다층기판 구조에 적용 가능한 수동회로 격리를 위한 연구

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A Study on Isolation Strategies for Passive Circuit Components in Multi-layered structure

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Abstract - In this paper, isolation strategies for improving broadband circuit performance and preventing noise arising from circuit component coupling are presented. Equivalent circuit parameters, including parasitic elements, are determined for capacitor and inductor structures. The effects of the relative position of the components with regard to a ground plane are considered in the equivalent circuits. Novel meshed ground structures are investigated to determine a configuration that improves the overall circuit performance.

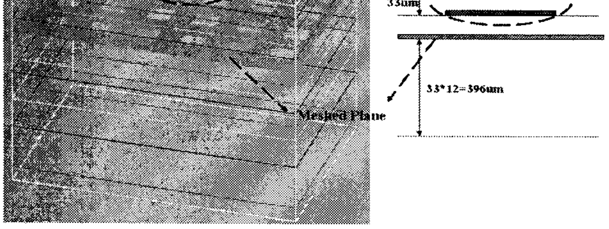
1. Introduction

Introduction: Modern design of duplexer and diplexer circuits has an increasing need for miniaturization to produce compact devices with greater utility. In order to achieve the compact design, multi-layered structures are designed. Low temperature co-fired ceramics (LTCCs) consist of materials with stable electrical properties for a broad frequency and temperature range. Additionally, these materials are available at relatively low cost, making them very attractive for mass production. The passive circuits typically consist of planar structures utilizing capacitors, inductors and transmission line components.

The layered structures introduces a design challenge that is often avoided in two dimensional layouts. Significant coupling between the elements will occur due to fringing fields and electromagnetic radiation from the open structures. In single plane devices, these effects are easily prevented through electromagnetic shields such as via 'walls'. In multi-layered devices, similar protection is possible by introducing ground planes between the layers. However, this solution adds cost by incorporating more layers and may not be an optimal solution as these planes will also couple to the components. Therefore, introduction of a shielding structure must provide benefits without introducing problems.

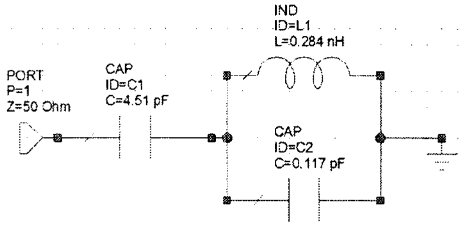
2. Design Procedure

In radio frequency (RF) and microwave circuit design, the process typically involves an initial circuit level simulation using an ideal circuit model. The design of the circuit components requires electromagnetic simulation. A simple structure of a capacitor is shown in Figure 1.

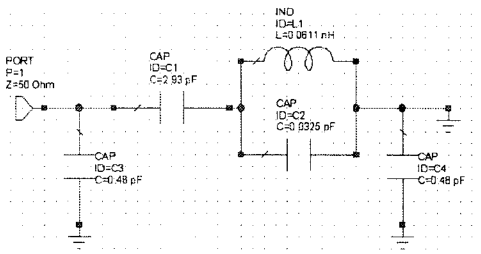


<Fig. 2> 3-D structure of a designed capacitor isolated by meshed ground

A square capacitor is implemented above a meshed isolation plane with the ground located at the bottom layer. Ideally, the circuit model for this device would be a single capacitor. However, due to the electromagnetic effects, a more complete model would include the self inductance of the capacitor and the capacitance of the feed lines, as seen in Figure 2a. Further complexity is introduced by consider the coupling between the plates to the metallic isolation mesh, with appropriate parasitic capacitances at the input and output ports of the circuit (Figure 2b).



<Fig. 3a> Equivalent circuit of capacitor



<Fig. 2b> Enhanced equivalent circuit of capacitor

Since the electromagnetic model is much more complex than the circuit model, refinement of the physical layout is usually necessary.

In order to achieve efficient optimization of the circuit layout, it is necessary to identify the dominant physical characteristics. In some of the studies, the isolation plane was solid. In this case, many of the physical parameters are obvious, such as the thickness of the layered material and the distance of the physical components from the isolation plane. When the meshed isolation plane is considered, the number of physical parameters increases significantly, where the shape of mesh structure, the periodicity of the mesh structure, the translational location of the circuit component relative to the mesh, and the vertical spacing will potentially affect the circuit response. Identifying how these parameters affects the structure is determined through a parametric study of the circuit response.

When assessing the scattering parameters of a passive high-frequency device the equivalent circuit is often based on physical parameters, as mentioned above. However, over a broad frequency range, transmission line effects will be introduced and a physics based low frequency model is often incomplete. Alternatively, a rational functions is implemented, using the expression,

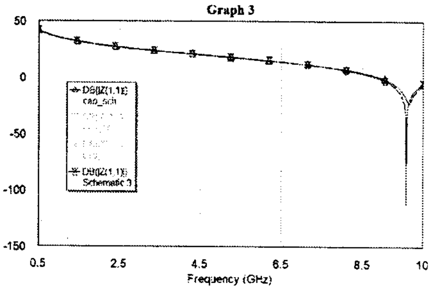
$$S_{ij}(f)=\frac{\sum_{k=0}^{n} c_k f^k}{\left(1+\sum_{l=1}^{m} d_l f^l\right)} \quad \text{......}(1)$$

where Sij are the S-parameters to be determined. The unknown coefficients, ck and dl, are used to obtain the zeroes and poles in the rational function, respectively. When performing a parametric study, the sensitivity of the poles and zeros to the design parameters is determined. As mentioned, when the circuit geometry becomes more physically complex, the number of simulations necessary to determine this sensitivity will require a large number of sampling points.

