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EXACT CALCULATION OF SCATTERING PARAMETERS OF THE COPLANAR-SLOT TRANSITION IN A UNILATERAL FINLINE TECHNOLOGY

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Abstract

The dominant and higher order modes, in both a unilateral finline and coupled unilateral finlines in the even and odd modes, are accurately described from a thorough spectral-domain approach. Then, coupling coefficients between eigenmodes at a coplanar-slot transition in a unilateral finline technology, which are to be used in the generalized scattering matrix formulation are directly computed in the spectral domain. Scattering parameters of the dominant mode in the Ka band are presented for both even and odd mode excitation of the coupled unilateral finlines.

1 - Introduction

The E-plane coplanar-slot transition like that shown in Fig. 1 forms a frequency independent 180° hybrid giving the basis for the design of broadband planar microwave and millimeter balanced mixers (1, 2). A complete review of these numerous realizations reveals the non existence of any rigorous electromagnetic analysis for this transition that can establish a solid basis for its design.

It is clear that an odd-mode excitation for the coupled unilateral finlines (coplanar line function), by assuring that the outer conductors have the same potential along the whole length, creats a balanced-unbalanced (balun) junction and hence its two arms are mainly decoupled. This is technically impossible and both of the even and odd modes are often excited and are coupled to the wave propagating on the other side of the junction.

The aim of this paper is two-fold : i) to give an accurate evaluation of four eigen modes for coupled unilateral finlines in the even and odd-modes excitations, by means of a thorough spectral domain approach (there is no previous results on this subject) and ii) to determine th generalized scattering matrix for the E-plane coplanar-slot transition by combining the direct modal analysis (3) and the Spectral Domain Approach.

2 - Evaluation of Eigenmodes in Coupled Unilateral Finlines

In the conventional spectral-domain approach, the field components of the hybrid guided wave are expressed in terms of the mth coefficient of the Fourier series with respect to x of the axial electric and magnetic field components. For a unilateral finline (4) then, the standard computational schema uses an admittance representation for the pair of functional equations relating the mth line amplitude of the fin surface current components to the mth line amplitude of the slot aperture field components at the $y = D$ interface.

The key point for an efficient eigenmode evaluation is the suitable choice of the set of basis functions into which the slot aperture fields have to be expanded. To describe both the dominant and the higher order modes, the aperture fields, expanded with the basis functions shown in table 1 for the even mode excitation and in table 2 for the odd mode excitation (coplanar waveguide function), are proved to be a judicious choice capable of describing at least four eigenmodes.

Dispersion characteristics of four eigenmodes in coupled unilateral finlines in the even and odd mode excitations are plotted in Fig. 2 for the shown line parameters.

3 - The E-Plane Coplanar-Slot Transition

The scattering matrix formulation of an axial waveguide discontinuity derived from a direct modal analysis is described in details in reference (3). It assembles both two reflection and two transmission matrix blocks. These matrix blocks have MXN elements according to the numbers M and N of eigenmodes that are used in field expansion in waveguides at each side of the discontinuity plane $z = 0$ (see fig. 1). During the derivation of matrix block elements, both coupling coefficients between eigenmodes at the discontinuity plane and power flow incident on it have been computed. By transforming them to the Fourier domain and using the Parseval's theorem, the computation is mode

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easier with the eigenmode spectral field components.

As an example, the E-plane coplanar-slot transition of Fig. 1, with W1 = 1 mm, W2 = 0,95 mm and s = 0,1 mm in Ka band, is analyzed. The first four eigenmodes in a unilateral finline with W = 1 mm were accurately determined and given in reference (4). After executing a number of systematic tests of convergence, the number of eigenmodes employed in each waveguide was the same (ie M = N = 4). Fig. 3 gives the module of calculated reflection and transmission coefficients for the transition for the even mode excitation.

4 - Conclusion

The spectral domain techniques were proven to be very efficient for calculating the dominant and higher order modes in coupled unilateral finlines in even and odd-modes excitations. Theses techniques when combined with the direct modal analysis are shown to be capable to determine the scattering matrix parameters of the dominant mode for the coplanar-slot transition in a unilateral technology for the unavoidable even mode excitation at the junction.

References

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(3) A. Wexler, "Solution of waveguide discontinuities by modal analysis", IEEE Trans. on MTT, Vol. MTT-15, pp. 508-517, 1967.

