Using MSC/EMAS in Simulating a Parallel Microstrip Transmission Line

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ABSTRACT

During a crosstalk study of two parallel and coplanar microstrip lines having identical width and thickness, the MSC/EMAS code was used to calculate the total current flows on the receptor line, and demonstrate the relationship between substrate height and crosstalk. The frequency used in the simulations was 200 MHz. One microstrip trace was driven by a 100 mA ideal current source and terminated with a 50 ohm resistive load. The other trace was terminated at both ends by two 50 ohm loads.

MSC/EMAS produced results that are accurate to within 4 percent of the closed form solution. It also clearly demonstrated that the magnitude of crosstalk, as a function of substrate height, asymptotically approaches a final value.

INTRODUCTION

In recent years, the numerical computation of electromagnetic (EM) fields has become an increasingly important tool in determining the complicated field results of a complex radiating structure. It can be applied to a broad range of EM problems. On the other hand, the available analytical solutions are limited to very simple geometries as in this selected microstrip line problem. Several basic numerical codes based upon the finite element technique, moment technique, or Geometrical and Uniform theory of diffraction are commercially available. In this paper, crosstalk between two parallel coplanar microstrip lines terminated by 50 Ohm loads (See Figure 1) and excited by a 100 mA ideal current source has been analyzed using the MSC/EMAS computer code. This geometry was chosen due to the fact that the closed form solution is available for comparison [1,2,3].

In Figure 1, a top view of the structure under investigation is shown. The generator strip is driven by an ideal current source at the near end and terminated at the far end. The remaining strip (receptor strip) is terminated both at the near and far ends..

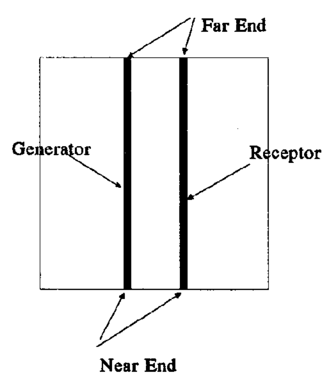

Figure 1. Top View of Microstrip Structure

A substantial amount of research has been done in the determination of an expression for Crosstalk. In [1], an expression in terms of a voltage ratio V_{NE}/V_S , based on circuit theory, has been given, and is shown in Equation 1.

$$\left|\frac{V_{NE}}{V_S}\right| = \omega\left(\frac{L_m}{2R} + \frac{R}{2}C_m\right) \qquad (1)$$

where,

L_m is the total mutual inductance,

C_m is the total mutual capacitance,

R is all termination impedances,

V_{NE} is the near end voltage of the receptor strip, and

V_S is the near end source voltage of the generator strip.

L_m and C_m can be determined from the per-unit-length values for which expressions are given in [4,5,6,7]. At a frequency of 200 MHz and 50 Ohm resistive load terminations, the crosstalk amplitude obtained viz. Equation 1 is accurate to within 1 dB [1].

With the use of the Thevenin equivalent theorem and identical 50 ohm loads at all terminations, Equation 1 can be rewritten in terms of current and is expressed in Equation 2.

$$\left|\frac{I_{FE}}{I_S}\right| = \omega\left(\frac{L_m}{2R} + \frac{R}{2}C_m\right) \qquad (2)$$

where now,

I_{FE} is the far end current of the receptor strip, and

I_S is the near end source current of the generator strip.

An initial MSC/EMAS finite element model of Figure 1 was constructed using only 3 dimensional elements. In the model, the terminating resistors were modeled using RES elements. These are scalar elements used to insert conducting properties into the conductivity matrix [8]. An isometric representation of the structure that was modeled is shown in Figure 2.

