FULL-WAVE MODELING OF MICRO-STRIP STEP DISCONTINUITY

N. LAKHLEF, F. LAKHLEF and L. NEHAOUA

Department of Electronics, Faculty of Engineering, University Ferhat Abbas, Sétif, 19000, Algeria.

Abstract

In this paper, we have developed an original full-wave theoretical model for the high frequency characterization of the micro-strip step discontinuity on an infinite dielectric substrate. The exact Green's function of grounded slab is used in tow-dimensional Galerkin method procedure in the spectral domain; so surface waves as well as space-wave radiation are included. The results Obtained have been compared with other results witch are obtained with other techniques.

KEY WORDS

Characterization, discontinuity, microstrip, Galerkin technique.

1. INTRODUCTION

Micro-strip discontinuities are very important part for characterization of micro-strip line basic constituent elements of [1-6]. The characterization of these discontinuities obtained by the quasi-static method [7], or by the method based on the equivalent wave-guide model. The first method only gives approached solutions for parameters of discontinuity in bases frequencies. The second approach gives a lot of information on the dispersion and its effects at high frequencies, but it does not take into account the losses due to radiation and to excitation of surface waves in the discontinuity. It is therefore of limited utilization. Then, the characterization of micro-strip line and its discontinuities require an accurate theoretical full-wave model accounting for electromagnetic coupling, space and surface waves excitation [1-18].

In this paper, we have developed a theoretical model to characterize the micro-strip step discontinuity on lessloss substrate, and carefully studies effects of the surface and space waves on circuit performances. In this model, we have applied our exact dyadic Green's function for of a grounded dielectric slab [1,2]. New integral equations for the electrical components near discontinuity are formulated, in spectral domain, using the developed exact dyadic Green's function [1-3]. Such a rigorous analysis is very often based on an integral equation formulation, typically solved with the method moments. In this paper, we apply our new algorithm of the tow-dimensional Galerkin's technique to the integral equations formulation for that type of discontinuity.

2. THEORETICAL BACKGROUND

Consider the discontinuities of micro-strip shown in fig.1. The substrate extends to infinity in x- and y-directions. The thickness of the metallization is assumed to be negligible in comparison with thickness of the substrate. Then, the surface current is assumed to flow only in the x- and y- directions in the strip [1-6].

Using the Maxwell's formulation and applying the tow-dimensional dyadic Green's function of the microstrip given in [1], yield the electrical field element integral equation expressed by [2,5]:

$$d\vec{E}(x,y)=\int_{x_0}\int_{y_0}\overline{\overline{G}}(x,y/x_0,y_0)\cdot\vec{J}_s(x_0,y_0)dx_0dy_0 \qquad (1)$$

where $\overline{\overline{G}}(x,y/x_0,y_0)$ is given in [4] and $J_s(x_0,y_0)$ is given by:

$$\vec{J}_s(x,y)=\begin{cases} g(x)g(y)\vec{i}+\frac{1}{W}\vec{j} & \text{for } -\infty<x\le W/2 \text{ and } |y|\le W/2 \\ \frac{1}{W}\vec{i}+g(x)g(y)\vec{j} & \text{for } |x|\le W/2 \text{ and } -\infty<x\le W/2 \end{cases} \qquad (2)$$

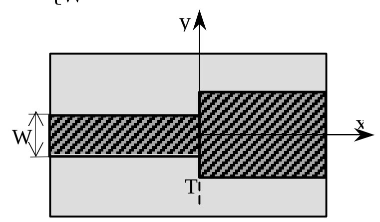


Fig. 1. Micro-strip line Step discontinuity.

We can extract the micro-strip characteristics by resolving the matrix equation, which has been developed in [1], using the least square procedure.

The integral equation of the step discontinuity (fig. 1.a) is written by imposing a boundary condition such as the total electrical field due to all the currents on the line, is null [1-9]. Equation (1) leads to:

$$\int_{x_0}\int_{y_0}\left[I_i(x_0,y_0)+I_r(x_0,y_0)+I_t(x_0,y_0)+\sum_{n=1}^{2N}I_n g_n(x_0)g_n(y_0)\right]$$
$$\cdot\int_{-\infty}^{+\infty}\int\hat{g}(k_x,k_y)e^{jk_x(x-x_0)+jk_y(y-y_0)}dk_xdk_ydx_0dy_0=0 \qquad (3)$$

where $g_n(\eta)$ is given in [1]. I_i, I_r and I_t are the incident, the reflective and the transmitted current components given by:

$$I_i(x,y)=e^{-jkx} \qquad (4)$$

$$I_r(x,y)=-Re^{jkx} \qquad (5)$$

$$I_t(x,y)=-Te^{-jkx} \qquad (6)$$

To analyze this discontinuity, three dominant modes are used in the representation of the incident, reflective and transmitted currents. The transmitted current I_t is introduced in the equation (3) with N additional PWS modes. These modes have to exist in $x_n = -nd$ for $n = 1, 2, \cdots, N$ and in $x_n=nd$ for $n=N+1, N+2,\cdots, 2N$. It results therefore 2N PWS modes, which are used in the new integral equation.

