



Taiyo Yuden MMIC Transmitter/Receiver Design Review and Measurement Results

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Presenter: Philip Smith: Ansoft

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- 2. Design and Evaluation**
 - **Millimeter-Wave MMICs**
- 3. Summary**



Creating
GLOBAL STANDARDS

Design Environment

Millimeter-Wave MMICs Measurement/Evaluation Technologies

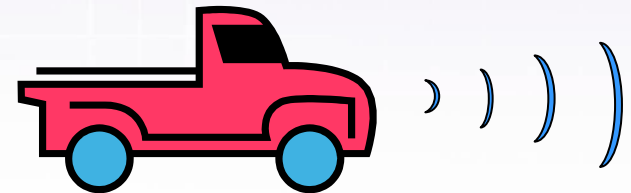
Millimeter Wave applications

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...



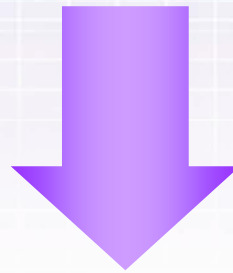
**Superior Measurement/Evaluation technologies
are *necessary* at Millimeter-Wave frequencies.**

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

TAIYO YUDEN
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

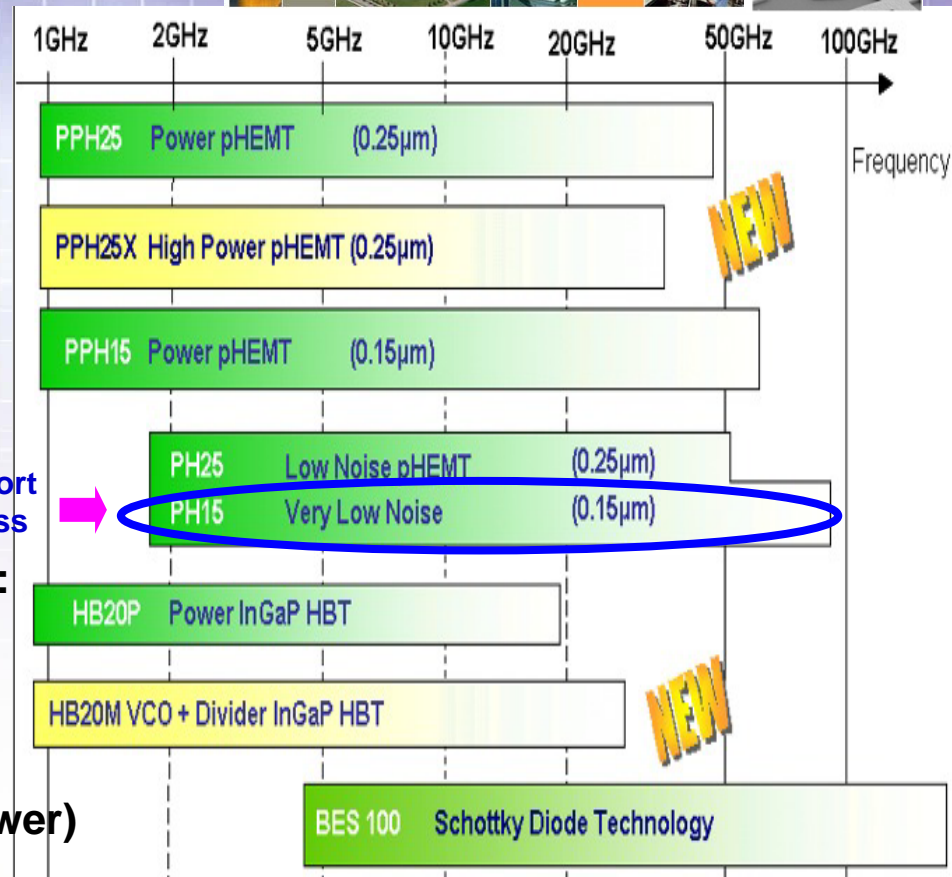
United Monolithic Semiconductors (UMS)

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
- Design manuals and Design Kit
 - 80GHz Support PH15 Process
- 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

Supporting processes including:

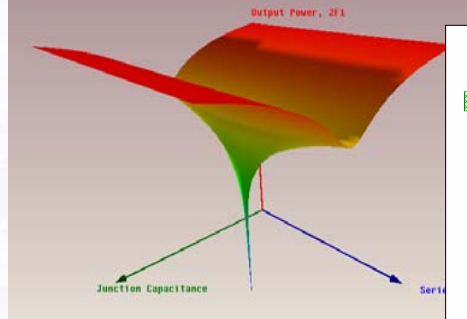
- Air bridges
- MIM capacitors
- TaN and TiWSi resistors
- 100um thinning
- Via-holes