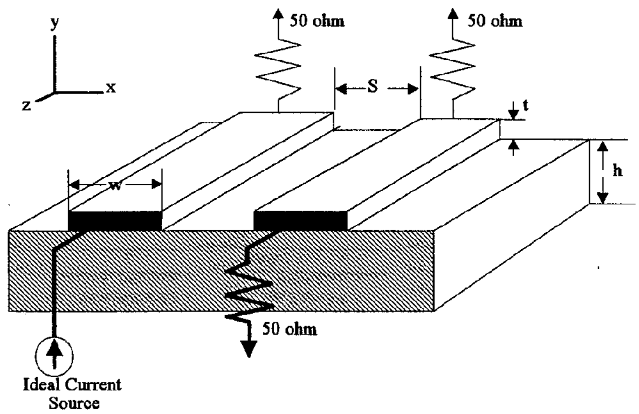

Figure 2. 3D View of Microstrip Structure

MODELLING TECHNIQUE

In the model, hexahedra and pentahedra elements were used. The current sources were two PCUR4s of which one was applied at the left edge, and the other at the right edge of the generator strip. PCUR4s are excitations that are applied directly to the electric scalar potential degree of freedom. When applied at the physical boundary of a problem, they represent total current entering the model at a grid point [8]. The magnitude of each PCUR4 was 50 mA, which results in a total of 100 mA entering the model. All terminating impedances were modeled using 29 zero dimensional RES elements connected in parallel and distributed along the width of the microstrip at each termination. The individual value of each RES element was 1450 ohms, which effectively yielded the desired 50 ohm equivalent resistance. The substrate was assumed linear, homogeneous, and lossless. The conductivity of the copper traces used is 5.7×10^7 Siemens/m. The mesh in the conductor was graded in such a way that the thickness of the elements which were next to an interface was less than one half of a skin depth. The finite element model used the following microstripline parameters: conductor width $w = 0.3$ mm, thickness $t = 0.0178$ mm. The substrate height h varied as follows: $0.5 \leq h \leq 10.0$ mm, the separation S between traces was = 0.45 mm, 0.6 mm, or 0.9 mm, and the substrate permitivitty ε_r was equal to 4.5. With MSC/EMAS Version 1, infinite boundary elements are not available. Therefore, the finite element models' total volume was approximately 13 mm in width, 15 mm in height, and 1 mm in depth. The bottom edge of the model served as the ground plane and therefore the distance from the bottom face of the model to the conducting traces varied between 0.5 mm and 10.0 mm. The distance from the traces to the left and right edges was approximately 6.5 mm. From the top of the model volume to the conductors was approximately 12.5 mm. These distances should minimize the effect of finite boundaries on the current distributions in the microstrip traces.

The boundary conditions used in the model were the following. For both x-z planes (top and bottom walls), and both y-z planes (left and right walls) of the model, perfect conductor boundaries were used (i.e. A tangential was zero, and DOF 4, the scalar electric potential, was also zero). The ground plane was placed at an initial distance of 1.6 mm away from the microstrip traces. On the front and back plane of the model, the magnetic vector potential A was constrained to exist only in a normal orientation to these planes (i.e. A tangential was equal to zero). The finite element mesh is shown in Figure 3.

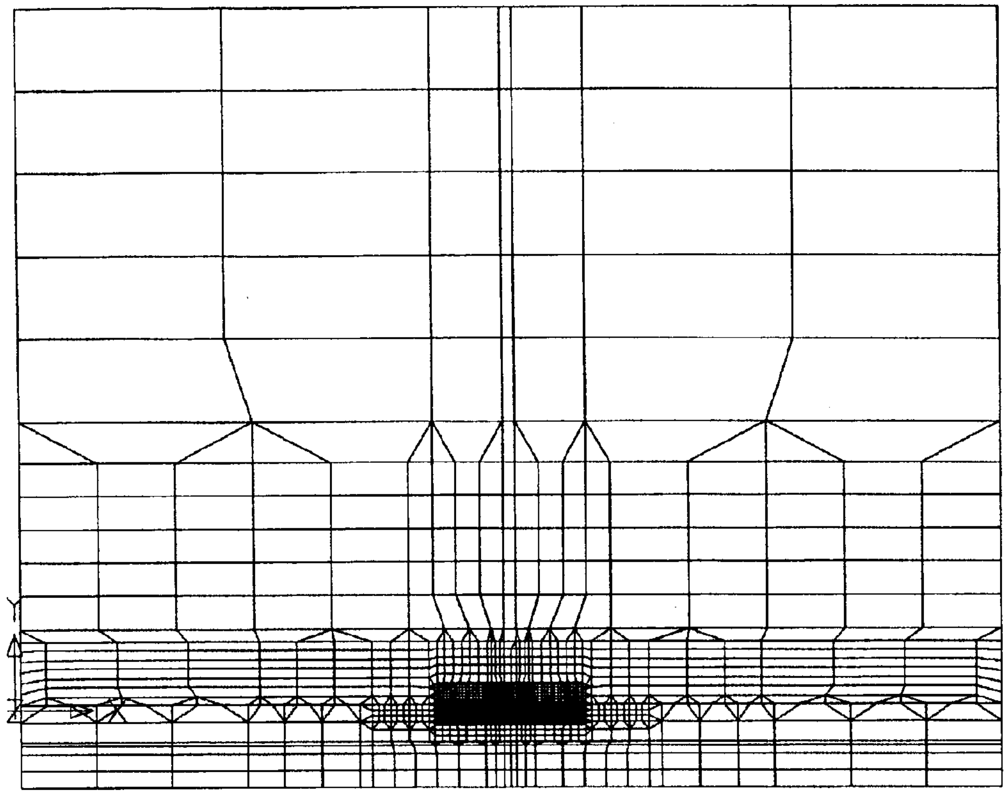

Figure 3. Finite Element Mesh

VALIDATION OF RESULTS

In order to determine the crosstalk in the receptor strip of the finite element model, the currents in the receptor strips' far end RES elements were summed and a net current was determined. This value was then divided by the current entering the model (100 mA), converted to a magnitude and compared with solutions provided by Equation 2.

