Characterization of Plated Via Hole Fences for Isolation Between Stripline Circuits in LTCC Packages

George E. Ponchak[1], Donghoon Chen[2], Jong-Gwan Yook[2], and Linda P. B. Katehi[2]

1. NASA Lewis Research Center, 21000 Brookpark Rd., MS 54/5, Cleveland, OH 44135
2. University of Michigan, 3240 EECS Building, Ann Arbor, MI 48109-2122

Abstract

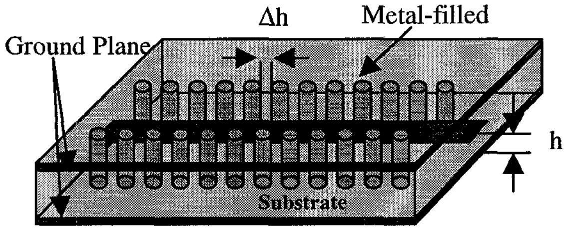
Reduced coupling between adjacent striplines in LTCC packages is commonly accomplished by walls made of plated via holes. In this paper, a 3D-FEM electromagnetic simulation of stripline with filled via fences on both sides is presented. It is shown that the radiation loss of the stripline and the coupling between striplines increases if the fence is placed too close to the stripline.

Introduction

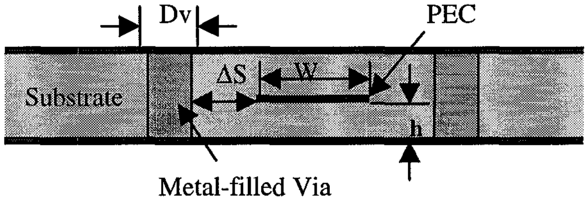
Smaller packages with more circuitry are required for the advanced RF systems being built today and planned for tomorrow. These new packages house a variety of high density circuits for data processing, biasing, and memory in addition to the RF circuits. While the size is being reduced and the complexity increased, the cost of the package must also decrease. To accomplish these contradictory goals, new packaging technologies are required.

Low Temperature Cofired Ceramics (LTCC) is an ideal packaging technology. The material has a moderate dielectric constant, $4<\varepsilon_r<8$, which permits wider strips and thus lower conductor loss than circuits on Si, GaAs, or Alumina. In addition, the loss tangent is on the order of 0.002 at 10 GHz which yields an acceptably low dielectric loss. LTCC packages are comprised of many 0.1-0.15 mm thick ceramic layers with transmission lines on each layer. This increases the level of integration by allowing bias, digital routing, and RF transmission lines and interconnects to be built up in three dimensions.

The multilayer character of these circuits leads to RF transmission lines which are not of microstrip type but of stripline type. Even with the high levels of integration LTCC offers, designers are required to decrease the spacing between striplines to meet the new size and cost requirements. In doing so, coupling between adjacent striplines severely limits the overall



(a)



(b)

Fig. 1 (a) Stripline with a continuous filled via fense on both sides (b) Cross section.

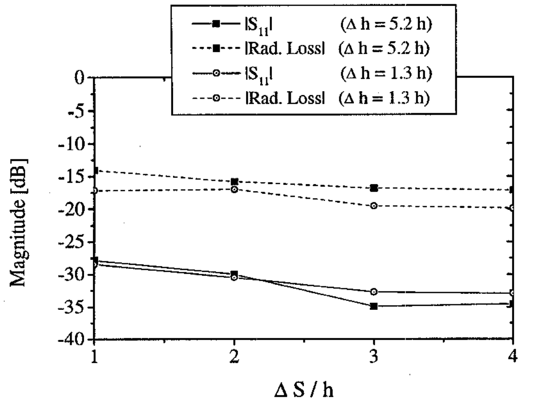
packaged circuit performance. As a solution to this problem, package designers have included filled via fences adjacent to the stripline to confine the electromagnetic fields around the center strip, partition the package and reduce electrical couplings [1-2].

In this paper, we utilize a 3D-Finite Element Method (FEM) [3] to evaluate stripline structures in the vicinity of filled via fences. It is shown for the first time that filled via fences increase the radiation loss of the stripline and decrease the coupling between adjacent striplines. Design guidelines are given to minimize these parasitic effects which degrade overall performance.