To resolve the characteristic equation (3), we enforce it by the multiplication by 2N+2 weighting or test functions:

$$\int_{-\infty}^{+\infty}\!\!\int \tilde{g}(k_x,k_y)\sum_{m=1}^{2N+2}F_{xm}(k_x)F_{ym}(k_y)\Bigg(\Big[(1-R)\cdot F^*_{xc}(k_x)-j(1+R)F^*_{xs}(k_x)\Big]F_y(k_y)+\sum_{n=1}^{N}I_nF^*_{xn}(k_x)F^*_{yn}(k_y)$$
$$+\Big[TF^*_{xct}(k_x)-jTF^*_{xst}(k_x)\Big]F_y(k_y)+\sum_{n=N+1}^{2N}I_nF^*_{xn}(k_x)F^*_{yn}(k_y)\Bigg)dk_x dk_y=0 \qquad (7)$$

where F_x, F_y, F_{mn}, F_{mc}, F_{ms}, F_{mct} and F_{mst} are defined in [4,9]. R and T are the reflection and the transmission coefficients given by [4,9]. The substitution of the double summation in the resulting integral equation, allows us to define the impedance matrix by:

$$\begin{bmatrix} Z_{11} & Z_{12} & \cdots & -(Z_{1c}+jZ_{1s}) & Z_{1ct}-jZ_{1st} \\ Z_{21} & Z_{22} & \cdots & -(Z_{2c}+jZ_{2s}) & Z_{2ct}-jZ_{2st} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ Z_{2N+1\,1} & Z_{2N+1\,2} & \cdots & -(Z_{2N+1c}+jZ_{2N+1s}) & Z_{2N+1ct}-jZ_{2N+1st} \\ Z_{2N+2\,1} & Z_{2N+2\,2} & \cdots & -(Z_{2N+2c}+jZ_{2N+2s}) & Z_{2N+2ct}-jZ_{2N+2st} \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ R \\ T \end{bmatrix} = \begin{bmatrix} -Z_{1c}+jZ_{1s} \\ -Z_{2c}+jZ_{2s} \\ \vdots \\ -Z_{2N+1c}+jZ_{2N+1s} \\ -Z_{2N+2c}+jZ_{2N+2s} \end{bmatrix} \qquad (8)$$

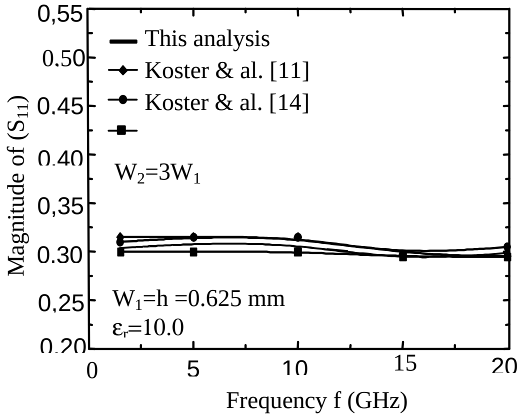
where the impedance matrix elements Z_{mn}, Z_{ms}, Z_{mc}, Z_{mst}, Z_{mct} are defined in [4].

Using the lower upper decomposition technique for inverting the resulting impedance matrix, we can resolve the matrix equation (8). This expression allows to obtain the reflection coefficient R, the transmission coefficient T and the I_n coefficients.

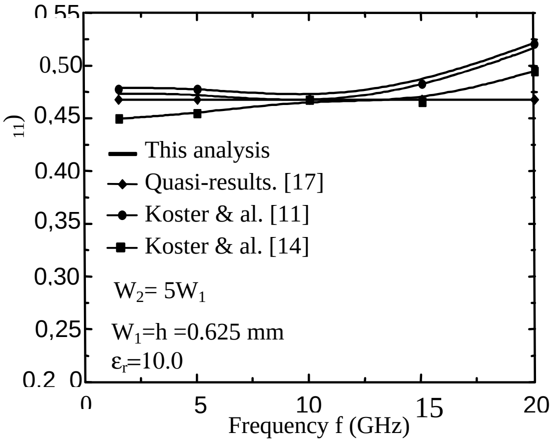
3. RESULTS

The fig. 2 gives amplitude of reflection coefficient of a microstrip Step discontinuity, versus frequency, for substrate of ε_r =10 and W_1=h=0.625mm with $W_2=3W_1$ (a) and $W_2=5W_1$ (b). Our results are compared with those of Koster [19,22] and those gotten by the qausi-static approach [20]. Our results as shown in fig. 4 are in good agreement with those of Koster [19,22] and with those of the qausi-static approach [20].

