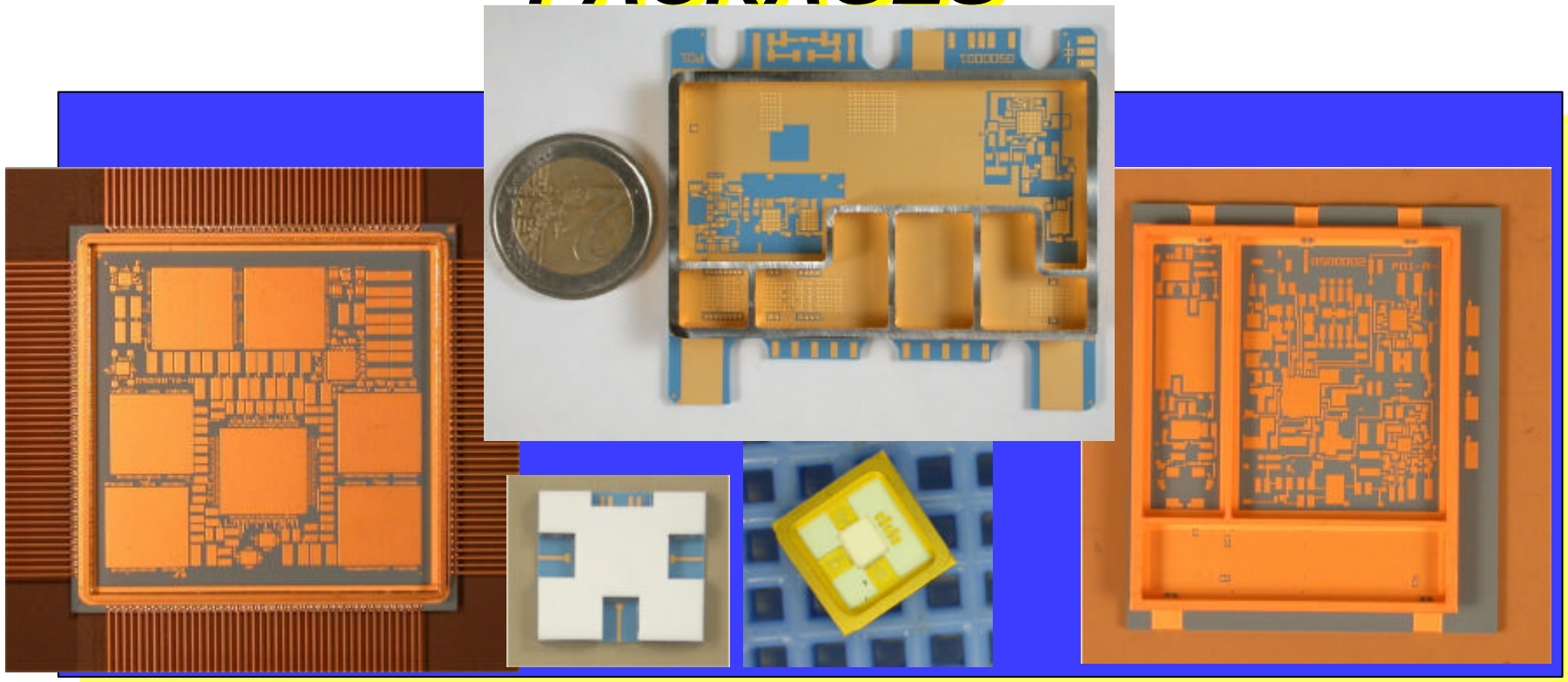
STATUS ON LTCC USE FOR SUBSTRATES AND PACKAGES



Alenia SPAZIO

ESA-ESTEC 27-04-05

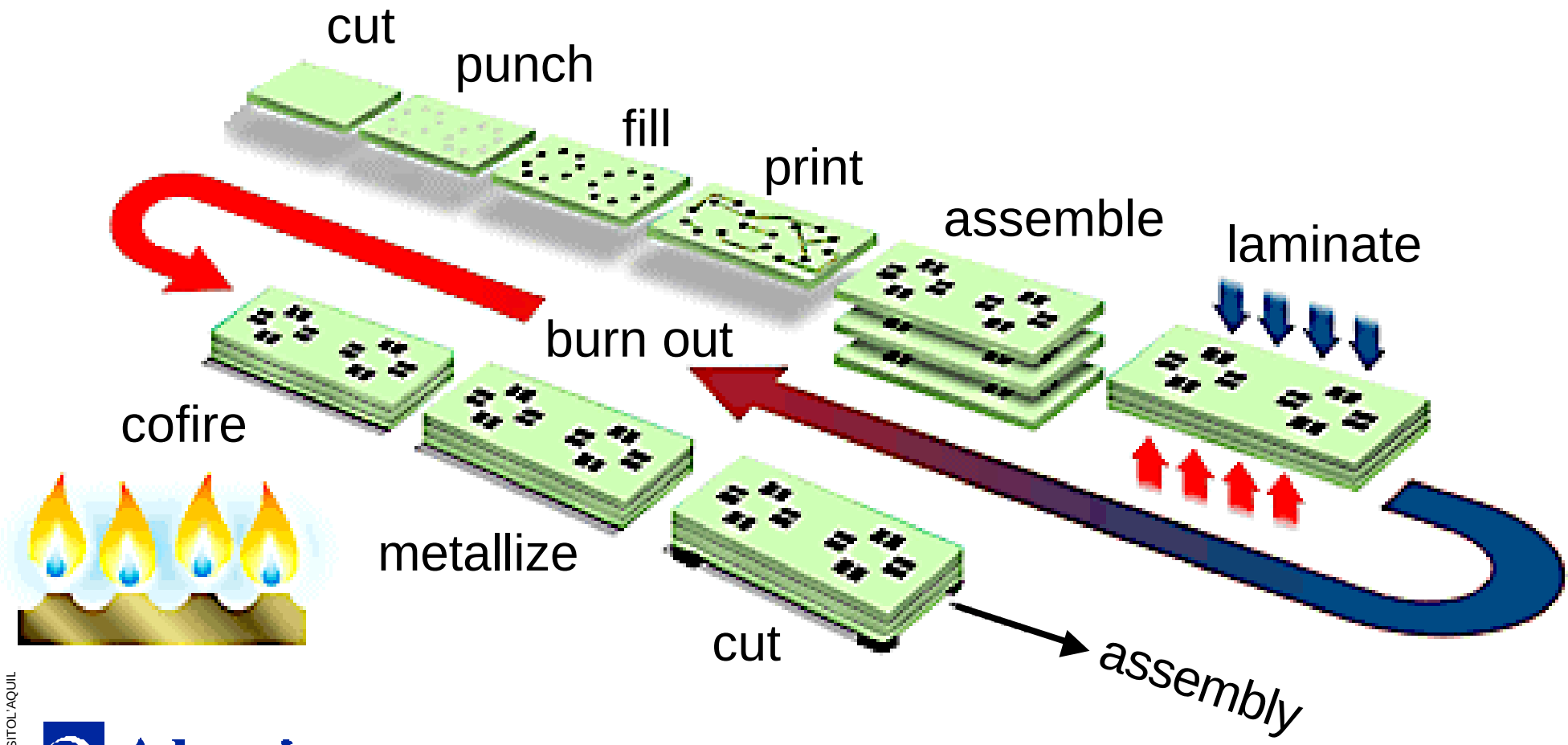
By: U .Di Marcantonio

A Finmeccanica Company

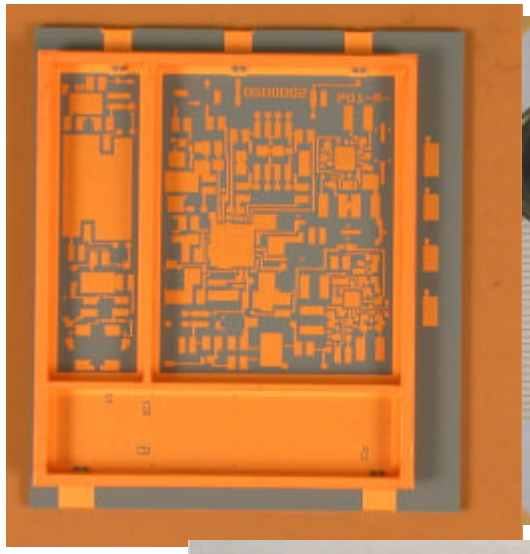
MICROELECTRONIC TECHNOLOGICAL LINES

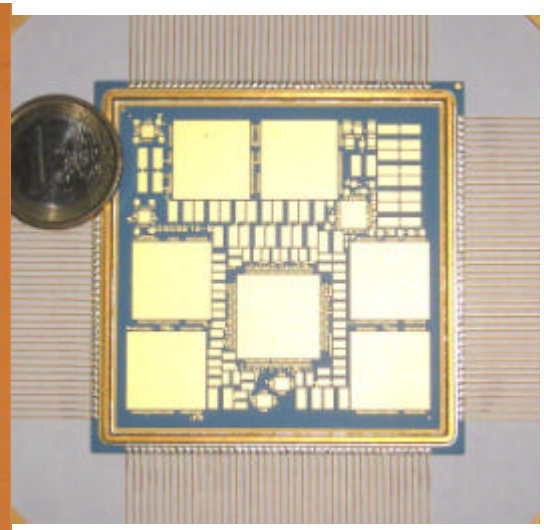
- LTCC technology has been set–up in Alenia Spazio (L'AQUILA PLANT) on 1994, technology based on the use of DUPONT materials and processes.
- Basic space qualified tapes are DuPont 951 and MW low loss tape 943.
- Standard multilayers involve 5-8 conductive layers plus ground and gridded internal layers on maximum sizes of 8x8cm.
- First flight use of this technology has been in control section of CAMPs, on NIMIQ and AMOS2 payloads (~2000).
- Alenia Spazio (ALS) manufacturing procedures and design rules for LTCC substrates and packages are frozen in a reference P.I.D. (PCP-14-50-001)

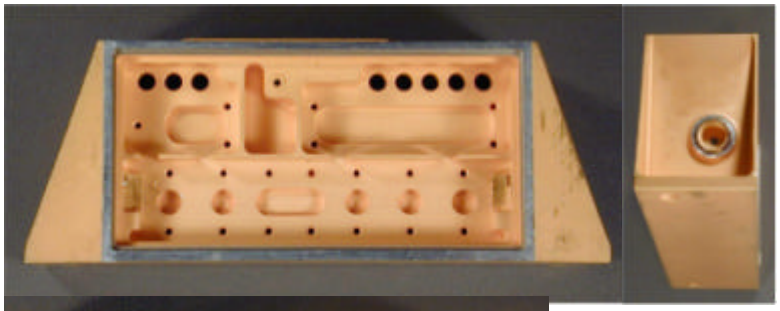
COFIRING PROCESS

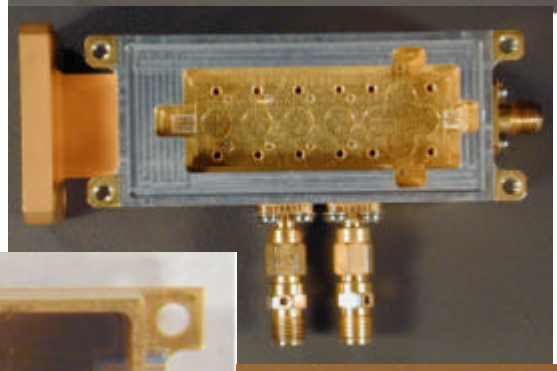


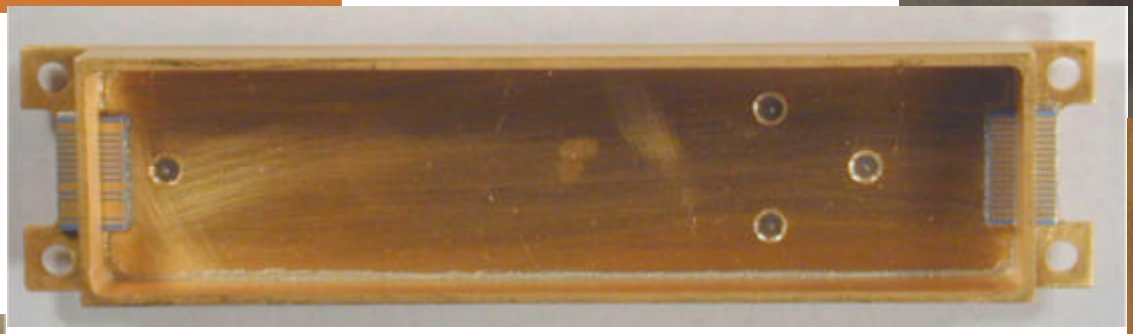
Alenia Spazio Packaging Solutions

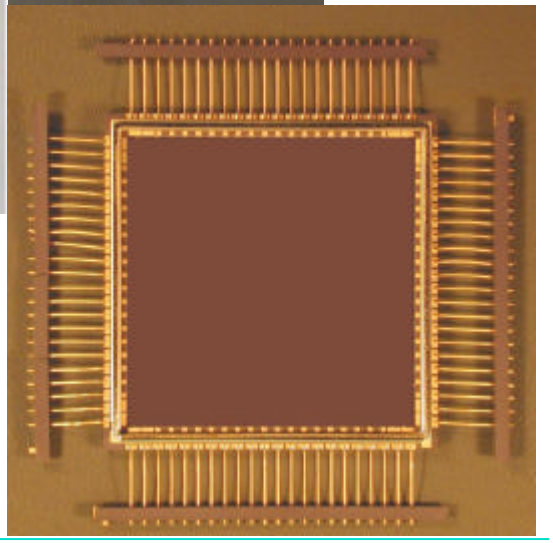


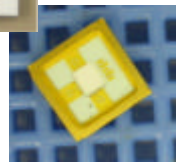


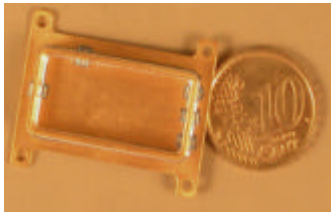


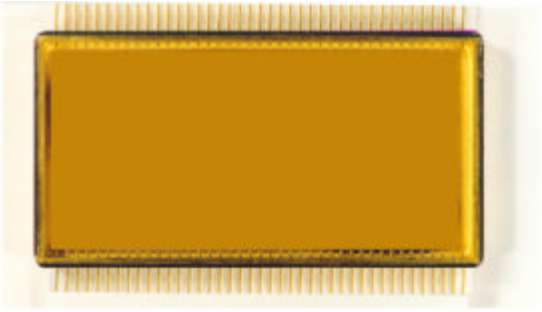












03/01-SITOL'AQUILA-4

Alenia SPAZIO

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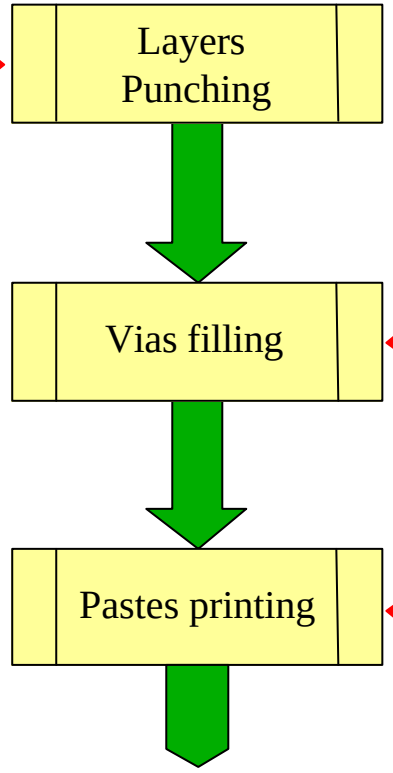
LTCC technology (Low Temperature Cofire Ceramic)

MANUFACTURING FLOW

Puncher (10 holes /s),
100-150 µm diameter

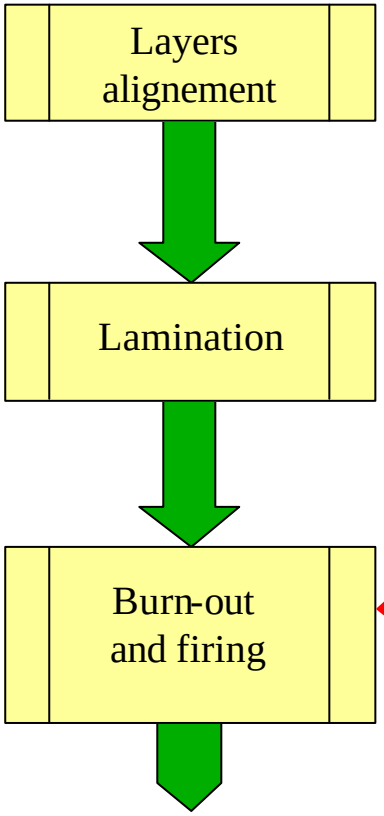


Screen Printing Machine - 100 µm lines

LTCC technology (Low Temperature Cofire Ceramic)

