Mikrovågskomponenter

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Chalmers University of Technology

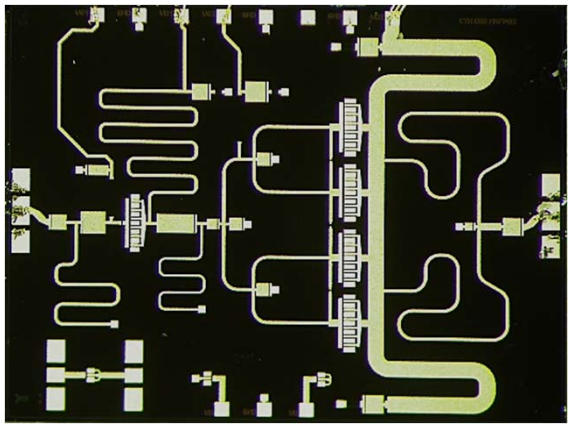
NRFPIII Seminar
November 15th, 2018

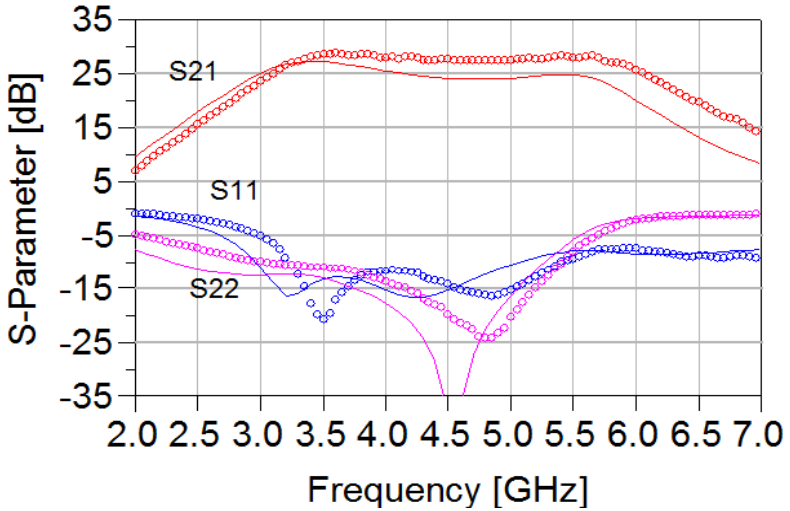
Outline

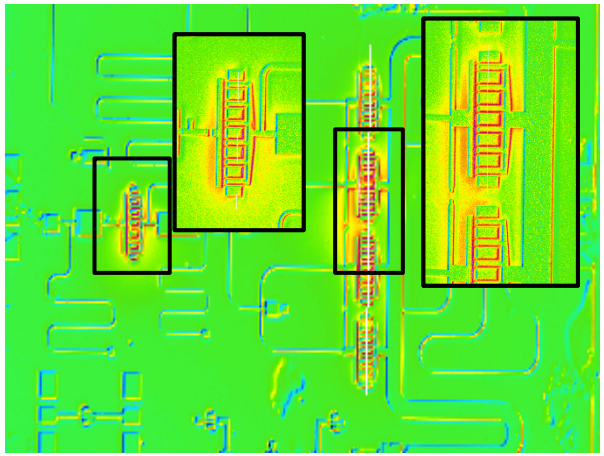
- Description, Motivation and goals
- Power amplifiers
  - C- Band
  - K – Band
- Mixers
  - Ku/Ku Band
  - Hybrid
- Questions

Description

NRFPIII ” Microwave Components” is a continuation from NRFPII







- Output Power: 26.5dBm
- Small signal gain: 28dB gain
- DC consumption < 2W
- Junction temperature < 112° C.
- OIP3 > 40dBm (41.7 dBm)

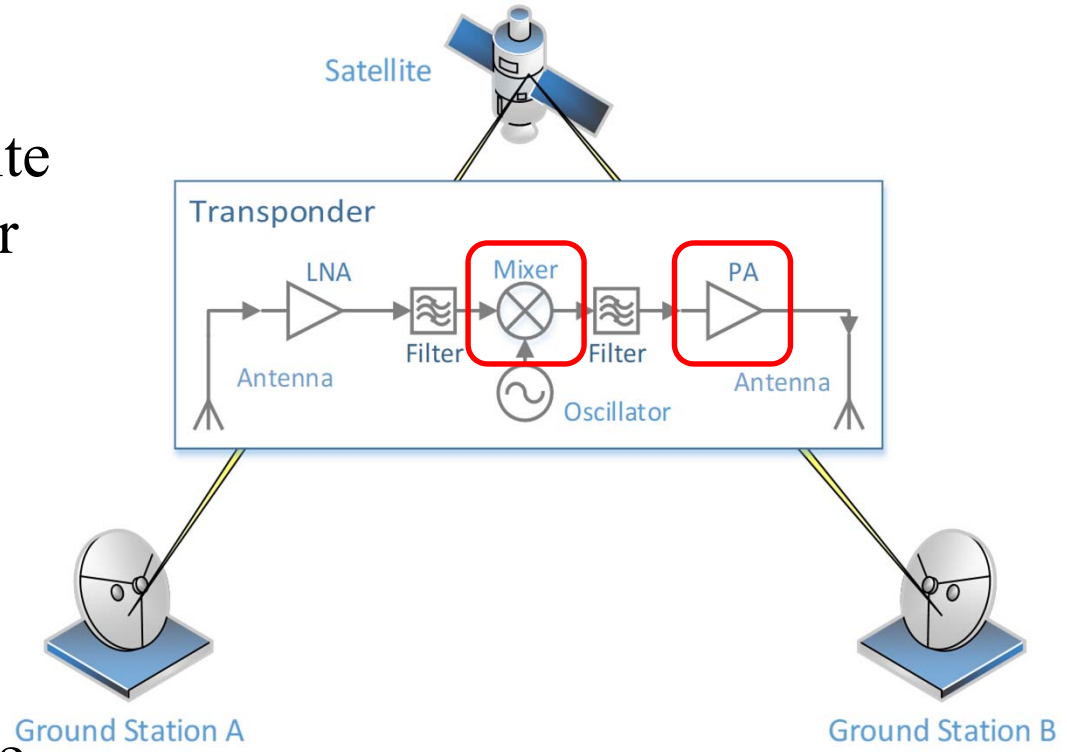
“Octave Band Linear MMIC Amplifier with +40dbm OIP3 for high reliability space applications”
Microwave Theory and Techniques, July 2016

Motivations

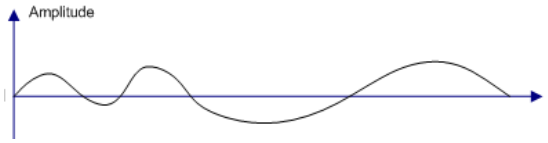
Multiple transponders per satellite
Multiple carriers per transponder

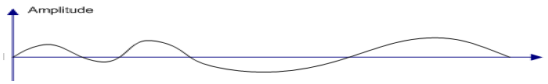
Multiple carriers will combine constructively demanding linearity performance for power amplifier

How to design for high linearity?



