3D Packaging Technology for Integrated Antenna Front-Ends

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***Abstract*— Thanks to Vertical Multi-Chip Module packaging technology (MCM-V), a novel concept of integrated antenna feed in Ka band has been developed. This technology enables the integration of active elements very close to the radiating surface, which reduces dramatically the weight and volume of the antenna. In this paper the different technological building blocks are described, and the measurements obtained on the first breadboard are discussed. The promising results obtained should lead to a major breakthrough for active receive antennas, driving down cost and complexity.**

I. Introduction

The improvement of organic materials now allows the introduction of non hermetic encapsulation for space microwave applications. Thales Alenia Space has been working on 3D Vertical Multi-Chip Module (MCM-V) technology for more than 10 years [1-5], developing for instance vertical interconnection up to 60GHz [6] and also 3D active building blocks (including LNA and HPA functions) for T/R module applications through the MARCOS program funded by the French Department of Defense (DGA).

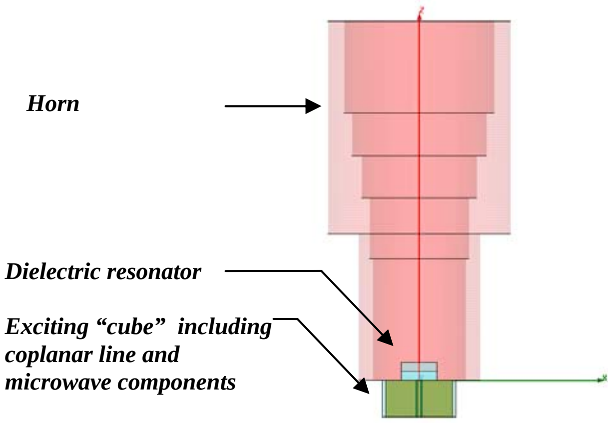

Fig. 1: The integrated feed concept

In this paper a novel feeding concept in Ka band (30GHz) based on an exciting "cube" realized in 3D packaging technology is described. It allows the integration of active components very close to the radiating plane, and reduces considerably the mass and volume compared to classical waveguide solutions.

After a first paragraph on MCM-V packaging technology, the concept of integrated feed will be described. Some information on the technological building blocks developed for manufacturing will then be given, and finally the measurements on the first breadboard will be commented.

II. 3D Packaging Technology

The 3D technology – also called MCM-V - is based on the full encapsulation in a resin, with an interconnection system etched on the surface of the "cube". The main steps are:

- manufacturing of the individual levels made on printed circuit board populated with passive and bare components (1),
- stacking in a mold with spacers (2),
- molding in an epoxy resin and polymerization (3),
- machining to the final size (4),
- plating and etching (laser routing) to define the interconnection between all the levels of the stack (5).

The different steps are resumed on Fig. 3.

The technology is available at 3D Plus company [7] and is already used in satellite payloads for digital equipments.

III. The Concept of Integrated Feed

The radiating element is a compact horn excited with a dielectric resonator. The innovation resides in the feeding by a line that is orthogonal to the resonator [8], etched on a printed circuit board (PCB) on which active devices can be mounted with standard chip on board technology.

