Cryo LNA 18-26.5 GHz

Building, Assembly, Testing

Technical Working Group:

A. Cremonini:	MMIC Design, Foundry and Measurement
J. Roda:	Jig Design and Drawing
S. Mariotti:	Assembly, Test & Measurement

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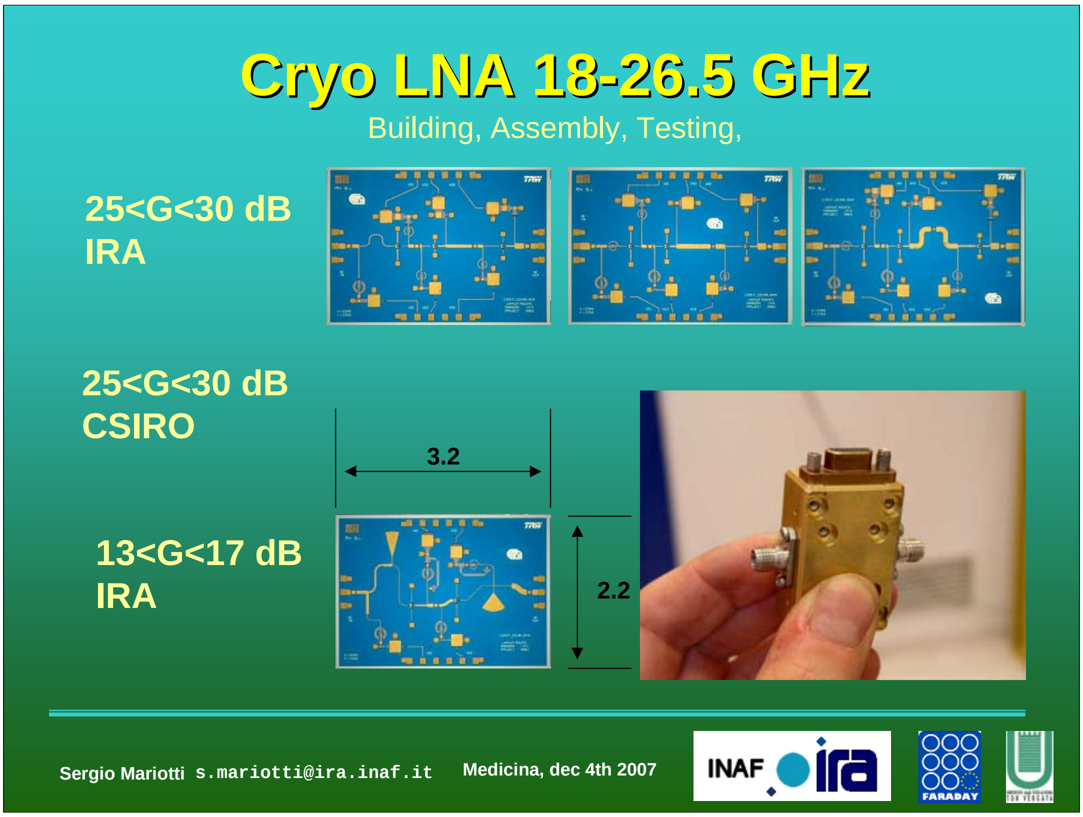


Five types of K band MMIC has been designed and produced:

A large redundancy has been chosen because

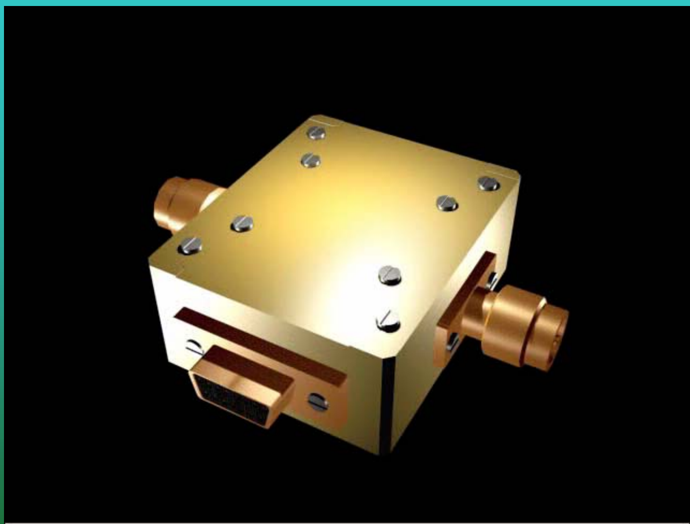
INAF-IRA (Cremonini) designed:

3 different types of 3-stages LNA to be used as front-end

1 type of 2-stages LNA, very well matched, to be used as cascadeable gain block.

In addition, one type of MMIC designed by CSIRO (R. Gough) has been added

Assembly: Movie



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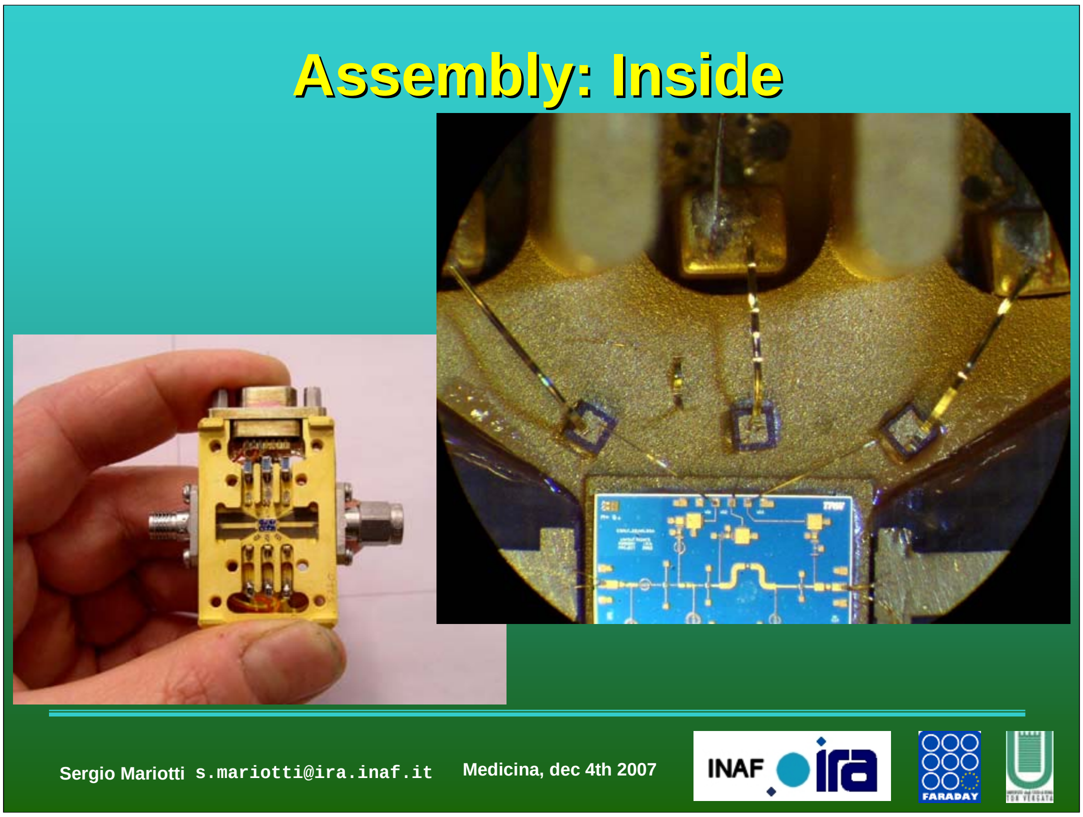

