Advanced Multi Chip Module Solutions for RF and Digital Space Applications: Status and Perspective

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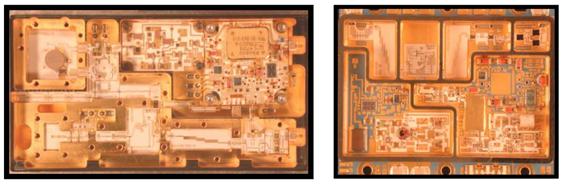
Abstract — **The evolution of space modules and equipment hardware is strictly related to the progress of enabling technologies in terms of available high reliable processes and devices, advanced interconnection and packaging techniques and high repeatability production systems. The evolution towards highly integrated microwave and digital hybrids implies an integrate study of electrical, thermal and mechanical properties and proper power dissipation and thermal management techniques. The paper will go through the last solutions conceived and applied by Alenia Spazio in its broad product portfolio for telecommunication, radar and scientific space electronics application.**

I. INTRODUCTION

Interconnection and packaging technologies are today's key elements in the design and development of advanced solution for all major elements of a space system. The possibility to integrate in a single ceramic tray complex functions combining a population of different devices is a key feature for conceiving RF, microwave and digital assemblies. Automatic or quasi-automatic assembly lines allows to significantly reduce the manufacturing and production costs making of the last generation MCMs hybrids a step towards a final system on chip solution. In this respect the evolution of high reliable Integrated Substrate Packaging (ISP) solutions is the most remarkable step done in the last three years in Alenia Spazio to support the competitiveness of the space electronics product portfolio. Advanced solutions have been studied for RF telecom equipment including MEMS based components (switches and matrices), for active phased array radar systems and for on board processing applications. The paper will give a short overview of some selected examples of last achievements.

II - MCM SOLUTIONS FOR RF PAYLOAD

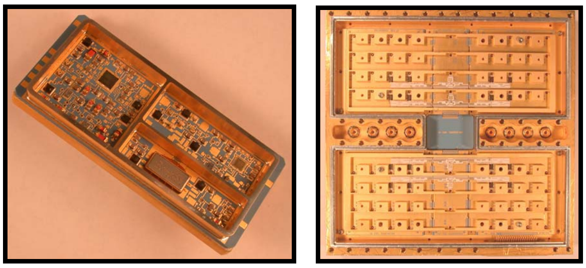
Payloads for telecommunication satellites are evolving in order to support the required increase in capacity and to implement transparent as well as regenerative architectures. In this trend the number of RF functions (receiver, frequency converters) is higher and compact solutions are needed in order o allow a stack of many functions in a single housing. Standard hybrid technology (see fig.1.a) evolved to this purpose towards microwave LTCC MCM solutions (fig.1.b) and more recently to true ISP modules (fig.2.a, 2.b).



(a) *(b)*

Figure 1 – Standard Hybrid solution (a, Ka band receiver) and LTCC ISP Solution (b, Ku Band receiver)

Microwave switch matrices are essential components in telecommunication systems since they enhance satellite capacity by providing full and flexible interconnectivity between the received and transmitted signals. The basic building blocks of switch matrices are the interconnect network and the switching elements and the LTCC technology can be used to build the network as well as realize the best integration with the active elements.



(a) *(b)*

Figure 2 – ISP Solution for RF(Ku/C/S band)-IF-BaseBand Converter(a), LTCC Solid State Swirch matrix(b)

III MEMS LTTC Packaging

MEMS switches are also very good candidate components for realizing the mentioned RF switch matrices. LTCC has demonstrated to be a good technology to be used for RF package applications, both because of its low cost and for its good performance. Moreover its 3D capability allows very compact and integrated design solutions. Alenia Spazio **LTCC Fab** has developed and manufactured a number of custom RF micro-package tailored to high frequency integration and MEMS switches. The RF input/output contacts of the package are microstrips. In order to couple the coplanar lines of the chip to the microstrips input/output of the package, a coplanar-microstrip transition, integrated in the LTCC body of the package, has been designed. Similarly to the RF lines, the DC actuation control pads of the switch reaches the outer world passing through vias buried inside the LTCC body of the micropackage.

