

IN-CIRCUIT TESTING OF COMPLEX CIRCUITS USING ON-WAFER PROBING AND ELECTROMAGNETIC COUPLED GROUND INTERCONNECTS

J. Kassner*, W. Menzel

Microwave Techniques, University of Ulm, PO Box, D-89069 Ulm, Germany

* now with IMST, Kamp-Lintfort, Germany

ABSTRACT

With increasing complexity, testing of the different functions of integrated microwave and mm-wave circuits gets increasingly difficult. A method is presented to perform in-circuit testing of different circuits and components either on a common substrate or on different substrates on a common carrier. Stubs are used to provide RF ground for on-wafer testing. Between the circuits on a common substrate, gaps are introduced which are closed by bond ribbons after testing. The method is tested at the examples of the combination of microstrip lines on GaAs and alumina and of the combination of a low and a high pass filter on a common substrate.

INTRODUCTION

Modern microwave and mm-wave circuits and front-ends are getting increasingly complex, consisting of a plurality of different functions realized as a combination of MMICs and hybrid integrated circuits. MMICs mostly are designed and extensively evaluated for fabrication in large quantities and tested separately on-wafer, but complex hybrid circuits including passive structures, maybe some active components, and the transitions to the MMICs and the outside "world" often are designed individually for a certain application. To this end, it would be advantageous to be able to test the different parts of such an arrangement either separately, but already mounted on a carrier, or with all structures already fabricated on a single substrate, i.e. to enable an "in-circuit" testing. Such a

technique requires an initial separation of the different structures on the substrate, and using microstrip circuits, the realization of ground interconnects in the inner parts of the circuitry. Furthermore, if MIMICs are placed side by side with an alumina substrate, test points are required at the edge of the substrate. Using via holes for this purpose, problems may arise separating the different alumina substrates after fabrication.

IN-CIRCUIT TEST STRUCTURE

A few years ago, on-wafer testing without via holes has been demonstrated [1]. This technique now is used to provide the necessary ground interconnects at the edge of or within a hybrid circuit, favorably at higher microwave or mm-wave frequencies. If test points are required in the inner part of a substrate, the interconnect lines are interrupted at the required test points by a narrow gap, and small stubs are added to both sides and both ends of the lines as shown in the example circuit given in Fig. 1.

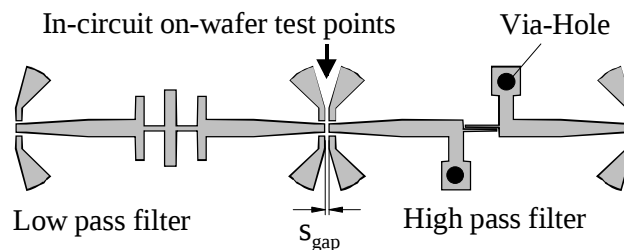


Fig. 1: Layout of the series arrangement of a low pass filter (left side) and a high pass filter (right side) including means for in-circuit testing (Substrate material TMM 10, $h = 0.38$ mm, $\epsilon_r = 9.2$).

Using an on-wafer prober, the individual functions are tested; possibly some tuning (e.g. laser tuning) can be done. Following this, the gap between the two interconnect lines is closed by ribbon bonds. If this gap is realized only within a circuit, its width can be controlled easily, no tolerances related to cutting substrates occur, and temperature expansion is known and easily controlled. This is much easier than joining a number of substrates fabricated and tested separately.

Two possible applications of such test methods were investigated. The first one concerns a joint arrangement of a MIMIC and a transition from microstrip to a metal waveguide. To check the transition and possible tune it – and this only can be done after mounting the substrate and the transition on the necessary carrier – a prober point was added to the edge of the alumina substrate.

A second test structure consists of the combination of a low pass and a high pass filter, resulting in a band pass characteristic (Fig. 1). To test this in-circuit measurement technique in more detail, its elements were designed, the coupling over the gap and a possible interference of the circuits by the testing stubs were investigated.

RESULTS

In a first step, stubs for on-wafer testing were designed for a good return loss in the frequency band of interest using a FDTD code [1] – [3]. Theoretical and partly experimental results of two interconnect structures for on-wafer testing [1] in the K- and V-band are shown in Fig. 2. For the frequency range centered around 20 GHz and 60 GHz, a -15 dB return loss and low insertion loss are achieved over a bandwidth of about 15 GHz and 25 GHz, respectively. In a second step, the performance of the circuits was investigated after the bond interconnect has been made between the adjacent parts of the circuit while the stubs for probing still are present. These results of the combination of microstrip lines on a MIMIC and

an alumina substrate in the V-band are plotted in Fig. 3. Return loss is better than -30 dB, indicating that the test point on the alumina substrate does not affect the overall circuit.