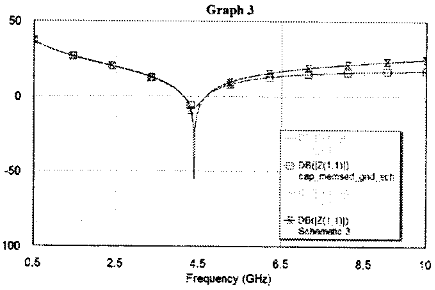
Equation (1) may be rewritten such that the division operation is eliminated.

$$\sum_{k=0}^{n} f^k c_k - S_{ij}(f)\sum_{l=1}^{m} f^l d_l = S_{ij}(f) \quad \text{......}(2)$$

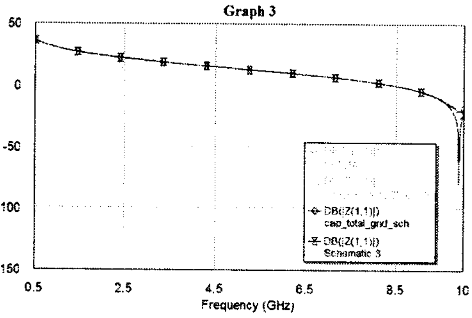
In this form, numerical singularities are avoided. Solutions to the expression can be obtained using an iterative process that will minimize the L2 norm. It is important to recognize that the function that is derived may not be consistent with the assumed physical equivalent circuit. As a test, a capacitor above a meshed isolation was investigated. In Figure 3, the electromagnetic simulation results of the input impedance are shown.



<Fig. 3a> EM result of capacitor's Zin without meshed isolation plane



<Fig. 3b> EM result of capacitor's Zin with meshed isolation plane

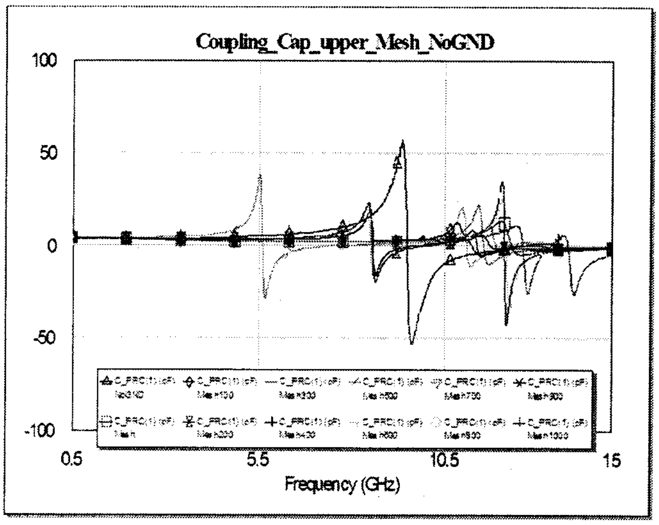


<Fig. 3c> EM result of capacitor's Zin with solid Isolation plane

The best fit function is determined from the S11 rational function. For simplicity, the rational function had a low order, yet demonstrates satisfactory agreement.

<Table 1> Variance of SRF by different mesh size

	Capacitance Value at 0.5GHz [pF]	Capacitance Value at 2.5GHz [pF]	Variance of capacitor	SRF (GHz)	Variance of SRF compared to without isolation meshed plane
No	3.643	3.642	-0.03	9.4880	0.00
Mesh 100um	4.168	3.175	-23.82	11.2100	18.15
Mesh 200um	4.157	3.758	-9.60	8.5390	-10.00
Mesh 300um	4.145	3.039	-26.68	11.5500	21.73
Mesh 400um	4.157	3.541	-14.82	8.5630	-9.75
Mesh 500um	4.155	4.256	2.43	5.6000	-40.98
Mesh 600um	4.106	3.651	-11.08	8.4970	-10.44
Mesh 700um	4.088	3.067	-24.98	11.0800	16.78
Mesh 800um	4.102	3.181	-22.45	12.1500	28.06
Mesh 900um	4.120	3.080	-25.24	12.1000	27.53
Mesh 1000um	4.110	3.102	-24.53	12.6000	32.80



<Fig. 4> EM result of capacitance by different size meshed isolate plane

3. Conclusion

In this paper, the effects of introducing a meshed ground structure as an isolation plane are studied in detail. The mesh elements are square, as shown in Figure 1. Again, considering the capacitor, the circuit response for three cases is shown in Figure 3. The comparison includes the meshed isolation plane, the solid isolation plane, and without an isolation plane. The vertical spacing between the capacitor and the plane is the same for both the meshed and the solid structures. This figure indicates the challenges inherent in the design process. Even with this relatively simple change, the impedance response yields no obvious insights between the three cases.

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