FLIP CHIP AND TAB INTERCONNECTS

FOR MILLIMETER WAVE MMICs

A COMPREHENSIVE STUDY

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ABSTRACT

This paper presents simulation results performed with a 3D FEM Software on flip chip and tape automated bonding interconnect of MMICs at millimeter wave frequencies (40 - 60 Ghz).

Parasitic propagation modes for CPW flip chip mounted MMICs are pointed out with proposed solution.

Measurement results obtained with LNA 38 and 55 GHz microstrip MMICs connected to alumina substrates with a 50 Ω coplanar tape are presented and show goodagreement compared to bare MMICs and to simulations.

INTRODUCTION

At millimeter wave frequencies (40 to 60 Ghz) either because of economic reasons for volume applications or/and for performances requirements of the systems, chip connections methods (wire bonding) become a limiting factor.

This has been now extensively described (1) and mainly flip chip methods are proposed (in the papers) to answer to the needs and to reduce length connections.

Two types of MMICs are encountered on the market : microstrip MMICs and coplanar MMICs. For microstrip MMICs, flip chip is a difficult method because ground plane of the MMIC requires to be connected to ground plane of the substrate. For CPW MMICs flip mounted, careful attention has to be paid on the parasitic modes propagating in the substrate and between MMICs and substrates.

3D simulations are therefore absolutely neccessary and can provide solutions to suppress parasitic modes and resonances. One alternative solution to connect MMICs chip at millimeter wave frequencies is to keep 50 Ω impedance between MMIC and mounting substrate or package (TAB). The two kinds of approach are hereafter described.

The work presented has been possible through a close cooperation between Dassault Electronique and IEMN for the simulation part.

TAB INTERCONNECTS

As opposed to bumps used in Flip Chip mounting a TAB is a distributed kind of interconnect and it can be considered at mm.wave lengths as a tapered coplanar line with typical length of about 500 µm as illustrated Figure 1.

The tape is made of kapton like material and etched gold plated copper conductors. Bonding between copper plated leads and MMICs use automatic thermosonnic process close to wire bonding. The process is compatible with standard MMICs pads (no bumps on the tape or on the chips).

To achieve wide band operation the characteristic impedance of this tapered line must be kept as close as possible to 50 Ω. The variation of the report substrate distance along the TAB can be compensated by the taper geometry (width of he central strip and of the slots). The thickness of the tape metallization is also an important parameter as illustrated Figure 2. The thicker the metallization the lower the characteristic impedance.

After optimisation of the tapered coplanar section TABs can exhibit return losses lower than –20 dB up to the V band as shown Figure 3a for various topologies. Return losses lower than –20 dB are needed to provide low return loss after TAB mounting of a MMIC chip as illustrated Figure 3b for a 1 mm long 50 Ω coplanar line etched on GaAs reported on an alumina substrate. Return losses lower than –15 dB can be achieved up to 75 GHz. These good theoretical results were confirmed by experiments on a TAB reported LNA chip at V band. Figure 4 shows the LNA gain measured with on wafer probing and the LNA gain after TAB mounting on an alumina substrate. The results are in close agreement and show the potential interest of this kind of MMIC chip interconnect.

FLIP-CHIP INTERCONNECTS [2] [3] [4]

Flip-Chip mounting (illustrated Figure 5) with automatic report is an attractive alternative solution for Multi Chip Modules using coplanar wave guides (CPW) technology.

But at mm.wave frequencies the electromagnetic behaviour of such interconnects is difficult to handle mainly due to the metallization of the substrate backside (implemented on purpose or by the circuit environment) which nucleates parasitic modes.

1 Parallel plate waveguide mode in the air-gap between the MMIC and the substrate. The resonant frequencies of this parallel-plate waveguide cavity can be pushed out of the operating frequency band by grounded bumps such as bumps ① in Figure 5.

2 Parallel plate line mode under the ground planes of the CPW which has the same symmetry as the CPW mode and thus cannot be suppressed by air bridge. This mode can be killed by via holes in the substrate as via holes ② in Figure 5.

3 Microstrip like mode generated by the central strip of the MMIC CPW with electrical field lines ending on the backside metallization of the substrate. This electrical field distribution can nucleate resonant modes within the waveguide cavity in the dielectric substrate limited by via holes ② the upper metallization of the substrate and the MMIC on top.

4 Slot line mode excited by the central strip of the MMIC CPW in the upper metallization opening of the substrate ③ in Figure 5.