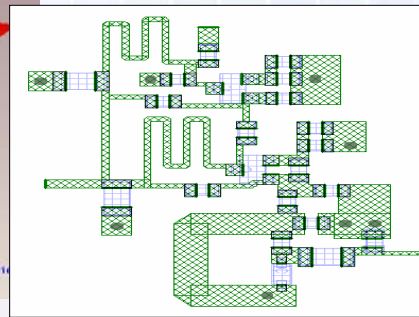
Millimeter-Wave MMIC Design Environments

Ansoft Designer /Nexxim ver. 3

NEXXIM Circuit Simulator



High speed Nonlinear Analysis

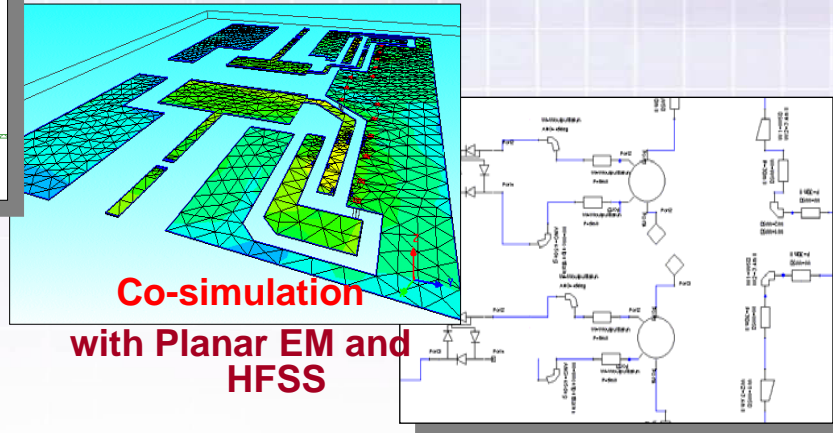


Layout changes are reflected in real time.

