widely known that a TEM mode may be sustained in a parallel plane region of finite width by closing the sides and including dielectric slabs as in Fig. 1. The field in

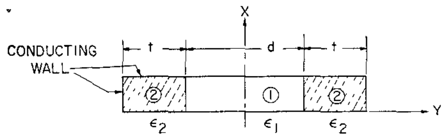

Fig. 1.

the dielectric-free region is strictly identical with a TEM mode at a single frequency (f_0) only; the curves of Fig. 2 have been prepared to show the bandwidth which may be achieved by permitting a given departure from a pure TEM mode.

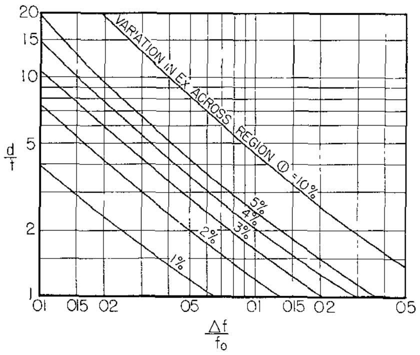

Fig. 2.

In region 1 of Fig. 1, the dependence of E_x on y may be expressed as

$$E_x \propto \cos \beta y. \tag{1}$$

The solution to Maxwell's equations for the case of Fig. 1 and assuming no variation with x is well known.

It is found that as the frequency is increased, β, which is real, decreases to zero and then becomes imaginary. The field which is identical to a TEM mode in region 1 is the degenerate case where $\beta = 0$. In this case it may be shown that

$$\frac{t}{\lambda_1}\sqrt{\frac{\epsilon_2}{\epsilon_1} - 1} = 0.25 \tag{2}$$

where the following nomenclature is used:

λ_1—Wavelength of a plane wave in an unbounded region of relative permittivity ϵ_1, *i.e.*, free space wavelength if region 1 is air-filled
ϵ_1—Relative permittivity in region 1
ϵ_2—Relative permittivity in region 2
t, d—Dimensions, in same units as λ_1
E_x—Electric field in x direction.

For a given wavelength and given value of ϵ_1 in region 1, (2) shows that there is a single infinity of pairs of t and ϵ_2 which are satisfactory, while d may have any value. If in a practical case, region 1 is the useful region, it would be desirable to minimize the width "t" of region 2. Eq. (1) shows that in this case the permittivity of the dielectric in region 2 should be as high as possible.

The above remarks apply only at a single frequency. To consider operation throughout a range of frequencies, the bandwidth may be defined in terms of allowable nonuniformity of E_x throughout region 1. This has been done in Fig. 2, which shows the amount of dielectric which must be used to obtain a given bandwidth. Curves are drawn for various allowable percentages of variation in E_x across region 1. At the low frequency end of the band the departure of E_x from uniformity across region 1 takes the form of a maximum at $y=0$, while at the high frequency end of the band E_x has a minimum at $y=0$.

For a given bandwidth (Δf) and permissible variation of E_x across region 1, Fig. 2 will give the parameter (d/t). By a slight rearrangement of (2):

$$\frac{d}{\lambda_1}\sqrt{\frac{\epsilon_2}{\epsilon_1} - 1} = 0.25\,\frac{d}{t}\cdot \tag{3}$$

Using this relation, and assuming λ_1 to be known,

$$d\sqrt{\frac{\epsilon_2}{\epsilon_1} - 1}$$

is established. It is interesting to note that regardless of how large d is, the bandwidth requirement may be met in practice merely by reducing ϵ_2/ϵ_1 toward unity. In some cases this may imply the use of drilled or expanded dielectrics. There is no lower limit to d either, since if ϵ_2 becomes inconveniently large, it is merely necessary to choose a *better* condition, *i.e.*, smaller per cent variation in E_x, from Fig. 2.

The following explanation may help to provide a physical picture. The TE_{01} mode of a rectangular waveguide of width a has a wavelength longer than the free space wavelength of a plane wave. If the waveguide is now filled with dielectric, the wavelength will be reduced. Hence there must be some dielectric constant for each value of a which restores the wavelength to its free space value. This is identically the relation given by (2) if we consider: 1) "free space" has been generalized to any dielectric medium of permittivity ϵ_1; 2) $a=2t$; and 3) $d=0$.

If now we reintroduce region 1 by splitting the waveguide and tapering it outward as in Fig. 3, it is at least plausible that the field in region 1 will resemble a TEM mode.

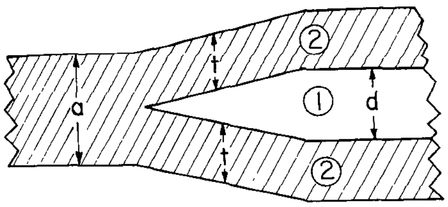

Fig. 3.

In practice, the configuration of Fig. 3 provides a possible method of setting up such a mode.

For completeness, it may be mentioned that the values of t and ϵ_2 could be different in each part of region 2.

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A Method of Analysis of Symmetrical Four-Port Networks*

The following errors appeared in the above article.[1] On page 248 the C term in the matrix for Fig. 11 should be $j(-a^2c^2 + 2ac + a^2 - 1)$. Also, on page 249 the term for T_{+-} for the rat race ring should be $T_{+-} = -j/\sqrt{2}$.

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* Received by the PGMTT, November 25, 1956.
[1] J. Reed and G. J. Wheeler, IRE Trans., vol. MTT-4, pp. 246–252; October, 1956.

Miniature Waveguide Flanges Unpressurized Contact Type*

I would like to call attention to the fact that RETMA Standard RS-166 with the above title and dated October, 1956, has been released. Copies of the Standard can be obtained through the Engineering Department of the RETMA, 11 West 42nd Street, New York 36, N. Y.

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* Received by the PGMTT, November 29, 1956.

Criteria for the Design of Loop-Type Directional Couplers for the L Band*

We have noted several errors in the above article[1] and the corrections are as follows:

Eq. 5(b) should read:

$$V_B \cong + \sqrt{\frac{Z_{20}}{Z_{01}}}\left(\frac{k_L - k_C}{4}\right) \cdot [1 - \cos \beta_0 (k_C + k_L) l \epsilon^{-j2\beta_0 l}].$$

Eq. (7) should read:

$$D = 20 \log_{10} \left| \frac{k_L - k_C}{k_L + k_C} \right| \frac{\sin \beta_0 l}{\beta_0 l}\cdot$$

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* Received by the PGMTT, November 1, 1956.
[1] P. P. Lombardi, R. F. Schwartz, and P. J. Kelly, IRE Trans., vol. MTT-4, pp. 234–239; October, 1956.