(4) M. Helard, J. Citerne, O. Picon and V. Fouad Hanna, "Theoretical and experimental investigation of finline disconinuities", IEEE Trans. on MTT, Vol. MTT-33, pp. 994-1003, 1985.

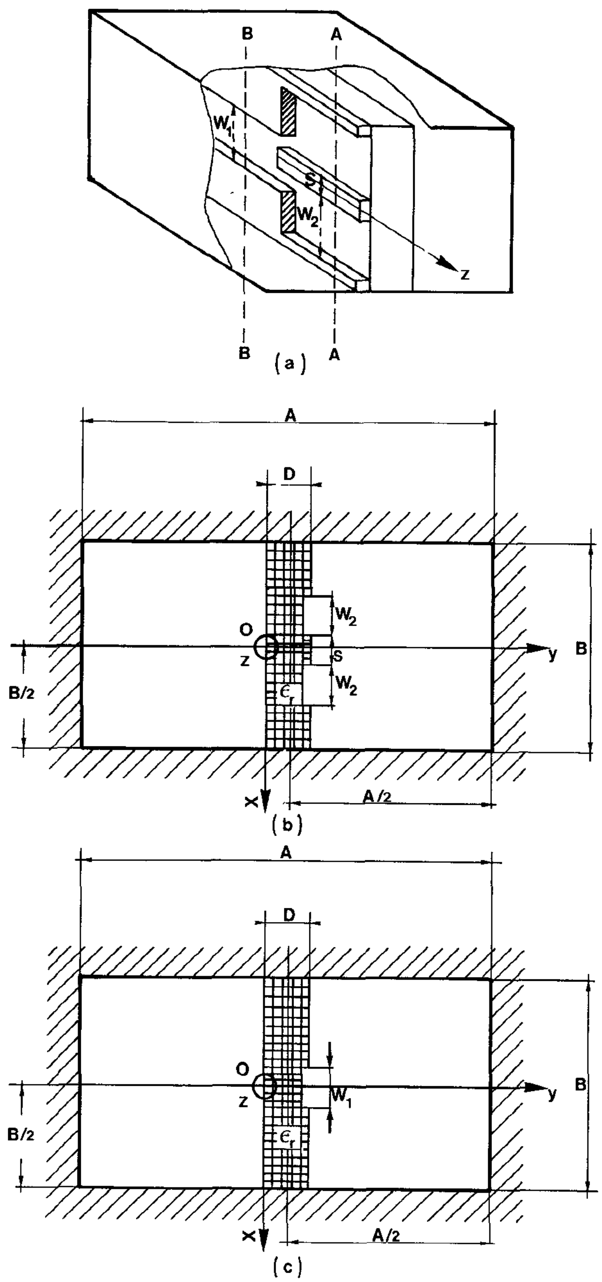


Fig. 1 : (a) The E - plane Coplanar-Slot Transition
(b) A - A Cross Section (Unilateral Coupled Lines)
(c) B - B Cross Section (Unilateral Finline)
(A=7 112mm B=3.556mm. D=0.254mm and ϵ_r=2.22)

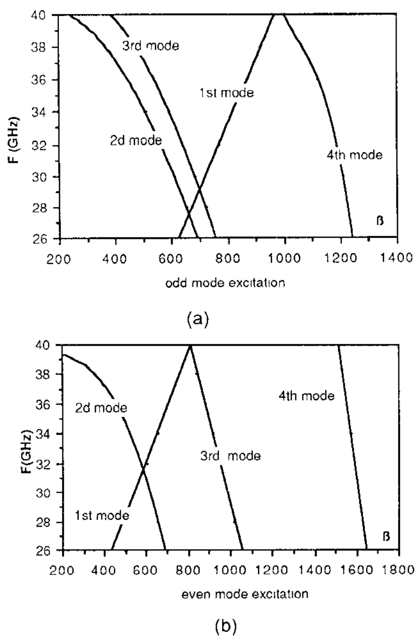


Fig 2 dispersion characteristic of four eigen-modes in coupled unilateral fin-lines