DESIGNER

Integrated Environment

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



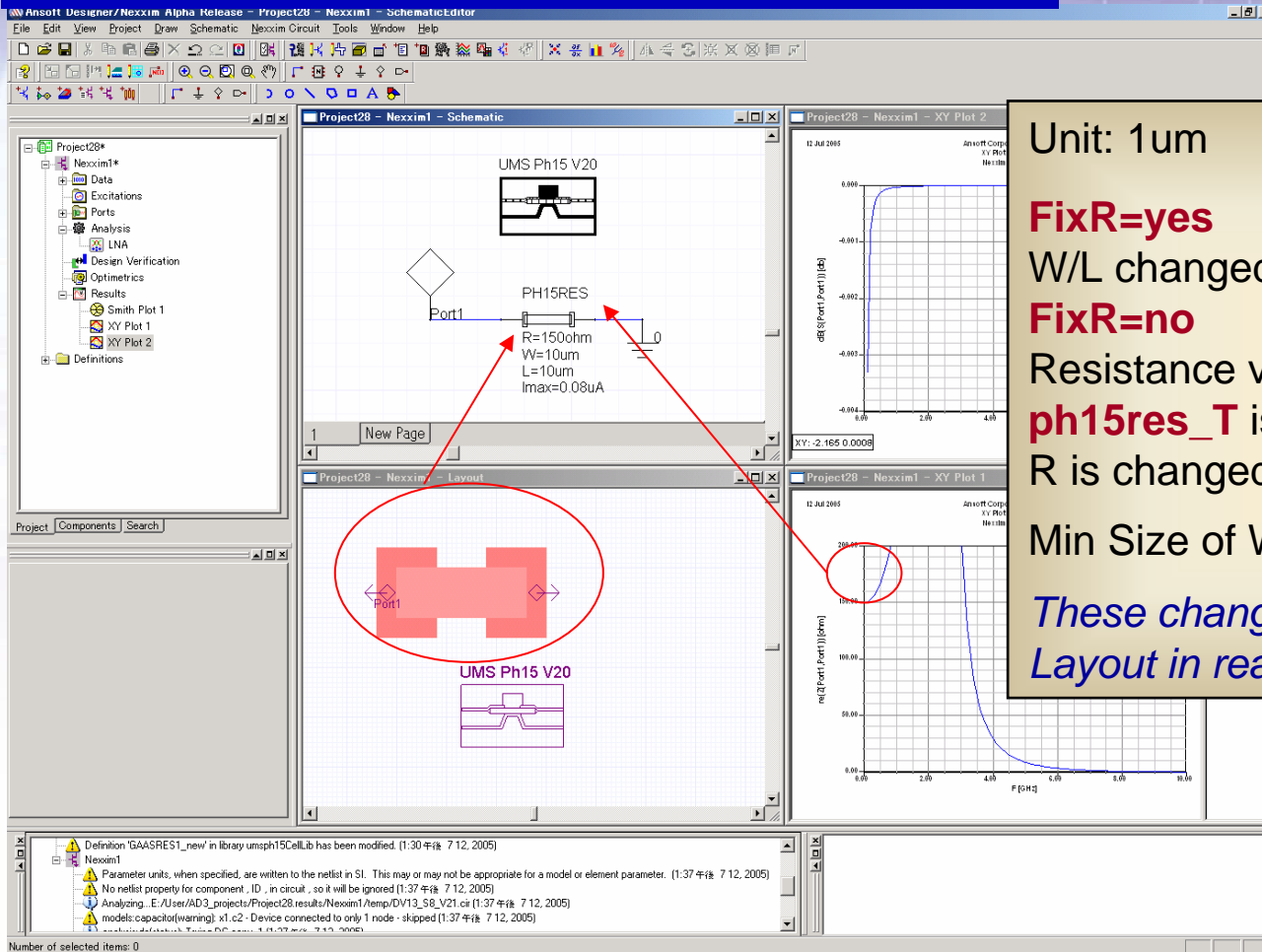
Co-simulation with Planar EM and HFSS

- 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



UMS PH15 DK for AD/Nexxim ver.3

Nonlinear Element Example

PH15 HOTFET: Part name=PH15HFET

The screenshot displays the Ansoft Designer/Nexxim interface. The main window shows a schematic diagram of a PH15HFET circuit. The circuit includes a gate terminal connected to a DC voltage source (V7) through a series inductor (L5) and a thru-hole component (THRU). The drain terminal is connected to a load inductor (L6) and a thru-hole component (THRU), which is then connected to a port (Port2). The gate is also connected to a thru-hole component (THRU) and a port (Port1). The circuit is powered by a DC source (V6) and includes a current source (A) and a capacitor (C3). The schematic is annotated with various components like C2, CUT, and L5.

Below the schematic, a layout view shows the physical layout of the device, with various layers and components highlighted in different colors (blue, green, red, yellow). The layout is connected to the schematic via arrows.

Two analysis plots are shown. The top plot, titled 'XY Plot 2', shows the current (Y1) versus frequency (F [Hz]). The bottom plot, titled 'XY Plot 1', shows the negative drain current (Negative(ID) [mA]) versus drain voltage (VD). The plot shows a non-linear relationship between the drain current and the drain voltage, characteristic of a hot electron transistor (HOTFET).

