It is hoped that this contribution will help designers of electromechanically tuned solid-state ("point") sources in deciding qualitatively those things which are within the realms of possibility.

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Two Oversize Waveguide-Polarization Diplexers

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***Abstract*—Two new types of quasi-optical waveguide-polarization diplexers are described. They are based on the use of a metal grating, or a dielectric plate at Brewster's angle, placed in an oversize circular 3-port junction. Their performances are measured at a wavelength of 4.28 mm in a standard microwave circuit and at 337 μm with the HCN laser beam.**

At millimeter and submillimeter wavelengths, quasi-optical circuit techniques were found to be more effective than more standard waveguide approaches. Here we report experimental results obtained with two types of quasi-optical polarization diplexers which once more confirm the preceding assertion.

These two systems use metal grids of parallel wires and dielectric plates at Brewster's incidence, and we shall call them for simplicity grid diplexer and plate diplexer.

A cross section of the grid diplexer is shown in Fig. 1. It consists of a circular 3-port junction, in the middle of which is placed a grid of parallel metal strips at 45° of incidence. An appropriate mechanical system permits the orientation of the strips in the right position with an accuracy of 0.1°. The circular waveguides of the junction have a diameter of 28.3 mm which is a standard dimension for the *X* band.

Two transition cones connect the output arms of the junction to the single-mode waveguide size of the working band (for instance, the 4-mm band). Each of the transition cones is continued by a circular-to-rectangular transition in the single-mode waveguide size, which is connected to a conventional rectangular waveguide. The position of this rectangular waveguide must agree with the electric polarization wanted in each of the outputs.

The input arm is connected with the free-space radiation by a circular horn. In a completely guided application this horn must be replaced by a third conical transition.

The grid we have used is of parallel aluminum strips with a width of 5 μm and period of 10 μm, made by photolithographic techniques on a polyethylene substrate approximately 1 mm thick, as described by Auton [1].

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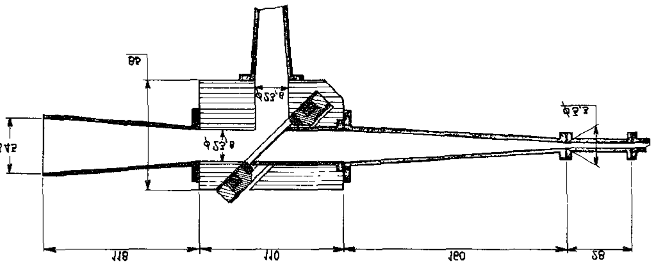

Fig. 1. Cross section of the grid diplexer. (Dimensions are in millimeters.)

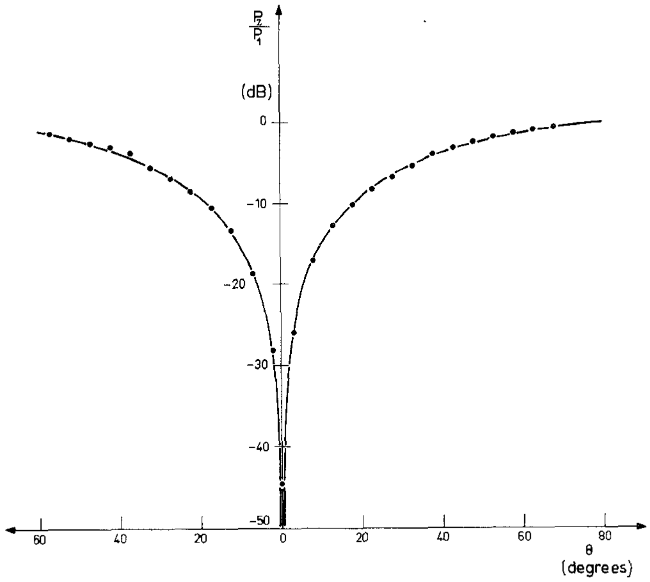

Fig. 2. Normalized power at the transmission output of the grid diplexer P_2/P_1 versus angle of polarization θ, for 70 GHz.