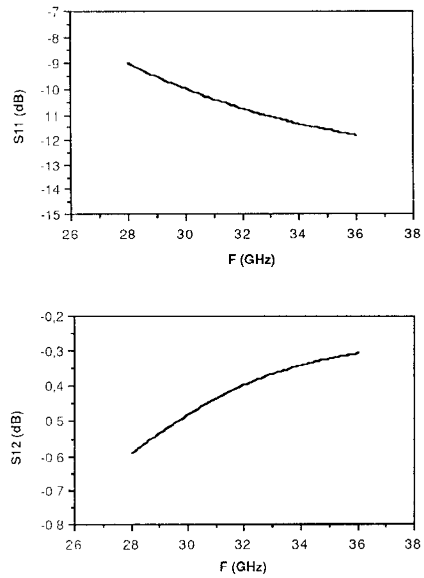


Fig 3 Reflection and transmission coefficients for the transition for the even modes excitation

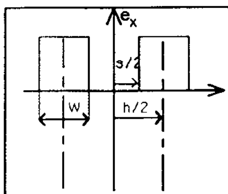
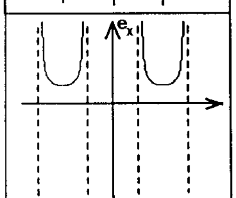
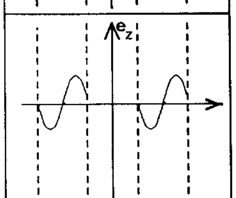
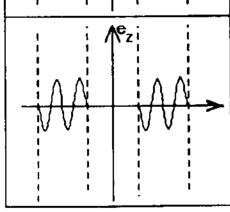
	F(x)		$\tilde{f}(m)$
	1 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$\frac{4}{B\alpha}\sin\alpha\frac{w}{2}\cos\alpha\frac{s+w}{2}$
	$\frac{1}{\sqrt{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$\frac{\pi w}{B}J_0\frac{\alpha w}{2}\cos\alpha\frac{s+w}{2}$
	$\pm\left(\frac{h}{2}-\lvert x\rvert\right)\sqrt{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$j\frac{\pi}{\alpha B}\cos\alpha\frac{s+w}{2}J_2\left(\alpha\frac{w}{2}\right)$
	$\frac{\pm\sin(4\pi(\lvert x\rvert+h/2)/w)}{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$j\frac{\pi w}{2B}\cos\alpha\left(\frac{s+w}{2}\right)$ $[J_0(2\pi-\alpha w/2)-J_0(2\pi+\alpha w/2)]$

Table 1 Basis functions and associated m th FOURIER coefficient of even mode

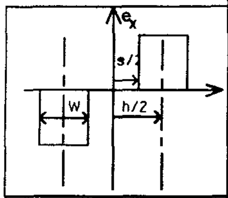
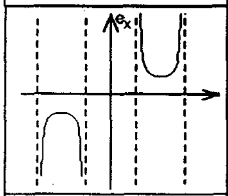
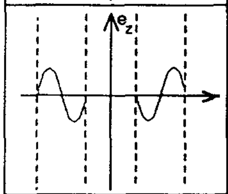
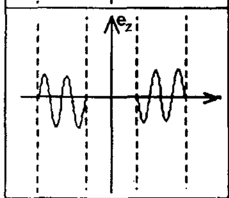
	F(x)		$\gamma(m)$
	± 1 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$\frac{4}{B\alpha}\sin\alpha\frac{W}{2}\sin\alpha\frac{s+W}{2}$
	$\frac{\pm 1}{\sqrt{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$\frac{\pi W}{B}J_0\frac{\alpha W}{2}\sin\alpha\frac{s+W}{2}$
	$\left(\frac{h}{2}-\lvert x\rvert\right)\sqrt{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$j\frac{\pi}{\alpha B}\sin\alpha\frac{s+w}{2}J_2\left(\alpha\frac{w}{2}\right)$
	$\frac{\sin(4\pi(\lvert x\rvert+h/2)/w)}{1-\left(\frac{2(\lvert x\rvert-h/2)}{w}\right)^2}$ 0	$s/2<\lvert x\rvert<s/2+w$ $\lvert x\rvert<s/2$ $\lvert x\rvert>s/2+w$	$j\frac{\pi w}{2B}\sin\alpha\left(\frac{s+w}{2}\right)$ $[J_0(2\pi-\alpha w/2)-J_0(2\pi+\alpha w/2)]$

Table 2: Basis functions and associated m th FOURIER coefficient of odd mode