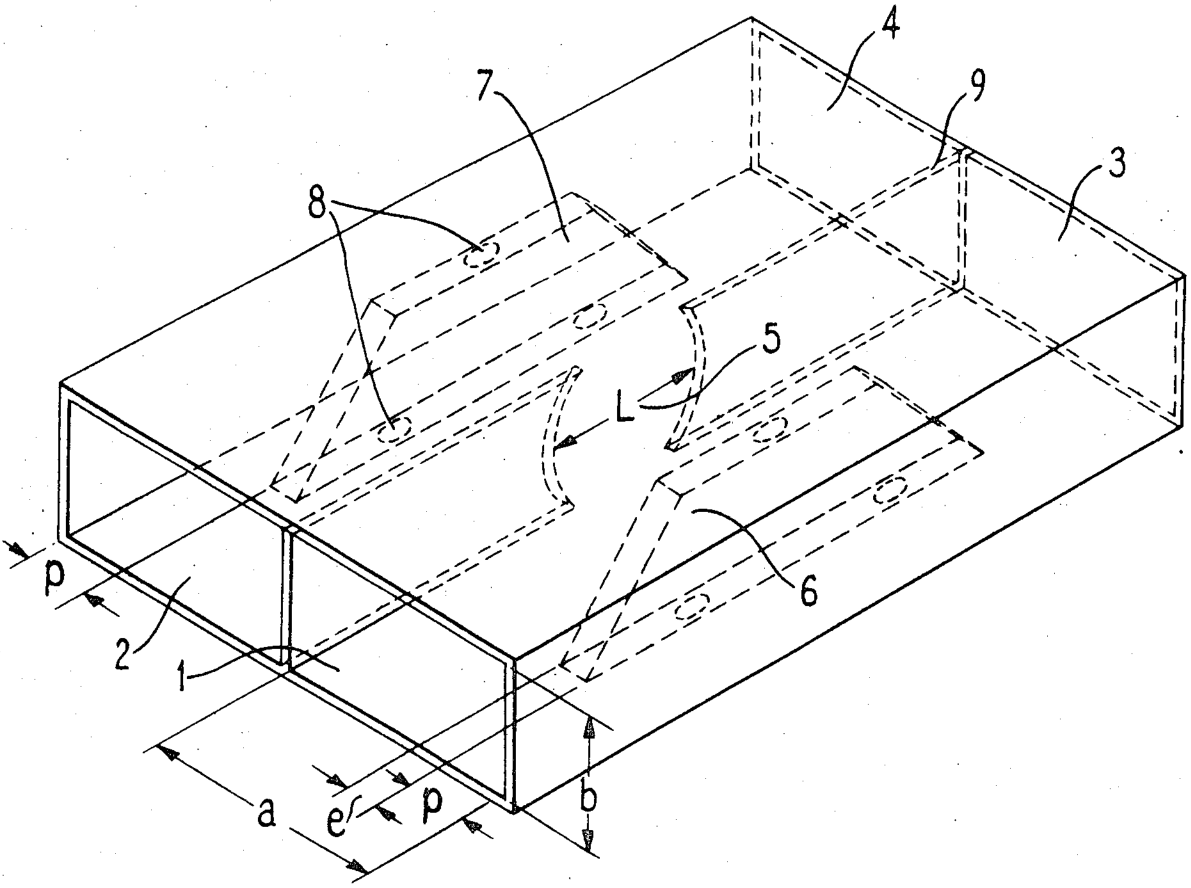
| 2,739,287 | 3/1956 | Riblet | 333/10 X |

*Primary Examiner*—Rudolph V. Rolinec
*Assistant Examiner*—Marvin Nussbaum
*Attorney*—C. Cornell Remsen, Jr.

[57] **ABSTRACT**

This invention relates to a microwave directional coupler, having an easily adjustable coupling coefficient. In a short-slot hybrid junction comprising two adjacent waveguide sections having a common sidewall with a coupling slot, two dielectric slabs having their planes parallel to the common wall plane are disposed, in front of the slot, respectively in the two waveguide sections and symmetrically with respect to the common wall. Variations of the coupling coefficient are obtained by moving symmetrically the two slabs in a direction perpendicular to the common wall. This solution preserves the decoupling and matching characteristics of the coupler.

