3D ACTIVE MODULES
FOR HIGH INTEGRATION ACTIVE ANTENNAS

Patrice ULIAN, Philippe MONFRAIX, Sébastien GEORGE,
Christian TRONCHE, Claude DREVON, Jean-Louis CAZAUX.
ALCATEL SPACE, 26 avenue J-F Champollion, 31037 TOULOUSE, FRANCE

ABSTRACT

This paper describes the different parts of active antenna sub-systems currently developed in Alcatel Espace. These modules are realized according to some new 3D RF packaging technologies, mainly based on moulding assembly.

INTRODUCTION

Thanks to recent multimedia technics and services, telecom markets are now increasing very quickly to achieve more and more personal and professional needs. Satellite systems have recently been involved with this market explosion, and many projects talk now about satellite constellation to propose multimedia service with a global earth coverage.

In Alcatel, the Skybridge project has been launched to fan out a 64 LEO satellites infrastructure with very high density and quality multimedia services. Another main project has been announced : Teledesic from Microsoft Corporation, which deals with 288 LEO satellites.

These new satellite markets introduce then a new parameter in spatial industry : the number of spacecrafts to develop. To reach those new markets, industrial space companies have to front the challenge of new production methods, to cross the fence between single and mass products, but with an identical quality holding.

In Alcatel Space, technical and technological solutions have been engaged for a long time to achieve this industrial revolution. The main problem concerns very high integration, able to significantly reduce spacecraft size and weight and then launching prices for constellation operators, but always matching with high capacity needs of multimedia bearer services.

As multimedia needs high coverage areas with LEO satellites, this maximum integration sight becomes critical on active antennas, more with Ka-band systems emergence. Technics and technologies have then been developed in Alcatel Space around 3D integration, in order to achieve very low meshing active antennas. Figure 1 shows a previous breadboard of an active antenna using 3D active radiating modules, detailed on Figure 2.

To realize such 3D RF modules, many questions are to be answered such as (Figure 3) :

I. How to wideband interconnect two RF plans ?
II. Which technology to achieve 3D assembly ?
III. Which technics for filtering interface between RF chain and radiating pattern ?
IV. Which technics to wideband interconnect Beam Forming Network and 3D module ?
V. Which kind of BFN to supply such modules ?

I. 3D RF INTERCONNECTION

In [1], we have already introduced a concept to realize wide band interconnection, based on coplanar lines properties. Measurements have been realized with a 60 GHz probe station on some evoluted test vehicles (Figure 4), and showed very good results, since VSWR is lower than 1.3:1 in [0-45 GHz] range (Figure 5), and despite of a resonance at 10 GHz, identified as a weakly coupled transverse mode created by the test vehicle.

Any active antenna sub-system can then be adressed with this 3D RF interconnection.

S21 measurement is not significant, because this test vehicle has been realized on high dielectric losses material, thus matching accurately the measurement with real performance of a single 3D RF interconnection. Nevertheless, S21 measurement is always compliant with coplanar line typical losses.

II. 3D ASSEMBLY TECHNOLOGY

To achieve 3D modules assembly, the work has been pursued on a very innovative technology based on moulding (Figure 6). After stacking, RF circuits are moulded with dielectric resins, machined and metallized. DC connections and 3D RF coplanar interconnections are then realized by laser etching.

This technology is very easy to process, and is generic for any frequency.

To demonstrate the matching between technical and technological solutions, one passive and 3 active (12, 20 and 30 GHz) modules have been successively realized (Figure 7). In active modules, MMICs have been introduced to provide amplification (LLA) and gain control (variable attenuator). Chips DC biasing and attenuator driving lines are visible on small sizes of active demonstrator on Figure 7.

In all cases, measurement shows consistent results (Figure 8), compliant with our computations. Technical and technological solutions chosen previously can then be considered as successful.

III. UPPER INTERFACE

For upper interface, we have chosen to replace bulky waveguide filters with new technics, such as hollow patch cavities, studied by IRCOM [2]. Main advantages of these solutions are low size for Ku- or Ka-Band with high quality factor, cavities stacking capability, coplanar access and direct coupling with radiating pattern (Figure 9).

