Creating GLOBAL STANDARDS

Taiyo Yuden MMIC Transmitter/Receiver Design Review and Measurement Results

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1. Millimeter-Wave MMICs
   - Design Environment
   - Measurement/Evaluation Technologies
2. Design and Evaluation
   - Millimeter-Wave MMICs
3. Summary

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Design Environment

Millimeter-Wave MMICs Measurement/Evaluation Technologies

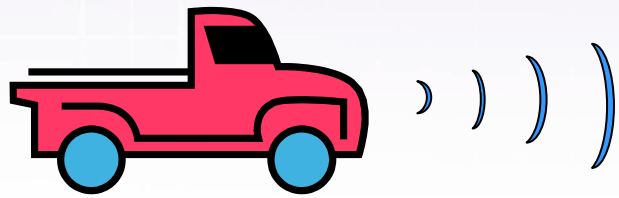
Millimeter Wave applications

60GHz

- Video Transmission Systems
- Wireless link for BS/CS satellite broadcasts
- Communication among Buildings

- 7GHz band available without license.
  - Japan: 59-66GHz USA: 57-64GHz
- Less interference with other wireless systems

77GHz Automotive Radar



94GHz Image Sensor, High Resolution Radar

Characteristics of Millimeter-Wave Circuits

Frequency > 30GHz
Short Wavelength

Parasitic Components
On the order of pH / fF
Cannot be ignored

Accuracy of
Elements / Circuits / Connections

Process/Mounting/Measurement…

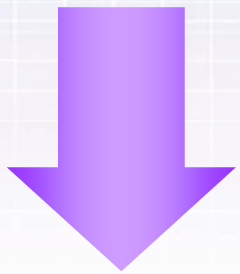
Superior Measurement/Evaluation technologies are *necessary* at Millimeter-Wave frequencies.

Design Features of Millimeter-Wave MMICs

Characterization of all MMIC circuit blocks is critical.

Systems, Tr characteristics, VCO, Mixer, LNA, PA, Filters, Antennas…

Development; Cost; Faster time to market…



Millimeter-Wave circuit design requires robust development environment

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Design Development Environments for Millimeter-Wave MMICs

Establishment of Millimeter-Wave MMIC Design Environments

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Requests, Proposals

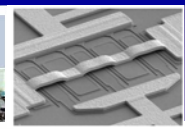
UMS
Information Supplement

Ansoft
Development of DK for AD

UMS PH15 design kit
Ansoft Designer / Nexxim ver.3

Millimeter-Wave MMIC Design Environments
MMIC Foundry

United Monolithic Semiconductors (UMS)

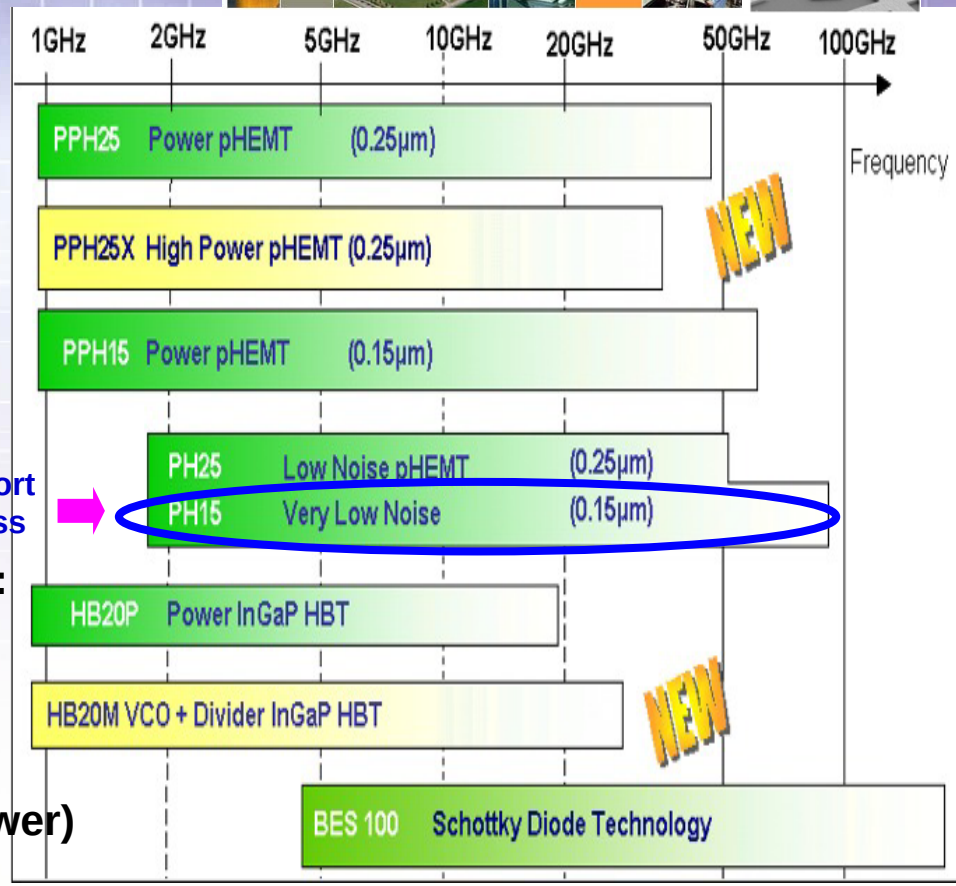


GaAs Foundry Service at UMS

- Excellent track record in manufacturing Millimeter-Wave MMICs
- Proprietary technologies and expertise
  - 0.25um and 0.15um pHEMT
  - 2um HBT
  - Schottky diode

  Supporting processes including:
  - Air bridges
  - MIM capacitors
  - TaN and TiWSi resistors
  - 100um thinning
  - Via-holes
- Design manuals and Design Kit
- Quality Control System for Wafers by PCM:
  - Test production
  - ASIC
- Additional Service Available:
  - 100% on-wafer testing (DC, RF and Power)
  - Dicing and Sorting
  - Visual Inspection

80GHz Support
PH15 Process



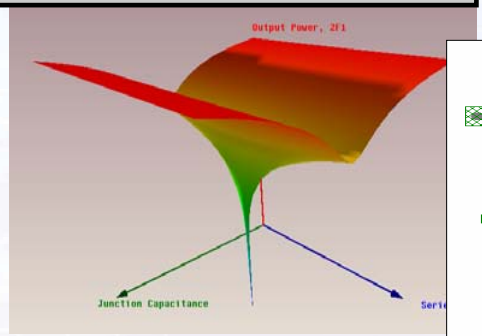
Millimeter-Wave MMIC Design Environments
Ansoft Designer /Nexxim ver. 3

NEXXIM Circuit Simulator

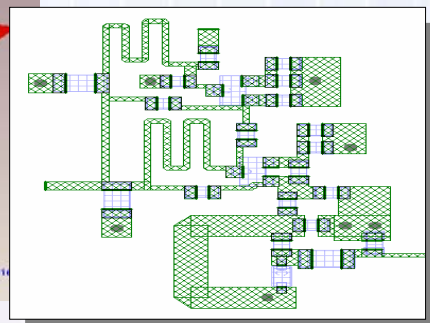
DESIGNER

Integrated Environment

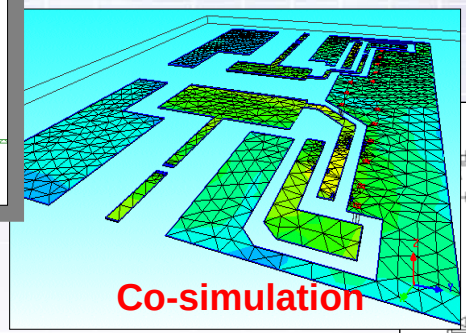
- Schematic Editor
- Layout Editor
- System / 2.5D Planar EM



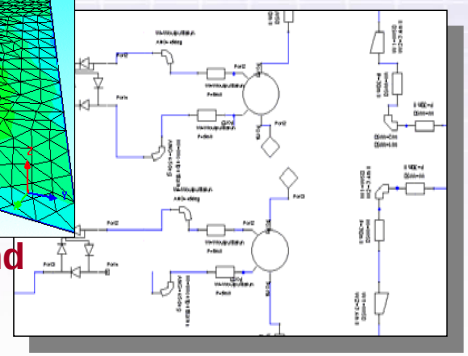
High speed
Nonlinear Analysis



Layout changes are
reflected in real time.



Co-simulation
with Planar EM and
HFSS

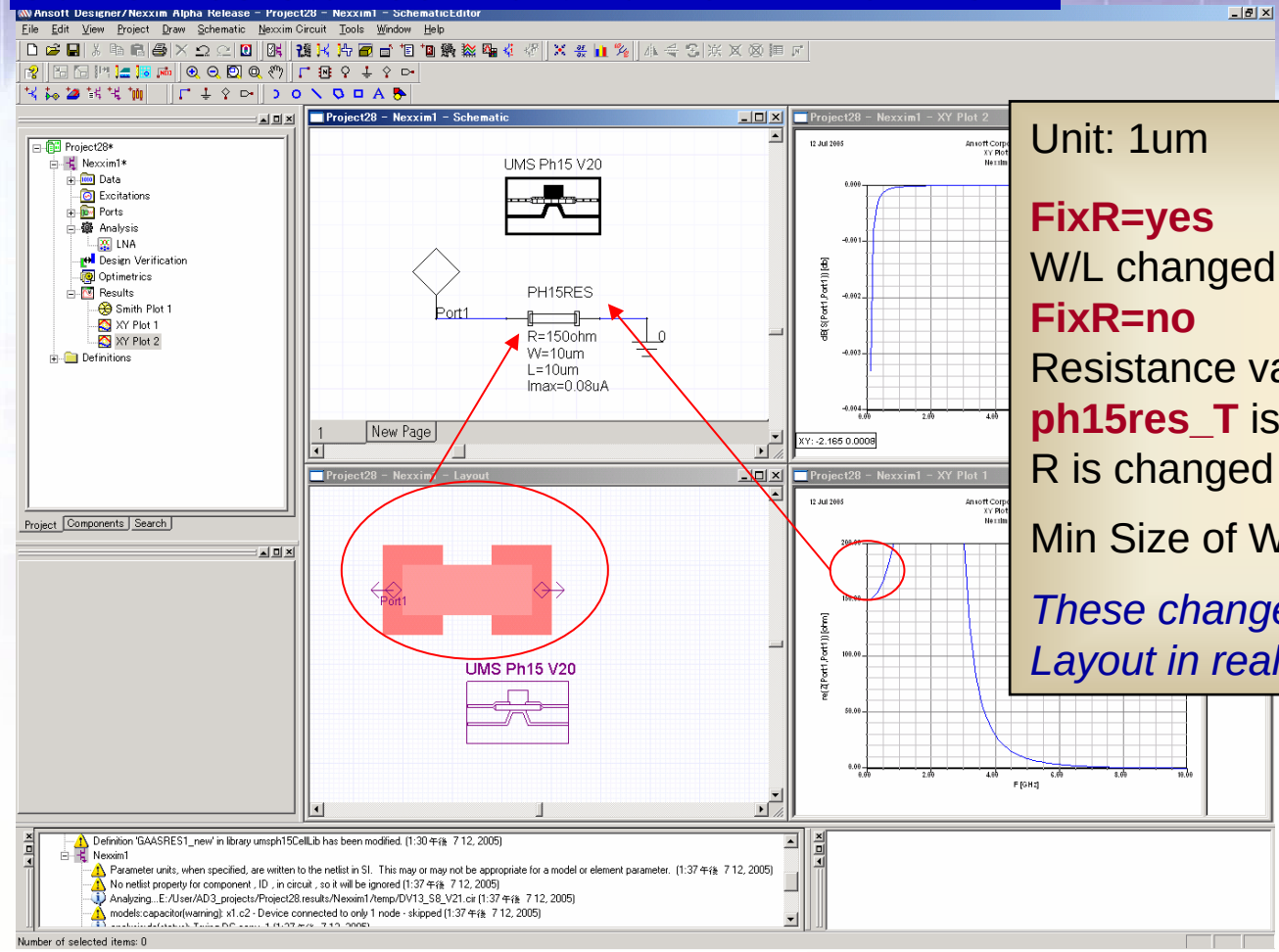


- Speed up design process
  - High-Speed Nonlinear Analysis
- Seamless integration
  - Circuit analysis
  - Layout
  - Electromagnetic Field Simulation

UMS PH15 DK for AD/Nexxim ver. 3

Passive Element Example

GaAs Resistance: Part name=PH15RES



Unit: 1um

FixR=yes

W/L changed to meet resistance value

FixR=no

Resistance value changed to meet size

ph15res_T is changed

R is changed according to temperature.

