THE INFLUENCE OF METALLIZATION THICKNESS AND MOUNTING GROOVES ON THE CHARACTERISTICS OF FINLINES

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ABSTRACT

The influence of metallization thickness and mounting grooves in unilateral and bilateral finlines is investigated with a fully hybrid mode analysis. The effect of these parameters on both the dominant mode propagation and the operating bandwidth can be significant and must be considered for accurate design.

INTRODUCTION

Little has been published so far on the effect of finite metallization thickness and mounting grooves on the dominant and higher order modes in finlines. Most authors neglect these structural details for two reasons. Firstly, they complicate the treatment of the field problem in these transmission lines and secondly, their influence is relatively small at frequencies below 50 GHz. However, at shorter millimeter-wavelength their effect becomes more and more pronounced because of the shrinking waveguide dimensions.

Only Vahldieck [1] and Beyer [2] offer some detailed but contradictory results on metallization thickness and mounting grooves, the data reported in [1] being confirmed by Kitazawa and Mittra [3].

THE EFFECT OF METALLIZATION THICKNESS

In the first part of our investigation the mounting grooves are not included in order to determine exclusively the influence of the metallization thickness on the dominant mode propagation in unilateral and bilateral finlines. Furthermore, the discussion is restricted to some representative configurations because it is impossible in this context to comprehensively describe the influence of metallization thickness for all combinations of slot widths, dielectric constants, substrate thickness, aspect ratios, frequencies and types of finlines.

Therefore, essentially three representative operating frequencies, two different slot widths and the most common substrate materials are considered in our investigation.

The range of the metallization thickness is restricted to values between 5 μm and 130 μm. A substrate thickness of 110 μm is considered to be a realistic average value. There are two fundamental results: firstly, a significant difference in the propagation constants of unilateral and bilateral finline. This difference increases with increasing metallization thickness. Secondly, for frequencies close to cutoff the propagation constant increases with increasing metallization thickness, while at bandend, it decreases with increasing thickness.

The difference between the propagation constants in commensurate unilateral and bilateral finlines depends on the frequency, slot width and relative permittivity of the substrate. In the lower range of the waveguide band (f =50 GHz, Fig. 1a,d), the propagation constant of the dominant mode in a bilateral finline can be over 4 percent higher than in a unilateral structure, whereas at 80 GHz, the situation is reversed.

For frequencies in the middle of the waveguide band, the difference becomes almost negligible (Fig. 1b,e). Furthermore, the dominant mode is hardly affected by the metallization thickness in this frequency range. For operating frequencies close to cutoff or at bandend, however, the influence is significant. At 50 GHz, for example, the propagation constant in both types of finlines increases by more than 5% when the metallization thickness grows from 5 μm to 130 μm; at the same time, the cutoff frequency decreases with increasing metallization as expected. This tendency changes at the end of the waveguide band where an increase in metallization thickness lowers the propagation constant.

This is surprising at first; one would expect that, like in the ridged waveguide, a thicker metallization means higher capacity per unit length, hence lower cutoff frequency, and higher propagation constant for all frequencies above cutoff. This is true for the finline only as long as the frequency is relatively low. However, at higher frequencies, the energy is more and more drawn into the substrate, causing the effective dielectric constant ($\varepsilon_{eff} = [k_z/k_0]^2$) to become larger than unity and to tend asymptotically towards ε_r of the substrate. In this frequency range, a thicker metallization retains more field energy in the air region between the fins, thus reducing the percentage of energy in the substrate and lowering the effective permittivity and propagation constant of the line. The dispersion characteristic of a fin line with thick metallization thus starts at a lower frequency than that of its counterpart with thin fins. But with increasing frequencies, the characteristics intersect each other, and the propagation constant of the thicker finline falls below that of the line with thin metallization. This phenomenon has also been confirmed by Kitazawa and Mittra [3].

THE EFFECT OF THE MOUNTING GROOVES

The finite metallization thickness affects the characteristics of unilateral finlines in the same way as those of bilateral finlines. This cannot be said about the mounting grooves, even though they

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generally lower in both structures the cutoff frequency of higher order modes and thus, reduce the operating bandwidth. The dominant mode in a bilateral finline is virtually insensitive to the groove depth as long as the structure is symmetrical (Fig. 2a). However, the dominant mode in a unilateral finline shows a strong interaction with the next higher order mode when the grooves are deeper than one third of the waveguide height. In Fig. 2b, this interaction occurs around 80 GHz, and results in a strong increase of the dominant propagation constant.

A similar effect can be observed in a bilateral finline in which the gaps have different widths (Fig. 3). In this case the interaction between the dominant and higher order modes occurs already at 65 GHz since the cutoff frequencies of the higher modes have been reduced further by the bilateral metallization. Obviously, in such asymmetric configurations the single mode bandwidth decreases significantly because the HE_3 mode (see Fig. 3) will be excited by an incident H_{10} mode. This does not occur when the bilateral finline is symmetrical, because then neither one of the two higher order modes will be excited. It is only under these circumstances that the finline structure preserves the advantage of a large single mode bandwidth.

