KA-BAND EQUIPMENT ASSEMBLY FOR MULTIMEDIA SATELLITE PAYLOADS

PATRICE ULIAN, HERVÉ LEVEQUE, AGNÈS RECLY, JEAN-CHRISTOPHE CAYROU, BERNARD COGO, JEAN-LOUIS CAZAUX

e-mail : patrice.ulian@space.alcatel.fr

ALCATEL SPACE INDUSTRIES, 26 Avenue J.F.Champollion, 31037 TOULOUSE, FRANCE
Tel: 33 (0)5 34 35 57 60 Fax: 33 (0)5 34 35 69 47

ABSTRACT

This paper describes new equipment generation developed in Alcatel Space Industries to meet recent multimedia needs for Ka-Band satellite payloads. These units are built as assemblies, and use building blocks packaged with new MCM technology.

INTRODUCTION

Multimedia services are one of the most promising market part for the future space-born systems applications. Already identified particularities and advantages of multimedia payloads are the following ones, based on on-board processing systems using either ATM or DVB processor :

- wide-band allocation that allows high data rate services ;
- multiple beam antenna increasing the service capacity ;
- easier universal coverage due to Ka-band antennas spot beams.

To achieve the multimedia services described above, the Ka-Band payloads shall include a high number of channels to process all the antenna spot beams. This involves a very large number of RF Ka-Band receivers and modulators.

To reduce cost and mass of these payloads, it is then obvious that units shall be very highly integrated and standardized. Both features can be met when using :

- new RF Multi-Chip-Module technology, which allows cheaper building blocks and tuneless RF chains ;
- an equipment assembly design, where centralization of Local Oscillator, TM/TC management and DC power supply helps really to decrease main dimensioning parameters for satellite payload.

The following paragraphs give details on the new MCM-C technology, then on the RF building blocks using this technology and finally on the assembly design and the impact of such an architecture on mass, volume and cost reductions for the equipment, but on DC power consumption and mission reliability too.

NEW MCM-C PACKAGING TECHNOLOGY

Hermetic micro-packages with ceramic RF&DC feedthroughs was previous RF packaging technology used in Alcatel Space Industries. Building blocks were then based on very simplified and tuneless functions : only 1 or 2 MMICs were used, to compose amplifier, mixer, or attenuator single functions. This packaging philosophy allowed very high modularity but its drawbacks were a high number of building blocks to manufacture, and long tuning on RF chain when all building blocks were linked.

New RF packaging technology MCM-C is a ceramic multilayer cofired substrate. The lines and vias are printed on the different layers then all the layers are cofired at high temperature (HTCC - High Temperature Cofired Ceramic). Wherever required, metal parts such as lead-frames, or seal rings can be soldered with a silver-copper eutectic. Then, all exposed surfaces are plated. On both sides of the final substrate, components can be bonded inside or outside hermetic areas (Figure 1).

Compared to solution based on micro-packages, the main advantages are :

- direct connection to the power supply and commands through the multilayer substrate (removal of DC feedthroughs) ;
- suppression of numerous mismatching RF connections (wire-bondings) between building blocks ;
- same substrate for RF & DC parts bonding.

As modularity and tuneless are main features for low cost achievement in spatial industry, Alcatel uses this new RF packaging technology to achieve now no more expensive single functions, but more elaborated building blocks. Size and weight are reduced, but manufacturing and tuning costs and cycles are also reduced.

This MCM-C technology is Flight Model qualified for STENTOR, the French technological satellite.

BUILDING BLOCKS

A new generation of compact products has been developed, with the support of European Space Agency : a Ka/C Band Down Converter, a C/Ka Band Up Converter, a wideband Amplifier and a Ka or C Band Modulator. They are realized using MCM-C technology which allows a mass reduction of about 30% compared to the existing micro-package generation.

At the present time, three MCM-C substrates have been designed and manufactured : a Down-Converter, an Up-Converter and an Amplifier. The last one (modulator) is underway. The two first substrates have been studied for accommodating different sub-systems, including RF, IF and multiplier sections (with an external LO). The third one can be used for several frequency bands (C-Band, Ka-Band, ...), with the possibility to have temperature compensation networks. Figure 2 shows both Down-Converter et Amplifier MCM substrates with associated RF chain generic synopsis.

Other MCM substrates dedicated to frequency converters and modulators shall be next developed to cover new multimedia needs (Ka/IF, Ka/C, Ka/Ka, C/Ka, IF/Ka, BB/Ka), which require extra fonctions as gain control or output power level limitation.

For frequency converters and amplifiers, generic synopsis of RF and IF chains have been defined (Figure 3), to keep mechanical compliance of MCM substrate whatever the performance requirement.

For 20 GHz modulators, two functional sections are identified :

- RF section, including 20 GHz direct modulation and gain control ;
- data interface, including synchronisation, level conversion and digital filtering of I and Q external data (up to 100 Mbit/s rate).

Figure 4 gives the block diagram of the Ka-Band modulator, with both RF and data building blocks. The modulator is based on MMIC functions mounted into a MCM substrate for the RF part and high rate digital ASIC onto PCB board for the data interface part.

