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CIRCUITS IMPRIMES MULTICOUCHES ET SPECIAUX

CNES / ESA

March 2009

RF / Microwave printed circuit boards for space applications

A l'attention de :

- C. VILLETTE (European Space Agency)
- J.L. LORTAL (Centre National d'Etudes Spatiales)

Copie :

- C. DREVON (Thales Alenia Space)

Dear Madam, dear Sir,

We would like to thank you for your interest in Cimulec know-how and manufacturing capabilities for RF / Microwave printed circuit boards.

Since late in the 90's, Cimulec worked in this field and is able to provide innovative solutions for special and complex RF / Microwave bare boards :

- standard multilayer or ***sequential build-up*** up to 20 layers (more if requested),
- RF materials such as ***thermoset, PTFE***, …
- embedded ***resistors***,
- RF openings,
- high frequencies up to 30 GHz,
- other tools are shown in this documentation.

The goal of this presentation is to propose to the European Space community our support and experience to develop new applications based on reliable, high quality, and tested solutions already used for space programs with Thales Alenia Space.

Cimulec is already the long term partner for Thales Alenia Space and we are manufacturing special RF /Microwave flying models for several programs ***(STENTOR, SYRACUSE, GLOBALSTAR, …)*** which are described in this document. For those programs, printed circuits boards were submitted to customer ***space qualification process*** with ***positive*** results and we would like to extend to an ESA qualification for the benefit of all European Space Industry.

Cimulec has the will to act as a ***European leader*** of the ***PCB space industry***, and support customers in their actual and future needs, for high technology bare boards.

We remain fully at your disposal, with your suitability, to discuss further in details this presentation and the advantages we can provide for European space applications.

Laurent BODIN	Jean-Pierre LUCAS	François-Xavier LUCAS
General Manager	President	Sales Manager

CONTENTS

1 - Company profile

1.1 Identity

- Cimulec
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  Tel : +33 387738673
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  Web : www.cimulec.com
  Email :
  . fxlucas@cimulec.com (Sales Manager)
  . lbodin@cimulec.com (General Management)

- Location : center of Europe, Ennery (Moselle)
- 4800 sqm. facility
- 71 employees
- Turnover : 8 M€ year 2008, 8 M€ forecast for 2009
- 90 % of the activity for military, avionic and space markets
- 48 % of sales for export (european zone)
- Qualification and certification : ISO 9001 V2000, EN9100, MIL-P 55110, MIL-P 50884 (copies available upon request)
- IPC Member

1.2 Domain of activity

Since foundation in 1979, Cimulec is involved in the manufacturing of special and complex multilayers, rigid-flex and microwaves printed circuit boards.
Cimulec produces printed circuit boards dedicated to military, avionics and space applications, from prototype to series.

Quality and reliability of our printed circuits boards reach the confidence of the main European customers for more than 25 years.

In 1996 began the first business and technical connections with Alcatel Espace within the framework of the project Stentor. Cimulec produced then its first embedded resistors using OhmegaPly thin film.
In 2008, Cimulec carried out the radiating panels for the active antenna Globalstar 2 (24 antennas with more than 300 RF boards).

1.3 References

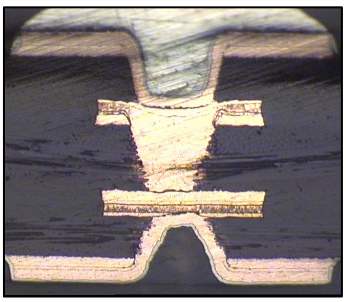
The main customers of Cimulec are the major actors in the military, aeronautics and space industry all over Europe. Among them:

- *France* : Dassault Equipements, Thales Airborn System, Thales Avionic, Safran, MBDA France, Thales Alenia Space, …
- *Germany* : EADS, Rockwell Collins, Dornier, Thales ATM, …
- *England* : BAE Sytems Avionics, Cinch,
- *Italy* : Galileo Avionica Difesa, Northrop Grumman, Elettronica, …
- *Spain* : Indra, Elcan, …
- *Denmark* : Terma
- *Turkey* : Aselsan, Havelsan
- *India* : Bahrat Electronic Limited

1.4 Printed circuit board technologies

Cimulec offers to its customers printed circuit board products using all technologies available for their applications, in accordance with the specific requirements, constraints and environmental of each system application.

- Multilayer PCBs
- Rigid-flex PCBs
- Multilayer with heat sink (inner or outer, C.I.C)
- Multilayer with buried and/or blind via holes
- Microwave PCB’s (high frequency)
- HDI PCBs, microvias PCBs
- Multilayer with embedded resistors
- Sequential build-up PCBs
- Combination of one or more elementary technology



1.5 Microwave boards for RF applications

Cimulec has produced high frequency and microwave printed circuit boards for many years and has gained substantial experience in using most materials including PTFE or thermoset resin system. The high level of quality and reliability is achieved through our skilled and experienced engineers or operators who are using the most advanced manufacturing equipments available.

Technical capabilities :
- standard multilayer or ***sequential build-up*** up to 20 layers (more if requested),
- RF materials such as ***thermoset, PTFE***, …
- embedded ***resistors***,
- RF openings,
- high frequencies up to 30 GHz,

With the knowledge and our long expertise in this field, our technicians can achieved an efficient communication with our customers, for all the aspects of the design of the printed circuits. We believe that this know-how gives the opportunity to define a cost effective, reliable and high quality product.

A long term partnership has been established with Thales Alenia Space (formerly Alcatel Space), in microwave printed circuits for space applications. STENTOR, SYRACUSE, MARCOS, LNA FAFR, embedded resistors are some examples of achievements or developments carried out with Cimulec. In 2007, after a design to cost development phase between the engineering teams of Thales Alenia Space and Cimulec, we began to produce and deliver the Globalstar2 radiating panels antenna. Up to now, more than 300 boards were produced by Cimulec.

There are several reasons which give us the feeling that RF printed circuits is a technology for the future:

- the needs for improved performances require higher signal speeds as well as better signal integrity: the control of specific technical steps during the manufacturing process of the printed circuits, and the use of dedicated materials with improved electrical properties, allows us to match these targets.
- laminates with improved electrical properties provide better thermomechanical properties compared to the standard epoxy or polyimide resin materials.
- the future developments will design printed circuits with embedded components (resistors, capacitors, filters for example).

Our will to develop RF application field results in an increase of turnover from 8 to 21% of the total Cimulec's turnover during the last 24 months, for these technologies. Cimulec was present as an exhibitor during the three last European microwave exhibitions (EUMW).
In 2005, a poster (Multilayer RF PCB for Space Applications) co-written by Alcatel Alenia Space/Cimulec was exhibited at EUMW Paris (Appendix 1).

At Cimulec, the improvements implemented on the flex-rigid products (historical technology of the company) are applied to microwave board products. Our people are thus able to answer all the mechanical requirements (cavities free of resin flow, RF openings, depth drilling with Z axis control, backdrilling,…) for RF boards.