So parasitic resonance can arise from various non wanted propagation modes. A classical mean to overcome this electromagnetic parasitic is to deposit thin lossy layers at adequate locations [5]. But since the electromagnetic energy is widely distributed in the whole structure this results in heavy losses ($\geq$ 3 dB). So the best solution is to try to kill this parasitic mode by non lossy metallic boundaries. One solution is proposed Figure 6a and the frequency behaviour at V band of this Flip-Chip interconnects is presented Figure 6b. Clean operation up to 60 GHz is possible with this topology up to 60 GHz at least.

CONCLUSION

Surface mounted device technology is still a challenge at mm.wave frequencies. Full 3D electromagnetic simulations are necessary to identify the possible coupling between numerous parasitic modes. Only a rigorous understanding of the Electromagnetic behaviour of these complex structures can allow proper boundaries to kill or limit the influences of these parasitic without losses.

Some efficient solutions have been proposed in this paper but this work is still underway to reach the upper limit of the W band (75-110 GHz).

ACKNOWLEDGEMENT

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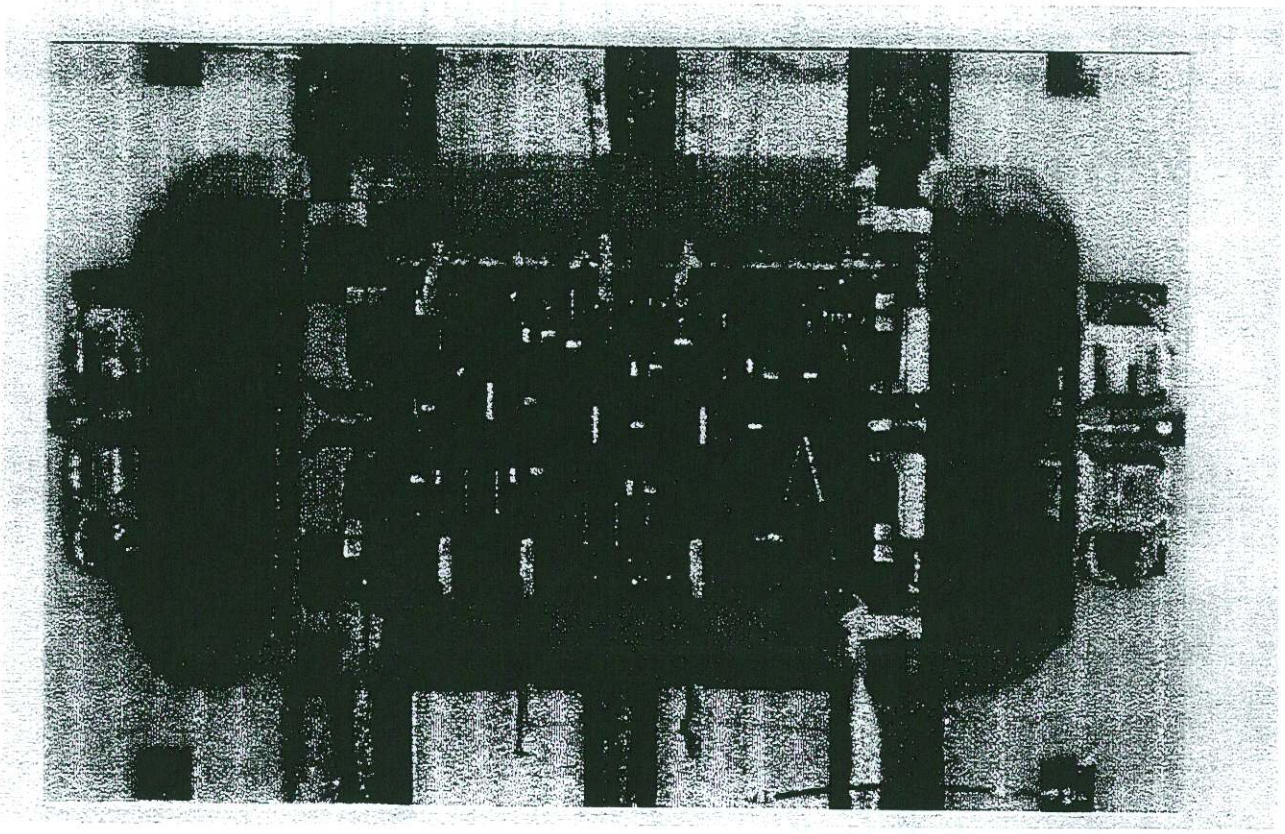
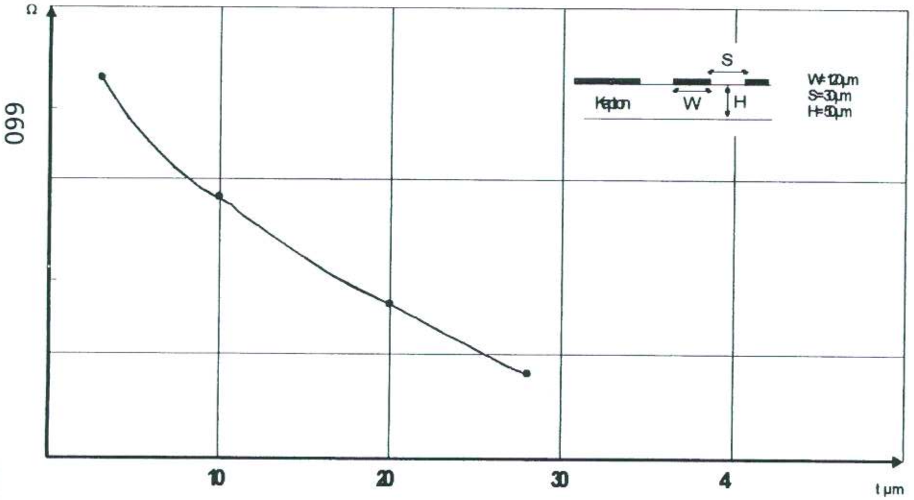
Figure 1