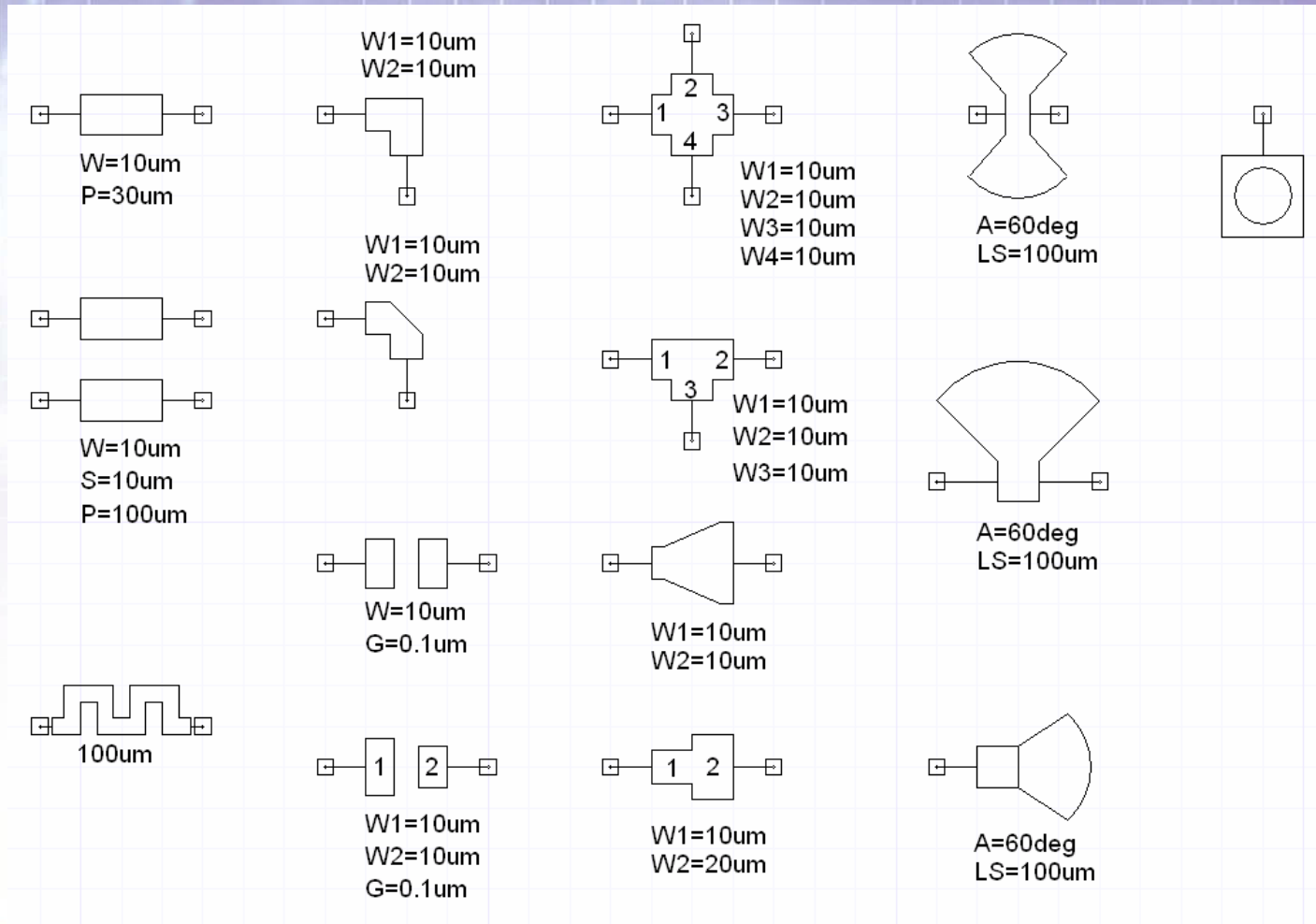
A 'Properties' dialog box is open, showing the parameters for the PH15HFET model. The parameters are as follows:

Name	Value	Unit	Evaluated Value	Description	Callback	Override
Model	PH15HFET			Model Name		
Wu	20	um	20um	Gate Finger Width	PH15HFET	<input type="checkbox"/>
NF	4			Number of Finger	PH15HFET	<input type="checkbox"/>
Igmax	0.25	mA	0.25mA			<input type="checkbox"/>
Status	Active					<input type="checkbox"/>

The central text overlay reads 'Schematic & Layout'.