MANUFACTURING FLOW

uniaxial lamination press for green tape



Burn-out oven

Firing belt oven (T_{max}=875°C)

Alenia SPAZIO

A Finmeccanica Company

LTCC technology (Low Temperature Cofire Ceramic)

MANUFACTURING FLOW

Top- layer metallization

Multilayer electrical test

Final mixed cutting phases

Flying Probe multilayer test

Dicing saws - 150µm cut

CO_2 LASER

Ceramic materials characteristics

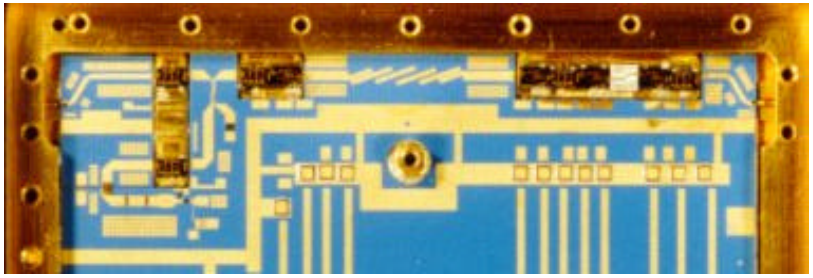
Material	LTCC			Alumina (99.6%)	HTCC	
	DUPONT 951 GreenTape	FERROTAPE A6-M	HERATAPE CT700		Al_2O_3 multilayer (EGIDE)	AlN multilayer (NTK)
Color	Blue	white	Blue	White	dark brown	dark brown
Composition	Glass/ Ceramic	Ca-B-Si glass	Glass/ Ceramic	alumina 99.6%	alumina >90%	AlN >90%
dielectric constant	7.8 @1MHz ASTM D 150	5.9±0.15 @10MHz	7.0÷7.9 @1 KHz	9.9 @1MHz	9.5 @1GHz	9.8 @1MHz 9.0 @10GHz
internal conductor	Gold,silver	Gold,silver	Gold,silver	-	tungsten	tungsten
Flexural strenght [Mpa] MANUFACTURER DATA	69 ASTM F 417	210 (4pt)		620 ASTM F 394	422	350
***Flexural strenght [Mpa]**	170			470		
Young modulus of elasticity [GPa] (ref. Brass=100Gpa)		92		344		350
thermal conductivity [W/m °C]	3.0 @ 25°C ASTM C 408	2.0	4.3	35.0	22 @ 25°C	**170 @ R.T.**
Thermal conductivity (with thermal vias) [W/m °C]	10 @ 25°C ASTM C 408	50	20	-	-	-
TCE (25°C¸300°C) [´ 10^{-6} °C]	5.8 ASTM C 327	7	6.7	7	6.5	4.4 (25°C÷400°C)

EVALUATION of LTCC Microstrip LOSSES

50 Ohm Microstrip attenuation (declared by Dupont)			
	Attenuation dB/In		
	5 Ghz	*10 Ghz*	*15 GHz*
951 Green Tape / Ag	0.15	0.34	0.50
99% Al_2O_3 / thin film Au	0.13	0.20	0.26
943 Green Tape / Ag	0.07	0.12	0.21

LTCC technology: advanced solutions

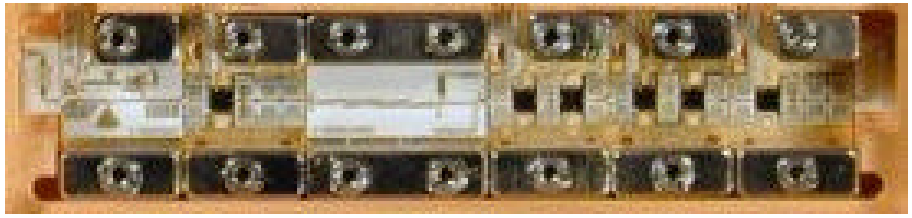
20 GHz RF CAMP (LTCC)



Performances

Gain	***23÷55dB***
Intermodulation	***36 dBc***
Flatness	**0.7dB@0.5GHz**
Return Loss	**17dB**

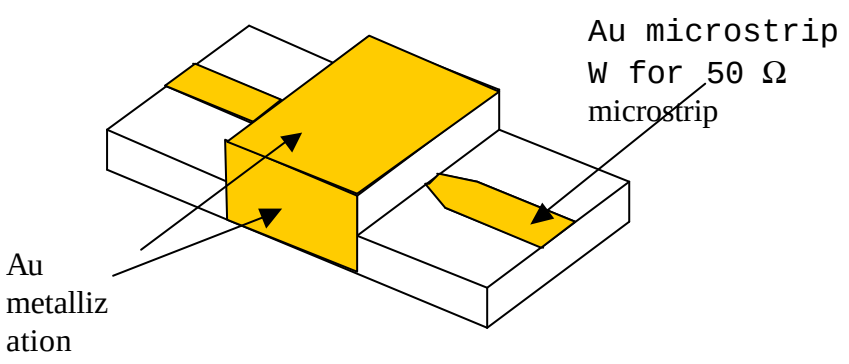
RF CAMP (Classic Technology)



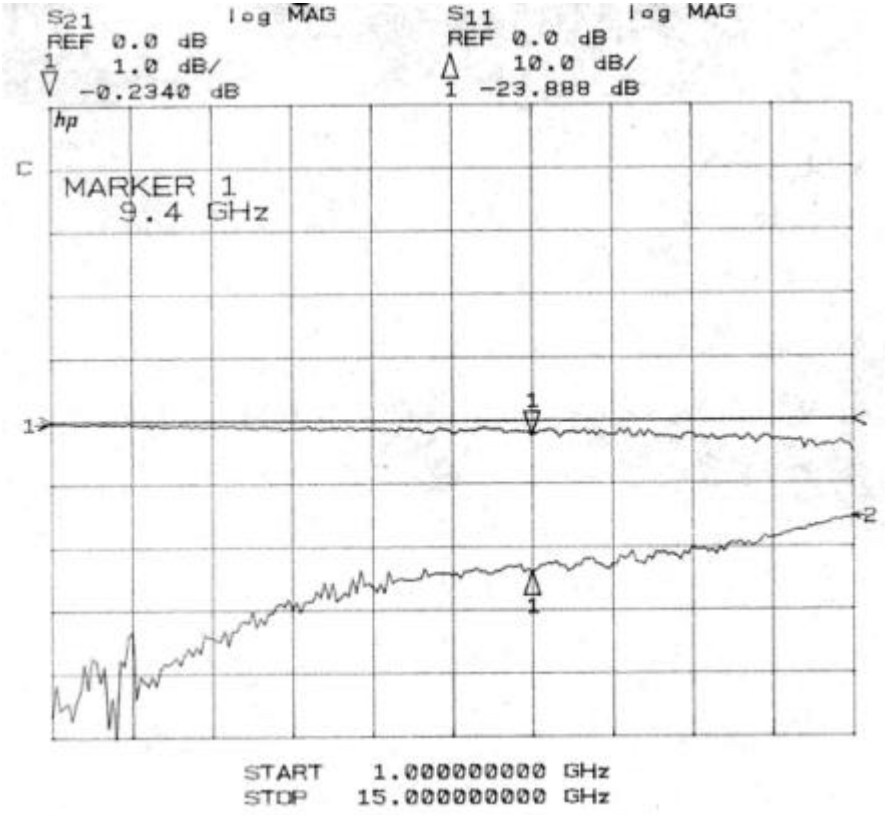
Performances

Gain	***23÷55dB***
Intermodulation	***33 dBc***
Flatness	**1.0dB@0.5GHz**
Return Loss	**18dB**

Qualification of LTCC micro - packages



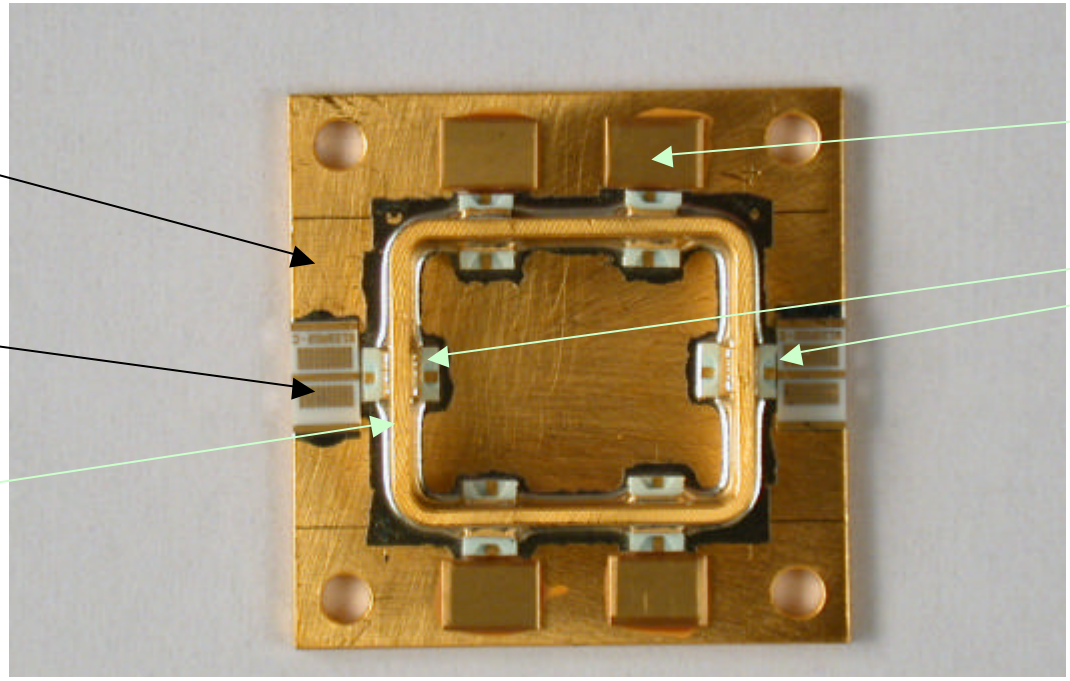
LTCC RF transition



Green Tape 943 transition

Qualification of LTCC micro - packages

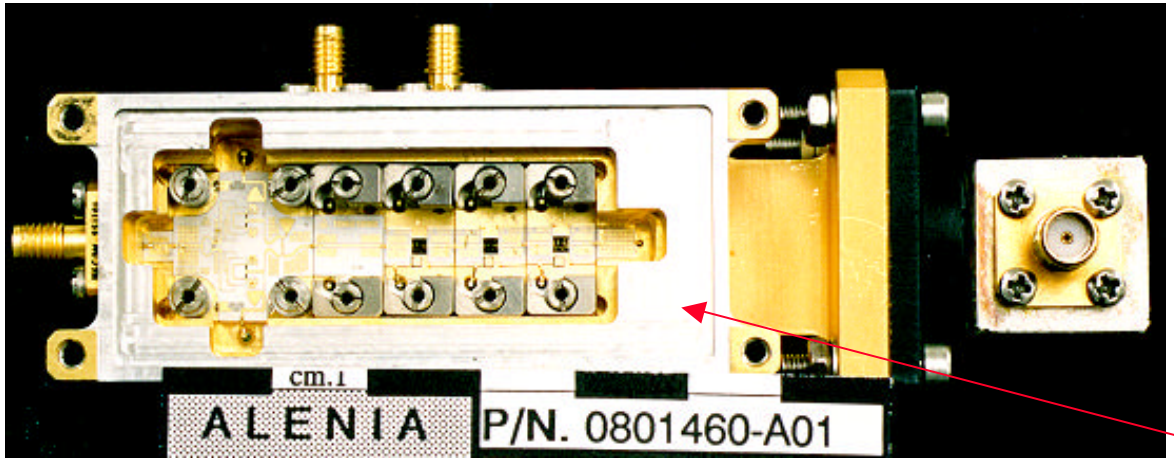
Metallic packages with LTCC ceramic transition (type A)



WCu carrier, 50 Ohm line, Kovar frame and LTCC transition are hermetically soldered with AuSn alloy. Soldering pads are glue with non conductive epoxy.

Hermetic sealing is performed with Kovar lid welded on Kovar frame by seam welding process

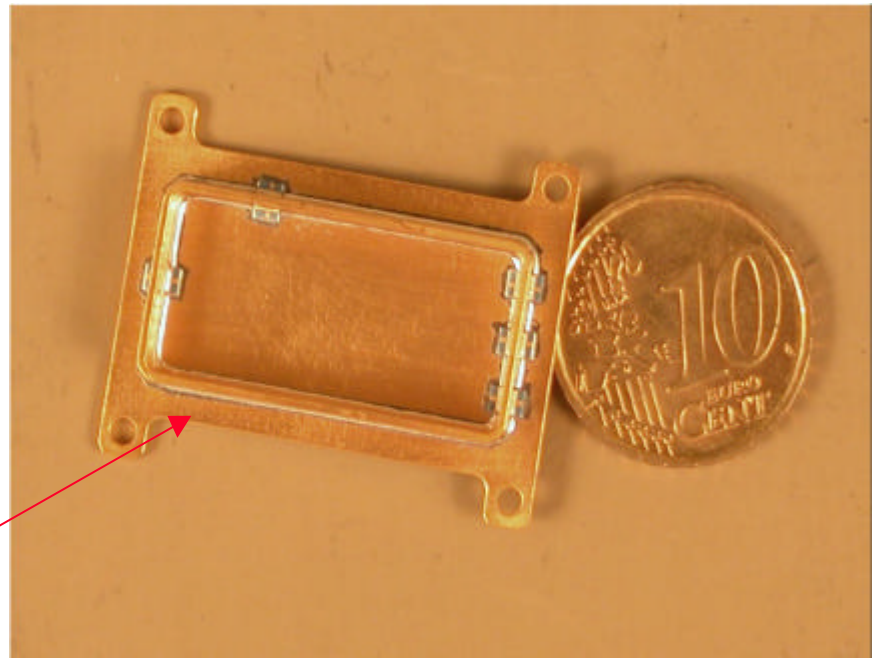
LNA package



- *Brazing of RF Hermetic Feeedthroughs*
- *Weight: 70g*
- *Dimensions: 87×23×35mm³*

STD

- *Metal-Ceramic package*
- *Base in Cu-W kovar frame*
- *RF Feedthroughs in LTCC*
- *Weight: 12g (without components)*
- *Dimensions:33×26×7mm³*



NEW

Alenia SPAZIO

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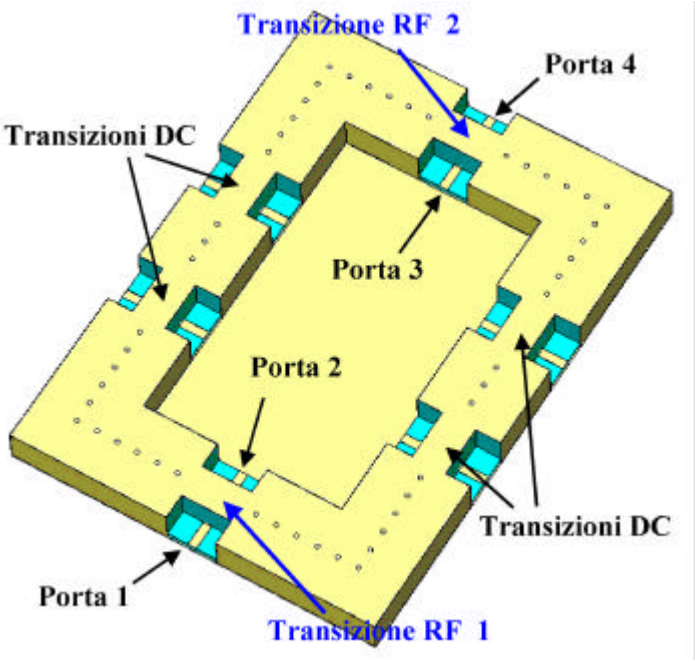
Qualification of LTCC micro - packages



SPECIFICATION:

BAND = 1 - 50 GHz

- **$|S_{11}| < -15$ dB**
- **$|S_{31}|$, $|S_{41}| < -60$ dB**

(NO COUPLING IN CAVITY)

