EFFECT OF PACKAGE SHAPE ON SPURIOUS COUPLING AMONG MICROSTRIP DISCONTINUITIES

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ABSTRACT

Effects of a metallic package on the performance of a microstrip circuit are attributed mainly to the modifications of spurious couplings among various discontinuities. This paper describes a method for computing the effect of the package shape on the interactions among discontinuities. It is shown that chamfering of the corners of a rectangular package can reduce the spurious coupling between two microstrip open-end stubs.

INTRODUCTION

Effects of package design on the performance of a microwave circuit contained therein has been a topic of recent interest [1-5]. In an earlier paper [3], a method for evaluating the effect of a rectangular package on the spurious coupling among microstrip circuit discontinuities had been reported. Extension of this approach for evaluating the effect of a rectangular shaped metallic package on performance of microstrip circuits was reported in [5]. The present paper considers package shapes other than rectangular, with the objective of minimizing the effect of package on the performance of the circuits contained inside the package.

APPROACH

The approach used is an extension of the procedure reported in references [3] and [5]. A surface located on the top side of the substrate containing the circuit is considered to separate the circuit portion below, from the rest of the electromagnetic fields above this surface in the package enclosure. Use of Schellkunoff's equivalence theorem allows all the sources underneath this surface to be expressed in terms of a distribution of equivalent magnetic current sources located on this fictitious surface separating the circuit and package regions. If we consider a very simple "circuit" configuration consisting of two open-ended microstrip lines connected to the input and output ports respectively as shown in Fig. 1, the equivalent magnetic current distribution obtained by implementing Schellkunoff's equivalence theorem may be approximated by a distribution of line sources of magnetic current shown in Fig. 2. Note that the package shape shown in Fig. 2 is a different non-rectangular shape than that shown in Fig. 1. These are the kinds of package shapes that have been investigated by the approach described in this paper. The magnetic current distribution shown in Fig. 2 can be considered as the source for the fields in the package enclosure. Interactions among various magnetic current elements give rise to spurious couplings among various parts of the microstrip circuit. In the simple example shown, we can calculate the electric current induced at the location "b" (shown in Fig. 2) as a result of a magnetic current source at the location "a". This leads to an equivalent admittance matrix representation of the spurious coupling [3] and, for the example being discussed, can be used for calculating the transmission from the port 1 to the port 2 caused by the presence of the package.

EVALUATION OF SPURIOUS COUPLING

For implementing the approach described above, we need to calculate the field produced by a magnetic current element inside the empty package volume. For a rectangular shaped package, this computation is carried out [3] by expressing the package fields in terms of eigenmodes of a rectangular cavity resonator. When the package has a non-rectangular cross-sectional shape (such as those shown in Figs. 1 and 2), the modal expansion approach is not valid. In the present work we have used a numerical method [6, 7] which combines edge-element/face-element time-domain (EFTD) and FDTD techniques. In this method updating equations for the E- and H-fields are derived by integrating Ampere's and Faraday's laws directly over prescribed surfaces and contours. A diagonalization technique is introduced to reduce the rectangular version of EFTD to the finite-difference time-domain (FDTD) method. For a structure that requires griding with both rectangular and conformal cells, the equivalent FDTD algorithm is used in the rectangular cell region to enhance the overall efficiency while the EFTD algorithm is used in the conformal-cell region to achieve high accuracy for curved boundaries. This time-domain field simulation approach has been verified for several test cases [6, 7].

NUMERICAL RESULTS AND DISCUSSION

Effect of package shape on spurious coupling between two microstrip open-ends has been investigated for the two

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geometries shown in Fig 1 and 2. FDTD/EFTD method mentioned earlier is used to calculate the value of the tangential magnetic field at location "b" for a unit magnetic current excitation at location "a" (Fig 2). Cell size in FDTD computation was taken to be 0.6 mm × 0.6 mm. Time domain computations were carried out at 8192 points with time step $\Delta t = 1.155$ ps. The magnetic current excitation is related to the input power at port 1. The tangential magnetic field at "b" is related to the induced electric current and hence the power coupled to the port 2. These lead to computation of the scattering parameter S_{21}.

