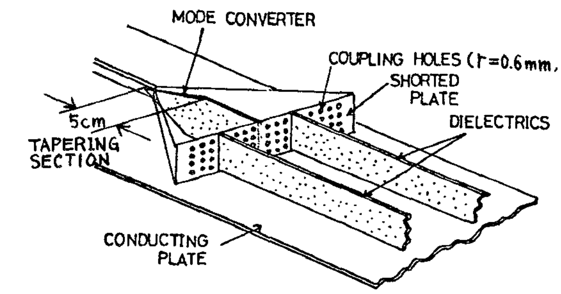

Fig. 4. External appearance of the mode converter in use with an upper conducting plate removed.

given by

$$\frac{1}{Q}=\frac{2k_z(A+B_+/\epsilon_r+1/2\alpha_x)}{k_0^2(A+B_++1/2\alpha_x)}\alpha+\frac{C}{l} \tag{9}$$

where C is a constant which is determined from the ohmic loss due to the devices such as the shorted plates and coupling holes except the DSH itself, and l is the length of the DSH guide. Therefore, the attenuation constant α is determined when the Q of this system is measured at the several different lengths of the DSH guide. In our experiment five different lengths were properly chosen between 0.2 m and 1.0 m.

The material chosen for the dielectric slabs was alumina. The thickness of the slabs was fixed at 0.5 mm throughout the experiments. ϵ_r and $\tan\delta$ of the slabs were found 9.1 and 1.0×10^{-3}, respectively, by the measurement at 50 GHz. Two conducting plates are copper. The space between the two plates was filled with styrofoam to support the dielectric sheets and maintaining proper position. ϵ_r and $\tan\delta$ of this material were found 1.02 and 8×10^{-5} by the measurement at 50 GHz. b is 3 cm.

The experimental results concerning attenuation versus da are shown in Fig. 2. Circled marks represent measured points and solid line denotes theoretical prediction with the $\tan\delta$ of 1.5×10^{-3}. In this graph the loss tangent used for the theoretical curve has been a little bit differently chosen in such a way that the best fit for the measured points was achieved. However, fairly good agreement of the tendency between the theoretical and experimental data has been achieved.

IV. Conclusion

The DSH guide was theoretically and experimentally investigated at 50 GHz and the experimental results were satisfactorily explained by the theoretical predictions. The transmission loss of the DSH guide has advantages of less than that of single-strip H guide under the condition of constant cross-sectional area of dielectrics. The difference of 4.5 dB/m was obtained by our experimental waveguide dimensions and material.

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Letters

A Simple Full-Band Matched 180° *E* Plane Waveguide Bend

FRANS C. DE RONDE

A recent publication by Kashyap [1] describes a simple 180° waveguide bend. However, a similar structure of marginally increased complexity has been used in the past to make a matched bend over a whole waveguide band [2].

In order to try to reduce the size of a long straight plain waveguide in use for a Reflectoscope [3], serpentine bends, especially in the E plane in order to have minimum reflection, were considered.

The 180° constant radius bends are easily made by using two sections of standard waveguide, soldered one on top of the other with a concave constant radius plunger forming the actual bend (Fig. 1). In this way the separation between the guides was just equal to double the wall thickness, namely 0.1 in for standard

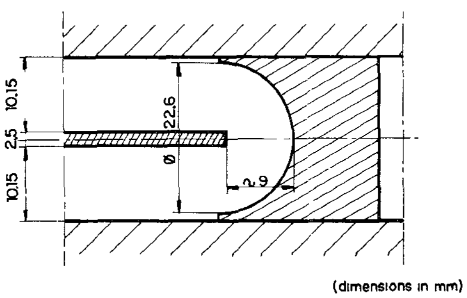

Fig. 1 Unmatched constant radius E bend.

X-band waveguide (WR 90). The concave movable short was constructed from a square piece of brass, machined with close tolerances to assure good contact with the broad faces of the waveguide walls.

The shunt capacitance, formed by the discontinuity between straight and curved waveguides, gave a maximum reflection of about 5 percent, occurring at the highest frequency in the band (8.2–12.4 GHz). Complete cancellation of this reflection was

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The author is with LEP, BP 15-94450 Limeil-Brévannes, France.