Tools for microwave applications :

Over the years Cimulec is developing and proposing tools dedicated to high frequencies applications:

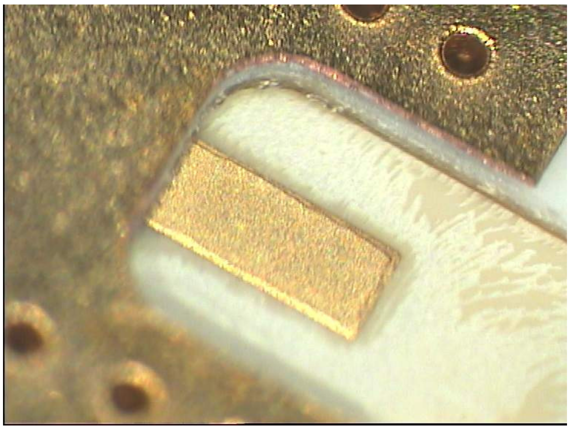
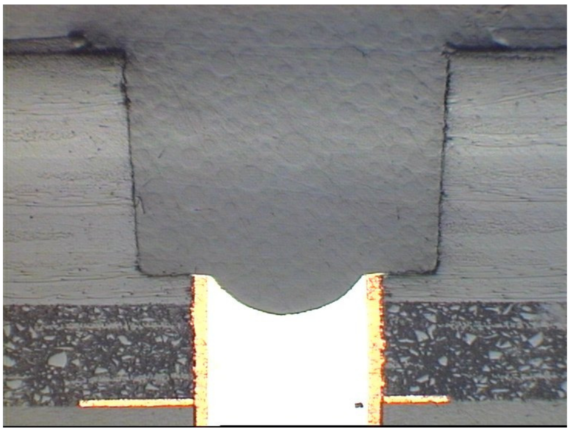
- **embedded resistors** (cf. § 1.6).

- **improved etching tolerances** (depending on design and product configuration).

- **improved face to face registration** on double sided laminates : coplanar tracks.

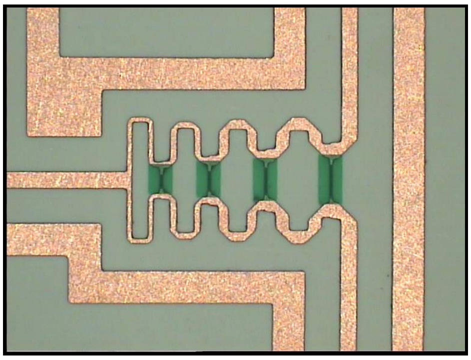
- **backdrilling** with « contact drill » option and flat drill bit : cutting of the barrel to avoid antenna phenomenon. In some cases, this solution allows the use of a standard plated through hole build-up instead of a sequential one to gives costs advantages.

- **RF openings** : signal access on the same RF layer is giving a better signal adaptation while minimizing the losses. For this purpose, Cimulec has developed a special process in order to minimize the risks of finish surface contamination (especially in the case of pure electrolytic gold used for wire bonding)

	
RF opening sample	Backdrilling with flat drill bit

1.6 Cimul-Ohm Technology (PCB with buried resistors)

For more than 10 years, Cimulec has proposed to its customers printed circuit boards with embedded resistors manufactured by using thin film resistive materials from Ohmega Technologies.



Resistors sample in a distribution board

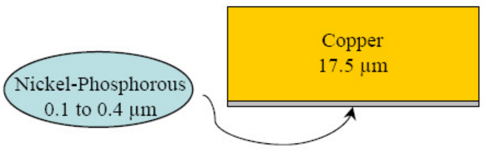
The Ohmega-Ply material used (available in a range of 25 to 100 Ohms/square) allows Cimulec to produce resistor values from a few units to several hundred Ohms.

This technology, mainly used for microwave applications, gives the following advantages:

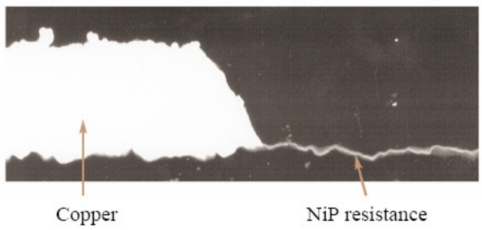
- signal division and/or distribution,
- in addition, RF openings minimize signal adaptation and losses,
- load resistors,
- assembly times reduction,
- dimensions, space and weight reduction…

↳ Resistive material

The material used to produce embeddded resistors is Ohmega-ply supplied by Ohmega Technologies. It is provided as a 17.5 µm copper foil including a thin nickel-phosphorous film of about 0.1 to 0.4 µm. Its characteristic resistivity is 25 Ω/☐ ±5% (other resistivity values are available upon request).



Ohmega-ply structure



Ohmega-ply 25 Ω/☐ microsection

↳ Supported material

Any type of dielectric can be used to support embedded resistors with Ohmega-Ply. The resistive material is laminated on the board material by using prepreg (such as speedboard C from Gore or prepreg associated with the laminates) depending on customer specifications and electrical characteristics.

1.7 Manufacturing capabilities and productibilities

The list of equipments available in Cimulec is shown in Annex 2 while Annex 4 describes the technical capabilities.

2 - Technical Heritage

2.1 Materials

Over the years, Cimulec has used most of the material with RF properties available on the market. Cimulec is in relation with all RF laminates manufacturers and is able to discuss about the future needs and developments.

List of RF materials used on a daily basis at Cimulec :

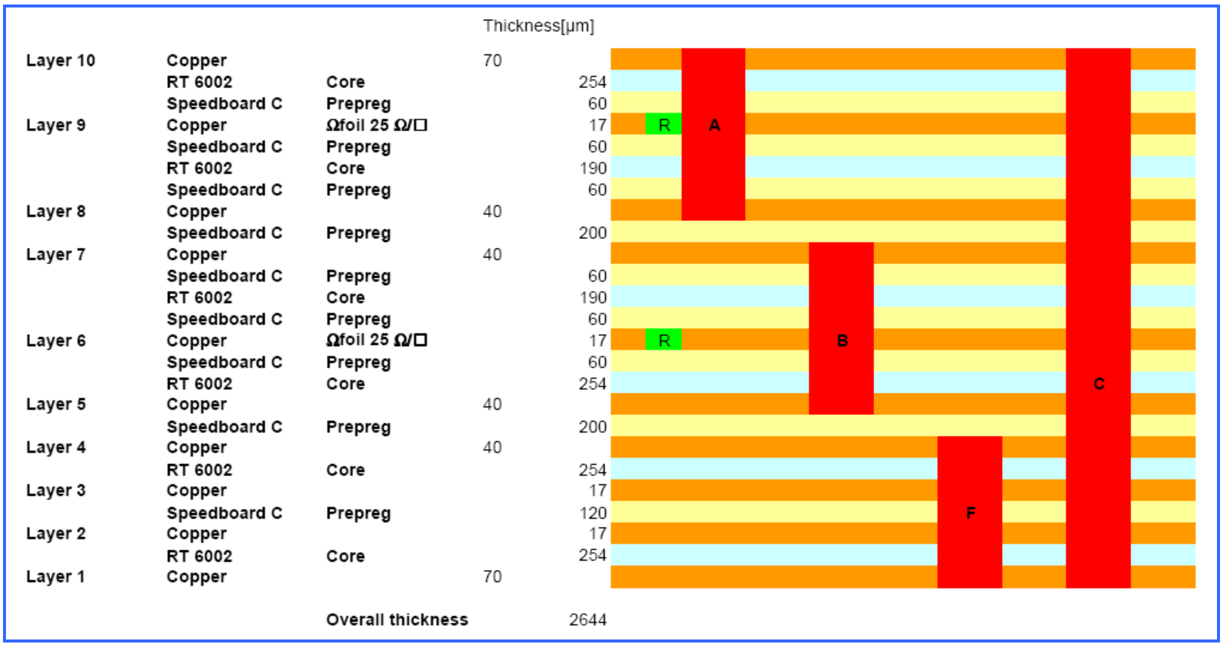
Manufacturer	Material
Rogers	RT 6002 RT 5870 / 5880 RT 6010 Ultralam 2000 RO 4003 / 4350 TMM10i
Arlon	CLTE-XT AD 600 Cuclad 250 Diclad 527 AR1000
Taconic	TLY