**5 Claims, 6 Drawing Figures**



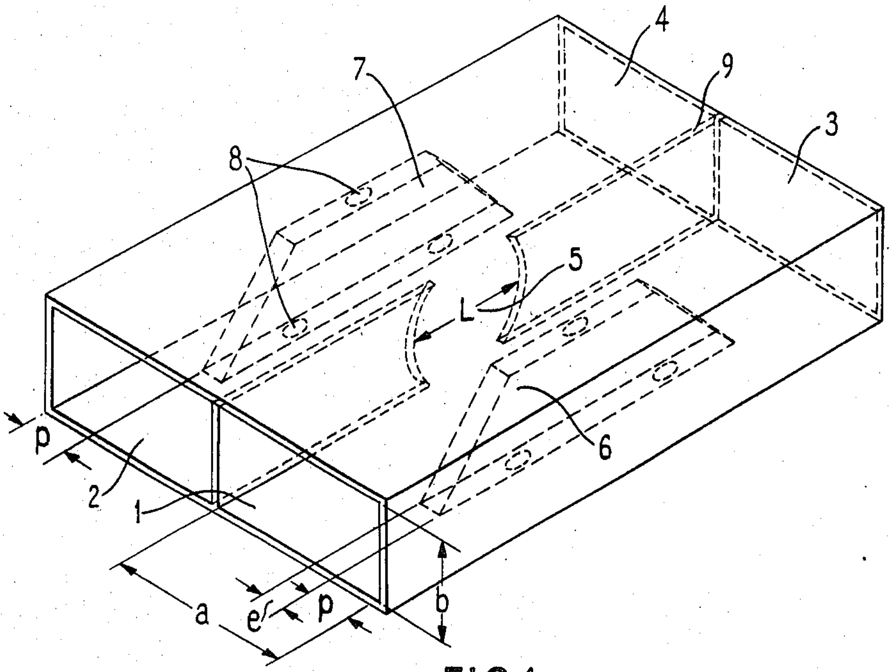
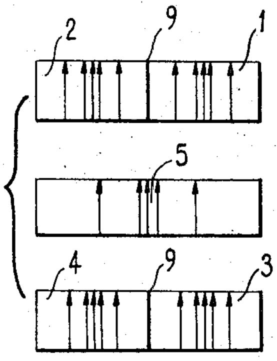