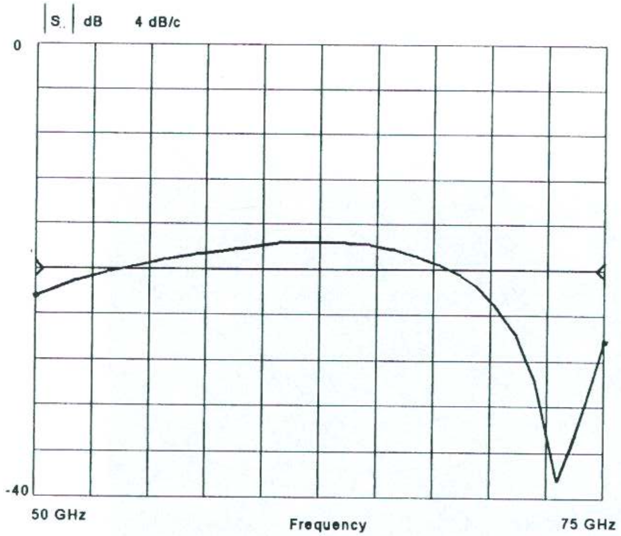
Millimeter wave LNA connected with a coplanar 50 Ω tape to a microstrip alumina.





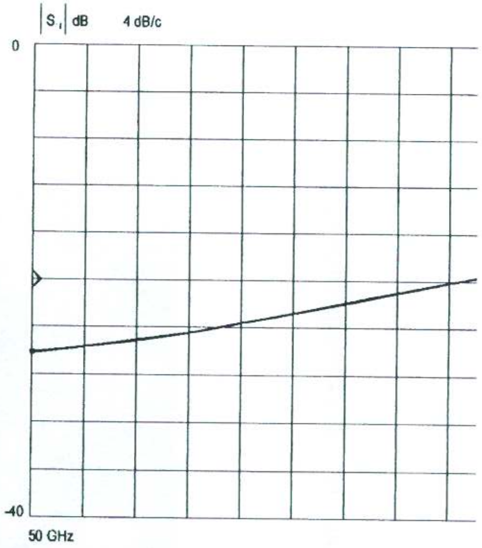
The characteristic impedance versus metallization