Main goal is to build those filters simultaneously with 3D modules, by introducing additive layers before the moulding, corresponding then to filter layers at the end of the process. Radiating pattern will then be etched with laser, as DC or RF lines.

Considering [2], extra simulations have been made to reach resonant frequency around 20 GHz. Results show a good isolation of the fundamental mode (> 1.5 GHz) and a very interesting quality factor (>1100) for a single 6 x 6 sq.mm x 2 mm high cavity. Load coupling coefficient with coplanar access line is about 44 at 20 GHz. A small and performant multipole filter should then be easily introduced in 3D RF modules to realize upper interface between radiating element and RF layers. After resolution of the trade-off low losses/wideband/low size, the main problem remains the enhancement of performance sensitivity with respect to moulding process tolerances to achieve non-tunable filters.

IV. LOWER INTERFACE

For lower interface, investigations have been driven around wideband technics with new technologies, like bumps reporting to achieve « flip-chip » interconnection (Figure 9). This concept is based on a very performant report technology already used for chips to achieve a good wideband interconnection (Figure 12) between the 3D RF cube and another module, which could be realized in 3D technology too, like the BFN (see lower).

V. BFN

Whereas 3D RF coplanar interconnection is wideband, available multilayer technologies do not meet such broad frequency response. Then, it has been decided to develop a BFN with same solutions as 3D modules themselves, to address the maximum number of active antennas markets.

In addition, to get the maximum advantage of this solution, it has also been chosen to design the BFN no more with horizontal layers, but vertical ones considering active antennas typical topology (Figure 10). This will notably reduce electrical lengths and losses with the moulding technology where 3D interconnections have to be routed at the edge of 3D module : in case of a "vertical" BFN, 3D RF interconnections routing will then be done on both largest sides of the BFN. An another important advantage is the capability to introduce MMICs inside the BFN itself (in case of multibeam management), and then to avoid some additive bulky external packaging for these chips.

Some technological breadboards have already been realized with large size 3D modules (Figure 11). Next work will be the report of GPO and K-connectors onto this BFN to link it to another external equipment. Simulations with HFSS of these types of connections onto the BFN show encouraging VSWR performance (Figure 12).

CONCLUSION

All these concepts and puzzle blocks have today reached some technical and technological maturity in Alcatel Space, so that next year developments should lead us to the realization of operational 3D active antennas in Ku- and Ka-band.

BIBLIOGRAPHY

[1] : P. Monfraix et al., ***New 3D low loss wideband microwave interconnection***, IEEE MTT-S 97 vol 3 pp 1551-1554

[2] : S. Moraud et al., ***A new planar type dielectric resonator for microwave filtering***, IEEE MTT-S 98 vol 3 pp 1307-1310

