IV-2. THE FIELD DISPLACEMENT FILTER — A NEW FAMILY OF DISSIPATIVE WAVEGUIDE FILTERS

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Rectangular waveguides with a full-height dielectric slab, as pictured in Figure 1, are frequently used in isolators and phase shifters. Numerical solutions to the fields have been obtained for the slab centrally located.[1] It is found that with increasing frequency the power flow is more and more confined to the dielectric slab. The electric field distribution is plotted in Figure 1 with frequency as a parameter. According to a suggestion by H. Seidel[2] this effect can be used to separate frequencies. Coupling apertures in the empty part of the guide will couple only at low frequencies; however, a sharp cutoff cannot be expected.

The author has performed extensive numerical studies of cases with arbitrary slab positions, during which the following interesting effect was observed: When the slab is moved away from the center, the sharpness of the transition from equally distributed power flow to power flow confined to the dielectric is increased. The maximum sharpness is obtained when the slab touches the waveguide wall. The electric field distribution for this case is shown in Figure 2. It can be seen that within 10% relative frequency the field changes from essentially the pattern of the empty guide to a mode that essentially propagates within the dielectric slab. The higher the permittivity of the dielectric, the sharper the transition becomes.

A quantitative fact points to the physical mechanism of this transition: one-quarter of the intrinsic critical wavelength coincides with the thickness "d" of the slab. Thus the critical frequency f_0 is the cutoff frequency of a dielectric waveguide that is formed by the slab with one surface short-circuited through the waveguide wall. The opposite surface acts essentially as an open circuit. This cutoff behavior explains the sharpness of the transition. If the dielectric slab is lossy, or is made lossy with an attenuating film, frequencies higher than f_0 will be attenuated. In the center-loaded case, however, no such cutoff frequency can be found below the already mentioned critical frequency f_0; consequently, the transition is slow.

A filter of this type with a waveguide of width a = 1.59" and with a theoretical critical frequency f_0 = 6 GHz (obtained with ε = 30 and d = .09") shows the attenuation plotted in Figure 3. The drop in attenuation above 7 GHz is explained by the occurrence of the distorted TE_{20} mode, and by the fact that in this case the attenuating film is placed against the inner surface of the dielectric slab where the E-field disappears at higher frequencies. Experiments with higher dielectric constants and films in the center of the slab are in process.

Such filters are of particular interest as harmonic suppressors. In such applications, one basic difficulty arises: if the fundamental frequency is in the normal operating range of the waveguide, the harmonic will be above the cutoff frequency of the TE_{20} mode. This mode will be confined to the slab only at frequencies where $\lambda_{dielectric} < 4d/3$; but before this critical frequency is reached, the TE_{30} mode will appear. Consequently, the range above cutoff of the TE_{20} mode is not very useful. This difficulty can be overcome by using a narrower waveguide and placing a second dielectric load in the center of the narrow section. Figure 4 is an illustration of this procedure; Scale A shows a display of the different cutoff frequencies $f_c^{m,o}$ of a waveguide loaded with only one slab in the above-mentioned manner. "PB" and "SB" designate passband and stopband, respectively. "UR" represents an uncertain region; here only certain modes are attenuated. "B" presents a similar display after the guide is narrowed down by a metallic wedge and slightly loaded in the center. f_0^{10} is not changed if the loading in the center is not too heavy; f_c^{20} is increased by narrowing the guide, but not affected by the center loading. f_c^{10} is increased by narrowing, but this is compensated by suitable loading at the center. The only essential difference is a wider stopband. This type of filter has been operated successfully. A numerical solution to the waveguide with both center and wall loading is in process, and will provide enough information for a straightforward design of such filters.

It is self-explanatory that a dissipative high-pass filter is obtained when the resistive film is placed in the central part of the guide. Frequency-sensitive couplers can be built in this way as well.

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References.

1. P. H. Vartanian, W. P. Ayres, and A. L. Helgesson, "Propagation in Dielectric Slab Loaded Rectangular Waveguide," IRE Trans. MTT-6, pp 215-222, April 1958.
2. U. S. Patent No. 2,963,661.

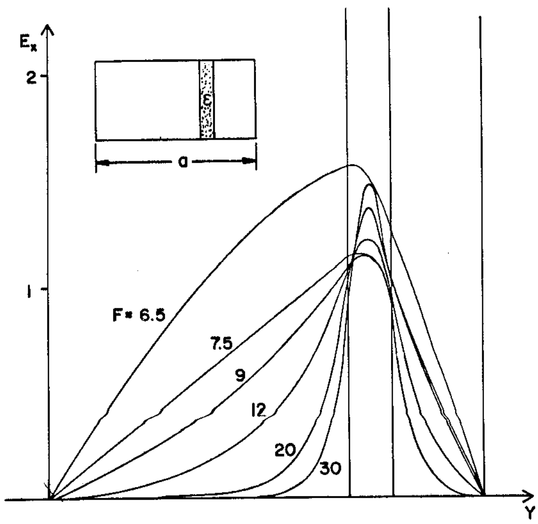

Figure 1. Waveguide Cross Section and Electric Field Distribution of the Distorted TE_{10} Mode. $F = \omega a \sqrt{\mu_0 \varepsilon_0 (\varepsilon - 1)}$

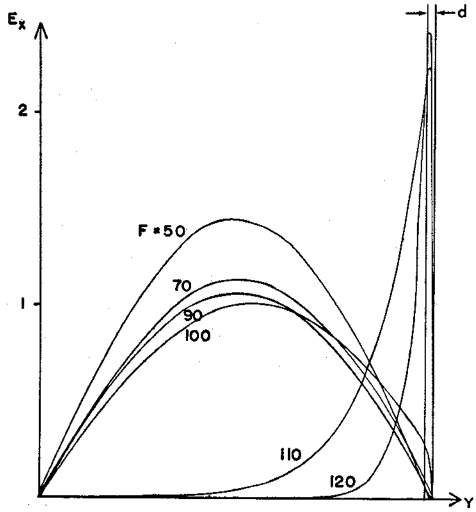

Figure 2. Electric Field of the Distorted TE_{10} Mode in a Sidewall Loaded Guide

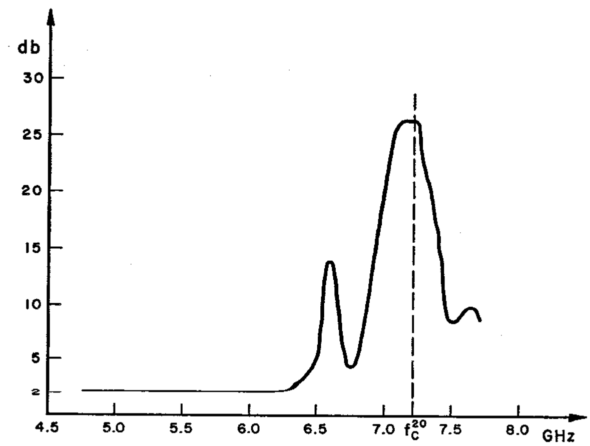

Figure 3. Attenuation of a Simple Field Displacement Filter

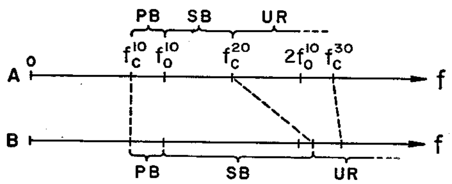

Figure 4. Cutoff Frequencies and Critical Frequency of (A) a One-Slab Filter, and (B) a Reduced-Width Two Slab Filter.

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