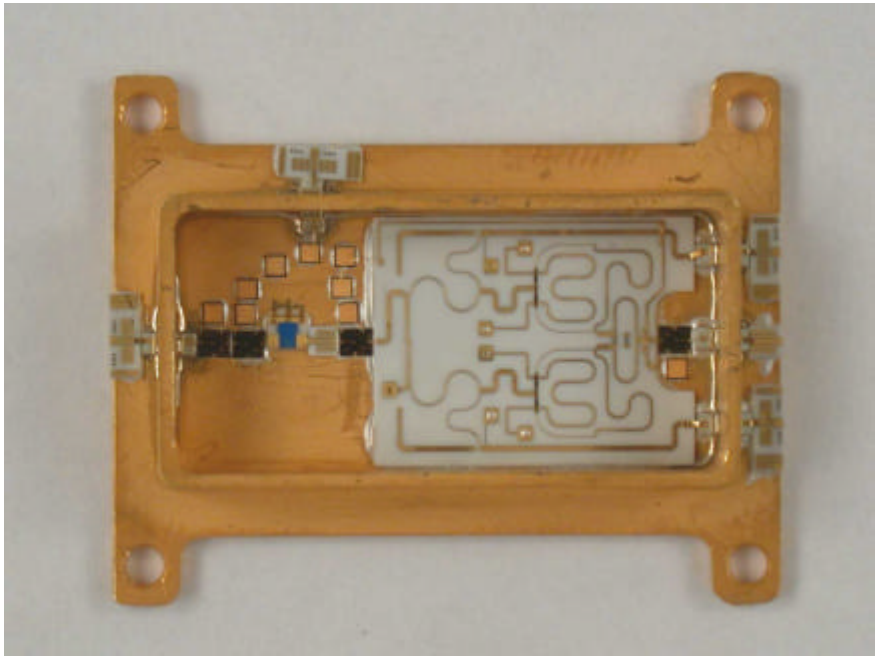
DIELECTRIC LTCC :

943 GreenTape - DuPont

$e_r = 7,4$

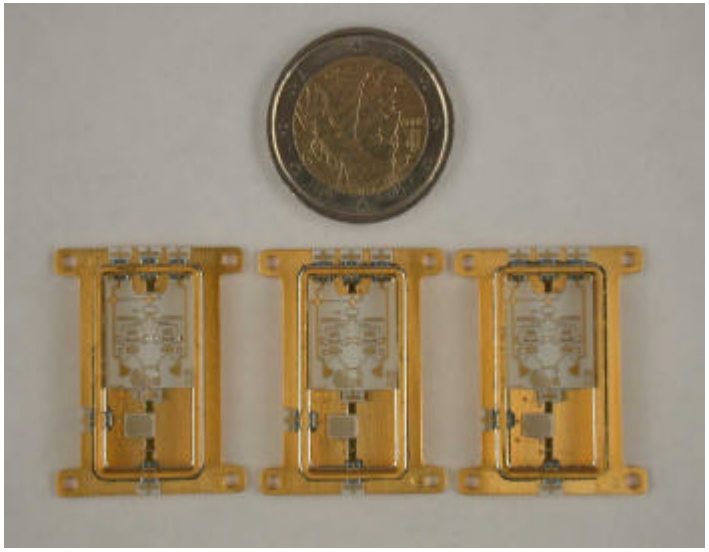
MW simulation by University of Perugia

Qualified LTCC Micropackage



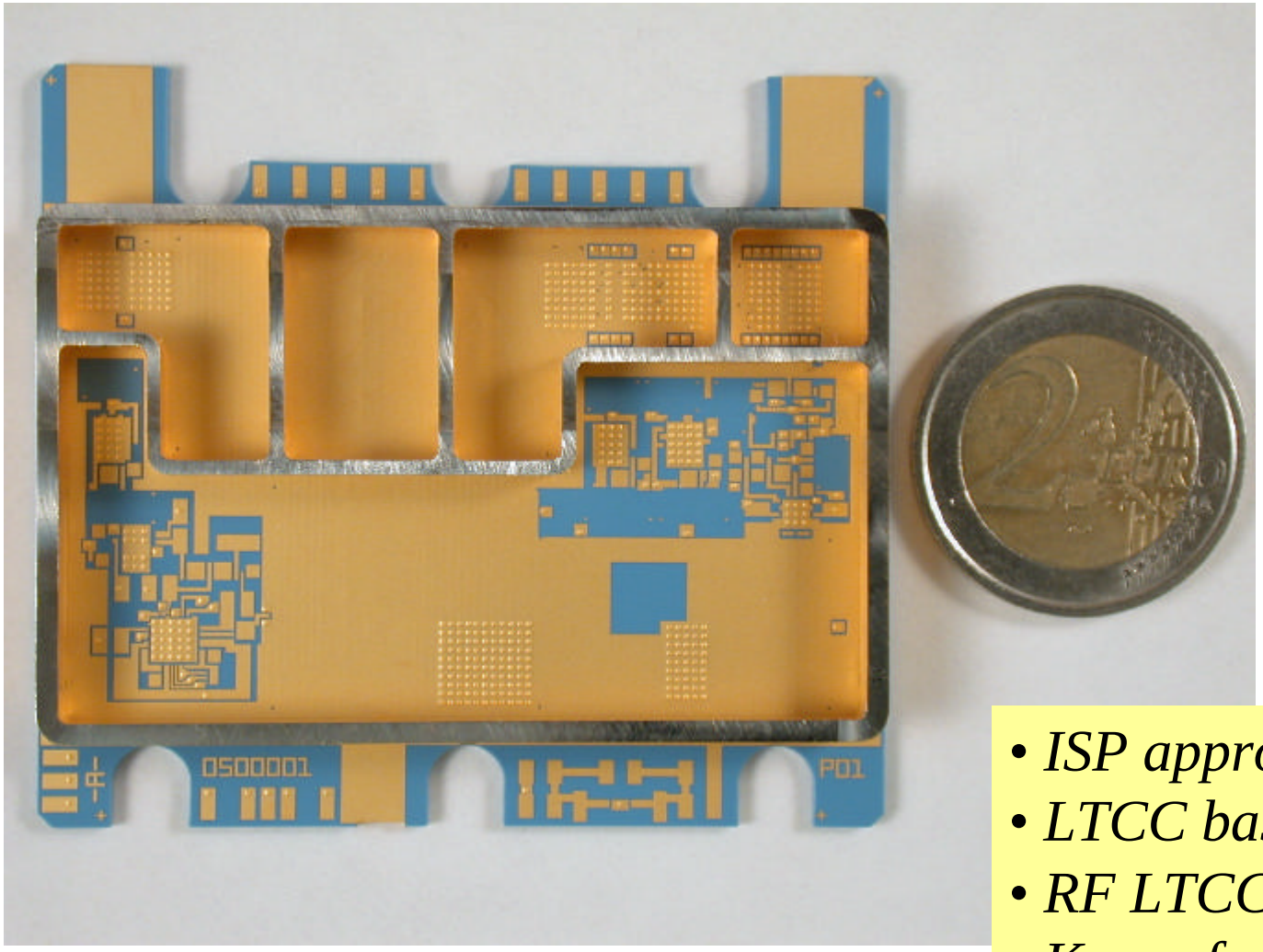
Low Noise Amplifier in C/Ku/Ka Band

- Metal ceramic Package
- Carrier in CuW and Kovar frame
- RF transitions in LTCC AuSn brazed
- Bonded chips



- Configurable in C & Ku/Ka band
- NF< 2,5 dB; Gain > 32 dB.
- Communication payloads: Measat,P904 (BSS)

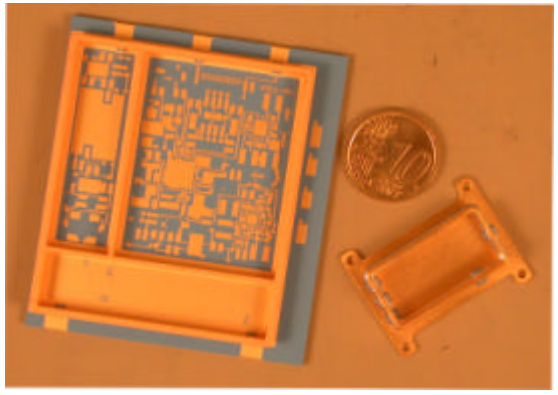
Ku Receiver LTCC package

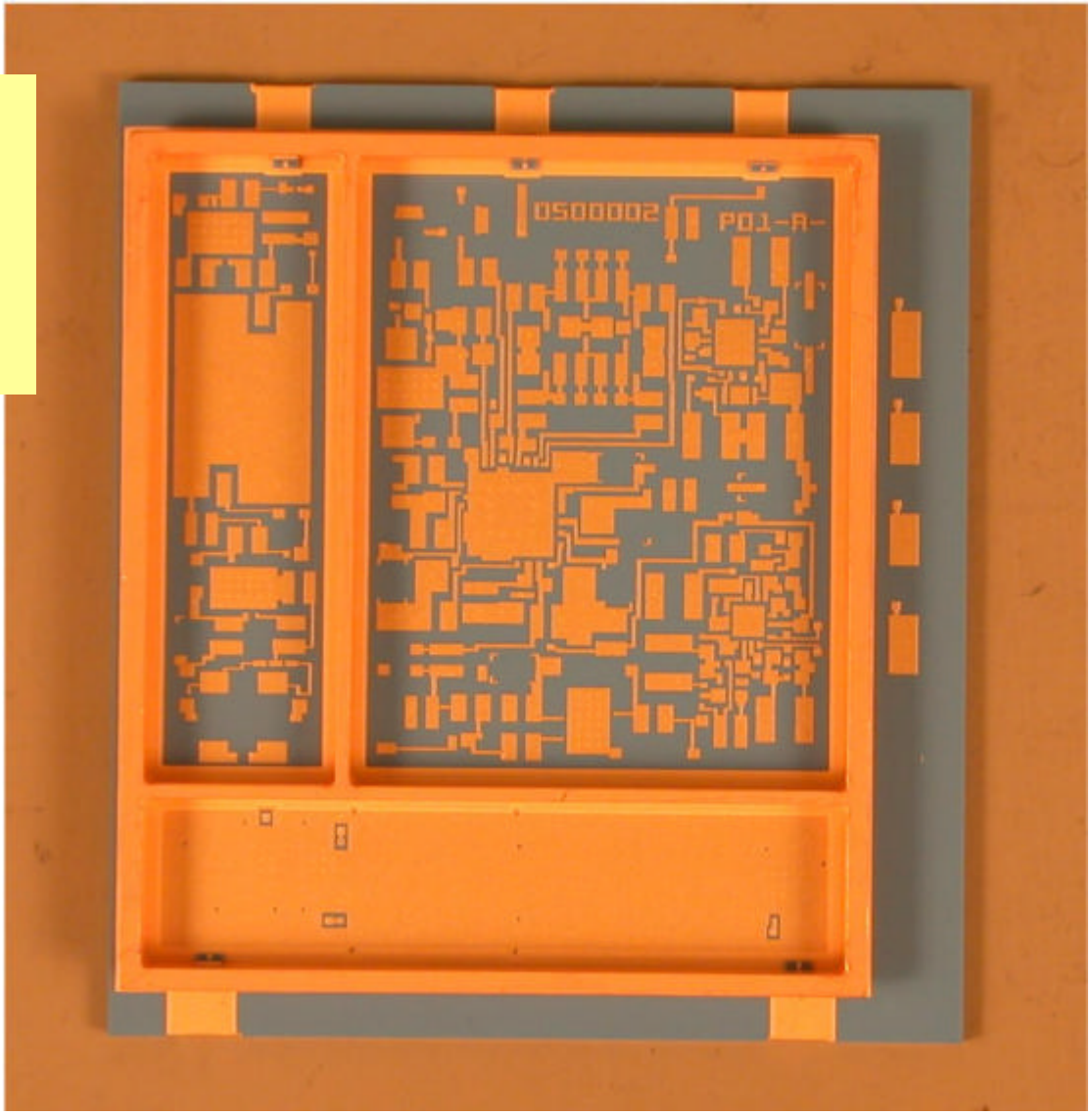


- *ISP approach*
- *LTCC base*
- *RF LTCC Feedthroughs*
- *Kovar frame*

Down Converter LTCC package

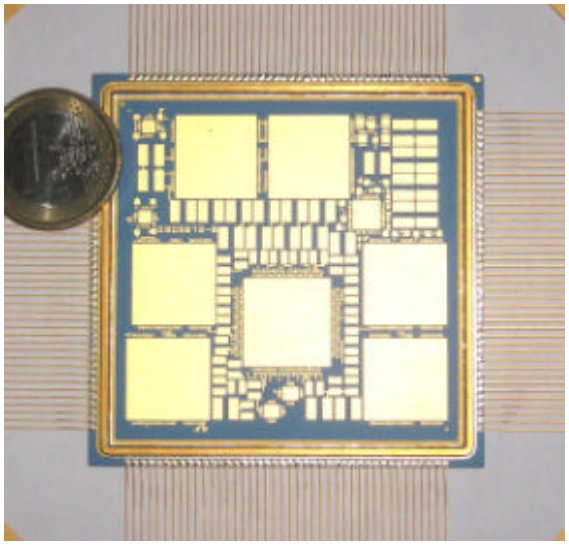
- *ISP approach*
- *LTCC base*
- *RF LTCC Feedthroughs*
- *Kovar frame*