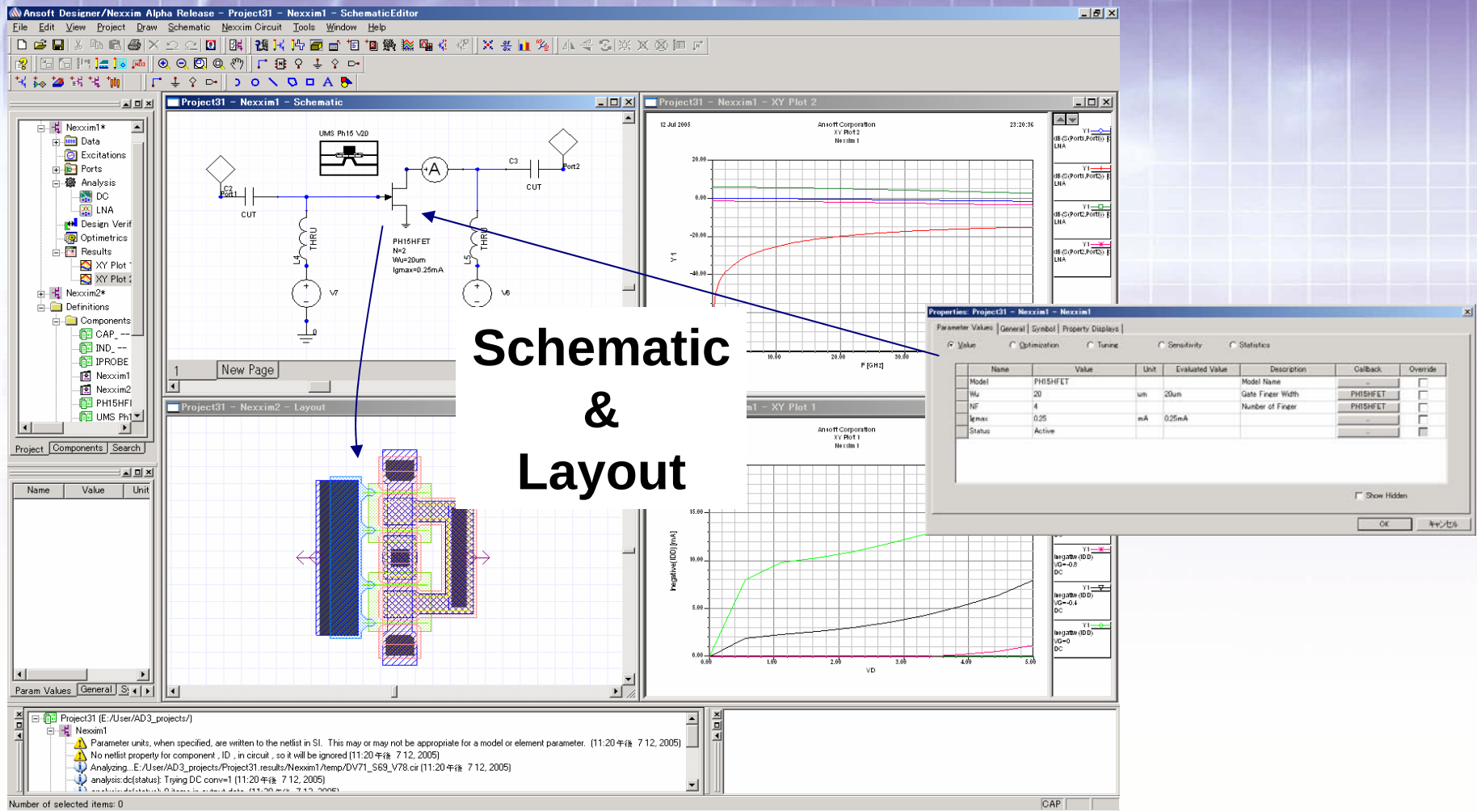
Min Size of W/L: 10um

These changes are reflected to the Layout in real time.

UMS PH15 DK for AD/Nexxim ver.3

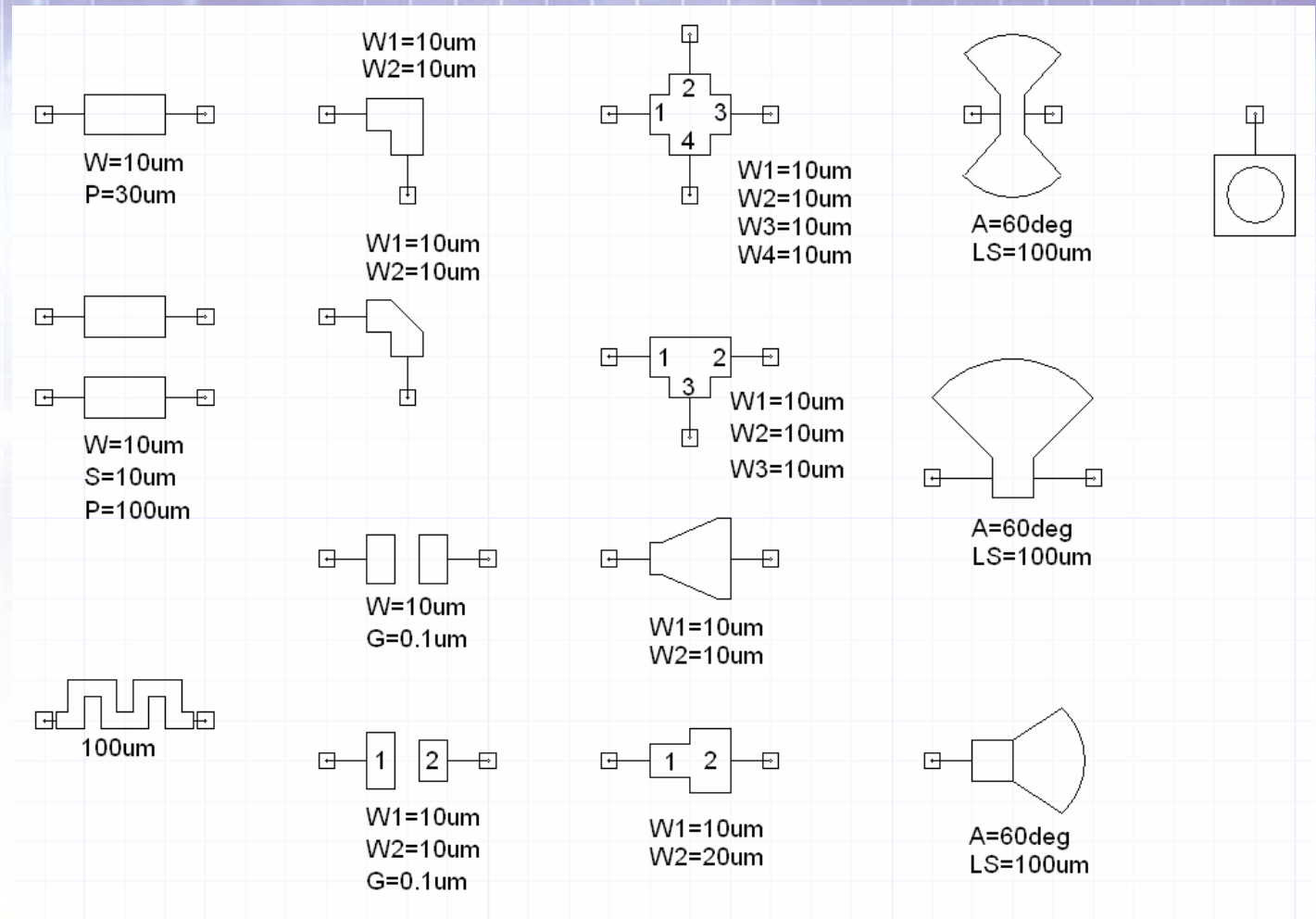
Nonlinear Element Example

PH15 HOTFET: Part name=PH15HFET



UMS PH15 DK for AD/Nexxim ver.3

Microstrip Elements



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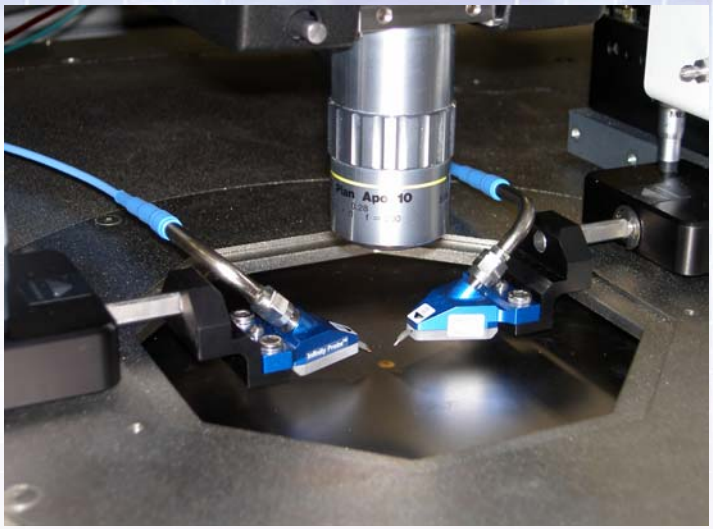
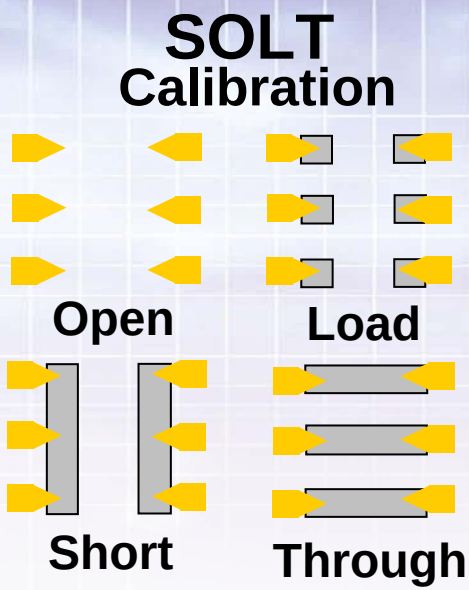
Millimeter-Wave Band Measurement/Evaluation Technologies

Millimeter-Wave Band Measurement/Evaluation Technology

Technology for High Resolution Measurement





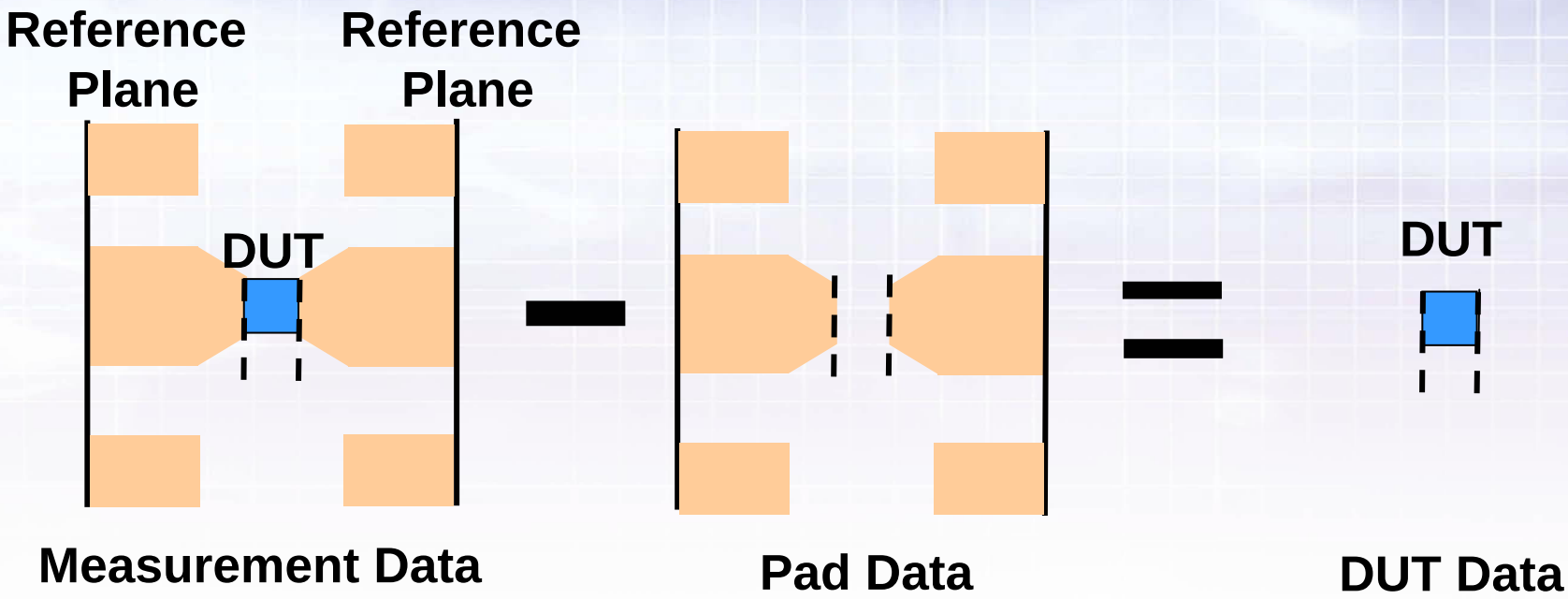
Electrical Length 1 degree = 5um @ 60GHz

(Thickness of GaAs Substrate 100um)