General Concepts

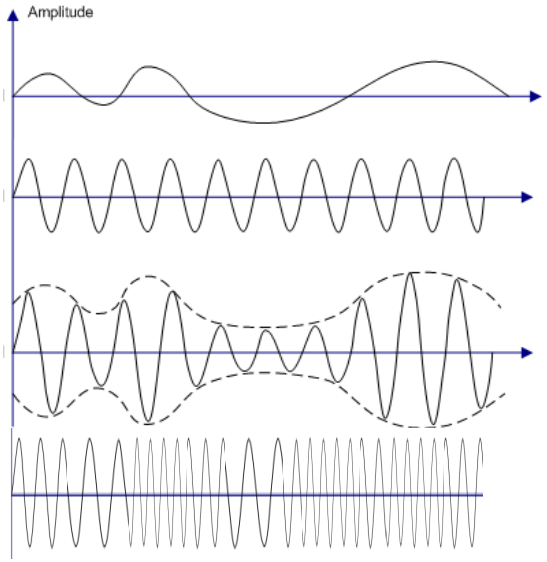




Carrier

AM

FM



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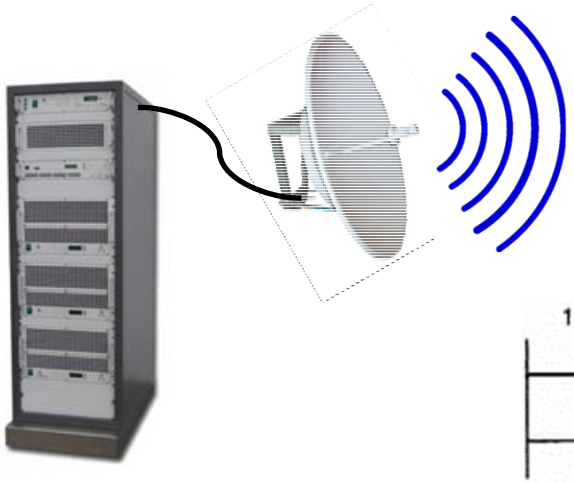

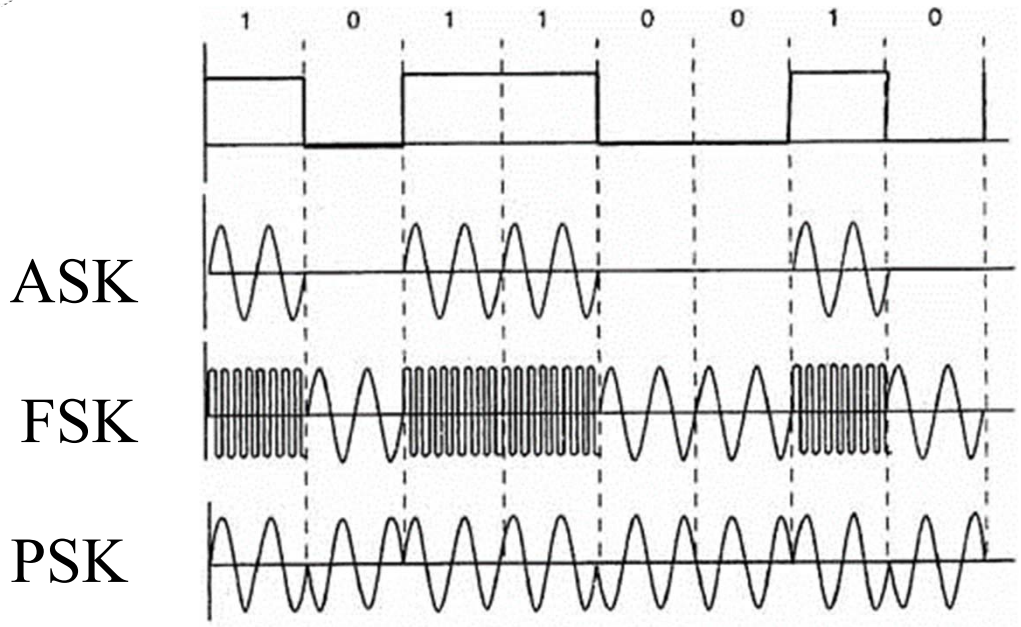

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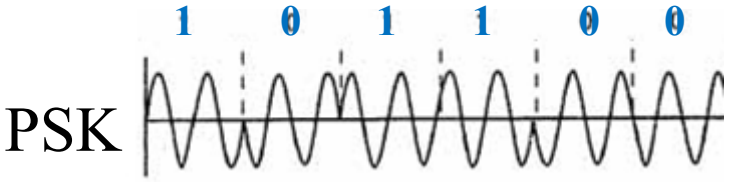
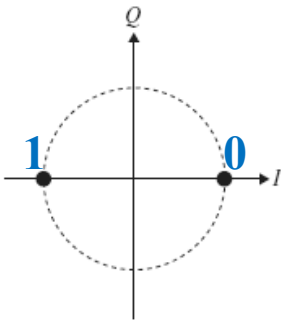
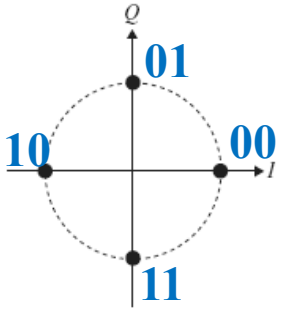
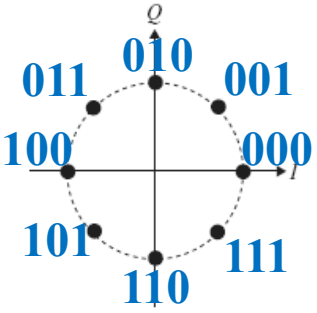