On Bottom-Left:

An interior view of the LNA. You may see, from Left to Right, the Input coaxial connector, the 50 Ohm adduction line, the MMIC, the Output 50 Ohm line, and then the output connector.

The six DC lines (Drains and Gates) are all “shielded” into the thin and deep channels and separated by thin metal walls.

On Top-Right:

A close view of the bond wires. The thinner is 25 micron thick while the thicker is 75 micron ribbon.

How Many LNA ?

Type	Stages	MMIC Q.ty		LNA Q.ty
CSR17_22LNA_ 01 A	3	115	300	
CSR17_22LNA_ 04 A	3	65		
CSR17_22LNA_ 05 A	3	120		16
CSR17_ 20 LNA_ 01 A	3		50	
CSR17_22LNA_ 07 A	2		130	16

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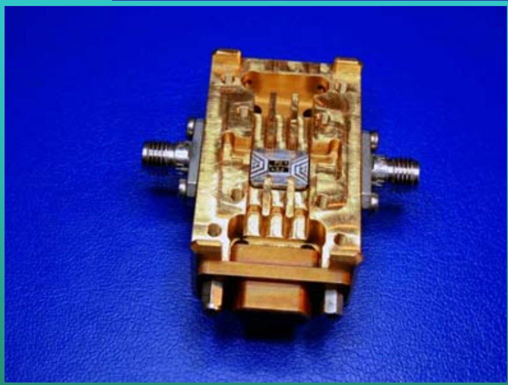
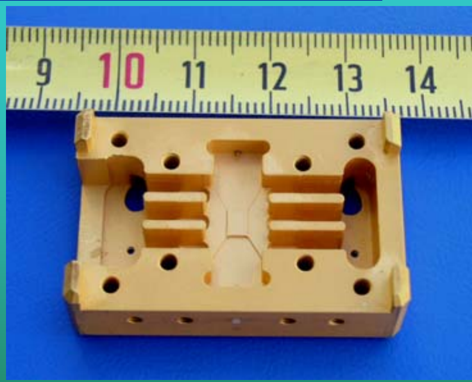
Lots of MMIC are available for each type.

The MMIC are passivated and their life is expected is greater than 10 years.

For the Multifeed receiver 14 Cryogenic LNA and 14 Post-Amplifier are needed, two LNA for each type will be stocked as spare parts.

Alloys





Brass:	17	ppm / °C
Al alloys (50xx, 60xx)	20	ppm / °C
CE7 ($Al_{30}+Si_{70}$)	7	ppm / °C
InP	4.5	ppm / °C

Brass-InP:
Crack 20%

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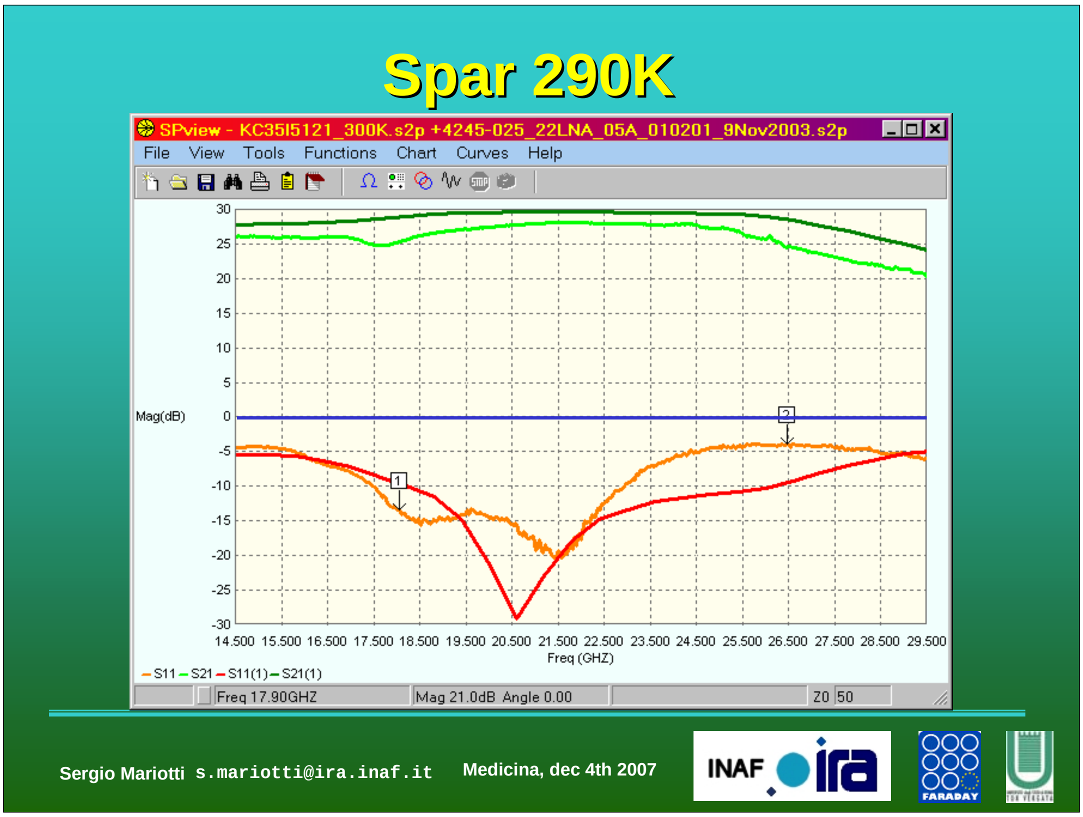
The Coefficient of Thermal Expansion (CTE) of the InP is close to 4.5ppm/°C.

