From full hybrid to 3D microwave packaging for space applications

Claude DREVON - Jean Louis CAZAUX

ALCATEL SPACE INDUSTRIES
BP 1187 - 31037 TOULOUSE CEDEX - FRANCE
Tel : +33 (0)5 35 34 61 02 - Fax : +33 (0)5 35 34 62 94
Email : Claude.Drevon@space.alcatel.fr

Over recent years, the miniaturisation of microwave functions was based on the use of hybrid technology. That included thin or thick film capability, micro or macro microwave packages and the design of MMICs. In the same time, many developments were running around the MCM technology, first for low frequency applications then for R.F. packaging. The future could be in the 3D technology, wafer scale integration and/or a mix with embedded passive components into Silicon.

1. Hybrid technology

In the 80's, most of the microwave hybrids were based on bare transistors associated with thin film substrates and heavy packages. Fig. 1 shows a typical example of a CAMP (Channel AMPlifier) with a monolithic Kovar® machined package associated with 50Ω glass sealed feedthroughs. The different parts of the microwave function (bare transistors, alumina substrates) were soldered on a metallic carrier, then the carriers were screwed into the package. The package was hermetically soldered.

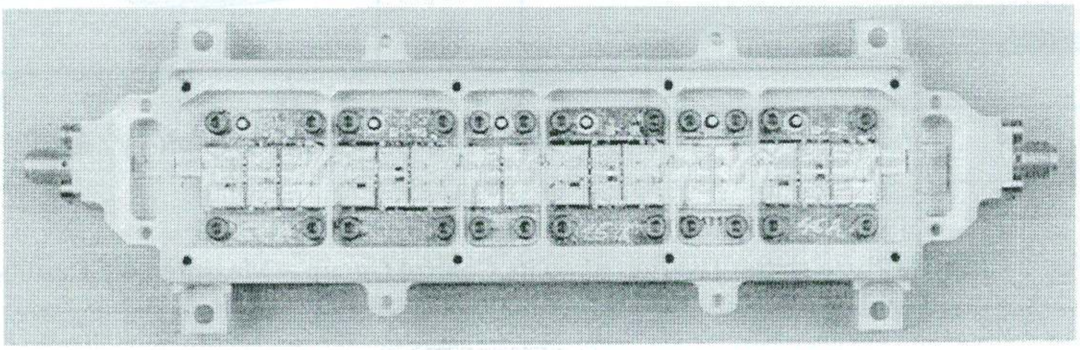

Fig. 1 - Channel AMPlifier in Kovar® package (around 150 mm long)

2. Micropackages

Beginning of 90's, a cut of 50% in price and weight was due to the use of MMICs and micropackages. As shown of fig. 2 and fig. 3, a micropackage is made of metallic parts for bottom and walls and 50Ω cofired ceramic feedthroughs. The transmission line in the feedthrough is a microstrip in the inner and external bonding areas, and a stripline under the wall. This new microwave packaging systems have been developed to :

- preserve the high intrinsic reliability of GaAs dice, notably by providing a contamination free environment,

- provide a high performance interconnection system, both within the module and to the outside world, for minimal degradation of the MMIC performance,
- achieve a high packaging efficiency (ratio between GaAs die and total package surface), for a full benefit of the size and weight reductions brought by MMIC utilisation,
- allow for easy integration of the completed MMIC based modules into the next level of packaging and interconnection.

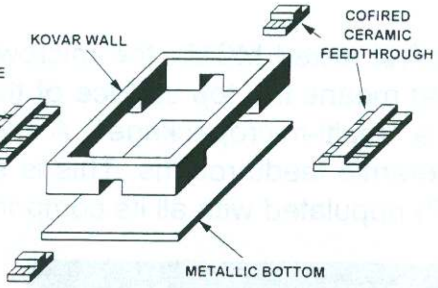

Fig. 2 - Principle of a microwave micropackage

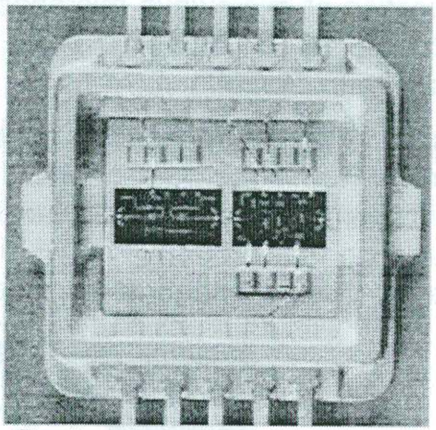

Fig. 3 - View of a micropackage (dimensions 12 x 11 x 3 mm)

But, without an effort on the miniaturisation of the low frequency part, the total volume, i.e. the gain in weight, is not sufficient. An example is given fig. 4 where the size of the microwave equipment is mainly ruled by the low frequency electronics.

