MMICs for multi pixel receivers

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Outline

- Introduction
- MMICs
- Semiconductor technology
- Scenario
- Examples of MMICs used in array receivers for radioastronomy
- Projects in progress
- Remarks on MMIC based devices
- Conclusions

Introduction

The evolution of instruments for radioastronomical observation is nowadays strongly oriented on developing and exploiting the array concept.

Array of antennas

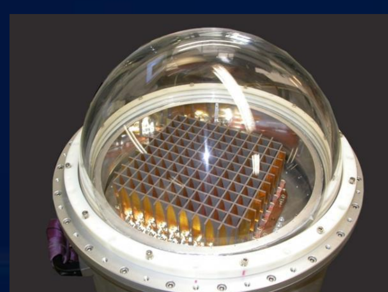

VLA

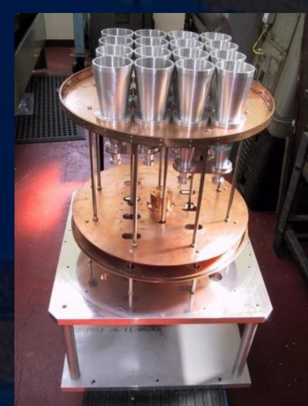

ATCA


ALMA


SKA

Array of receivers


C-band


Ka-Band


K-band

Introduction

Several aspects of this concept are attractive:

Focal plane array receivers

Improve antenna observing efficiency allowing faster surveys

Increase Sensitivity especially for radiometric purposes

Phase Array receivers

Increase System Flexibility allowing beamforming and steering

Allow the generation of more than one beam

MMICs

In the technologies applied to radioastronomy interest in MMICs grows as the needs of low cost, small scale production, high integrated solution.

Hybrid devices, created with discrete components provide paramount performances, but the realisation on large scale has high cost, assembling time, reliability strictly related on manufacturing.

MIC vs MMIC

Active devices are manufactured using the same process

Active device selection is possible

Passive Catalog is the entire market

MMIC is a MUST for mass production

And

MIC "fine Art" Skills are a MUST in order to maximize MMICs performances exploitation

MMICs selection is possible

Passive Catalog is limited by foundry process

MMICs performances are less human skills dependant

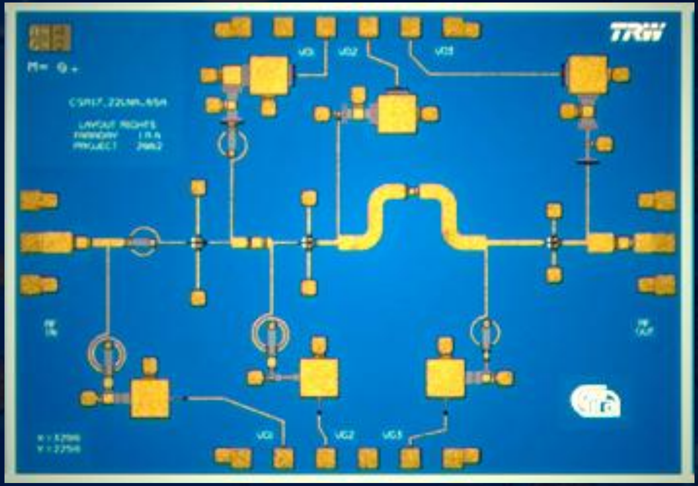
MMICs developing cost is higher

MMICs is less expensive for small mass production

MMIC technology allows to include in a single chip several active and passive components in order to realise a function or a set of functions.

Assets:

- Lower cost
- Fast production
- Higher repeatability and reliability



Fundamental requirements are:

- Low power consumption
- Low noise

An asset for radioastronomical application : CryoREL

Semiconductor technology

InP HEMT→

- Best consolidated process for noise and cryo applications
- State of the art at 35nm with applications up to 350 GHz

InP mHEMT →

- InP on GaAs : one more degree of freedom in the process
- EU foundries, no ITAR , no geopolitical availability dependency
- Preliminary cryo results in Q and W band

InSb HEMT → Extremely Low power consumption .