UMS PH15 DK for AD/Nexxim ver.3

Microstrip Elements



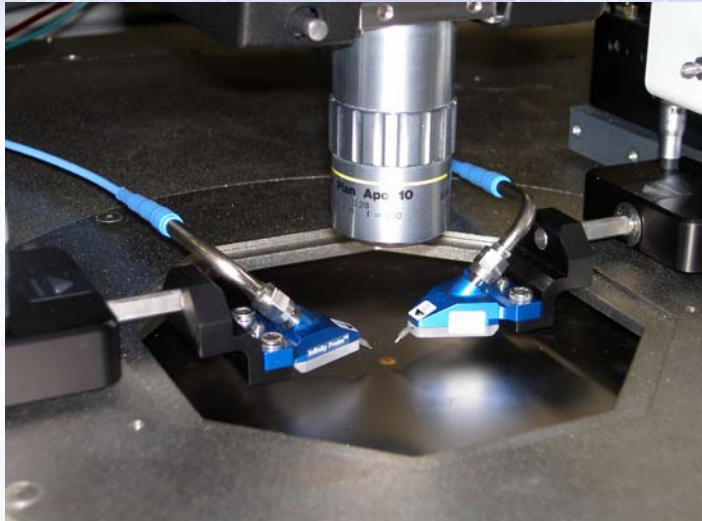


Creating
GLOBAL STANDARDS

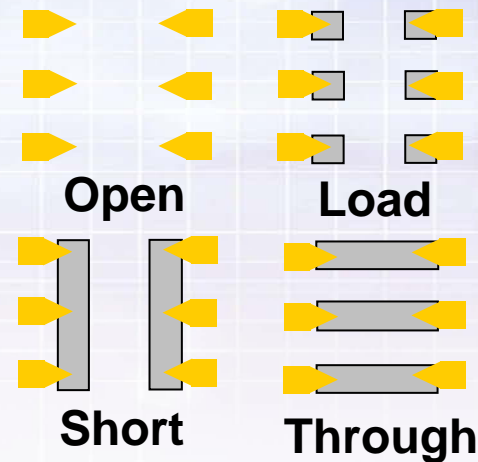
Millimeter-Wave Band Measurement/Evaluation Technologies

Millimeter-Wave Band Measurement/Evaluation Technology

Technology for High Resolution Measurement



SOLT Calibration



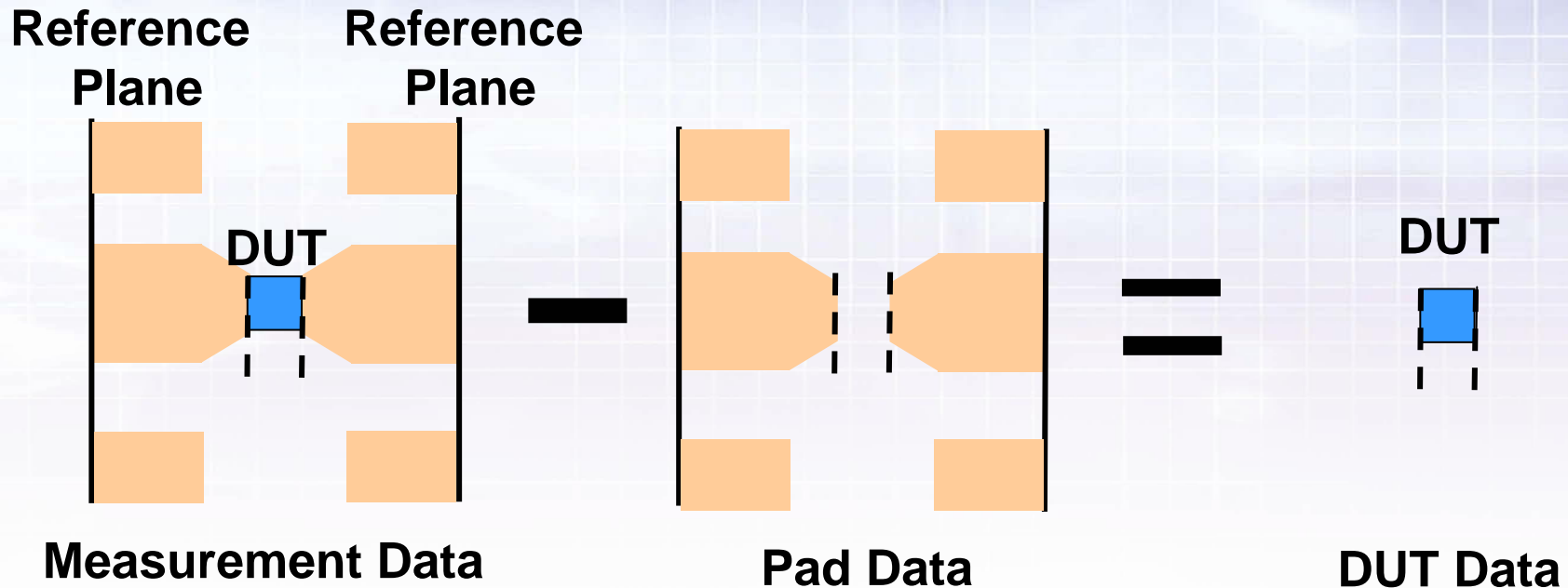
Electrical Length 1 degree = 5um @ 60GHz

(Thickness of GaAs Substrate 100um)

Contact position must be accurately controlled

Measurement/Evaluation Technology of Millimeter-Wave Band

Technology for Accurate Compensation



Compensation Method

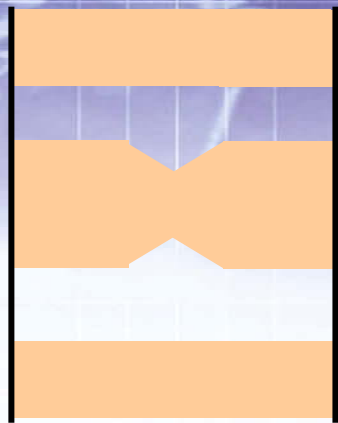
	Phase	Loss	Impedance Mismatch
Electrical Length	✓		
Electrical Length and Magnitude	✓	✓	
De-embedding	✓	✓	✓

