AN ELECTROMAGNETICALLY COUPLED PACKAGE FEED-THROUGH STRUCTURE FOR MULTILAYER CARRIER SUBSTRATES

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ABSTRACT

Theoretical and first scaled experimental results are presented for an electromagnetically coupled feed-through structure for multilayer carrier substrates. This structure combines an inherent DC isolation with an improved hermetic sealing, as no conductor – at least for the RF – needs to penetrate the top layer of the substrate. The design of this interconnect is done using a FDTD software.

INTRODUCTION

With increasing frequency, interconnects to and between MMICs and feed-throughs into hermetically sealed packages are becoming more and more difficult due to the discontinuities associated with bond wires and "thick" dielectric walls of the package [1]. A solution to part of these problems is the integration of several components on a common carrier plate and in a common package. For a compact integration of microwave and mm-wave front-ends, multilayer structures are used as carrier substrates which can support a complex interconnect network [2]. A possible material for such substrates is low temperature cofired ceramics (LTCC), [3]. With such a concept, a connection into the package may be performed in a lower metallization level on the basis of a triplate-type transmission line. The connection to the lower metallization level can either be performed by vias or by electromagnetic coupling through a slot (Fig. 1). While a via-based interconnect gives a wide band performance down to DC, an electromagnetic coupling as described in this contribution, exhibits both an inherent DC isolation and an improved hermeticity, as no metallization is penetrating the top ceramic layer. In both cases, leakage of power at the transition due to parallel plate modes has to be prevented by a sufficient number of ground-to-ground vias around the transition.
Electromagnetic (EM) field coupling for interconnects and package feed-through structures for mm-wave MMICs has been successfully demonstrated in [4].
The structure for the EM-coupled feed-through is shown in Fig. 1, right side. A connecting microstrip line approaches the package from its outside. The power then is coupled through a slot into a lower level of the carrier substrate, guided by a triplate line below the package wall, and is coupled back into the interior of the package.

THEORETICAL CALCULATION

The 3D structures involved in this transition were calculated with a FDTD method [5], using absorbing boundary conditions according to [6], and a system identification method [7] to speed up calculations and to improve the frequency resolution. Half of the (symmetric) feed-through structure is shown in Fig. 2 as it is used for the calculation.

The transition is intended for communication applications in the 28 GHz band, so a first design was done for that band. In a first step, a single transition from microstrip to triplate was calculated. With this transition, a sharp resonance was observed which, however, could only be resolved using the system identification method [7] to enable a reasonable computation time of the FDTD procedure. A thorough investigation of this resonance revealed its origin from the vias between the triplate ground planes. Modifying the via positions, the resonances can be shifted and do not play a critical role for the transition (Fig. 3).
Theoretical performance of a package feed-through – a double transition from the microstrip to the triplate and back to the microstrip line - is shown in Fig. 4. Line length of the triplate line between the transitions is chosen to get a chebishev type filter performance. Return and insertion loss for a LTCC substrate are plotted in Fig. 4, showing a return loss of better -20 dB in the 25 to 31 GHz band.
In Fig. 5, the Poynting vector distribution is plotted in a cross section of the structure. The energy flow clearly can be seen. In the area of the triplate $\lambda/4$-stub (bottom left), power is flowing to the end of the line on top and back in the bottom. This clearly indicates the existence of two modes – the triplate and a parallel plate mode which is confined to the transition by the vias between the ground planes.
With respect to the tolerances of the mm-wave range ($\pm 25\ \mu m$), some improvement of the LTCC technology is necessary, especially concerning reproducibility of the dielectric constant and the layer thicknesses. Furthermore, finer metallization structures are required. This development is going on, and the original design is presently being fabricated.

EXPERIMENTAL RESULTS

In between, a test structure at lower frequencies using commercially available soft substrates was designed and tested, giving the results as shown in Fig. 6. One problem with this structure was found in mounting the different layers together without an air gap, therefore some discrepancies between theory and experiment can be stated. Nevertheless, the principle performance can be seen clearly, even two (out of band) resonances occurs both in theory and experiment, giving confidence to the design.

CONCLUSION

An EM-coupled feed-through structure for multichip/multicircuit components in a common package, integrated on a multilayer carrier substrates has been presented. This interconnect combines an inherent DC isolation with an improved hermetic sealing, as no conductor – at least for the RF – needs to penetrate the top layer of the substrate.