For geometry of Fig 1, the spurious coupling represented by S_{21} is plotted in Fig 3. The package dimensions are 14.4 mm × 24 mm × 6.0 mm. For $\varepsilon_r = 10.5$ and substrate height = 1.27 mm, the characteristic impedances of two lines are 51 ohms. Fig 3 shows a strong coupling at the resonance of TM_{110} mode which for a perfect rectangular package (x = 0 mm) occurs at 12.01 GHz. Cuts at the corners (of dimension x) shift this resonance frequency as shown in this Figure. Normally in selecting package dimensions, these resonances are avoided, and it is the spurious coupling away from the resonance frequency (say at 2.0 GHz) that we are more concerned with in the present investigation. We observe that by a suitable choice of x (= 2.4 mm in this case), this spurious coupling can be reduced from -48 dB to -57 dB. As shown in Fig 4, the variation of $|S_{21}|$ with the dimension x is not monotonic and the optimum value can be calculated by the analysis described in this paper.

Effect of triangular chamfering of the corners (as shown in Fig 2) on the spurious coupling between two open-ends is shown in Figures 5 and 6. Again, observations similar to that for package shape of Fig 1 are valid in this case also. The spurious coupling S_{21} can be reduced by an optimum choice of the dimension x. In this case also, the best results are obtained for x = 2.4 mm.

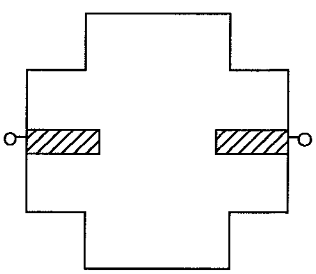

Fig. 1 A canonical configuration of two open-ended microstrip line sections inside a non-rectangular shaped package.

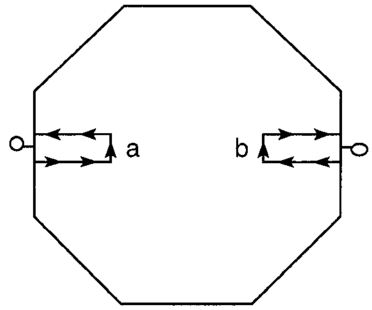

Fig. 2 Equivalent magnetic current distribution corresponding to the two open-ended microstrips in Fig 1 shown in a package with a different non-rectangular shape.

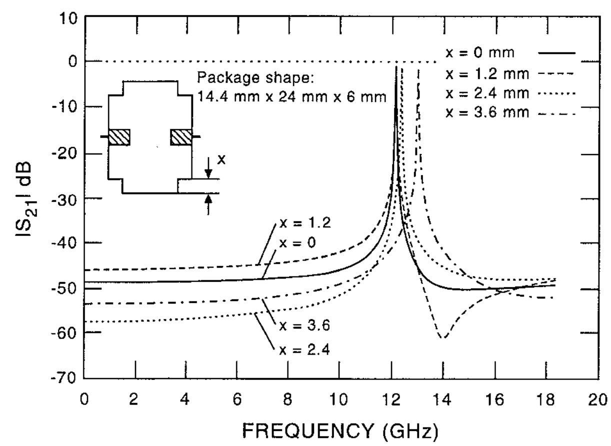

Fig. 3 Spurious coupling $|S_{21}|$ versus frequency for various values of dimension x for the package shape shown in Fig 1.

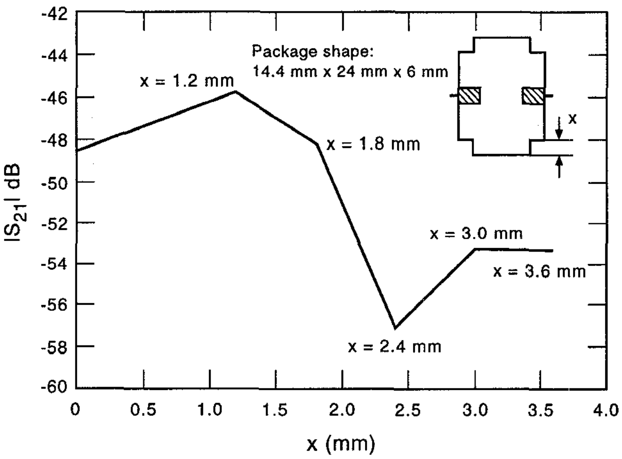

Fig 4. Variation of spurious coupling $|S_{21}|$ at 2.0 Ghz as a function of the dimension x for the package shown in Fig 1.