The CTE of the most common metals like Aluminum alloy or Brass alloy are around 20ppm/°C.

It's evident that for the join of different materials stressed by a strong temperature change, the risk is the break into fragments or crumbs

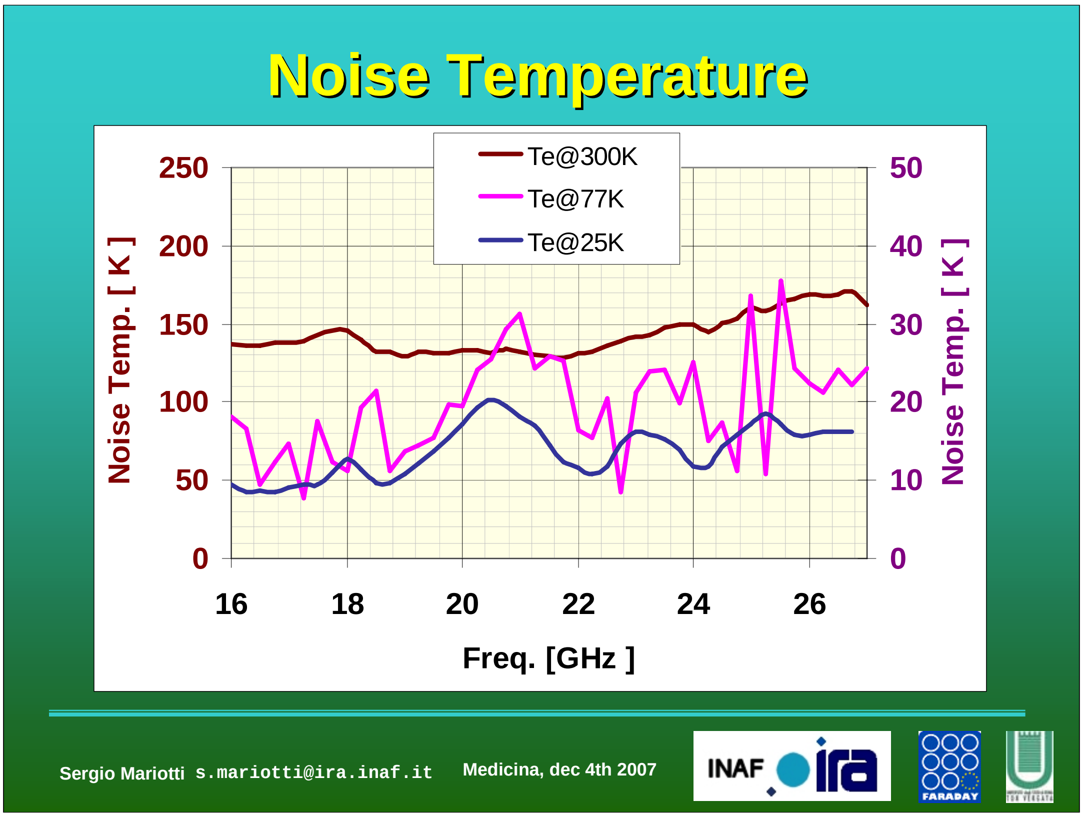
To reduce the risk, has been chosen a special alloy which have a limited CTE (only 7 ppm/°C). The common alloys like Brass or Aluminum alloy may be accepted only for very few prototypes but not for mass production.

The *Osprey®* CE7 is composed by Al_{30} +Si_{70} .It's hard to machine, fragile as glass and it has poor electrical conductivity. But it's (relatively) cheap, may be gold plated and machined by factory respecting our drawings.



The dark-colored curves shows GAIN and IRL of the MMIC alone, while the light-colored curves shows the performances of the same MMIC once it has been mounted into the metallic jig (box).

Apparently the curves are very similar expect that the IRL around 24…27 GHz which is far from the target.The because depend on two main causes: the discontinuity and gaps of the adduction lines and (mainly) the spurious coupling of the cavity (shown later).



The curves shows the Noise Temperature for the same LNA at three different Physical Temperatures (290K, 77K, 25K).

The LNA Drain currents has been tuned for the best noise.

Please note that the strong reduction of T_e vs T_{fis}.

The avg T_{e300} is 140K , the avg T_{e77} is 20 K, the avg T_{e25} is 14 K

Also please take a look to the “hill” around 19…22 GHz, explained into next slide.

Matching Errors

$$Te = 290 \cdot (F - 1) \qquad F = F_{\min} + 4 \cdot \frac{R_n}{Z_0} \cdot \frac{\left|\Gamma_{opt} - \Gamma_S\right|^2}{\left|1 + \Gamma_{opt}\right|^2 \cdot \left(1 - \left|\Gamma_S\right|^2\right)}$$

$$Te = T_{\min} + 290 \cdot 4 \cdot \overbrace{\frac{R_n}{Z_0}}^{0.01\ldots0.03} \cdot \frac{\overbrace{\left|\Gamma_{opt} - \Gamma_S\right|^2}^{0.25}}{\left|1 + \underbrace{\Gamma_{opt}}_{0.5\ldots1.5}\right|^2 \cdot \left(1 - \left|\underbrace{\Gamma_S}_{0.4\ldots0.7}\right|^2\right)}$$