ACKNOWLEDGMENT

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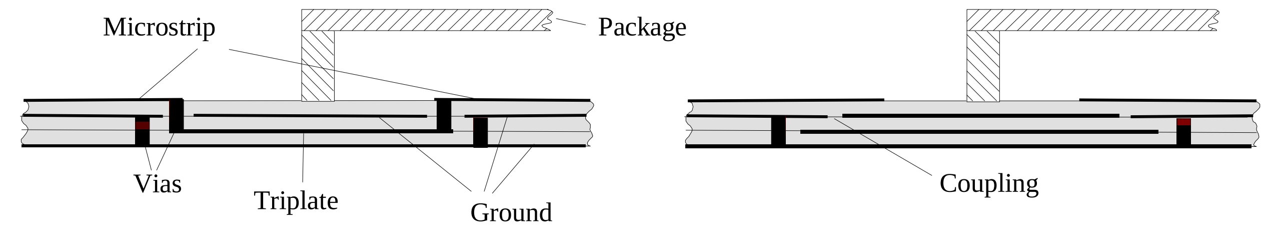

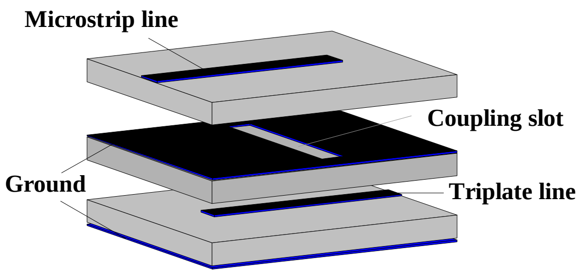

Fig. 1: Cross section of a via-coupled (top left) and an electromagnetically coupled (top right) feed-through arrangement and key structure of the feed through structure.(left).

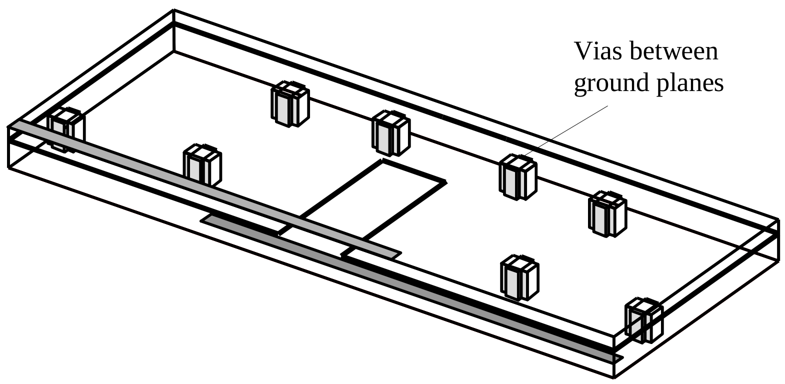

Fig. 2: Details of the structure for the FDTD calculation (half of the symmetric structure only

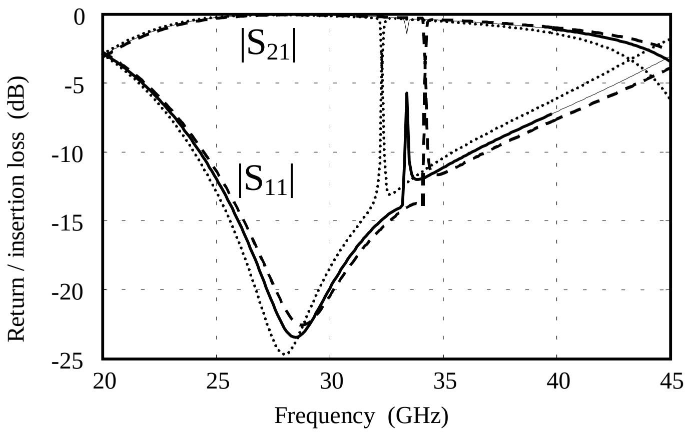

Fig. 3: Computed return and insertion loss of a single transition from microstrip to triplate line with different via positions (—— **:** reference, ······· and **– · –** **:** ± 50 µm).

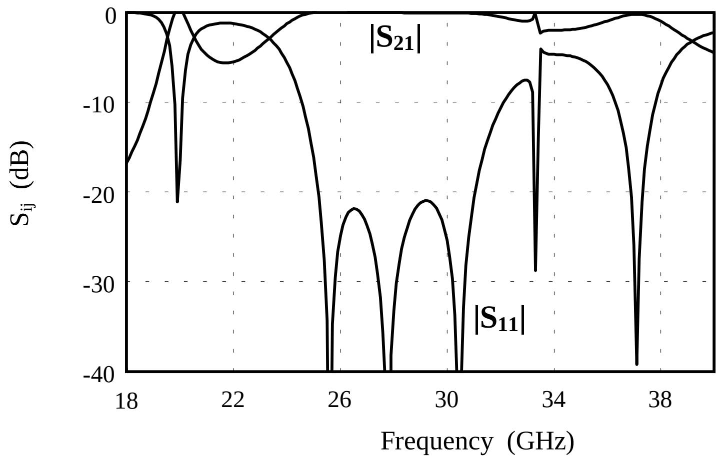

Fig. 4: Theoretical results of a Ka-band feed-through structure.

