Low Power (5mm x 5mm) MMIC

Khaled Elgaid
Iain Thayne
University of Glasgow
kelgaid@elec.gla.ac.uk

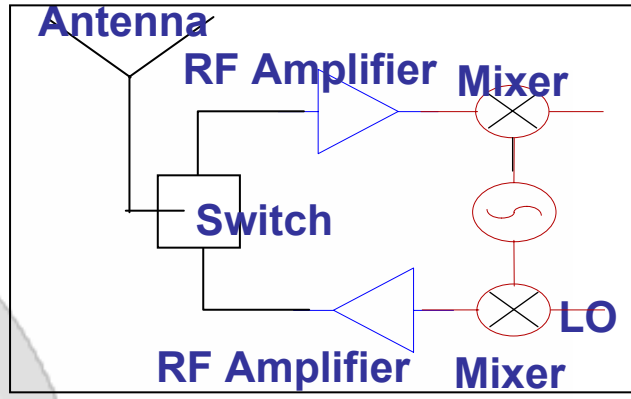
Presentation Outline

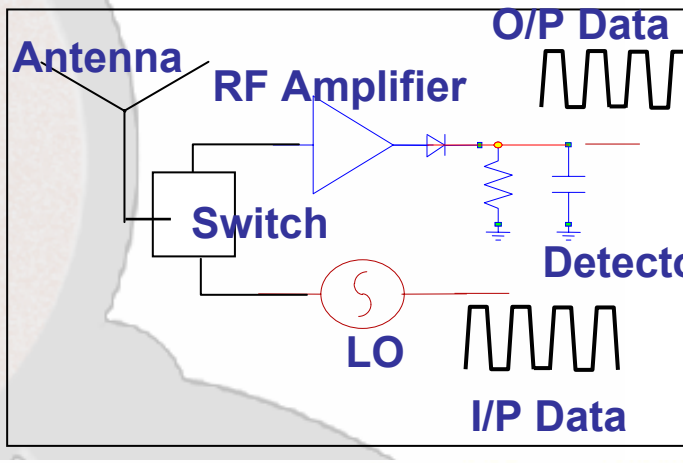
- RF TX/TR Systems Options
- RF TX/TR Components
  - Active (Transistor)
    - DC – Power Consumption
    - RF
    - Noise
  - Passive
    - Capacitors
    - Spiral inductors
  - Designed Subsystems MMICs
    - Oscillator
    - Amplifier
- 5x5 RF TX/TR MMIC
- Conclusions