Let us suppose that the strips are parallel to the plane of incidence and that the incident field is also polarized parallel to this plane. By the well-known properties of the metallic grids [2] almost all of the incident power P_1 must be reflected and leave the junction by the reflection arm, and the power P_2 at the transmission arm must be zero. In practice this zero will be due not only to the filtering properties of the grid but also to the filtering properties of the rectangular waveguide at the output, because by its position it transmits only the electric field polarized perpendicularly to the plane of incidence.

Now, if the plane of polarization of the incident field makes an angle θ with the plane of incidence, an ideal diplexer must give the normalized power $P_2/P_1 = \sin^{-2}\theta$ at the transmission output.

Values of P_2/P_1, in decibel, versus the angle of polarization θ have been measured at 70 GHz and are shown in Fig. 2. They are in agreement with the theoretical values.

The experimental minimum $(P_2/P_1)_0 = -45$ dB, which we can name the directivity of the diplexer, is particularly important because the little variations of angle $\delta\theta$ that can be read by the diplexer are of the order of arctan $(P_2/P_1)_0^{1/2}$. In a conventional fin-line diplexer for the 4-mm and the 2-mm band the directivity is about 30 dB, which means that the quasi-optical diplexer described here is much more accurate.

Measurements of directivity of the grid diplexer have also been made at 890 GHz with the HCN laser beam. In this case neither the cone transitions nor the waveguides shown in Fig. 1 are necessary, and the 3-port junction alone is used. The result is $(P_2/P_1)_0 = -31$ dB.

It must be pointed out that the dielectric substrate of the grid introduces some asymmetry in the diplexer. If it was symmetric the normalized power P_3/P_1 at the reflection arm, for $\theta = 90°$, would be of the same order of the above mentioned directivity, say -45 dB. But the dielectric substrate has a nonnegligible reflectivity. A theoretical calculation based on the equivalence with the theory of the trans-

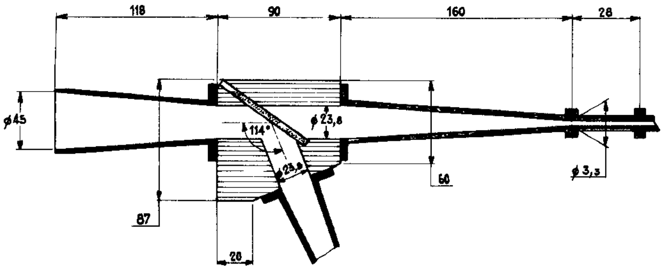

Fig. 3. Cross section of the plate diplexer. (Dimensions are in millimeters.)

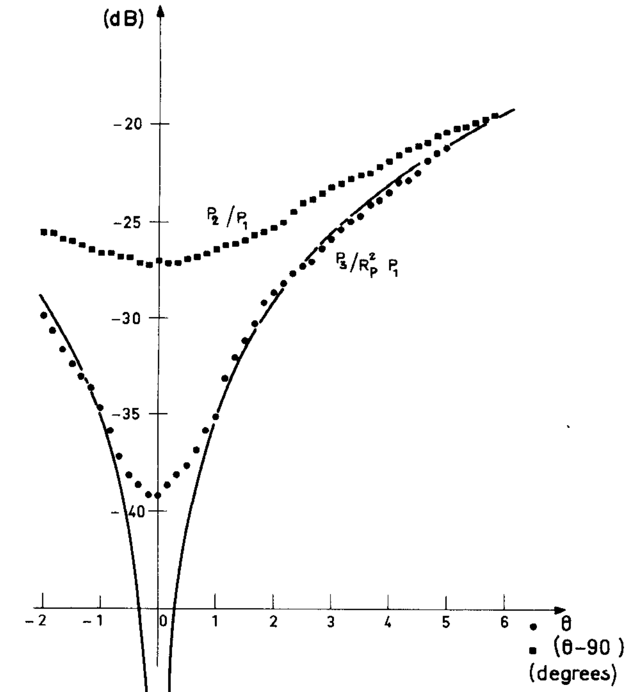

Fig. 4. Normalized power at the reflection output $P_3/R_p^2P_1$ versus θ, and normalized power at the transmission output P_2/P_1 versus $(\pi/2-\theta)$, for the plate diplexer at 70 GHz.

mission lines [3] shows that for 70 GHz, the metal grid with the dielectric substrate gives a reflected power $(P_3/P_1)_0=-12$ dB when $\theta=90°$. But the rectangular waveguide, placed in the right position at the reflection arm, cuts off this spurious power, and experimentally we obtained $(P_3/P_1)_0=-40$ dB.