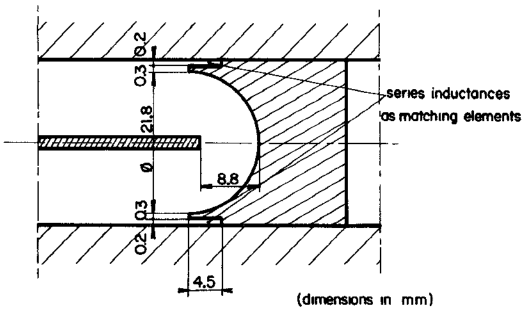

Fig. 2 Full band matched constant radius E bend.

obtained by matching the discontinuity by series inductances, formed by the short and narrow gaps between the plunger and the broad faces. The gap dimensions were optimized empirically (Fig. 2). As the residual reflection (though no more than one percent) was still too much for a periodic reflection, the idea was abandoned for the Reflectoscope. A straight piece of precision drawn waveguide, although about 3 m long, was, therefore, used. However, the design of the bend, as shown in Fig. 2, may be of interest for applications with less severe demands.

Of course, Kashyap's solution of a flat plunger is simpler, but far more critical and extremely narrow band; also, total reflection will occur somewhere in the waveguide band and this could have serious consequences. The simple modifications, described above, thus confer considerable benefits.

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Determination of Conductor Losses in Planar Waveguide Structures (A Comment to Some Published Results for Microstrips and Microslots)

REINHOLD PREGLA

***Abstract*—Waveguide conductor losses are mostly determined from the fields in the lossless case. In planar waveguide structures with sharp edges special care has to be taken, because then the fields can be quite different from those in the lossless case. This paper will explain why the calculated results are poor in some cases.**

The attenuation constant α of a wave in a waveguide is given by

$$\alpha = \frac{1}{2}\frac{P_d}{P} \tag{1}$$

where P is the power transmitted by the wave and P_d is the time average of the dissipated power per unit length. The result of this equation is exact if P_d and P are determined exactly. In practice, however, most difficulties arise in the determination of P_d,

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The author is with Allgemeine und Theoretische Elecktrotechnik, Fernuniversität, Hagen, D-5800 Hagen, Germany.

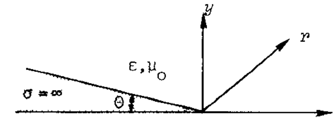

Fig. 1. A perfectly conducting wedge.

which, especially for conductor losses, cannot be carried out exactly. In many cases the part of P_d, that is due to conductor losses, can be approximated by

$$P_d = R_s \int_C |H_t|^2 \, dZ \tag{2}$$

where R_s is the surface resistance and $|H_t|$ is the amplitude of the magnetic field at the conductor surface (C) in the lossless case. Equation (2) gives accurate results only, if the fields in the lossy and the lossless cases are approximately the same. An important exception to this occurs at sharp points and corners extending outward from conductors [1]. The reason for this is, that for both cases the fields are too different. Therefore, it is not allowed to use (2) for the calculation of the losses of planar waveguides such as microstrips, microslots, etc. (which some authors do).

Some mathematical arguments will be given here. Because of the edge condition [2] for a perfectly conducting wedge (Fig. 1) the field $|H_t|$ increases for small values of r as

$$|H_t| \sim \frac{1}{\sqrt{r}} \tag{3}$$

for an infinitely thin plate ($\theta = 0$) and as

$$|H_t| \sim \frac{1}{\sqrt[3]{r}} \tag{4}$$

for a 90° wedge ($\theta = \pi/2$). In both cases the field has a singularity at the edge, but if the conductivity remains finite, the field decreases to a finite value. Thus the difference is considerable. A calculation of conductor losses on the strips in microstrips or microslots with the field for lossless and infinitely thin strips gives not only poor results, but is principally impossible: With a behavior according to (3) the integrand in (2) has a pole of first order and the integral does not exist. Therefore, it is clear that the calculations of conductor losses in [3] "are very sensitive to the order of solution." The solution cannot converge with increasing order; the results are useless.

The same principal error is found in the so-called "thin strip program" in [4]. In this program too, the calculated losses should increase indefinitely with increasing order of solution for the current distribution. Considered physically, it is clear that it is impossible to use the field of the infinitely thin conductors, because there must be a certain volume into which the field can penetrate in the lossy case.

If the fields of lossless conductors with finite thickness and rectangular cross sections are used for the calculation [4]–[7], the integral in (2) remains finite, because the field behavior at the corners is according to (4). However, the current density in the real case is not infinite, so this will lead to an error in the theoretical results, which is as yet unknown, because the real current distribution in the lossy case is not known. Especially for the odd mode of coupled microstrips [5]–[7] and for microslots, where the losses arise essentially from the adjacent edges, the error might be considerable. Therefore, it should be clear that the theoretical results for the attenuation constant should not be used uncritically.

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