A drop-on band-pass filter for mm-wave multi-chip modules (MCM) on LTCC

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Abstract **-- LTCC is increasingly used to realize multi-chip modules, even in the mm-wave frequency range. Fabrication tolerances of the LTCC structures, however, still are limiting the performance of band-pass filters integrated directly on the LTCC substrate. This contribution therefore describes the design and the performance of a separate filter chip based on alumina which simply is placed on top and glued to the LTCC substrate using non-conductive epoxy. A special electromagnetic field coupling is used to provide both the interconnect of signal lines and filter ground. The design includes special measures to reduce the tolerance requirement for filter placement and glue thickness.**

I. INTRODUCTION

Complex microwave and mm-wave front-end including a number of MMICs as well as interconnect lines and hybrid components today often are realized as multi-chip modules (MCM) on low-temperature cofired ceramic (LTCC) [1] – [3]. In some applications, band-pass filters are required within these front-ends [4]. In the mm-wave range, a medium to narrow-band filter may require tolerances in the range of a few µm, today not realizable due to the LTCC production process including shrinking of the material. Therefore, a filter was developed using a separate small alumina substrate. To enable an easy implementation of the filter to the rest of the circuit, field-coupling was used, so that the filter simply can be glued on top of the LTCC substrate; no further steps are necessary.
The complete filter design and optimization was done using an in-house FDTD code.

II. DESIGN OF THE BAND-PASS FILTER

The three resonator filter is based on side-coupled resonators on top of an alumina substrate with capacitively coupled input and output lines. This capacitive coupling is realized using broadside coupled microstrip lines [5], where input and output lines are on the bottom side of the substrate. To this end, the ground plane in the coupling area has to be removed, and another ground plane layer of the LTCC substrate now serves as ground plane for input and output lines (Fig. 1). Principally, ground planes of alumina and LTCC substrate could be connected by vias in the LTCC, and input and output lines of the filter could be directly connected to interconnect lines on top of the LTCC substrate. This solution, however, leads to stringent tolerance requirements for placing the filter on the carrier substrate and to the procedure to connect the metallization structures on both substrates by soldering or silver epoxy. A critical item is the strong influence of a possible air gap between the substrates. To overcome these problems, another field coupling was introduced for both interconnect lines and ground plane (Fig. 1).

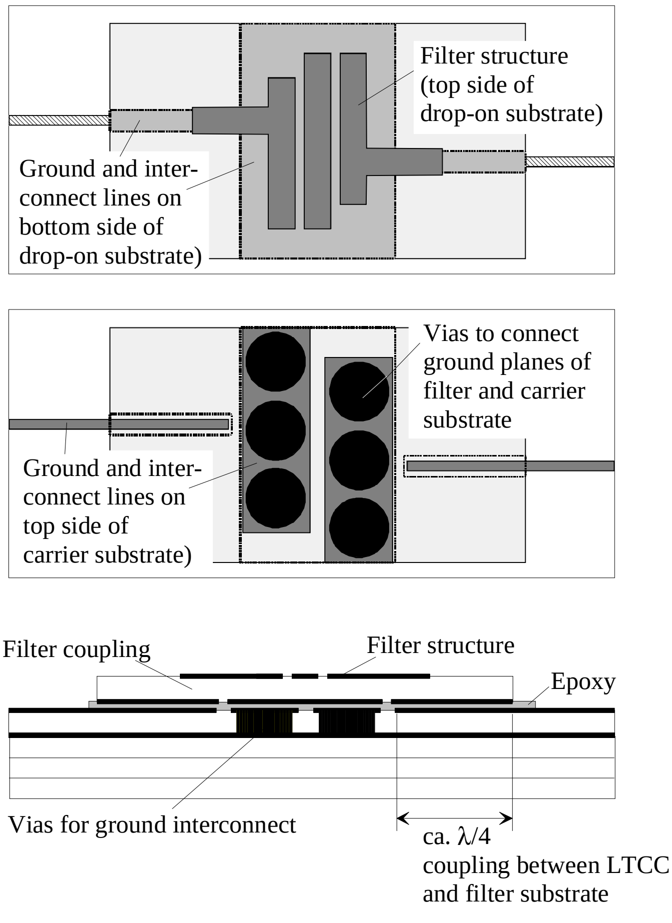

Fig. 1: Principle layout and cross section of the drop-on filter.