2.2 RF / Microwave Technical Heritage

2.3.1 Programs with space qualification:

Period	Program	Type of board	Quantity	Description
1998	STENTOR	BFN		11 layers SBU board. RT6002 / Speedboard C and OhmegaPly
2002	SYRACUSE III / SICRAL 2	10 layers BFN board BFN repartitor board interco BFN board Antennas		10 layers SBU board. RT6002 / Speedboard and OhmegaPly Double sided on RT 6002 Double sided on RT 6002 and QP 35N
2004	DOMINO 2	Carrier for LNA FAFR (Chip on Board technology). Up to 30 GHz	50 active modules boards. 47 passive modules boards	RO 4003 double sided 0.3 mm thick. Surface finish electrolytic NiAu
2007 2009	GLOBALSTAR 2	Radiating panels	more than 300 boards FM + EQM / EBB / HC	4 layers standard PTH RO4003 / Speedboard and OhmegaPly, backdrilling. 5 mm thick.
2008 2009	FLIP	Test vehicle similar to Syr III BFN	1 board	10 layers SBU board RO4000 with embedded resistors

➢ ***STENTOR***, year 1998(see Annex 5)

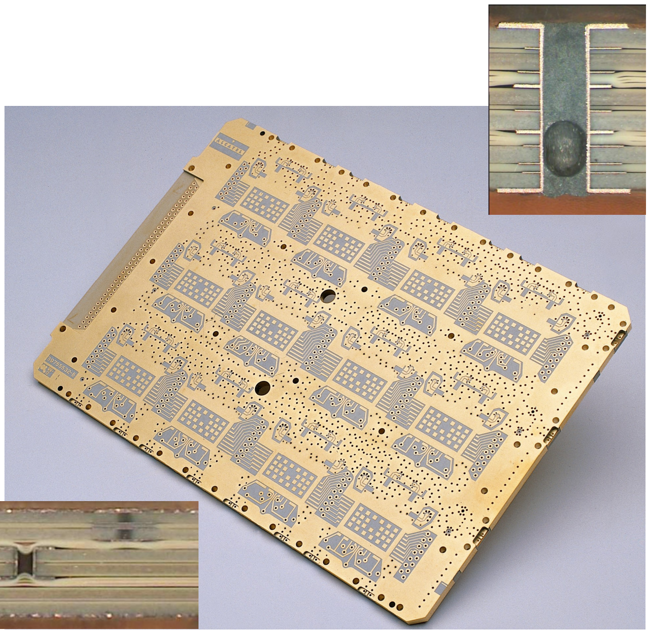


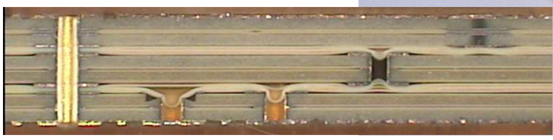
STENTOR build-up

- ***SYRACUSE III / SICRAL 2*** : year 2002 (see Annex 1)

Summary :

- *10 layers 4 drilling séq.*
- *PTFE material RT 6002*
- *265 x 165 mm*
- *3 sequences with resistors*
- *Finishing ENIG*
- *Space application*

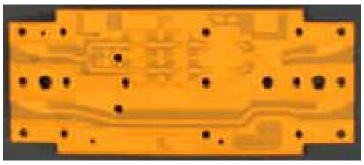




BFN Syracuse with embedded resistors

- ***DOMINO 2 : year 2004***

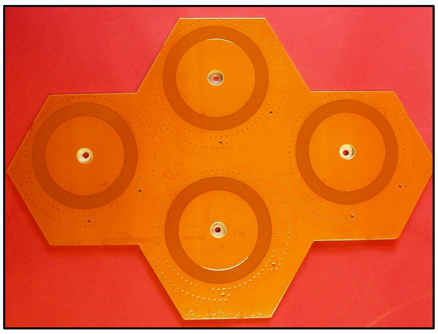
  Double sided board RO 4003
  Thickness : 0.3 mm



LNA FAFR module

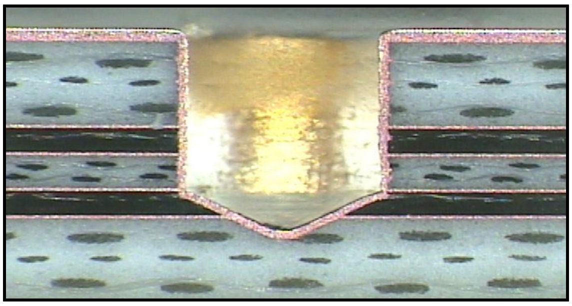
- ***GLOBALSTAR 2 : 2007-2009***

  Multilayer (4 layers) RO4003 with embedded resistors and backdrilling
  Thickness : 5 mm
  Surface finish : ENIG + coverlay



Radiating panel GLOBALSTAR 2

- ***SAPHIR :*** year 2007 - 2008
  Multilayer (6 layers) mix materials (RO 4003 and polyimid) and depth control drilling
  Thickness : 1.6 mm
  Mix surface finishes : ENIG and electrolytic gold



Saphir - Depth drilling sample

2.3.2 Bare boards R&D for space applications

Bread boards R&D for space applications : in partnership with Thales Alenia Space, Cimulec has worked and is still working on RF / Microwave boards development.