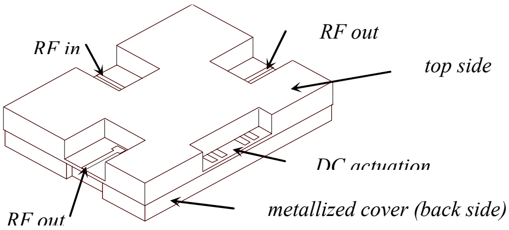


Figure 3 – RF MEMS Packaging Solutions

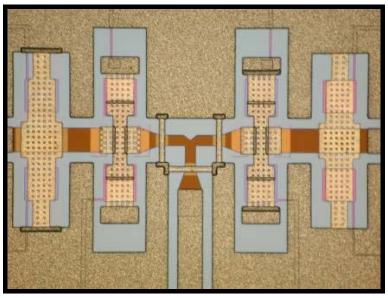


Figure 4 – MEMS Switch (developed with ITC-IRST)

The chip is lodged upside down into the package from the back side of the latter (see fig.5). The input/output pads of the chip are bonded to the package with gold microwires while the grounding is assured by a metallized cover attached to the ground ring on the back side of the LTCC package. In this way, by turning the closed package upside down, we have the ground on the back side and the input/output ports, both the RF microstrips and the DC pads, on the top side. The design leads to several advantages including a single bonding for each signal line and high compactness . This means that the RF signals go from the coplanar ports of the chip directly to the microstrip ports of the package and provided good performance of the MS-CPW transition, the reduced number of bonding leads means a reduced RF signal distortion.

Finally the cost is very low because no metal parts are present, assembly time is reduced and a significant high production yield has been achieved. The package body has been manufactured taking advantage of LTCC and the cover has been manufactured with standard alumina. Test results show a stable performance over the interesting RF band and a predictable small insertion loss contribution to the overall test set-up. This device set-up shows a good flatness and a few dB fractions of insertion loss up to 30 GHz. These performances are compliant to the package application because its loss contribution to the housed SPDT chip switching path is minimized.

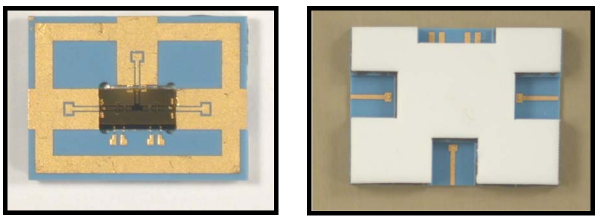


Figure 5 – RF MEMS Packages

IV. Interconnection And Packaging Solutions for Millimeter Wave

In the latter years the exploitation of very high frequency space communication links progressed for commercial applications (broadband Ka band systems), telecommunication experiments and scientific missions. If the market penetration of end-to-end Ka band satellite solutions has been in some how delayed by the collapse of many telecom business plans presented in the early years of this decade, today's the market is turning to a more solid positive outlook with interesting growing expectation for production of Ka band equipment. At the same time proof-of-concept studies and enabling work is on going to exploit bands like Q and V potentially very interesting for dual-use as well as for future generation commercial telecom systems. Under a contract sponsored by ESA and co-funded by the company, Alenia Spazio is studying next solutions (receiver, frequency converters, channel amplifier and linearizers) for V band next generation payloads. Processes for advanced devices (i.e.M-Hemt) and interconnection/packaging are again the key enabling factors. A large effort is dedicated to the study of the Waveguide to Microstrip transition and, in cooperation with Alcatel-Thales III-V labs (former TRT), to the evaluation of hot via and collective wiring technology.

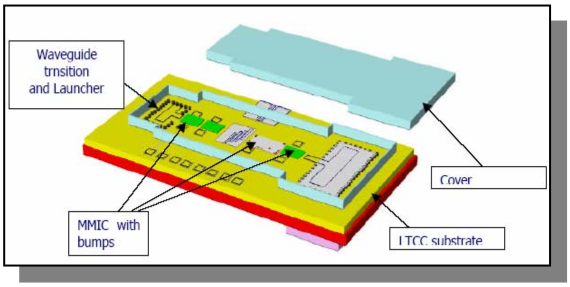


Figure 6 - V Band receiver ISP Module

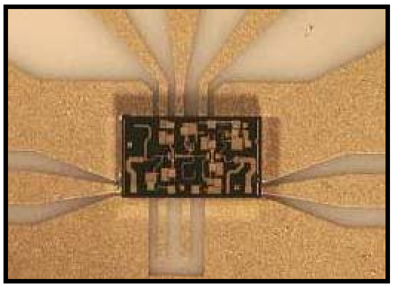


Figure7 - MMIC Assembly with DC and RF Bumps (ATL Lab)

V. DIGITAL MCMs

LTCC Multi chip module is today the preferred solution for massive on board processing. Today's advanced processes for digital integration support, also for high reliability application, the integration in a single chip of many millions gross equivalent gates. The corresponding non recurring cost is extremely high and very few applications can support a proper return of investment.