Non-conductive epoxy serves as another dielectric separating interconnect lines and ground planes on both substrates. The coupling length for the interconnect lines was chosen to a quarter wavelength; in this way, a very broadband transition is realized which is much less sensitive to dielectric thickness of the epoxy and placement of the filter substrate. The shape and size of the ground plane section on top of the LTCC substrate was optimized to provide a good ground connection and to avoid resonances within the desired frequency range. As a result, the filter substrate simply can be glued on top of the LTCC substrate. No air gap exists, as the complete filter substrate area is covered with the glue with a thickness of 5 – 10 µm. A variation of the position of the filter chip of ±30 µm does not affect the filter performance, probably twice or three times that value are acceptable.

III. Results of the filter

To be able to do tests of this filter without going through the LTCC fabrication process, a band pass filter on alumina was designed for a placement on an alumina carrier substrate as well. Center frequency and bandwidth are 29 GHz and 3 GHz, respectively, and a 0.1 dB chebichev design was chosen. Both filter and carrier substrate were 0.127 mm thick. Fig. 2 shows a photograph of a carrier substrate with one drop-on filter and another coupling area for such a filter. For the experiments performed at this stage of the work, wax was used to fix the filter to the carrier substrate. Design and experimental return and insertion loss are plotted in Fig. 3. A reasonable agreement between theory and measurement can be stated. Insertion loss amounts to 1.6 dB.

IV. Conclusion

Design and performance of a filter chip on an alumina substrate have been demonstrated. the filter chip simply is placed on top and glued to the LTCC substrate using non-conductive epoxy. A special electromagnetic field coupling is used to provide both the interconnect of signal lines and filter ground. With a special coupling arrangement, tolerance requirement for filter placement and glue thickness have been reduced.

Acknowledgment:

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V. References

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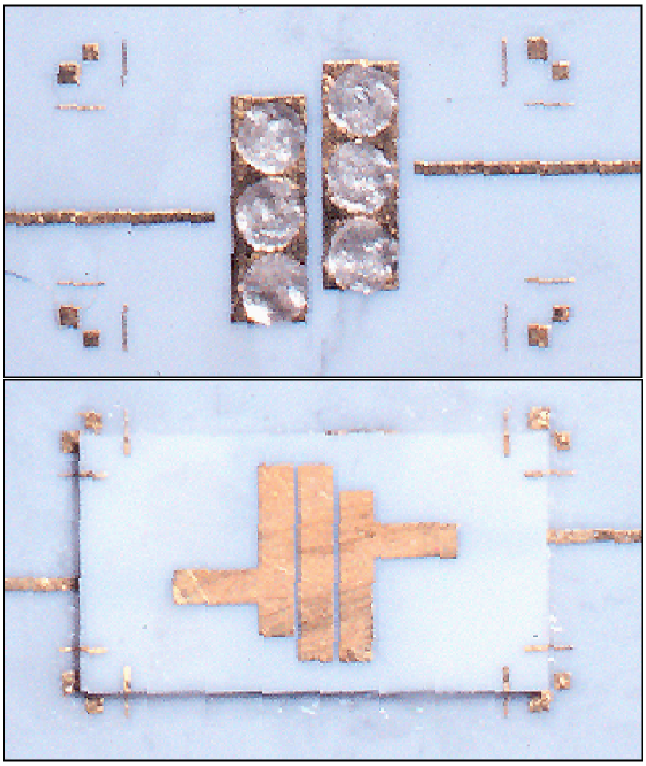

Fig. 2: Photographs of carrier substrate with coupling structure and drop-on filter placed on top of the substrate.

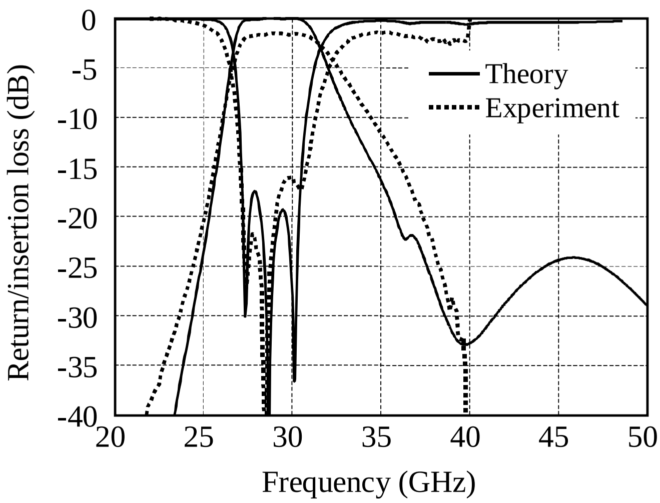

Fig. 3: Theoretical and experimental return and insertion loss of a 29 GHz drop-on filter.