Close-From Model of Shunt Capacitance and Inductance of Microstrip Step Discontinuities

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Abstract—**Some results for the inductance and capacitance associated with a step discontinuity in a microstrip are available. We present a model on the based of K.C. Gupta proposal for inductance having a maximum deviation 5% and average deviation 3% for $\in_r$ = 9.6 and compare the numerical calibration with de-embedding techniques used in the planar electromagnetic (EM) simulation (SONNET) for $\in_r$ = 2.3, 4.0, 15.1, 20.0 & 40.0. These techniques are used to eliminate the port discontinuities brought by the current/voltage exciting source. The closed form model for step shunt capacitance having a maximum deviation 10% and average deviation 4.66% for $2.3 \le \in_r \le 40.0$ against numerical results of the internal equation method. The models have average deviation 0.027 for the C_p and 0.015 for L_s against the results of Sonnet.**

I. INTRODUCTION

SEVERAL rigorous methods and experimental investigation have been used to determine the inductance loss of microstrip line with change its width in wide and narrow line. In this work we present the closed-form expressions to compute the step discontinuity shunt capacitance C_p and series inductance L_s. The closed-form expressions are obtained by improving the model suggested by Hoffman [4] for the capacitance C_p and the model suggested by Gupta for the inductance L_s. Our empirical models are obtained through the process of multidimensional logistic curve fitting. The static data are also generated from the commercial EM- software Sonnet [5] at 1 GHz. The accuracy of the present models is tested against the wide-ranging parameters obtained from these two sources. We further tested the models by incorporating the equivalent circuit model of the step discontinuity in the commercial circuit simulator- Microwave Office [6] and comparing the scattering parameters against the response obtained from the EM simulator- Sonnet [5].

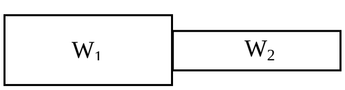

Figure1. Step discontinuity in microstrip

II. SHUNT STEP DISCONTINUITY CAPACITANCE C_p

The effective relative permittivity $\varepsilon_{r,eff1}$ of microstrip #1 and its characteristics impedance on air substrate $Z_0(\varepsilon_r = 1)$ are obtained from the closed- form expressions of Hammerstad and Jensen [4]. However, the shunt step discontinuity capacitance C_p computed by this method is much in error. It can be improved by incorporating an improvement factor $IF\ (\varepsilon_r\ , \mathrm{W_1/h}, \mathrm{W_2\ /h})$ that is a function of widths of both microstrip lines and relative permittivity ε_r of the substrate.

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The corrected shunt step discontinuity capacitance $C_{p(corr)}$ is given by

$$C_{p\,(corr\,)} = \left[\frac{C_p}{IF\ (\in_r\ , \mathrm{W_1/h},\ \mathrm{W_2\ /h}\ )}\right] \tag{1}$$

The improvement factor is obtained by the multidimensional logistic curve fitting of the reference data extracted from the graphical results of Gupta and Gopinath [1]. The data on the improvement factor, over the wide range of parameters ε_r , W_1/h and W_2/h; are generated by comparing the C_p computed by equation-1. Accuracy of the present model has been tested over the wide range of parameters against the results of Gupta and Gopinath [1]. Fig.2 demonstrates accuracy of the present model for the step discontinuity on substrate $\varepsilon_r = 9.6, W_2/h = 1$ and also results are shown in Fig.3 for $\varepsilon_r = 40$, $W_2/h = 1$.

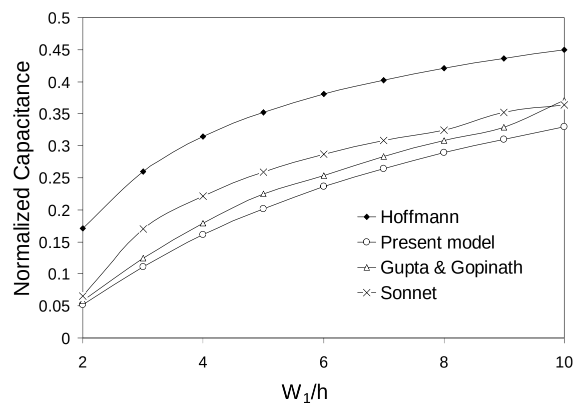

Figure2. Normalized step discontinuity capacitance for $\varepsilon_r = 9.6, W_2/h = 1$

III. SERIES STEP DISCONTINUITY INDUCTANCE

In this section we adopt the model of Gupta et al. and use an empirically determined multiplying correction factor Y to get the improved model. The multiplying correction factor Y is obtained by the multidimensional curve fitting the data on Y generated by comparing the results against the reference data. The corrected step discontinuity inductance $L_{s(corr)}$ and its normalized form are given as

$$L_{s\,(corr)} = L_s\ Y \qquad (a) \qquad L_{n(corr)} = \frac{L_{s\,(corr)}}{L_{w2}\ h} \qquad (b) \tag{2}$$

The reference data are extracted from the graphical results of Gopinath et al. [5] and further data are generated from the commercial software Sonnet [5].

$$\mathrm{Y} = \mathrm{Y_1}\left(\frac{\mathrm{w_1}}{\mathrm{h}}\right)^{-\mathrm{Y_2}} \tag{3}$$

IV. SCATTERING PARAMETER OF DISCONTINUITY CIRCUIT MODEL

We can simulate the circuit model in the Microwave Office [6] after calculating the component values from our present closed-form model. The microstrip step structure can be constructed in the Sonnet [5]. Fig.6 shows such comparison of S_{21} and S_{22} for ε_r = 9.6, W_2/h =1.0, W_1/h =5.0.