Could be the future for Large arrays cryogenic applications

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Scenario

InP HEMT

NCG

HRL

InP mHEMT

IAF (D)

OMMIC (F)

InP , InSb HEMT

Chalmers Univ. (S)

OPTEL (I)

UMAN (UK)

ETH (CH)

Some examples of MMICs used on Array receivers for radioastronomy

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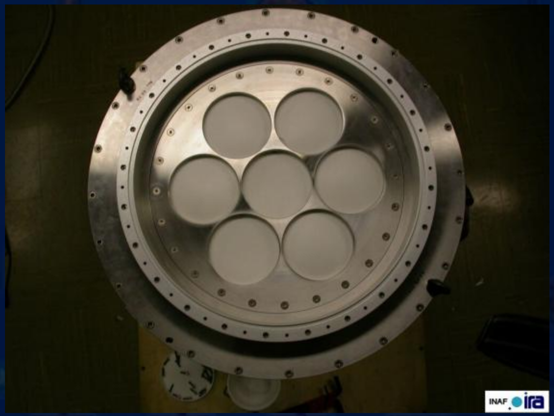
FARADAY

Designed By INAF-IRA

Tested on 32 mt Medicina radiotelescope

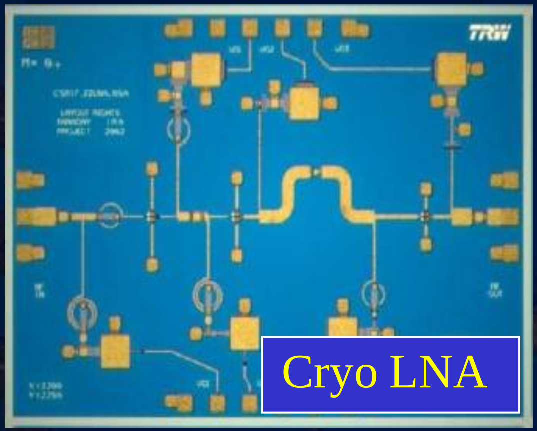
Final Destination 64mt SRT

- Multifeed Focal Plane Array
- 7 Horns - 14 Channels
- Working from 18-26 GHz
- For Secondary Focus
- Heterodyne architecture
- Cryogenically cooled