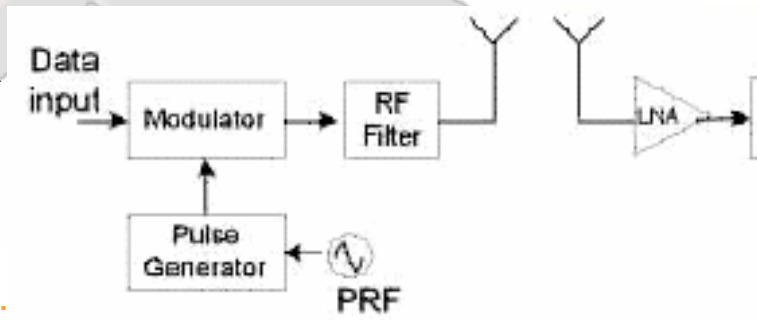
TX/TR System Overview

Three Possible RF TX/TR Systems

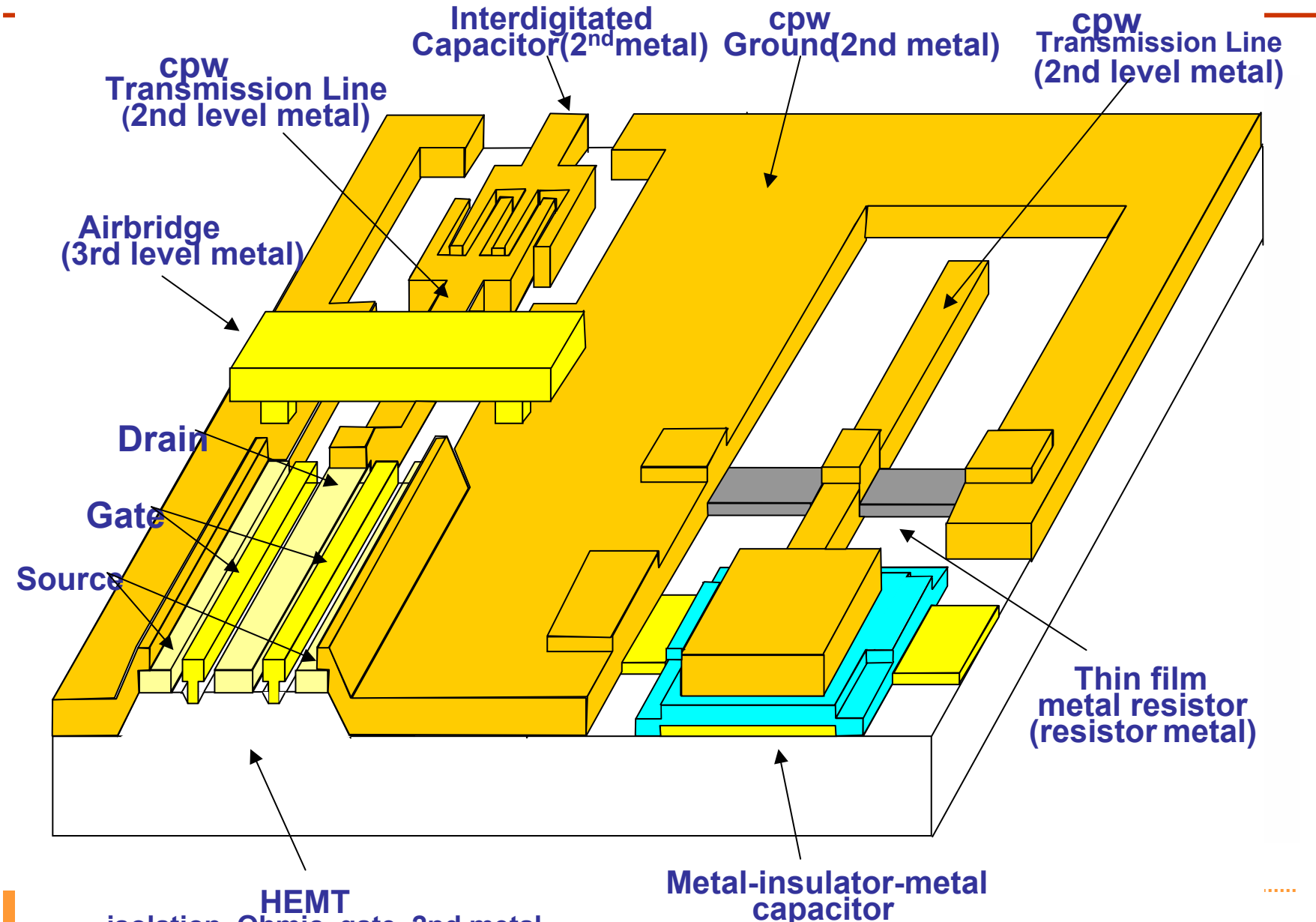
- **Frequency carrier base (narrow-band)**
  - Up/Down conversion (MIXER)
    - Requires extra subsystems
    - More power consumption
    - Flexibility Data Transmission
  - Direct Modulation/Detection
    - Restricted Data Transmission
    - Low power consumption
- **NON Carrier Base System (UWB)**
  - Issues with antenna Design/Size/DSP
  - Wide bandwidth
  - Low power consumption