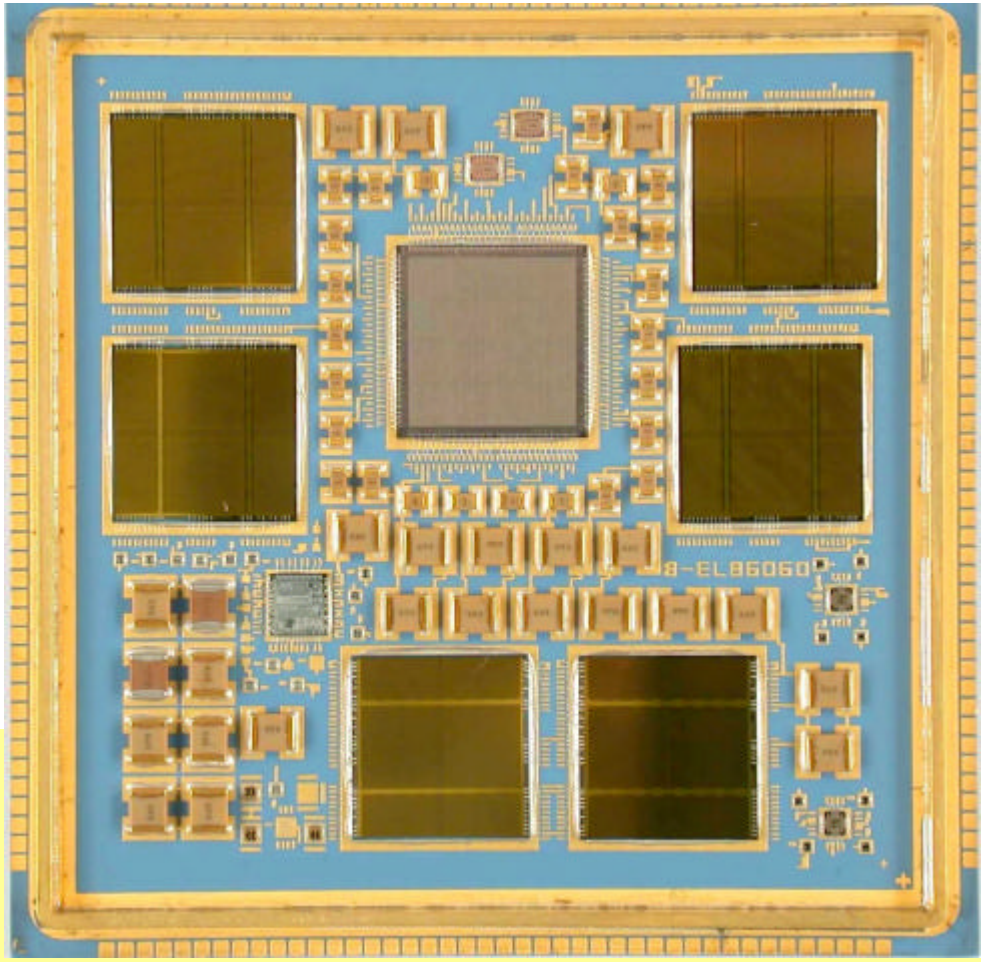




Alenia SPAZIO

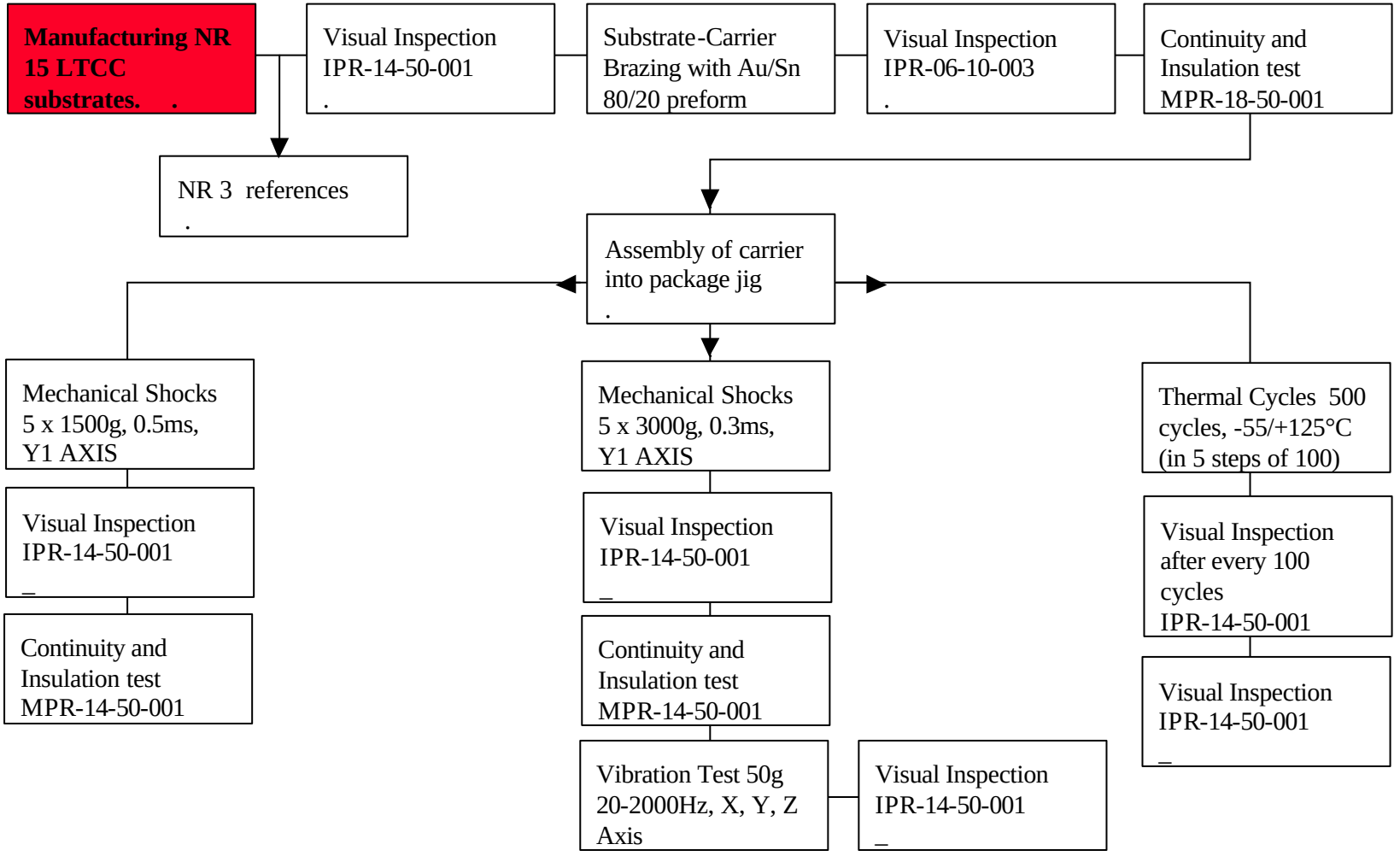
Digital Demodulator LTCC package



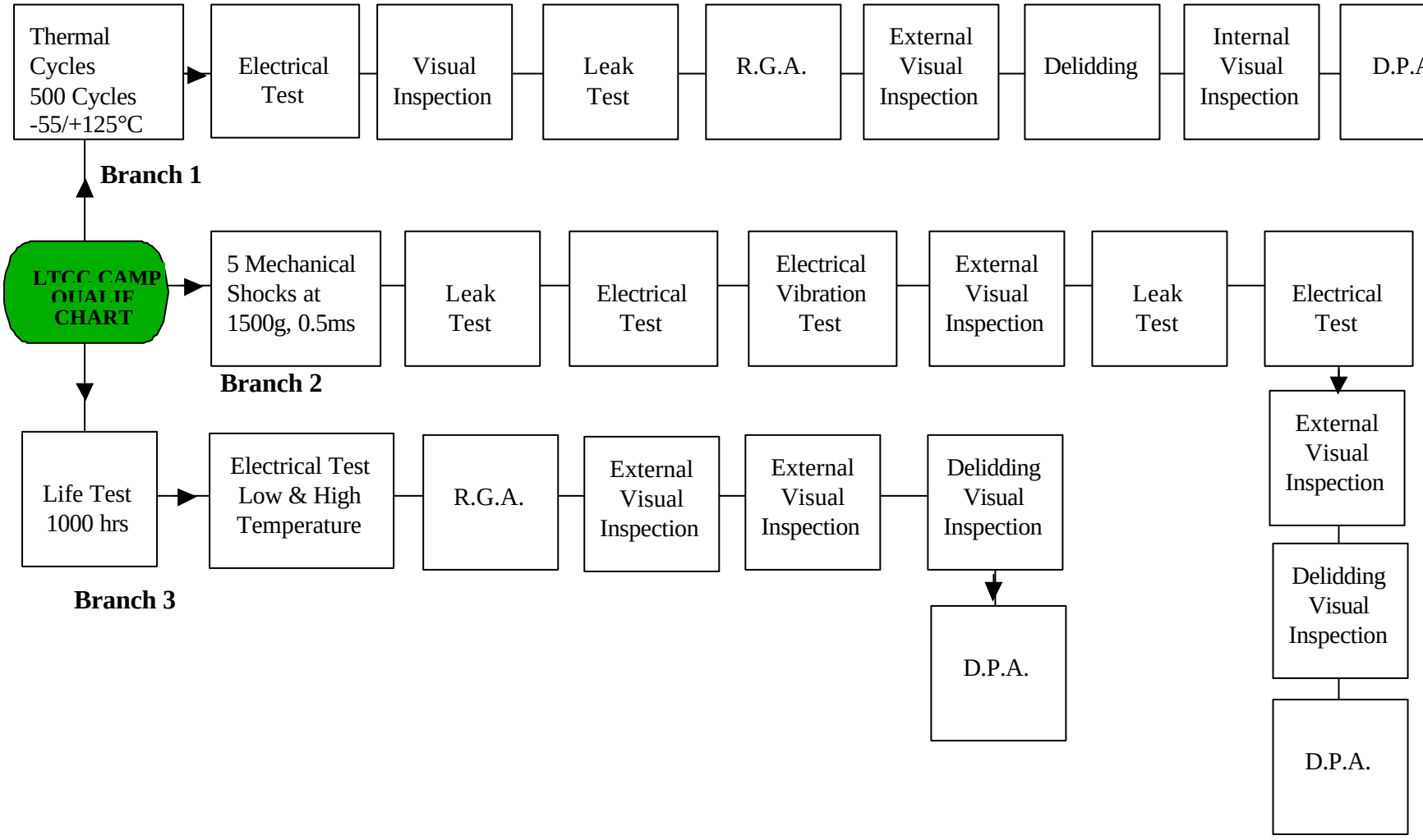


- *ISP approach*
- *LTCC base*
- *Kovar frame*
- *future integration improvement by Ball Grid Array connections*

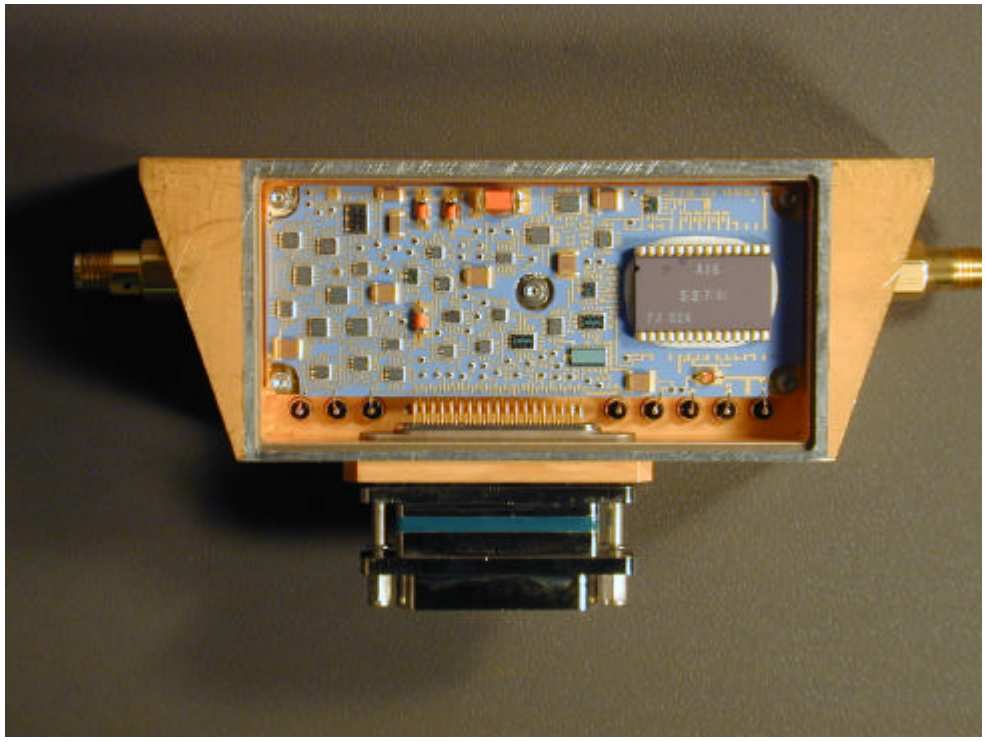
Evaluation Test Chart on LTCC Test Vehicles

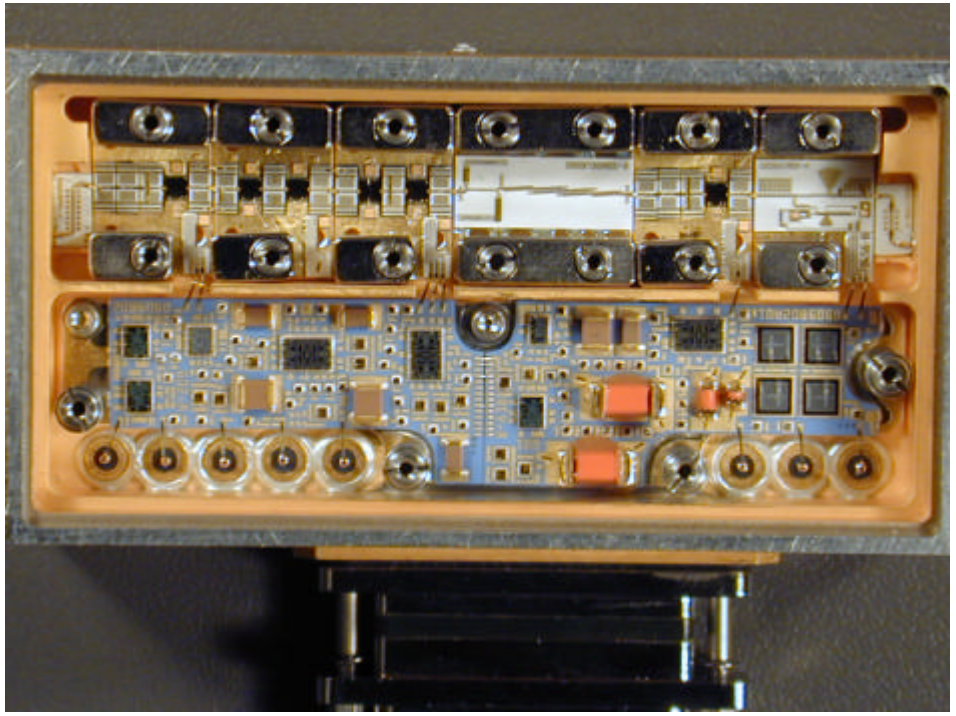


Qualification Test Sequences for LTCC Channel Amplifiers



FIRST ALS FM CAMP BY LTCC TECHNOLOGY

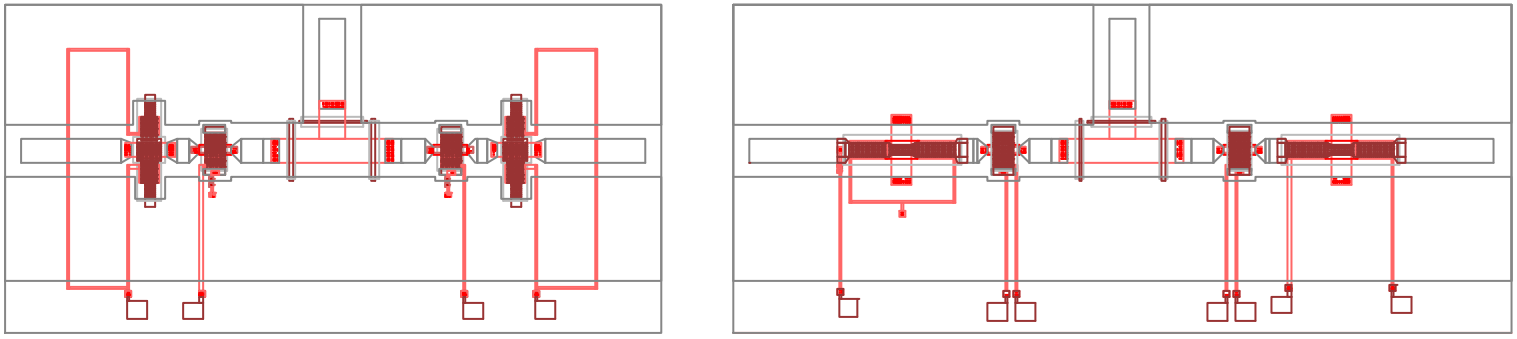




LTCC MICROPACKAGES FOR RF SWITCH MEMS

•Definition of the switches to be packaged:

Single Pole Double Through MEMS switches working up to about 40GHz have to be packaged. The switches are built on silicon by an external foundry and have DC control pads, other than coplanar RF in/out lines.



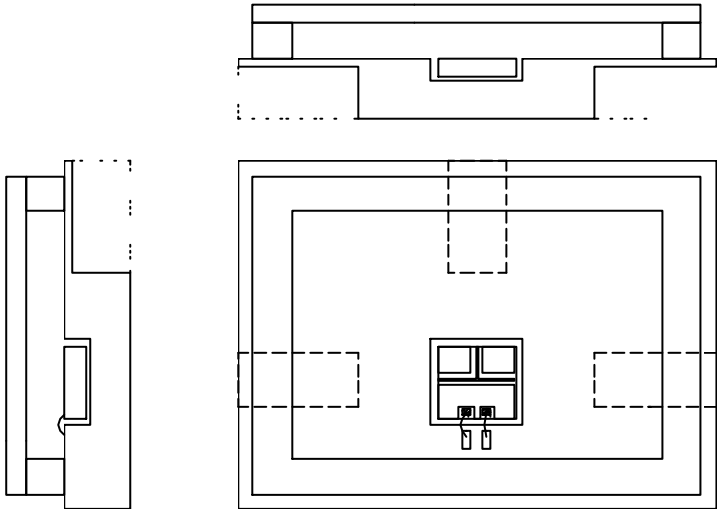
Layout of the Alenia Spazio SPDT MEMS switch (small version and large version)

LTCC MICROPACKAGES FOR RF SWITCH MEMS

•Preliminary technological design of the micro-packages:

A preliminary design of the micropackages has been discussed in order to fit the following requirements:

- **-Dimension of the chip to be packaged**
- **-Dimension of the proposed microstrip-coplanar (MS-CPW) transition**
- **-LTCC technological limits (line/gap, mechanical requirements,…)**
- **-Hermeticity of the package**
- **-Cost**



Preliminary layout of the package

LTCC MICROPACKAGES FOR RF SWITCH MEMS

•Simulation of microstrip-coplanar transitions on LTCC packages:

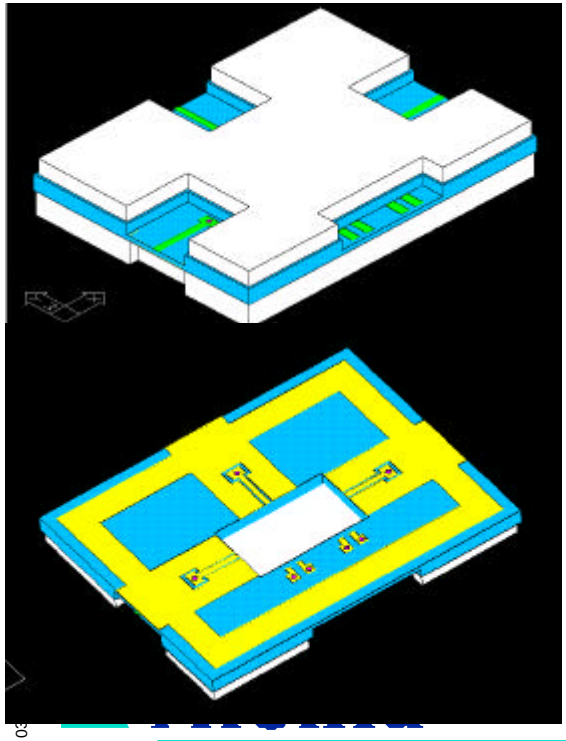
Once the preliminary design of the micropackages has been decided, the MS-CPW transition has been simulated. The design of the transition take into account the LTCC technology limits and the preliminary package design.

