The characteristic impedance Z_0 of the rectangular coaxial transmission line is then given by [1, eq. (13)], that is,

$$Z_0 = \frac{376.7K(k_0)}{4K'(k_0)} = 94.18\frac{K(k_0)}{K'(k_0)}. \quad (4)$$

Now, (4) determines k_0 corresponding to z_0 and sequentially, (3), (2), and (1) give α, k, and the shape of the rectangular coaxial line with the outer and inner ratio 2:1.

However, we cannot derive a rectangular coaxial line for any given impedance by this theory because the side-length ratio between outer and inner rectangles is restricted to 2:1. The characteristic impedance obtained by this method is restricted to the following:

$$0 \leq Z_0 \leq 36.81$$

where 36.81 is the value for the case when the coaxial line is square, though this value is 36.771 in [6, table I].

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A Waveguide Applicator for Sheet Materials

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***Abstract*—A partially loaded waveguide applicator for uniform heating of high-attenuation sheet materials is described. Experimental results are presented to exhibit its performance.**

INTRODUCTION

Microwave heating systems are finding greater acceptance as efficient economical means of industrial processing. One of the most important classes of industrial microwave systems concerns the heating of thin web or sheet materials. Various types of applicators have been designed to make efficient use of available power and heat the material uniformly. One of the earliest forms of such applicators is the serpentine or the meander-line applicator. Although quite efficient, it has problems of uniformity due to attenuation as well as due to standing waves in the system by reflections in the waveguide bends and at the edges of the web. Various schemes have been suggested to overcome these problems [1]–[5]. Most of these schemes become impractical when the attenuation of the web is very large. For such webs most of the microwave energy is attenuated before it reaches across the other end of the web, resulting in an extremely nonuniform heating. Use of tapered ridge waveguides has been suggested by Bleackely *et al.* [6] to overcome this problem. This letter presents another method of improving the uniformity by introduction of low-loss tapered dielectric slabs along the waveguide walls.

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THEORY

The basic principle involved is depicted in Fig. 1. It shows a rectangular waveguide partially loaded with two identical low-loss dielectric slabs. The introduction of the dielectric slabs tends to concentrate the field in the dielectric region and reduce the field in the middle of the waveguide. The reduction of the field in the center of the waveguide depends upon the dielectric constant, thickness, and position of the slabs. The theoretical analysis for such structures is well known and has been dealt with in detail by many authors [7], [8]. Some experimental results are presented in Table I to illustrate the effect. They were obtained by introducing slabs of materials having various dielectric constants and thicknesses into an X-band waveguide operating at a frequency of 9.9715 GHz. The results indicate that with appropriately shaped dielectric slabs one may be able to achieve a wide range of field intensity profiles along the length of a waveguide.

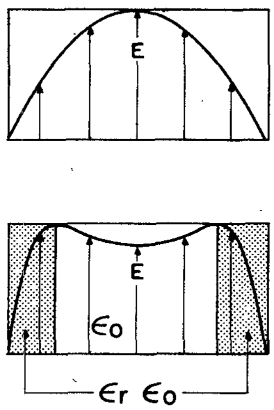

Fig. 1. Reduction in field strength of a waveguide due to dielectric loading.

TABLE I
REDUCTION IN FIELD STRENGTH OF AN X-BAND WAVEGUIDE FOR VARIOUS DIELECTRIC LOADINGS

DIELECTRIC	THICKNESS (INCHES)	INPUT VSWR	INSERTION LOSS (dB)	REDUCTION IN FIELD STRENGTH (dB)
	0.080	1.01	0.02	0.7
POLYSTYRENE	0.160	1.02	0.03	1.6
$\varepsilon_r' = 2.54$	0.240	1.02	0.45	3.3
	0.080	1.01	0.04	0.5
PLEXIGLASS	0.160	1.07	0.30	1.4
$\varepsilon_r' = 2.59$	0.240	1.02	0.85	3.6
	0.080	1.08	0.20	1.2
STYCAST	0.160	1.32	2.45	10-15
$\varepsilon_r' = 7.00$	0.240	2.35	3.85	18-19

APPLICATION TO SHEET MATERIALS

Fig. 2 shows a waveguide with two identically tapered dielectric slabs. This configuration may be used for uniform heating of sheet or web materials with high attenuation. The dielectric constant and the taper length *b–c* of the slab are determined by the width and attenuation of the sample to be processed. These may be determined with the help of data similar to those given in Table I. The taper *a–b* is decided by the amount of mismatch that can be tolerated.