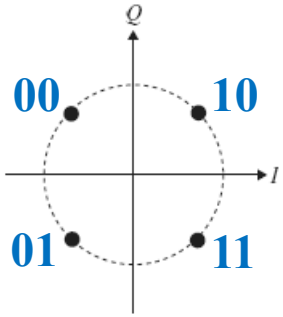
BPSK



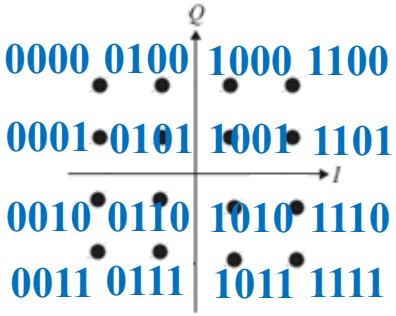
QPSK



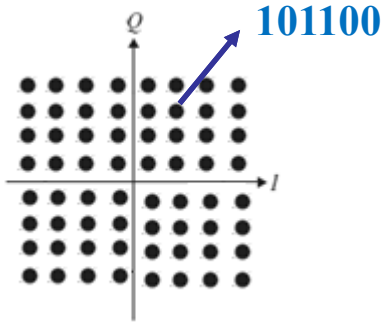
8PSK



4QAM

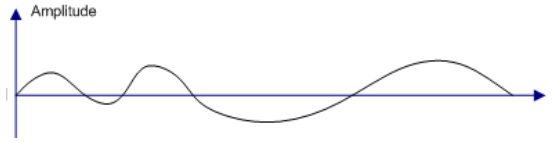


16QAM



64QAM

General Concepts

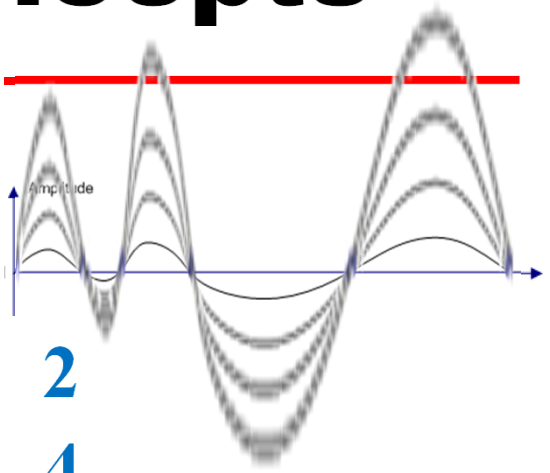


1

2

4

8

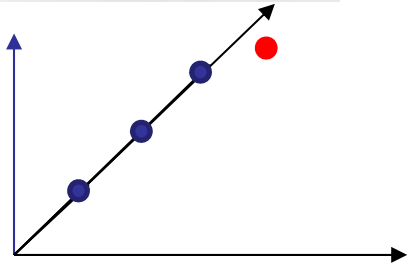


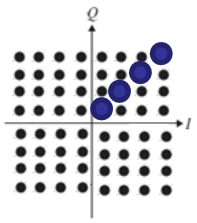
2

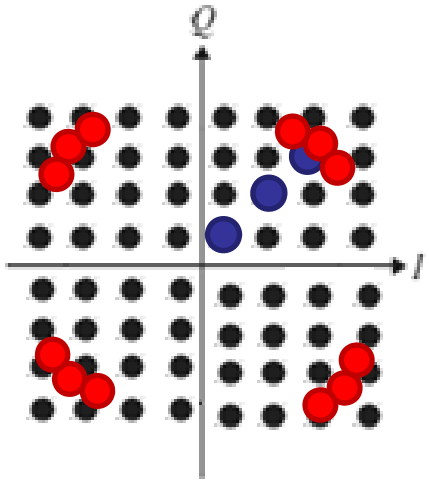
4

8

10







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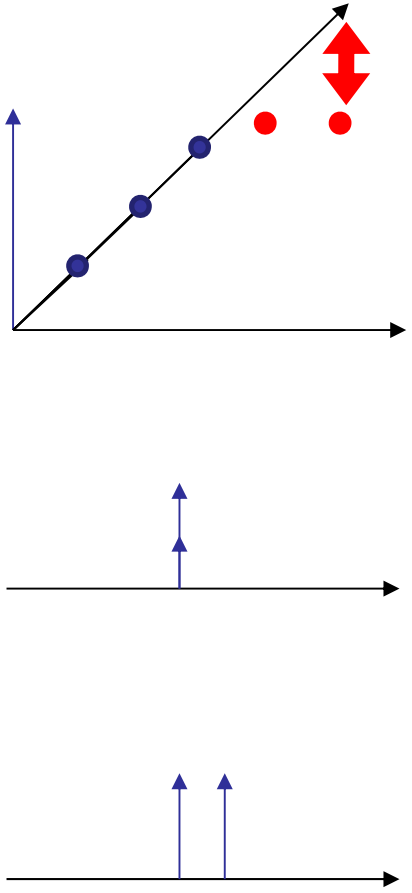

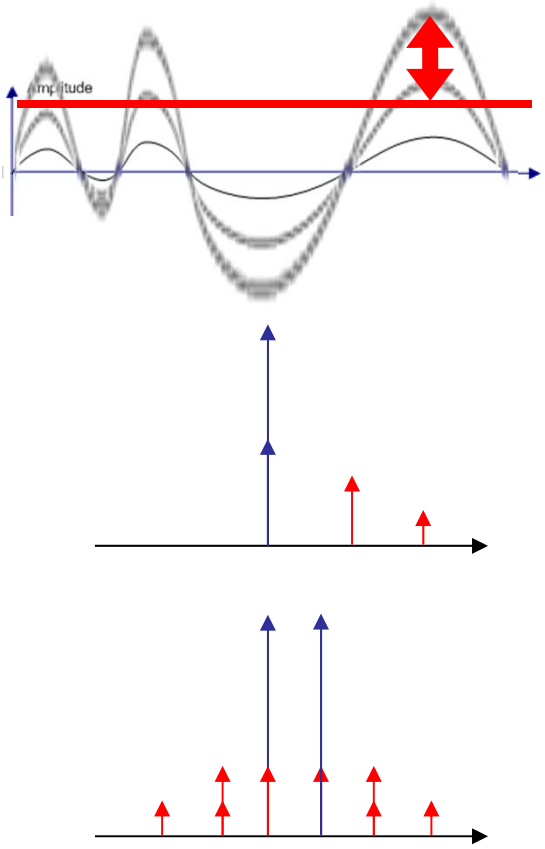

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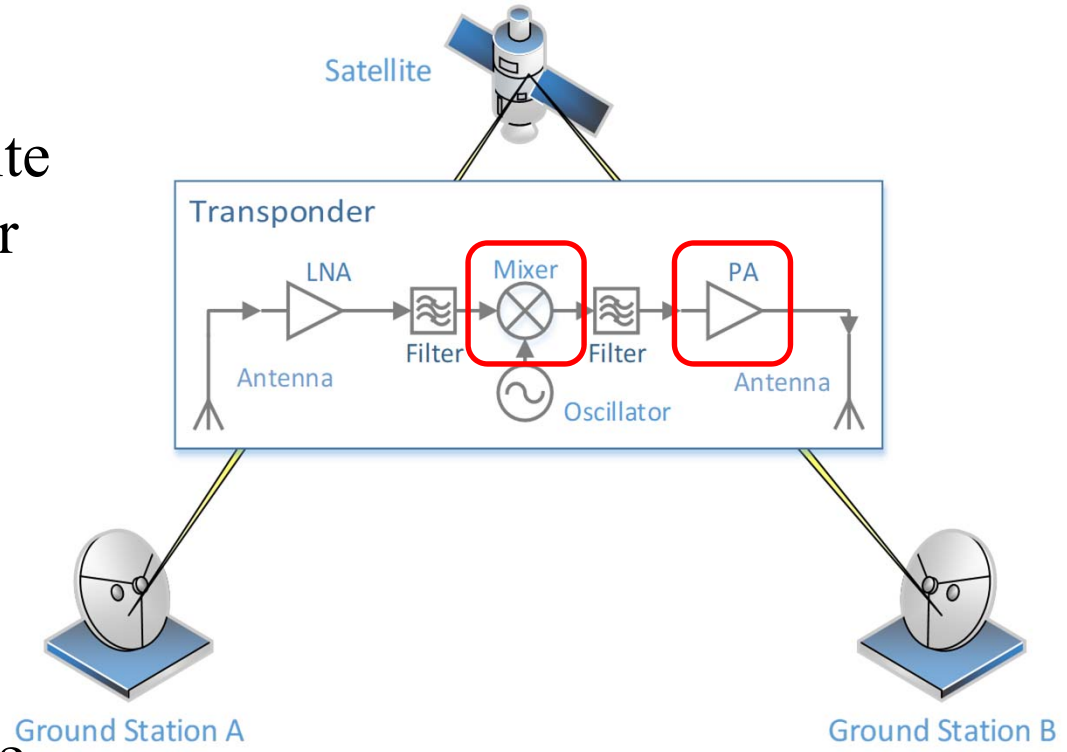

Goals

NRFPIII: **Microwave components**

Goals:

1. Develop a state of the art prototype GaN MMIC Power Amplifier

2. Develop a state of the art prototype low spurious mixer for the 14 to 12 GHz conversions (GaN or GaAs)

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C-Band High Linear Amplifier