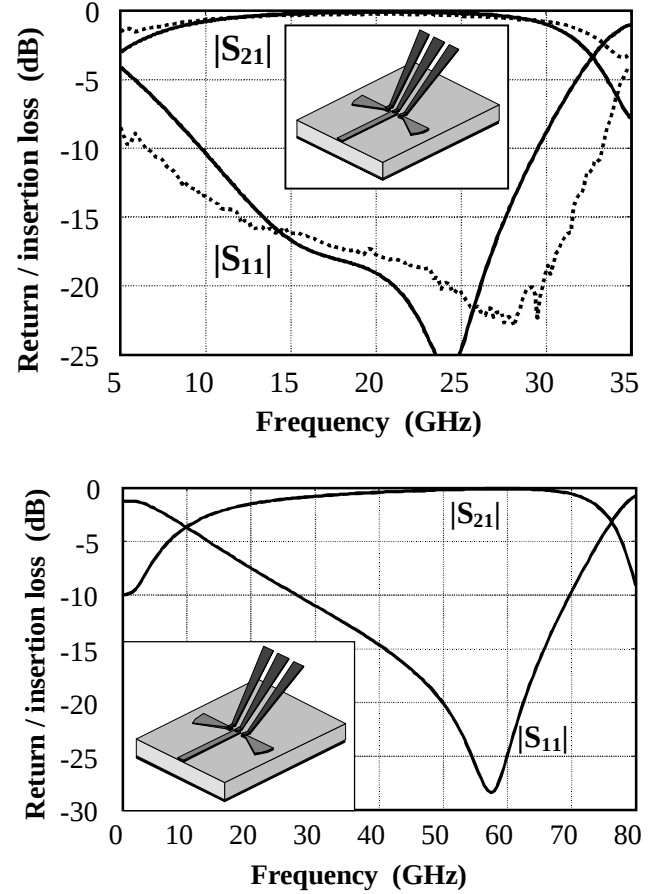


Fig. 2: Theoretical (FDTD) and experimental results of a transition from microstrip to on-wafer probes using stubs for ground interconnect.

(Alumina substrates, $\epsilon_r = 9.6$, top: K-band, $h = 0.254$ mm, bottom: V-band, $h = 0.127$ mm.)

The performance of the in-circuit test points was again investigated theoretically and experimentally with the other example, too. Firstly, the performance of two of the test points placed side by side was investigated. The gap should provide a reasonable decoupling of the structures, and connecting the two lines by bonding, the remaining stubs should not lead to a disturbing mismatch at the testing points. The results of

these calculations are plotted in Fig. 4. The gap provides an isolation of -15 dB at 20 GHz, and connecting the lines, the return loss is better than -15 dB.

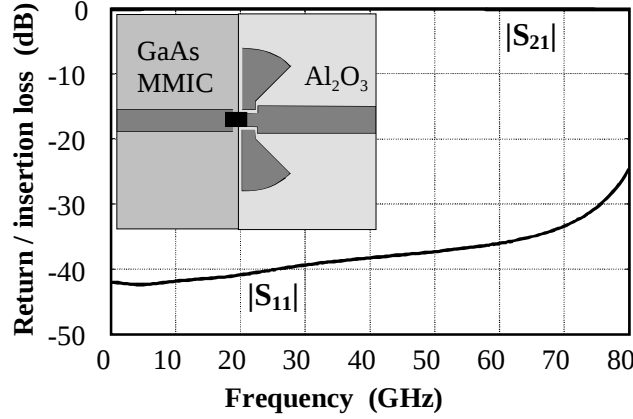


Fig. 3: Theoretical (FDTD) results of a bonded interconnect of two microstrip lines on alumina and GaAs substrate with in-circuit test stubs being present.

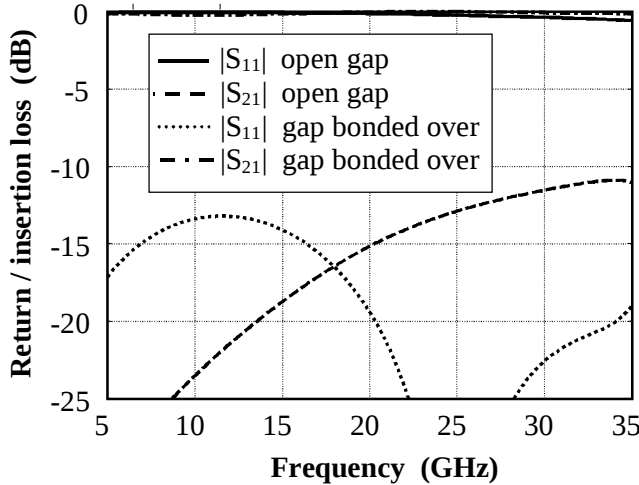


Fig. 4: Performance of two testing interfaces placed side by side (FDTD calculations, gap width between transmission lines 0.1 mm).