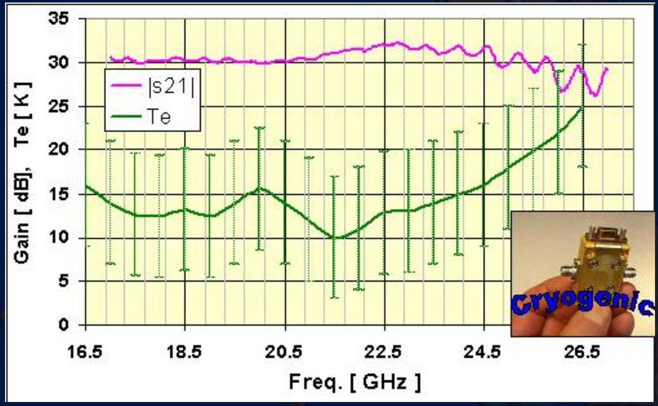


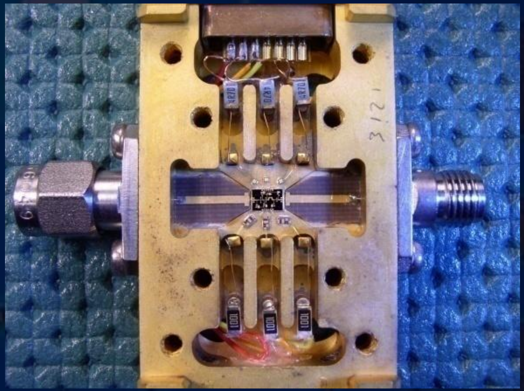
MMICs application :LNAs

NGC 0.1 InP HEMT
- 14 Cryo LNAs
- 14 “warm” LNAs

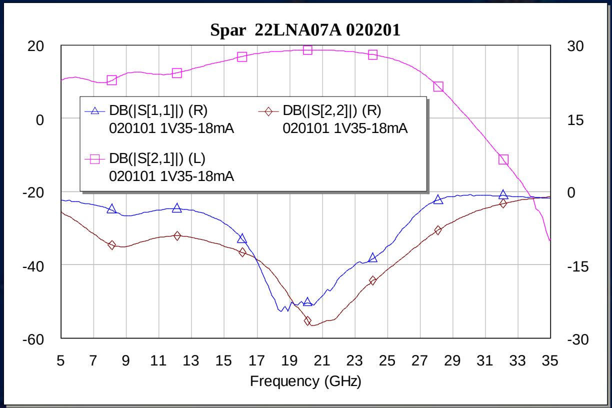


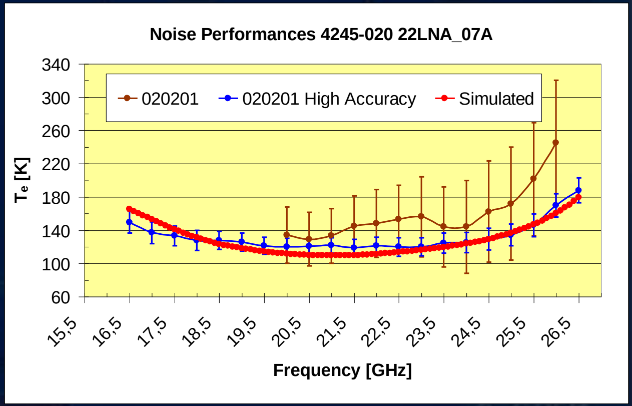
Cryo LNA





“Warm” LNA

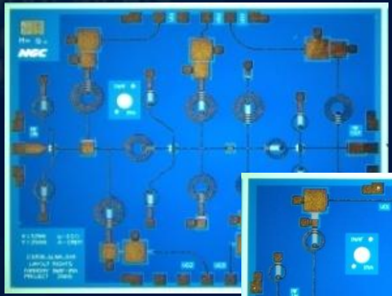




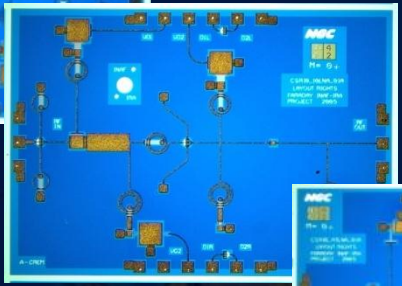
MMICs Extra results

NGC 0.1 InP HEMT

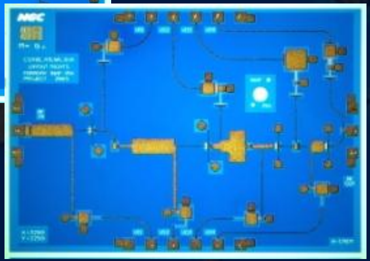
7 Cryo LNAs Designs between 4 to 120 GHz



4-8 Ghz

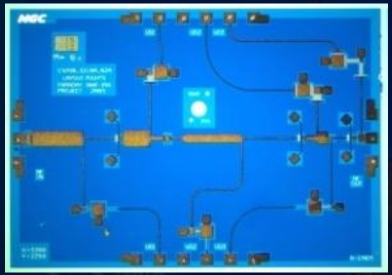


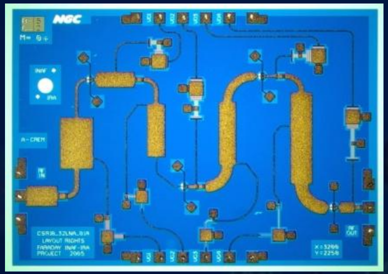
8 - 12 Ghz



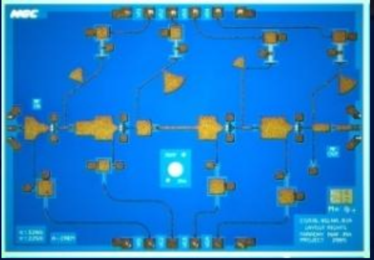
33-50 Ghz

26 - 40 Ghz

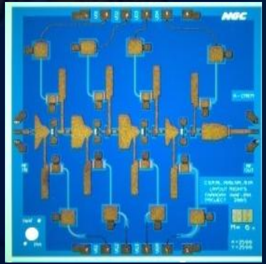




60-85 Ghz



70 - 100 Ghz



OCRA-F

Designed By JBO (UK)

Final Destination Torun (PL)

- Multifeed Focal Plane Array receiver
- 8 (later 16) Beams
- Working from 26-36 GHz
- Pseudo correlation Direct Detection Architecture
- Cryogenically cooled