$T_{\min} \propto T_{fis}$

$R_n = f(T_{fis})$

$$(T_{\min} + 3) < Te < (T_{\min} + 30)$$

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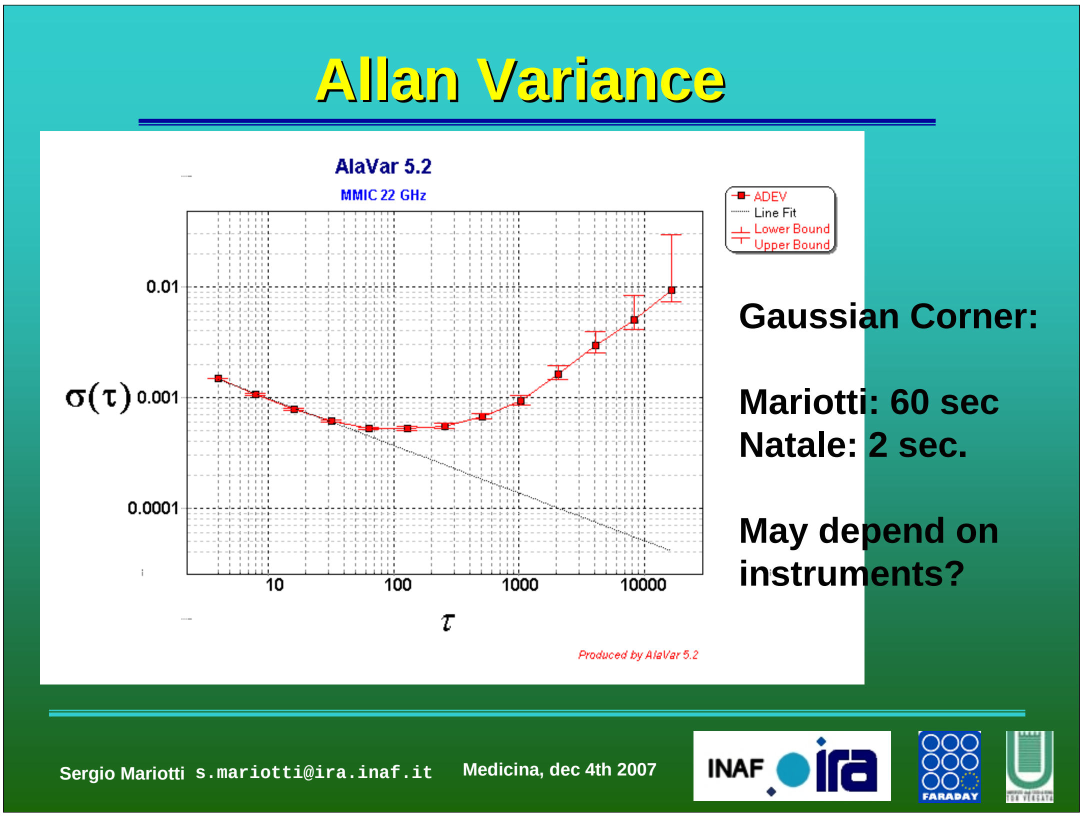
Given the two well known equation on the top, by joining them we obtain the one in the center of the page.

Now applying the typical and plausible values to the complex numbers (acceptable mistakes or incapacity to match input network), we obtain that the actual Te into a cryogenic environment, is higher than the minimum possible of 3 to 30 [K].

The effect is more evident at cryogenic temperatures because Tmin (which is proportional to Tamb) became a very small value.



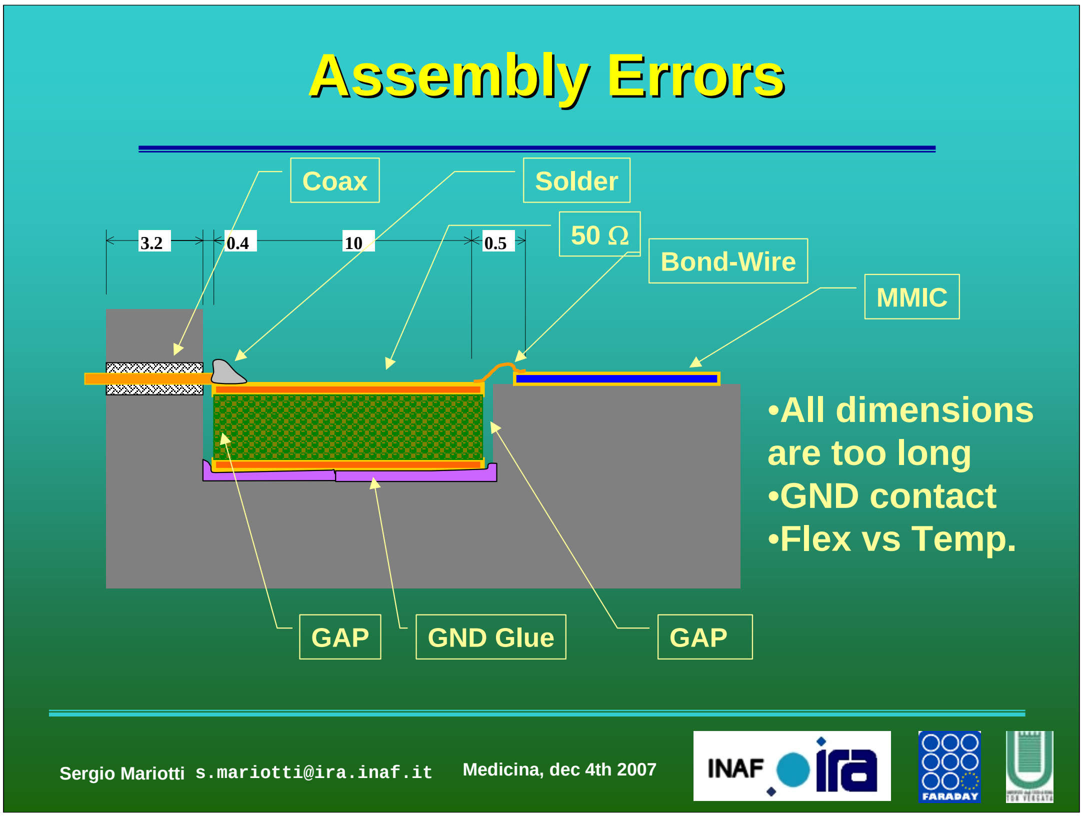
The Allan Variance curve shows the boundary of the gaussian noise.

For InP, the literature gives values slightly less than 10 seconds.

For the same LNA, measurements performed with BO-Med owned instruments shows a corner close to 60 sec. While measurements performed with instruments of Arcetri group shows a corner close to 2 sec.

The two measurements are relative a two different scenarios, the first conducted on the MMIC alone, room temperature and CW signal while the latter for a complete receiver, cryogenic, noise.
But even if the conditions are very different, the distance between the two results appear to far.

The work is in progress , the target is find a credible result.



Gap: The length of the PCB is shorter than the nominal, the unwanted effect is a gap between the contacts. Every GAP is a discontinuity that produces reflections. The RL quickly make worse for frequency greater than 25 GHz.