These substrates have been designed to be compatible with Alcatel MMICs chipsets and a large number of commercial MMICs. Several configurations can be realized with the same MCM in order to have the right answer to each program at minimal cost.

ASSEMBLY ARCHITECTURE

To answer to the very important number of RF units required on a Ka-Band multimedia satellite payload, MCM technology is mandatory but not sufficient.

To reduce mass, size and cost per RF channel, one of the best solutions remains the design of assemblies, allowing DC power supply, LO generation and TM/TC management to be common to many RF channels, at the minimum required to comply with the payload reliability.

Five sub-systems have been identified to build assembly architecture : RF slices up to 16, each including one or more RF functions, LO slice, TM/TC manager, DCDC converter and a connection module, to achieve LO carrier, DC voltages and TM/TC distribution between sub-systems. Figure 5 summarizes assembly functional design.

All vital functions, as LO, DCDC and TMTC, operate in cold redundancy to increase reliability. They are all independant, which allows any cross-strapping between them, upon any failure of anyone of them.

RF SLICE

RF Down- or Up-Converter slice (Figure 6) shall include 2 MCM substrates for both RF and IF chains, and a third substrate for management of each RF slice by TMTC.

For modulators, one RF slice can include up to 4 RF modulating chains, implemented on MCM substrates too. The remote TMTC management is realized through a single module for all RF functions.

LO SLICE

LO slice is optional, but can be associated to assembly if payload does not include a Frequency Generation Unit with dedicated synthesis.

It provides nominal + redundant LO carrier, in [7-14 GHz] range, using Dielectric Resonator VCO with MMIC negative resistance. Long-term stability is achieved through Phase Locked Loop referenced with a thermal controlled quartz, or with external reference provided by payload.

LO harmonics used for frequency conversion are always generated in RF slices, to avoid high frequency LO distribution, which losses and mismatch are more critical than for X- or Ku-Band distribution.

DC POWER SUPPLY

A DCDC conversion module realizes power supply interface with primary power bus on payload to provide secondary voltages to all assembly sub-systems. It is designed to reach a good power efficiency, whatever the current number of active RF slices.

This DCDC converter is switched ON or OFF through pulse commands coming from payload manager.

TMTC MANAGEMENT

Telecommands and telemetries of assemblies are managed in two stages :

- first, a common TMTC module talks with payload manager through serial link :
  - it receives commands from payload manager and transmits them to the matched sub-system (RF or LO slice) through pulse digital signals or internal 16 bit serial link ;
  - it receives status and measurements from assembly sub-systems (through analog, digital or serial way) and transmits them to payload manager ;

- second, each sub-system is able :
  - to understand commands coming from the common TMTC module and execute them thanks to Alcatel home-designed ASICs microcontrollers ;
  - to send status and measurements to the common TMTC module.

Analog telemetries are used for output level measurement, although digital signals are used for ON/OFF switching commands. All other TM/TC travel via internal serial link.

LO, DC & TM/TC SIGNALS DISTRIBUTION

Distribution of RF & LF signals is achieved with a passive multi-layer PCB, connecting each other all sub-systems of assembly.

Whether connection technics for LO slices, TMTC and DCDC modules are quite conventional, easy plug connectors solutions have been spread to RF slices to meet manufacturing and testability cost reduction.

Figure 7 shows assemblies architectures for both down-converter and modulator units.

PAYLOAD PERFORMANCE IMPROVEMENT

The main interest of assemblies is for payload building. Main improvements of equipment from payload architect point of view deal with :

- DC power consumption : it is reduced from 30 to 40% ;
- Mass : reduced up to 50 % ;
- Size : reduced from 30 % ;
- Reliability : improved from 2.2 FITs to 0.08 FITs per RF channel for a 16/12 redundancy configuration ;
- Recurrent cost : reduced from 40 to 45 %.

These analysis led in Alcatel Space Industries show real improvement of units when gathered in assemblies.

CONCLUSION

Future payloads for multimedia applications will use Ka-Band equipment assemblies. These assemblies will rely on the new microwave MCM-C technology. Architecture of these advanced units allows a significant improvement of all dimensioning parameters for satellite payload architects, and proves their matching with multimedia needs.

ACKNOWLEDGEMENT

The authors would like to thank G. GATTI from ESA/ESTEC for his support.