Contact position must be accurately controlled

Measurement/Evaluation Technology of Millimeter-Wave Band

Technology for Accurate Compensation

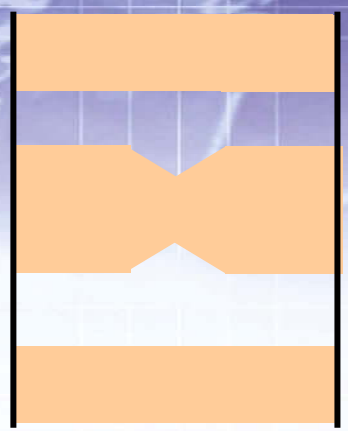


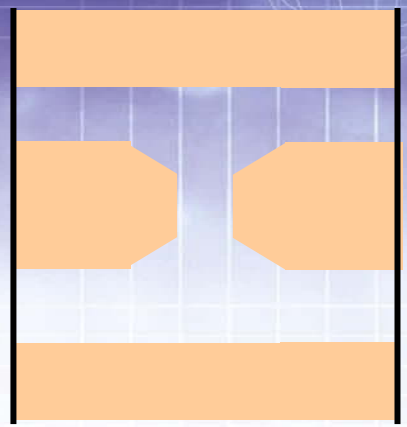
Compensation Method

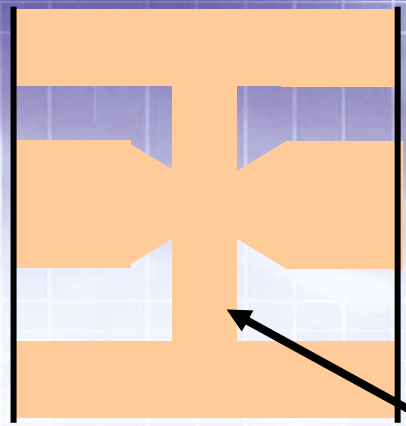
	Phase	Loss	Impedance Mismatch
Electrical Length	✓		
Electrical Length and Magnitude	✓	✓	
De-embedding	✓	✓	✓

Equivalent Circuit for Pad → **De-embedding**

Extraction of pad data

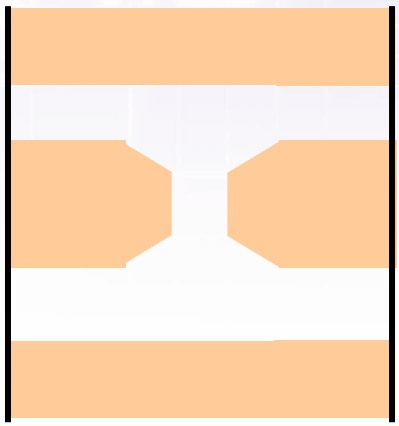




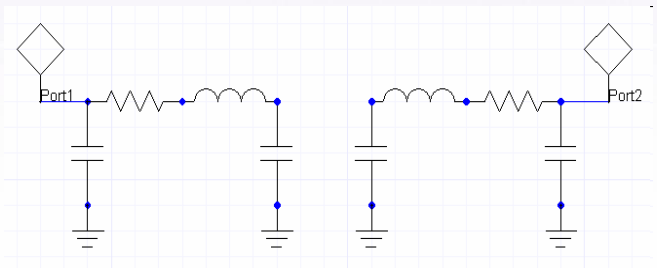


Excess Inductance

Thru Open Short



Pad



Equivalent circuit

De-embedding

Easier?

more accurate?

Problem Definition

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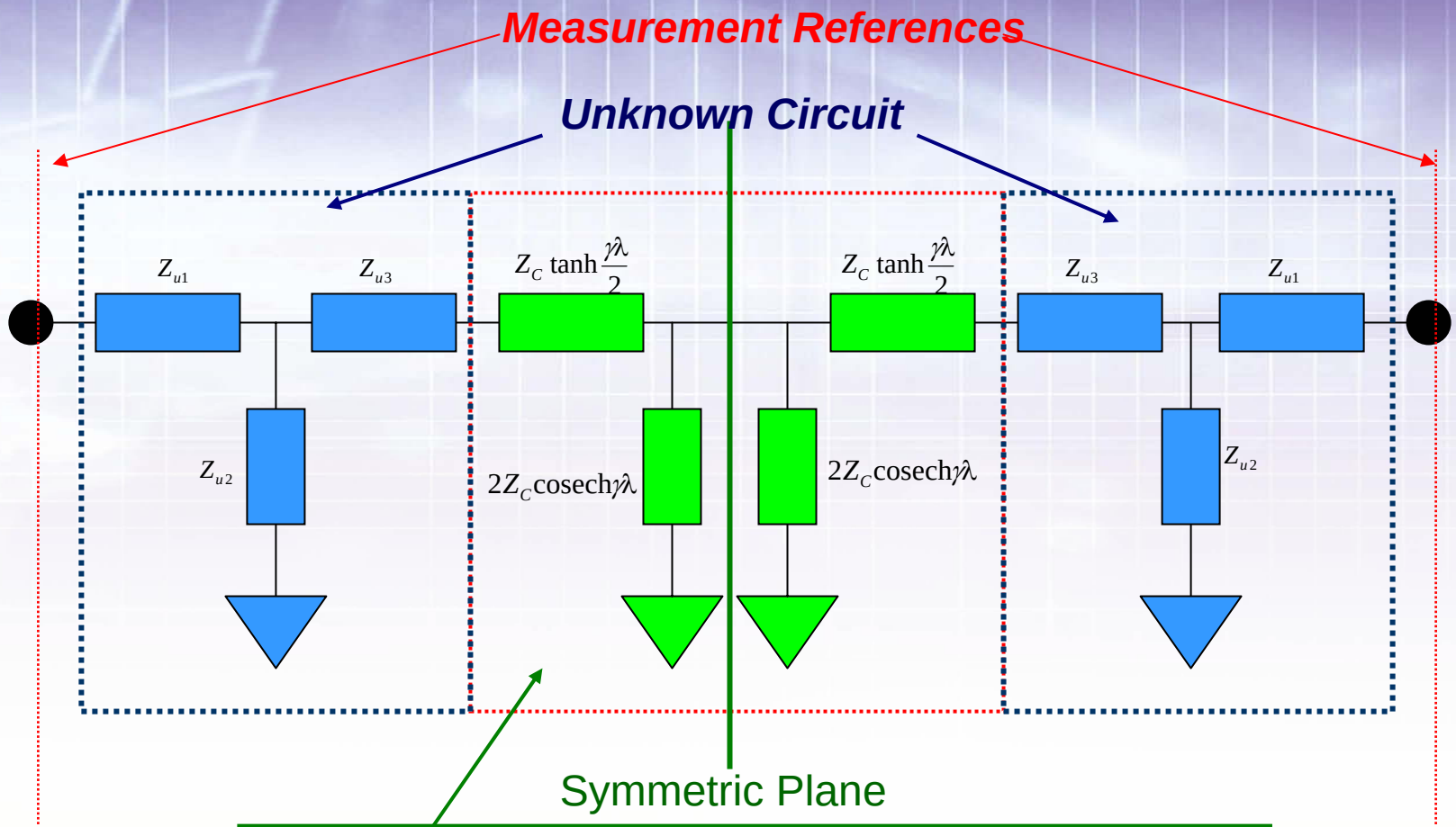
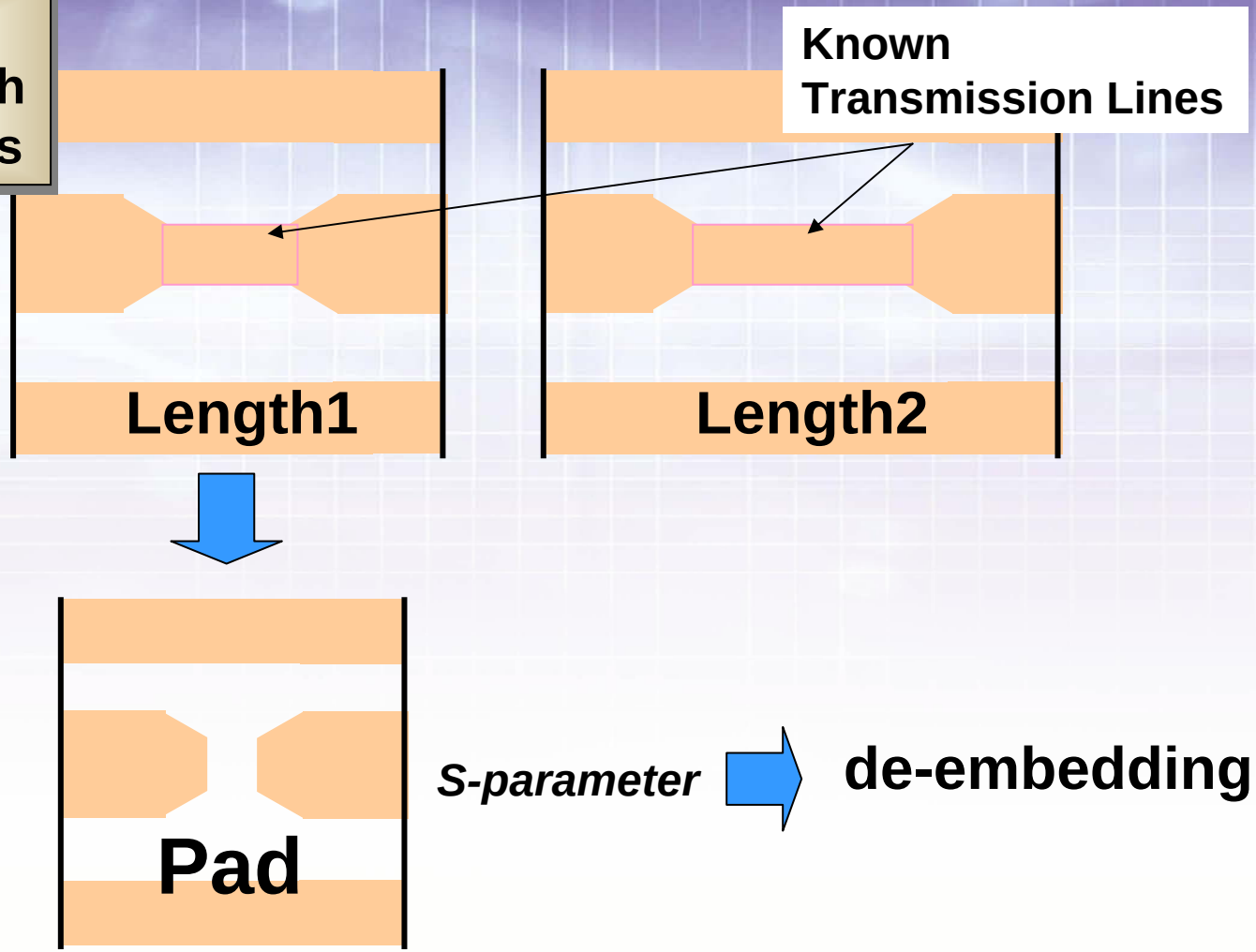


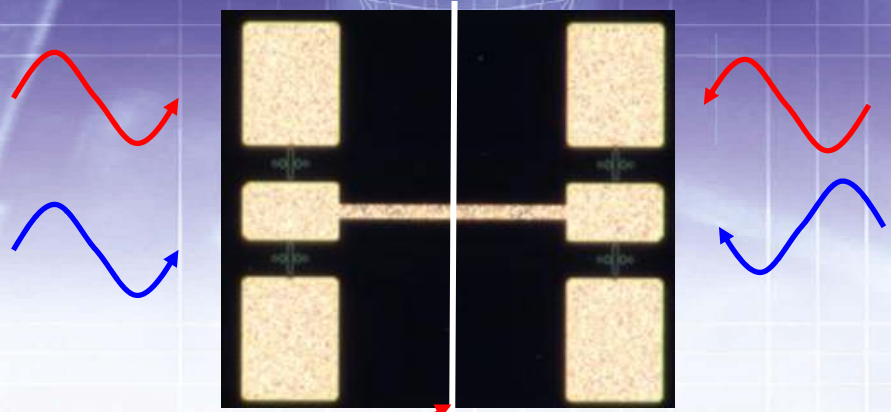
Transmission Line: ***Characteristic Impedance and Transmission coefficients are known***