FIG.1

FIG.2a



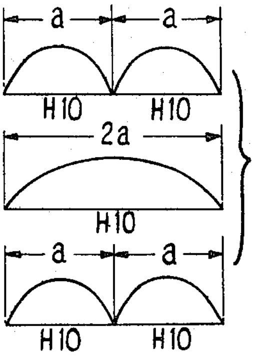


FIG.2b

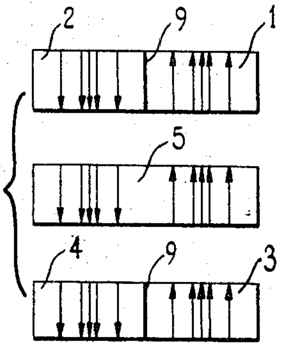


FIG.3a

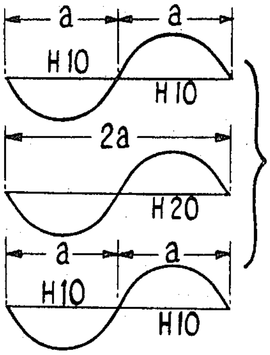


FIG.3b

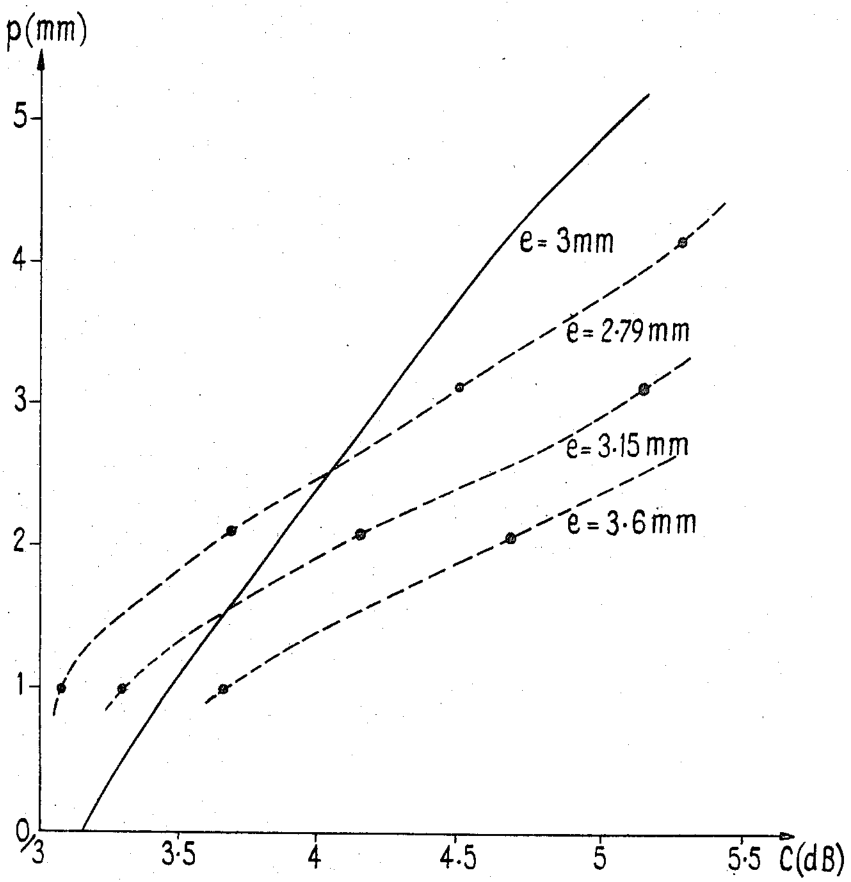


FIG.4

# VARIABLE DIRECTIONAL COUPLER

## BACKGROUND OF THE INVENTION

This invention relates to a directional coupler for microwaves which permits the coupling coefficient to be easily adjusted.

In numerous microwave applications, where it is required to split microwave energy, as for example in feeding antenna arrays, it is very useful to have available directional couplers having different coupling coefficients that are adjusted to have different predetermined values.

Several solutions are known. A first consists of varying the coupling hole sizes so as to vary the coupling coefficient. However, this process is relatively expensive and difficult to deal with because it requires specific machining for each coupling coefficient value.

A second solution has been recommended for couplers, hereafter referred to as topwall or broad wall couplers, having a coupling slot which is small with respect to wave length, described for example in the article "Directive couplers in wave guides" by M. Surdin, issued in the "Journal I.E.E." review, vol. 93, 1946, pages 725–735. In such couplers comprising two waveguide sections coupled through their broad walls, the electric field intensity is varied at the coupling slot by inserting into one or both waveguide sections dielectric slabs normal to the common broad wall including the coupling slot. The dielectric slabs are movable along a direction parallel to that broad wall and normal to the corresponding waveguide portion axis so as to vary the electric field intensity on the coupling slot and thus change the coupling coefficient. However, such couplers produce only relatively low couplings (coupling coefficient having a value higher than 10 dB). In addition, this technique cannot be applied to so-called sidewall couplers with two waveguide sections coupled through their sidewalls.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a sidewall coupler having an easily adjustable coupling coefficient.

It is a further object of the present invention to provide such a coupler of the "short-slot hybrid junction" type with a coupling coefficient adjustable to about 3 dB.

According to a broad aspect of the invention, there is provided an improved directional sidewall coupler of the type wherein first and second waveguide sections having a sidewall as a common wall are provided with a coupling slot, wherein the improvement comprises first and second dielectric slabs positioned within said first and second waveguide sections, respectively, symmetrically with respect to said common wall in front of said coupling slot, and having planes which are parallel to said common wall, and means for positioning the plane positions of said slabs with respect to said common wall.

Other advantages and features of the invention will appear more clearly from the following description of the invention, said description being made in conjunction with the accompanying drawings, in which:

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of the directional coupler according to the invention;

FIGS. 2*a*, 2*b*, 3*a*, and 3*b* are diagrams to explain coupler operation; and

FIG. 4 shows curves illustrating variations of coupling coefficient as a function of dielectric slab position.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a directional coupler of the short-slot hybrid junction type as described, for example, in the article "The short-slot hybrid junction" by H. J. Riblet, issued in the review "Proceedings of the I.R.E." of February 1952, pages 180–184. Such a coupler is a sidewall coupler comprising two waveguide sections having cross-sectional diemsnions a and b and having a sidewall as a common wall **9**, said common wall **9** being provided with a coupling slot **5** of length L. Such a coupler has four ports, two, **1** and **3**, on the main waveguide, and two, **2** and **4**, on the auxiliary waveguide.