Equivalent Circuit for Pad

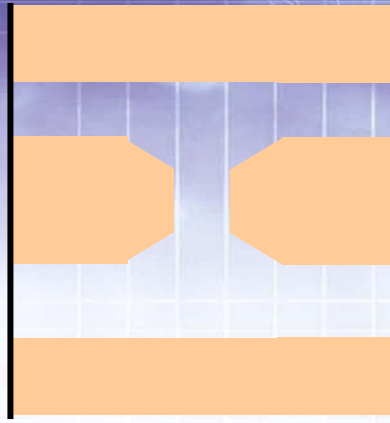


De-embedding

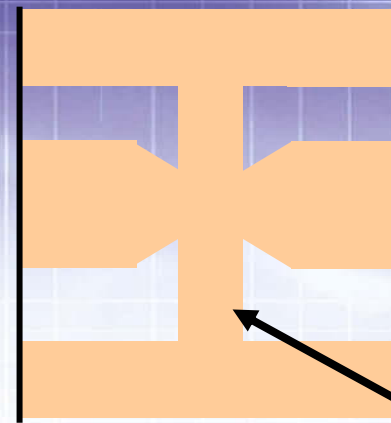
Extraction of pad data



Thru

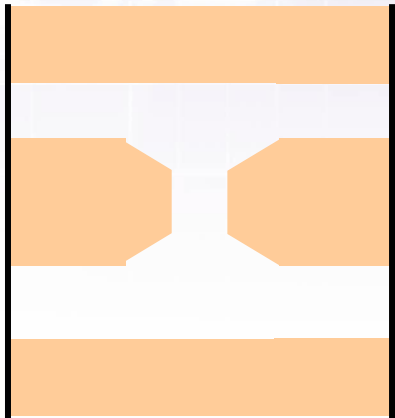


Open

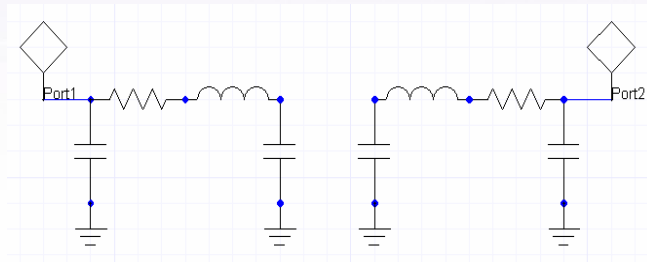


Short

Excess Inductance



Pad



Equivalent circuit



