MMICs for multi pixel receivers

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Outline

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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 performances are less human skills dependant.
- MMICs developing cost is higher.
- MMICs is less expensive for small mass production.

MMICs selection is possible.

Passive Catalog is limited by foundry process.
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
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
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](image1)

![“Warm” LNA](image2)

![Noise Performances](image3)

![Spar 22LNA07A 020201](image4)

![Noise Performances](image5)
MMICs Extra results

NGC 0.1 InP HEMT
7 Cryo LNAs Designs between 4 to 120 GHz

- 4-8 GHz
- 8-12 GHz
- 26-40 GHz
- 33-50 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
MMICs application: LNAs, Phase switches

NGC 0.1 InP HEMT
8 Cryo LNAs
8 Cryo phase switches

FARADAY MMIC LNA #1. Noise temperature and gain measurements $T_{lna} = 15$ K 27.08.04

FARADAY MMIC LNA #1. Noise temperature and gain measurements $T_{lna} = 15$ K 27.08.04

MMIC Phase switch #2 @ 18 K. phase shift between states. 08.10.04

MMIC Phase switch #2 @ 18 K. phase shift between states. 08.10.04

average across 10GHz BW = 170 degs
Pharos

Facilities: JBO

Design: Pharos Consortium led 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

GaAs 70nm LNA, Flanged, 300K

freq, [GHz]

|S21| (dB)

freq, GHz

|S11| (dB)

freq, GHz

GaAs 70nm LNA, Flanged, 300K IRL ORL Gins
Projects in Progress
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
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

Noise Performances 4245-020 22LNA_05A

Noise Temp [K]

Freq. [GHz]
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
Thanks
For your attention
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