The possibility to integrate in a single ceramic tray a number of smaller ASICs is for this reason very attractive as intermediate step toward a true system on chip solution for space hardware.

Fig.8 shows the last complex digital LTCC MCM designed and produced by Alenia Spazio. The hybrid is the core of the third generation DVB processor, the so called SkyPlex processor, looking o a breakthrough integration factor which allows to realize a 60 % weight reduction with respect to the flying Enhanced Skyplex equipment. The module, a complete DVB digital demodulator, is conceived around a complex CMOS ASIC, 480 pads at about 95µm pitch, and six SRAMs, with about 60 pads. Moreover other dice, for the A/D conversion section and LVDS interfaces and passive components are integrated. The presence of such a kind of circuitry requires a multilayer technology capable to reach at least 200µm/200µm line/gap to route the signals. The LTCC technology meets this complexity requirements, leading to the advantage to have low conductor losses (noble metals are used as conductors) and low cost. The routing of the digital demodulator circuit has been done inside the LTCC multilayer substrate, with gold conductors. The substrate has been used as a base to build a hermetic package to contain the dice and a gold plated kovar ring has been hermetically brazed onto the top of the LTCC base. The dice and the passive components are mounted onto the substrate, with chip and wire technology, in the area inside the kovar ring. A kovar lid is welded onto the ring in order to hermetically seal the components. The in/out connections of the module are located in the four sides of the LTCC base (outside of the hermetically sealed area). The result is an extremely compact integrated substrate package hybrid module (see figure) that occupies about one quarter of the area that would be occupied by a similar circuit with packaged components soldered onto a PCB. Moreover LTCC has another advantage. In fact, due to the shortening of the signal tracks made by gold conductors, a strong reduction of the noise has been observed with respect to the PCB version.

VI. ADVANCED Solutions for TRM

Phased-array radar systems, based on active electronically scanned antennas (AESA) populated with a high number of Transmit/Receive (T/R) modules are on the cutting edge of advanced radar technology and in the near future will be used in many application domains (terrestrial, naval, avionic and space).

To be competitive over conventional radars, AESA systems must provide improved performance, but above all must be competitive in terms of reliability and cost.

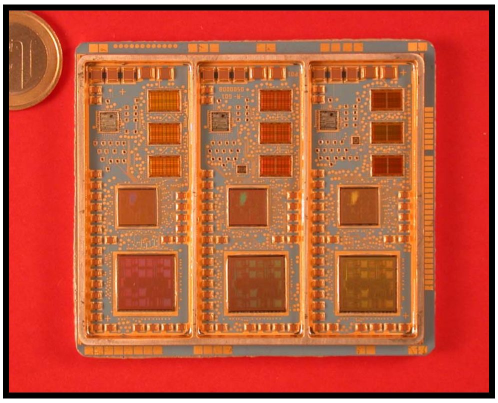


Figure 8 – SkyPlex on Chip Digital MCM

Also in this case there is no doubt that interconnect and packaging is a key enabling technology in the development of cost effective TR module solutions. For present and future application the most interesting packaging technology is the LTCC which allows an Integrated Single Package (ISP) approach based on a Multilayer Ceramic substrate: by simply brazing a proper metal frame and a cover lid the required hermeticity is obtained. The quality of the ceramic substrates enables to include in the inner layers both DC lines for power supply and digital commands, and RF striplines reducing the space needed for the routing.

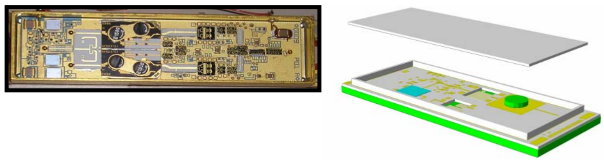


Figure 9 – Single LTCC TRM (a); next generation ISP TRM (b)

In particular a high numbers of layers, digital and RF section integration and a innovative approach for power dissipation have been developed and qualified for space application.

VII. CONCLUSIONS

In this paper examples of MCMs, ISP and in general advanced hybrid technologies based on ceramic substrates have been presented. The so called LTCC Fab represents a technology asset developed by Alenia Spazio in the last decade and it is today one of the most modern facility available in Europe for space and defense application. A continuous R&D program is running in order to make available all the technology solutions required by the product competitiveness.