3D MICROWAVE MODULES FOR SPACE APPLICATIONS

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ABSTRACT

This paper describes the design, manufacturing and measurement of **3D microwave modules**. The vertical interconnection between stacked circuits is based on an shielded homogeneous coplanar line with a 90° vertical structure. The fabrication of these modules is in relation with the "*MultiChip Module Vertical*" technology, originally developed for digital applications. The electrical measurement in the Ku band demonstrates very good results.

INTRODUCTION

Nowadays, the major trends for telecommunication satellites are for **mobile phone and multimedia applications**. Several programs have been announced and widely advertised in the newspapers. This includes the spectacular **low earth orbit constellations** such as GLOBALSTAR®, TELEDESIC®, CELESTRI® and SKYBRIDGE®. For these last systems, high traffic capacities induce the design of many active antennas, either in the Ku or Ka frequency band. In order to meet the requirements in term of dimension of the lattice, it has been demonstrated in [1] and [2] that the integration of these antennas into 3D modules offers many advantages, each of these modules representing a radiating element.

In this paper, we propose a new **3D microwave packaging** for active antennas applications and we show the design, manufacturing and measurements of 3D microwave modules, including microwave components such as MMICs devices.

POSITION OF THE PROBLEM

The first problem of 3D integration was the design of a **wide band vertical interconnection** between the different stacked microwave levels. This was solved using an shielded homogeneous coplanar line with a 90° vertical structure (cf. Figure 1) [3]. The design was performed using HFSS (*High Frequency Structure Simulator*), a commercial finite element software from HEWLETT PACKARD, and the measurement showed very good results up to 35 GHz (cf. Figure 2).

The second problem was to define a **3D technology** that could achieve the stacking of microwave circuits and the vertical interconnect. The "***MultiChip Module Vertical***" technology, called MCM-V and originally developed for digital applications [4], correctly met our constraints. The 3D modules assembly can be detailed in six steps :

1. **design** of the RF circuits,
2. **stacking** of the RF circuits,
3. **moulding** with a dielectric resin,
4. **cutting** to obtain the final geometry,
5. **metallisation** of the 3D structure,

6. **laser routing** to make the electrical connections.

The DC and microwave electrical interconnections are realized by etching the metallisation with a UV laser.

Different pre-design activities were defined to evaluate the substrates, the encapsulant and the microwave chips in one hand and the technical or technological features in other hand. For instance, in a technological point of view, we have to see if there was a good matching between the different coefficient of thermal expansion of the different kind of materials used in the stacking.

DESIGN OF THE 3D MODULE

For the design, we used an organic substrate with a dielectric constant of 10 and loss tangent around 15.10^{-4} at 10 GHz). It is laminated with a copper foil of 9 microns to improve the tolerance on the width of the microwave transmission line (about ±10 microns).

It was decided to design and manufacture an **active 3D module in the Ku band** [10.7; 12.7 GHz], taking advantage of all the background knowledge in this frequency range.

This module is divided into three vertical levels, each level including one MMIC chip (see Figure 3). These three active devices are **two low level amplifiers and one voltage-controlled attenuator**, designed for Rx Ku band (11.5 GHz). Surface mounted capacitors for DC biasing are also included in the module.

The chosen horizontal transmission line is coplanar wave-guide, consistently with the vertical interconnection. The total dimension of this module, presented in Figure 4, is **20*10*9 mm^3** and its weight is approximately 5 grams.

The measurement was performed with a Willtron 360 B network analyser on the Cascade Microtech Summit 10600 probe test station. The input and the output of the probe station were located on the top of the 3D module.

The electrical results are presented on Figure 5. The input reflection coefficient is lower than -15 dB from 10 to 12.7 GHz, which accurately corresponds to the input reflection coefficient of the first amplifier in the microwave chain. Also shown is the effect of the voltage-controlled attenuator on the gain versus frequency characteristic of the complete device (cf. Figure 5). These results are in good agreement with our simulation results, while taking into account the insertion losses of the 3D interconnection. The latter, which are in the range of 0.5 dB/mm near 11.5 GHz, has been extracted from measurement on a 3D passive test pattern which is reported on Figure 2.

CONCLUSION

A 3D module with several MMICs has been designed (Ku band) and manufactured, using the MCM-Vertical technology. The measurement shows very good characteristics, completely in agreement with the simulation results.

This clearly demonstrates that this technology, combined with some concepts of wide band microwave interconnection, is a very interesting solution for very integrated equipment.

As a further step now, on going developments deals with the design and the manufacturing of 3D modules in the Ka frequency band.

BIBLIOGRAPHY

[1] E. D. COHEN, "**High Density Microwave Packaging Program**", IEEE MTT-S, 1995, pp. 169-172.

[2] I. FAVIER et al., "**Nouvelles Technologies de Modules Actifs Associées aux Antennes Actives Intégrées**", Séminaire Antennes Actives, Juin 1997.

[3] P. MONFRAIX et al., "**New 3D low loss, wide band microwave interconnection**", IEEE MTT-S Symposium, 1997, pp. 1551-1554.

[4] C. VAL et al., **"3D Interconnection for Ultra-Dense MultiChip Modules"**, *IEEE Trans. CHMT*, Vol. 13, n°4, December 1993.

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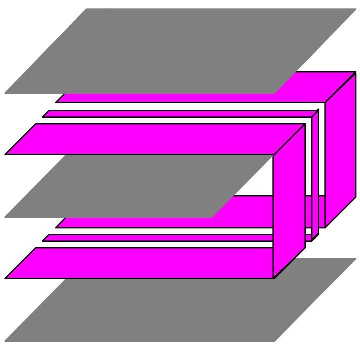


Figure 1 : Schematic of the RF vertical interconnection.