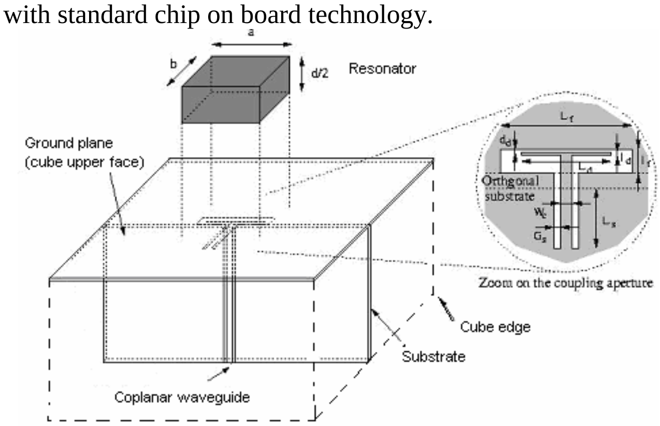

Fig. 2: Resonator fed by an orthogonal CPW line

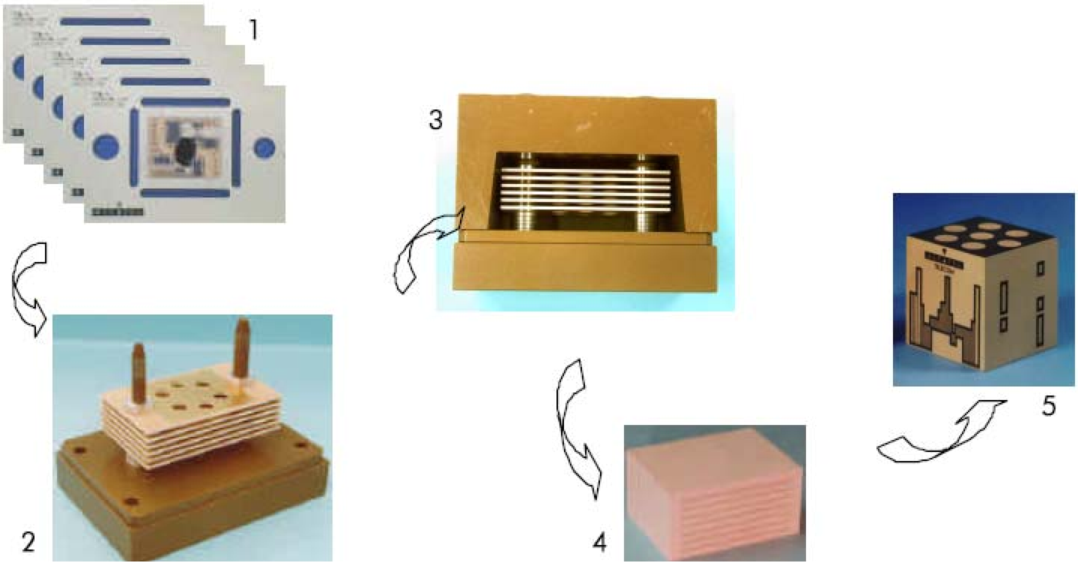

Fig. 3: Principle of 3D technology

The PCB is moulded in a "cube" of resin using MCM-V packaging technology. The transition from the PCB to the dielectric resonator is realized through a coupling aperture (see Fig. 2). The MCM-V module is called the exciting "cube" of the horn, and these two elements, plus the resonator, constitute the integrated feed.

IV. TECHNOLOGICAL BUILDING BLOCKS

Prior to the realization of the breadboard, the manufacturing process needed some improvements in order to comply with the constraints of an operating frequency in Ka band:

- Upgrading of the electrical interconnection through the coupling aperture
- Development of a connector access at 30 GHz

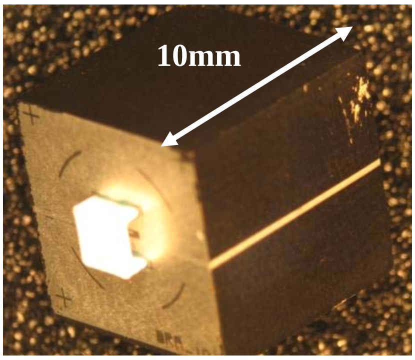

Fig. 4: Breadboard of the exciting "cube"

A. *Etching process on MCM-V modules for Ka band application*

One faces some limitations with standard laser etching process on MCM-V modules for microwave application. The patterns are etched too deeply in the resin, and due to the point of impact of the laser, the edges of the pattern are indented. These two defaults lead to electrical losses enhanced with the increase in frequency. In the case of the integrated feed concept, the accuracy of the dimensions of the coupling aperture directly impacts the transmitted power from the PCB to the resonator.