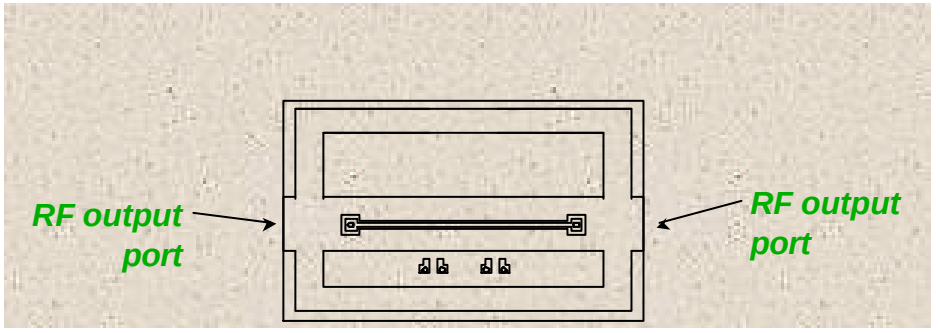
MS-CPW-MS transition on LTCC

LTCC MICROPACKAGES FOR RF SWITCH MEMS

•Final design of the LTCC micro-packages:

The final design of the package has been tailored onto the simulated transition and onto the chip layout. A dummy package version, with a line in the place of the chip cavity, has been produced together with the packages, in order to test the behaviour of the transitions without the influence of the chip.





Dummy package inside

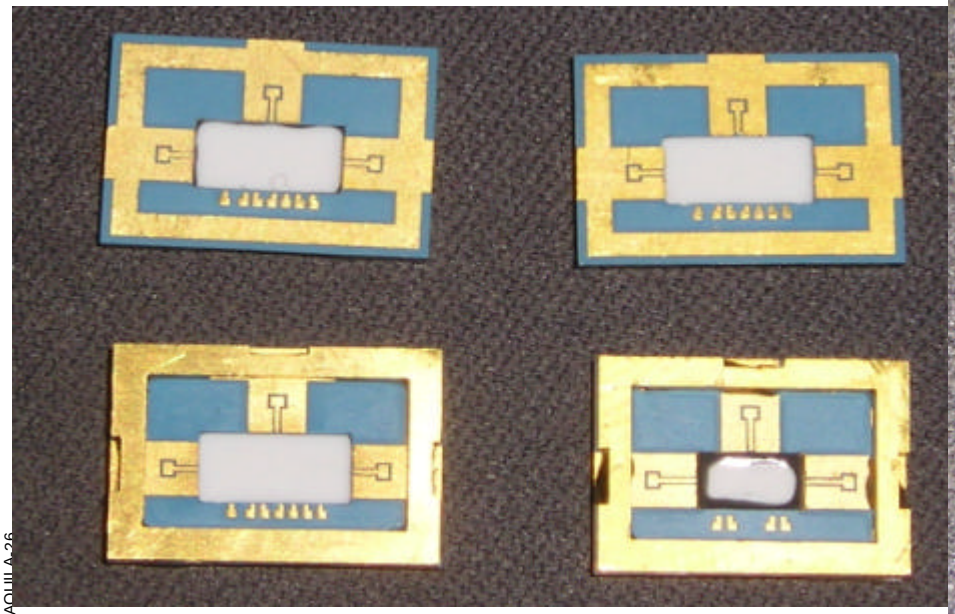
(a coplanar line is present at the place of the cavity for the chip)

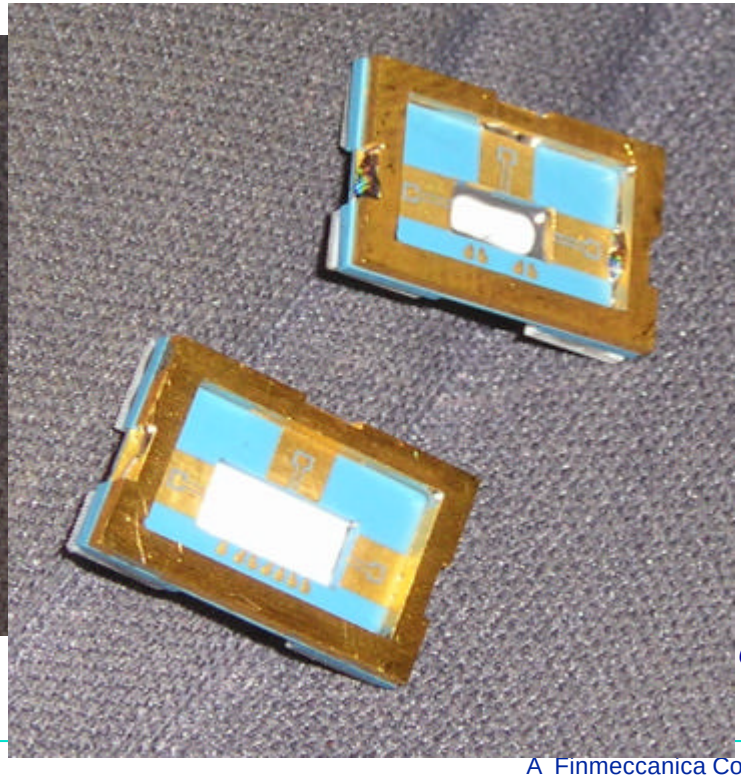
3-D layout of the package.
Top view (top) and bottom view showing the cavity for the lodging of the MEMS chip without the cover (bottom)

LTCC MICROPACKAGES FOR RF SWITCH MEMS

•Production of the LTCC micro-packages:

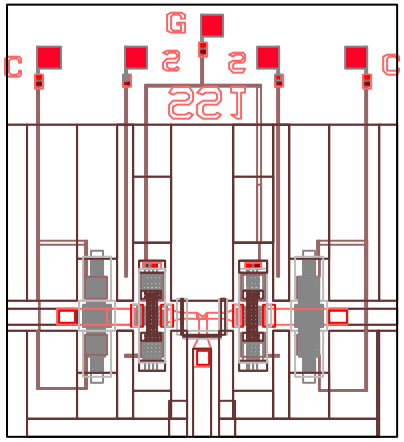
Two micropackages has been completely manufactured: one for the short version chip and one for the long version chip.

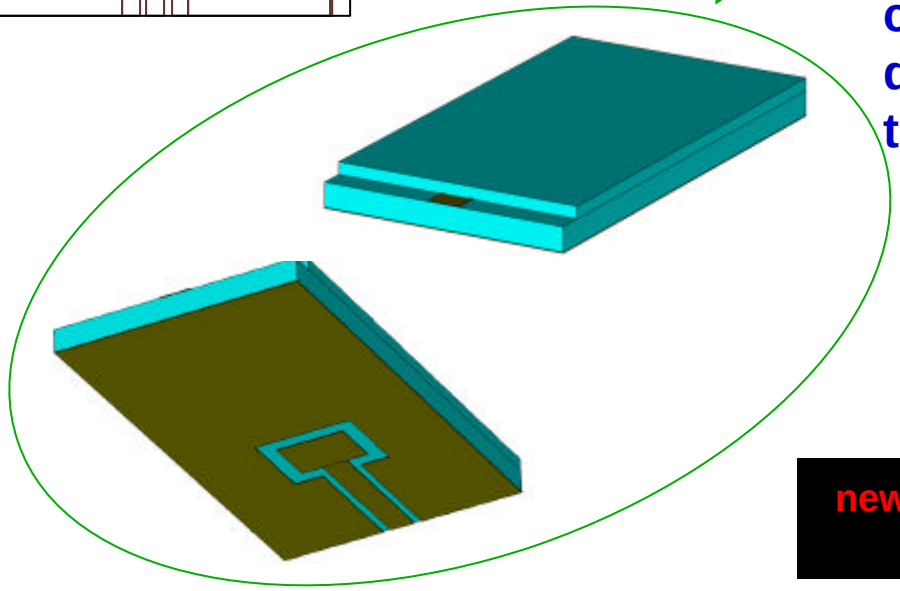




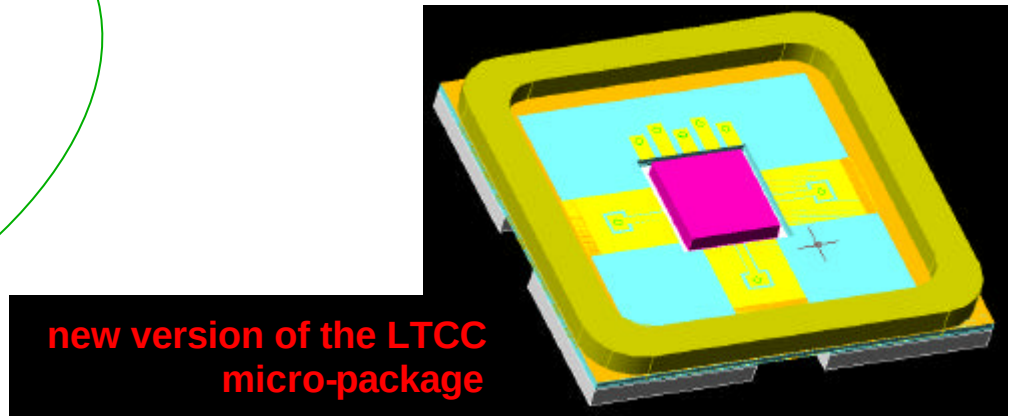
continue...

LTCC MICROPACKAGES FOR RF SWITCH MEMS





- **The new version of the MEMS switch to be packaged has been defined.**
- **The MS-CPW RF transition has been re-designed in order to reduce package leak rate. The transition has been optimised for low loss LTCC.**
- **The package re-design has been completed by using the new MEMS design and the new Low Loss LTCC transition design.**

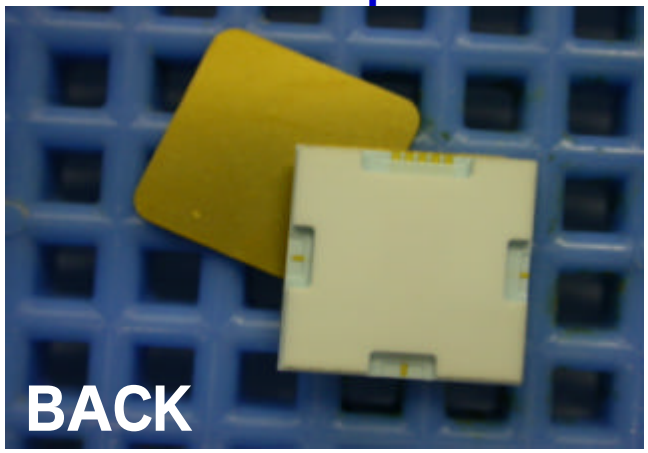


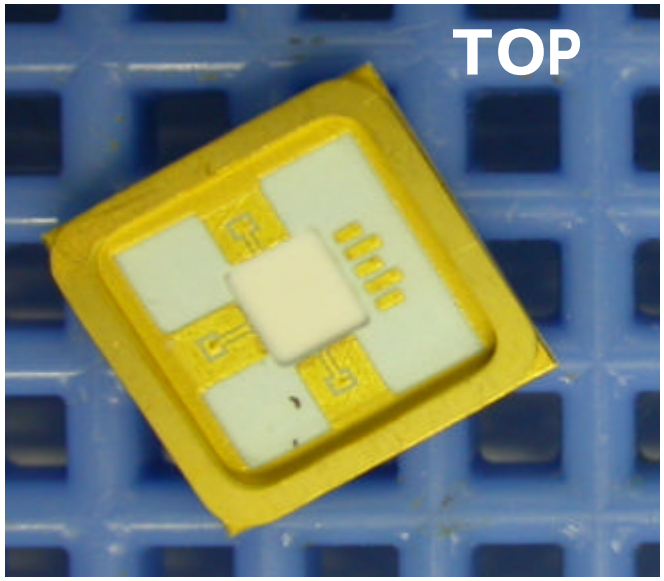
new version of the LTCC micro-package

LTCC MICROPACKAGES FOR RF SWITCH MEMS

The manufacturing of the new version of the LTCC micro-packages is in progress:

- **the LTCC part has been manufactured**
- **the mechanical parts have been procured**





The whole activity is forecast to be completed within Q2-05:

- **Set-up of a RF test equipment for micro-packaged MEMS switches**
- **RF test of the packaged MEMS switches**
- **Environmental test of the LTCC micro-package**

Alenia SPAZIO

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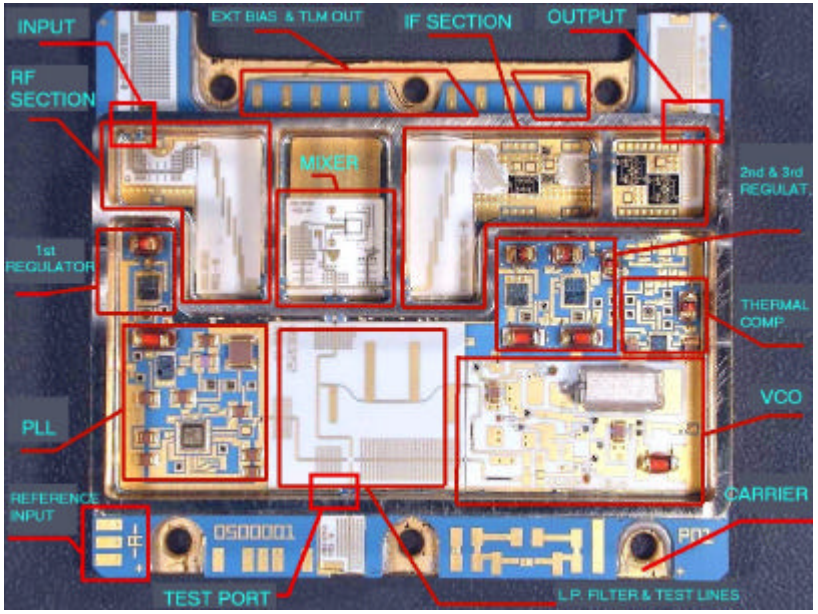
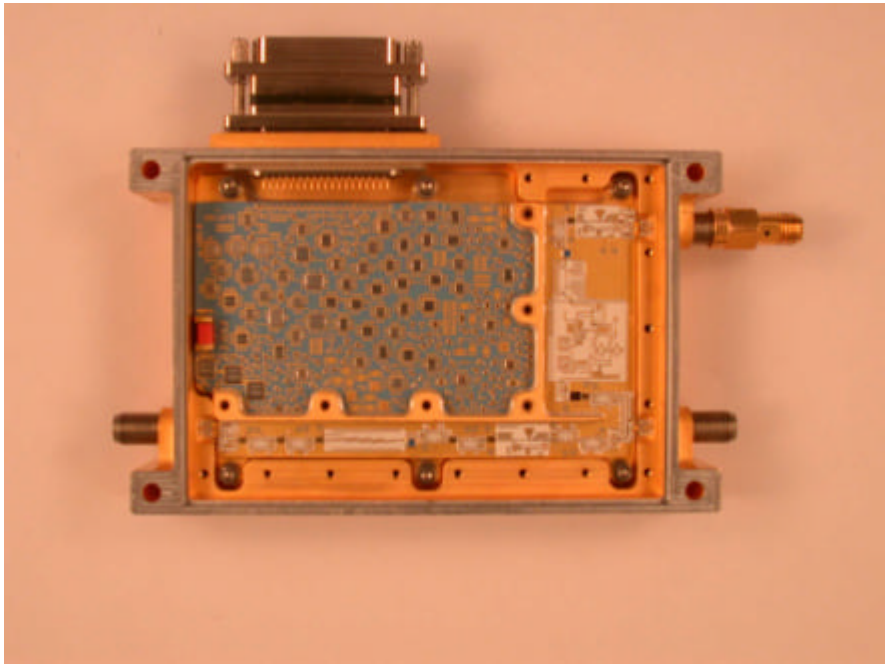
LTCC- Ku,C Down Converter/Receiver



- LTCC ISP approach with frame and carrier brazed Au Sn
- RF LTCC transitions AuSn brazed
- Number of di layer: 8
- Metallizzation: Au/Ag screen printed inner layers
- External Carrier in Kovar/ AlSi

- C, Ku e Ku+ Bands
- Base Components: Input filter,Mixer,IF section, PLL(VCO+SYNTHESIZER), Thermal Compensation available.
- TCXO as well OCXO frquency generations have been evaluated
- Telecommunication payload reduced weight (from1000gr(old DC) to 450gr)