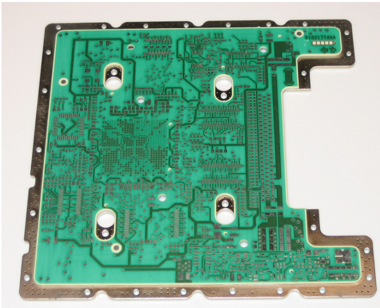
Period	Program	Type of board	Quantity	Description
2003	PEA MARCOS		65 boards with 15 different designs	3 layers board RT 6002 / Speedboard with RF openings
2003 2004	DOMINO 2	OL distribution board	1 prototype and 2 EQM boards	3 layers board RT 6002 / Speedboard with RF openings
2003 2004	MARCHE CNES PCB HYPER	Test vehicle with with basic BFN patches	2 boards	6 layers standard PTH board. RO 4000 + MPass resistors + RF openings
2006	E-CUBES	Elementary bricks	26 boards	RO 4003 double sided 0.8 mm thick.
2006	AGORA	Elementary bricks for technological trials	30 boards	RO 4003 double sided 0.3 mm thick. Surface finish electrolytic NiAu
2007	EAF PRODUITS FI	Test vehicle similar to Syr III BFN	1 board	10 layers SBU board RO4003 / GPY
2007	ADAPTATION FILTRE SAW	Filters	20 boards	Single side boards. RO 4003 0.8 mm thick

Period	Program	Type of board	Quantity	Description
2007	GLOB-TOP DE PUISSANCE	Elementary bricks for technological trials		RO 4003 0.3 mm thick. 32 x 27 mm. Surface finish electrolytic NiAu
2007	TETE INTEGREE KA/FI	Filters		Single side boards. RO 4003 0.3 mm thick
2008	ACE 2 / ARASCOM	Antennas with MEMS components	20 boards in 2 different design	RO 4003 0.3 mm and 0.6 mm thick with tight tolerances for lines and spaces
2008	TETE INTEGREE KA/FI	Filters	84 boards	Single side boards. RO 4003 0.3 mm thick
2008	E-CUBES	Elementary bricks	15 boards + 2 test vehicules	3 layers SBU RO4000 with complex routing
2008	FLIP	720MHz FI Filters	32 boards	RO 4003 double sided 0.8 mm thick.
2008 2009	MARCHE CNES PCB HYPER SUITE	Test vehicle similar to Syr III BFN	1 board	10 layers SBU board RO4000 with embedded resistors
2008 2009	Material study	Resonating rings + coplanar lines	4 rings and lines per material	Study on 13 different material
2009	SMARTIS	Elementary bricks for switch matrix demonstrator		4 different boards type with RO 4000 (single side, 4 layers, 6 layers and 5 layers SBU)

2.3.3 Other RF / Microwave programs

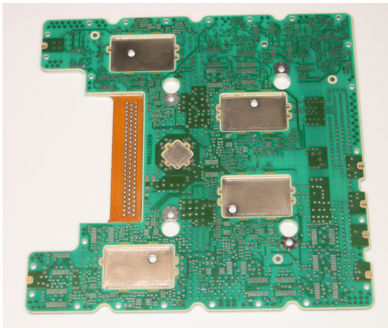
➢ Cimulec is also working in the field of RF / Microwave applications for many customers either in the military, avionics or others industrial segments. The boards produced there can be ***SBU with mix materials, striplines boards including embedded resistors (RO 4003 or RT6002), mix RF / BF including internal copper heat sink.***

Multilayer RF/BF SBU with internal heat sink



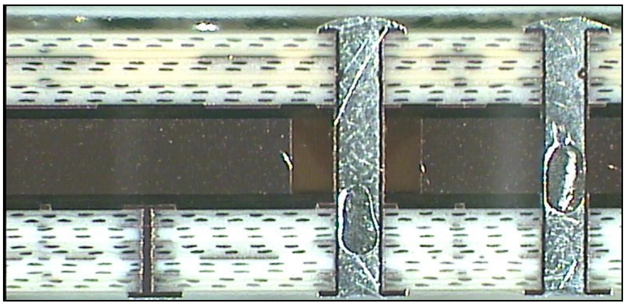
Summary :

- *12 layers / 3 drilling seq.*
- *RO 4003 material*
- *Copper sink thickness : 0.8 mm*
- *Total thickness : 3.2 mm*



Finishing :

- *RF openings : pure gold (bonding)*
- *nickel on sink level*
- *Selective refused SnPb elsewhere*



Mix RF /BF RAFALE board microsection

➢ During year 2007, Cimulec produced for an INFINEON subsidiary a new concept of test board for SDRAM:

- mix material RO 4003 and FR4 High Tg,
- 17 layers sequantial build-up
- 3 resistive layers (OhmegaPly 100 Ω/☐) with resistors implemented in the BGA area,
- impedance controlled,
- 3 backdrilling depth
- pad-on-hole technology,
- surface finish : ENIG and electrolytic gold cobalt.

This board was exhibited during the annual IPC convention in 2008 (see Annex 3).

3 - Quality System Management

➷ Quality policy, organisation :

Our Manual Quality, conforms to the requirements ISO 9001 Version 2000 and EN9100, described the Quality policy of Cimulec and the organization in place to satisfy the requirements with our customers. Since many years, Cimulec has developped a permanent improvement process.

➷ Products quality :

Our procedures and manufacturing instructions all the controls necessary to ensure the quality required by our customers and conformity taking into consideration related specification.
Cimulec records all the manufacturing traceability : material lots, operations logging, …

The key control points :

- automatic optical inspection for inner layers,
- panel registration after lamination (X-Ray),
- microsections (build-up, registration, metallisation, final product),
- electrical tests,
- visual inspection,
- mechanical controls,

➷ Control report :

A control report is written for each delivery. This document gives following information:
- the description of the controls carried out by CIMULEC: visual, mechanical, surface finishes thicknesses,
- control on microsections : thickness of basic copper, plated through holes copper thickness, …
- laminates references used in production (lot number, references, …).

Annex 1

Multilayer RF PCB for Space Applications : technological and interconnections trade-off

M. Paillard [1], F. Bodereau [1], C. Drevon [1], P. Monfraix [1], J.L. Cazaux [1], L.Bodin [2], P. Guyon [2]

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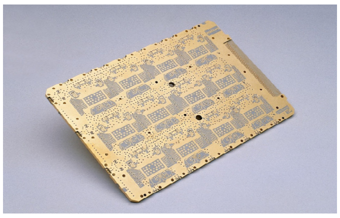
Multilayer RF Printed Circuits Boards with embedded passives are complex structures to manufacture and to package while keeping good RF performances. Here, technological solutions aimed at simplifying these issues are proposed : the use of thermoset materials instead of thermoplastic laminates and an original interconnection technique based on "RF openings" machined in the edges of the boards. Two breadboards based on these solutions have been developed and demonstrate very good RF performances between 5 and 15 GHz.

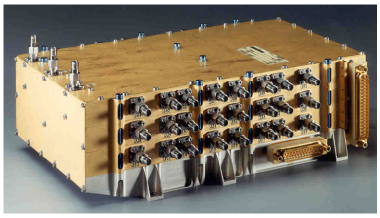


External view of a 12 layers RF PCB with embedded resistors manufactured by Cimulec

Complex multilayer boards at Alcatel Alenia Space

- operating frequency : 5-15 GHz
- large dimensions (up to 265 x 165 mm)
- up to 12 layers
- with embedded resistors
- sequential construction (up to 5 sequences)
- high reliability for space harsh environment

Applications : Beam Forming Network (BFN)
Local Oscillator frequency distribution



BFN with 4 stacked multilayers PCB

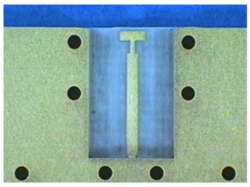
Thermoset vs Thermoplastics substrates

Thermoplastics (PTFE)	Thermosets
☺ low losses	☺ good thermo-mechanical stability
	☺ "FR4-like" manufacturing processes
☹ poor thermo-mechanical stability	☺ homogeneous associated prepreg with low bonding temperature
☹ prepreg with high bonding temperature	☺ low cost
☹ require specific manufacturing processes	☹ higher losses than thermoplastics

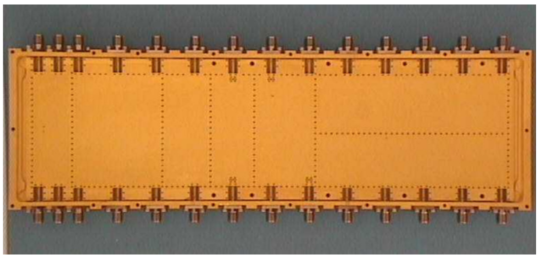
⇒ Manufacturing issues limit the overall RF performances of complex multilayer PCB based on thermoplastic materials.