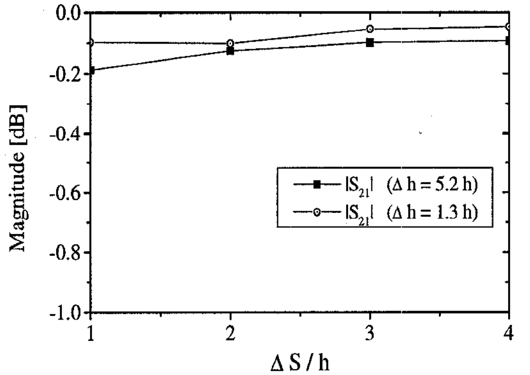
Results

The cross section of the stripline structure is shown in Figure 1. Throughout this paper: the relative These values are all standard for typical LTCC

0-7803-4471-5/98/$10.00 (c) 1998 IEEE



(a)



(b)

Fig. 2 (a) Return loss and radiation loss, $1-|S_{11}|^2-|S_{21}|^2$, of stripline with a continuous via fence as a function of Δh/h and ΔS/h, (b) Insertion loss.

diameter, Dv, is 0.25 mm; the width, W, of the stripline is 0.19 mm to yield a 50 Ohm characteristic impedance; and the thickness, h, is 0.25 mm. The distance between the stripline and the vias is kept greater than 0.25 mm and the via-to-via spacing ranges between 1.3 and 5 times the via diameter. These values are all standard for typical LTCC processes and thus make these results directly applicable to the packages being designed today.

The first structure investigated is a single stripline with a via fence on both sides of the strip as shown in Figure 1. This is a typical structure to ensure suppression of the parasitic parallel plate waveguide modes. The transmission lines are first analyzed over the frequency range of 10 to 40 GHz. It is found that the scattering parameters do not vary by more than a few percent over this frequency range as long as $2\Delta S+W<\lambda_d/2$ where λ_d is the wavelength in

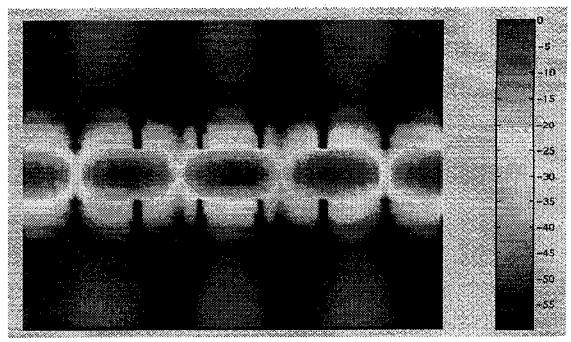


Fig. 3 Electric field distribution of stripline with a continuous via fence at 25GHz with ΔS/h=1 and Δh/h=5.2.

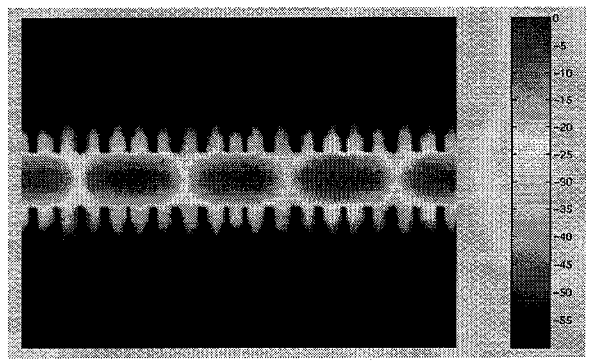


Fig. 4 Electric field distribution of stripline with a continuous via fence at 25GHz with ΔS/h=1 and Δh/h=1.3.

the dielectric. This condition is necessary to avoid the excitation of dielectric filled rectangular waveguide modes. Based on this finding, the results are presented as a function of the line geometry with the average of the scattering parameters plotted. Figures 2 (a) and (b) show the magnitude of S_{11}, S_{21}, and the radiation loss, $1-|S_{11}|^2-|S_{21}|^2$, as a function of the transmission line geometry. It is seen that the reflection coefficient, the insertion loss, and the radiation loss all decrease as the separation between the strip and the via holes, ΔS/h, increases. Reduction of the parasitic effects levels off as ΔS/h approaches 2. Furthermore, it is seen that the insertion loss decreases as the distance between the via holes decreases. Field distribution for a stripline with large narrow via hole spacing are shown in Figures 3 and 4 respectively. These plots indicate that the closely spaced via fence completely confines the