RF System Components



Active (Transistor) DC

Output characteristics

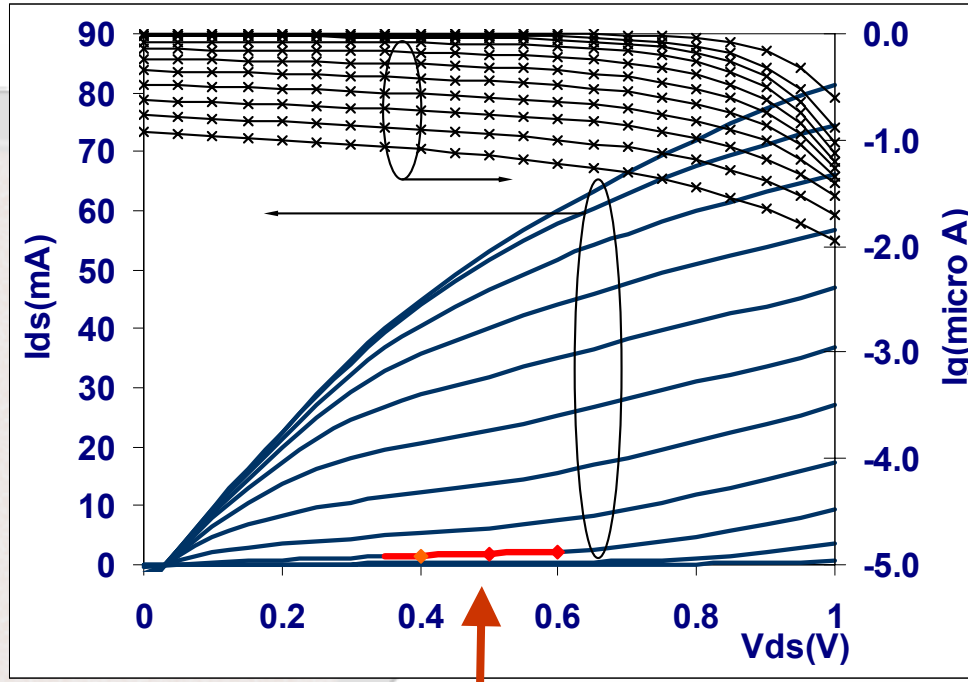
mHEMT

2 x 50μm gate width

50nm T-gate

Vds 0V - 1.0 V

Vgs = 0V - 1.0 V in - 0.1 V steps



Low power operation mode < 600μW

Vds 0.3 to 0.6V

Vgs -0.8V

Ids = 0.8mA – 1.15mA

Gate leakage current < 1 μA

DC power consumption could be reduce further by reducing device physical size

Active (Transistor) DC

Transfer characteristics

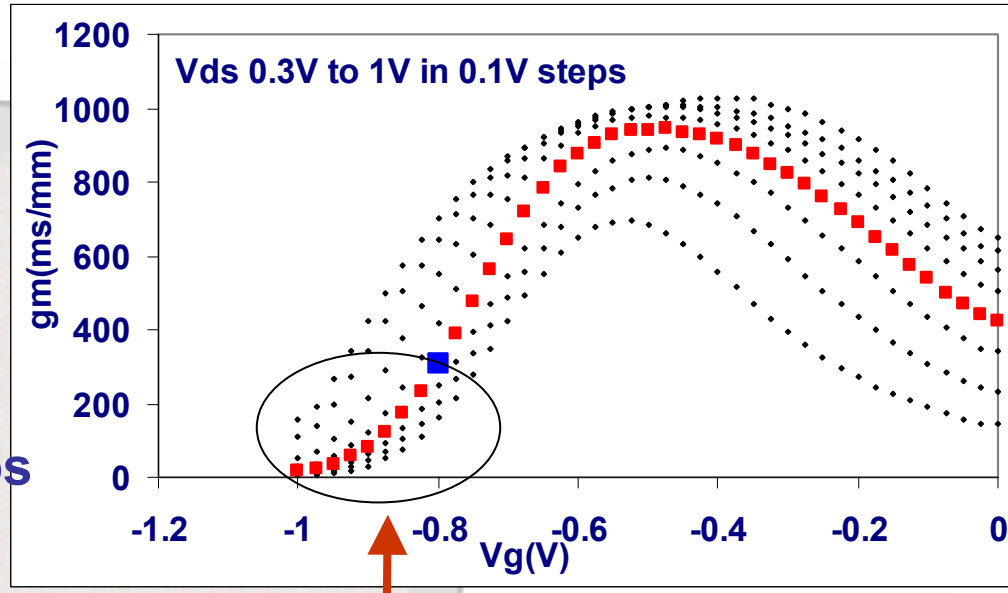
mHEMT

2 x 50μm gate width

50nm T-gate