RF interconnections in Multilayer PCB

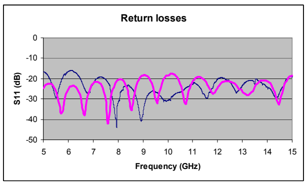
- Plated Through Holes and Laser microvias
  - for inner interconnections
  - limited positioning accuracy and reproducibility
- RF openings
  - for external interconnections
  - good ground plane continuity
  - good reproducibility
  - mechanically and laser machined with tight tolerances at the PCB shop
  - compatible with different substrates and surface metallization

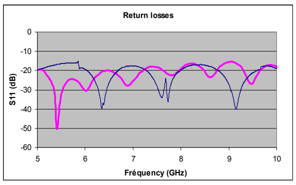


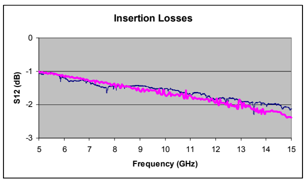
RF opening

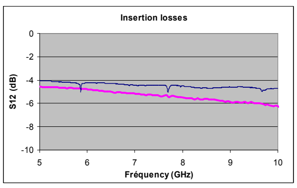


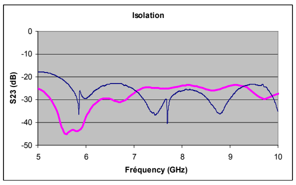
6 layers thermoset-based breadboard manufactured by Cimulec











S parameters measurements of a 50 Ω line in stripline configuration (top) and a Wilkinson power divider (right) on a 3 layers PTFE-based (blue line) and a 6 layers thermoset-based (pink line) RF PCB.

Conclusion

Complex multilayer RF Printed Circuit Boards with embedded resistors have been designed, manufactured and tested to benchmark PTFE and thermoset based substrates and prepregs. Advantages and drawbacks of both technologies are discussed and thermoset laminates are demonstrated to offer similar RF performances to their PTFE-based counterparts but with easier and more accurate manufacturing processes. In parallel, an original and very reproducible interconnection technique based on "RF openings" machined in the edges of the circuit has also been demonstrated. This method offer new solutions for interconnections of multilayer boards to their environment without any degradations of the RF signal. By combining all these technological solutions, very good RF performances have been demonstrated on different test structures up to 15 GHz.

ALCATEL ALENIA SPACE
An Alcatel/Finmeccanica company

cimulec

EN/AS/JISQ/9100 :2003/S1
AERO/2006/26678

Annex 2

Main equipements available in Cimulec

- 2 AOI equipments (Automatic Optical Inspection)
- 2 clean rooms class 100000 with 4 laminar air flux benches class 100
- 2 dry film laminators
- 5 exposure stations including one LDI (Laser Direct Imaging)
- 1 automatic exposure line
- 2 development lines
- 2 etching machines (acid and alkaline)
- 1 post-etch punch
- 4 multilayer assembly benches
- 2 automatic vacuum laminating presses
- 9 drilling and routing machines (25 spindles)
- 1 X-ray inspection equipment
- 1 plasma for hole preparation and cleaning
- 1 low build copper metallization line (thin copper)
- 1 electrolytic copper, tin, lead plating line (with reverse pulse plating)
- 1 pilot line for copper µvias filling
- 2 flying probes electrical testing machines (ATG A2 and A5 including embedded passives option)
- 1 line for soldermask
- 1 YAG laser ESI 5300
- 1 automatic line for ENIG and chemical tin
- 1 Hot Air Leveling
- 1 photoplotter

ANALYSE & CONTROL

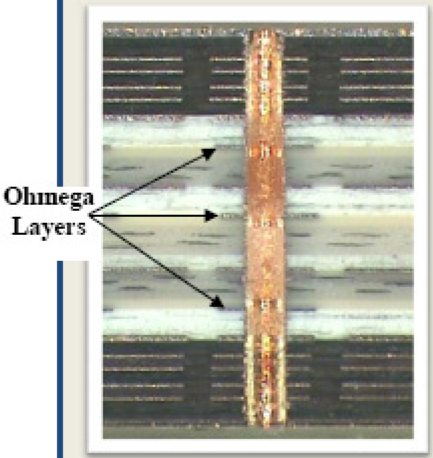
- 1 VRT chamber (thermal shock)
- 1 ionograph (ionic contamination measurement)
- 1 microsection equipment
- 1 fischerscope (surface finish measurement) and 1 CPVS analyzer (chemistry concentrations)
- 1 differential scanning calorimeter for Tg analyses (DSC)
- 1 laboratory for chemistry analyses
- 1 Polar CITS 500 for impedance control

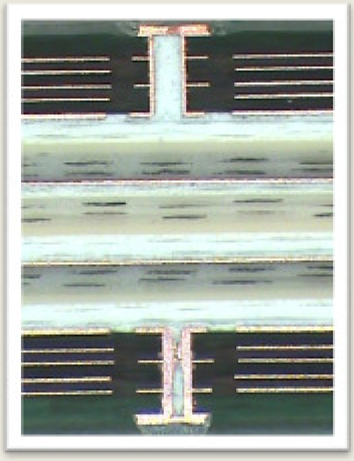
Annex 3 (IPC convention 2008)

Ohmega
Ohmega Technologies, Inc.