Figure 2



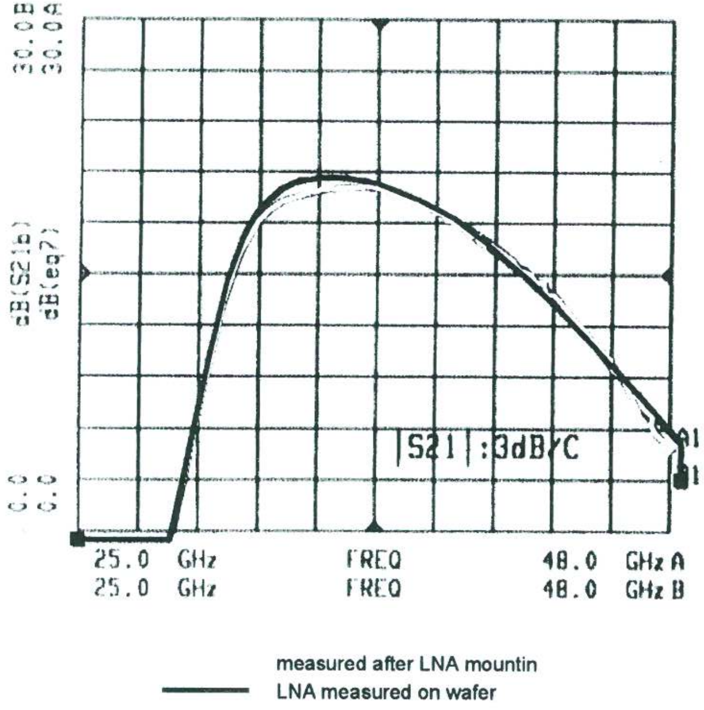
MMIC reported on alumina substrate with 50 Ω line two TABs