In future versions of the grid diplexer, more appropriate metal grids must eliminate this small but existing asymmetry (which was not observed at 890 GHz).

We shall now describe the plate diplexer, shown in Fig. 3. It is similar to the grid diplexer with the difference that the grid is replaced by a dielectric polyethylene plate and that the angle of incidence is not 45° but 57°, which is very near the Brewster's angle for polyethylene.

The Brewster's-angle effect is essentially asymmetric because the incident field parallel to the plane of incidence is completely transmitted, but the incident field perpendicular to this plane is only partially reflected. The reflected power is $P_3=R_p^2P_1$ where R_p is the reflection coefficient at the Brewster's angle, and it is maximum when the relation between the thickness of the plate l and the wavelength λ is

$$\frac{l}{\lambda}=\frac{2K+1}{4n\cos i_B}, \qquad K=0,1,2,\cdots$$

where n is the refractive index and i_B is the Brewster's angle. In the best conditions R_p^2 is of the order of 3 dB.

The plate diplexer is then much more asymmetric than the grid diplexer, and we see in Fig. 4 the difference between the zero of P_2/P_1 near $\theta=90°$ and the zero of $P_3/R_p^2P_1$ near $\theta=90°$, measured at 70 GHz. The value $(P_2/P_1)_0=-27$ dB shown in Fig. 4 is justified by the polarizing effect of the rectangular waveguide at the transmission arm, because with a circular-waveguide output it would be $(1-R_p^2)$, say slightly greater than -3 dB.

The value $(P_3/R_p^2P_1)_0=-37$ dB indicates an effective directivity greater than that of the fin-line diplexer. This means that for angles of incidence $\theta=0°$ the plate diplexer has a better accuracy for little $\delta\theta$ variation. The performance of this diplexer is inferior to that of the grid diplexer, but on the other hand it is extremely simple and of negligible cost. Measurements with the HCN laser beam gave $(P_3/R_p^2P_1)_0=-27$ dB.

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Modified H Guide for Millimeter and Submillimeter Wavelengths

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Abstract—**A theoretical and experimental investigation is being made of a modified form of H guide as a possible guided wave structure for millimeter and submillimeter wavelengths. The effects of channels in the conducting planes to support a dielectric film has been studied by scaled-up models at 3-cm wavelength. Low losses, even at the shorter wavelengths, are predicted. The channels may be used to filter unwanted higher order modes, and the use of high-permittivity dielectric is suggested to further reduce the guide attenuation.**

I. Introduction

Conventional guiding structures for electromagnetic waves at microwave frequencies present problems of high attenuation and small physical size when scaled for shorter millimeter and submillimeter wavelengths. No guiding structure has yet been devised which is ideal for such wavelengths, but H guide, first described by Tischer [1], has potential application at these wavelengths.

H guide utilizes a dielectric sheet which is perpendicular to two conducting planes, forming a letter H in cross section as in Fig. 1(a), to propagate a surface wave. It can be shown that one mode, the $_0PM_{11}$, which has an electric field distribution mainly parallel to the conducting planes and a magnetic field entirely parallel to the dielectric surface, exhibits a low-loss wall attenuation characteristic as for the TE_{01} mode in circular guide. It is thus an obvious candidate for high-frequency low-attenuation transmission.

II. Attenuation

Total, i.e., wall and dielectric, attenuation of H guide calculated for submillimeter wavelengths using standard techniques is shown in Fig. 2. Curve (a) has been calculated for a guide width of 1 mm, (b) for a guide width of 1.5 mm, and (c) for a guide width of 2 mm. In all cases, a dielectric loss angle of 10^{-3} and an effective metal conductivity of 10^7 S/m has been assumed. The metal conductivity value is of the order indicated by the work of Bled *et al.* [2] and Vershinina and Meriakri [3]. For comparison, the experimental values of attenuation for rectangular guide obtained from [2] and [3] are also shown in Fig. 2.

III. Mode Purity

By choosing a suitable dielectric thickness and by use of an appropriate launching device, it should be possible to excite only the $_0PM_{1n}$ modes where $n=1$, 3, 5. As the cutoff plane separation of

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