FIGURES

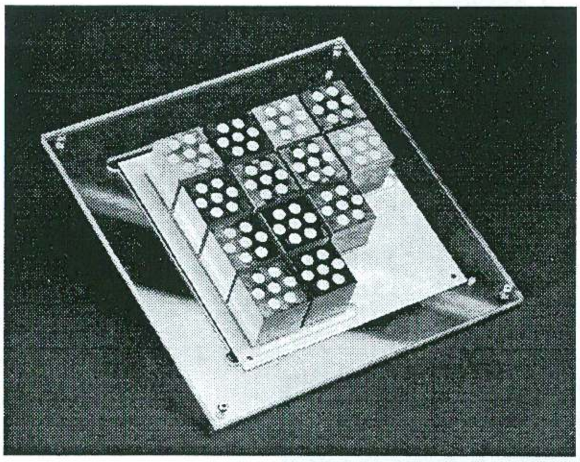


Figure 1 : Example for a 3D Directed Retry Array

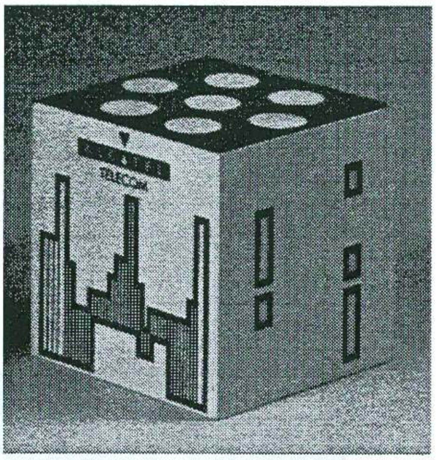


Figure 2 : 3D active module for active antenna

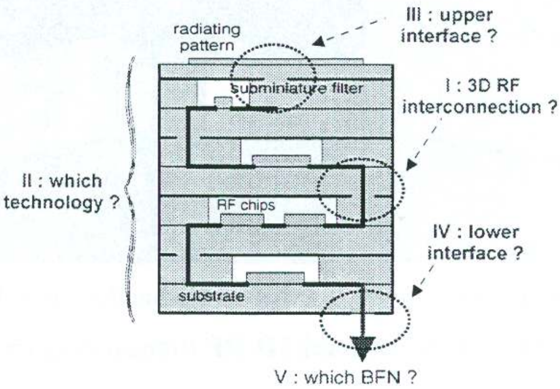


Figure 3 : Main technical questions for 3D active module achievement

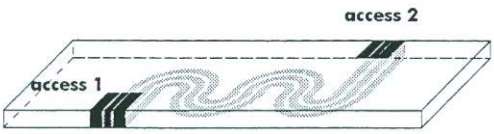
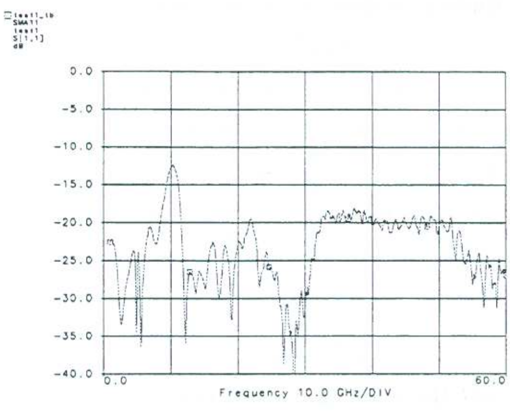
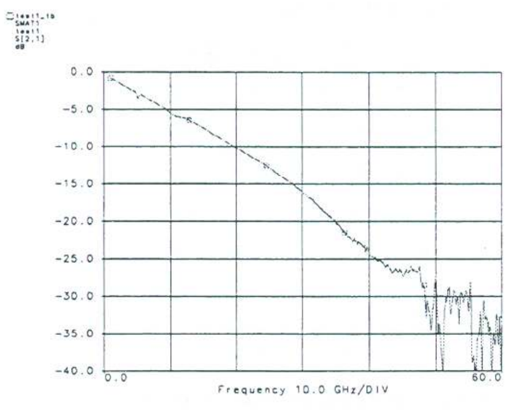