- Alternative to the GaAs amplifier from NRFPII

- GH25 GaN MMIC process from UMS Semiconductors
  - Power Density 4W/mm
  - Cut off Frequency 25GHz

- Designed following the method proposed in the NRFPII project:
- 1. Nonlinear device modeling
- 2. Junction temperature prediction
- 3. Circuit design

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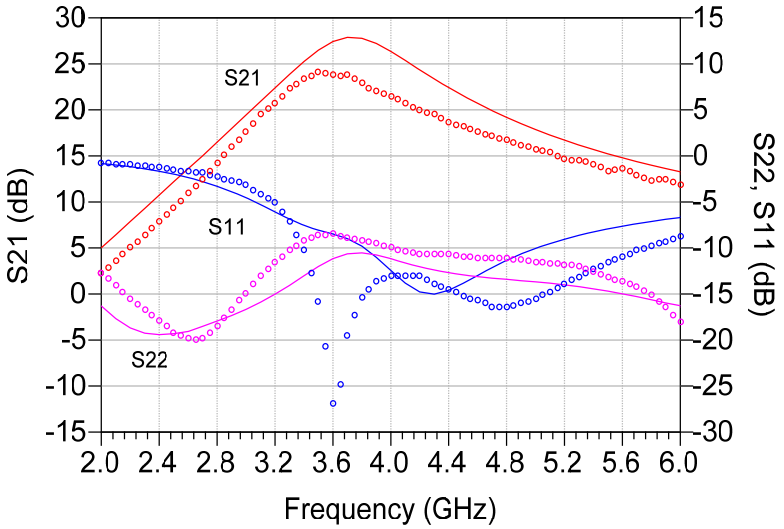
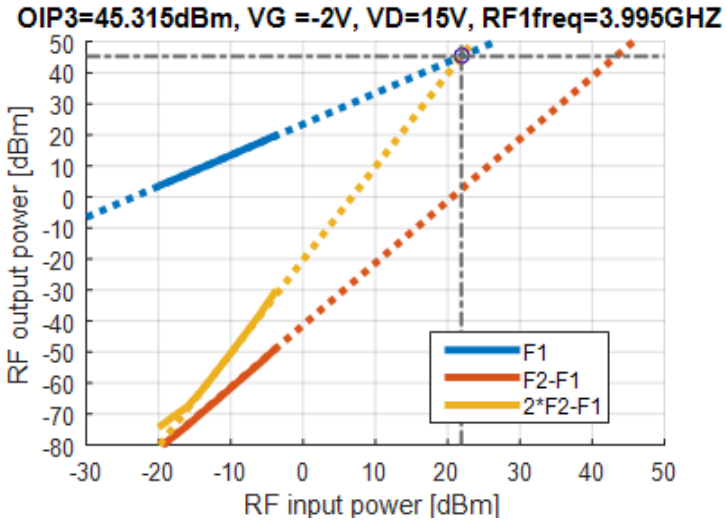
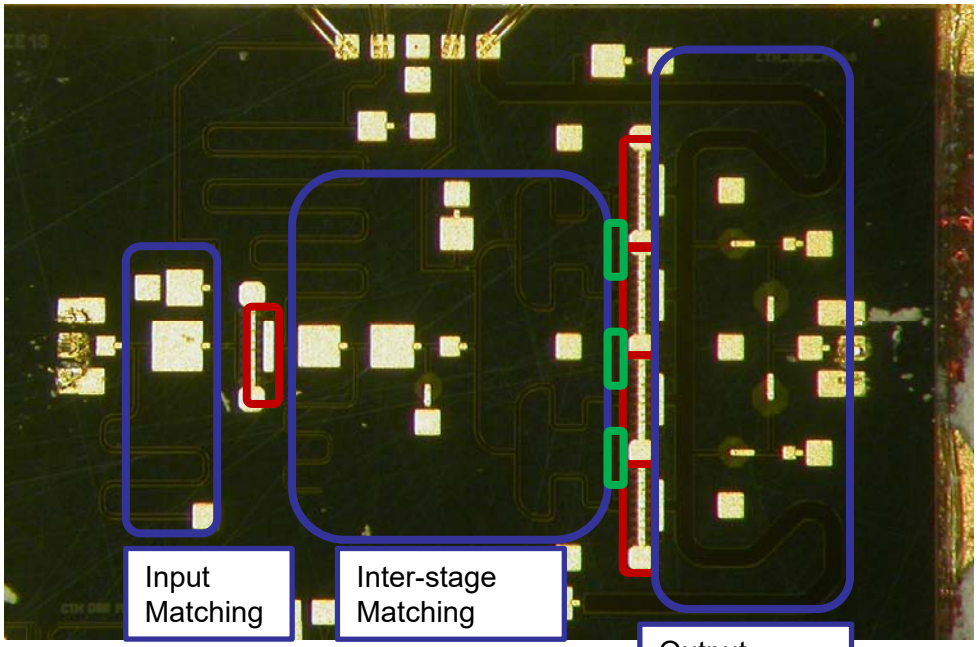
C-Band High Linear Amplifier





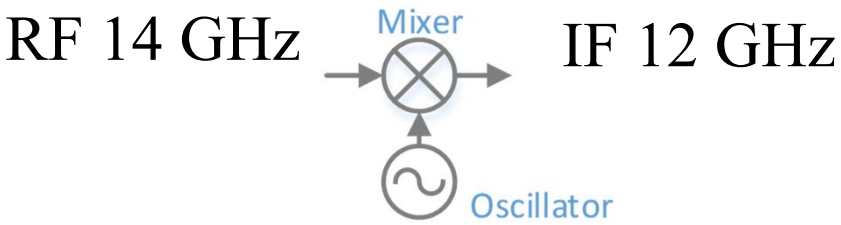


- 4 Watts output power
- Small signal gain: 24.6dB gain
- OIP3 > 45dBm
- Expected lifetime > 10^6 hours @ 200˚C

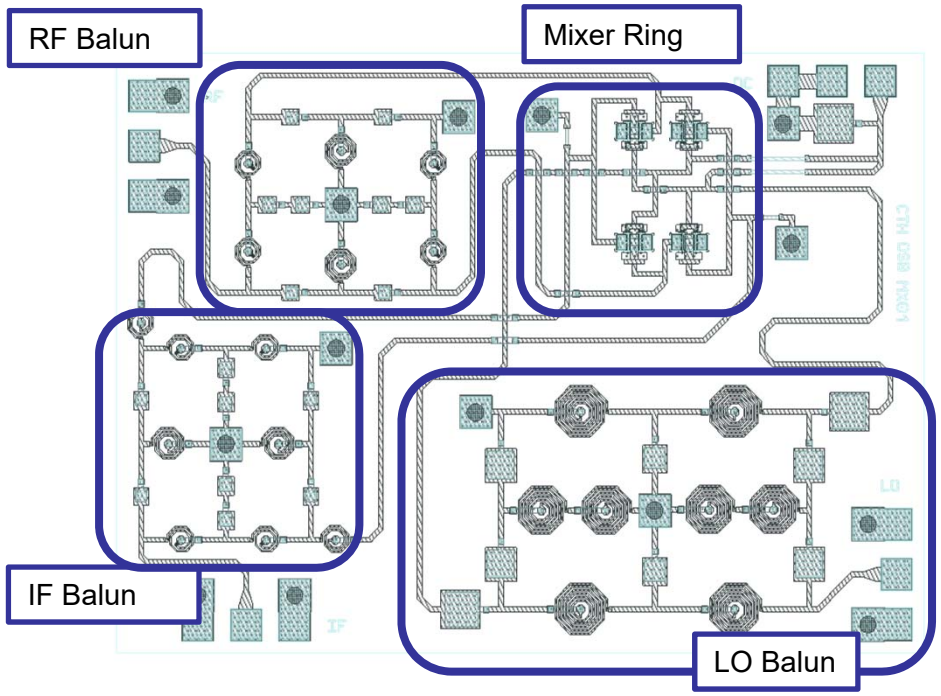
"4 W Highly Linear And reliable GaN Power Amplifier for C-Band Applications". Asia Pacific Microwave Conference, Nanjing, China

KU/Ku Mixer

- Intended for on board transponder focused on low spurious behavior
- GH25 GaN MMIC process from UMS Semiconductors
- High integration of passive structures
- Possibility to integrate with other microwave components.

