ON-WAFER MEASUREMENT OF MICROSTRIP-BASED MIMICs WITHOUT VIA HOLES

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ABSTRACT

Typically, on-wafer measurements of microstrip based MMICs require via holes as ground contacts. To avoid these, the design of ground contacts for on-wafer probing at mm-wave frequencies using eletromagnetic field coupling is presented in this paper. Theoretical and experimental results of the respective transitions are given as well as a test deembedding this transition from the behaviour of a transmission line.

INTRODUCTION

Applying coplanar-probe on-wafer measurements to microstrip circuits requires additional ground contacts typically realized by extra via holes realized close to the microstrip input port. For the production of these circuits, an excess number of vias may reduce the yield, and a closely spaced row of vias at the chip edges even may affect the stability of the thinned wafer during the backside processing. On the other hand, at mm-wave frequencies, wavelength on GaAs becomes small enough to realize transmission line structures on a MIMIC without excess space requirement. For example, a quarter wavelength stub at 80 GHz is only 0.2 - 0.3 mm long.
Therefore, we investigated stub-type RF ground contact arrangements for on-wafer probing. A first approach to this problem already was presented in /1/ based on a semi-circular radial stub surrounding the end of the microstrip line, requiring, however, too much space, and a standard access to the microstrip line no longer was possible.

ELECTROMAGNETICALLY COUPLED GROUND CONNECTIONS

The basic arrangements investigated in this paper are sketched in Fig. 3; in a first step, however, a transition according to Fig. 1 was tested.

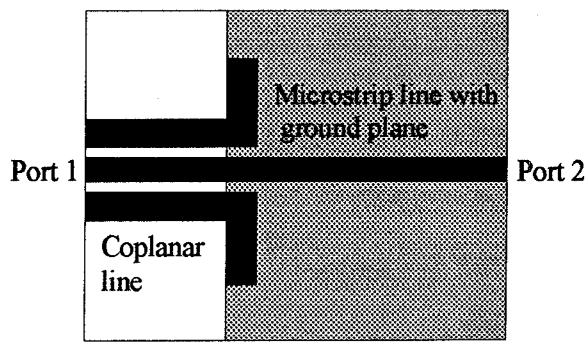

Fig. 1: Transition from coplanar waveguide to microstrip line.

A theoretical analysis, and based on this, some optimization of the circuits were performed using a mode matching procedure and the FDTD method /2/, /3/. Due to the required ideal shielding in the mode matching calculation, resonant mode occurred leading to

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resonance peaks in the results not existing with the real open structures. In addition, complex modes had to be taken into account leading to a high numerical effort. Therefore, the following theoretical results were computed with the FDTD method and absorbing boundary conditions /4/ to limit the volume in which the calculations had to be performed.

Vector network analyser measurements using a TRL calibration were made of two transition placed back to back connected by homogeneous microstrip lines of different lengths. In this way, the performance of a single transition could be deembedded. To enable an easier fabrication of the test structure without GaAs technology, the basic investigations were done with frequency scaled models using easily available substrates (Rogers RT Duroid 6010 and TMM10).

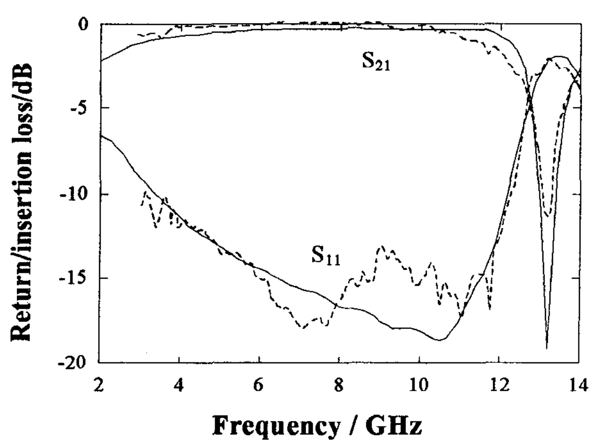

Fig. 2: Theoretical (—) and experimental (---) return and insertion loss of a transition from coplanar waveguide to microstrip line according to Fig. 1 (Substrate thickness h=0.635 mm, ε_r=11, line width w=0.545 mm, slot width s=0.25 mm, ground strip width 0.5 mm, stub width 1 mm, stub lengths 3.23 mm).

Fig. 2 presents theoretical and experimental results of a pure planar transition from microstrip to coplanar line according to Fig. 1. The test circuit was designed for the frequency range from 5 to 10 GHz on a 0.635 mm thick substrate with a dielectric constant of 11. The microstrip line impedance was kept at 50 Ω, and no matching circuit was added. Excellent agreement with experiment and a suitable performance over a 40 % bandwidth is achieved as shown in Fig. 2. Even the sharp resonance of the structure around 13 GHz is modeled very well.

In a next step, rectangular as well as radial stub like structures were investigated as RF ground connections (Fig. 3) for real on-wafer prober measurements. The thickness of the substrate material was 0.38 mm, the dielectric constant 9.2. The center frequency for the design was chosen to 20 GHz.