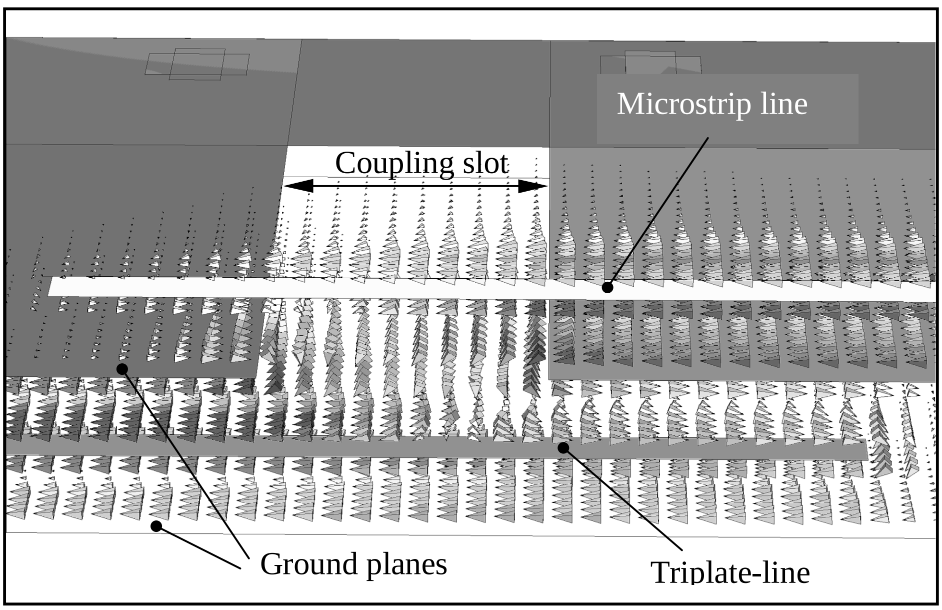

Fig. 5: Poynting vector distribution in transition.

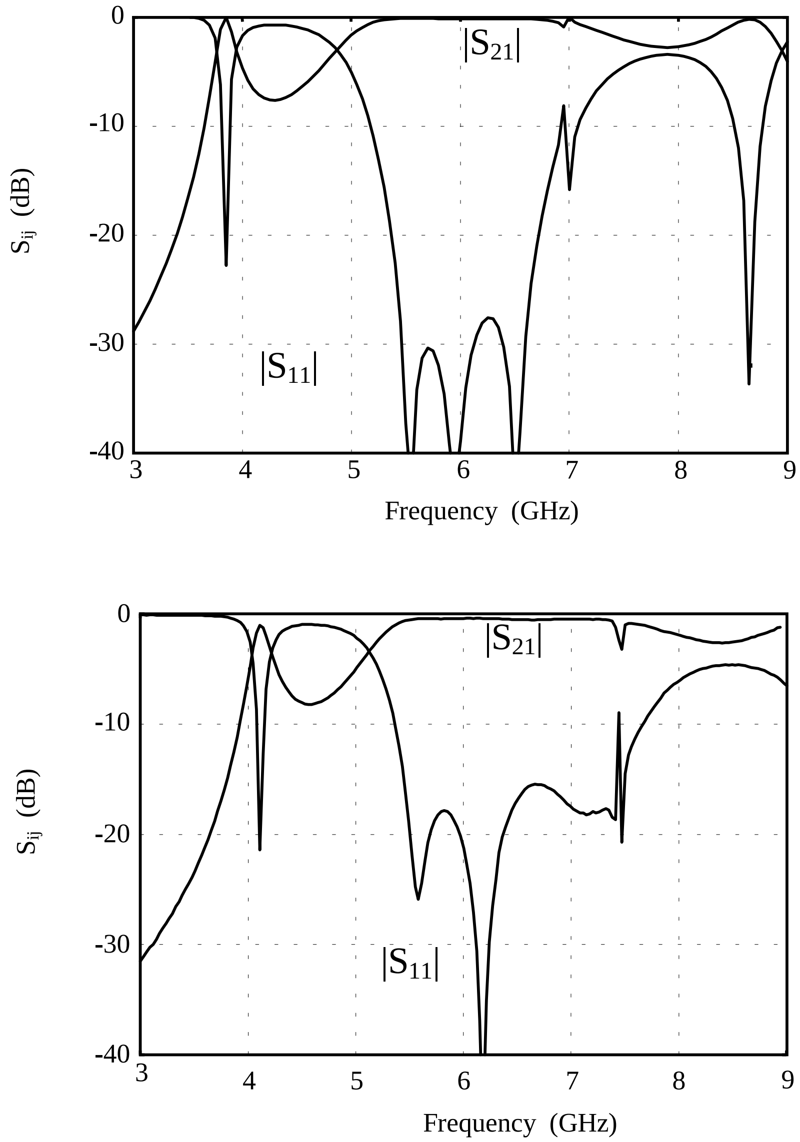

Fig. 6**:** Theoretical (top) and experimental (bottom) results of a scaled feed-through structure.