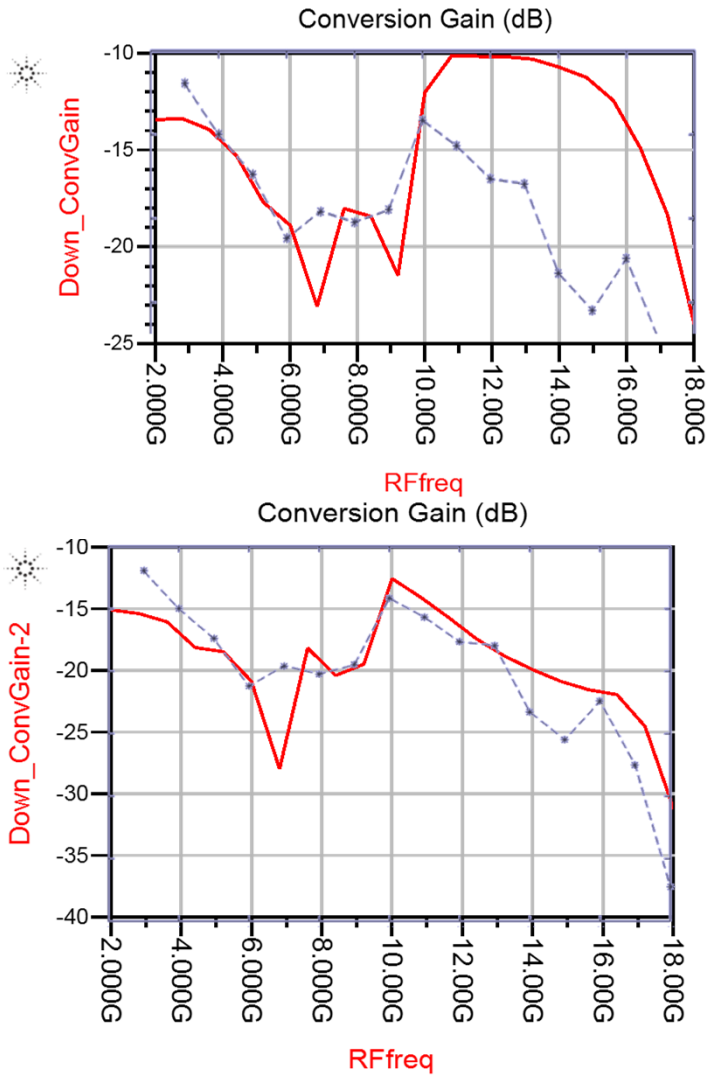


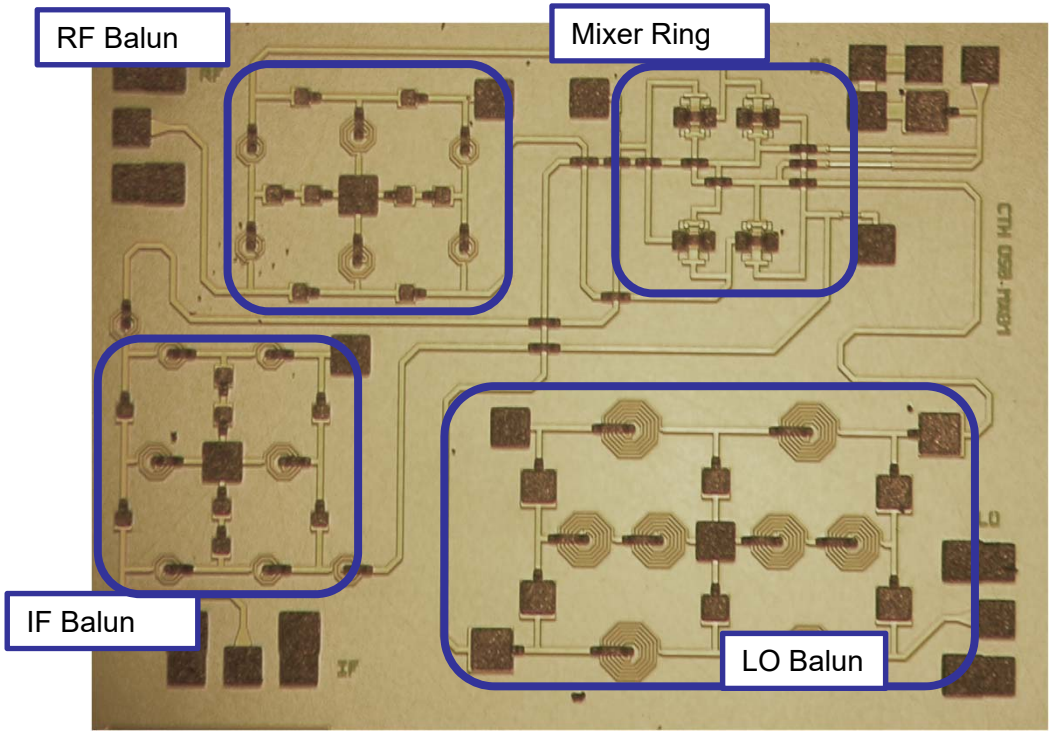
KU/Ku Mixer



- Double balanced mixer topology:
  - RF and LO inputs are divided out of phase
  - Improves isolation and linearity.
- On-chip Baluns