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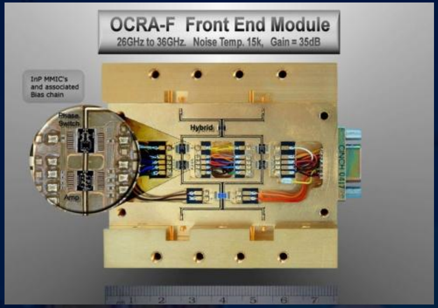
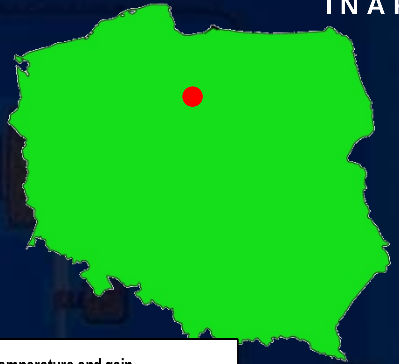
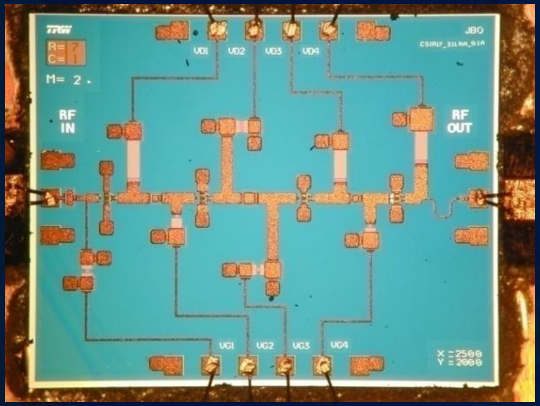
MMICs application :LNAs, Phase switches