According to the invention, there are provided in each waveguide section, in front of coupling slot **5** and symmetrically with respect to the plane of common wall **9**, a dielectric material slab, either **6** or **7**, respectively, of thickness *e* whose plane is parallel to the plane of common wall **9**. The distance from each plate to the external side wall of each waveguide section is indicated by *p*. By changing distance *p*, the coupling coefficient is varied in the coupler. As shown in FIG. **1**, dielectric slabs are fixed with feet **8** which are themselves fixed to the waveguide broad walls, slabs **6** and **7** being forced between feet **8**. Of course, the slabs may also be directly fixed to waveguide walls. Operation of the coupler according to the invention will be described with reference to FIGS. **2** and **3** which make it possible to analyze coupler operation by means of two distinct modes A and B. Parts (*a*) in FIGS. **2** and **3** illustrate electric field configurations in various coupler cross-sections corresponding to ports **1** and **2**, to slot **5** and to ports **3** and **4**, respectively. Parts (*b*) of FIGS. **2** and **3** illustrate electric field amplitude patterns in those same cross-sections. In mode A, FIG. **2**, it is assumed that two phased transverse-electric modes $H_{10}$ are excited in both waveguide sections on ports **1** and **2** in such a manner that electric field amplitudes are given by:

$E'_1 = ½$

$E'_2 = ½$ .

In front of the coupling slot and assuming that dielectric slabs have been removed, it results a waveguide with a double broad wall 2*a* wherein a mode $H_{10}$ is propagated. Thus, on ports **3** and **4** electric fields will be:

$E'_3 = e^{-j\,\beta_1\,L/2}$

$E'_4 = e^{-j\,\beta_1\,L/2}$

where $\beta_1$ is the propagation constant for mode $H_{10}$ in waveguide of dimension 2*a* and disregarding propagation through waveguide sections of width a that is performed in an identical manner in operation modes A and B.

In operation mode B, FIG. **3**, assumption is made that two opposite phase modes $H_{10}$ are excited in the two ports **1** and **2**, such that:

$E''_1 = ½$

$E''_2 = -½$ .

In front of coupling slot **5** in waveguide of dimension 2*a* (dielectric slabs having been removed), a mode $H_{20}$

will be propagated and, in a same manner as previously, it results in ports **3** and **4**:

$E''_3 = e^{-J\beta_2 \; L/2}$

$E''_4 = - e^{-J\beta_2 \; L/2}$

where $\beta_2$ is the propagation constant for the mode $H_{20}$ in the waveguide of width **2***a*.

If modes A and B are superimposed, it results

$$E_1 = E'_1 + E''_1 = 1 \qquad E_2 = E'_2 + E''_2 = 0$$

$$E_3 = \frac{e^{-j\beta_1 L} + e^{-j\beta_2 L}}{2} = e^{-j(\beta_1+\beta_2)L/2} \cdot \cos\ (\beta_1 - \beta_2)\ \frac{L}{2}$$

$$E_4 = \frac{e^{-j\beta_1 L} - e^{-j\beta_2 L}}{2} = -je^{-j(\beta_1+\beta_2)L/2} \cdot \sin\ (\beta_1 - \beta_2)\ \frac{L}{2} \cdot$$

Thus it appears that, when microwave energy is applied to port **1**, port **2** is entirely decoupled and that energy is coupled to port **4**, the coupling coefficient being equal to:

$C = (E_1)^2/(E_4)^2 = 1/\sin^2\ (\beta_1 - \beta_2)\ L/2.$

According to the invention, use is made of dielectric slabs inserted parallel to the common wall into the waveguide of width **2***a*, which causes the propagation constants $\beta_1$ and $\beta_2$ to vary as a function of slab position in the waveguide and, this, in a different manner for modes $H_{10}$ and $H_{20}$. Thus, the amount $\beta_1 - \beta_2$ is varied and, as a consequence, the coupling coefficient *C*.

A good matching is maintained for the coupler by shaping the slabs as an isosceles trapezium. A good decoupling is maintained for the coupler by locating the two dielectric plates in symmetric positions with respect to the common wall **9**. The relative phase shift between the two outputs **3** and **4** remains equal to $\pi/2$.