Pin Solder: An extensive experience has been gained using Sn/Pb/Ag alloy rather than Epotek H20E; the latter is much more lossy.

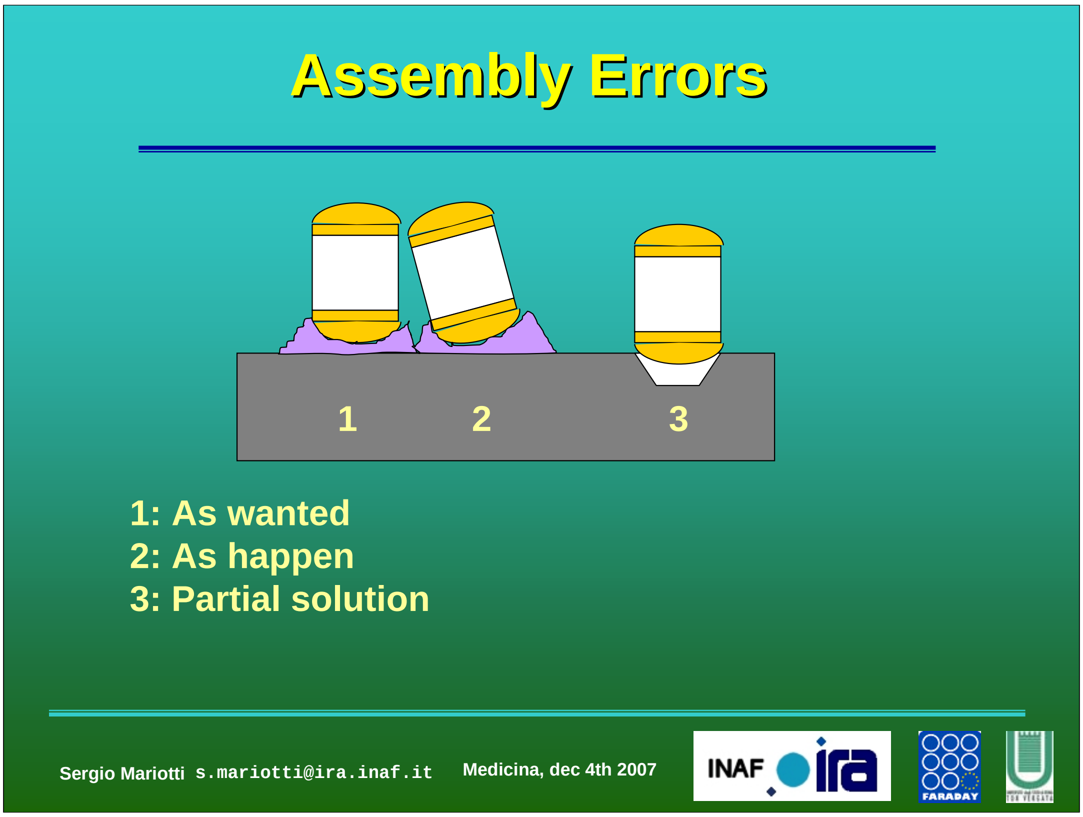
50 Ohm line: GND has been glued (Epotek H20E) and soft soldered (Sn/Pb/Ag). All prototypes glued showed an higher Te. And the PCB tend to detach once is cooled. Sn/p/Ag alloy has a better behavior even if the detach problem is not completely solved.

The soft laminate tend to became U curved with a consequent risk of break of the bond wire.

The risk is a partial detach of the GND that cause a $\lambda/4$ resonant stub, often observed in cryo environment.

Bond Wire: The bond wire length is “too long”, every mm is 1 nH !. Where possible 2 or even 3 bond wires has been placed.

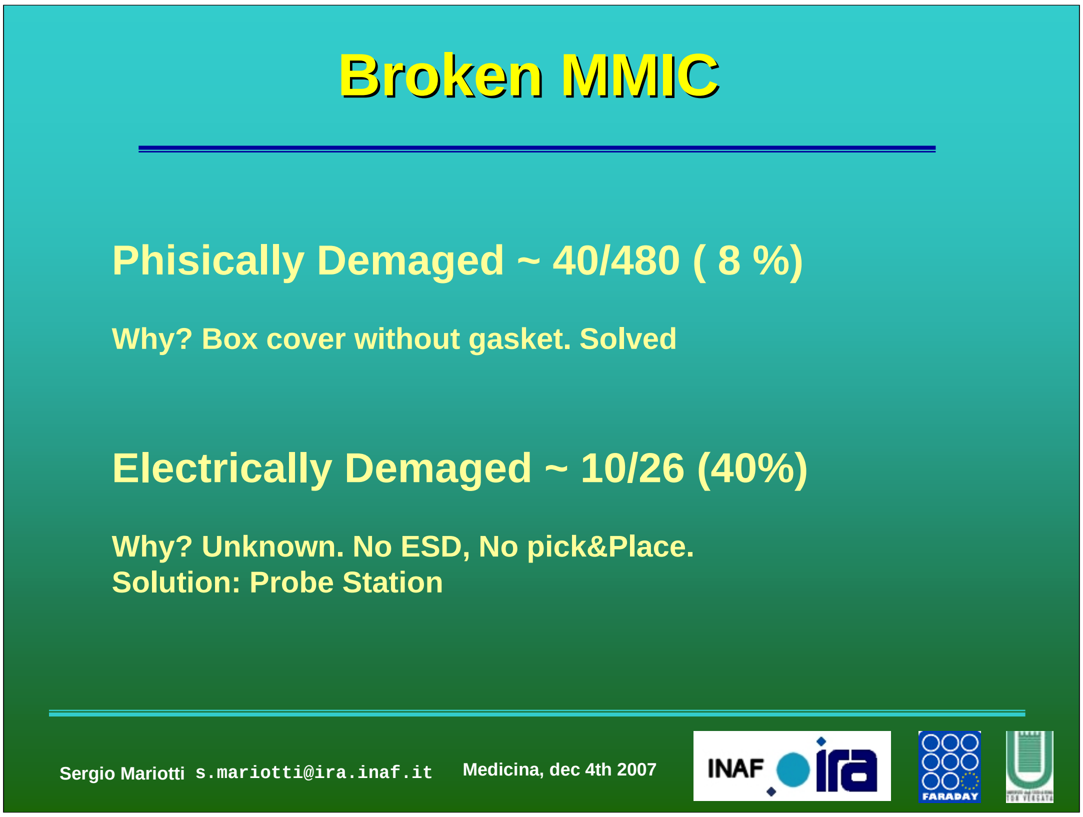
Also the bond strength is very poor on the PCB. The repeatability of the bonding on PCB is less than 10 % (with fixed bond machine parameters and the same environmental conditions.