Vds 0.3V to 1.0V in 0.1 steps

Vgs = 0V to - 1.0 V in - 0.1 V steps



Low power operation mode < 600μW

Vds 0.3 to 0.6V

Vgs < - 0.8V

Ids = 0.8mA – 1.15mA

Transconductance (gm) ~ 310ms/mm

Active (Transistor) RF

RF Performance

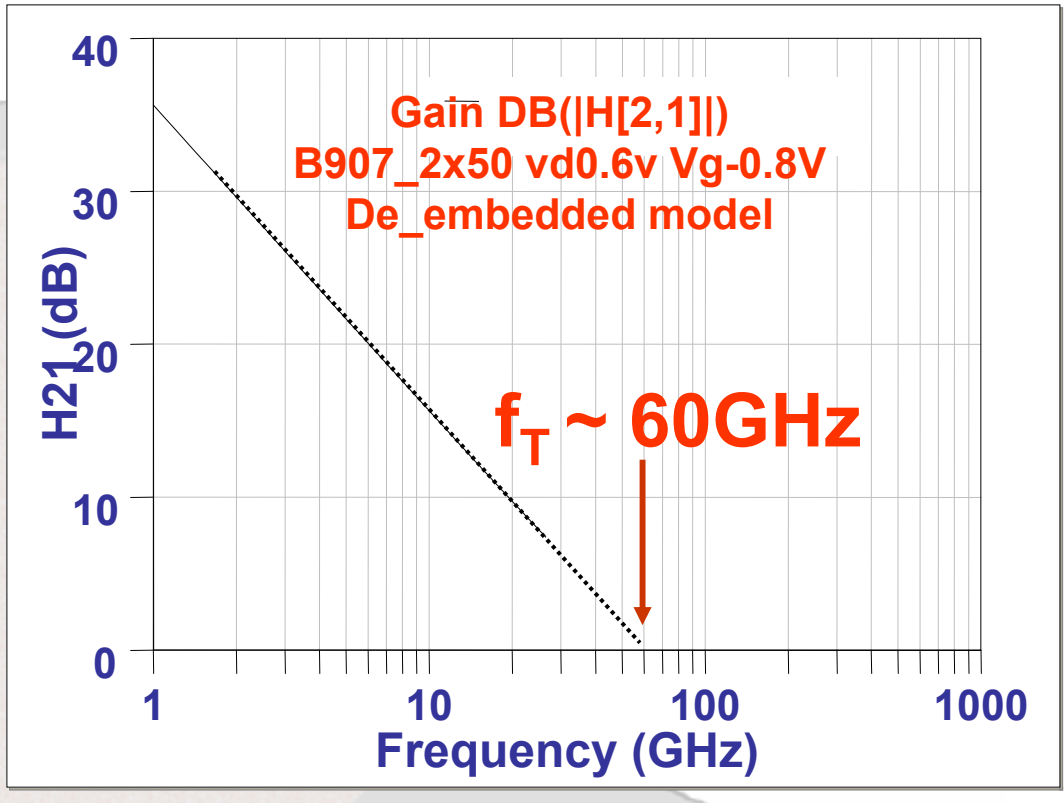
mHEMT
2 x 50μm gate width
50nm T-gate

Vds 0.6 V
Vgs = - 0.8 V

The device showed Exceptionally high RF performance of

f_T ~ 60GHz

at Low power operation mode < 600μW



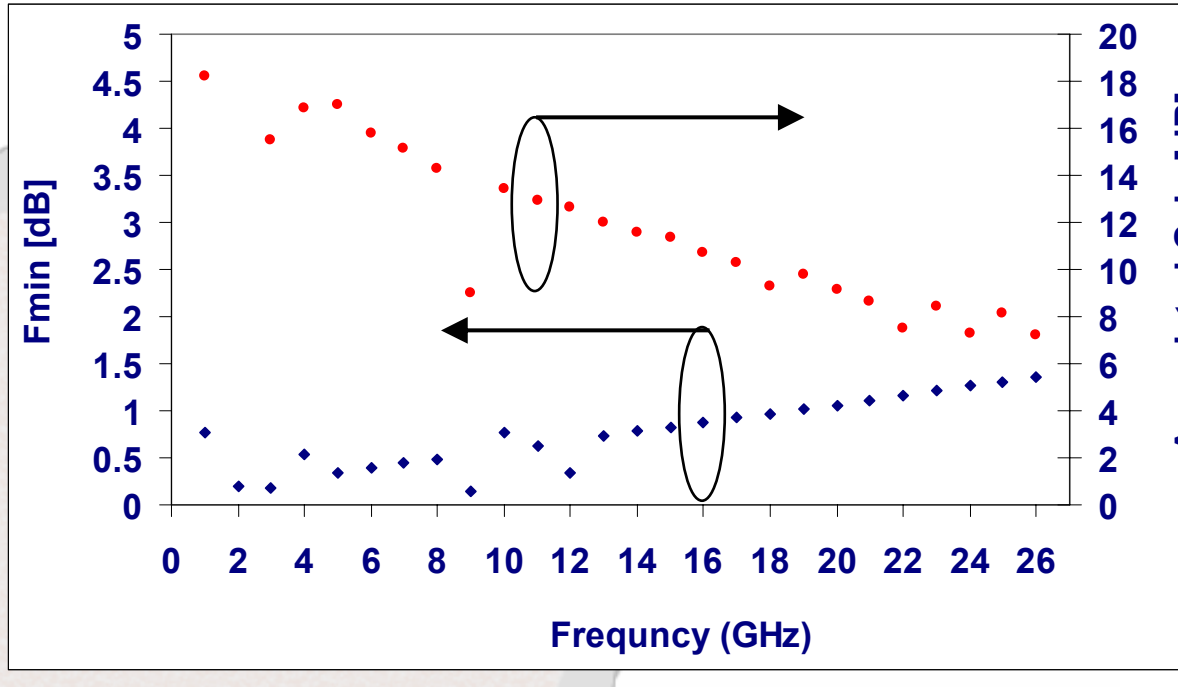
Higher Operating Frequencies ~ 25GHz TX/TR is possible

