An Oversize Waveguide Directional Coupler Using Two Prisms Interface-Matched by Means of the Brewster's-Angle Effect

Abstract—**A quasi-optical oversize waveguide directional coupler with two prisms that are interface-matched by means of the Brewster's-angle effect is described. Experimental results showed that the coupler worked satisfactorily over the frequency range from 50 to 90 GHz.**

An oversize waveguide directional coupler operating on the quasi-optical principle has been developed [1], [2]. It consists of two dielectric prisms placed in the junction of two oversize waveguides crossed in the *H* plane. The waves are coupled through the exponentially damped evanescent wave that exists in the spacing between the prisms. Coupling is varied by adjusting the prism separation. To realize a high directivity, the transverse planes of prisms are made to be reflectionless by means of the quarter-wavelength matching layers, which are usually made of quarter-wavelength slabs or slots fabricated on the prism surfaces. This type of matching layer is difficult to fabricate because of its small dimensions; furthermore, it limits the bandwidth. Interface-matching is also possible by means of the Brewster's-angle effect, which has been successfully applied to the plane wave [3], [4].

In this correspondence, an application of this principle to the oversize waveguide direc-

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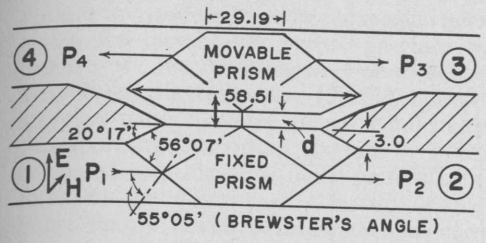

Fig. 1. Sectional view of the directional coupler.

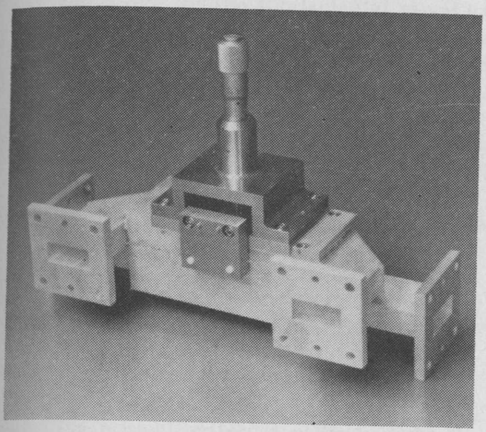

Fig. 2. External view of the directional coupler.

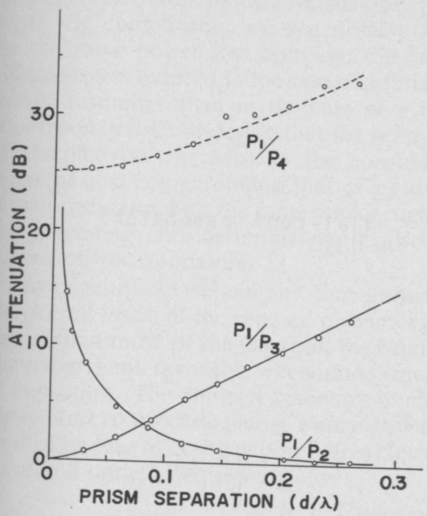

Fig. 3. Transmission characteristics of the directional coupler as a function of d/λ. Solid lines: theoretical values. Circles: experimental values obtained at 87 GHz.

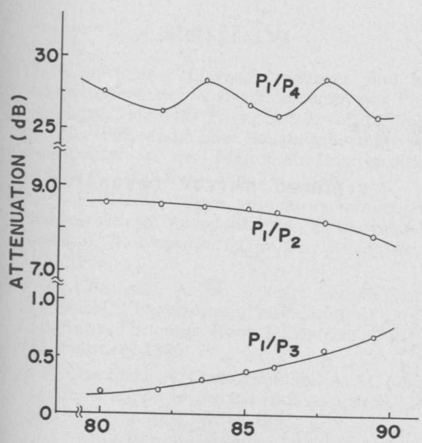

Fig. 4. Frequency characteristics of the directional couplter; $d/\lambda=0.03$.

tional coupler operating in a frequency range around 90 GHz is described and the experimental results are given.

A cross section of the directional coupler cut by an E plane is shown in Fig. 1.

The coupler consists of two Teflon prisms and two oversize waveguides. An external view of the assembled waveguides is shown in Fig. 2. One prism is fixed in the lower waveguide and the other is movable in the upper waveguide to adjust the prism separation and, hence, the coupling. The dimensions of the waveguide (WR-90) are about ten times as large as those of the dominant mode waveguide. The dimensions of the prisms were determined using the value of the dielectric constant $\epsilon_r=2.05$, which was measured at 85 GHz, and are shown in Fig. 1.

The basic principle of operation of the coupler is the same as that mentioned previously, except that the waves in the prisms are E-plane coupled because the electric fields are required, in this case, to be polarized in the plane of incidence.

When power P_1 is incident upon port 1, the power is transmitted to ports 2 and 3, as indicated by P_2 and P_3 in Fig. 1, and ideally no power is transmitted to port 4. However, in a practical device, a small amount of power is transmitted to port 4, P_4. The amount of the power transmitted to each port for a unit incident power, which can be expressed by the attenuation, depends on the degree of prism coupling, i.e., the prism separation d/λ.

Values of the attenuation P_1/P_2, P_1/P_3, P_1/P_4 versus the prism separation d/λ are measured by the substitution method at several frequencies between 80 and 90 GHz. Typical measurements taken at 87 GHz are shown in Fig. 3 and are in agreement with the theoretical values. The attenuation between ports 1 and 4 (conjugate ports) is higher than 25 dB. The decrease of the attenuation between the conjugate ports for small prism separation can be explained by the existence of a small reflection from the tapered section of the upper waveguide, which is indispensable for the adjustment of prism separation.

Fig. 4 shows the frequency characteristics of the coupler when the prism separation distance was held constant at $d/\lambda=0.03$. As expected from the theory, no remarkable variation of P_1/P_2 and P_1/P_3 was observed over the measured frequency range.

The insertion loss of the coupler has two components, i.e., the reflection loss and the dissipation loss in the dielectric prisms. The reflection loss can be estimated from P_4, which consists of two waves. One is the portion of power P_3 that is reflected from the prism interface at port 3 and reflected again from the totally reflecting plane. The other is the portion of power P_2 that is reflected from the prism interface at port 2 and transmitted through the totally reflecting plane. Therefore, since the coupling between the prisms is known and P_4 can be measured, the reflection coefficient at the prism interface (by symmetry, reflection coefficients are equal at all four ports) is obtained. For the experimental data shown in Fig. 3, this is estimated to correspond to the voltage reflection coefficient of 0.056. When the multiple reflection is considered for the worst case, it corresponds to the maximum reflection loss of 0.05 dB. While the measured dielectric loss of the prism was 0.25 dB, the insertion loss of the coupler, except that of the H-plane right-angle corner, was estimated to be less than 0.3 dB within the frequency range previously mentioned. The insertion loss of the H-plane right-angle corner (Fig. 2), including the mode conversion loss, was confirmed to be less than 0.2 dB at frequencies above 50 GHz and, hence, did not limit the wide-band performance of the coupler.

The directional coupler was designed to operate around 90 GHz; however, it was found experimentally that it can operate satisfactorily at frequencies as low as 50 GHz with only a minor variation of the attenuation between the conjugate ports.

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