FENCE GUIDE FOR MILLIMETER WAVES

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Summary: In this paper a new waveguide for millimeter waves called "Fence Guide" is discussed. A description of the guide, the field distribution, and its characteristics is presented.

Introduction

The fence guide is a new waveguide on a dielectric substrate particularly well suited for millimeter wave circuitry. The guide is a modified Hguide in which the solid metallic strips forming the sidewalls have been replaced by two rows of parallel conducting posts as illustrated in Fig. 1b. This approach permits integrated design of circuitry on a single dielectric slab.

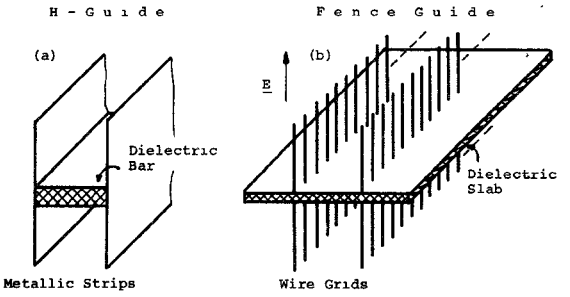

Figure 1. Waveguide Structures.

The new guide has characteristics similar to those of the Hguide which has been studied by a number of investigators [1,2,3]. It is a hybrid waveguide in which the fields are concentrated in one transverse direction (vertical direction in Fig. 1) by surface wave guidance and are confined in the other transverse direction by the rows of conducting posts. For waves electrically polarized parallel to the posts, the two wire grids formed by the posts represent effective reflectors. The low-loss wave mode of the Hguide, in turn, has this polarization. If waves are generated in or launched into the region between the rows of posts, they travel between these "fences" formed by the posts along the dielectric slab.

[1] F. J. Tischer, WESCON Records, Pt. 1, pp. 4-12, August 1958.

[2] Y. D. Deneskin, Telecomm. Radio Engrng. (from Russian), Vol. 18, pp. 37-46, 1963.

[3] F. A. Benson, and R. F. B. Coulon, Proc. IEE (London), Vol. 8, pp. 1311-1320, 1966.

Characteristics of the Guide

The field analysis shows that the components of the field intensities in the guide are those of surface waves reflected between the sidewalls formed by the wire grids. In the analysis, the wire grids are represented by reactive walls with surface impedances equal to those of the wire grids. The field components are found to be products of constants and three independent functions for the distributions in the directions of the three coordinates x, y, z (see Fig. 2). They are,

$$\begin{Bmatrix} E_{x,y,z} \\ H_{y,z} \end{Bmatrix} = K\, F_x(x)\; F_y(y)\; F_z(z),$$

where

$$F_x^{air} = e^{-\alpha_x |x|}\;;\; F_y^{diel.} = \begin{Bmatrix} \sin k_x x \\ \cos k_y x \end{Bmatrix}$$

$$F_y = \begin{Bmatrix} \sin k_x x \\ \cos k_y x \end{Bmatrix}\;;\; F_z = e^{-jk_z z}\,.$$

The constants k are different for the various components and depend on the wave excitation, frequency, and the structural and electric parameters. The field distributions in vertical direction above and below the dielectric (F_x) are exponential decays typical for surface waves. Inside the dielectric they are sine and cosine functions. In the y direction, we have standing waves also represented by trigonometric functions. The propagation in the z direction is described conventionally by $\exp(-jk_z z)$.

The propagation constants are related by

In air:
$$k_o^2 = -\alpha_x^2 + k_y^2 + k_z^2,$$
$$k_o^2 = 2\pi/\lambda\,,$$

In dielectric:
$$k_o^2 \varepsilon_r = k_x^2 + k_y^2 + k_z^2,$$
$$k_x \tan(k_x d/2) = \varepsilon_r \alpha_x$$

The guide wavelength can be found by the following consideration. First one assumes sidewalls in the form of wire grids a distance b apart. Since the sidewalls have a reactive surface impedance, they can be replaced by solid sidewalls with a spacing b'. The value of b' is chosen such that the hypothetical surface impedance at $b/2$ from the center (at a distance Δb from the solid sidewall) equals that of the wire grid. The characteristics of the fence guide are then similar to those of an Hguide with solid sidewalls a distance b' apart. The guide wavelength is found to be somewhat smaller than that of a guide with solid walls a distance b apart.

The attenuation of the fence guide consists of contributions by the dielectric losses in the slab, conduction losses in the wire grids, leakage through the openings on the top and bottom. Measurements of the Q value of shorted sections of the guide at 35 GHz gave values of up to 2000. This, in comparison with the value of a few hundred for strip lines, indicates that the attenuation is a fraction of that of microstrip lines in the same frequency range.

Circuit Design

Components such as power dividers, directional couplers, hybrid rings, resonators, and other circuit elements can be designed with the fence guide as a basis. As a consequence complete fence guide circuits can be placed on a single dielectric slab in a similar manner as it is done with microstrip circuits at lower frequencies. Since the cross-sectional dimensions of the guide are in the order of magnitude of standard waveguides, tolerance problems at the design of circuits are not excessively severe. The small dimensions of the guide and of components at millimeter waves and the structural form make circuitry very practical and suitable for mass production.