The fig. 3. a. and fig. 3. b. gives magnitude of transmission and reflexion coefficients respectively of a micro-strip Step discontinuity, versus frequency substrate of ε_r =10 and W_1=h=0.625mm with $W_2=3W_1$ and $W_2=5W_1$ Our results are compared with those of Koster [19,22] and those gotten by the qausi-static approach [20]. Our results are in good agreement with those of Koster [19,22] and with those of the qausi-static approach [20]. And our results are sometimes in perfect concordance with other method's results.



(a)



(b)

Fig. 2. Frequency dependent magnitude reflexion coefficients of micro-strip Step discontinuity.

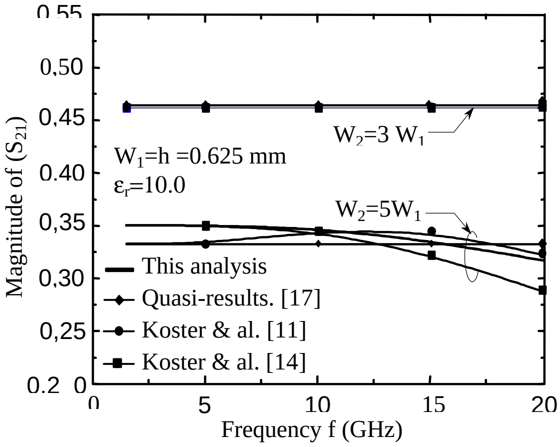


Fig. 3. Frequency dependent magnitude transmission coefficients of micro-strip Step discontinuity.

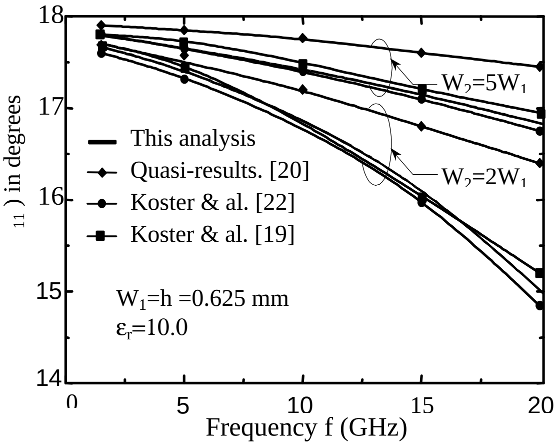


Fig. 4. Frequency dependent argument transmission coefficients of micro-strip Step discontinuity.

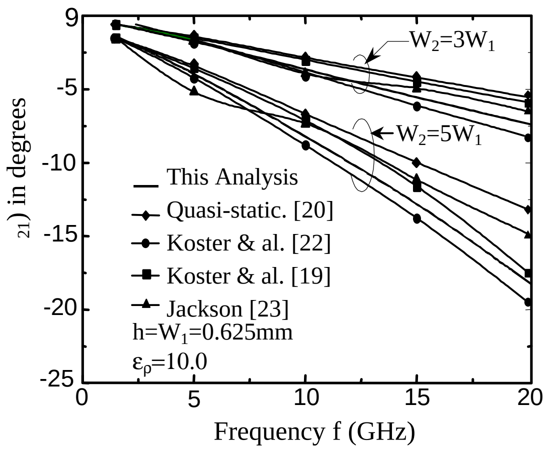


Fig. 5. Frequency dependent argument reflexion coefficients of micro-strip Step discontinuity.

The fig. 4. gives magnitude of transmission and reflexion coefficients of a micro-strip Step discontinuity, versus frequency substrate of ε_r =10 and W_1=h=0.625mm with $W_2=3W_1$ and $W_2=5W_1$ Our results are compared with those of Koster [19,22] and those gotten by the qausi-static approach [20]. Our results are in good concordance with those of Koster [19,22] and with those of the qausi-static approach [20].

The fig. 5. gives argument of transmission coefficient of a micro-strip Step discontinuity, versus frequency substrate of ε_r =10 and W_1=h=0.625mm with $W_2=3W_1$ and $W_2=5W_1$ Our results are compared with those of Koster [19,22] and those gotten by the qausi-static approach [20]. Our results are in good concordance with those of Koster [19,22] and with those of the qausi-static approach [20].