MICROWAVE BOARD WITH OhmegaPly® EMBEDDED RESISTORS

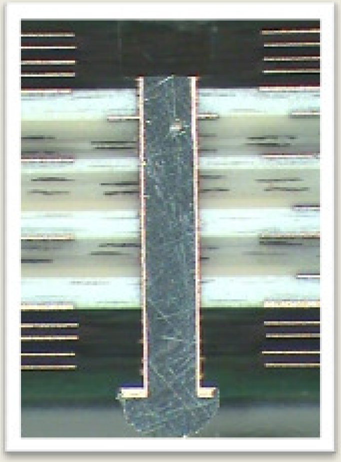
Courtesy of CIMULEC (France)

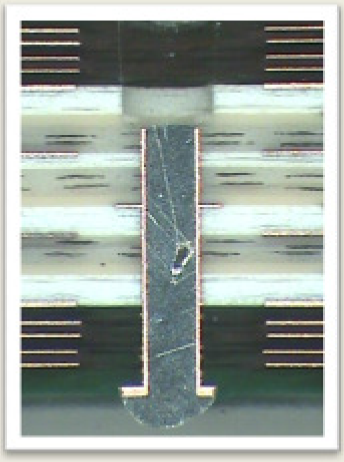


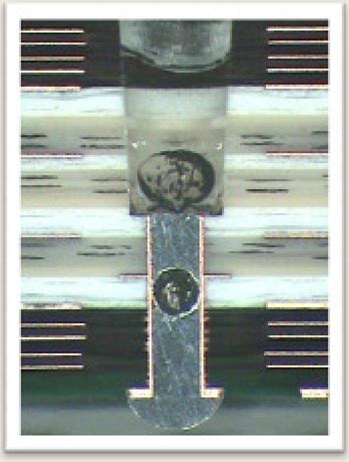


17 layers board with 3 drilling sequences

- ☞ dimension : 330x230 mm
- ☞ thickness : 3 mm
- ☞ aspect ratio : 10
- ☞ mix materials
- ☞ impedance controlled,
- ☞ 3 resistive layers,
- ☞ pad-on-hole technology,
- ☞ backdrilling with three different height,
- ☞ surface finish : ENIG and electrolytic AuCo

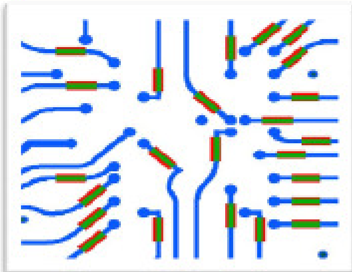






OhmegaPly® resistors :

- 96 resistors implemented on 3 different layers in the BGA (pitch 0.8 mm) region.
- Resistor nominal value : 700 Ohms
- Resistor dimensions : 1960 x 280 µm
- OhmegaPly® sheet resistivity : 100 Ω/☐



cimulec

CIMULEC : Z.I. Les Jonquières 57365 ENNERY (France)
http://www.cimulec.com

MULTILAYERS – FLEX RIGID – SPECIAL PRINTED CIRCUIT BOARD MANUFACTURER

AFAQ
EN/AS/JISQ/9100 :2003/S1
AERO/2006/26678

4031 Elenda Street, Culver City, California 90232-3799 - *Phone:* (310)559-4400 - *Fax:* (310)837-5268 – www.ohmega.com

Annex 4

Product Class

☞ *Standard products*

- Double sided PCB
- Multilayer PCB from standard plated through holes to sequential multilayer (buried and/or blind via holes)
- Multilayer PCB with microvias
- Rigid-Flex PCB

☞ *Special products*

- Multilayer PCB with metal core
- Multilayer with external heat sink
- Impedance controlled PCB
- Mixed material PCB
- Microwave PCB
- PCB with embedded resistors

Note for Microvias : Type I, II, or III according to IPC / JPCA - 2315.

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Manufacturing Capabilities

Base materials

Epoxy Tg ≥ 130° C
Epoxy Tg ≥ 150° C
Epoxy Tg ≥ 170° C
Low CTE Epoxy
Polyimid
Adhesiveless flexible material
Heat sink : copper / aluminium
Metal core : copper invar copper
PTFE (Microwave PCB)
Other materials (on request)

Material manufacturers Cimulec is working with : Isola, Hitachi, Arlon, Neltec, DuPont , Rogers, Taconic ...

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Manufacturing Capabilities

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AFAQ
EN/AS/JISQ/9100 :2003/S1
AERO/2006/26678

Surface finishes

	Typical thickness
Electrolytic Ni/Au (subcontracted)	5 µm / from 0.5 to 3 µm
Electroless Ni / Immersion Gold (ENIG)	Ni 4-7 µm ; Au 0.05-0.12 µm
Immersion Tin	> 1µm
Tin Lead reflow	7 - 12 µm
Organic Surface Passivation (MecSeal)	0.2 µm
Hot Air Levelling (SnPb)	
Chemical silver (subcontracted)	0.15 µm
Mixed Surfaces on request	

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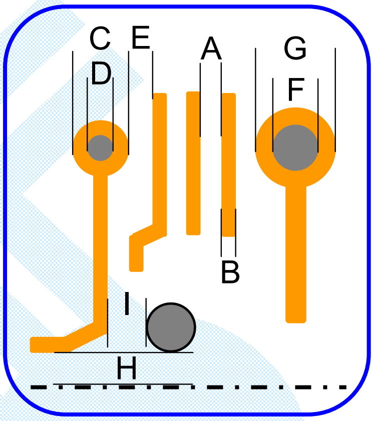
Manufacturing Capabilities

Design rules

		Standard (µm)	***Special*** (µm)
Line Space	A	90	75
Line Width	B	90	75
Micro Via Pad Diameter	C	300	250
Micro Via Drill Diameter	D	120	90
Line to Pad Space	E	100	80
Mechanical Drill Diameter	F	250	200
Board Edge to Route Clearance	F	350	200
Unplated Hole to Route Clearance	I	350	200
Pad Diameter for Mechanical Drills	G	550	400



Notes : - *values given in this table are minimum that can achieved*

- *Design Rules Check is performed according to the board size and copper thicknesses*

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Manufacturing Capabilities

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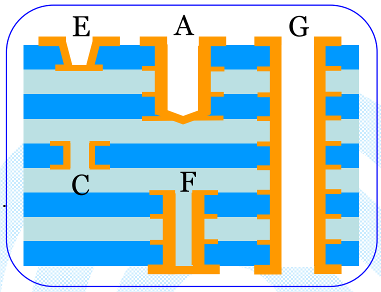
AERO/2006/26678



Vias Types and Plated Through Hole

		Limits	
		Standard (µm)	**Special** (µm)
Diameter of Blind Via (Depth Controlled)	A	250	200
Diameter of Buried Via (Resin Filled)	C	250	200
Diameter of Micro Via (Laser Drilled)	E	120	90
Diameter of Blind Via (Resin Filled)	F	250	200
Diameter of Through Via (Mechanical Drilled)	G	250	200
Aspect Ratio of Blind Via (Depth Controlled)	A	<= 1	<= 1
Aspect Ratio of Buried Via (Resin Filled)	C	<= 8	<= 8
Aspect Ratio of Micro Via (Laser Drilled)	E	<= 1	<= 1
Aspect Ratio of Blind Via (Resin Filled)	F	<= 8	<= 8
Aspect Ratio of Through Via (Mechanical Drilled)	G	<= 8	<= 8

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Manufacturing Capabilities

Miscellaneous

☞ *Solder Mask (Probimer 77 9000 HF)*

	Standard (µm)	**Special** (µm)
Solder Mask Line Width	150	100
Solder Mask Clearance Diameter	100	60
Solder Mask Coating Thickness	20	N.A.