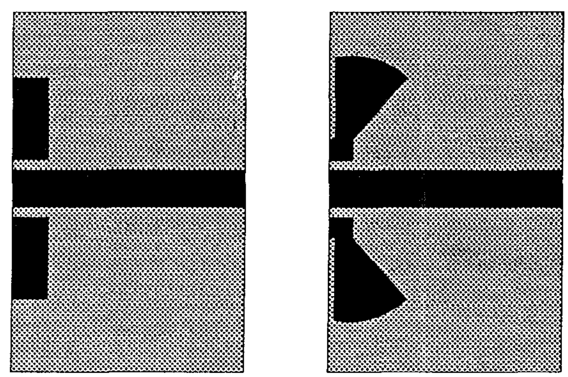

Fig. 3: Rectangular and radial stubs to provide the RF ground connection.

Once again, theoretical and experimental results agree quite well, except for the poles in the return loss. For return loss values below -15 dB, however, the accuracy of the measurements together with the deembedding procedure for the single transition is limited.

As it can be expected, the radial stub arrangement exhibits the larger bandwidth compared to the rectangular one. For a return loss of 10 dB, the theoretical relative bandwidths are 70 and 90%, respectively.

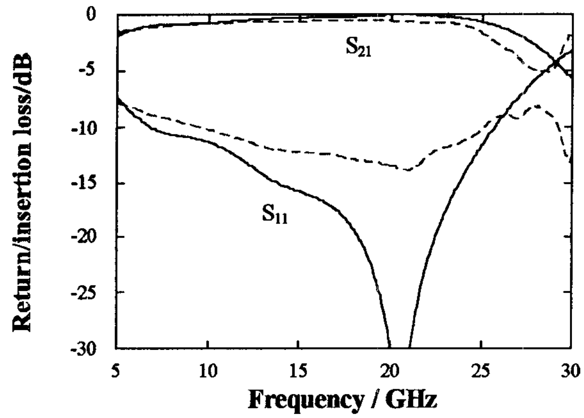

Fig. 4: Theoretical (—) and experimental (---) results for a transition using rectangular stubs
(Substrate thickness h=0.38 mm, ε_r=9.2, line widths w=0.1 mm, slot width s=0.05 mm, ground strip width 0.05 mm, stub width 0.334 mm, stub lengths 1.62 mm).

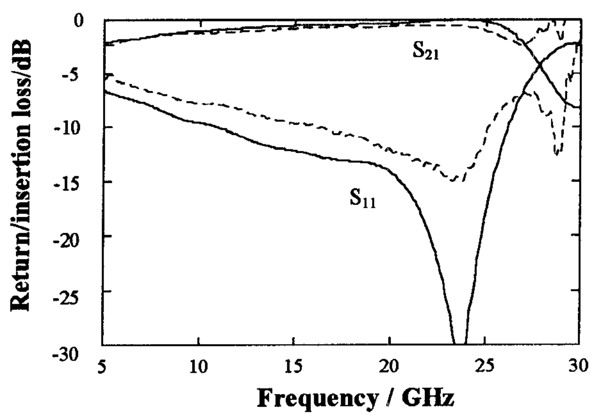

Fig. 5: Theoretical (—) and experimental (---) results for a transition using radial stubs
(Substrate thickness h=0.38 mm, ε_r=9.2, line widths w=0.1 mm, slot width s=0.05 mm, ground strip width 0.05 mm, stub radius 1.62 mm, stub angle 30°).

As a final test, the reference planes for the measurement were shifted to the microstrip region, i. e. the transition from wafer prober to the microstrip line was deembedded from the raw measurement results using microstrip calibration structures. Fig. 6 shows the return loss of the homogeneous microstrip line as a result of this procedure. Some problems occurred with the TRL calibration around and above 30 GHz, but below, with a residual return loss of about 35 dB, the results are very satisfying.

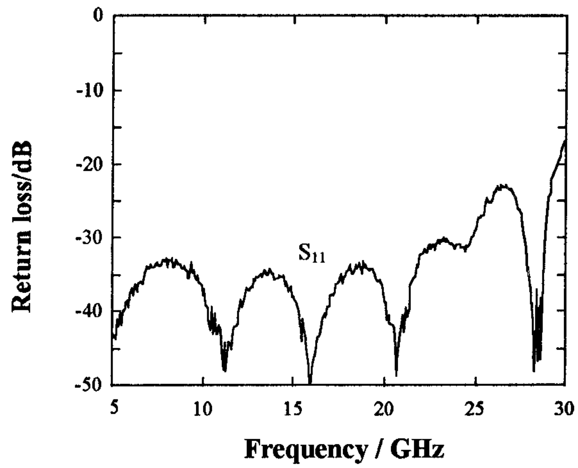

Fig. 6: Return loss of a homogeneous microstrip line after deembedding the via-less prober contact (Dimension according to Fig. 5).

CONCLUSION

It has been shown that on-wafer measurements for mm-wave MMICs based on microstrip transmission lines can be done without via holes. The necessary ground plane interconnects are achieved using quarter-wave structures printed at the sides of the microstrip input lines. At mm-wave frequencies, these stubs become small enough to be compatible with the requirement for small circuit area.

In a next step, this technique will be combined with electromagnetical coupling as interconnect technique for mm-wave MMICs to avoid high precision bonding /5/

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