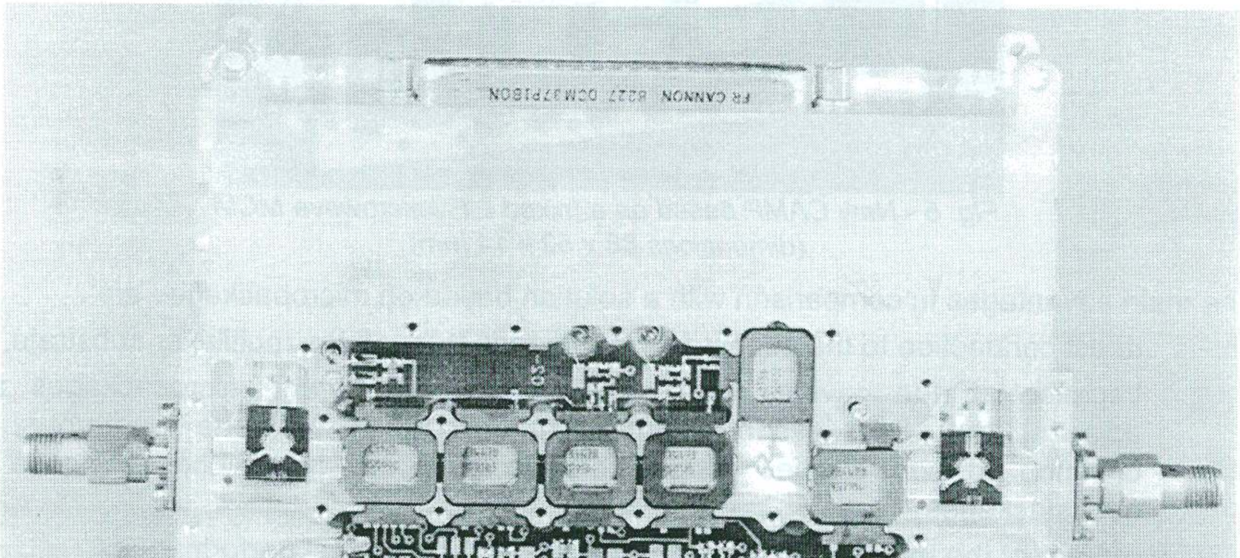

Fig. 4 - Comparison in surface between L.F. and microwave parts

3. MCM's

Among the various types of MCM's, the MCM-C is a multilayer substrate based on aluminium oxide. The lines and vias are printed on the different layers then all the layers are cofired at the same time at high temperature (HTCC - High Temperature Cofired Ceramic). Wherever required, metal parts such as lead-frames, heat sinks and/or seal rings could be soldered with a silver-copper eutectic. Then, all the exposed surfaces are plated. On both sides of the final substrate, components could be bonded in an hermetic area or outside of the walls defining the hybrid areas.

This HTCC technology is intrinsically one of the most reliable technology because the substrate contained buried metallization as an integral part of the alumina ceramic microstructure. Multilayer ceramics have been used for a long time to build packages like side braze packages, LCC, CQFP or PGAs.

Based on the experience acquired by Alcatel Space Industries in the development and the qualification of microwave micropackages, it was decided to reuse, as far as possible, all the knowledge of Alcatel Space Industries in the field of microwave micropackages working up to 30 GHz.

In order to limit the technological risks for a first mixed MCM, the microwave signals are not embedded in the ceramic multilayer. That means the top surface of the substrate is a ground plan which is use as the base of a "multi-micropackage". A multicavity wall is soldered on that ground level with all the ceramic feedthroughs. This is shown on Fig. 5 with a top view of a channel amplifier (CAMP) populated with all its components.