LINEARIZED CHANNEL AMP(Ku/C Band)



- Application of LTCC ISP concept:

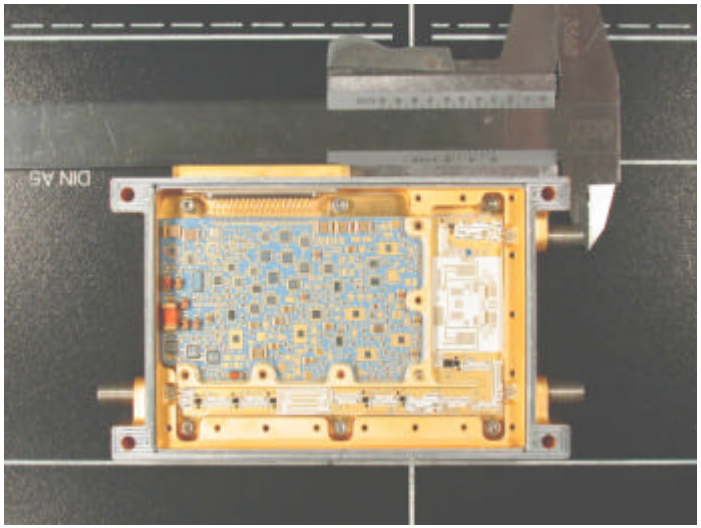
  ceramic board and added on Rf sections in thin film technology
- Cavity built using metallic frame and vias holes
- 14 active layers
- Lightweight carries in kovar ,and AlSiC (under evaluation)

- Same building blocks for C and ku band
- ALC and FGM mode, Pout in ALC 36-24dBm, Gain 60-36 dB, thermal compensation
- Mass=180 gr
- In production for MD3 program payload applications

C - Ku Band LCAMP

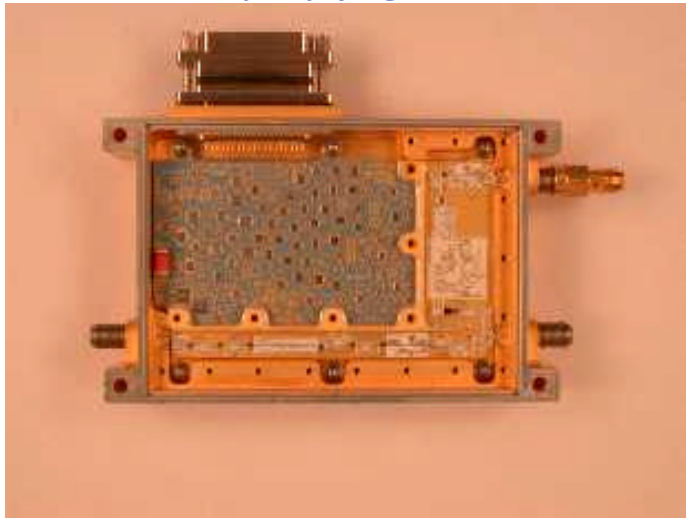
Parameter	Guaranteed Performance
Operating Frequency Range	3400-4200 MHz
FGM and ALC modes Input Power	-57 to –22 dBm
FGM gain range	>60 dB
ALC Mode Output Power Range	> 36 dB
(LCAMP+TWT BEDD) Phase Shift 3 dB IBO	< 12 °
(LCAMP+TWT BEDD) (C/I3) 6 dB OBO	> 23 dBc
DC power Consumption at 6.5 V	3.5 W
Mass	180 gr
Thermal Compensation	Analogue
Acceptance temp. range	-5 to 75 °C
Command and TLM Interface	Lockheed Martin BUS A2100

C - Band LCAMP

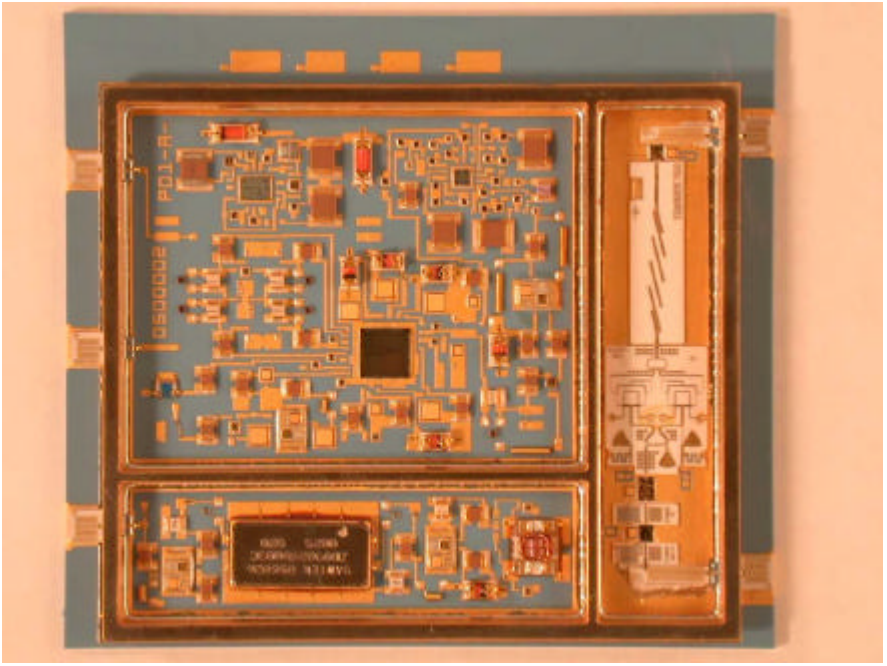


Parameter	Guaranteed Performance
Operating Frequency Range	12.25 to 12.75 GHZ
FGM and ALC modes Input Power	-59 to –24 dBm
FGM gain range	>36 dB
ALC Mode Output Power Range	> 24 dB
(LCAMP+TWT BEDD) Phase Shift at sat	< 6°
(LCAMP+TWT BEDD) (C/I3) 3 dB OBO	> 29 dBc
DC power Consumption at 6.5 V	3.7 W
Mass	180 gr
Thermal Compensation	Analogue
Acceptance temp. range	-10 to 66 °C
Command and TLM Interface	BSS (SWSI)

Ku - Band LCAMP



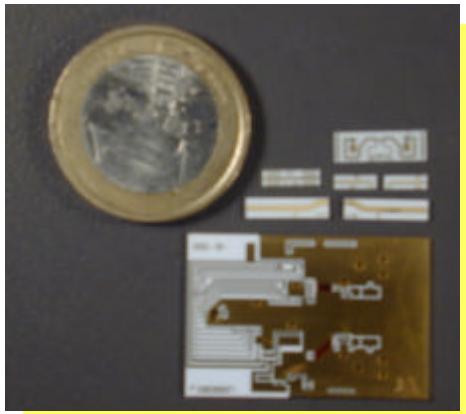
Ku/IF/BB Down Converter

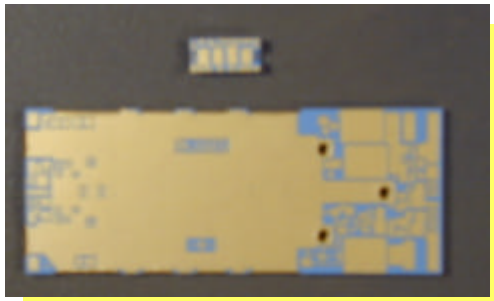


- LTCC ISP approach with frame and carrier in kovar brazed with AuSn to ceramic
- **Brazed MS-S-Ms transitions brazed on kovar frame**
- **Number of layers:9**
- **Mixed system of metallization based on Au/Ag**
- **AlSi package**
- **Double conversion converter with 2 filter sections;BB = 20Mhz; it presents an analog ASIC for integrated PLL**
- **Output frequency: 50 MHz.**
- **Payload applications**

Active antenna hybrid circuit substrates

Ceramic modules, belonging to T/R modules and TDL hybrids, needed for signal distribution, built using 2 different technologies: thin film and LTCC



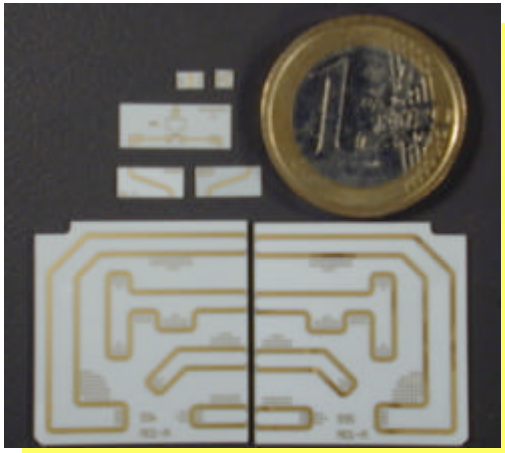


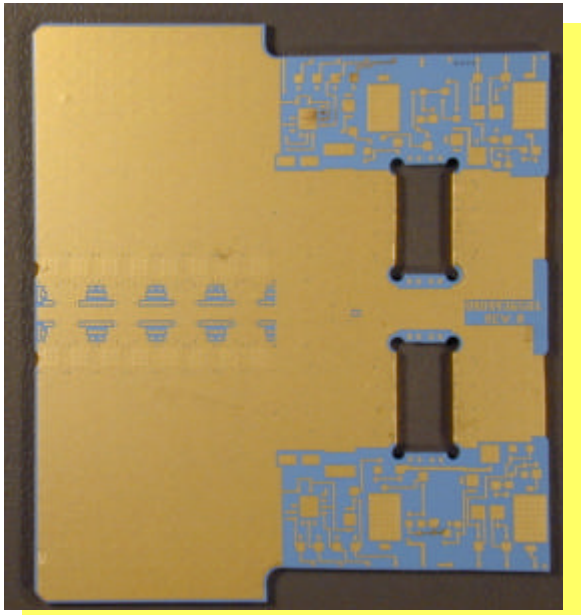
TR Module

Ceramic substrates
in LTCC
TDL: 1 type
TR: 2 types

Ceramic substrates
in thin film
TDL: 7 type (23 pz)
TR: 7 types

TDL Module





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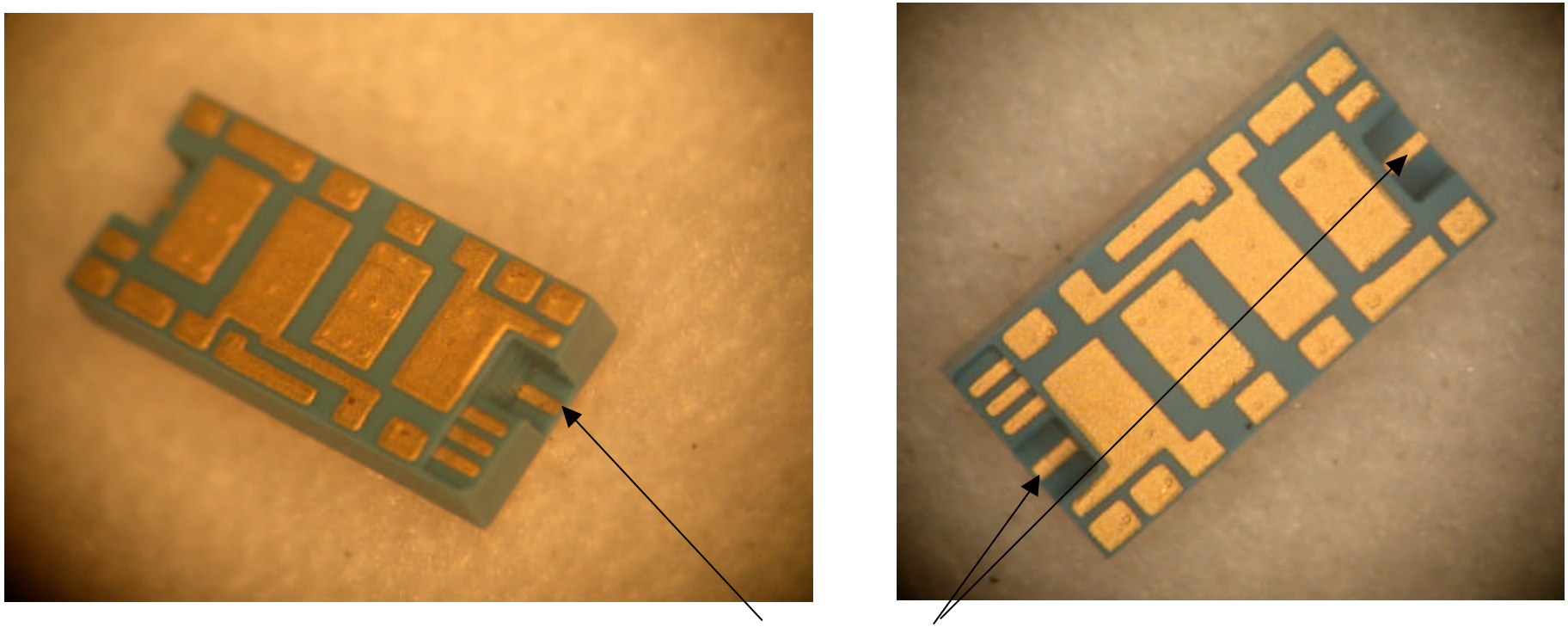
3D-LTCC multilayer substrate for T/R

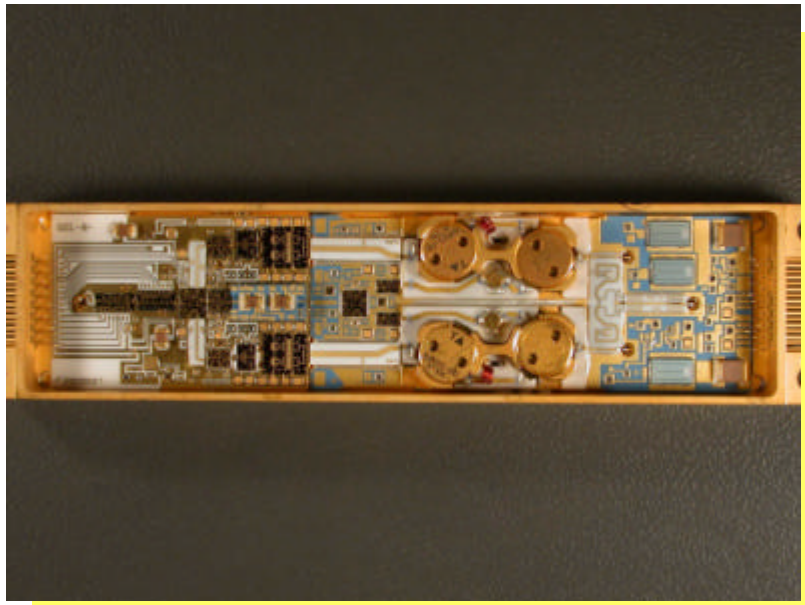


microstrip-stripline-microstrip RF line

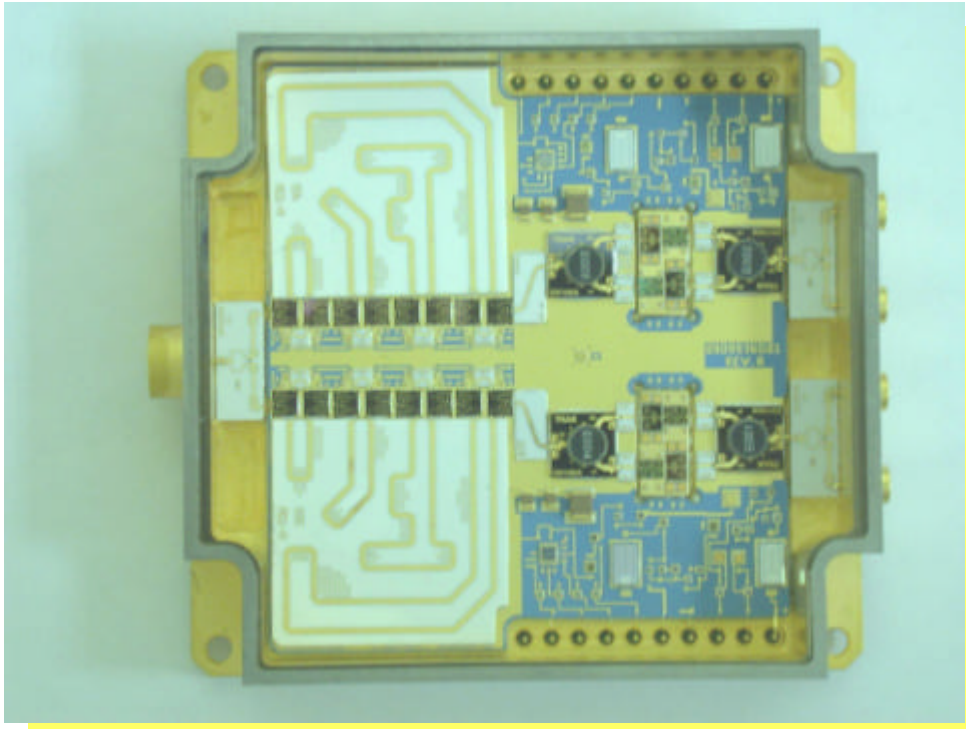
(technological solution used for SAR2000/COSMO T/R module)