KU/Ku Mixer

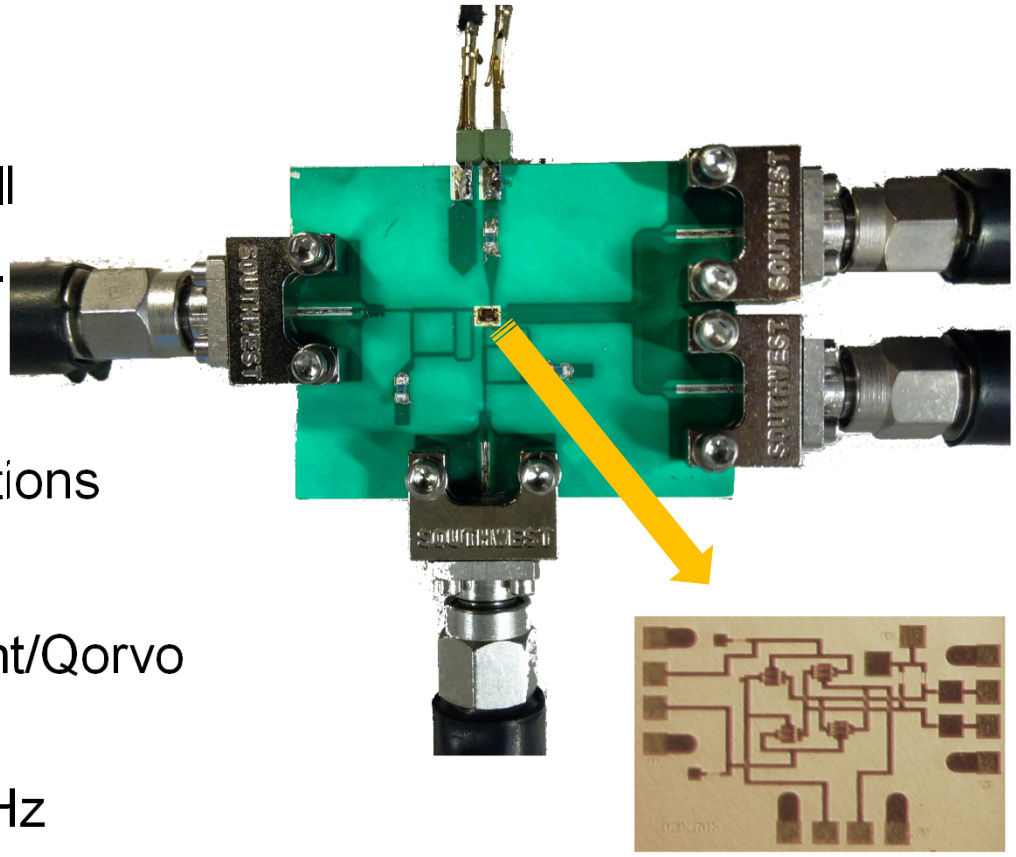




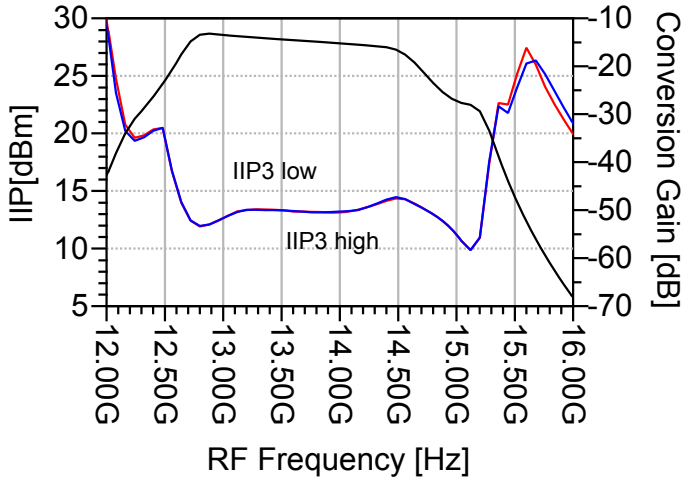
- Technology is suitable for the intended application
- The topology is highly sensitive to unbalances in the ring inputs

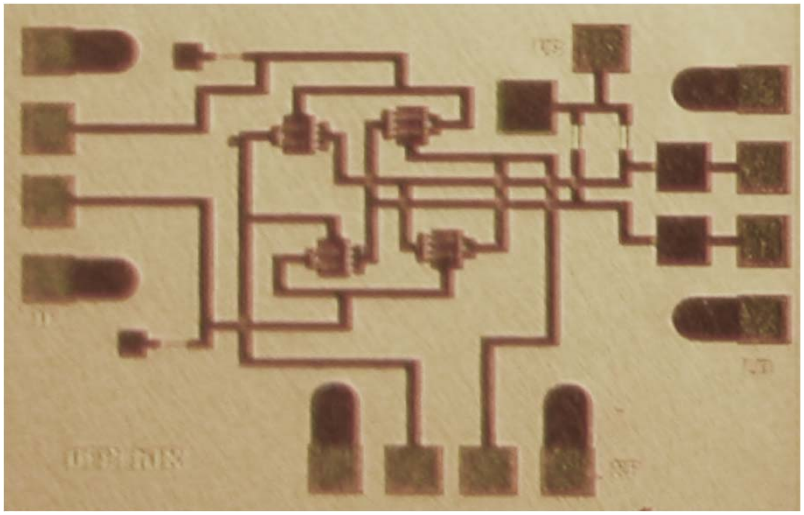
Hybrid GaN Ring Mixer

- Hybrid Mixer
  - MMIC transistors ring cell
  - Baluns designed in PCB.
  - IQ RF, IF, LO signals generated externally
  - Different bands of operations
- GaN TQGaN15 from TriQuint/Qorvo
  - GaN on SiC
  - Cut off frequency 120 GHz
  - High break down voltage



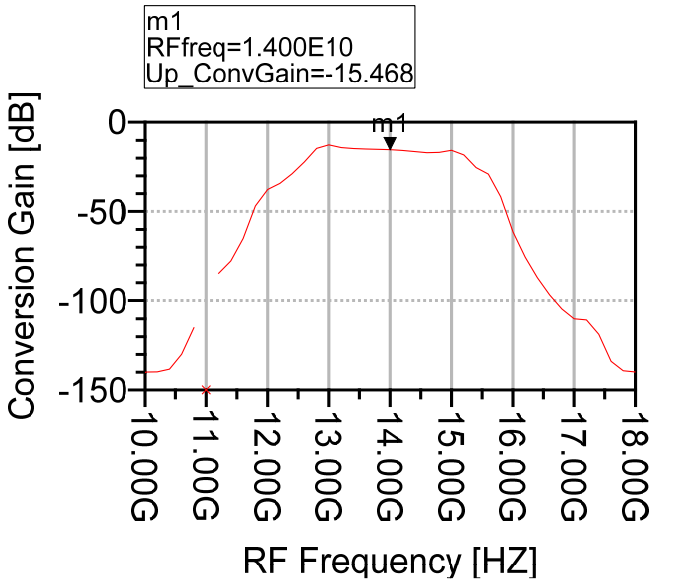
Hybrid GaN Ring Mixer

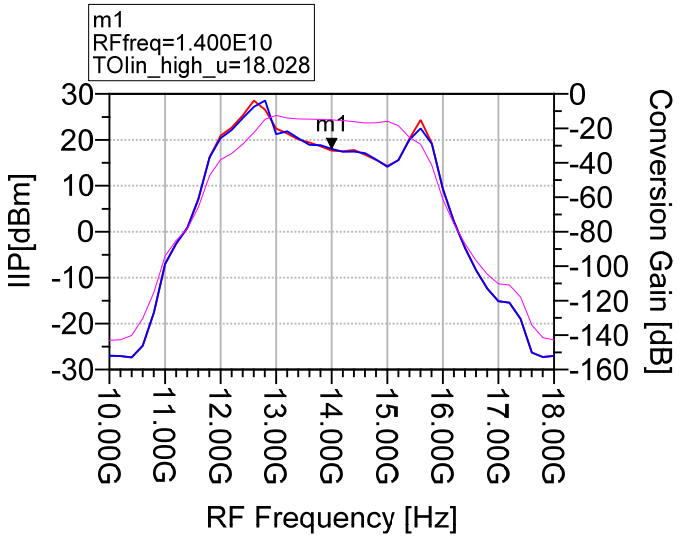




- Simulation results:
  - Input RF -20 dBm @ 12.75 – 14.8 GHz
  - LO Power 10 dBm @ 2.3 GHz
  - CL 10.7 dBm
  - IIP3 > 10 dBm
  - Low spurious (2RF-7LO)

