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Design of Optimal Finline Taper in Multilayered structure with Spectral Domain Immittance Approach

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***Abstract*—In millimeter wave applications, it is often necessary to use transitions between waveguide and planar circuits. Finline structures can be used effectively to this purpose. In multilayered case, it is necessary to analyze the structure with numerical method such as spectral domain immittance method. The design procedure uses the cutoff frequency for each taper width. The dispersion data in a single layer are compared with those in literature. The performance of the designed finline taper is verified with the FEM simulation using HFSS.**

I. INTRODUCTION

In millimeter wave frequencies, it is often required to connect waveguide to printed circuits especially for measurement and interchanging the power between them. Therefore, it is necessary to design appropriate transition structure having low insertion loss. Finline structures are appropriate for this purpose and widely used. The characteristic impedances of the waveguide and the finline are usually different. So, it is required to design appropriate finline taper to reduce mismatching loss. Synthesis of the optimum finline taper has been usually performed based on the dispersion relation of the structures [1]. The calculation of the dispersion relation has been performed using various numerical techniques. However, most techniques are usually adequate to one dielectric layer case.

The proposed technique in this paper can be applied to the optimum design for multilayered structure which is often necessary for mechanical reasons. The technique basically expands the general spectral domain immittance technique (SDIT) [2, 3] to be applicable to the general finline structures including the unilateral, bilateral, antipodal finlines. The calculated cutoff frequencies at each slot width are compared with the results in the literature in the case of one dielectric layer for verification. In this paper, one of the bilateral structure is chosen and designed using the proposed method. The designed finline taper are analyzed using the HFSS commercial FEM simulator, to verify the technique.

II. ANALYSIS OF DISPERSION RELATIONS USING SDIT

To illustrate the formulation process, consider the multilayered finline structure which is shown in Fig. 1. This structure is analyzed using SDIT for dispersion relation, especially for cutoff frequency. The well known homogeneous integral equation in each layer can be coupled through appropriate boundary conditions to obtain coupled equations. The coupled equations are solved for unknown cutoff frequency at each slot width.

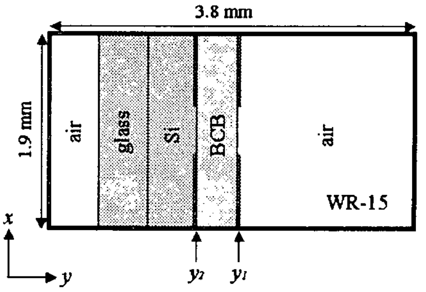

Fig. 1. Geometry of bilateral finline in multilayered structure

$$\begin{bmatrix} \hat{J}_x(k_y,y_1) \\ \hat{J}_z(k_y,y_1) \\ \hat{J}_x(k_y,y_2) \\ \hat{J}_z(k_y,y_2) \end{bmatrix} = \begin{bmatrix} \hat{G}_{xx}^{11} & \hat{G}_{xz}^{11} & \hat{G}_{xx}^{12} & \hat{G}_{xz}^{12} \\ \hat{G}_{zx}^{11} & \hat{G}_{zz}^{11} & \hat{G}_{zx}^{12} & \hat{G}_{zz}^{12} \\ \hat{G}_{xx}^{21} & \hat{G}_{xz}^{21} & \hat{G}_{xx}^{22} & \hat{G}_{xz}^{22} \\ \hat{G}_{zx}^{21} & \hat{G}_{zz}^{21} & G_{zx}^{22} & \hat{G}_{zz}^{22} \end{bmatrix} \begin{bmatrix} \hat{E}_x(k_y,y_1) \\ \hat{E}_z(k_y,y_1) \\ \hat{E}_x(k_y,y_2) \\ \hat{E}_z(k_y,y_2) \end{bmatrix} \tag{1}$$

where $\hat{J}_x$ and $\hat{J}_z$ are unknown current densities on the strip and $\hat{G}_{xx}^{ij},\hat{G}_{xz}^{ij},\hat{G}_{zx}^{ij},\hat{G}_{zz}^{ij}$ are the components of admittance matrix, which are the functions of cutoff frequency. By using the Galerkin's method, we obtain homogeneous matrix equation. Cutoff frequency can be obtained from the condition that the determinant of the matrix equals zero.

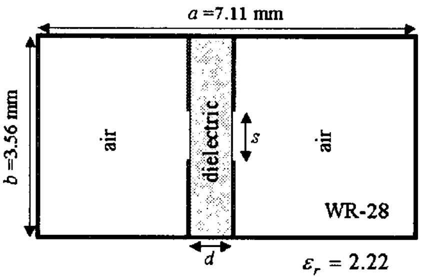

Fig. 2. Bilateral finline in a single layer

The simulation results are verified for the single layer structure in Fig. 2. The good agreements with the literature [4] are obtained as in Table I.