CONCLUSION

This paper has illustrated the effects of finite metallization thickness and substrate mounting grooves on the dispersion characteristics of unilateral and bilateral finlines, as calculated with a hybrid mode analysis. The main conclusions can be summarized as follows.

a) Finite metallization thickness lowers the cutoff frequency of the dominant mode in both unilateral and bilateral finlines.

b) At frequencies well above cutoff, the propagation constant in finlines with thick fins is lower than that in finlines with thin fins.

c) The mounting grooves have little effect on the dominant mode in symmetrical bilateral fin lines. However, the dominant mode in unilateral finlines shows anomalous behaviour due to interaction with the next higher order mode if the grooves are deeper than about one third of the waveguide height. The single mode bandwidth is reduced accordingly.

These effects vary somewhat with the frequency and the dielectric constant of the substrate and are particularly pronounced at very short wavelengths due to the shrinking waveguide dimensions.

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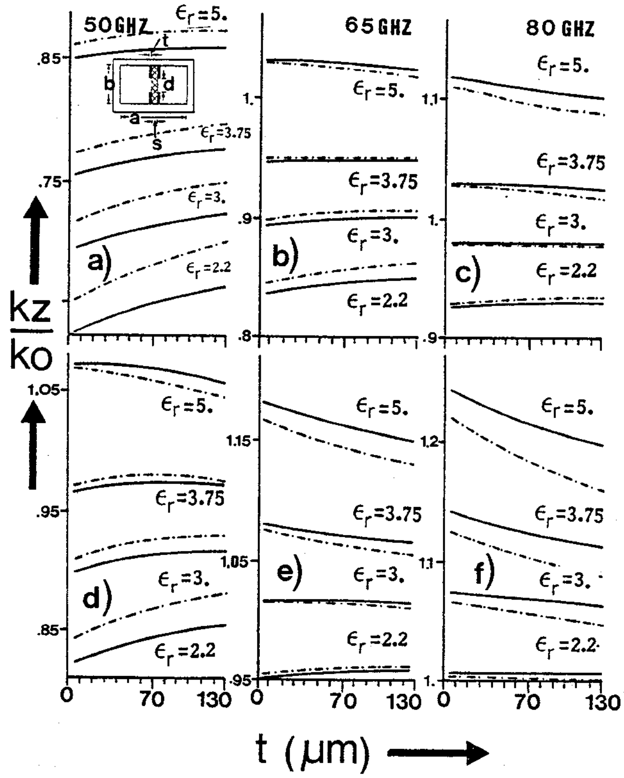
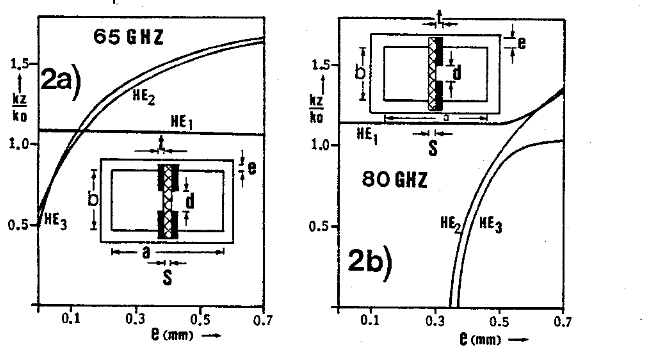


Fig.1 Influence of the metallization thickness on the dominant mode in unilateral (———) and bilateral (–·–·–) finlines. Waveguide dimensions: a=3.1 mm, b=a/2, e=0., s=110.μm, ε_r=3.75. a)-c) d=0.775 mm, d)-f) d=0.35 mm.



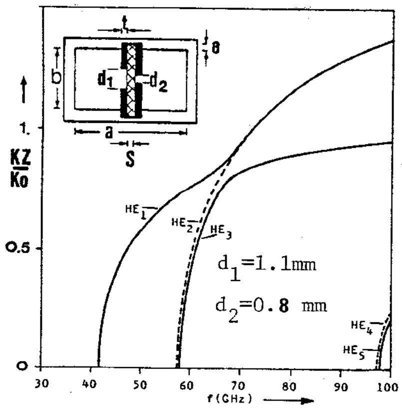


Fig.2

Influence of the mounting grooves on the dominant and next two higher order modes in bilateral a) and unilateral b) finlines. a=3.1mm, b=a/2, t=10μm, d=0.35 mm, s=110μm, ε_r=3.75.

Fig.3 Dispersion characteristic of a bilateral finline with different gap width. a=3.1mm, b=a/2, s=50μm, ε_r=3. , t=10μm, e=0.5mm