Hybrid GaN Ring Mixer

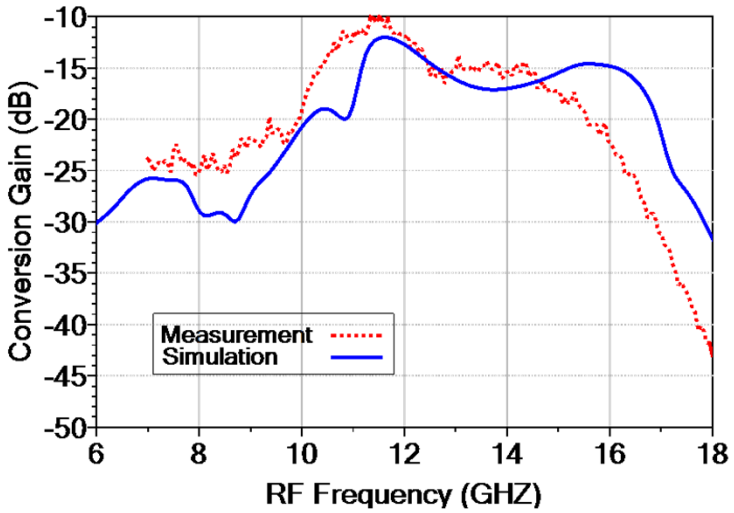


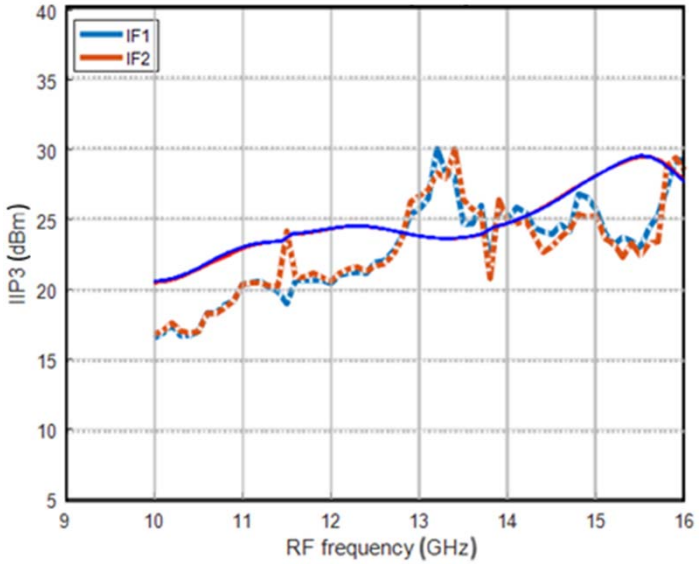


Up converting mixer 14/20 GHZ

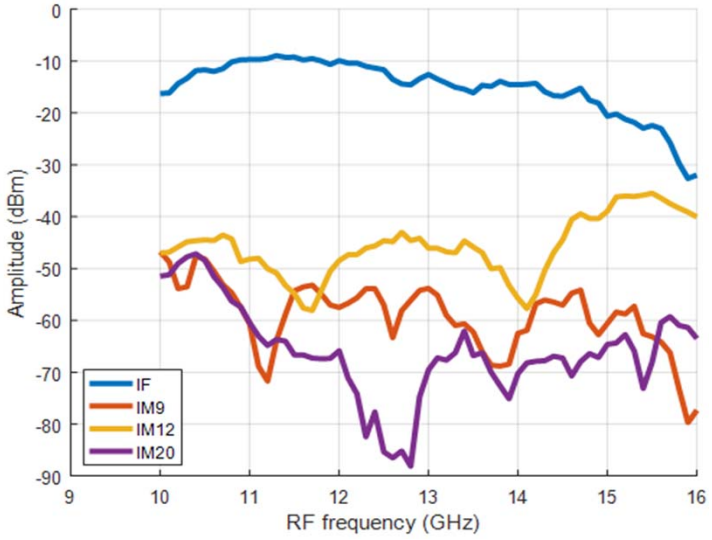
- RF frequency: 12,75 – 14,8 GHZ
- IF Frequency: 17,3 – 21,2 GHz
- LO power= 18 dBm
- Vg= -2.7 V
- RF power -20 dBm

Hybrid GaN Ring Mixer

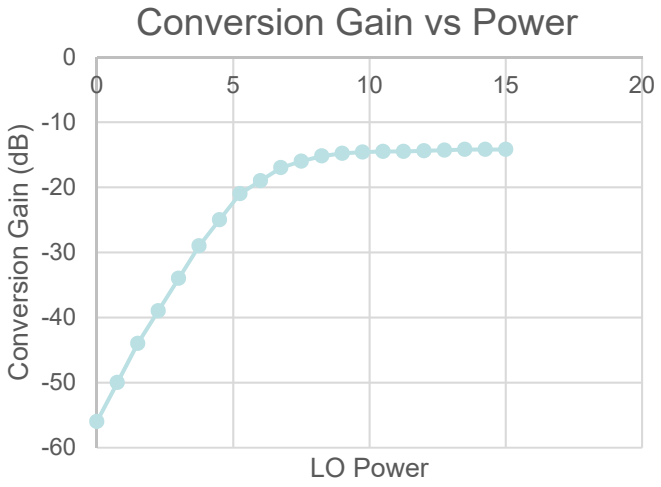


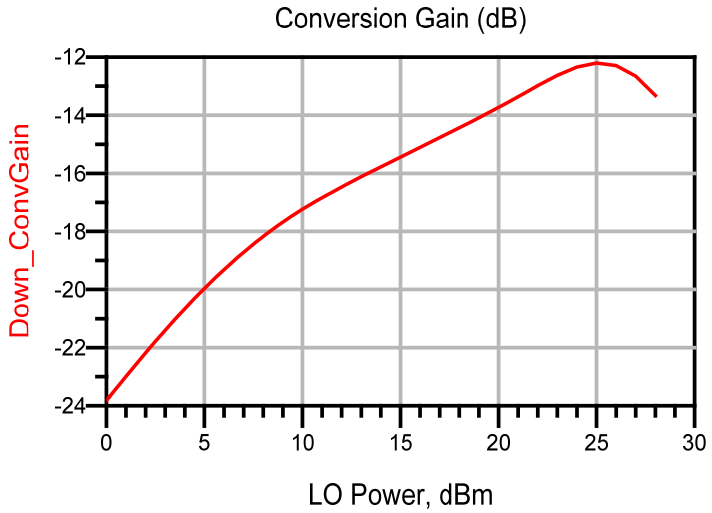


- Measurement results:
  - Input RF -20 dBm @ 13 GHz
  - LO Power 13 dBm @ 2.3 GHz
  - CG -15 dBm
  - IIP3 > 10 dBm
  - Low spurious (2RF-7LO)



Hybrid GaN Ring Mixer





Despite the good results, we were expecting state of the art results. however after verification with the foundry the process had some problems during fabrications that affected the power performance of the device.

This work will be published in journal

THANK YOU!

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Swedish National Space Board

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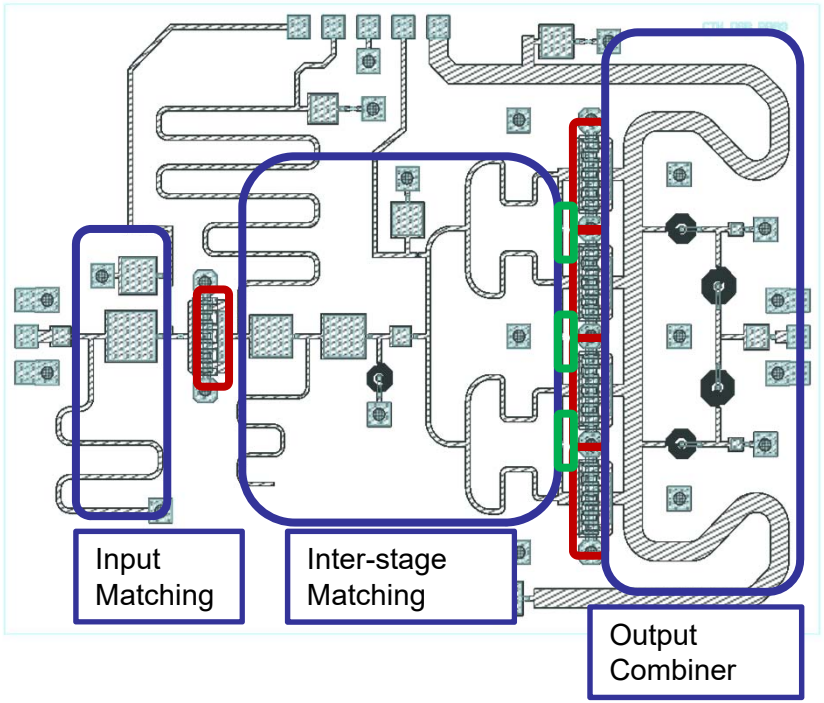
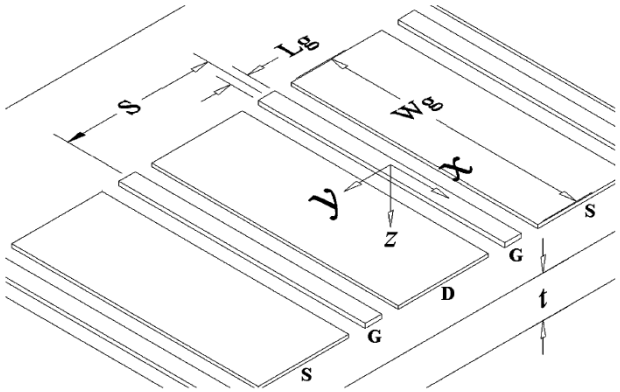

Input
Matching
Inter-stage
Matching
Output
Combiner

1. Junction Temperature Prediction

Darwish

$$T_{ch} = \left(T_o{}^{-0.23} - 0.23(\theta P_{diss})T_o{}^{-1.23}\right)^{(-1/0.23)}$$

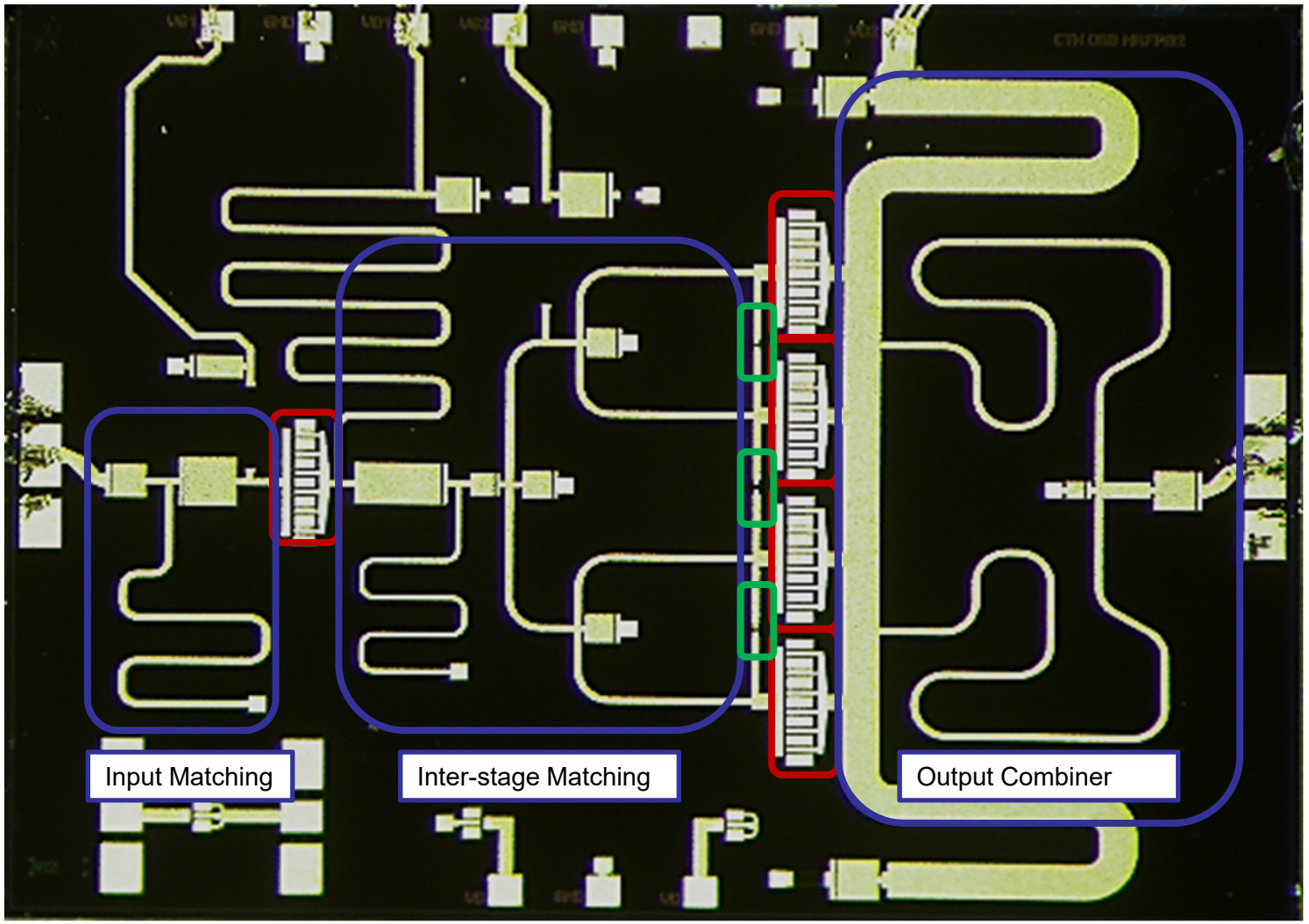


$$V(z) = \frac{z-1}{z+1} \qquad f(w) = \sqrt{\frac{\sqrt{w}+1}{\sqrt{w}-1}}$$

$$h(x) = \frac{\sqrt{1+g\left(\sqrt{2x}\right)}+1}{\sqrt{1+g\left(\sqrt{2x}\right)}-1} \qquad g(y) = \left(\frac{W_g}{y}\right)^2$$

$$\theta = \frac{1}{\pi W_g \kappa} ln\left(\frac{V\left[f\left(g\left[\sqrt{2s}\right]+1\right)\right]}{V\left[f\left(g\left[L_g\right]\right)\right]}\right) + \frac{1}{2\pi s\kappa} ln\left(\frac{h(2.3t)}{h(s)}\right)$$

Thermal conductivity: $\kappa(t) = 568.73\, T^{-1.23}\ W/(\,cm\,K)$


Input Matching
Inter-stage Matching
Output Combiner