Easy-to-use approach using Ansoft Designer

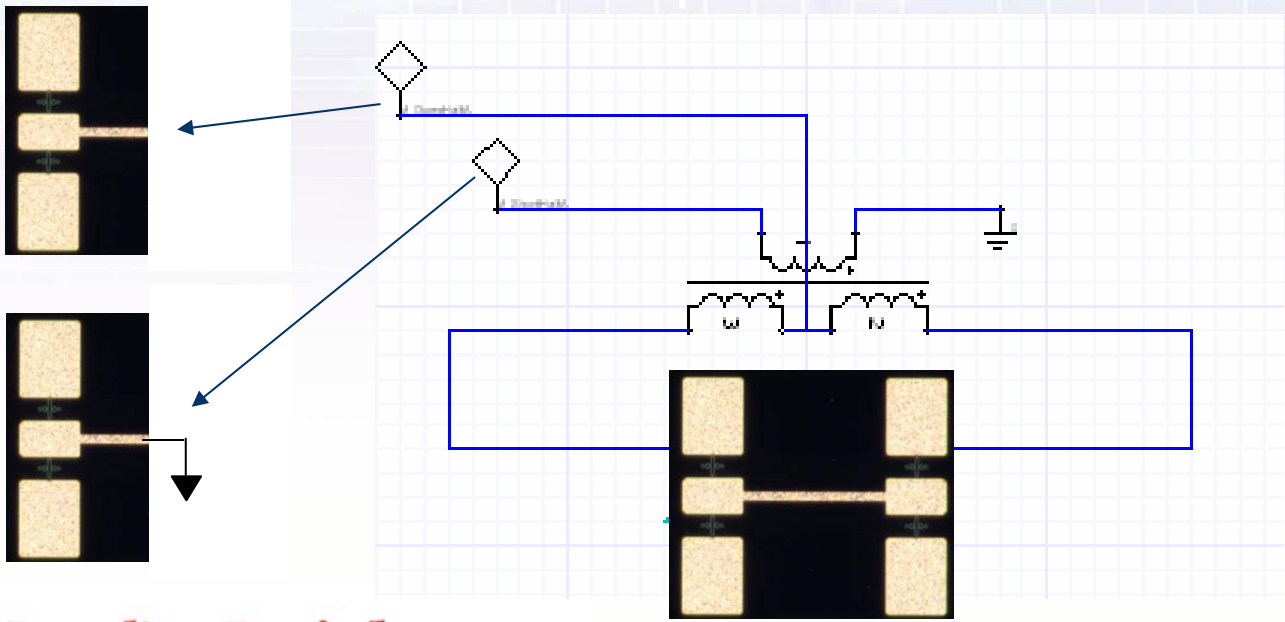
Uses two different length lines with pads



Principle of this method

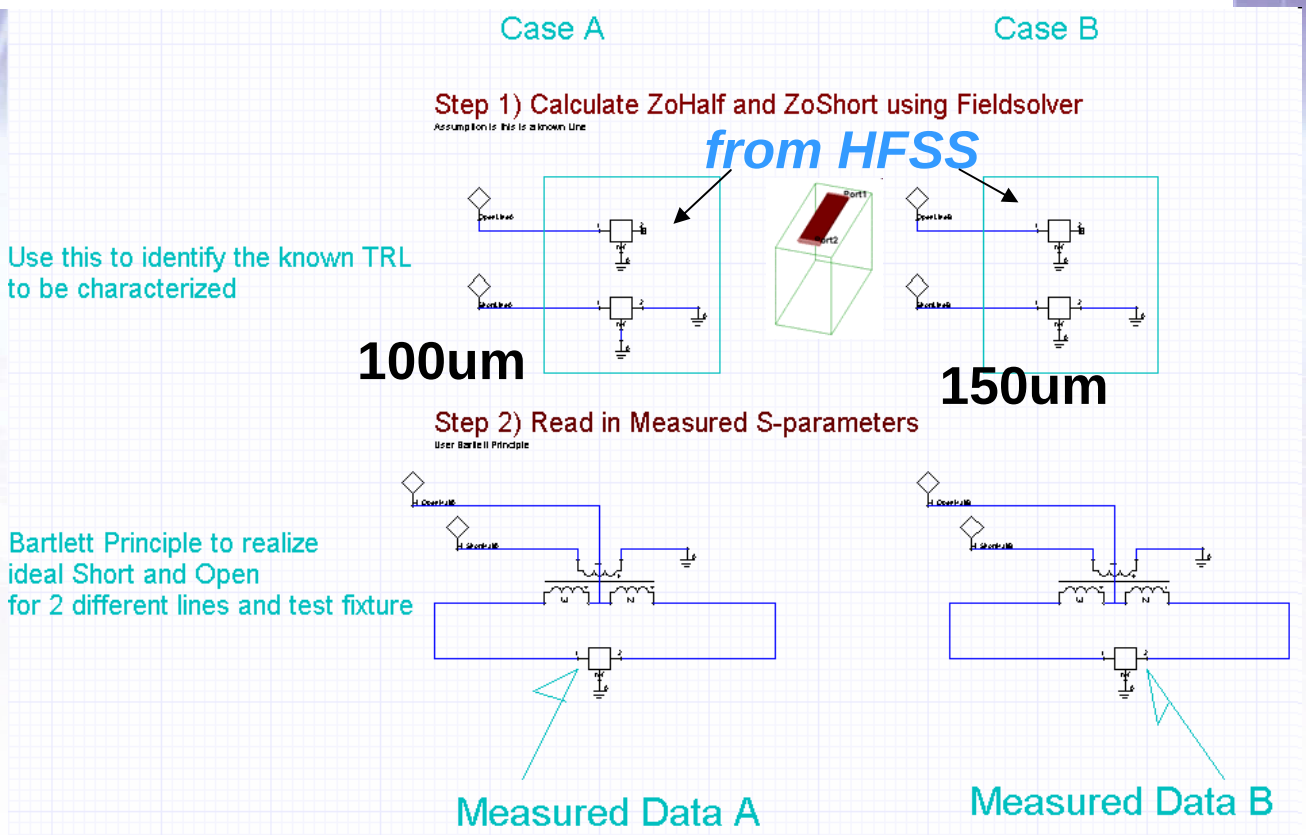


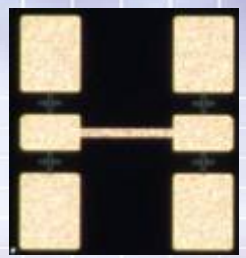
Virtual Open and Short Conditions



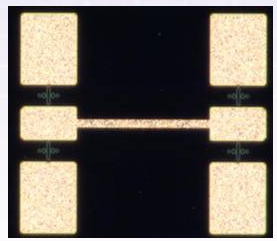
Easy-to-use approach using Ansoft Designer

Ideal Data (two different length lines)





Case A 200um

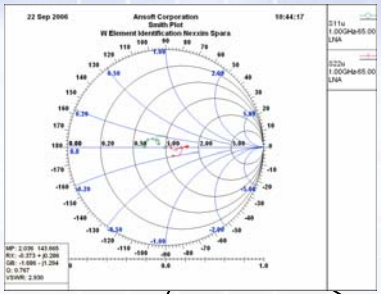


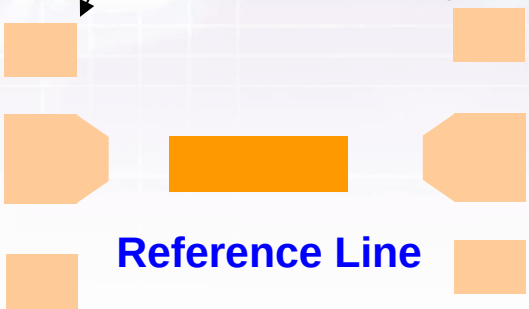
Case B 300um

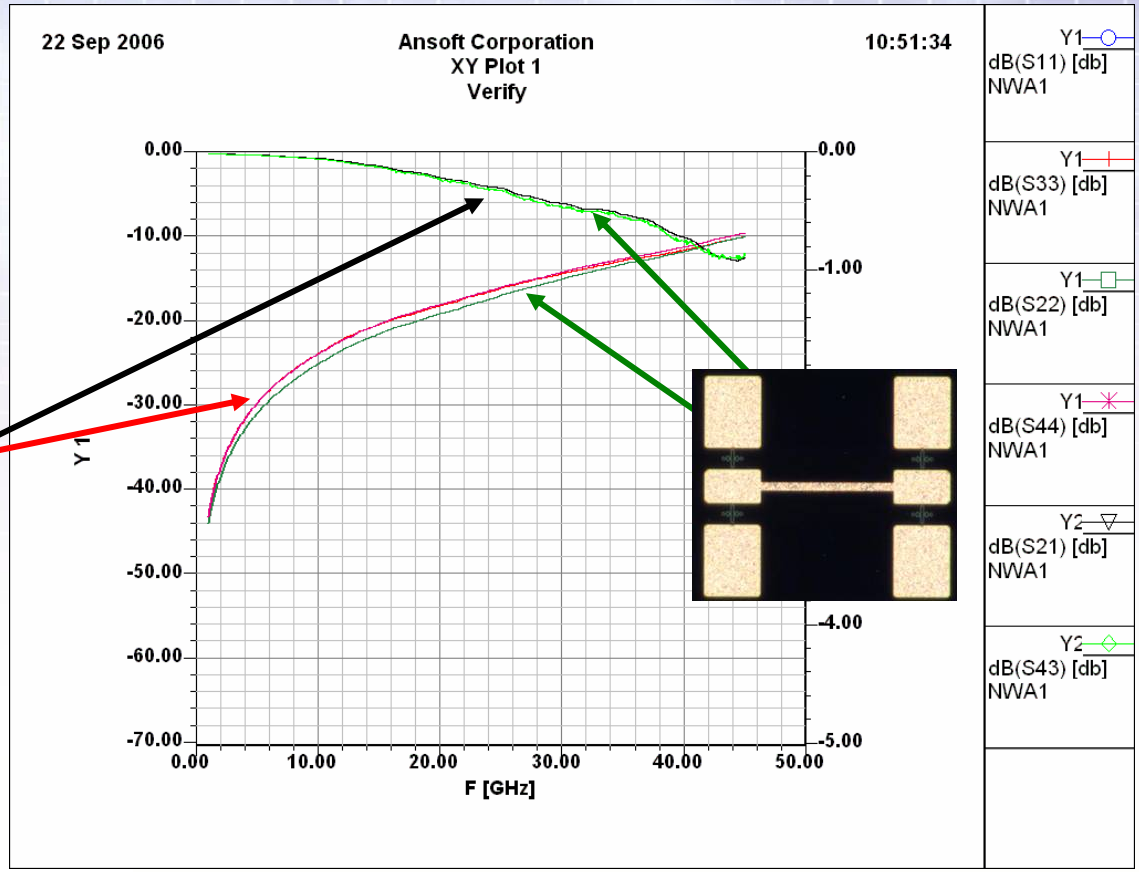
Measured Data (two different length lines with pads)

Algorithm integration in AD project

Verifying the Connector Extraction with Measured Results







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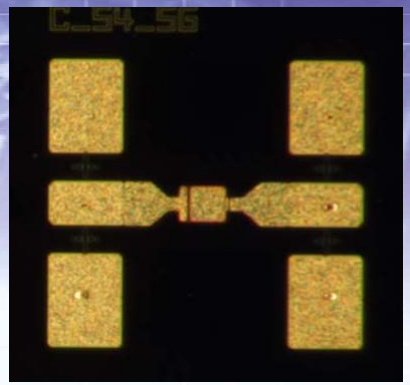
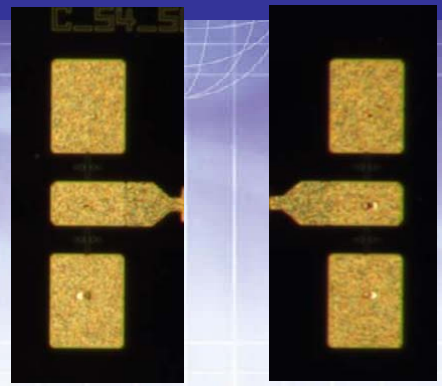
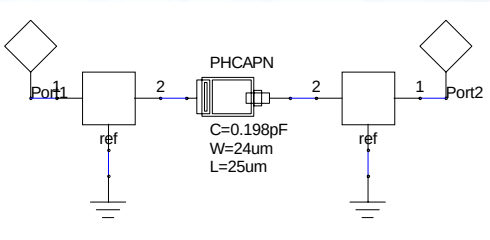
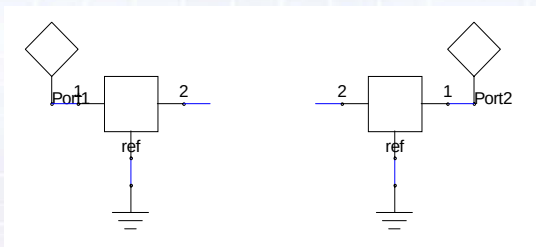
Design and Evaluation of Millimeter-Wave MMICs