Phase shifts between inputs and outputs vary with the coupling coefficient. Indeed, when *p* is varied, it causes the amount $(\beta_1+\beta_2)$ to vary. The low selectivity advantages of the initial coupler, without dielectric slabs, still exist in the coupler according to the invention. In a preferred embodiment, the dimension a is so selected that, in the waveguide of width **2***a* in front of the coupling slot, there exists only the modes $H_{10}$ and $H_{20}$.

In a typical embodiment, waveguide sections of width $a = 21.15$ mm were used for a frequency range centered on 9.500 MHz. The length *L* was so selected that, the dielectric slabs being removed, a coupling coefficient of 3 dB 1 reached at 9.500 MHz, i.e. $(\beta_1 - \beta_2)\ L/2 = \pi/4$ and $L = 30$ mm.

The dielectric slabs used were made of polytetrafluoroethylene, known under TEFLON (trademark) of dielectric constant 2.1. Each trapezoid-shaped slab has a broad base of 4 cm, a narrow base of 2 cm and a thickness $e = 3$ mm. Each slab was fixed by feet made of a copolymer of styrene, known under REXOLITE (trademark) of dielectric constant 2.54, which may be easily fixed to metal waveguide walls.

The full-line curve of FIG. **4** represents measured coupling coefficient variations as a function of the distance *p* for the so designed coupler. Dotted lines of FIG. **4** are theoretical curves for various values of thicknesses *e*, as shown in FIG. **4**. Those theoretical values have been calculated from the theory given by R. Seckelmann in the article entitled "Propagation of the TE modes in dielectric loaded waveguides" issued in the IEEE Transactions on Microwave Theory and Techniques, vol. MTT–14 No. 11, November, 1966, pages 518–527.

It is to be noted that *C* may be continuously varied between 3.1 and 5 dB. Differences from theoretical values to measured values may mainly result from approximations introduced into the above-mentioned theory as well as, among other, from the discontinuity influence produced by the coupling slot for wave of mode $H_{10}$ which passes from a width-*a* waveguide to a width-**2***a* waveguide.

The desired coupling may be achieved with an accuracy of ± 0.05 dB, provided that dielectric slabs are positioned with an accuracy of ± 1/10 mm.

The coupler, illustrated in FIG. **1**, has been made with dielectric material slabs which are secured to waveguide section broad walls. But obviously, mobile slabs, movable by any known means, may also be used and, for instance moved by mechanical means, provided that however slab moves be always symmetrical with respect to common wall **9**.

Of course, the described embodiment does not limit the scope of the invention and the principle thereof could also apply to other types of couplers with long or short slots. The principle of the invention may also apply to broad wall coupler with large coupling slot. But this would raise important problems about electric field distorsion and matching which does not exist for sidewall couplers.

We claim:

**1.** An improved directional sidewall coupler of the type wherein first and second waveguide sections having a sidewall as a common wall are provided with a coupling slot, wherein the improvement comprises:

first and second dielectric slabs positioned within said first and second waveguide sections, respectively, symmetrically with respect to said common wall in front of said coupling slot, and having planes which are parallel to said common wall; and

means for positioning the plane positions of said slabs with respect to said common wall.

**2.** A coupler according to claim **1**, wherein said first and second slabs are trapezoid-shaped.

**3.** A coupler according to claim **2**, wherein said positioning means include plastic feet fixed to waveguide section walls between which said first and second slabs are forced.

**4.** A coupler according to claim **1**, further including means for enabling said first and second slabs to be moved symmetrically along an axis normal to said common wall.

**5.** A coupler according to claim **1**, wherein the transverse thickness of said slabs is controlled so as to produce a desired coupling coefficient.

* * * * *

## UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,758,879 Dated September 11, 1973

Inventor(s) D.E.Beguin-B.Chiron-M.P.G.Cuq

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Cancel --- 75 Inventors: Daniel E. Beguin, Saint-Prix;
Bernard Chiron, Nanterre; Michel P.
G. Cuo, Chilly-Mazarin, all of
France

Substitute --- 75 Inventors: Daniel E. Beguin, Saint-Prix;
Bernard Chiron, Nanterre; Michel P.
G. Cuq, Chilly-Mazarin, all of
France

Signed and sealed this 25th day of December 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents