COMPUTER AIDED DESIGN MODELS FOR UNILATERAL FINLINES WITH FINITE METALLIZATION THICKNESS AND ARBITRARILY LOCATED SLOT WIDTHS

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ABSTRACT

This paper presents closed form design equations for the phase constant of unilateral finlines with finite metallization thickness and arbitrarily located slots. The equations are based on numerical data obtained using the highly accurate conservation of complex power technique.

I. INTRODUCTION

There has been a number of numerical methods for computing the phase constant of finlines [1,2,3] which assume the fin thickness to be negligible. Such an assumption is valid for most practical purposes. As a result closed form design equations were developed based on this assumption [4].

Recently, it has been pointed out that the assumption of zero fin thickness is invalid for extremely narrow fingaps, high substrate dielectric constants and sufficiently finite thicknesses [5,6]. With the use of a highly accurate method based on the conservation of complex power technique (CCPT) [7], we have thoroughly investigated the effect of the metallization thickness on the finline performance and have found that the error of neglecting the fin thickness can go as high as 7 percent. In the present work we have presented highly accurate models for the cutoff wavelengths in unilateral finlines over the range (see Fig.1) $\epsilon_r \leq 4.0$, $t/a \leq 0.02094$, $1/64 \leq s/a \leq 1/8$ and $1/32 \leq d/b \leq 1/2$. The expressions derived are accurate to within ±0.8 percent of numerical results. Using the expressions for the cutoff wavelength, the dominant mode propagation constant can be evaluated within 1.3 percent of numerical results.

II. CLOSED FORM EQUATIONS FOR THE PHASE CONSTANT

the phase constant is given by

$$\beta = \frac{2\pi}{\lambda_o}\,[\epsilon_e(f)]^{\frac{1}{2}} \tag{1}$$

where λ_o is the free space wavelength and the effective dielectric constant $\epsilon_e(f)$ is obtained from

$$\epsilon_e(f) = k_e(f) - (\lambda_o/\lambda_{ca})^2 \tag{2}$$

λ_{ca} the cutoff wavelength of the homogeneous finline, is given by

$$\lambda_{ca} = 2\,(a-t)\left\{1+NX+(2.75+0.2\,t/a)[t/(a-t)]\,b/d\right\}^{\frac{1}{2}} \tag{3}$$

$$N=(4/\pi)\,(1+0.2\,[b/(a-t)]^{1/2})\,(b/(a-t)) \tag{4.a}$$

$$X=-\ln\sin(0.5\pi d/b) \tag{4.b}$$

$k_e(f)$, the frequency dependent equivalent dielectric constant, is obtained from

$$k_e(f) = \epsilon_r - \frac{(\epsilon_r - k_c)}{1+\left\{\frac{s}{a}\left[\frac{f-f_c}{f_c}\right]^{1/2}\right\}^{(1+0.06b/d)}} \tag{5}$$

where k_c, the value of $k_e(f)$ at the cutoff frequency f_c of the finline, is given by

$$k_c = 1 + \frac{s}{a}(a_1X+b_1)\,(\epsilon_r-1) \tag{6}$$

and

$$a_1 = p_o + p_1\ln\frac{a}{s} + p_2\,(\ln\frac{a}{s})^2$$

$$b_1 = q_o + q_1\ln\frac{a}{s} + q_2(\ln\frac{a}{s})^2$$

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$$p_o = 2.455 - 69.366\,(t/a) + 1826.189\,(t/a)^2$$

$$p_1 = 2.5646 + 54.2675\,(t/a) - 1381.6\,(t/a)^2$$

$$p_2 = 0.7837 - 18.954\,(t/a) + 466.3185\,(t/a)^2$$

$$q_o = 2.1697 + 3.638\,(t/a) + 240.356\,(t/a)^2$$

$$q_1 = 3.4661 - 7.3661\,(t/a) - 180.6\,(t/a)^2$$

$$q_2 = -0.6149 + 3.11624\,(t/a) + 19.605\,(t/a)^2$$

The equation for the phase constant is valid within the range of the fundamental mode operation. The error may be in the order of ± 2 percent outside this range. For non centered fingaps in the y direction the parameter X has to be replaced by [8]

$$X = \ln\left\{cosec(0.5\pi d/b)\,.\,cosec(0.5\pi\,(1-2e/b))\right\}$$

Where e is the distance of the center of the fingap from the center of the housing.

Table I compares the computed results using the above equations, with those obtained using the numerical technique. Although the above equations are valid for d/b up to 1/2, the effect of the finite metallization thickness is almost negligible for $d/b \geq 0.35$. Moreover the upper bound of t/a (i.e. 0.02094) is rarely encountered in practice. Figures 2 and 3 compare the computed results for the propagation constant and the agreement inspires confidence in the above models.

The equation suggested for characteristic impedance is based on Meier's homogeneous ridged waveguide definition [9] and is given by

$$Z_o(f) = \left(Z^{pv}_{o\infty}/\sqrt{\epsilon_e(f)}\right)\left\{\frac{k_e(f)-1}{k_c-1}\right\} \quad (7)$$

$$Z^{pv}_{o\infty} = \frac{120\,\pi^2\,d/\lambda_{ca}}{f_1 + q\,f_2} \quad (8)$$

where

$$f_1 = 2\frac{d}{\lambda_{ca}}\cos^2\frac{\pi t}{\lambda_{ca}} + \pi\frac{t}{2\lambda_{ca}} + \frac{1}{4}\sin^2\frac{\pi t}{\lambda_{ca}} \quad (9)$$

$$q = \left[\frac{d/b\cos^2(\pi t/\lambda_{ca})}{\sin^2((a-t)/\lambda_{ca})}\right] \quad (10)$$

$$f_2 = \left[\pi(a-t)/2\lambda_{ca} - \frac{1}{4}\sin^4(a-t)\pi/\lambda_{ca}\right] \quad (11)$$

III CONCLUSION

This paper presents simple but accurate models for the phase constant and characteristic impedance in unilateral finlines with finite metallization thickness and arbitrarily located slots. The use of the models does not need any solution of transcendental equations and are simple enough to be programmed in a pocket calculator.

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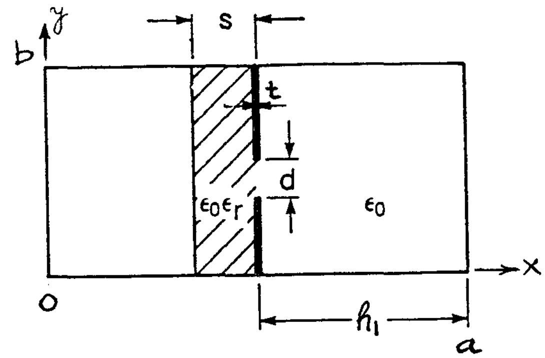

Fig. 1. Unilateral Finline

TABLE 1

Cut off frequency in GHz. εr ≈ 3.00, a = 3.2 mm, b = 1.6 mm				
s/a	d/b	CCPT		PRESENT MODEL
		t = 0	t = 23.5 μm	
1/16	1/2	35.754	35.544	35.235
	1/4	29.390	29.043	29.043
	1/8	24.914	24.479	24.729
	1/16	21.774	21.159	21.260

CCPT = Conservation of Complex Power Technique

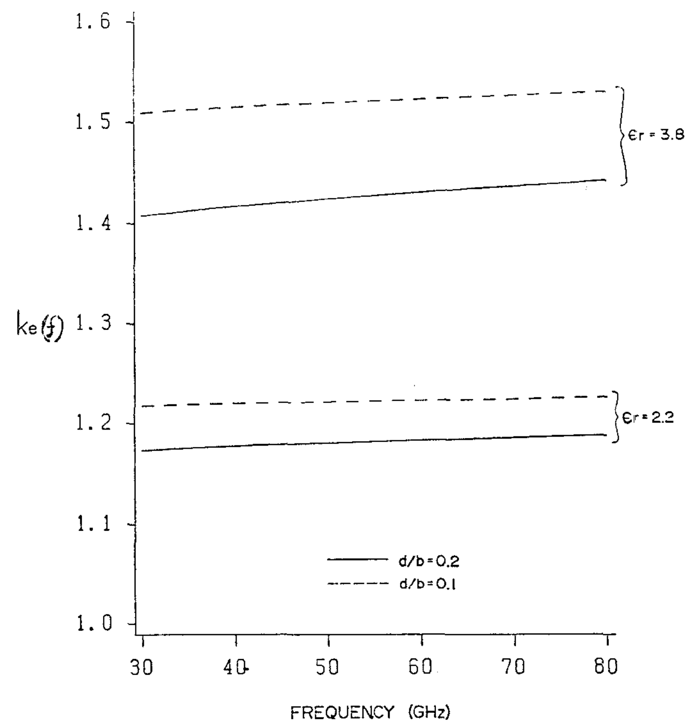

Fig. 2. The equivalent dielectric constant versus frequency for different slot widths, $a=2b=4.7752\ mm$, $s=0.127\ mm$, $h_1=2.3876\ mm$, $t=0.1mm$.