Assembly problem: component floating

During soldering, due to high density of Sn/Pb alloy, the capacitor will flow.

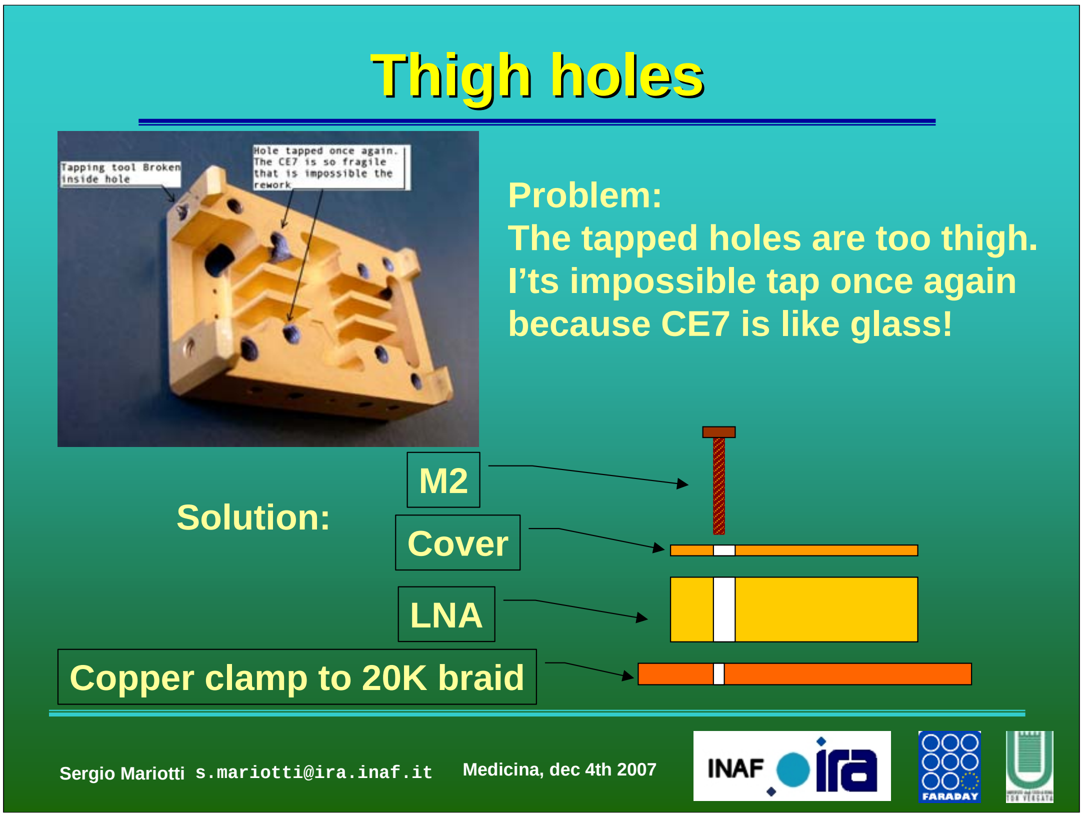
A solution (even a partial solution) is to create a milled seat even smaller than the capacitor dimension. The example shows a conical seat



We received from CSIRO some broken MMIC (8%). The cause has been found into a problem related to the containing box, especially a lack of the paper gasket foils between box and it’s cover. Problem solved.

After many MMIC has been glued and wire-bonded into the jig, most MMIC resulted broken (40%). At present I may exclude Electrostatic damage as well a damage caused by Pick & Place because everytime the MMIC has been picked into a free area.

The solution will pass trough a DC test of the MMIC immediately before mounting. For this operation a probe station is needed.

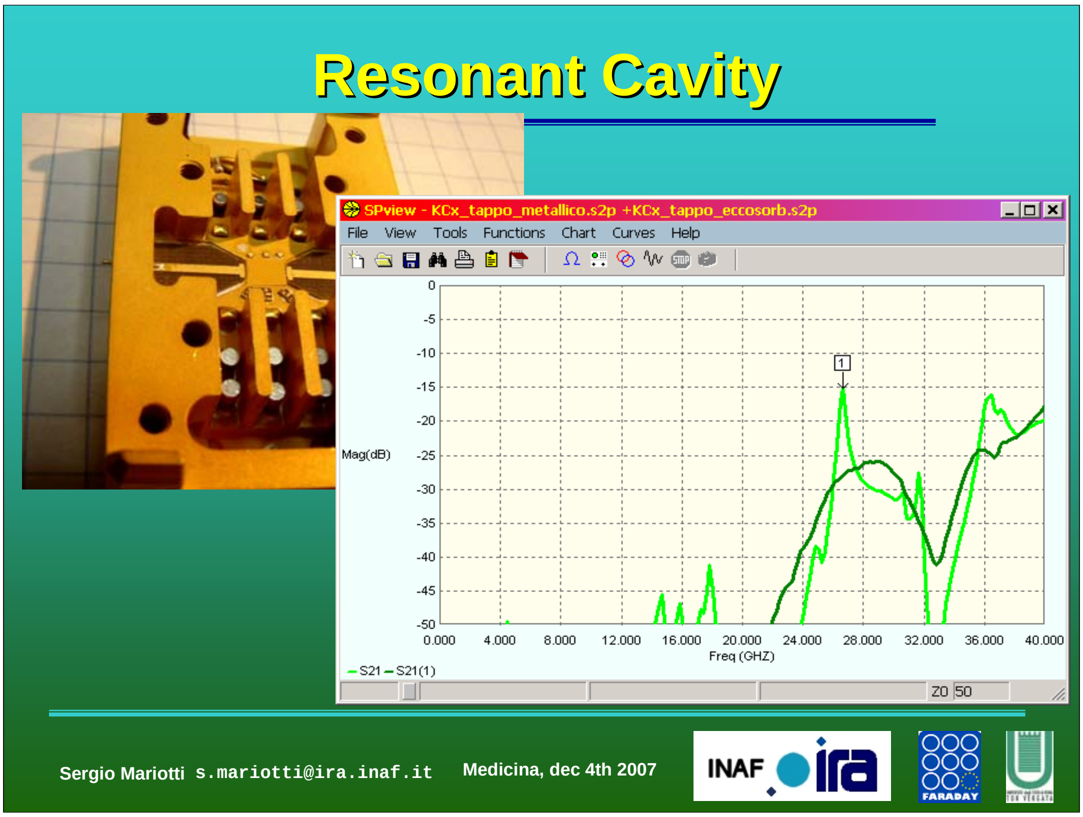


All Jig has been produced whit thigh tapped holes. Instead M2.5 the holes had smaller diameter.