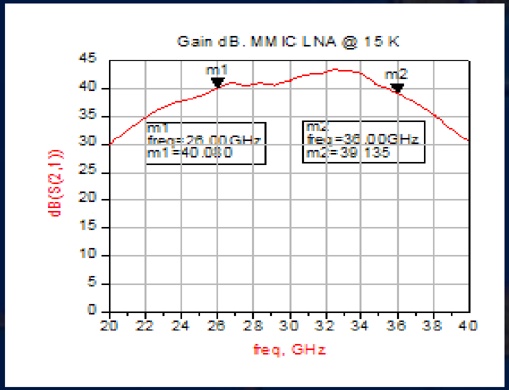
NGC 0.1 InP HEMT

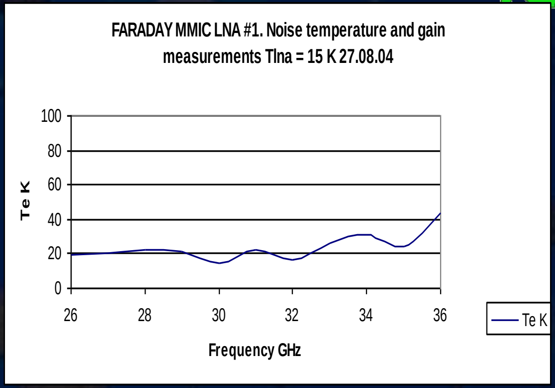
- 8 Cryo LNAs
- 8 Cryo phase switches

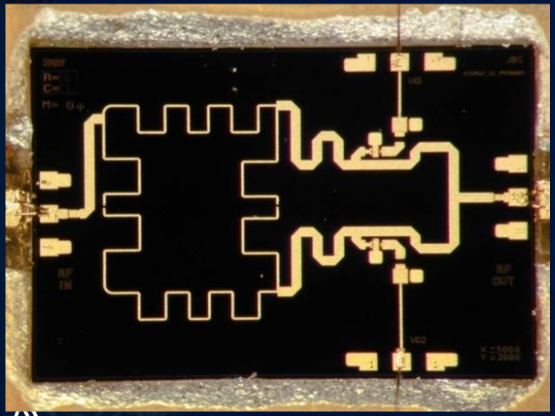


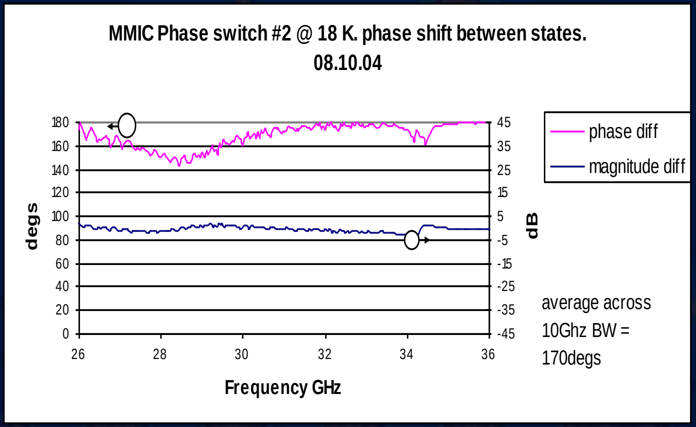








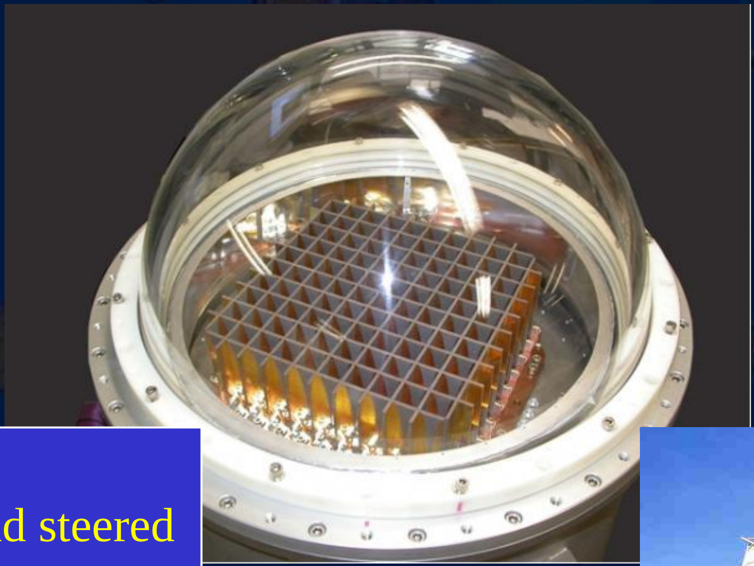




Pharos

Facilities : JBO

Design :Pharos Consortioum leaded by ASTRON

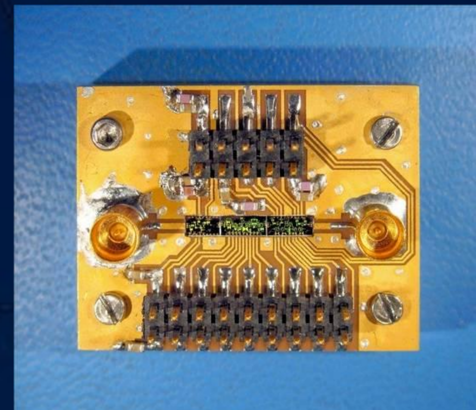


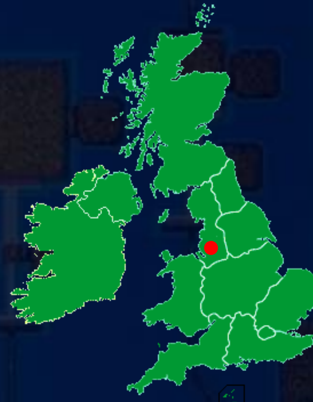
- Vivaldi Dense Phased Array
- 4 beams electronically formed and steered
- Single polarisation
- Working from 4 to 8 GHz
- For Primary Focus
- Cryogenically cooled

MMICs application :LNAs, Phase switches

OMMIC ED02H GaAs HEMT Process

- 24 Cryo LNAs (20K)
- 52 Buffers Amplifiers (77K)
- 52 Phase controller (77K)
- 52 Amplitude controller (77K)