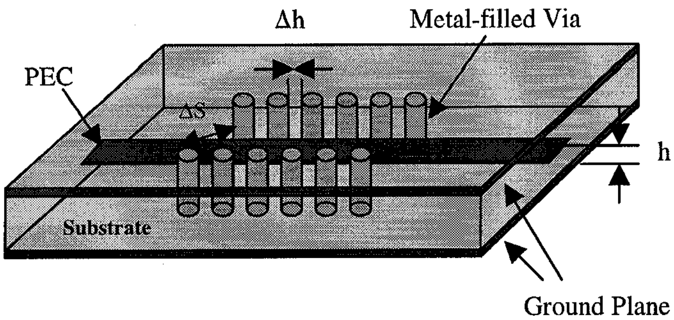
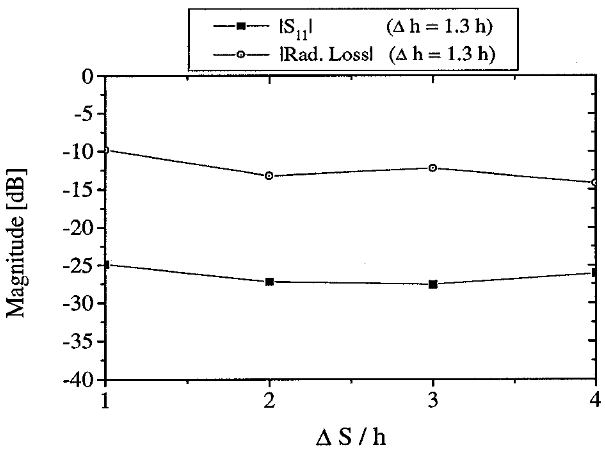
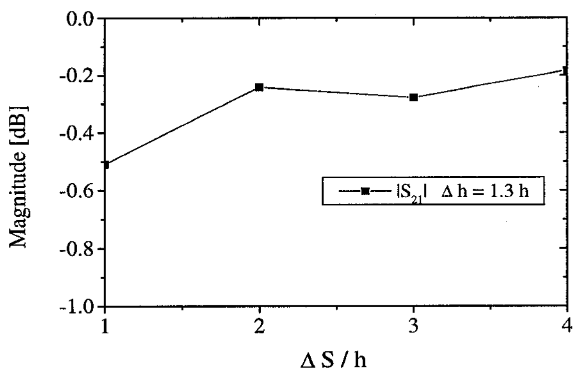


Fig. 5 Stripline with a short section of a filled via fence on both sides.



(a)



(b)

Fig. 6 (a) Return loss and radiation loss, $1-|S_{11}|^2-|S_{21}|^2$, of stripline with a short via fence as a function of $\Delta S/h$, $\Delta h/h=1.3$, (b) Insertion loss of stripline with a continuous via fence as a function of $\Delta S/h$, $\Delta h/h=1.3$.

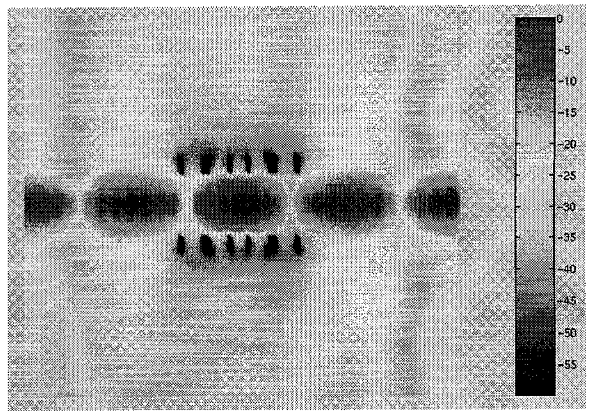


Fig. 7 Electric field distribution of stripline with a short via fence at 25GHz with $\Delta S/h=1$ and $\Delta h/h=1.3$.