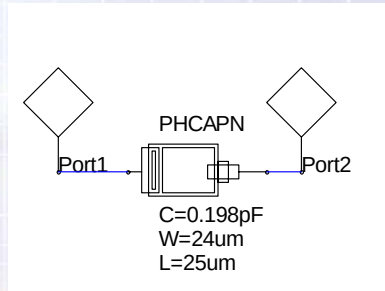
Capacitors

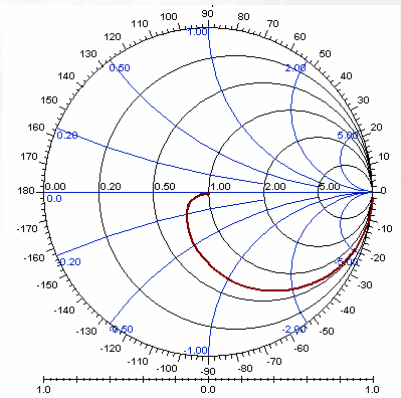


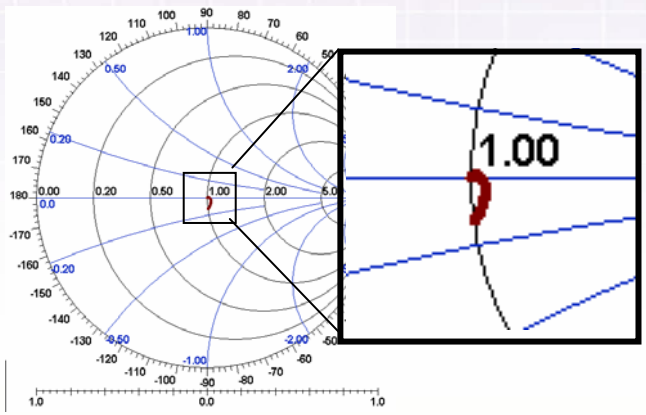


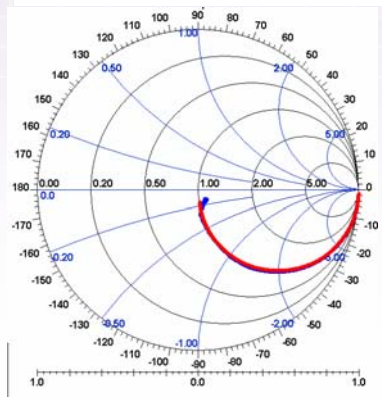












Measurement

Pad Equivalent Circuit

Capacitor

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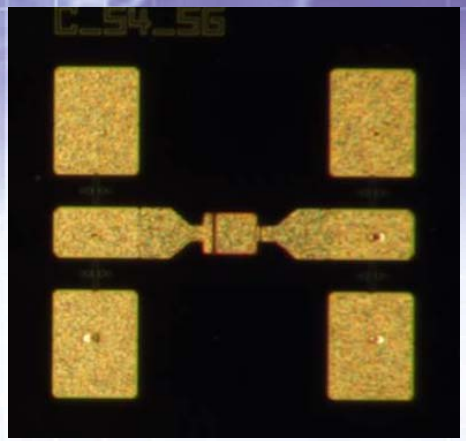
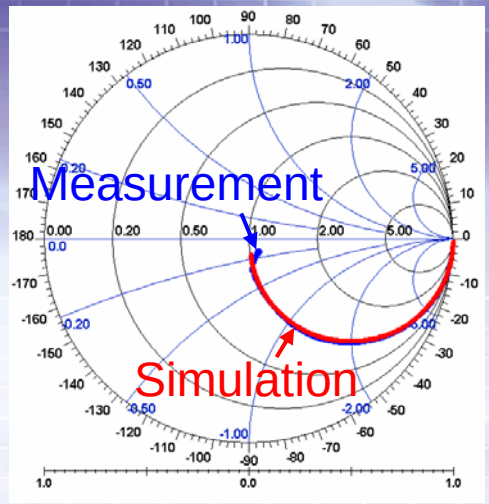
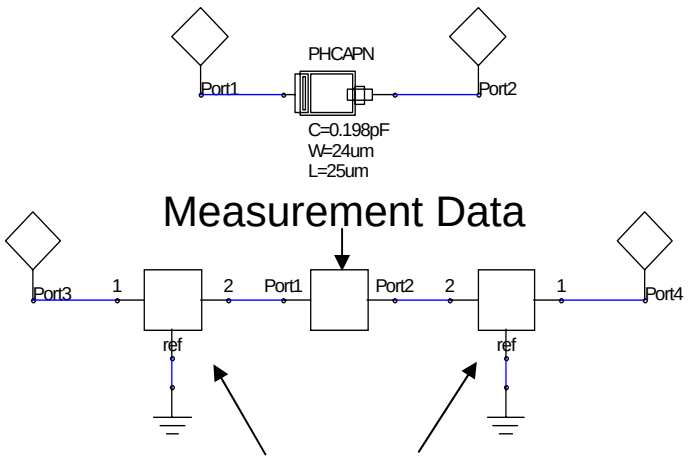
Capacitors



Capacitor Photograph

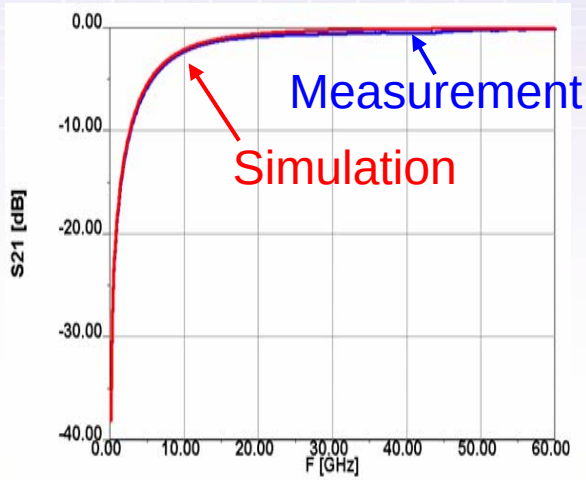
S11



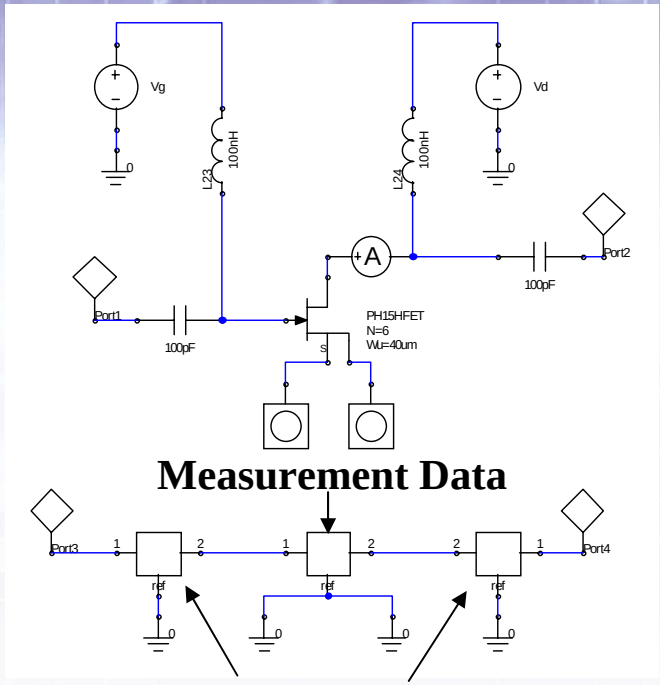


de-embedding Pad Data

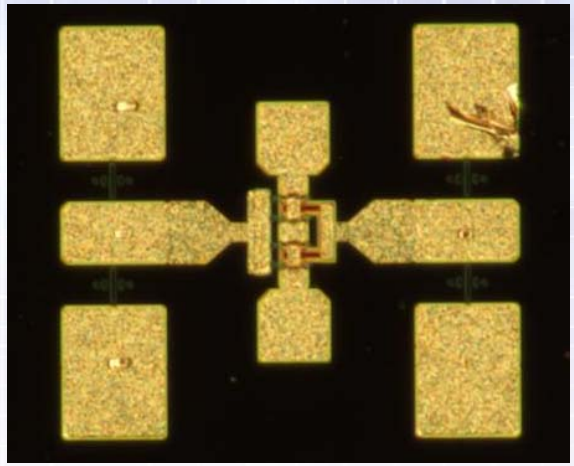
S21



Measurement and Simulation agree well.



de-embedding Pad Data



FET Photograph

FET

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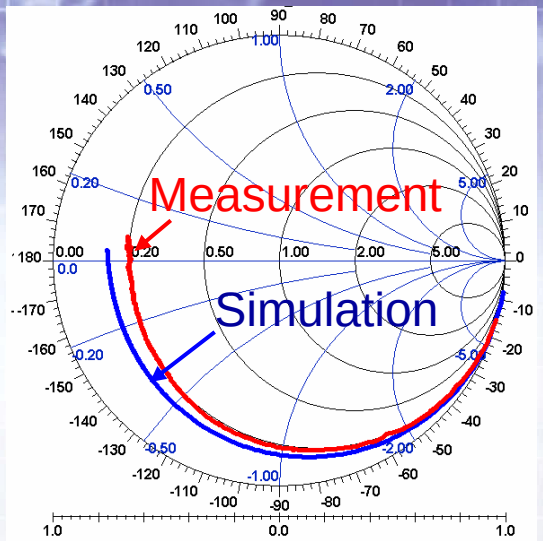
S11



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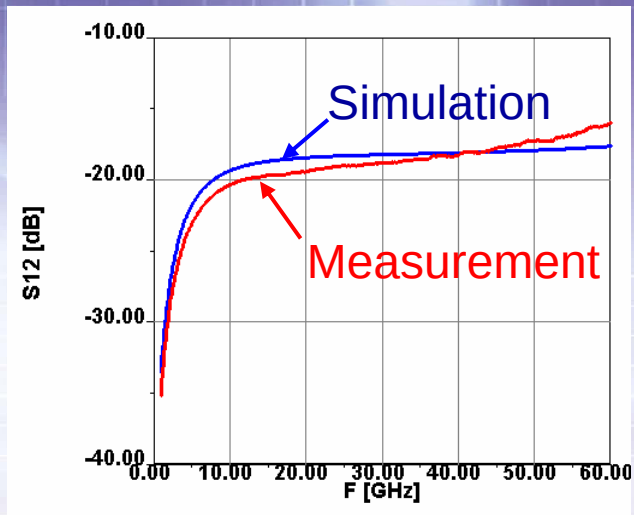

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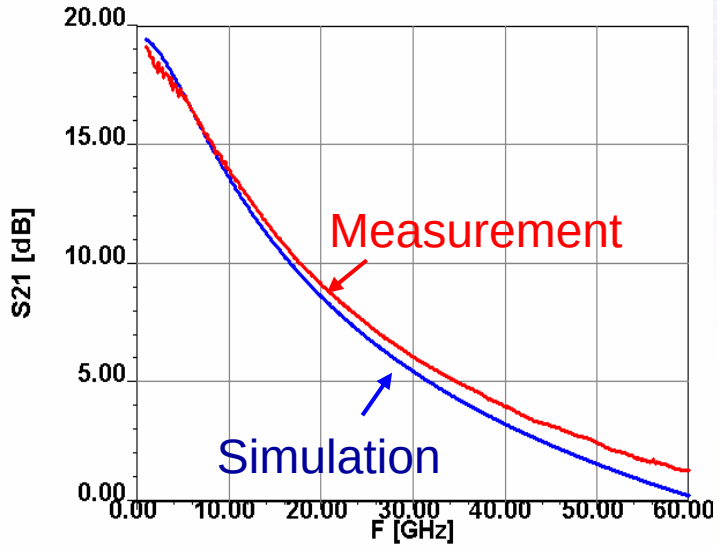

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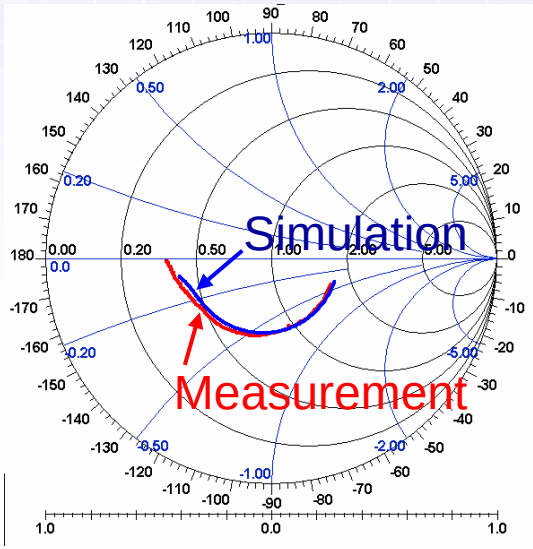

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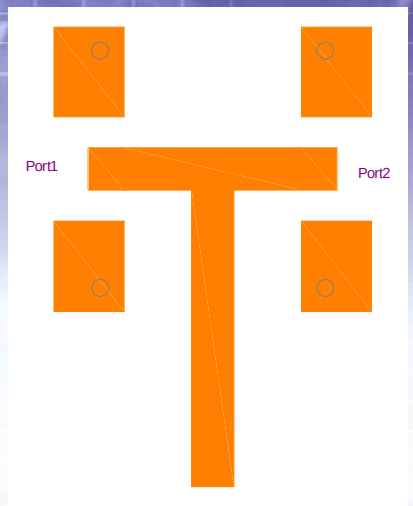
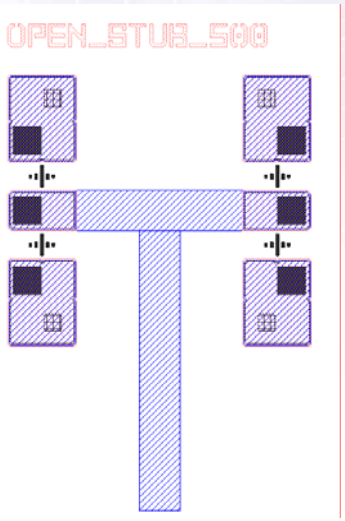
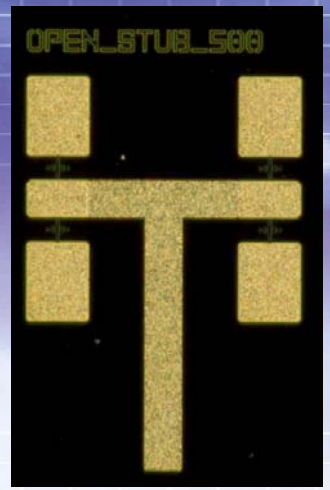
Open Stub