☞ *Routing Tolerances*

- Standard : ± 150 µm
- Special : ± 100 µm
- Laser routing : ± 40 µm

☞ *EtchingTolerances*

- Standard : according to copper thickness
- Special : down to ± 10 µm on agreement

☞ *Board Size*

- Standard : up to 580 x 417 mm
- Special : greater on request
- Overall Thickness : up to 4.8 mm

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Manufacturing Capabilities

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AERO/2006/26678

Inspection report

- Qualification and conformance inspection according to MIL-PRF-55110
- Qualification and conformance inspection according to MIL-P-50884

- IPC-6011, 6012, 6013, 6016 class I, II or III

- According to your requirements
- Acceptability of printed boards according to IPC-600 class I, II or III
- Acceptability of printed boards according to ECSS-Q-70-11A

- Electrical Test :
  flying probes ; test voltage : up to 500 V DC (> 10 MΩ)

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CIRCUITS IMPRIMES MULTICOUCHES ET SPECIAUX

Manufacturing Capabilities

Annex 5

Multilayer Printed Circuit Board at 12-14 GHz with MCMs and MMICs

Claude DREVON

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ALCATEL SPACE INDUSTRIES

ABSTRACT

The development of active antennas for space applications, and more particularly for constellations, has reinforced the need for RF BFNs - Beam Forming Networks. A BFN connects m RF inputs to m RF Outputs to form N independent and simultaneous beams. The resulting matrix has m x n internal connections. Typically, this number runs into the hundreds which make it impossible to be implemented with classical connectors.

So, a multilayer printed circuit board working at such a frequency has been developed. This required important work in the field of core materials and design to get the microwave electrical performances, mainly when the signal is going from an internal level to another one. Because of the need for resistors to load the combiners, more than a hundred of resistors have been implemented in the internal layers.

A configuration using MCM-C modules, including MMICs, on a multilayer printed circuit board has been studied and manufactured. This gives a mass of 16 gr. for each point of connection in comparison with the 35 gr. obtained with classical single layer structures. All the parts are working up to 14 GHz.

A full description of this mixed Beam Forming Network will be presented included the MCMs and the printed circuit boards. This very large multilayer printed circuit boards (314 x 148 mm) working up to 14 GHz are designed with 11 layers. This configuration is going to be qualified for space applications.

Key words : MCM-C, R.F. multilayer board, Beam Forming Networks

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1. INTRODUCTION

The development of active antennas for space applications [1], and more particularly for constellations, has considerably reinforced the need for RF BFNs - Beam Forming Networks. The following BFN connects 3 RF Inputs to 48 RF Outputs to form 3 independent and simultaneous beams. The resulting matrix has 3 x 48 internal connections. Typically, this number runs into the hundreds, which make it impossible to implement with classical connectors for industrial reasons and because of the total weight of the equipment.

So, an alternative based on a multilayer PCB (Printed Circuit Board) at high frequency, associated with specific MCMs, has been developed. In comparison with other study [2], the complexity has been considerably improved due to the frequency and the number of layers to be implemented in the PCB.

2. Main developments

2.2. Multilayer printed circuit board

The development of a multilayer printed circuit board working at such a frequency required important work in the field of core materials and design to get the required electrical performances, mainly when the signal is going from an internal level to another one. The main points to be developed were :

- characteristics of the dielectric material and symmetry in the internal layers for the stripline design of the electrical lines,
- buried resistors for the Wilkinson,
- accesses at different levels in the multilayer board.

2.2.1. Dielectric and stripline design

The dielectric material is based on Teflon® [3] and all the propagation signal is made by a stripline system, that means lines are between two ground plans (Fig. 1).

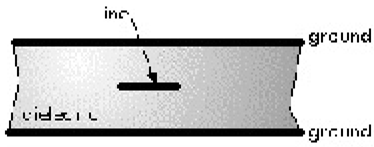

Fig. 1 – Principle of a stripline

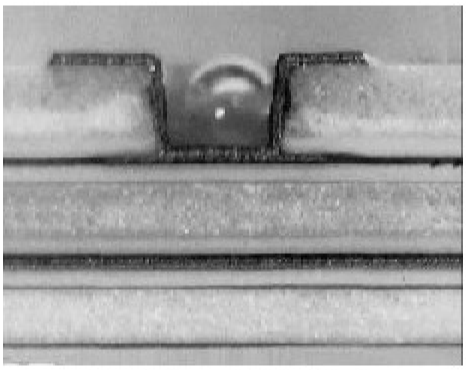

Fig. 2 – Laser drilled via-hole

All the interconnections through the PCB are made with metallized via holes, most of them are blind or buried. For the last level of interconnection, laser drilled via-holes were implemented to connect the RF signals.

This board is fully symmetric to prevent the electrical signal of mismatch in the length and minimise the bowing of the final circuit.

2.2.3. Wilkinson

All the combinations between the different signals are based onto Wilkinsons. This special design (Fig. 3) required a load resistance of 100Ω.

That means than more of a hundred of resistors have been implemented in the internal layers. Because of the assembly of a numerous number of layers and expected R.F. performances, those resistors have to be as thin as possible. This could be achieved with the use of the Ohmega-Ply® system [4] where the resistor level is directly included into the copper level of the board. This required a special process to etch the lines and the resistors in two different steps.

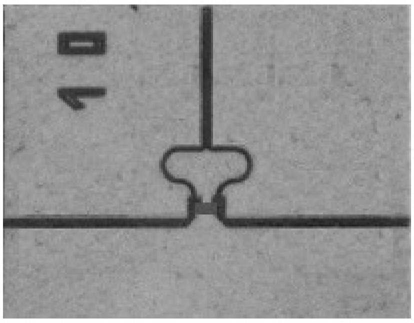

Fig. 3 – Principle of a Wilkinson

2.2.2. Openings

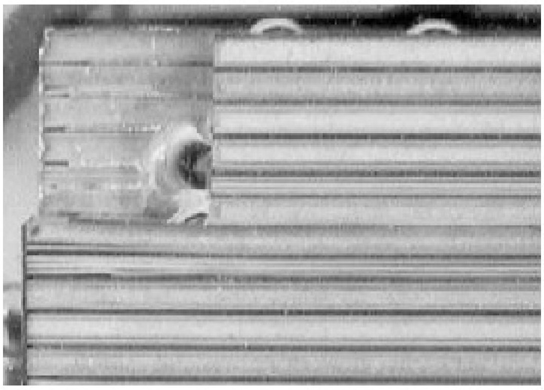

Fig. 4 – Opening in the PCB

Each board includes 3 Ins / 16 Outs at different internal levels which need openings with tight tolerances during machining. The following figure (Figure 4) shows such a part of the Printed Circuit Board.

At the end, we developed a 11 layers printed circuit board (approx. 314 x 148 mm) which is working up to 14 GHz. An external view of this board is shown on Fig. 5.