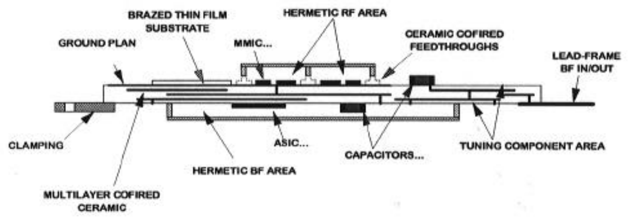

Figure 1 : MCM Technology cross view

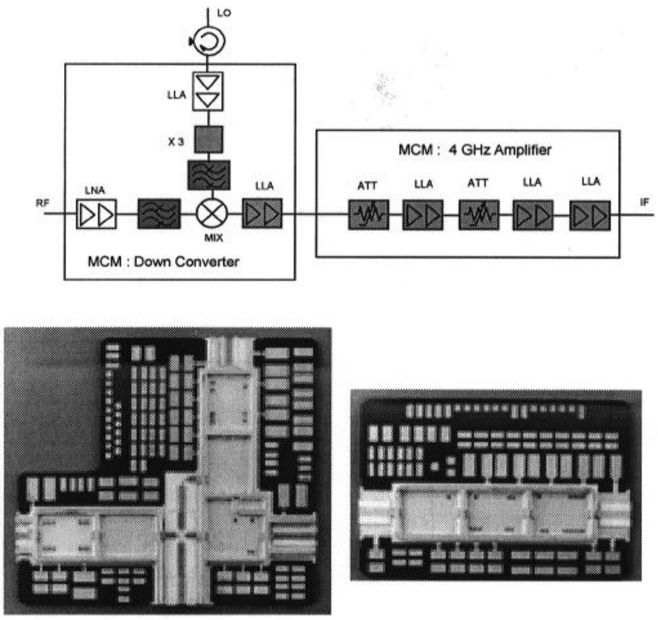

Figure 2 : Down-Converter and Amplifier MCM substrates

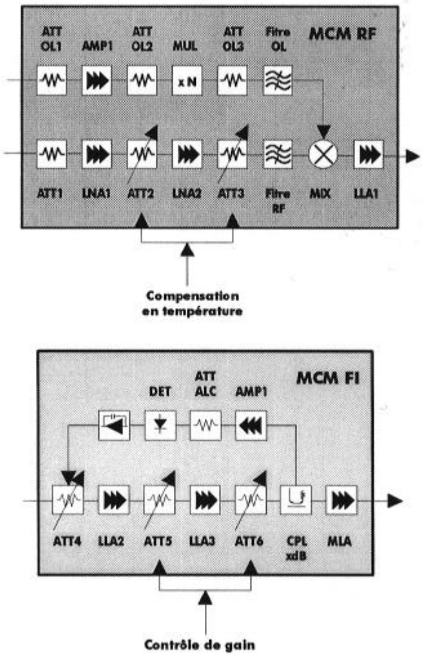

Figure 3 : MCM substrates definition for multimedia down-converters

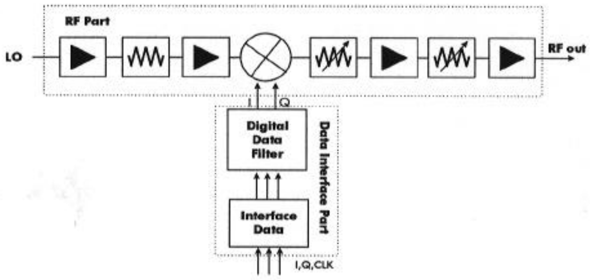

Figure 4 : Modulator RF chain

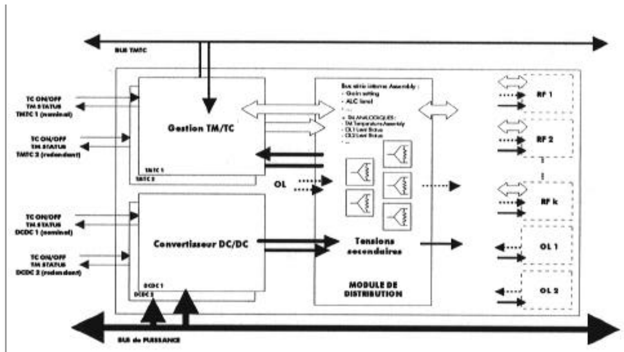

Figure 5 : Ka-Band Assembly block diagram

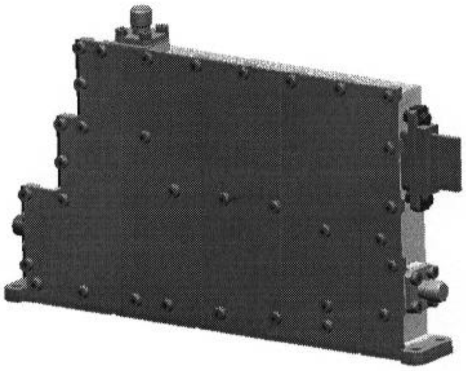

Figure 6 : Ka/C Down-Converter RF slice

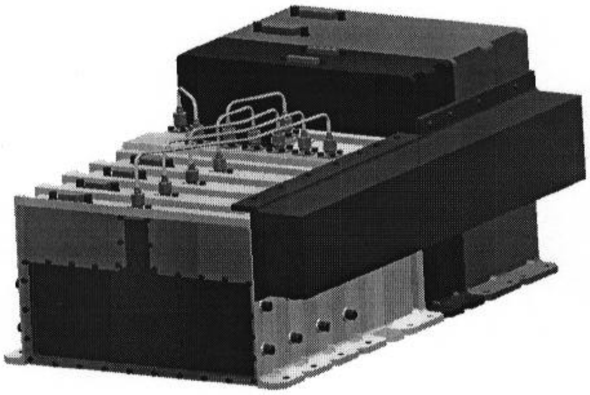

Figure 7 : Ka-Band Down-Converter or Modulator Assembly