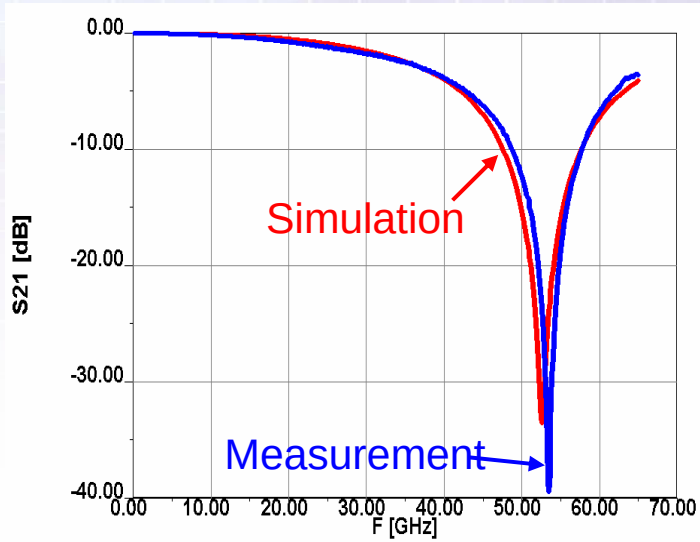
EM model



Layout



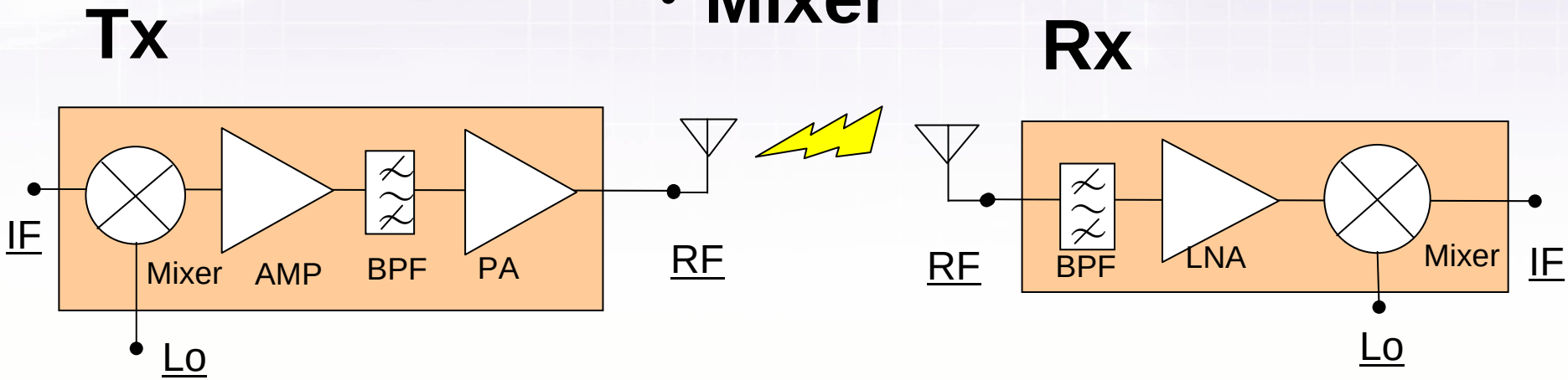
Open Stub Photograph



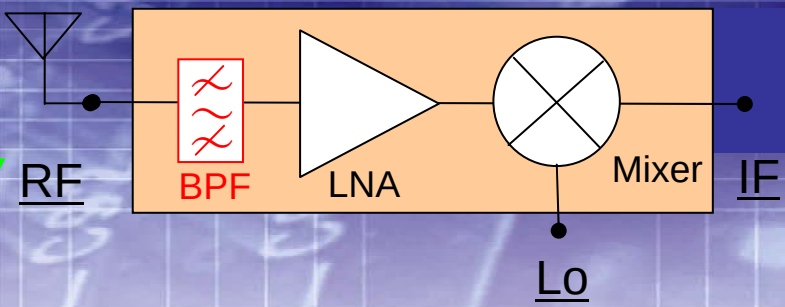
Measurement corresponds with Simulation.

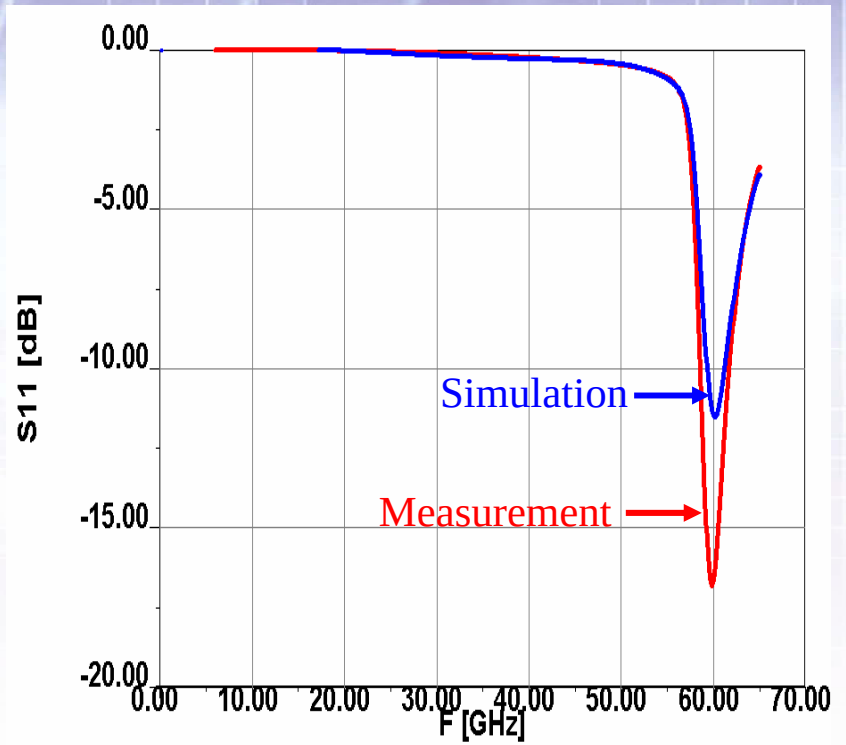
Evaluation of MMIC components

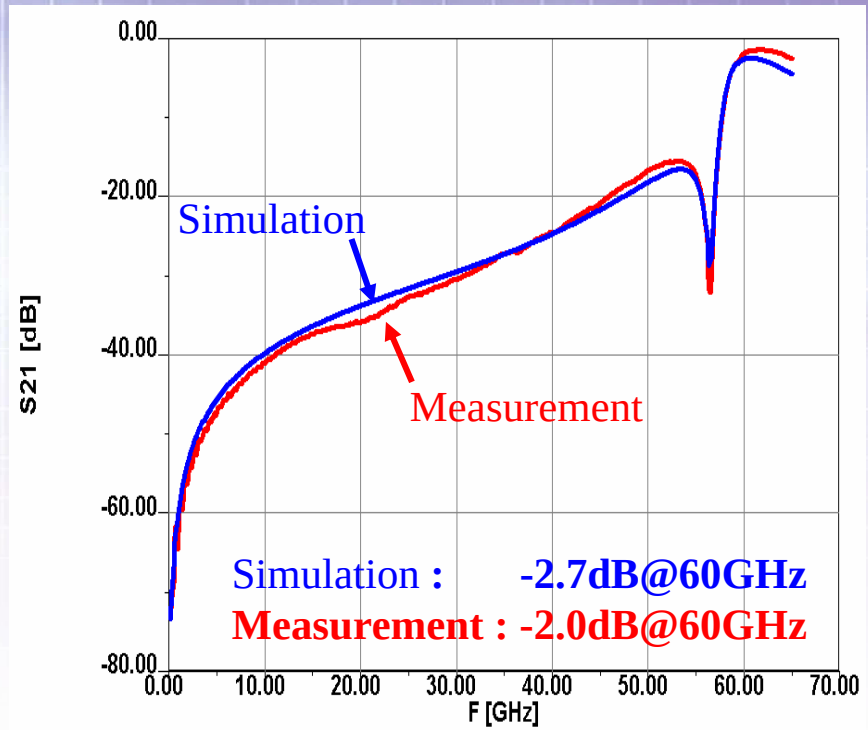
- Filter
- LNA
- PA
- Mixer



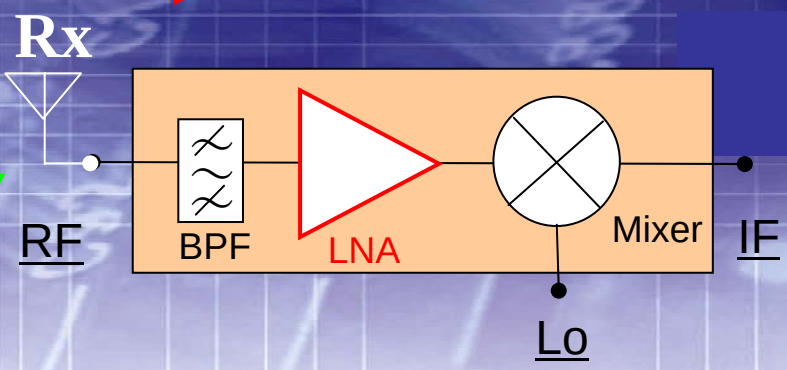
Filter


RF
BPF
LNA
Mixer
IF
Lo


0.00
-5.00
-10.00
-15.00
-20.00
S11 [dB]
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
F [GHz]
Simulation
Measurement


0.00
-20.00
-40.00
-60.00
-80.00
S21 [dB]
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
F [GHz]
Simulation
Measurement
Simulation : -2.7dB@60GHz
Measurement : -2.0dB@60GHz