TABLE I. NORMALIZED CUTOFF FREQUENCY OF THE DOMINANT MODE IN BILATERAL FINLINE

d/a	s/b	SDT	Empirical	SDIT
1 / 4	1 / 2	0.16833		0.16826
	1 / 4	0.13814	0.13695	0.13780
	1 / 8	0.11779	0.11876	0.11751
	1 / 16	0.10387	0.10298	0.10376
1 / 8	1 / 2	0.17973		0.17985
	1 / 4	0.14489	0.14365	0.14448
	1 / 8	0.12058	0.12154	0.12019
	1 / 16	0.10409	0.10283	0.10394
1/16	1 / 2	0.19279		0.19290
	1 / 4	0.15732	0.15577	0.15643
	1 / 8	0.12955	0.13073	0.12934
	1 / 16	0.11014	0.10972	0.10994
1/32	1 / 2	0.20399		0.20409
	1 / 4	0.16925	0.16987	0.16809
	1 / 8	0.14110	0.14183	0.14055
	1 / 16	0.11941	0.11842	0.11926

II. OPTIMUM FINLINE TAPER DESIGN

The taper design for non-TEM structures begins with the following input reflection coefficient expression.

$$R(\eta)=\int_{-\theta}^{\theta} C\cdot K(\xi)e^{-j\eta\xi}d\xi \qquad (2)$$

with $\theta=\xi(l)=-\xi(0)$. The normalizing constant C is

$$C=\frac{1}{4}\ln\left[\left(\frac{f_{c1}}{f_{c2}}\right)^4\left(\frac{1-f_{c2}^2/f_0^2}{1-f_{c1}^2/f_0^2}\right)\right] \qquad (3)$$

Here, f_{c1} and f_{c2} are the cutoff frequencies at the two ends of the taper. The coupling distribution $K(\xi)$ along the taper is chosen so that the reflection coefficient is below a certain value $R_{\max}$ for frequencies $f>f_0$. The distribution that gives the minimum value of R is the Dolph-Chebyshev polynomial.

The design procedure of the finline taper begins with the calculation of cutoff frequency f_{c1} and f_{c2} for the slot width s_1 and s_2 respectively, which are the values at each end of the finline transition. The cutoff frequency distribution in ξ-domain is the following :

$$f_c(\xi)=f_{c1}\cdot\left[F/2+\sqrt{F^2/4+(1-F)\cdot\exp(4CI(\xi))}\right]^{-1/2} \qquad (4)$$

where $F=(f_{c1}/f_0)^2$, $I(\xi)=\int_0^{\xi}K(\xi')d\xi'$, $D=R_{\max}/C$, and $\theta=\cosh^{-1}(1/D)$.

The finline slot width distributions are obtained by matching the cutoff frequency from SDIT with the above cutoff frequency distribution. The design process begins from the first slot width s_1 and it is iterated until the final slot width s_2 is achieved with increasing the length of finline taper.

III. DESIGNED CONTOUR AND NUMERICAL RESULTS

The designed contour for the case of Fig. 1 with the maximum reflection coefficient −30dB is shown in Fig. 3.

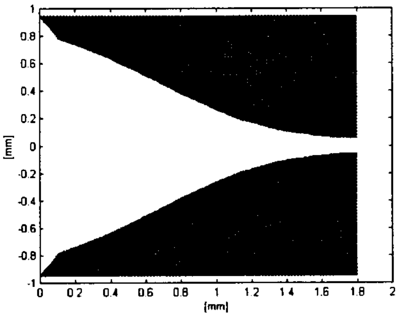

Fig. 3. The designed contour of finline transition in multilayered structure

The verification of the above transition is performed with HFSS, which shows good results as in Fig. 4.

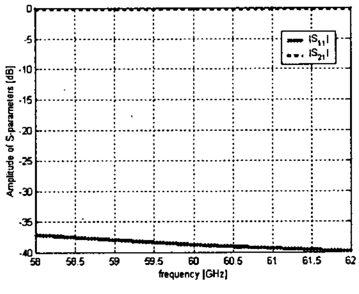

Fig. 4. S-parameters of finline taper from HFSS

IV. CONCLUSION

The optimal finline transition taper in multilayered structure was designed using spectral domain immittance approach with optimal cutoff frequency distribution. The cutoff frequency calculation results were compared with the results from literature. The shape of finline taper showed good results which was verified by a commercial FEM software HFSS.

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