The fig. 6. gives argument of reflexion coefficient of a micro-strip Step discontinuity, versus frequency substrate of ε_r =10 and W_1=h=0.625mm with $W_2=3W_1$ and $W_2=5W_1$ Our results are compared with those of Koster [19,22] and those gotten by the qausi-static approach [20]. Our results are in good concordance with those of Koster [19,22] and with those of the qausi-static approach [20].

4. CONCLUSION

An analysis by the full wave approach using a two dimensional Galerkin's method has been used for typical step discontinuities in the microstrip line. The magnitudes of the scattering parameters are calculated versus frequency and compared with previous calculations. The importance of ameliorations is also addressed. The accuracy of our results has been checked with an excellent agreement with the different approaches. This analysis can help in the design of microwave integrated circuits, particularly for the high frequencies and the planar structures. Such analysis should aid to characterize more complicated discontinuities in the microstrip line.

REFERENCES

[1] G. W. Hanson, ″Numerical formulation of dyadic Green's functions for planar bianisotropic media with application to printed transmission lines″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No. 1, Jan. 1996, pp. 144-151.

[2] S. G. Mao, J. Y. Ke and C. H.Chen, ″Propagation characteristics of superconducting microstrip lines″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No 1, Jan. 1996, pp. 33-40.

[3] N. Lakhlef, ″Modélisation des Discontinuités Step, Coude, la Jonction en T et la Jonction croisée de la Ligne à Microruban par l'Approche Full-Wave Basée sur la Fonction de Green Exacte et et la Méthode de Galerkin Améliorée″, Master dissertation, *Univ. of Setif, Algeria, May 2000.*

[4] W. P. Harokopus and P. B. Katehi, ″Characterization of microstrip discontinuities on multilayer dielectric substrates including radiation losses″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 37, No. 12, Dec. 1989, pp. 2058-2066.

[5] R. N. Simons, N. I. Dib, and P. Katehi, "Modeling of coplanar stripline discontinuities", *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No. 5, May 1996, pp. 711-716.

[6] X. Zhang and K. K. Mei, ″Time-domain finite difference approach to the calculation of the frequency-dependent characteristics of microstrip discontinuities″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 36, No. 12, Dec. 1988, pp. 1775-1787.

[7] N. I. Dib, and P. B. Katehi, "Characterization of three-dimensional open dielectric structures using the finite difference time domain method", *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No. 4, Apr. 1996, pp. 513-518.

[8] F. Djahli, A. Mayouf and M. Dekik, ″Modeling of microstrip open end and gap discontinuities by an ameliorated moments method″, *Int. Journal of Electronics*, Vol. 86, No. 2, Feb 1999, pp. 245-254.

[9] H. Y. Yang and N. G. Alexopoulos, ″Microstrip open end and gap discontinuities in substrate superstrate structure″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 37, No. 10, Oct. 1989, 1542-1546.

[10] B. Souny H. Aubert and H. Baudrand, ″Elimination of spurious solutions in the calculation of eigenmodes by moments method″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No. 1, Jan. 1996, pp. 154-157.

[11] N. L. Koster and R. Jansen, "The microstrip step discontinuity: a revised description", *IEEE Trans. Microwave Theory and Techniques*, vol. MTT-34, no. 2, pp. 213-223, Feb. 1986.

[12] A. Farrar and A. T. Adams, ″Multilayer microstrip transmission lines″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 22, No. 10, Oct. 1974, pp. 889-891.

[13] A. H. Hamade, A. B. Kouki, and F. M. Ghannouchi, "A CAD-suitable approach for the analysis of nonuniform MMIC and MHMIC transmission lines", *IEEE Trans. Microwave Theory and Techniques*, Vol. 44, No. 9, Sep. 1996, pp. 1614-1617.

[14] N. L. Koster and R. Jansen, "The equivalent Circuit of the Asymmetrical Series Gap in Microstrip and Suspended–Substrate Lines", *IEEE Trans. Microwave Theory and Techniques*, vol. 30, pp. 1273-1279, July 1982.

[15] A. G. Engel and P. B. Katehi, ″Frequency and time domain characterization of microstrip-ridge structures″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 41, No. 8, Aug. 1993, pp. 1251-1260.

[16] R. W. Jackson and D. M. Pozar, ″Full wave analysis of microstrip open end and gap discontinuities″, *IEEE Trans. Microwave Theory and Techniques*, Vol. 33, No. 10, Oct. 1985, pp. 1036-104.

[17]. C. Gupta, R. Garg, and I. J. Bahl, "Microstrip Lines and Slotlines", *Artech House*, inc. 1979.