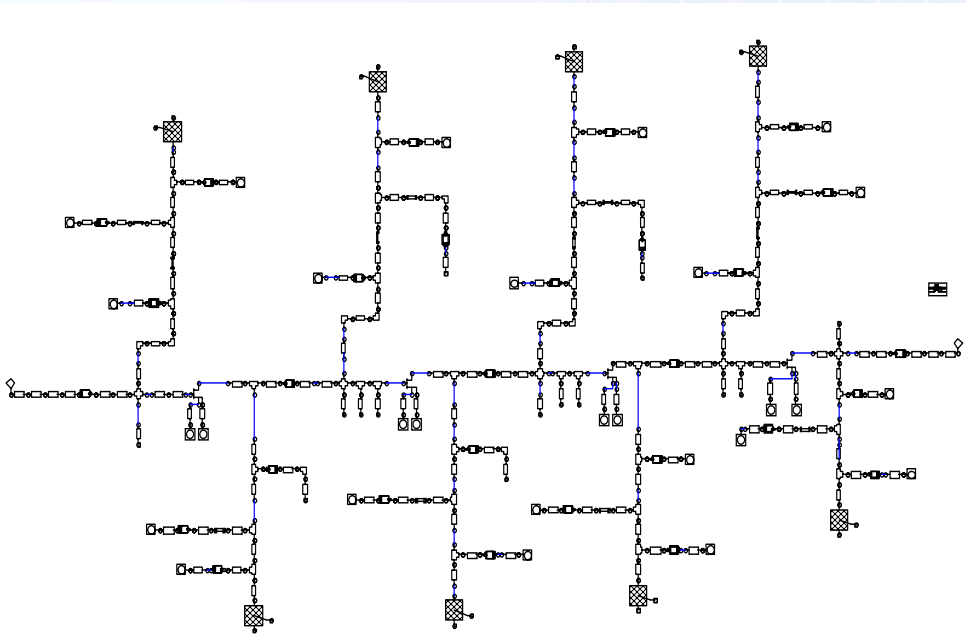
LNA

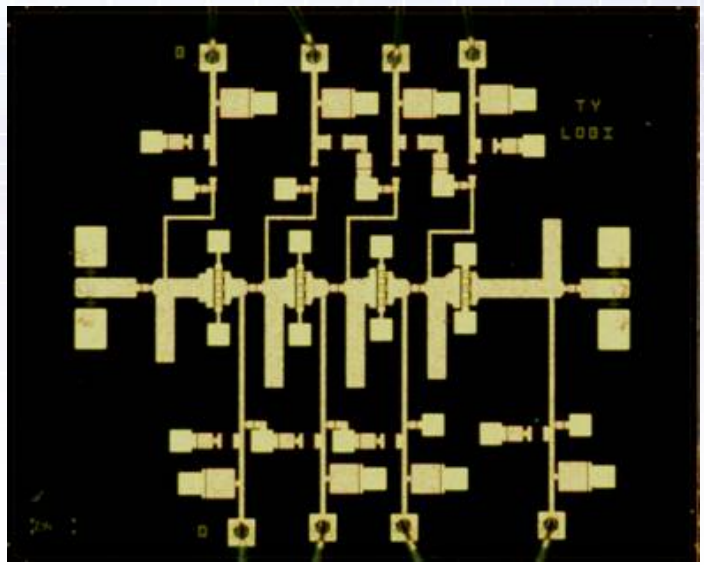


Four Stage LNA

Size 2.2mm × 2.8mm

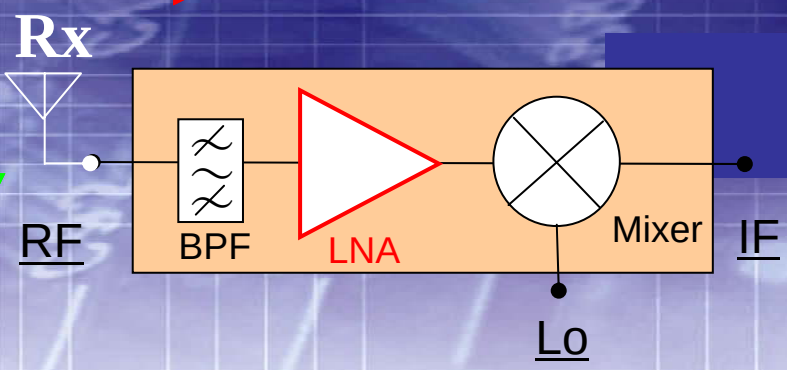
Vd = 2.5V Id = 130mA

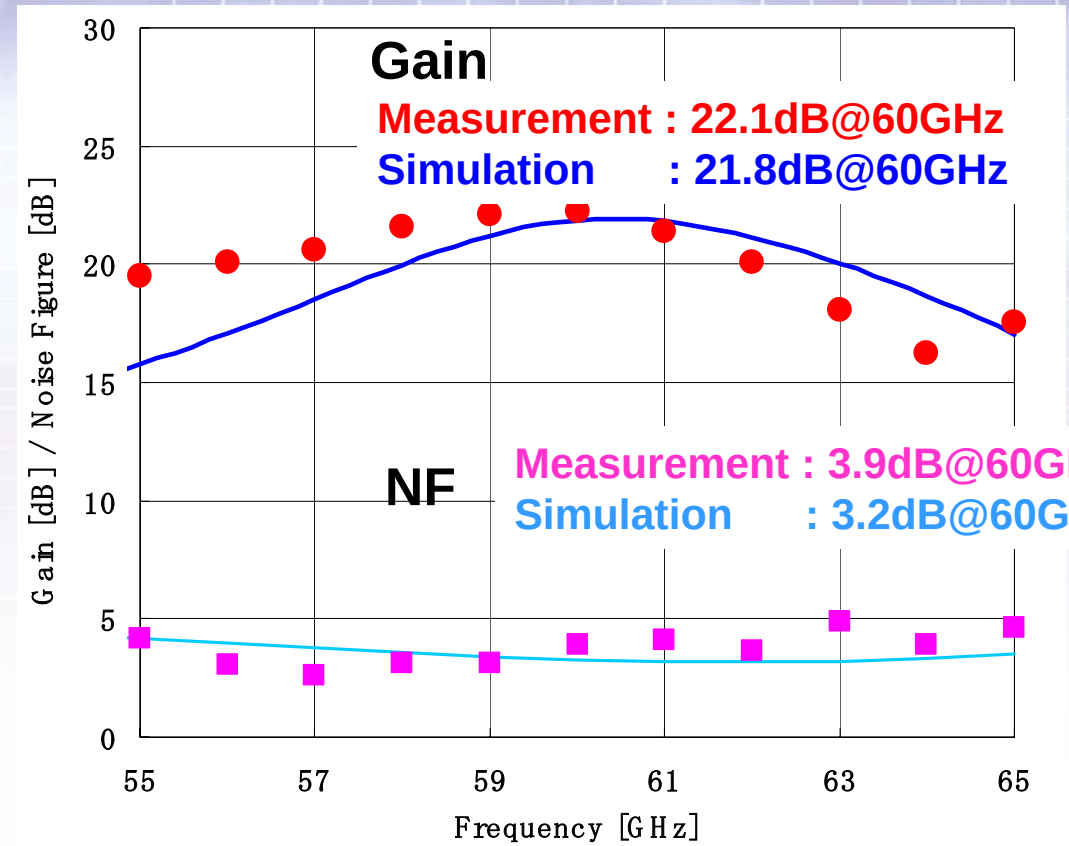




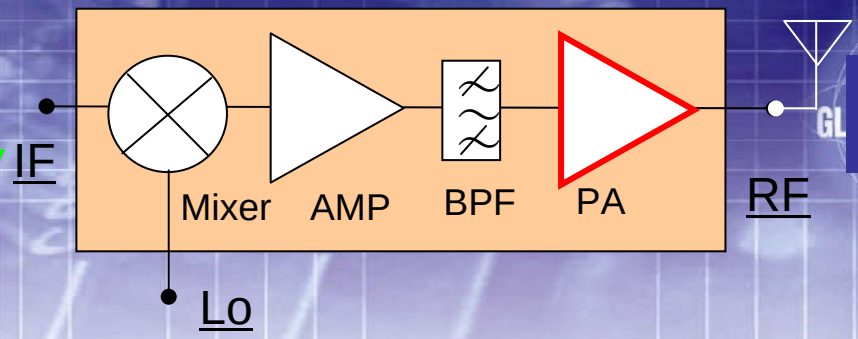
LNA Photograph

LNA





Measurement comparatively corresponds with Simulation.