Figure 4 : Improved 3D RF coplanar interconnection test vehicle



S11



S21

Figure 5 : Wideband measurement of 3D RF coplanar interconnection

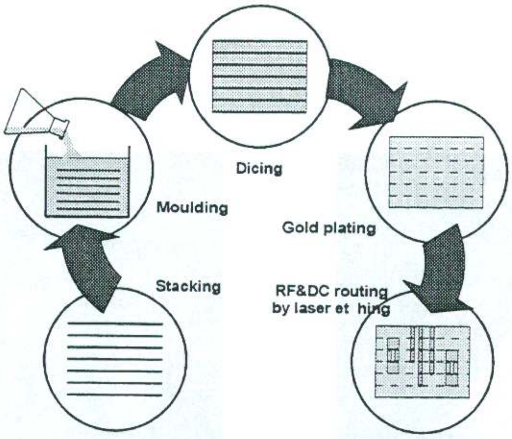
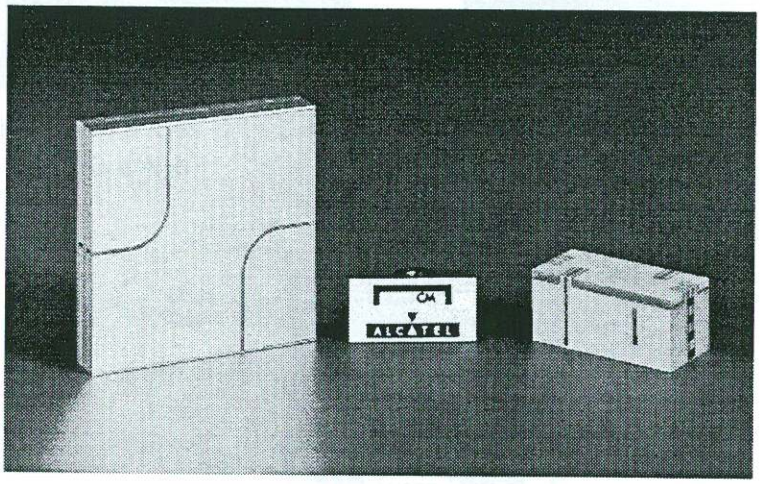
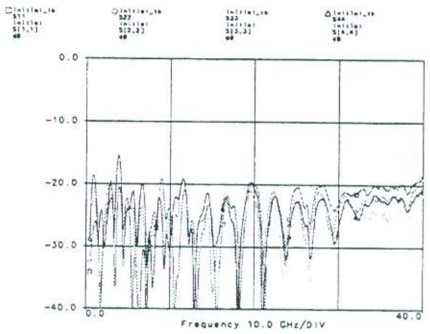


Figure 6 : 3D assembly technology

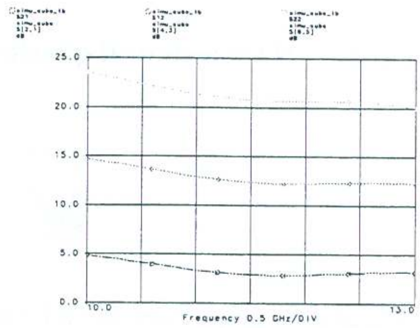


Passive cube Ku- or Ka-band active cube

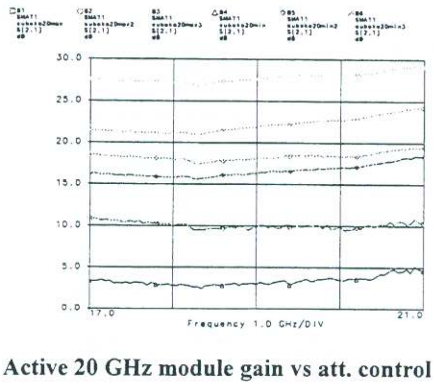
Figure 7 : Operational 3D RF demonstrators