Active (Transistor) NOISE

Noise Figure

mHEMT
2 x 50μm gate width
50nm T-gate

Vds 0.6 V
Vgs = - 0.8 V



Low power operation mode ~ 600μW

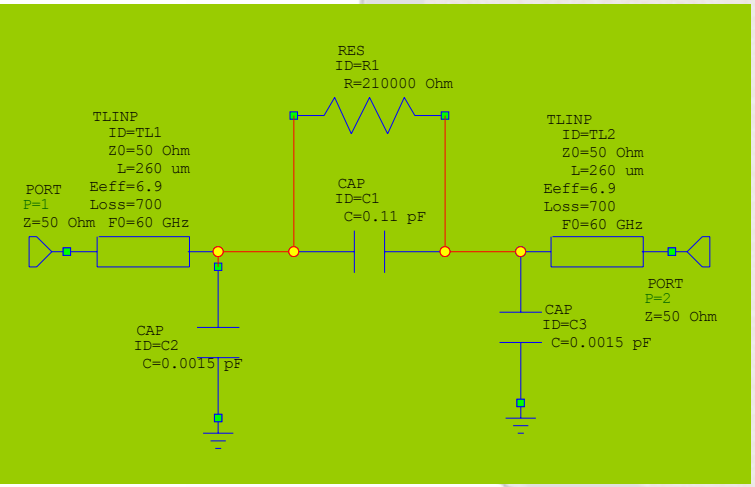
Exceptionally low noise < 1.3 dB up to 26GHz

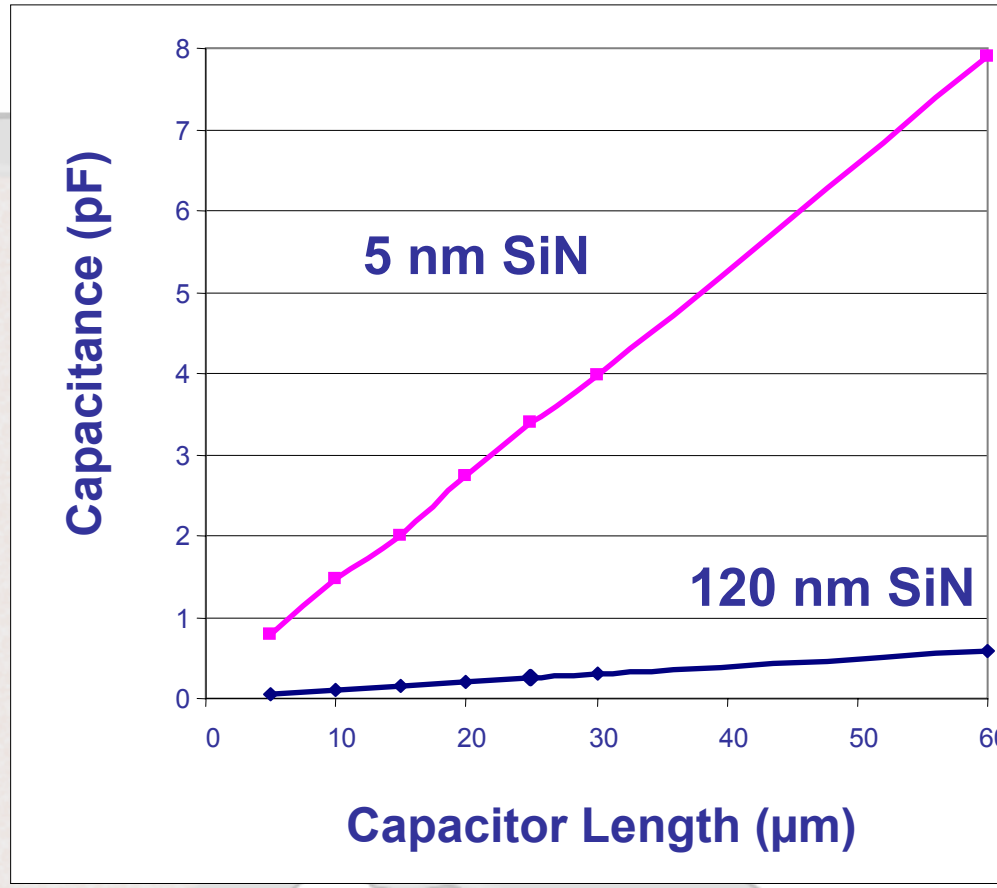
High Associated Gain performance of 7.3dB and better up to 26GHz

Passive Components

Capacitors

20 mμ wide MIM
5 – 60 mμ Length
SiN Thickness 5nm and 120nm
SiN deposited at 22ºC