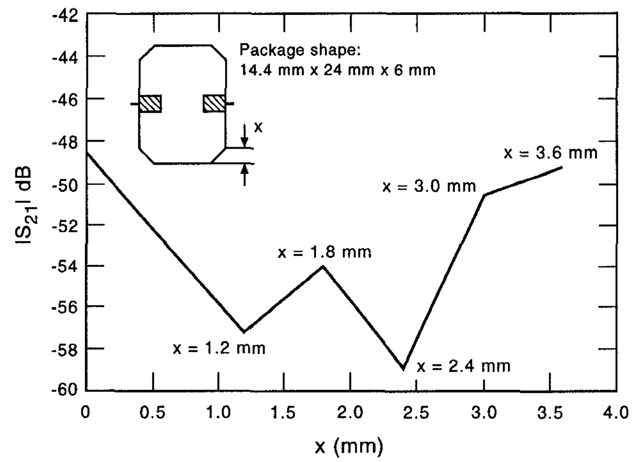

Fig 6. Variation of $|S_{21}|$ at 2.0 Ghz as a function of the dimension x for the package shape shown in Fig 2.

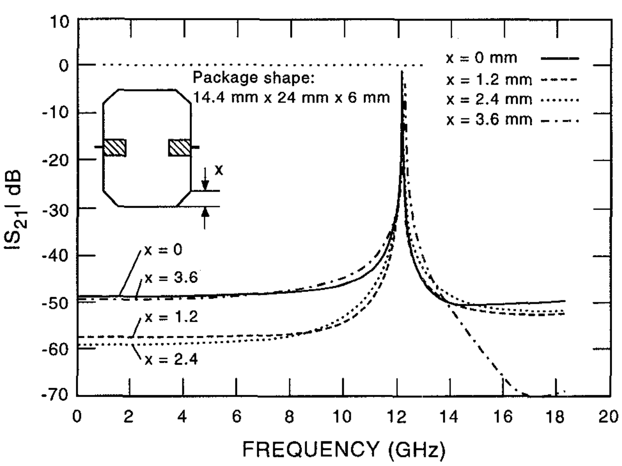

Fig 5. Variation of $|S_{21}|$ with frequency for various values of the dimension x for the package shape shown in Fig 2.

CONCLUDING REMARKS

A method for estimating the effect of the package shape on the spurious coupling among microstrip discontinuities is presented. The method makes use of equivalent magnetic current modeling of discontinuities and analysis of an empty package with equivalent magnetic currents. Sample results presented show that certain modifications of the rectangular shape can reduce the amount of coupling between two open-ended microstrip stubs. The approach proposed in this paper is well suited for CPW circuits also and the results for some canonical CPW structures will be presented at the symposium.

REFERENCES

1. J.J. Burke and R.W. Jackson, "Reduction of parasitic coupling in packaged MMICs," IEEE MTT-S International Symposium Digest, pp. 255-258, May 1990.

2. J.J. Burke and R.W. Jackson, "A simple circuit model for resonant mode coupling in packaged MMICs," IEEE MTT-S International Symposium Digest, pp. 1221-4, June 1991.

3. A. Sabban and K.C. Gupta, "Effects of packages on parasitic coupling among microstrip discontinuitiesin MMICs, " International Journal Microwave Millimeter-Wave CAE, Vol. 1 (4), pp. 403-411, 1991.

4. R.M. Perry, et al., "A computationally efficient method for modeling circuits housed in non-rectangular packages," IEEE MTT-S International Symposium Digest, pp. 1527-29, 1994.

5. K.C. Gupta, "A network modeling approach for effects of metallic packages on microstrip circuit performances," IEEE 3rd Topical Meeting on Electrical Performance of Electronic Packaging, Proceeding, pp. 159-162, 1994.

6. C. Thng and R.C. Booton, "Edge-element time-domain method for solving Maxwell's equations," 1994 IEEE MTT-S International Microwave Symposium Digest, Vol. 2, pp. 693-696, 1994.

7. C. Thng, R.C. Booton, and K.C. Gupta, "FDTD compatible edge-element, face-elements time-domain method for electromagnetics," Int. Jr. of Microwave-Millimeter wave CAE, Vol. 6, No. 1, pp. 58-68, January 1996.