Figure 3a

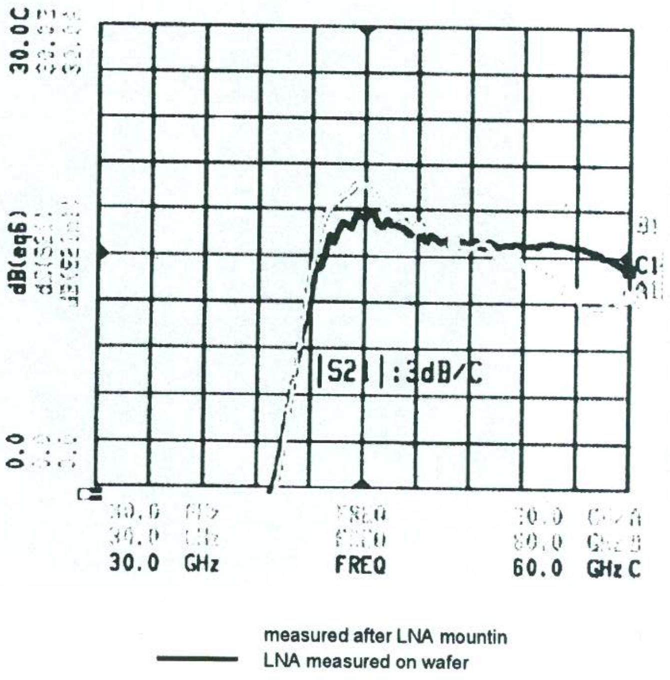


One TAB transition

Figure 3b



Figures 4



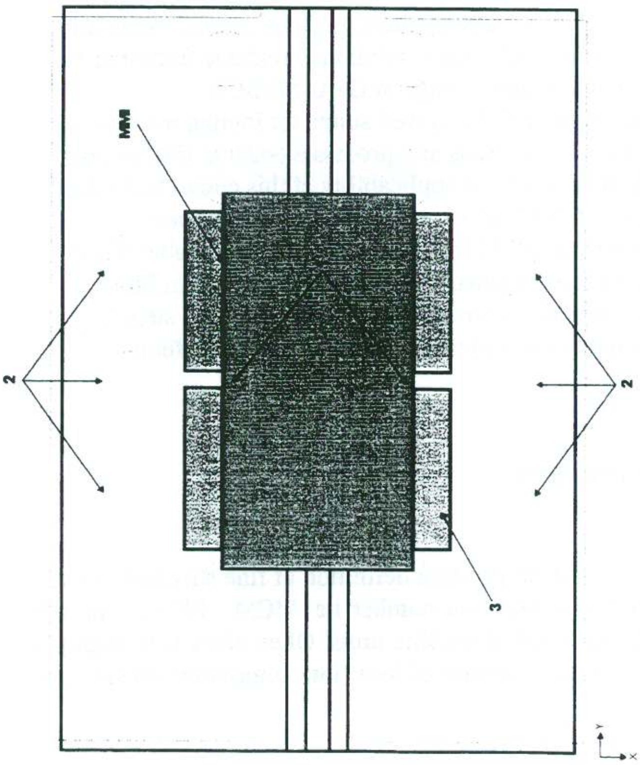


Figure 5

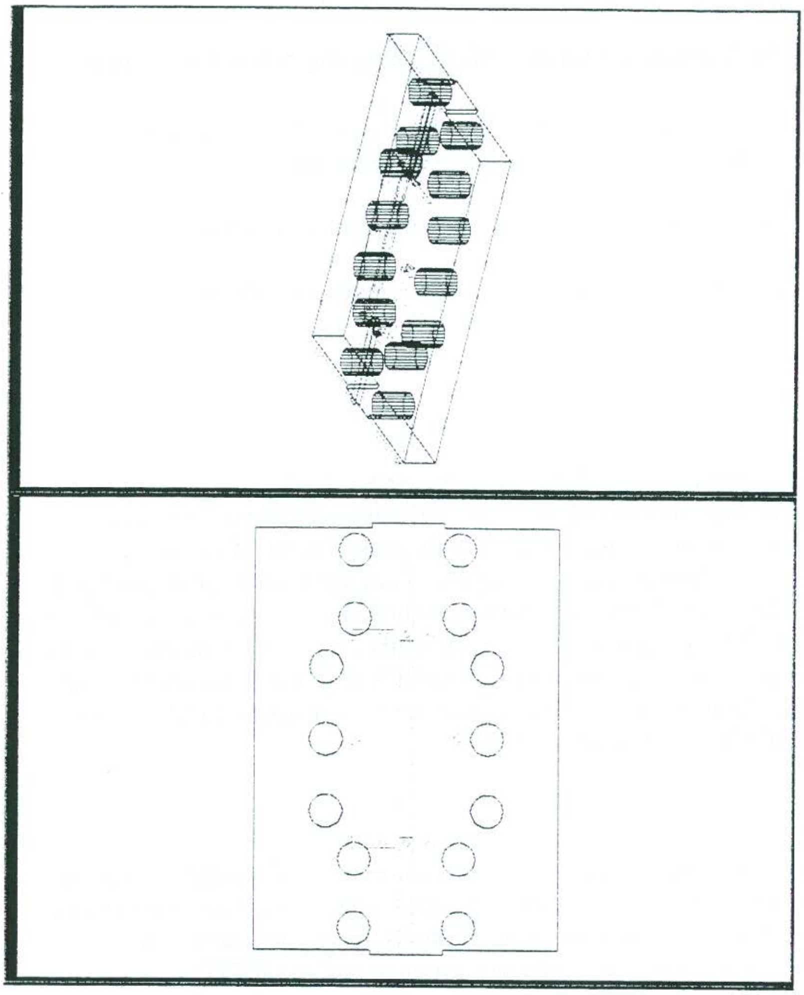


Figure 6a

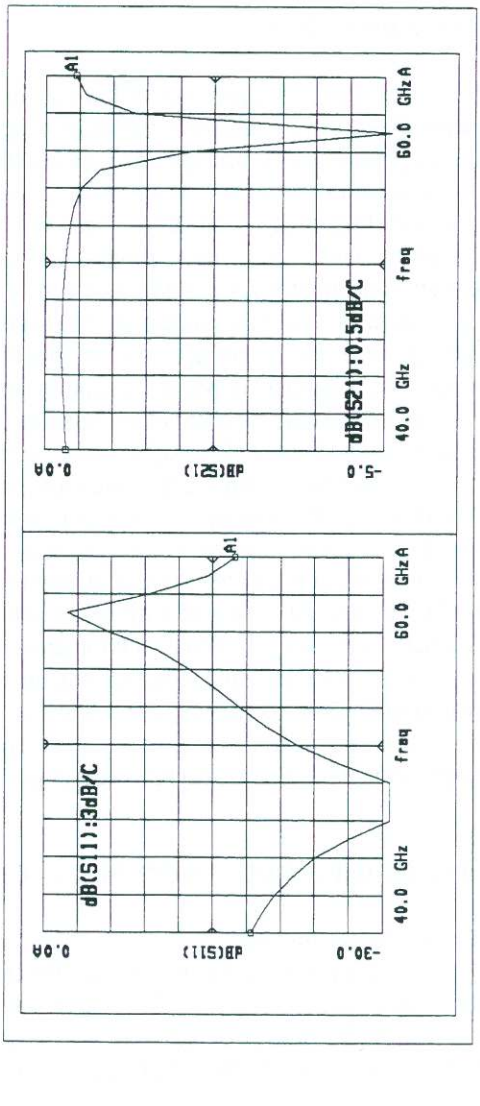


Figure 6b