Capacitance Density = 7 fF/mμ²

Using Novel 5nm thick SiN MIM capacitors, Capacitance increased by 13 fold

REDUCE CIRCUIT SIZE – LOSS

Passive Components

Inductors

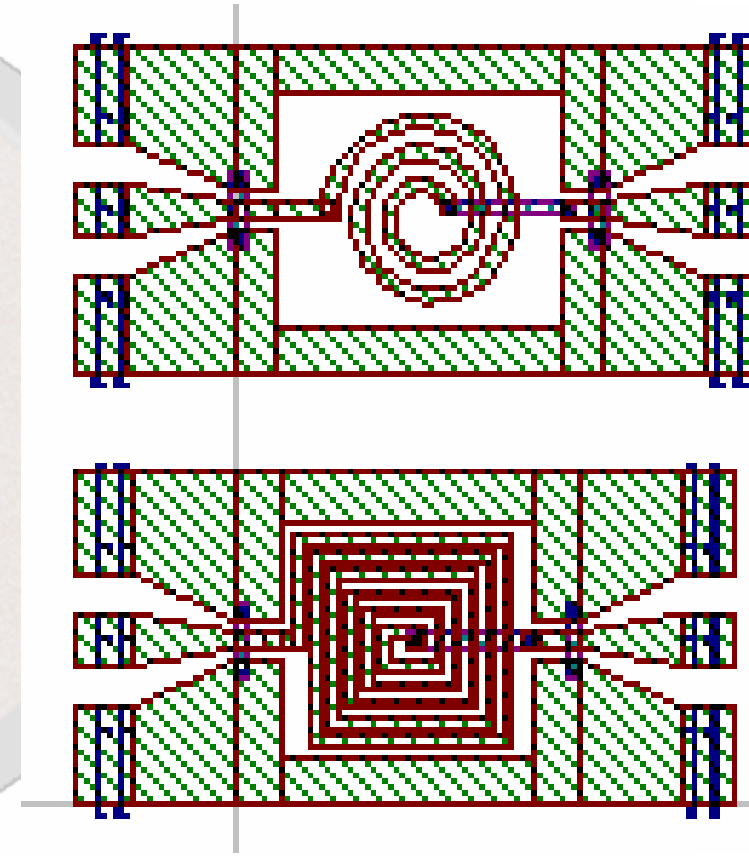
Build a Library model

Investigate Inductor Q

- Spiral
- Square
- different geometry

What are the steps

- Layout design
- EM Modelling
- Fabrication
- Measurements
- Extract modelling



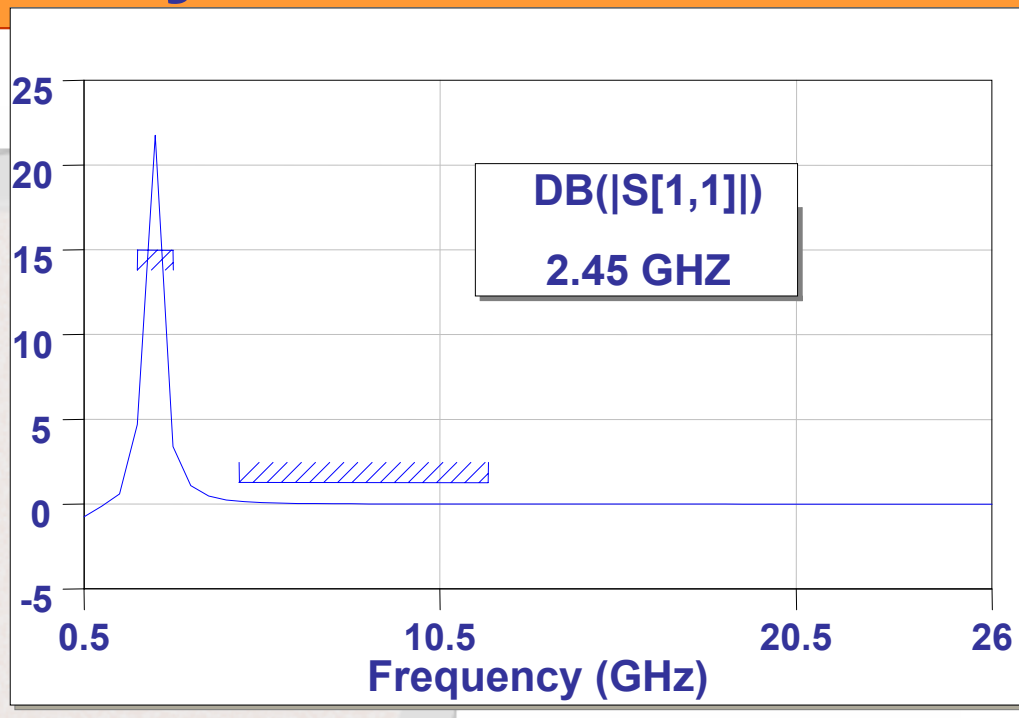
Designed Subsystems MMICs

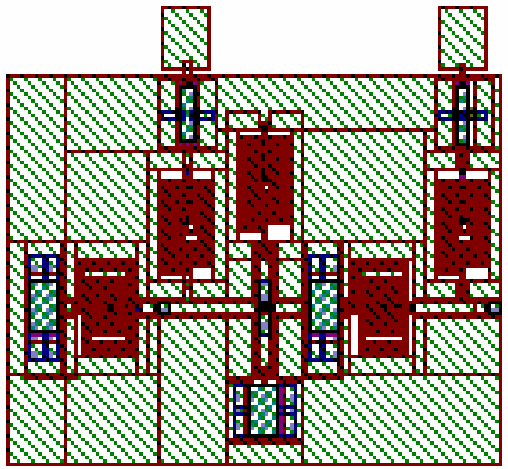
2.45 GHz MMIC Oscillator

mHEMT