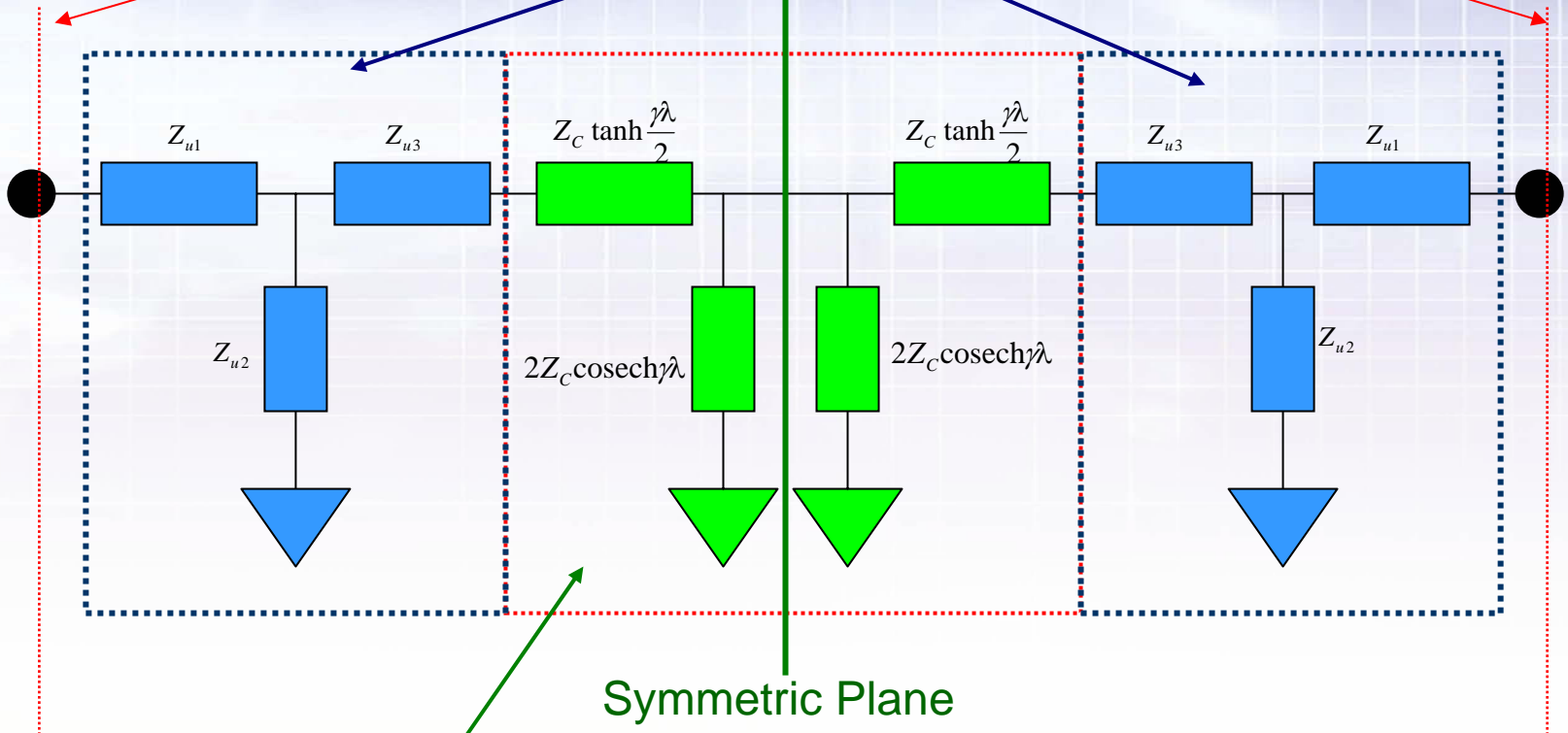
De-embedding
Easier?
more accurate?

Problem Definition

Creating
GLOBAL STANDARDS

Measurement References

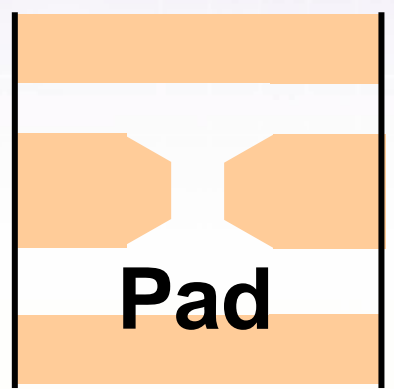
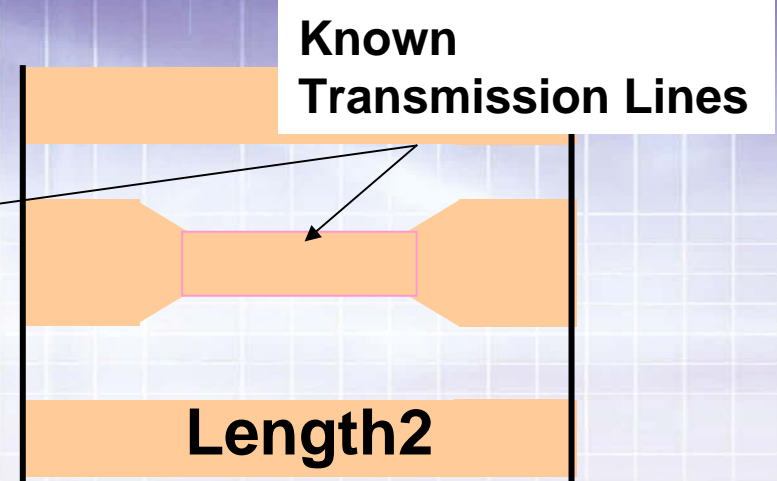
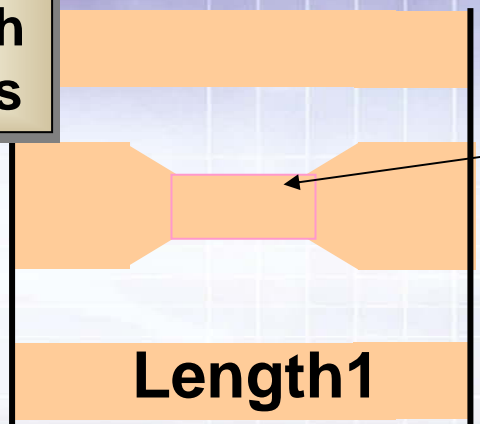
Unknown Circuit