For the manufacturing of the integrated feed breadboard, chemical etching on the face of the "cube" was investigated in collaboration with 3D Plus company. Electrical performances of coplanar lines etched by chemical and laser etching have been compared. On the same metallization, one gets a 50% decrease of the RF losses with chemical etching (0.023dB/mm versus 0.046dB/mm at 15GHz).

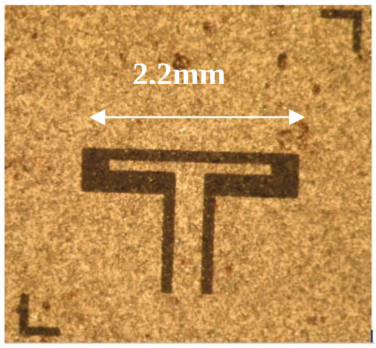

Fig. 5: Coupling aperture pattern realized by chemical etching on the face of the "cube"

B. *The connector*

The connector selected is a Rosenberger push-on, well match for Ka band (mini SMP).

The connector is mounted on the face of the «cube» directly in contact with the PCB line that is accessible on the edge of the "cube". The face is entirely metallized and the signal line is isolated from the ground by etching, as shown in Fig. 6.

For mechanical reason, instead of a "Surface Mount Technology" as in [5], it was chosen to have a machining of the module. A hole is drilled at the location of the pad, and the pin of the connector is pasted with conductive glue inside the hole, i.e. at the location of the signal line.

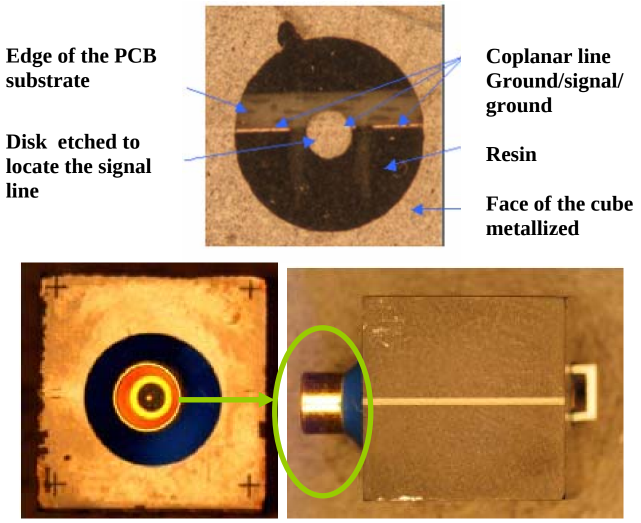

Fig. 6: a) Mark etched on the face of the cube to repair the location of the signal line – b) Connector mounted on the "cube"

To characterize the transition from the connector to the PCB, the [S] parameters of a module with a connector at each end have been measured, and are shown on Fig. 7.