Active antennas LTCC Hybrid Modules

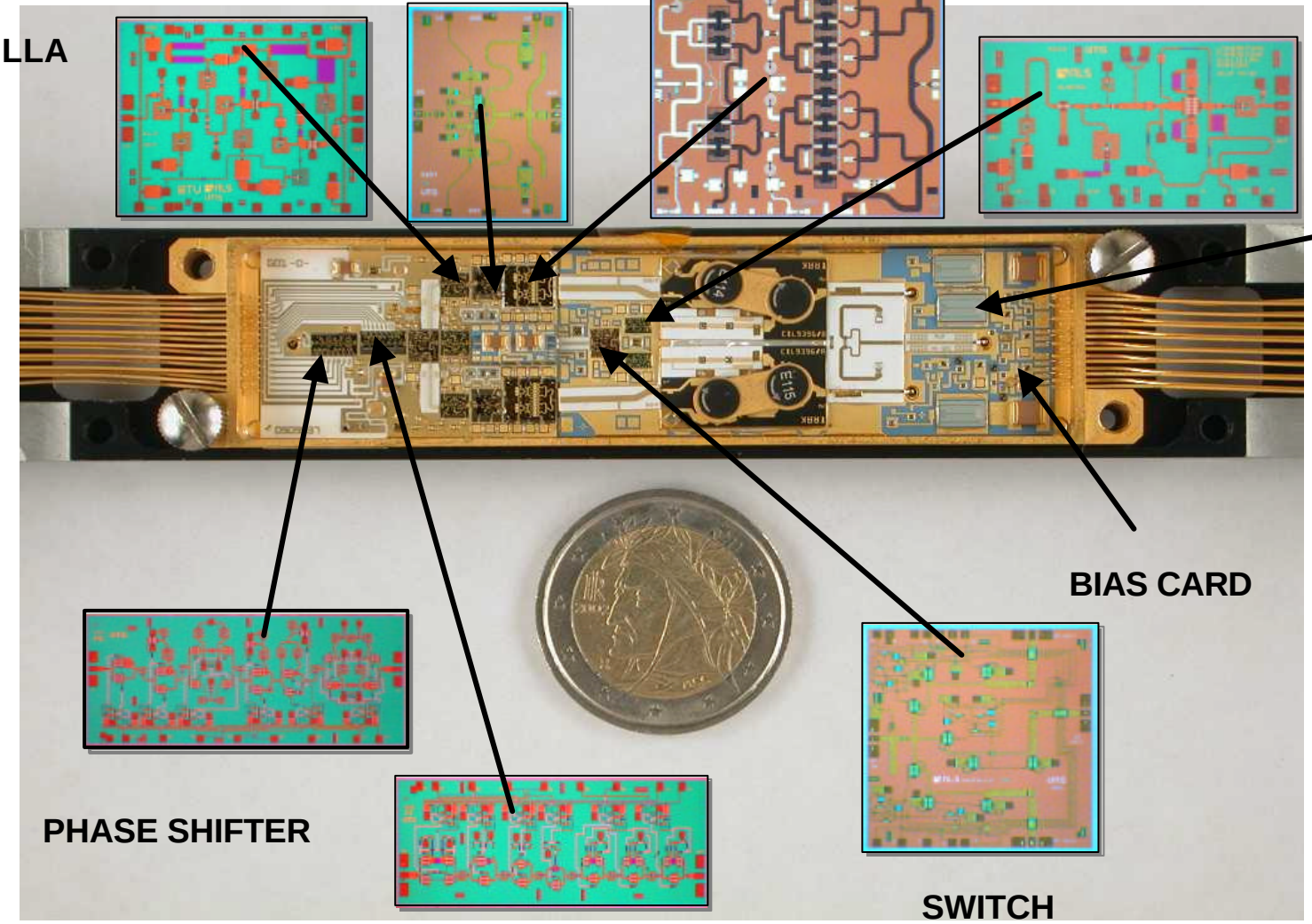
T/R Module



True Delay Line Module



COSMO X-band T/R Module



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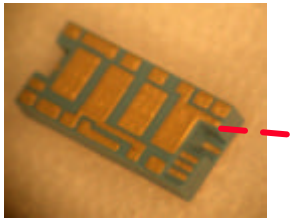
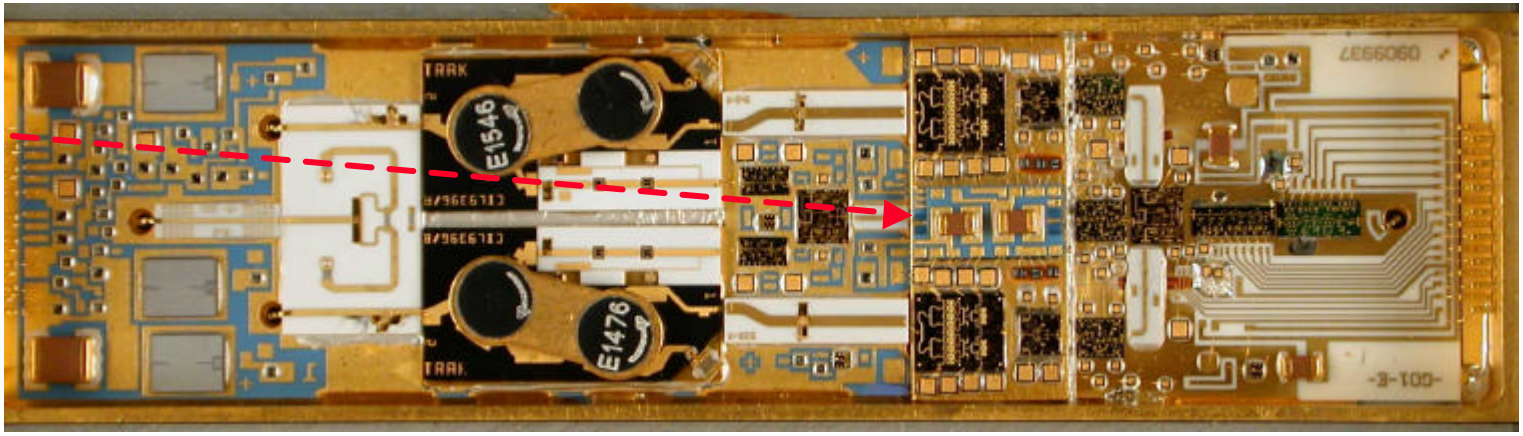
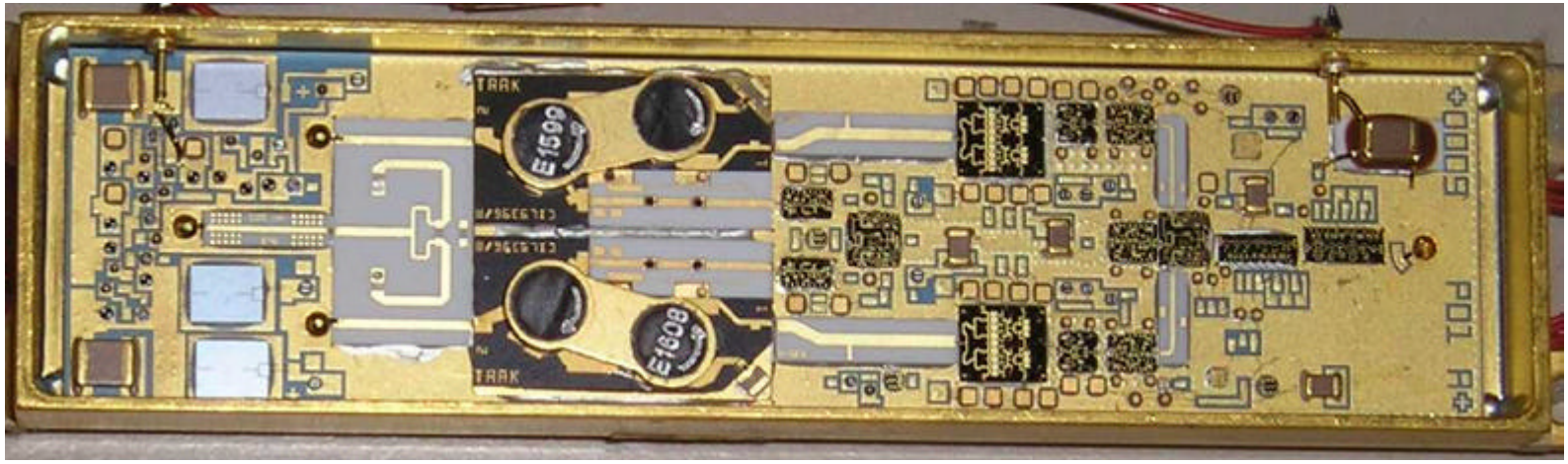
X-Band LTCC T/R Modules in ALS



COSMO T/R module (EQM/FM)



PIDEA project T/R module advanced version (BB)



Single larger LTCC multilayer with embedded RF lines and solderless DC connections on LTCC base (back side)

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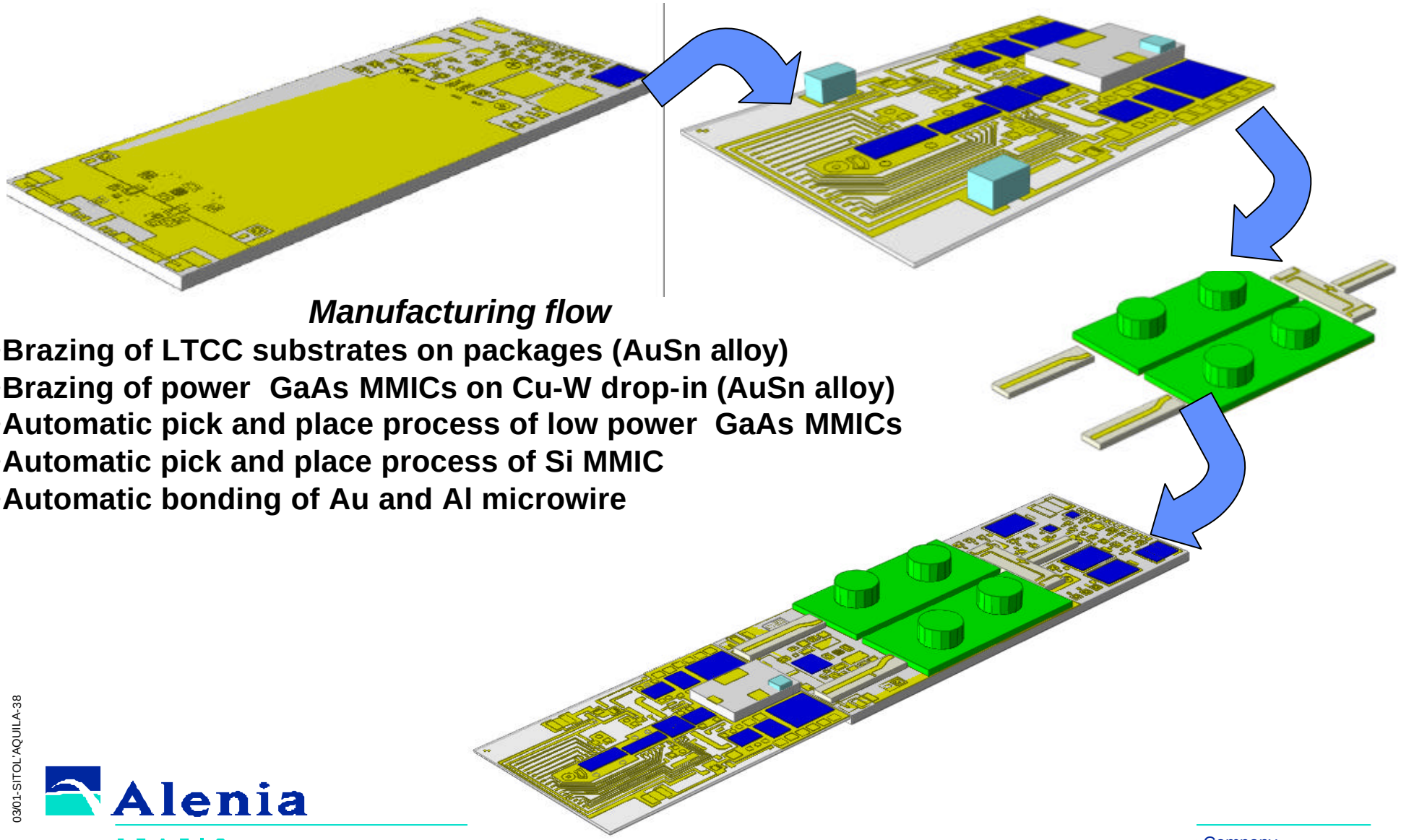
Cosmo TR Module basic assembly phases



Manufacturing flow

- Brazing of LTCC substrates on packages (AuSn alloy)
- Brazing of power GaAs MMICs on Cu-W drop-in (AuSn alloy)
- Automatic pick and place process of low power GaAs MMICs
- Automatic pick and place process of Si MMIC
- Automatic bonding of Au and Al microwire

X-Band LTCC T/R Modules Qualification

Evaluation Activity

Life test on a T/R lot submitted to 1100,2700,4000 hours (Tj=135°C) , succesfully completed.

-More than 150 modules submitted to complete S-Class screening, including thermal measurements (-40°C / +60°C) with 100 switch cycles both at cold and at hot temperature extremes(-40°C,+80°C).

-900 thermal cycles plus mechanical shocks @3000g 0.3 ms on dummy samples for isolators validation

Qualification Activity

- Investigation on 38 s-class T/R modules , submitted to qualification campaign according

to ESA PSS-01-612 , has been successfully completed

-2000 hrs life test at Tj=135°C

-500 thermal cycles (-55/+125°C)

-2000 hrs high temperature storage(125°C)

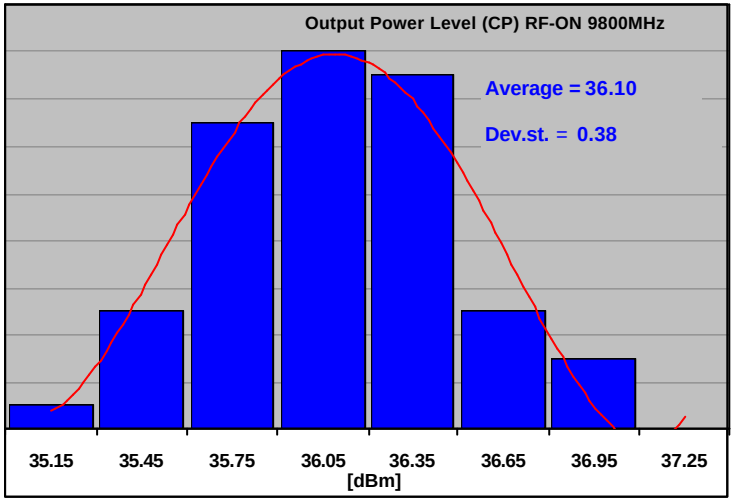
- Vibration and mechanical shocks

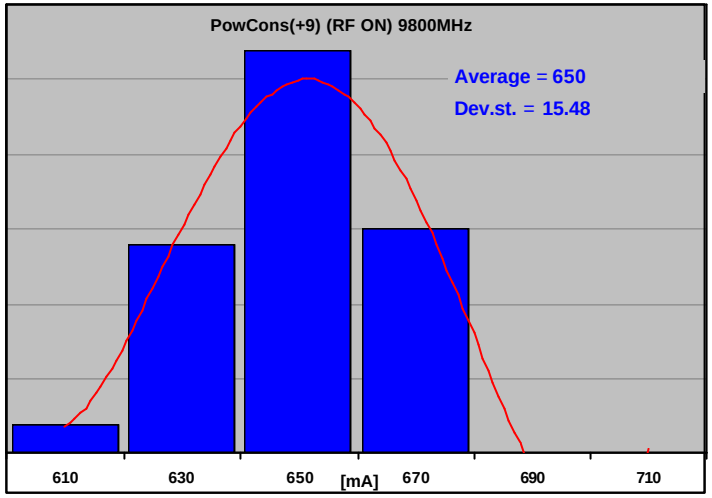
-720 thermal fatigue cycles(-40°C/+80°C)

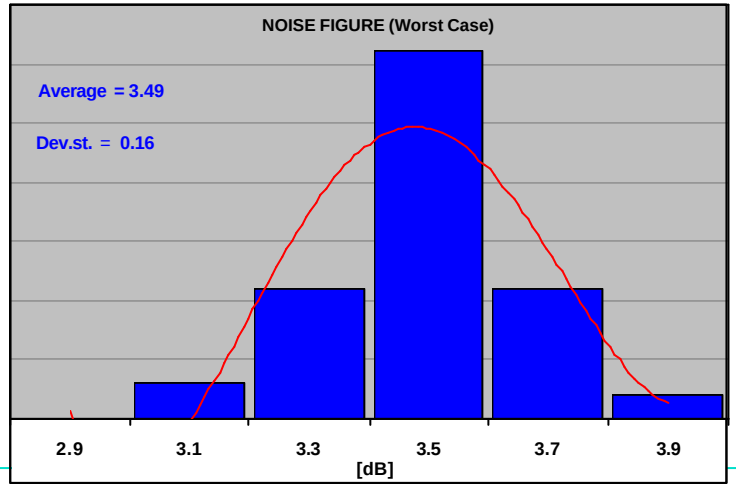
Statistical Analysis on T/R MODULES

Tabella riassuntiva - **Lotto 577 (FM-14)** 28 moduli testati

	PowCons(+9) RF-OFF [mA]	PowCons(+9) RF-ON [mA]	Output Power cp2.5 [dBm]	Gain cp2.5 [dB]	Noise Figure worst case [dB]
H	584.1	647.2	36.1	37.5	3.55
V	585.8	653.7	36.1	37.3	3.44







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LTCC Cosmo T/R Modules Yield

- 1500 X-band T/R modules have to be produced for 1 Cosmo satellite: today rate is more than 200T/R month: most of measured PPKs on individual process of the lots are higher than theoretical expected values(1.33).
- The most of sub techniques yields are between 90-95%
- Brazing processes yields on power dies are located within (80-95%)(acoustic control)
- T/R modules yields on space screening are in the range of 95% (85%expected)
- Current target cost reduction achievements are related to short testing phases and high quality level of feeding parts (packages ,ceramics, components…)in manufacturing kits.