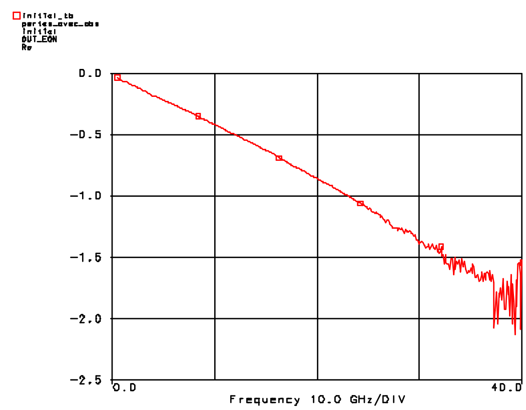


Figure 2 : Insertion loss measurement of the 3D interconnection [0; 40 GHz].

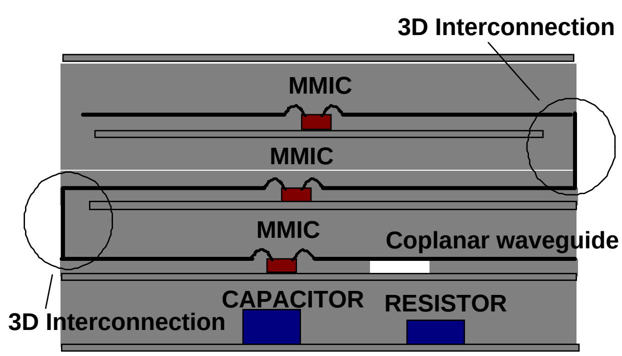


Figure 3 : Schematic of the 3D integration.

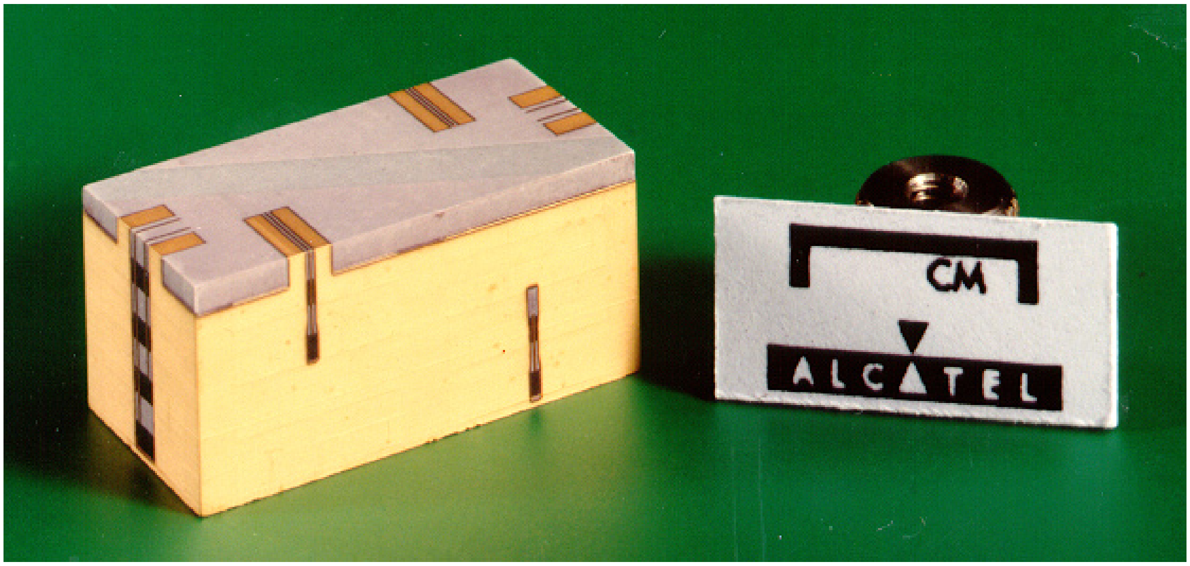
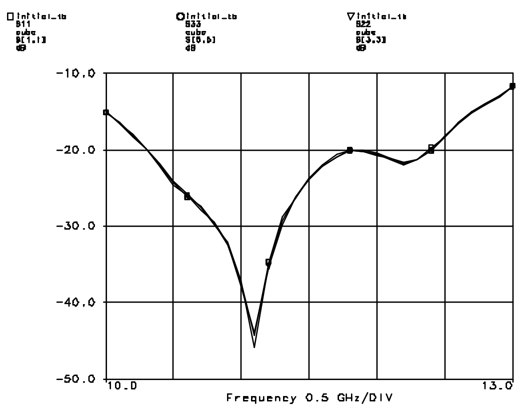
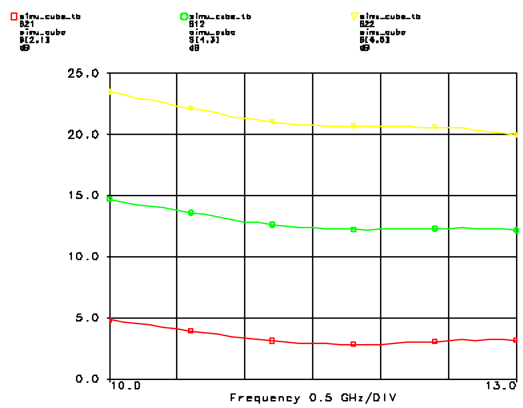


Figure 4 : 3D microwave module by ALCATEL ESPACE (dimension : 20 mm * 10 mm * 9 mm).



Return loss



Gain according three source voltage commands on the attenuator

Figure 5 : Measurement of the 3D module.