TABLE I

PERCENTAGE ERROR BETWEEN GOPINATH, PRESENT MODEL WITH SONNET (REFERENCE) FOR CAPACITANCE

W_1/h	$\in_r$ = 2.3		$\in_r$ = 4.0		$\in_r$ = 15.1		$\in_r$ = 20.0	$\in_r$ = 40.0
	GOPI	P.M	GOPI	P.M	GOPI	P.M	P.M	P.M.
2.0	7.0	29.5	18.4	16.1	20.2	15.6	21.8	17.4
3.0	20.0	7.2	20.0	25.8	5.4	3.9	20.0	23.4
4.0	21.0	14.0	21.1	17.6	5.8	0.5	23.6	12.6
5.0	11.8	9.9	12.9	11.8	1.7	7.0	18.2	6.8
6.0	6.1	5.8	10.6	7.3	0.78	4.7	10.4	3.2
7.0	0.81	0.54	8.6	3.5	1.1	3.7	10.4	0.68
8.0	2.5	1.52	4.8	1.1	1.4	4.6	7.6	0.97
9.0	3.2	1.1	5.4	0.25	0.96	2.2	9.4	1.8
10.0	7.2	5.0	0.25	0.75	1.8	1.2	7.1	0.29

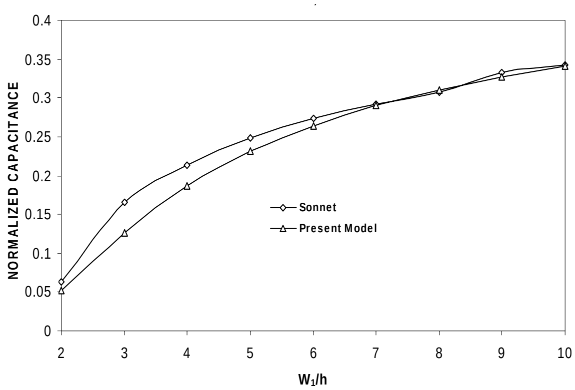

Figure3. Normalized Capacitance using sonnet ε_r = 40, W_2/h =1.0

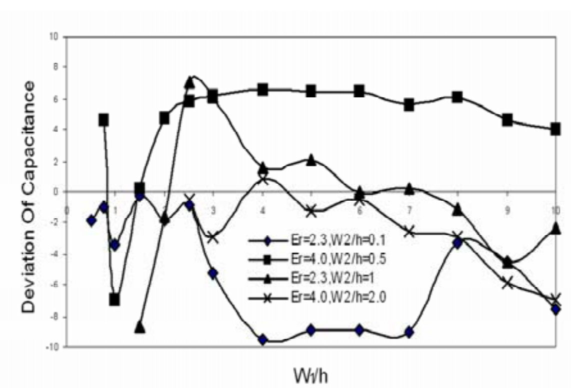

Figure4. Deviation of capacitance with W_1/h

V. RESULTS

The static model needs improvement for its operation in high frequency range. The present models and MOM results against the results obtained from Sonnet are shown in Table-1 and Table -2. The present model has average deviation 0.04 and MOM has average deviation 0.043 from the results of Sonnet. With increase in relative permittivity the average deviation of the present model decreases as for ε_r =20.0 it is 0.031.

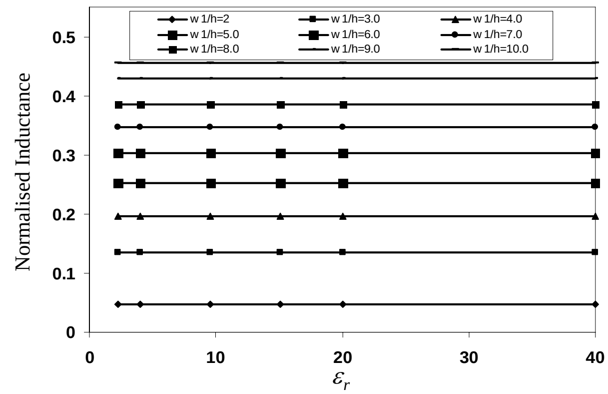

Figure5. Behavior Inductance using SONNET for different ε_r

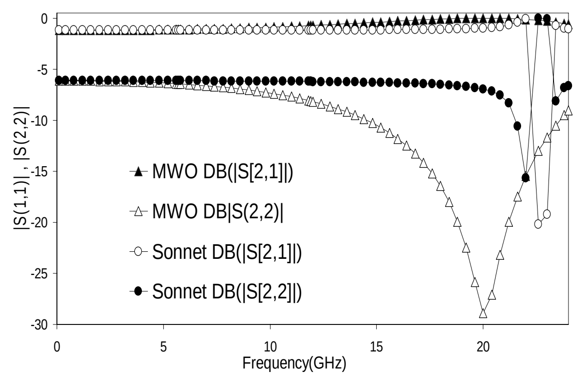

Figure6. Comparison of circuit model against Sonnet for ε_r = 9.6, W_2/h =1.0 and W1/h = 5.0

TABLE II

PERCENTAGE ERROR BETWEEN GOPINATH, PRESENT MODEL WITH SONNET (REFERENCE) W_2/h =1.0, $\in_r$ = 9.6 FOR INDUCTANCE

W_2/h	SONNET(Ref)	Present model	Gopinath
2.0	0.048	10.4	20.8
3.0	0.135	0.74	5.92
4.0	0.197	2.0	3.04
5.0	0.253	4.30	2.76
6.0	0.303	4.6	-
7.0	0.347	5.1	-
8.0	0.386	5.1	-
9.0	0.429	6.7	-
10.0	0.456	5.2	-

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