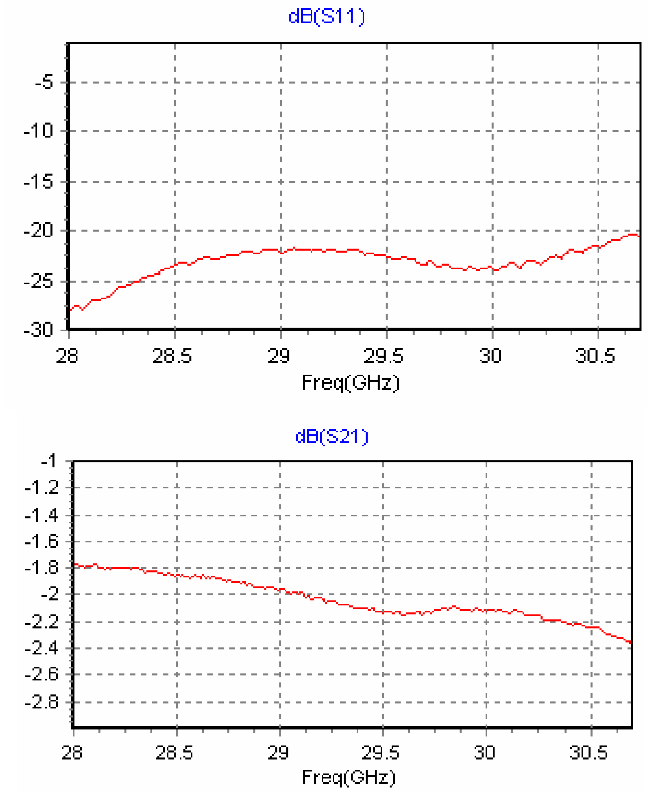

Fig. 7: Measured S parameters of a module with a connector at both ends

These parameters have been measured with a network analyzer calibrated in V band using V/mini SMP adapters. The elements measured are the adapters, the connectors and a 10mm long coplanar line altogether. In the range 28-31GHz the reflection coefficient |S11| is inferior to –20dB. Losses of about 2dB have been measured in transmission but this measurement includes the impact of the adapters that are not taken into account in the calibration step.

V. Test of the Breadboard

The performances of the integrated feed mounted in a compact horn have been measured in an anechoic chamber. The configuration is shown on Fig. 8.

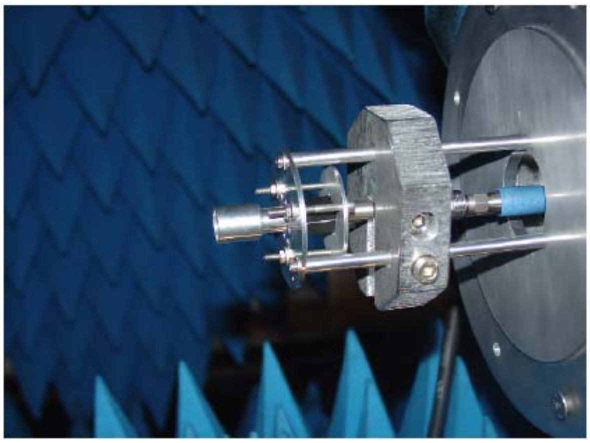

Fig. 8: Measurement configuration

The reflection parameter |S11| has been characterized. The difference observed between simulation and measurement is explained by a slight misalignment of the coupling aperture etched on the module compared to the edge of the PCB, which is confirmed by back simulations (see Fig. 9). This problem of misalignment of the etching mask has been studied and solved after the manufacturing of these first breadboards.

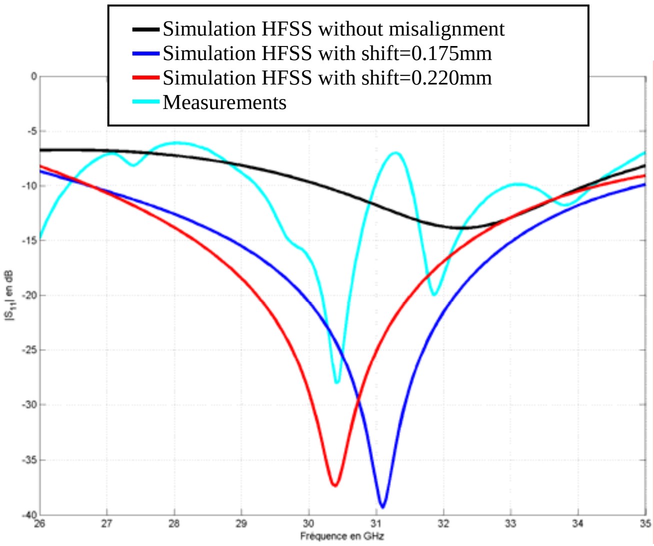

Fig. 9: Reflection parameter |S11| – Comparison of measurement and simulation

When comparing the measured radiation pattern at 30GHz to the radiation pattern obtained by simulation with an ideal excitation of the horn, one can see that the expected performances have been reached. The level of cross polarization is higher in the experiment compared to the ideal case, but it stays under –20dB. This phenomena is due to the slight misalignment of the coupling aperture.