An *S*-band applicator was constructed to test the aforementioned theory. The dimensions of the dielectric slabs, as well as the measured field pattern in the middle of the waveguide, are shown in Fig. 3. This variation in field can be used to achieve uniform heating of a lossy web by passing the web through a slot in the wide dimension of the waveguide as shown in Fig. 2. Fig. 4 demonstrates the heating properties of this applicator as compared to an ordinary waveguide applicator. The heating patterns were recorded on heat-sensitive paper in a WR-340 waveguide operating at 2450 MHz. The heat-sensitive paper was affixed to the material with the help of a double-sided sticky tape. Fig. 4(a) shows the heating pattern obtained for a low-loss material (Bristol board, 0.0058 dB/in) in an ordinary waveguide. Fig. 4(b) shows the heating pattern obtained for a higher loss material (Bakelite, 0.33 dB/in) in the same waveguide. Fig. 4(c) and (d) indicates the heating patterns obtained in the proposed applicator for the low- and high-loss materials, respectively. Comparison of Fig. 4(b) and (d) indicates that the dielectric applicator achieves a much more uniform distribution than that obtainable by the ordinary waveguide applicator. The usefulness of the applicator may be limited to a certain maximum power level depending upon dielectric loss of the tapered slabs. In the present case input power levels up to only 400 W were used. Higher power levels could have been used without overheating the dielectric slabs.

Finally, the applicator may also be useful in monitoring moisture content of high-attenuation sheet materials.

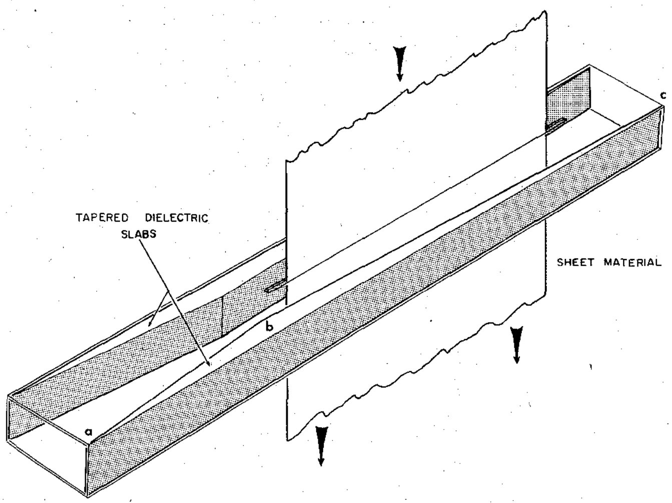

Fig. 2. A waveguide applicator for high-attenuation sheet materials.

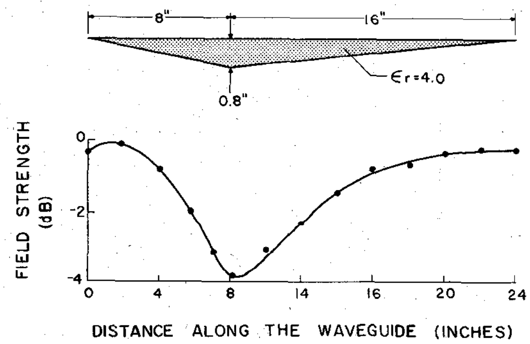

Fig. 3. Variation of electric field along the length of the waveguide applicator.

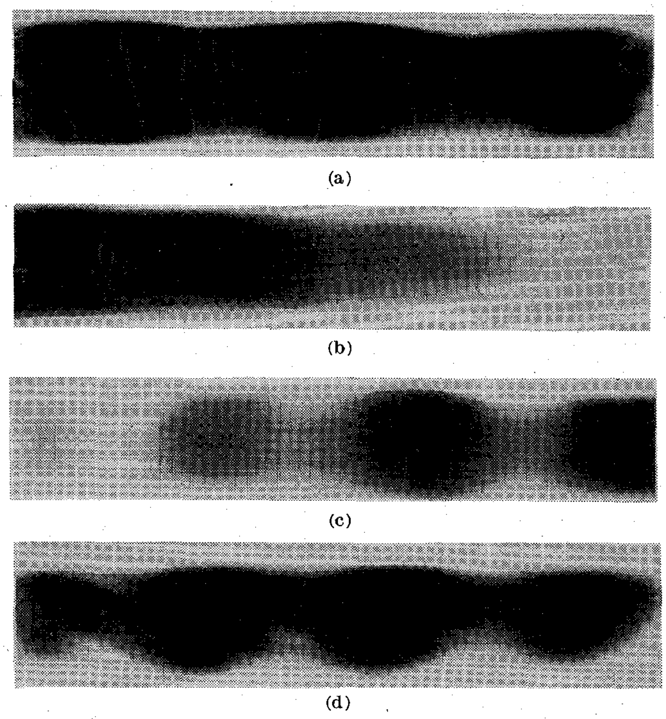

Fig. 4. Heating patterns for various conditions. (a) Low-loss material in an ordinary waveguide. (b) High-loss material in an ordinary waveguide. (c) Low-loss material in the waveguide applicator. (d) High-loss material in the waveguide applicator.

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