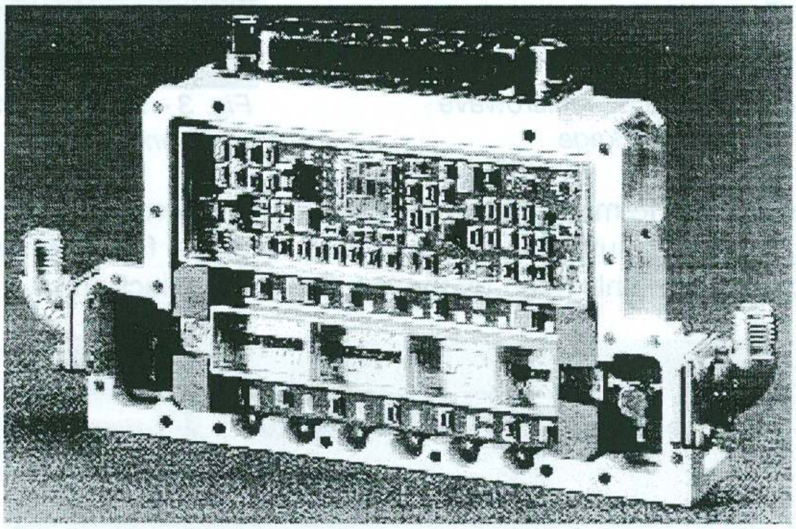

Fig. 5 - New CAMP based on a mixed L.F./microwave MCM (dimensions 88 x 52 x 14 mm)

The main advantages in comparison with a solution based on micropackages are :

- direct connection to the supply and commands through the multilayer substrate,
- because all the cavities corresponding to the different micropackages are adjacent, there are less microwave connections. In fact, one feedthrough is common to two cavities instead of two plus the wire ribbon in case of micropackages,
- reusing of the well known feedthroughs with their electrical performances.

If necessary, thin film alumina substrates could be bonded on the top of the multilayer. This could be useful to have tighter tolerances on the lines for functions like filters.

As an example, the change from full Kovar® package to MMICs in micropackages then MCM involved a drastic reduction of weight for a full channel amplifier from 550 grams, to 250 grams then 90 grams. This could be easily seen on fig. 6 where the three generations of CAMP are compared.

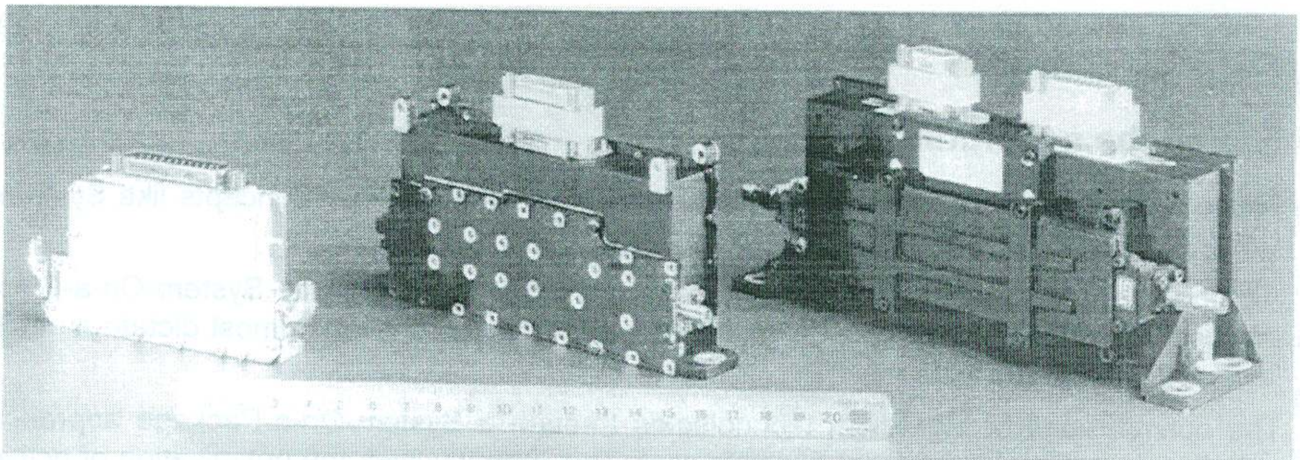

Fig. 6 - Impact of MCM on miniaturisation

4. 3D technology

For the next future, the 3D R.F seems a good choice. The vertical interconnection between stacked circuits is based on an shielded homogeneous coplanar line with a 90° vertical structure. The manufacturing of these modules is directly in relation with the "MultiChip Module Vertical" technology, originally developed for digital applications. The schematics of the RF vertical interconnection and of the 3D integration are shown on fig. 7 and fig. 8.