Since the behavior of the CE7 is similar to glass, it became nearly impossible to tap once again the holes without damage.

After a long and slow agreement whit the Supplier, the solution has been the following:
- No one machining on LNA

- Use of M2 screws instead M2.5, this screws will be screwed into a new copper made, back-flange that acts twice function: became a sandwich for the LNA and thermal clamping to better connect to the 20 K cooling source.

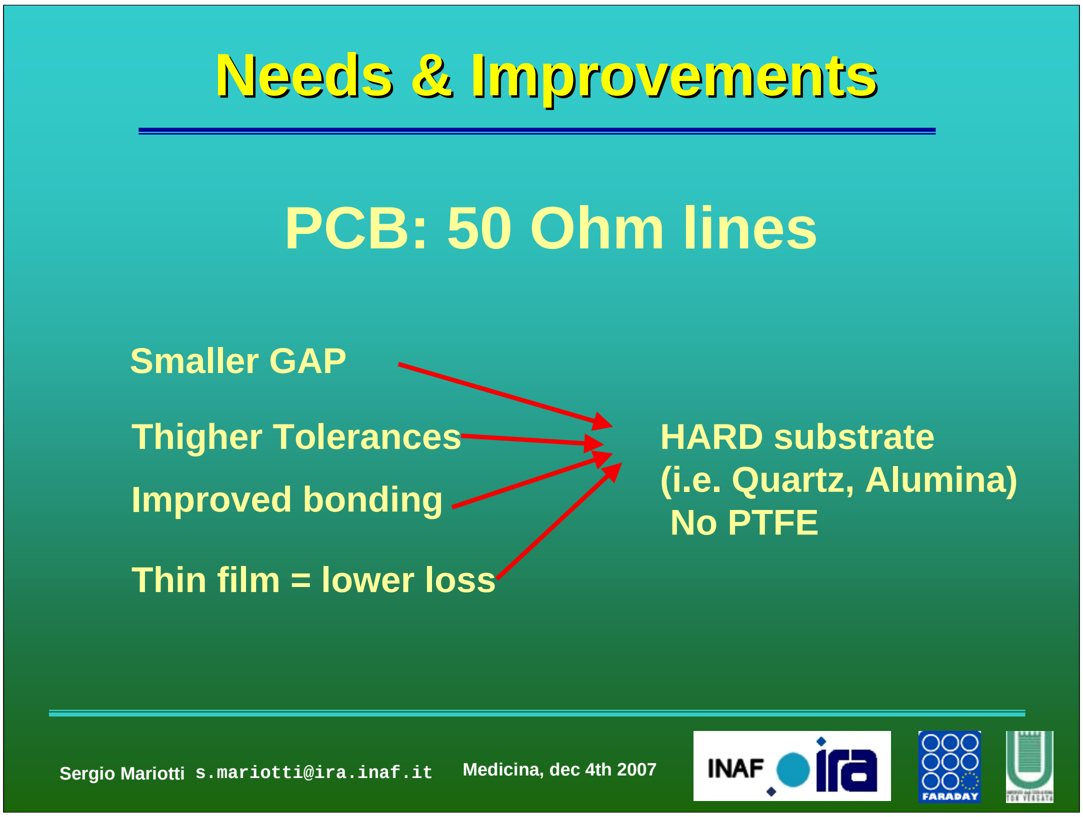


Please, take a look at the cavity where the MMIC will be placed.

The two 50 Ohm lines , isolated and non touching, are cavity coupled.

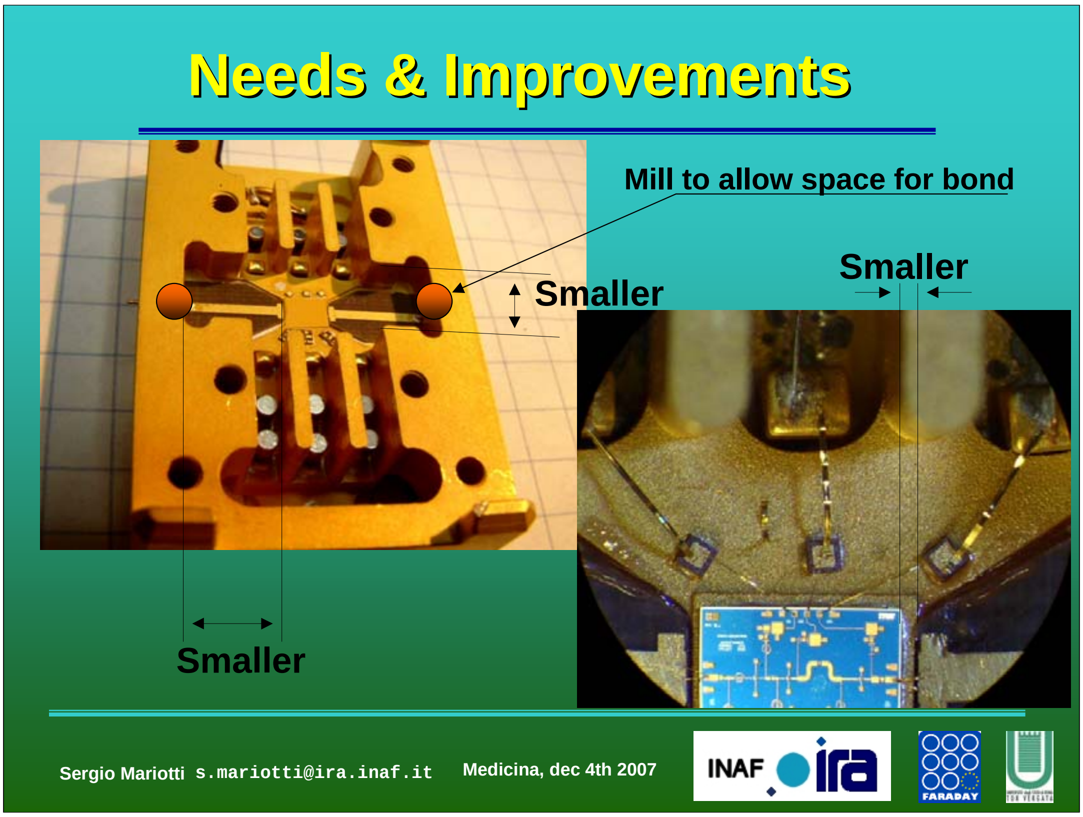
The light curve shows the coupling when the jig is closed with a metal cover, while the dark curve shows the behavior of a cover with a small ECCOSORB glued to it.