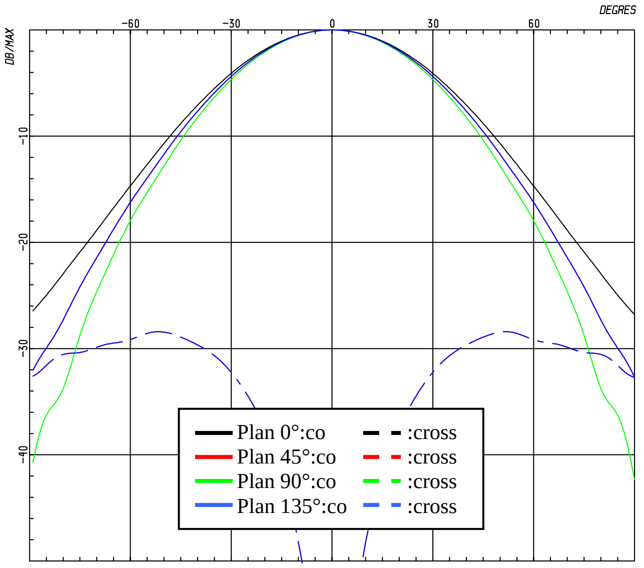

Fig. 10: Simulated radiation pattern of the horn excited by an ideal feed at 30 GHz

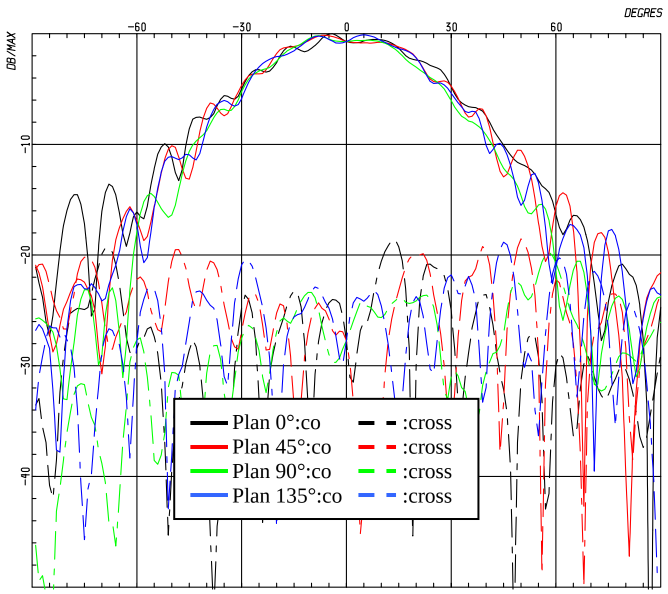

Fig. 11: Measured radiation pattern of the horn excited by the integrated feed at 30GHz

VI. Conclusion

In this paper the concept of an integrated feed in Ka band using 3D packaging technology has been successfully validated. The performances of the tested modules meet the expectations.

After a presentation of the concept, the technological improvements required for the manufacturing of the breadboard have been detailed. The design of microwave patterns on the face of 3D modules has been improved using chemical etching, compared to the standard laser routing. The implementation of a microwave mini SMP connector on the "cube" for an application at 30GHz has been validated.

Future work will consist in designing and testing an active integrated feed module containing microwave active and passive components. The design of a passive feed in dual polarization is also an important milestone, since this property will bring promising capabilities to Focal Array Fed Reflector active antennas, not achievable with standard technology.

Acknowledgment

The authors wish to acknowledge the European Union for funding parts of the work mentioned above through the European project e-Cubes (contract n° 026461), as well as the French Space Agency CNES for its support under contract n°R-506/TC-0003-028.

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