Statistical Analysis on X- band LTCC/TR

TR MODULE PROCESS CAPABILITY

LOTTO 559 - 1°	Livello di SUBSTRATO					Livello di MODULO ASSIEME						
INDICATORI	SHEAR per Test Bagnabilità (F>1.33)	Pull Test di STRAPPO (F>1,33)	Pull Test microfili per Bondability (>1.33)	Misure elettriche	Ispezione / Accettazione	X RAY	Sonoscan	Shear Test Confidence FACTOR F (F>1,33)	Pull microfili PPK (>1.33)	Insulation to RF PIN	HANDLING	Ispezione / Accettazione
PROCESSI	# F	# F	□ PPK - F # (dopo Ageing)	° Yield	° Yield	° Yield	° Yield	# F	□ PPK	° Yield	° Yield	° Yield
Substrati THIN FILM	5.47	2.17	1,45 - 5,2	98,7%	100%							
Substrati LTCC		1.52	1,56 - 3,7	98,1%	100%							
Brasatura Package						97.5%				100%		
Brasatura Carrier W/Cu							95%				97.5%	
Incollaggio Chips								1.98				
Interconessione									1.87			
Cicli termici												100% (su 32 pz)
Sigillatura (LEAK TEST)												100% (su 32 pz)
RGA su LOTTO												
Shock meccanici												100% (su 32. pz)
PIND												96.8% (31/32 pz)
D.P.A del LAT												

leggenda:

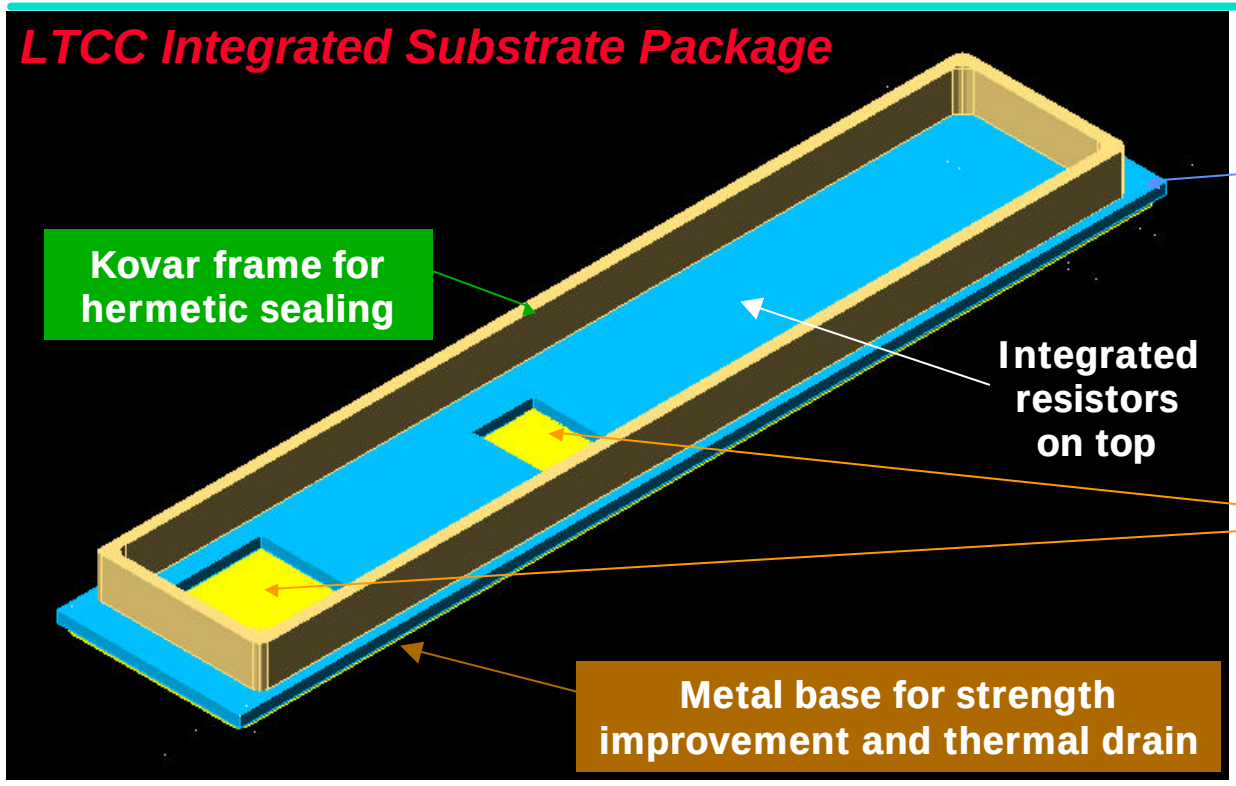
° INDICATORE DI YIELD [%]

FATTORE DI SICUREZZA [valore minimo: F_{min}=1,33] $F = \frac{Measured\ \ Value}{Spec.\ \ Limit}$

□ PPK Process Performance Index [valore minimo: PPK_{min}=1,33] $PPK = \min\left[\left(\frac{T_s - \overline{X}}{3\sigma}\right), \left(\frac{\overline{X} - T_i}{3\sigma}\right)\right]$

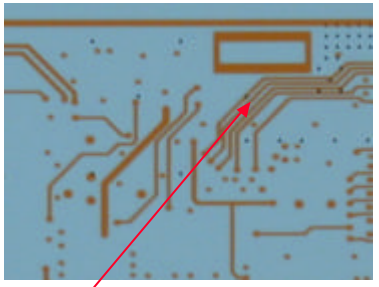
Prepared by Elio Picchione

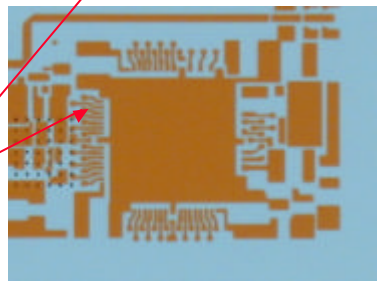
T/R Module trends: ISP-LTCC



LTCC multilayer substrate

LTCC substrate windows to braze power components directly onto the metal base





100um/100um Line/gap

Advantages with respect to the standard approach:

- *lower number of parts to be managed and assembled*
- *higher production yield*
- *improved reliability*
- *cost reduction*
- *...*

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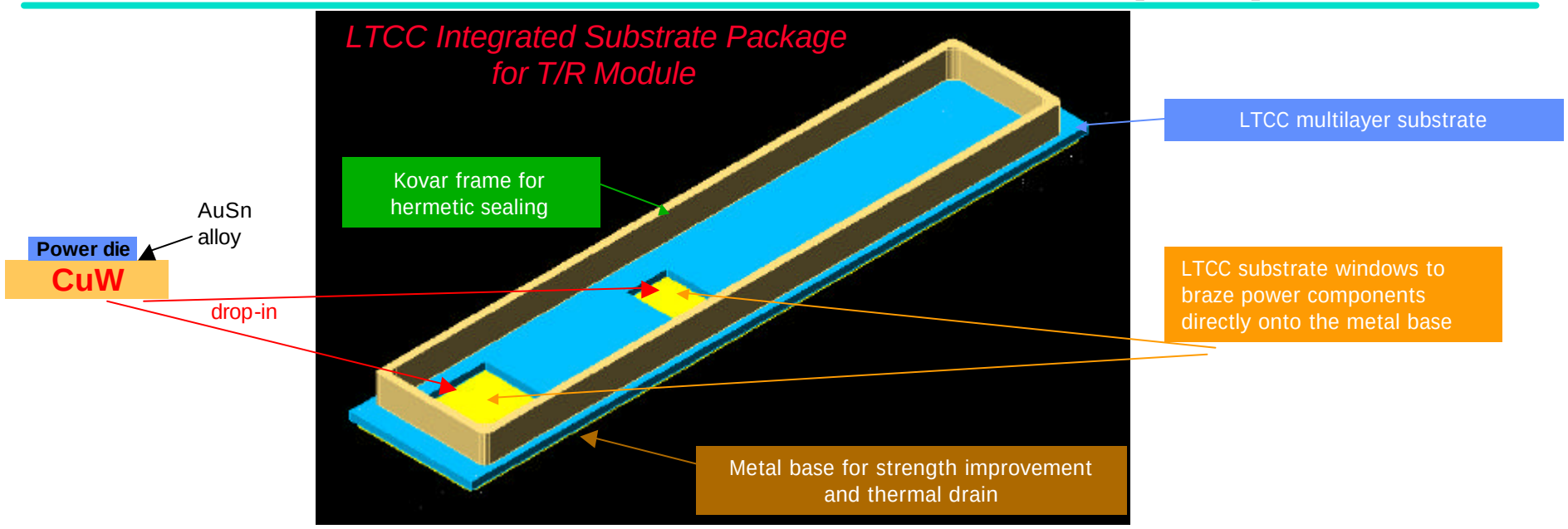
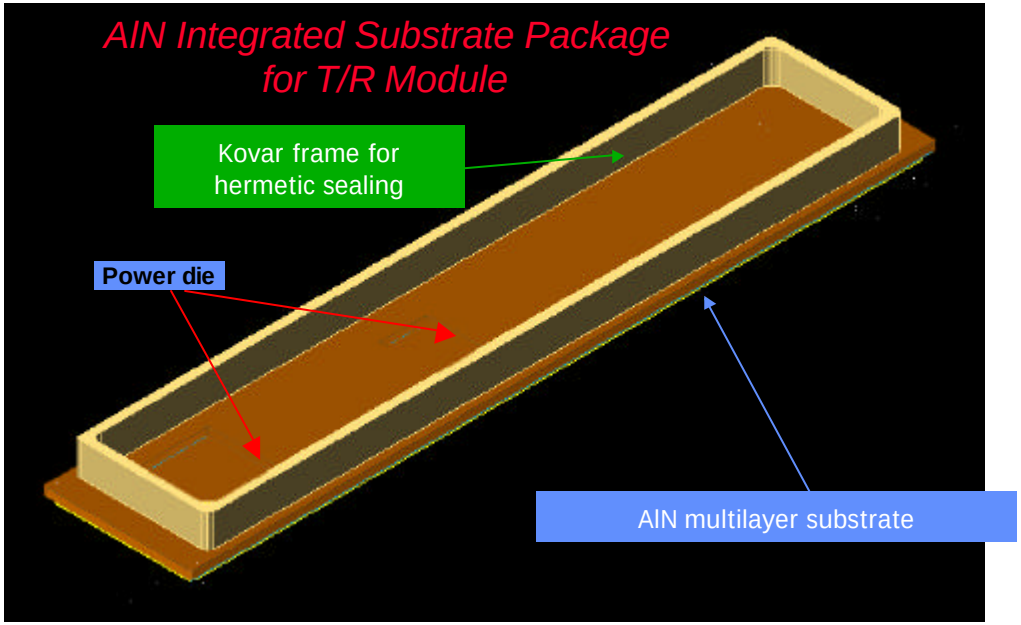
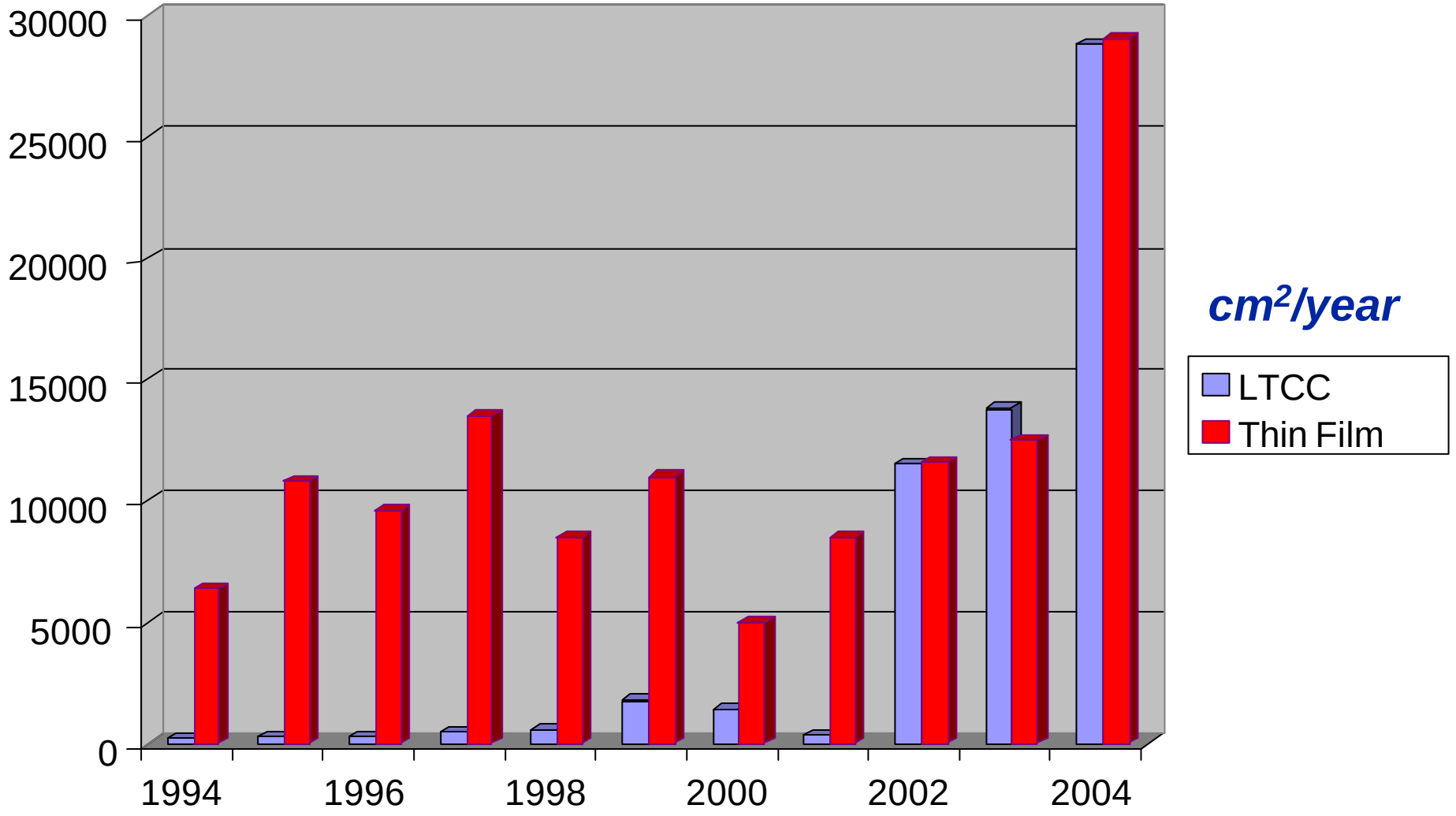
T/R Module trends: Aluminum Nitride (AlN)





Ceramic Substrates production in Alenia Spazio AQ



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