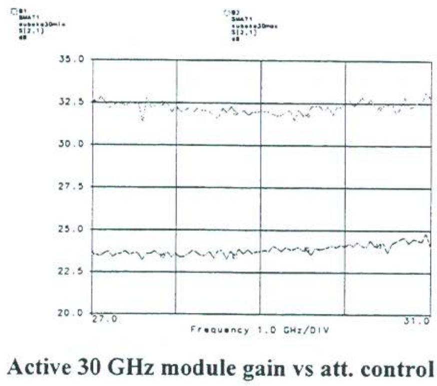
S11 passive cube



Active Ku-band module gain vs att. control

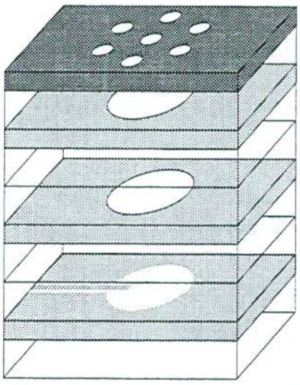


Active 20 GHz module gain vs att. control

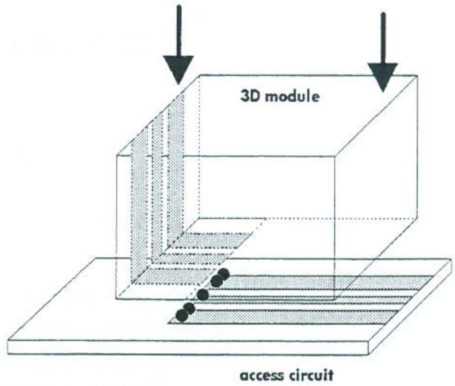


Active 30 GHz module gain vs att. control

Figure 8 : RF Measurements for passive, Ku- and Ka-band 3D modules



Multilayer subminiature filter
for 3D active modules upper interface



« Flip-chip »-like interconnection
for 3D active modules lower interface

Figure 9 : Solutions for upper and lower interfaces of 3D active antennas modules

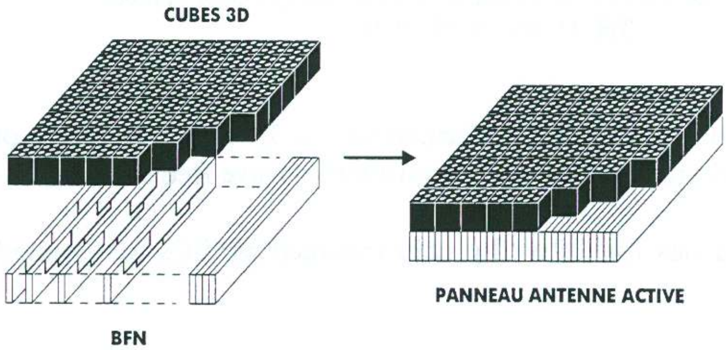


Figure 10 : Vertical design for BFN for 3D active antennas

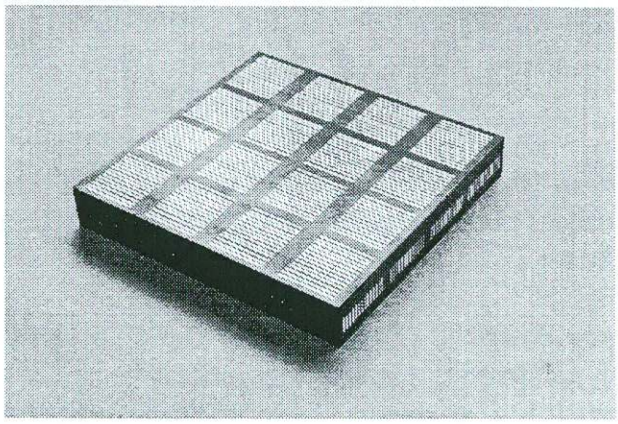
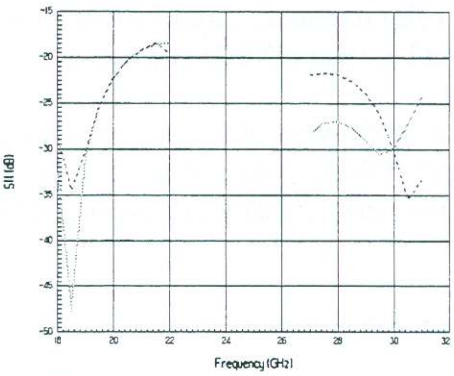
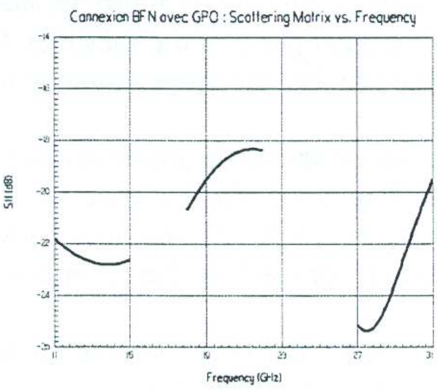


Figure 11 : Large dimension moulding



« Flip-chip »-like interconnection



GPO connector

Figure 12 : Simulated VSWR performance for BFN interfaces