Gate Length = 50 nm T-gate
Gate width = 2x50 μm
Vds = 0.6V
Vgs = - 0.8V
Id = 1.15mA

DC power consumption ~ 600μW

Chip size 2.3x1.2mm



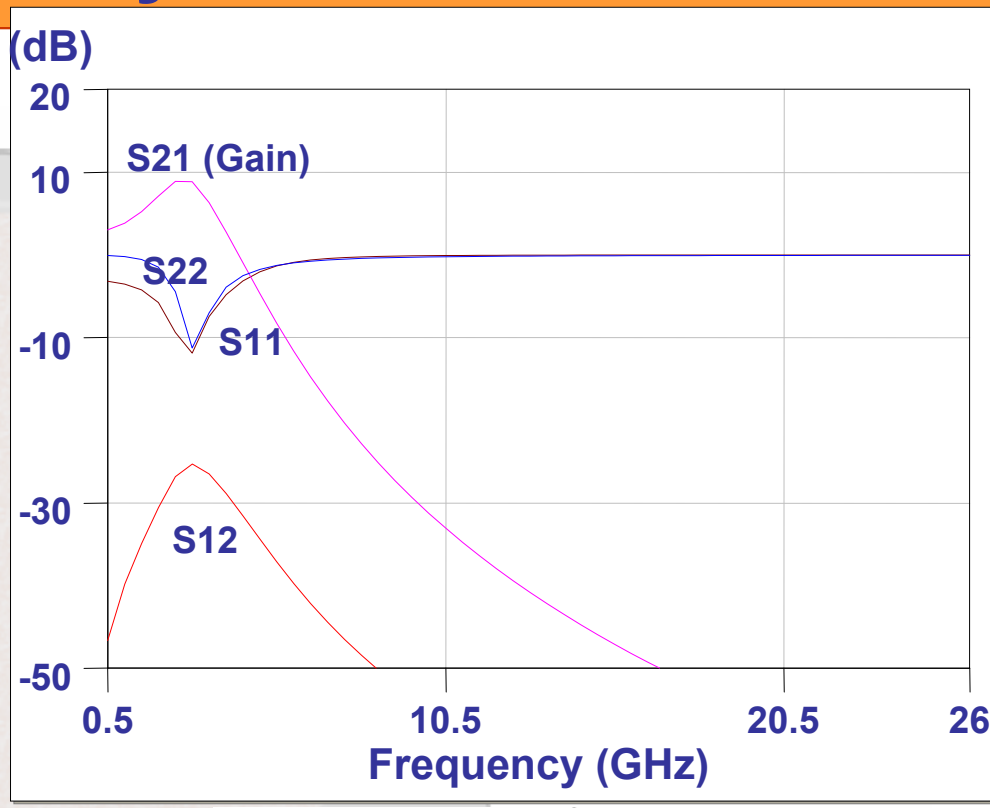


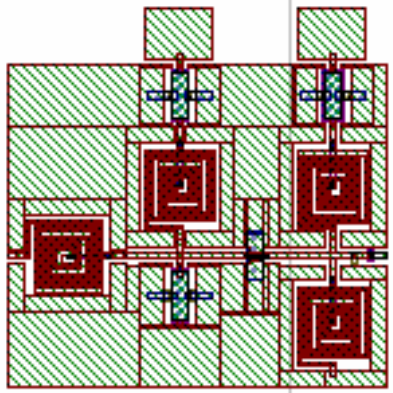
2.45GHz Designed MMIC Oscillator Layout

Designed Subsystems MMICs

2.45 GHz MMIC Amplifier

- Single Stage
- mHEMT
- Gate Length = 50 nm T-gate
- Gate width = 2x50 μm
- Vds = 0.6V
- Vgs = - 0.8V
- Id = 1.15mA
- DC power consumption ~ 600μW
- Gain ~ 9dB
- Return Loss < - 8dB
- Isolation < - 27dB
- Chip size 1.25x1.2mm