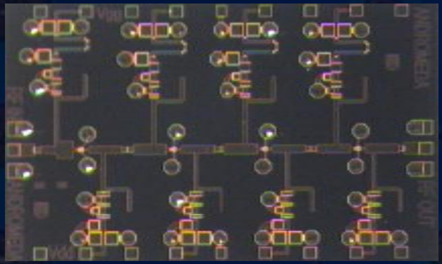


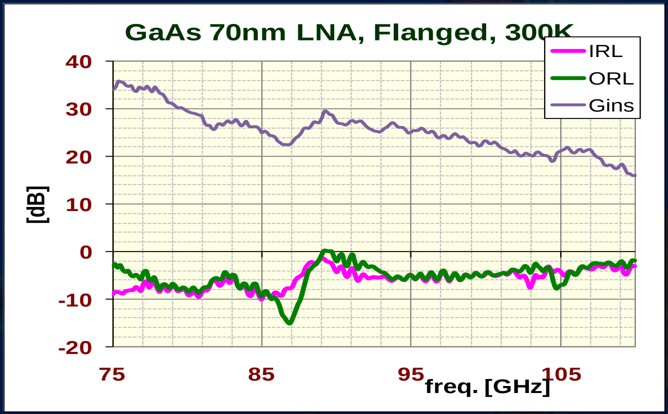


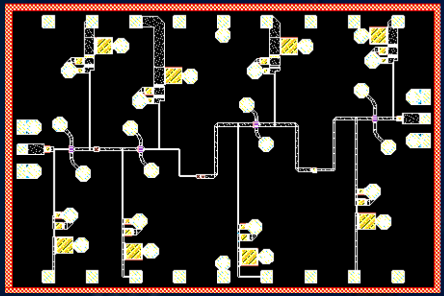
Pharos MMICs Extra results

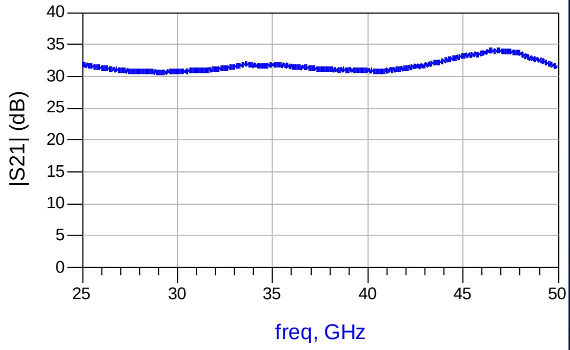
OMMIC D007IH 70 nm InP on GaAs mHEMT Process

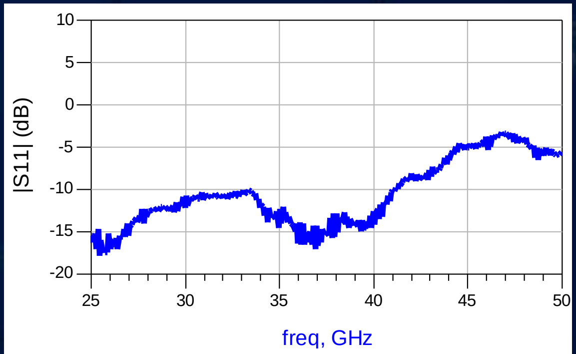
- Q-band LNA
- W-band LNA











Projects in Progress

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Apricot (All Purpose Radio Imaging Cameras on Telescopes)

FP7 Project funded within Radionet

Partners: UMAN, MPfIR,IRA,UTV, CAY, TCfA, FG-IGN

Aim : Define architecture and validate technologies for multi purposes large format focal plane "radio camera"

Frequency range : 33-50 GHz (Q-Band).

Design a MMIC Q band heterodyne receiver chipset using mHEMT foundry process available at OMMIC and IAF

LNA
Mixing
Multiplier

APRICOT

ASImm

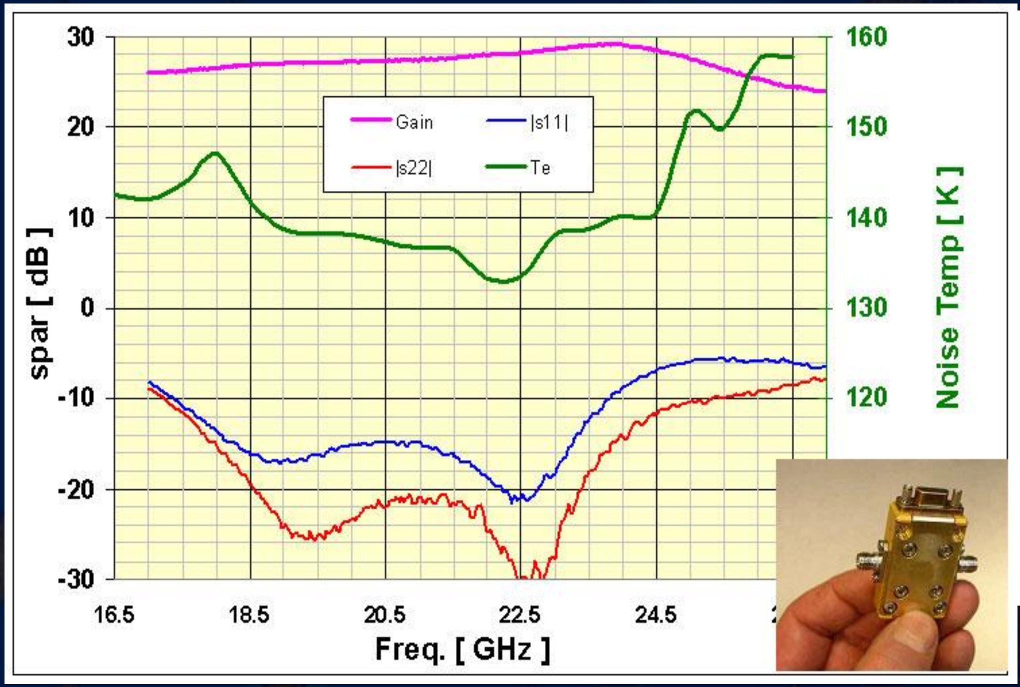
Project funded by ASI (Italian Space Agency)
Partners: Thales (as prime contractor), Officine Pasquali
INAF, UNI-MI, UNI-GE, UNIROMA1,CNR
Aim : Validate technologies for future space experiments
Frequency range : W-band