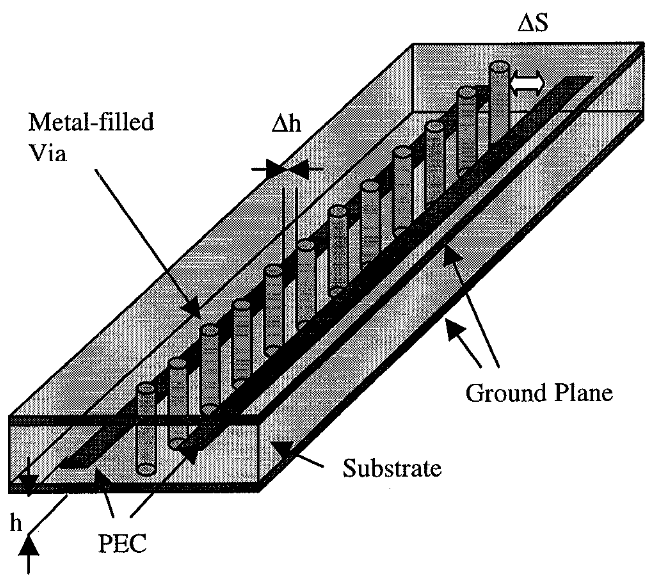


Fig.8 Adjacent striplines separated by via fences.

electromagnetic field while the wider spaced via holes permit a significant leakage of power. Note that ΔS/h=1 in both of these field plots.

In case where we need to locally improve isolation, the continuous via fence may be replaced by a short via fence as shown in Figure 5 [2]. Figures 6 (a) and (b) show the simulated performance for this line. It is seen that the scattering parameters and radiation loss vary with ΔS/h in the same way as the continuous via fence. However, upon comparison with Figures 2 and 3, there is 5 dB degradation in the line characteristics. Figure 7 shows that this is due to the perturbation of the fields upon reaching the via fence on either side of the strip.

The electromagnetic fields that escape the confinement of the via fences and result in radiation loss cause coupling between adjacent striplines as shown in Figure 8. Figure 9 shows the magnitude of the total electric fields for two striplines separated by a via fence with ΔS/h=0.615 and Δh/h=0.764 (h=0.7366mm). The stripline on the left has an imposed voltage on it while the stripline on the right is coupled. Separation of the field into its components shows that electric field in the plane of the strips is approximately 10 dB greater than the electric field normal to the strips near the via fence. The large magnitude of this parallel field component is due to the small via size and large value of Δh/h, resulting –10 dB coupling between the strips. Although perfect conductors were assumed in this study, the current distribution on the strip with a close via fence is expected to cause an increase in conductor loss compared to the conventional stripline case.

Conclusions

It has been shown that when filled via fences are placed too close to the stripline, radiation loss increases resulting in coupling between adjacent striplines. To minimize the radiation loss, the via fence should be kept at least four times the ground plane separation away from the strip, or ΔS/h>2. Furthermore, the use of via fences locally only where isolation is required, can actually degrade the stripline characteristics by causing a large perturbation in the electric fields that normally extend on either side of the strip.

Acknowledgement

The authors would like to thank the University of Michigan Center for Parallel Computing (CPC), which is partially funded by NSF grant CDA-92-14296 and Ford Motor Company, for the use of computational facilities.

References

1. J. W. Gipprich, "EM modeling of via wall structures for high isolation stripline," Digest for Workshop WWFC, Interconnect and Packaging Technologies and Issues, IEEE Int. Microwave Symp., San Diego, CA, pp. 78-114, June 1994.
2. J. Gipprich, C. Wilson, and D. Stevens, "Multilayered 3-D packaging issues," Digest for Workshop WFC, Interconnects and Packaging for RF Wireless Communications Systems, IEEE Int. Microwave Symp., Denver, CO, June 8-13, 1997.
3. J.-G. Yook, N. Dib, and L. Katehi, "Characterization of High Frequency Interconnects using Finite Difference Time Domain and Finite Element Methods, " IEEE Trans. Microwave Theory Tech., pp. 1727-1736, vol. 42, Sep. 1994.

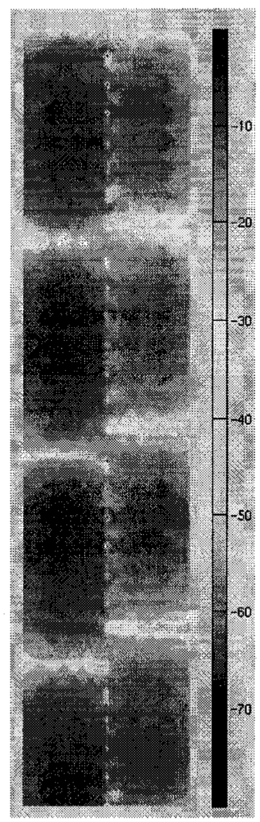


Fig. 9 Electric field distribution of two striplines separated by a continuous fence f=10GHz, ΔS/h=0.45, and Δh/h=0.5).