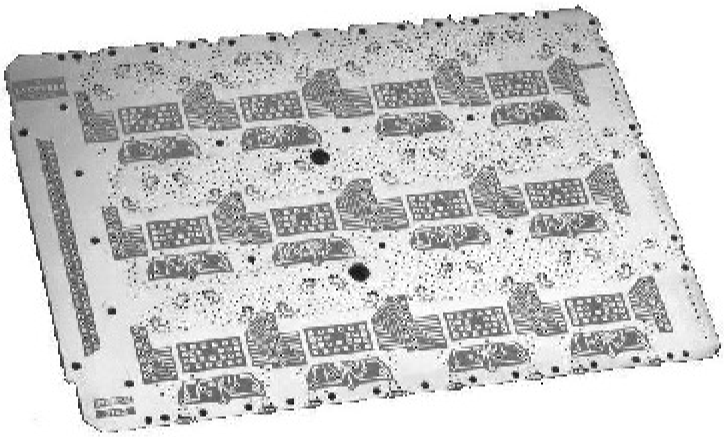

Fig. 5 – External view of the Printed Circuit Board

2.2.3. MCM-C at 12 GHz

Based on the experience of Alcatel Space Industries in the frame of mixed L.F./R.F. MCMs [5], a new module MCM-C has been developed, based on aluminum oxide. The HTCC (High Temperature Cofired Ceramic) technology is intrinsically one of the most reliable technologies because the substrate contains buried metallization as an integral part of the alumina ceramic microstructure.

The choice was made for a full ceramic package with a Kovar ring for the attachment of the lid. One of the challenges was to minimise the length of the R.F. connections when the module is bond to the board. So, thin ceramic bottom layers were used to reduce those connections to keep all the electrical performances.

Two R.F. cavities have been implemented with In/Outs for the R.F. signals with two digital MMICs for monitoring the amplitude and the phase. The ASIC, which pilots the two channels, is implemented in the L.F. cavity. This is shown on Fig. 6. The external dimensions are around 25 x 28 mm (1 x 1.1").

A particular care has been taken about all the grounding, especially into the ceramic walls.

As a back-up solution, pads are available on the top of the module for all the DC and command signals.

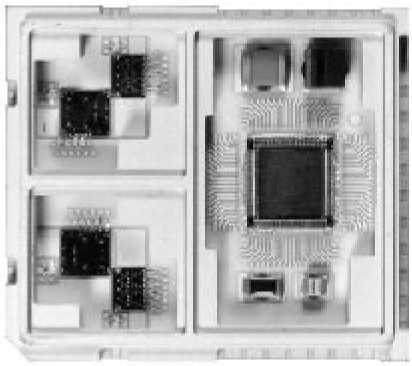

Fig 6 – Top view of the MCM

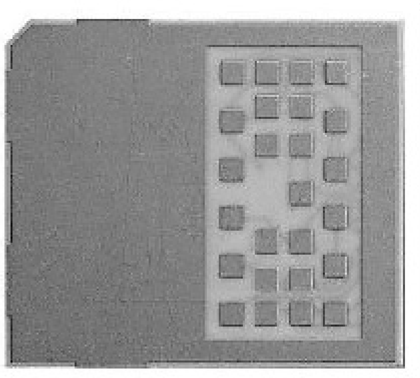

Fig 7 – Bottom view of the MCM

The design of the bottom of this module (Fig. 7) includes the ground plan, in front of the R.F. cavities, and small areas for all the low frequency connections (commands, supply...).

2.3. Assembly of MCMs on the Printed Circuit Board

A global assembly system has also been developed to bond the MCMs (12 on each side) to the board. In a single operation, the mechanical attachment and the L.F. connections are achieved. Then, only the high frequency connections are ribbon bonded; thus minimizing the number of steps in the manufacturing process. Fig. 8 shows on the same picture the bottom of the MCM and the area on the PCB where it has to be bonded.

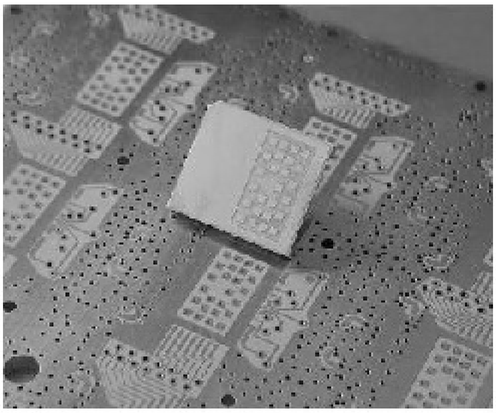

Fig. 8 – MCM on PCB

All the MCMs are bonded with epoxy glue purchased in a film form. Special tools have been developed to get two types of preform : one for the ground and the other for all the dots.

The preforms are put onto the MCMs, and then both sides of the PCB are populated. The polymerization is made following a proprietary process.

Then, the In/Outs for R.F. signals are connected by parallel-gap of gold ribbon (12.5 x 250 µm). The choice of ribbon allows keeping all the electrical performances of the full board.

4. Description of the full equipment

Because of the number of In/Outs and to minimize the size of the boards, the BFN has been splitted up to several parts. Three identical boards make the first 3 Ins to 16 Outs. Then three of them are connected to a 3 to 9 power divider through a vertical board for the RF signals. That means a special interconnection system based on a flex RF board has been developed to have a 90° connection system.

A DC/DC converter plus an interface have been added to interface the 72 ASICs with the calculator of the payload.

The full breadboard is shown on Fig. 9 with a size of 270 x 180 x 93 mm.

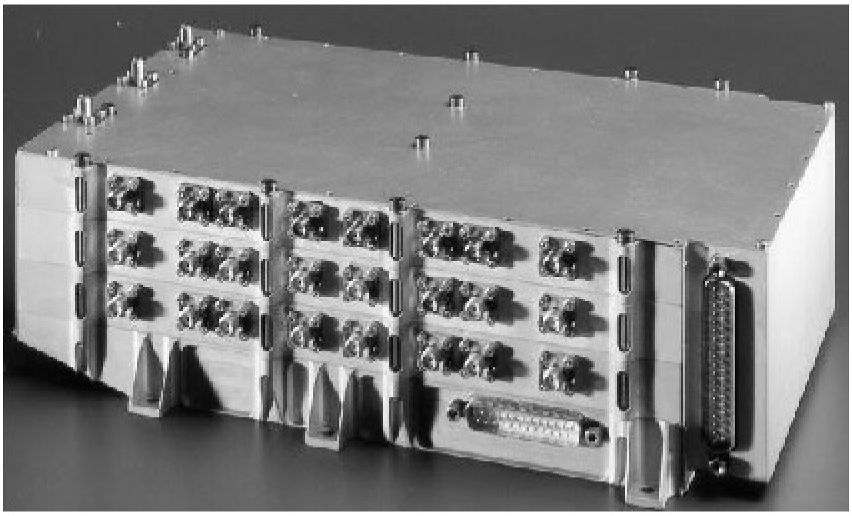

Fig. 9 – Complete equipment

This equipment passed all the tests for space applications.

5. Conclusion

The use of a multilayer R.F. printed circuit board for the design of this BFN permitted an important reduction in weight and volume. In comparison with "standard" technologies from the 90's based on a microstrip design on alumina substrate, this new architecture gives a mass of 16 grams for each point in connection instead of 35 grams.

In parallel with this new high frequency board, an original process has been developed for a global assembly of the MCMs to the board. The gain in term of cost is important because of the reduction of the number of wire bonding.

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[5] C. Drevon and al., "Mixed L.F./R.F. MCM", Proceedings of the 1997 Electronic Components and Technology Conference (ECTC), San Jose, California, pp 497-501