Design W-band devices radiometric purposes using OMMIC MMIC mHEMT foundry process and IAF mHEMT foundry process

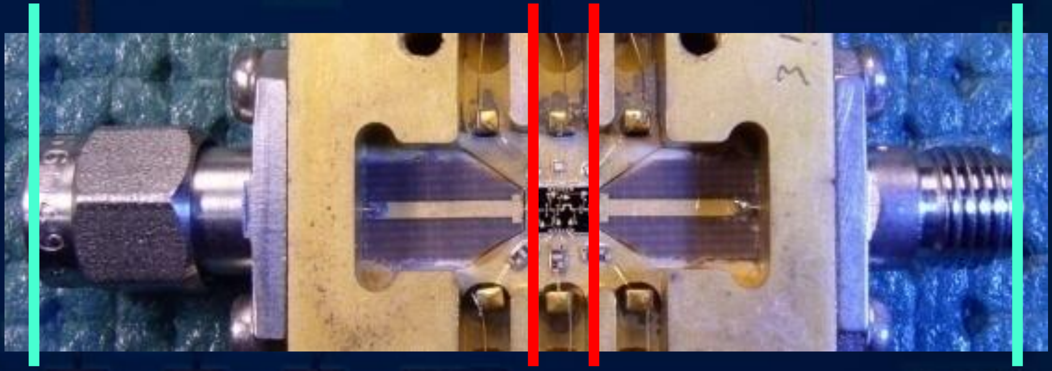
Improve Packaging and Assembling Techniques

Remarks on MMIC based devices

MMIC Design



This could be a MMIC designer trap



Wiring

100 Dual Polarization channels at WR-22
200 four stages LNAs
1800 Wires

100 Dual Polarisation channels at WR-10
200 + 200 five stages LNAs
4400 Wires

Separate stage biasing is important in order to compensate the temperature effect and find the best trade off between noise, gain , match and...☹ Oscillations

Embed a cryogenic bias supply "remotely controlled"

Improve cryomodels and Foundry process

Release flexibility specifications

MMIC Packaging

Housing could waste most of efforts devoted in MMIC design in order to obtain state of the art results

Housing has influence on

Self resonances

Matching (Gain and Noise)

Reliability

Crucial Aspects are:

Housing Alloys

Attaching method

The choice is not unique BUT is APPLICATION DEPENDANT

For Cryogenic MMICs devices, Differential CTE between all the joined elements MUST be carefully taken into account , because STRESS between components can DAMAGE them

Conclusion

- Array receiver architecture make the MMIC opportunity more than attractive. Several examples of array receivers already prove it.
- Semiconductor scenario give several opportunity to exploit MMIC potentiality
- Excellent MMIC design is a necessary starting point but it is not SUFFICIENT
- MIC designers experiences and manufacturer skillness are NECESSARY in order to realise the devices

- Radioastronomy can get many advantages by MMICs
- Developing an MMIC foundry process oriented to cryogenic radioastronomical applications is NOT a foundry mainstream
- MMICs R&D on foundry process and on devices is EXPENSIVE
- Radioastronomical community MUST SYNERGICALLY INVEST on it

Research Groups involved in the described activities

ASTRON

INAF

THE UNIVERSITY of MANCHESTER

FARADAY

APRICOT

CSIRO

CAY

PHAROS

Max-Planck-Institut für Radioastronomie

Mecsa

agenzia spaziale italiana

INAF

Thanks
For your attention

A. Cremonini