It is evident that around 26 GHz for Gain > 25 dB the risk of self oscillation is very high.



Improvements:
Switching from PTFE based PCB to Hard PCB like Quartz or Alumina, we may reduce the gap (because closer tolerances), we may improve bonding efficiency and reduce the loss (both metal and dielectric).

In orser to reduce the loss of the microstrip, the line width (W) should still remain constant (even if ε_r increase) and the surface roughness should be very low (thin film technology).



Improvement:

The 50 Ohm lines length should be reduced.

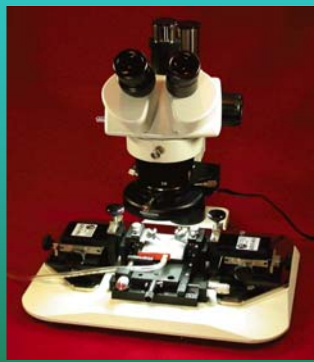
The Cavity dimensions should be reduced.

The MMIC pedestal dimension should be reduced (will reduce bond-wire length).

A deep milling should be made close to coax pin. This milling will create space for bonding tool. The target is replace the solder joint with a boding.

Needs & Improvements

Check & Test MMIC
before gluing into jig



Maintenance & Troubleshooting
of assembled LNA

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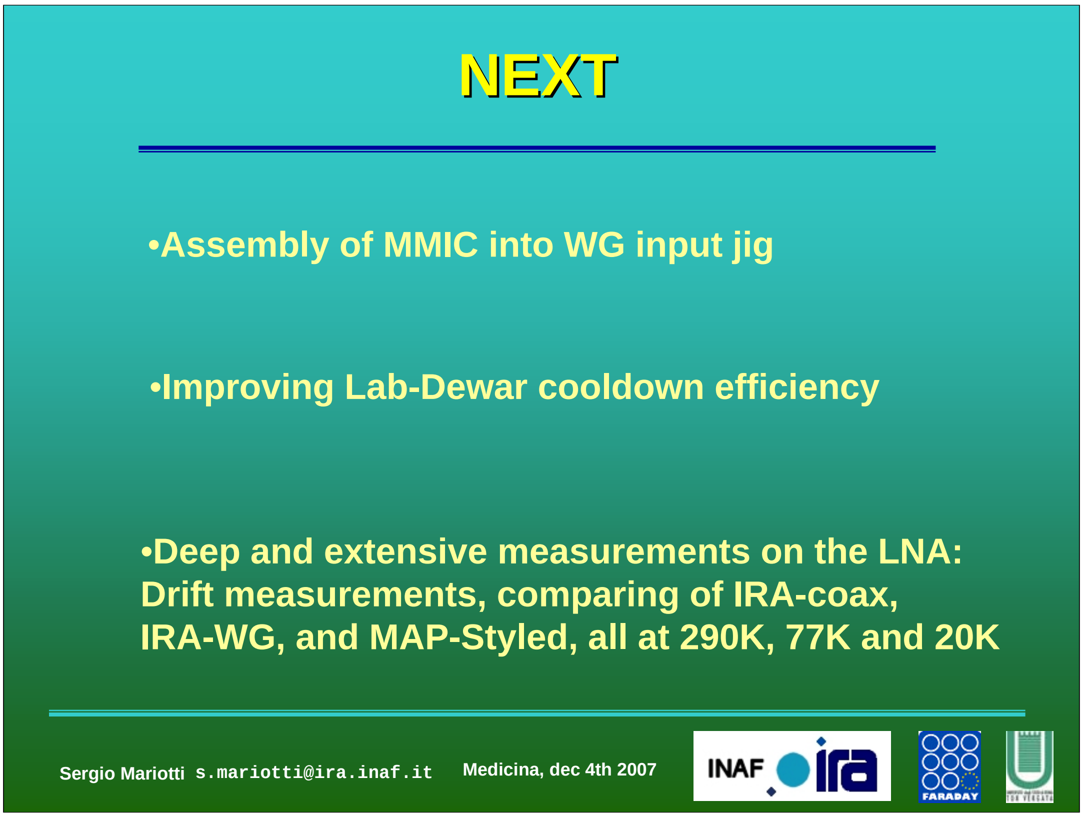
A Personal probe station is a cost effective instrument capable to test MMIC before gluing and bonding. 5K€.



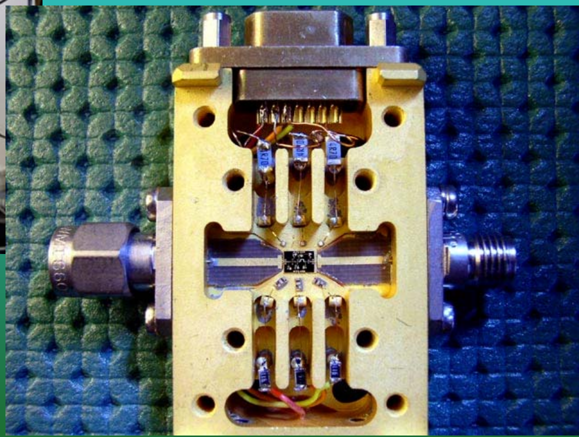
Next jobs:

Assembly of few prototipes of LNA using the same MMIC but equipped with a waveguide input port.

Improving the cryogenic capability of the laboratory by restyling the test&measurement dewar. The cooldown time will be reduced.

Deep test & measurements on LNA, drift measuremet, comparing of the following LNA; IRA-MMIC-Coax, IRA-MMIC-WG, MAP-Styled, all at 290K, 77K, 20K.

Thanks



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