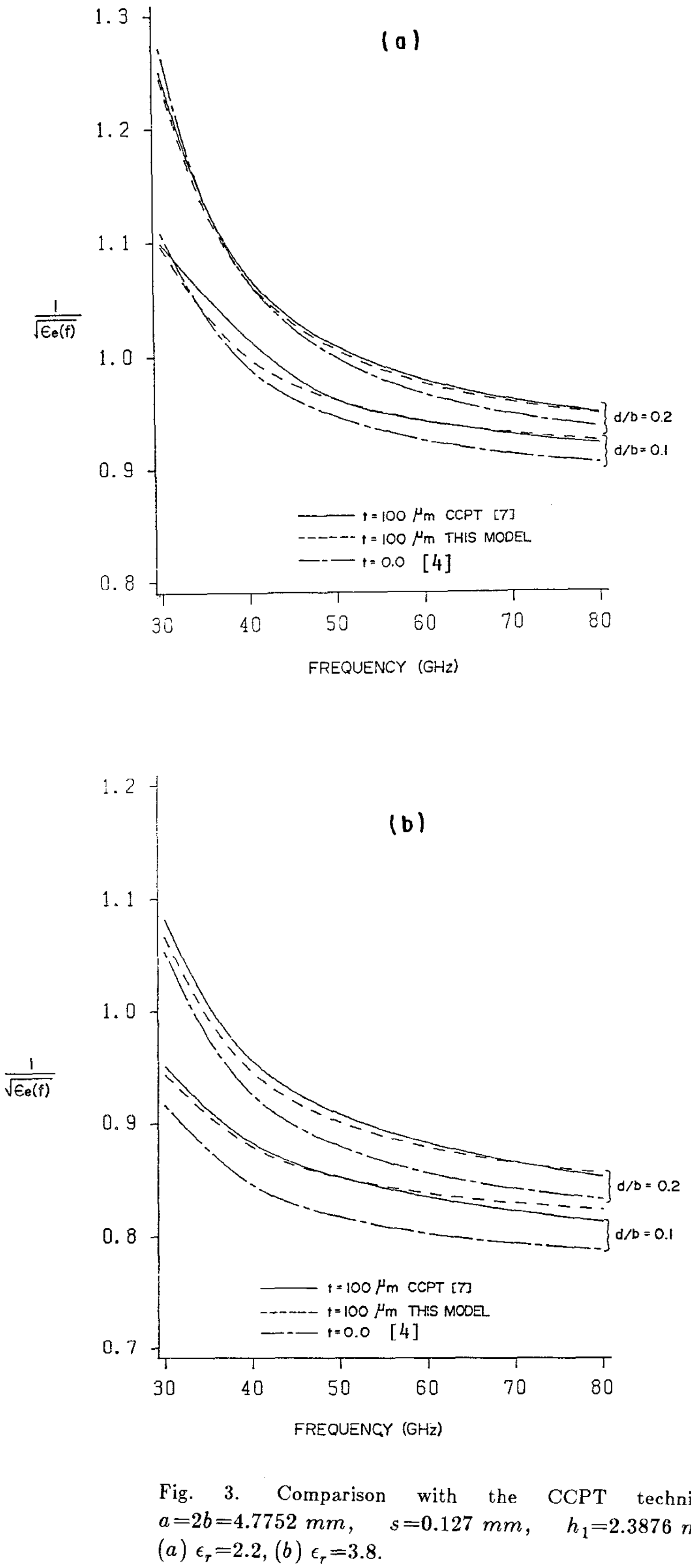

Fig. 3. Comparison with the CCPT technique, $a=2b=4.7752$ *mm*, $s=0.127$ *mm*, $h_1=2.3876$ *mm*, (a) $\epsilon_r=2.2$, (b) $\epsilon_r=3.8$.