Following this, as test structures, a low pass and a high pass filter were designed and placed on a common substrate, separated by a gap in the connecting transmission line and equipped with testing pads as described before (Fig. 1). Return and insertion loss of these components were

tested in this arrangement, showing a good agreement between designed performance and measurements (Fig. 5).

Finally, a gold ribbon was bonded across the gap, and the combination of low and high pass filter was tested as a whole. Fig. 6 gives both computed and measured results, showing the success of the procedure described in this contribution.

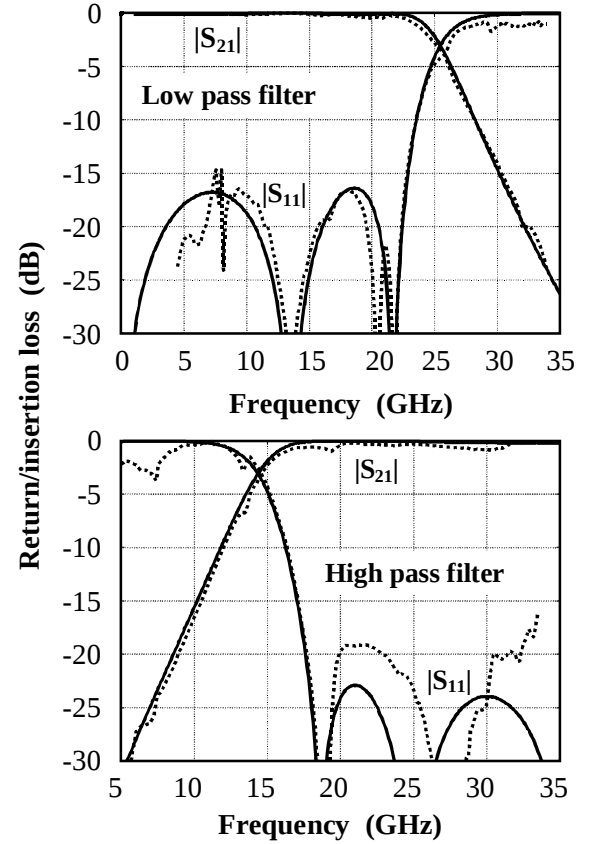


Fig. 5: Theoretical (FDTD) and experimental results of a low pass filter (top) and a high pass filter (bottom) placed side by side on a common substrate and using in-circuit testing (solid lines: theory, dotted lines: experiment).

CONCLUSIONS

A method to perform in-circuit measurements of complex microwave and mm-wave circuits has been demonstrated. To this end, gaps in the transmission lines between the different functions together with stubs for ground interconnects

enable separate testing. After this, the gaps were bonded over to reconnect the circuits. This principle is demonstrated successfully at the example of the combination of a low and a high pass filter, forming together a band pass filter.

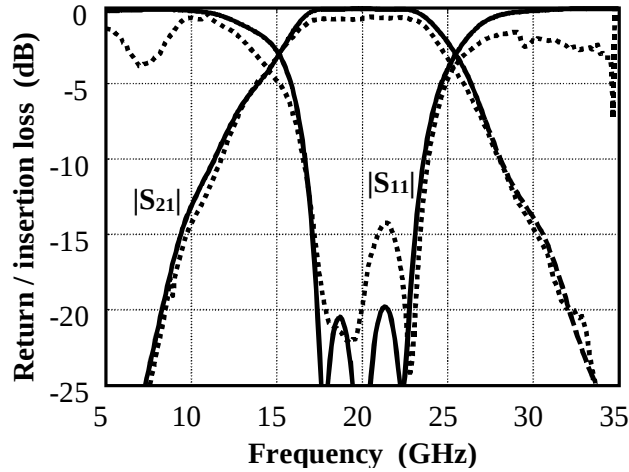


Fig. 6: Theoretical and experimental results of a combined low and high pass filter placed side by side and bonded together on a common substrate using in-circuit testing (solid lines: theory, dotted lines: experiment).

REFERENCES

- [1] G. Strauß, P. Ehret, W. Menzel: On-Wafer Measurements of Microstrip Based MIMICs without Via Holes. IEEE Intern. Microw. Symp. MTT-S 1996, San Francisco, pp. 1399 - 1402.
- [2] K.S. Yee: Numerical Solution of Initial Boundary Value Problems Involving Maxwell's Equation in Isotropic Media. IEEE Trans. Antennas Propagation, vol. 14, May 1966, pp. 302-307.
- [3] W. Thiel, W. Menzel: An efficient FDTD analysis of a waveguide-to-microstrip transition. 28th Europ. Microw. Conf., 1998, Amsterdam, Vol. 2, pp. 576 – 580.

Acknowledgment: This work partly was funded by the German Ministry of Research under contract no. 16 SV 420/1.