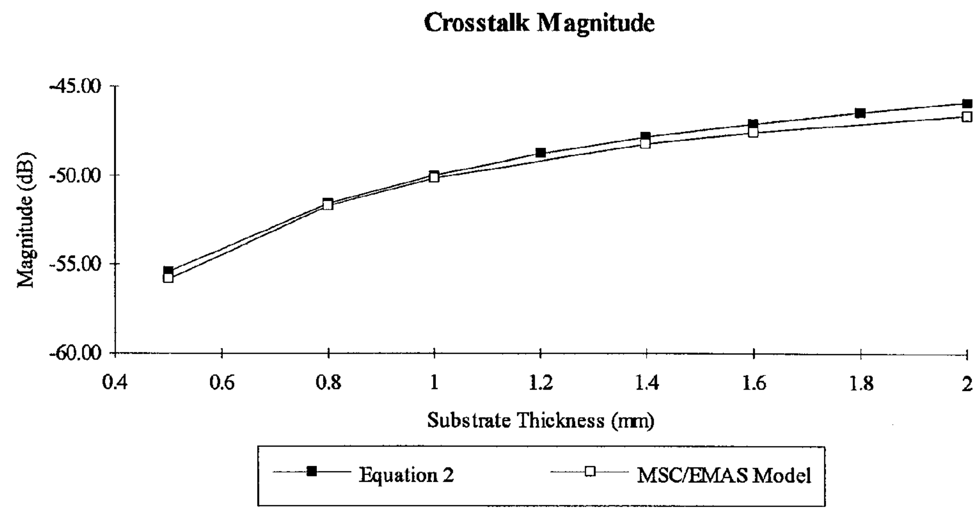

Figure 4. Equation 2 vs. MSC/EMAS Results

Figure 4 shows the crosstalk amplitude as a function of dielectric thickness which varies from 0.5 mm to 2.0 mm. Excellent agreement is seen in Figure 4, with the average difference being less than 4 %.

In Figure 5, MSC/EMAS results are shown for crosstalk amplitude as the substrate height is varied from 0.5 mm to 10.0 mm, for three different line spacings *S*. Again, the nonlinear relationship between crosstalk and substrate height is seen.

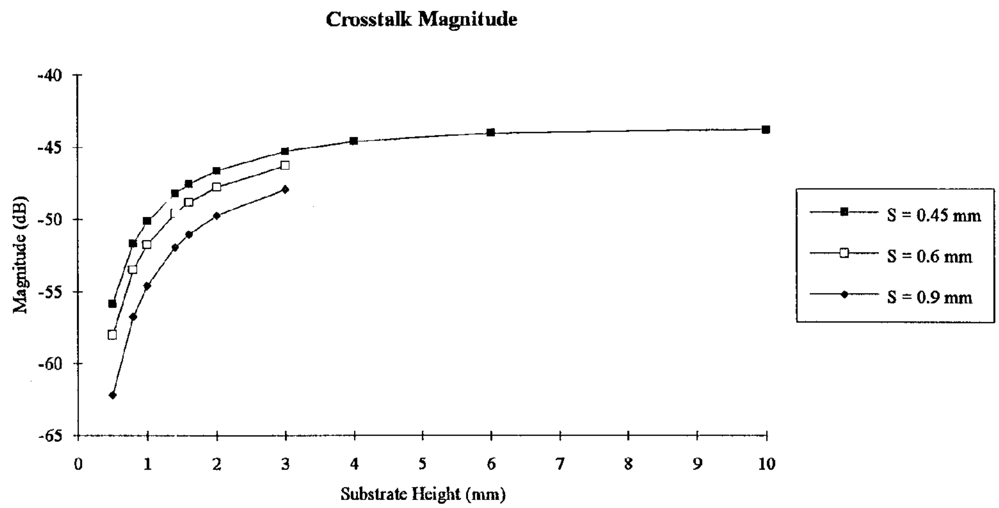

Figure 5. Crosstalk as a Function of Substrate Height *h*, and Separation *S*

CONCLUSION

It is shown that MSC/EMAS can effectively be used in the calculation of crosstalk. The results produced are quite accurate when compared to published results, with an average discrepancy in crosstalk magnitude of less than four percent. MSC/EMAS also clearly showed that the crosstalk magnitude asymptotically approaches a maximum value when the substrate height is varied.

A distinct advantage of MSC/EMAS, however, is that the finite element method can also be used in crosstalk simulation in which circuit model approximations are not appropriate. An example of these types of problems are microstrip junctions, or microstrip structures which are comprised of nonlinear and/or anisotropic materials.

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