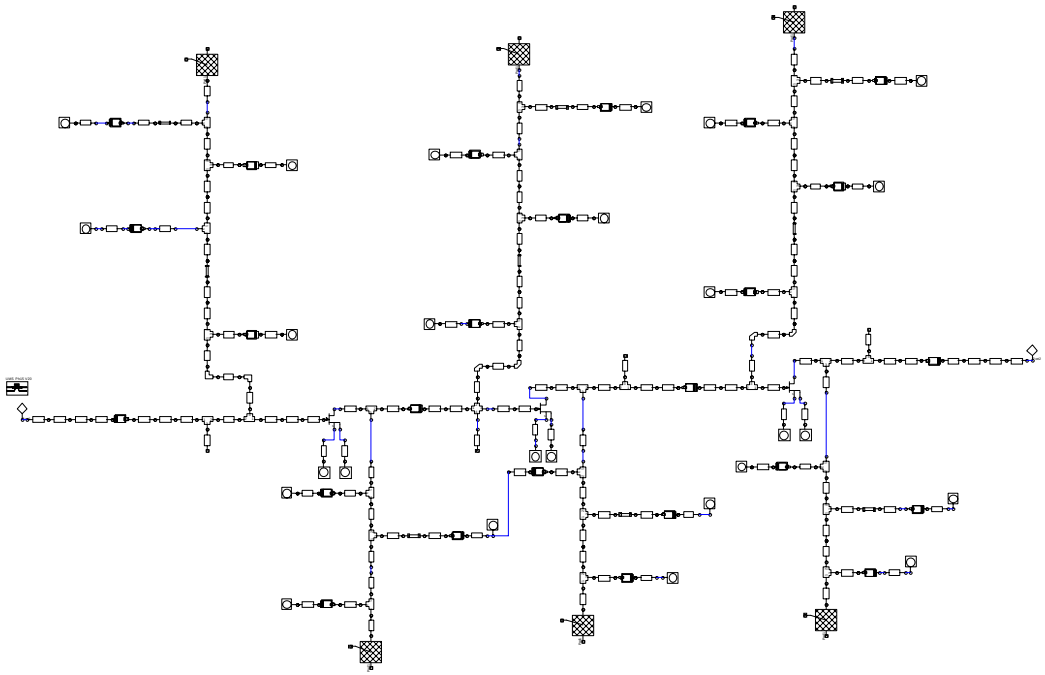


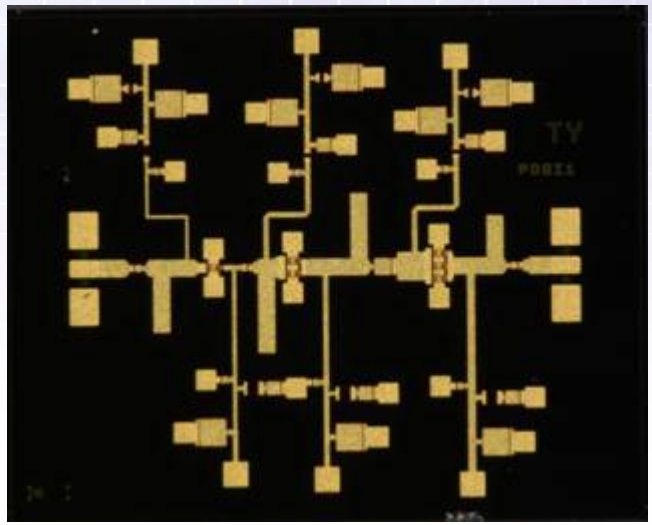
PA

Three Stage PA

Size 2.2mm × 2.8mm

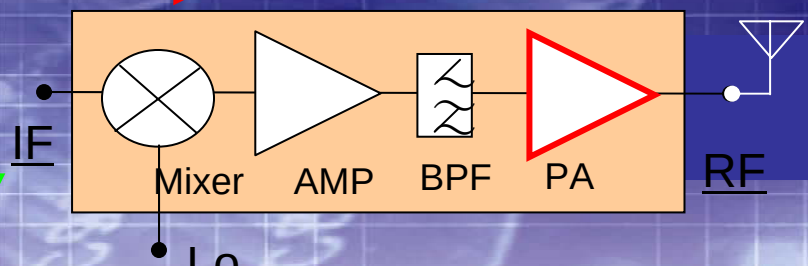
Vd = 2.5V Id = 85mA

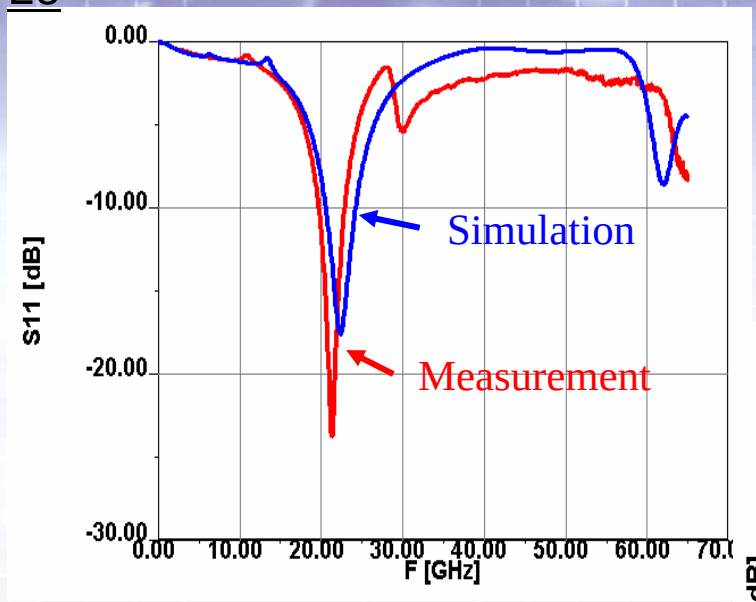


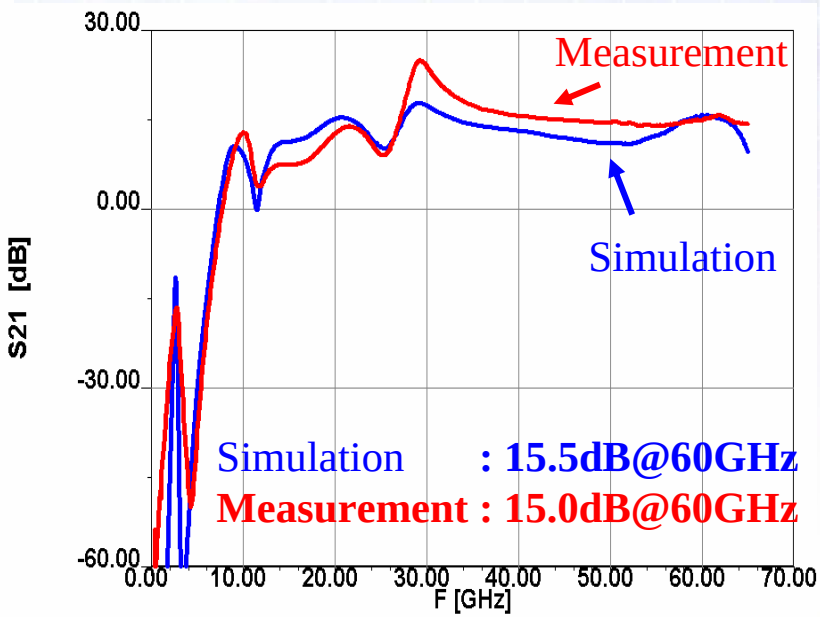


PA Photograph

PA

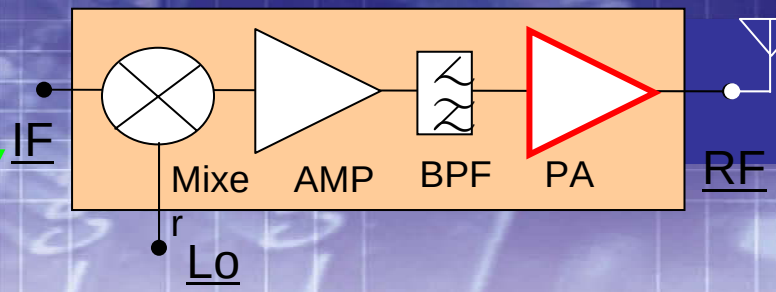


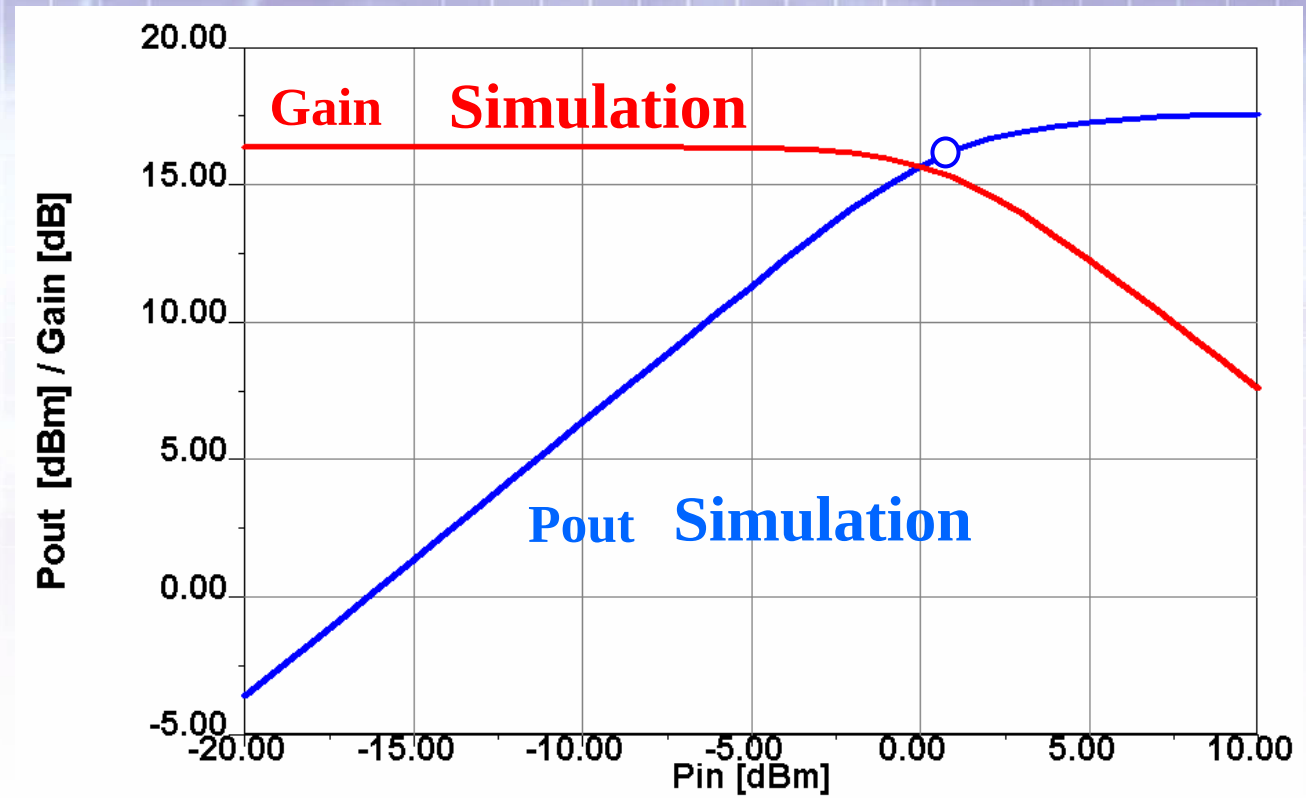




Measurement comparatively corresponds with Simulation.

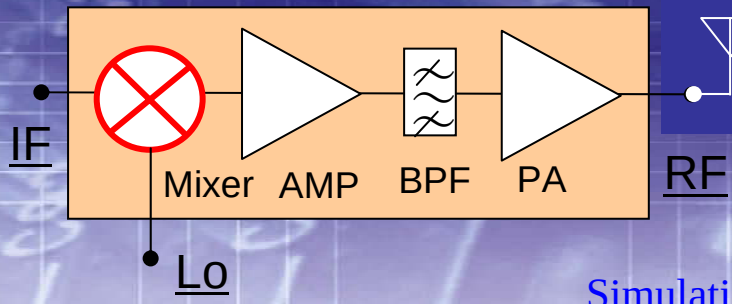
PA

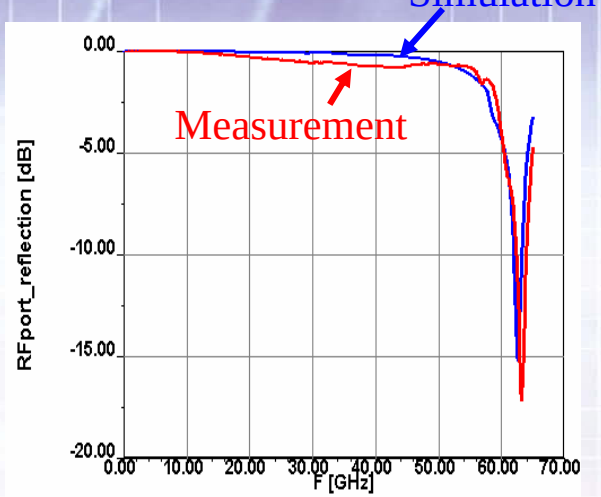


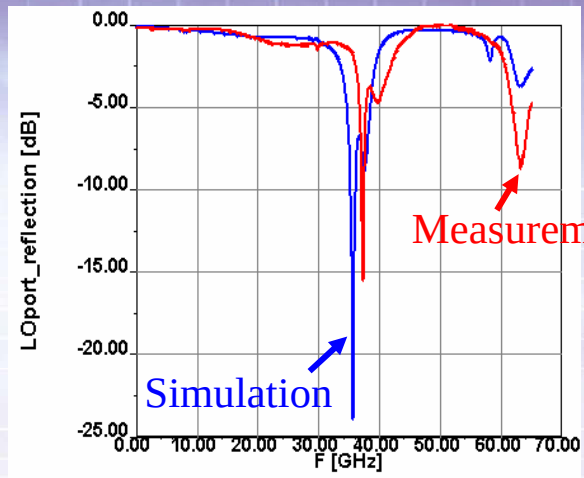


Simulation P1dB 16.3dBm @Pin=1dBm

Mixer



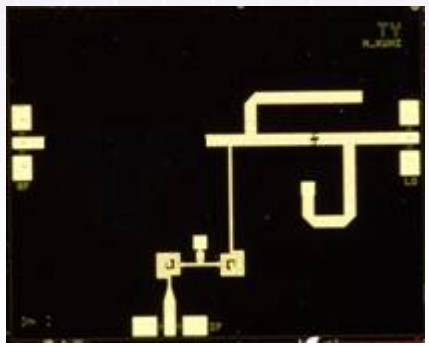




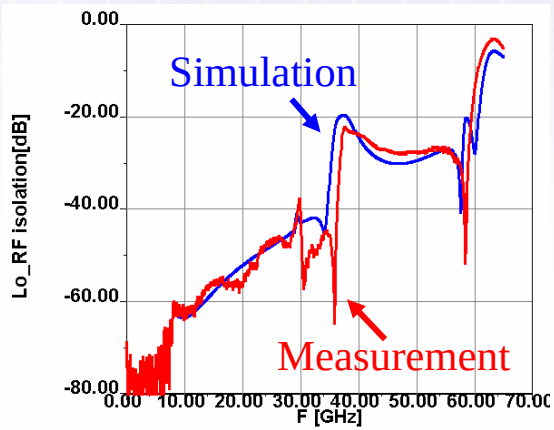
Size 2.2mm×2.8mm

RF:60GHz

Lo:29.5GHz



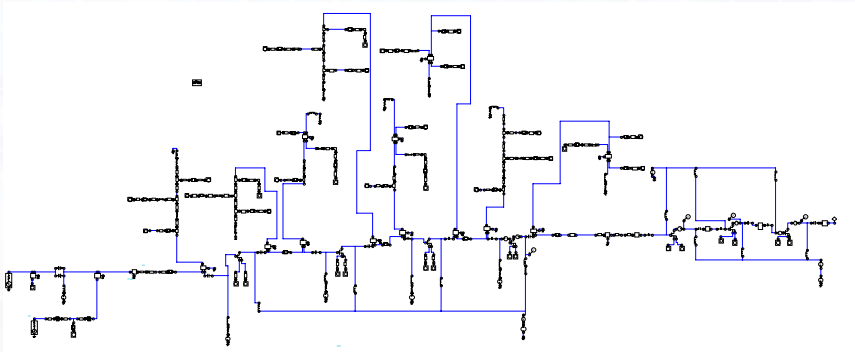
Mixer Photograph



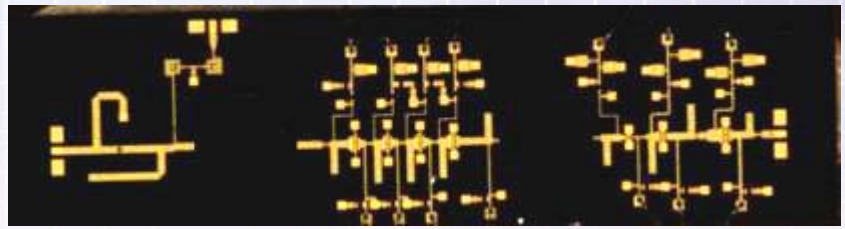
Measurement corresponds relatively well with Simulation.

Circuit Design of Transmitter and Receiver

High speed calculation is necessary to analyze large scale integrated circuits!



Transmitter

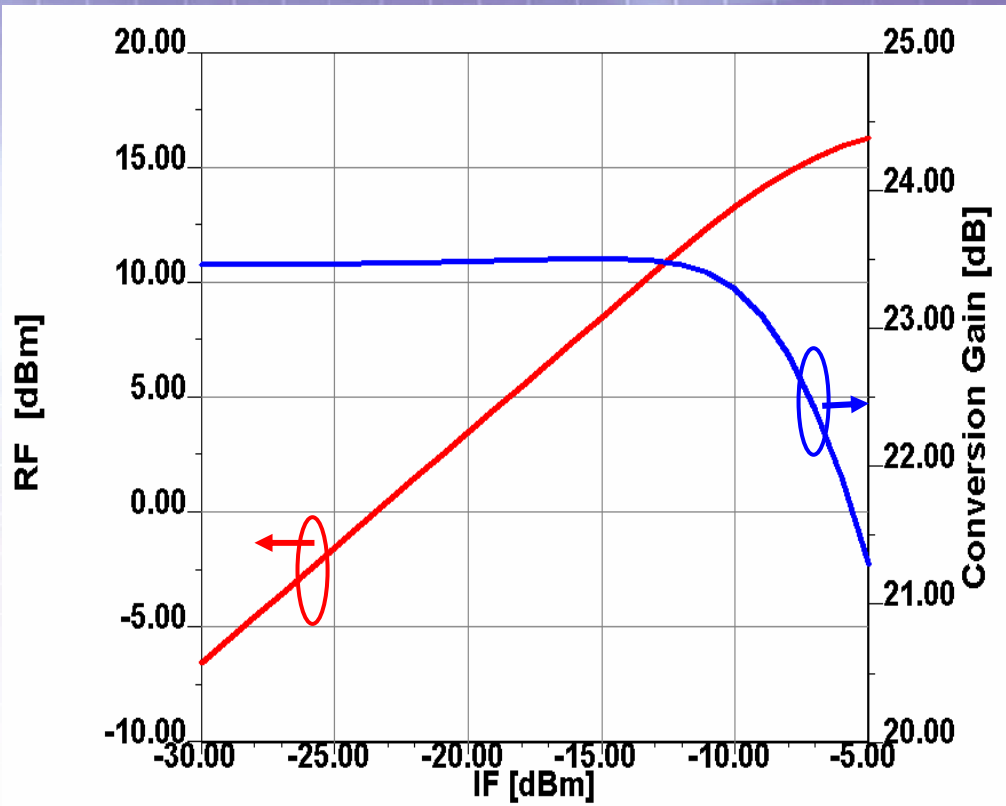


Tx Photograph

Simulated Transmitter Results

Conditions:

RF Frequency : 60GHz
Lo Frequency : 29.5GHz
IF Frequency : 1GHz
Power Sweep : -20dBm~0dBm
Harmonics : 5



Nexxim is able to analyze large scale integrated circuits.

Summary

- **Taiyo Yuden**
  - Material/Lamination Technologies
  - Various products using these technologies
- **Taiyo Yuden provides**
  - High Frequency Products, Technology and Services
- **Millimeter-Wave MMIC**
  - UMS PH15 Design kit
  - Ansoft Designer / Nexxim ver.3
  - measurement corresponds well with simulation

Contact Us

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  - ***mviglione@ansoft.com***