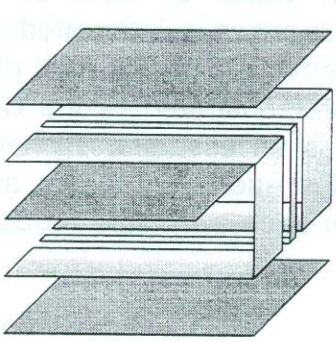

Fig. 7 - Schematic of the RF vertical interconnection

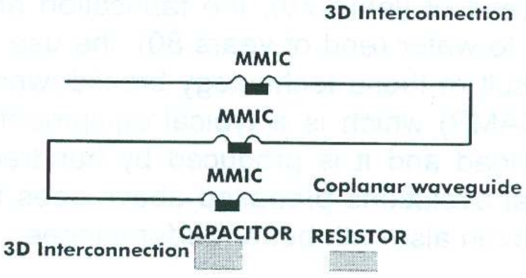

Fig. 8 - Schematic of the 3D interconnection

A full 3D module with several MMICs has been designed (in Ku Band) and manufactured using the MCM-Vertical technology (see fig. 9).

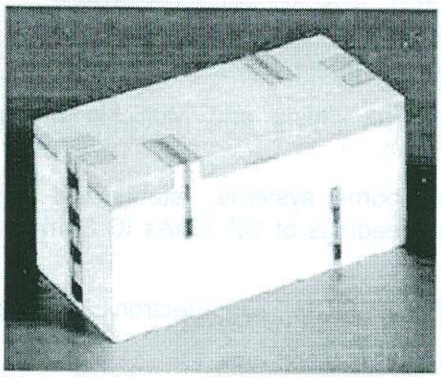

Fig. 9 - 3D microwave module by Alcatel Space Industries (dimensions : 20 x 10 x 9 mm)

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.

5. And the next future...

Those technologies could be associated with other miniaturisation concepts like System-On-a-Chip (SOC) and/or System-On-a-Package (SOP).

Although very high levels of integration have been demonstrated with System-On-a-Chip, practical limitations such as costs, schedule, performances and risk almost dictate a much lower level of integration.

The optimal used of ingredient technologies through a System-On-a-Package approach will allow to achieve the lowest possible cost. This then involves the optimisation of active device selection, the intelligent partitioning of functions between the active and passive media for the specific subsystem architecture adopted, the co-design of the application specific active and passive devices and optimisation of the module manufacturing, assembly and test.

6. Conclusion

In the satellite communication arena, the needs to reduce costs and weight of satellite payload is the final critical issue. This has been achieved in the last thirty years with several major technological steps : the development on wafer of MESFET AsGa transistors (end of years 70), the fabrication of monolithic microwave integrated circuits generalised to wafer (end of years 80), the use of MCM ceramic substrates (end of years 90). The result of these technology breakdowns has been demonstrated by the Channel Amplifier (CAMP) which is a typical equipment because it is an essential element of a satellite payload and it is produced by hundreds of modules each year. Each different technological evolutions proposed above sees the weight of such a module reduce by a factor of 2, even also with better performances.

7. References

[1] M. Pecht and al., "An Approach to the Development of Package Design Guidelines", Nov./Dec. 1992 INSIDE ISHM

[2] P. Lautier and al., "GaAs MMIC die assembly", 1992 European GaAs Applications Symposium

[3] C. Drevon and al., "Advanced packaging for active antenna", EuPac'94 1st European Conference on Electronic Packaging Technology, p132-134

[4] D.A. Doane and P.D. Franzon, "Multichip Module Technologies and Alternatives - The basics", New York : Van Nostrand Reinhold, 1993, p234-235

[5] B. Hargis, "Advanced Ceramic packaging and Multichip Modules", March/April 1994 Advancing Microelectronics, p45

[6] J.L. Cazaux, "MMIC for space-borne systems : status and potential", Dec./Jan 1995 Microwave Engineering Europe. Also in proceedings of 16th GaAs IC Symposium, Philadelphie, USA, 16-18 Oct. 1994

[7] C. Drevon and al., "Mixed L.F./R.F. MCM", 47th Electronic Components and Technology Conference, San Jose (CA) - May 18-21st, 1997 - p497-501

[8] P. Monfraix and al., "3D Microwave Modules for Space ", 1998 IEEE MTT-S International Microwave Symposium Digest - p1289-1292