2.45GHz Designed MMIC Amplifier Layout

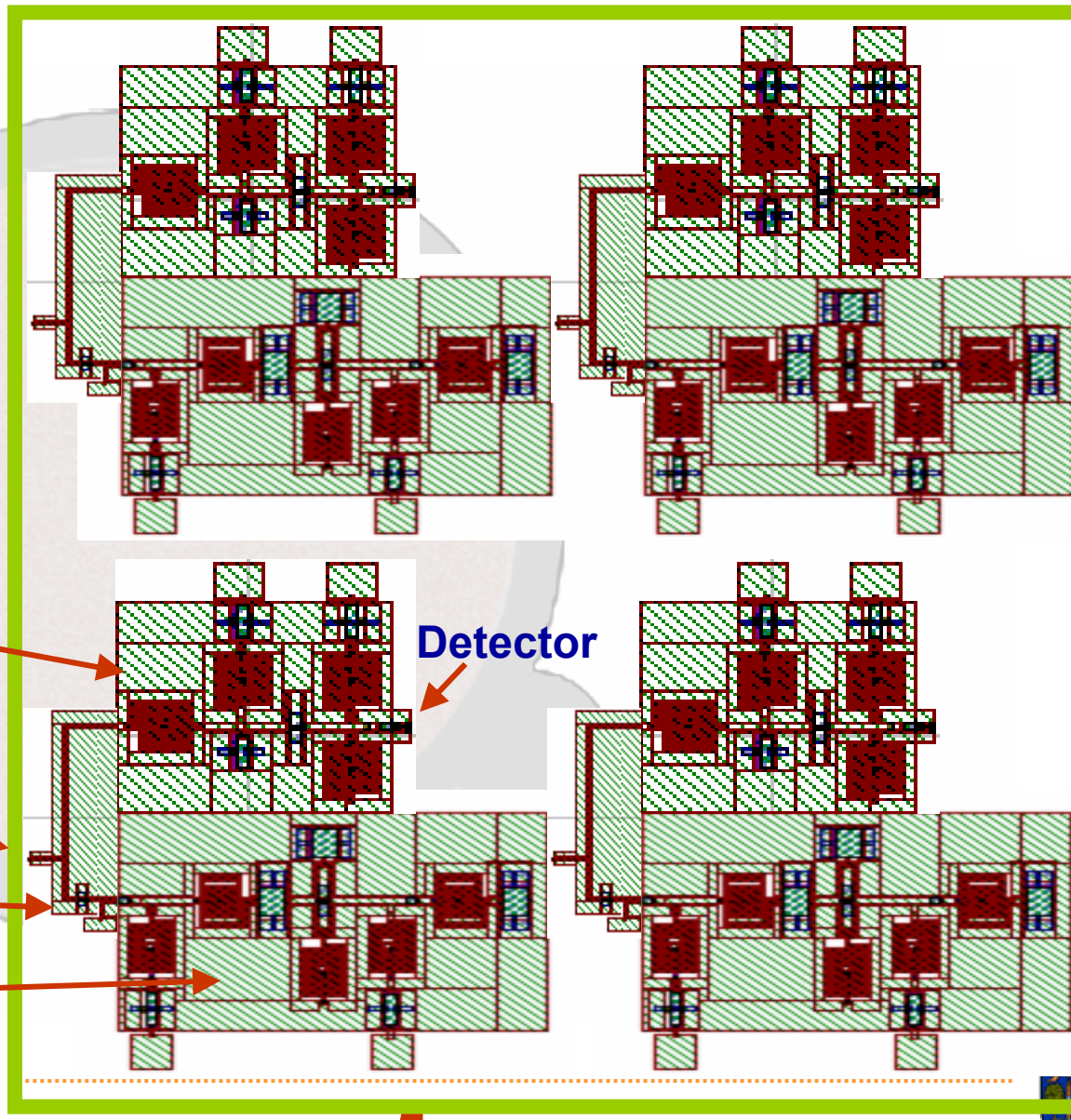
Designed 5mmx5mm TX/TR System MMICs

ayout of 4 Designed TX/TR
n a 5mmx5mm

OTAL DC Power
onsumption for the TX/TX
ystem ~ 1.2mW

Both TX/TR are **ON**

hip size ~ 2.5mmx2.5mm



Conclusions

- WE have Investigated three Possible RF TX/TR Systems

- Active devices been Develop
  - Very Low DC Power Consumption
  - High Gain
  - Excellent RF Performance at low power mode ft ~ 60GHz
  - Low Noise Figure

- Compact Capacitors using very thin (5nm) SiN Dielectric SiN

- Inductors Equivalent Circuit models is required (for lower frequency operation)

- MMIC subsystems been Designed
  - LNA and Oscillator ~DC Power Consumption ~ 600W

- MMIC been Designed
  - Chip size ~ 2.5mm x 2.5mm, with low power consumption

  - Higher Frequency ~20GHz System should be considered
    - Easier antenna integration
    - Allow different design methodology