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

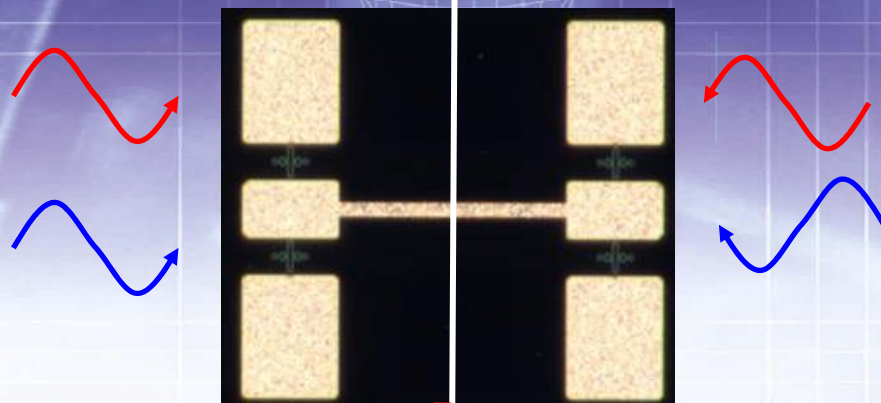
Easy-to-use approach using Ansoft Designer

Uses two different length lines with pads

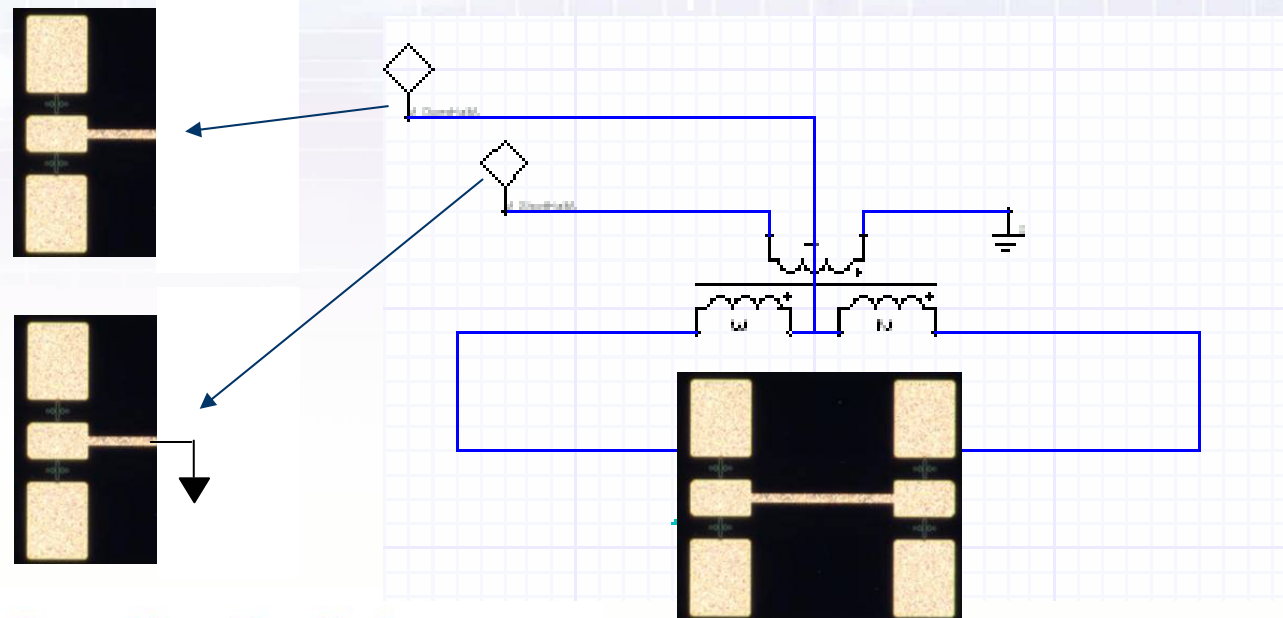


S-parameter → de-embedding

Principle of this method



Virtual Open and Short Conditions



Easy-to-use approach using Ansoft Designer

Ideal Data (two different length lines)

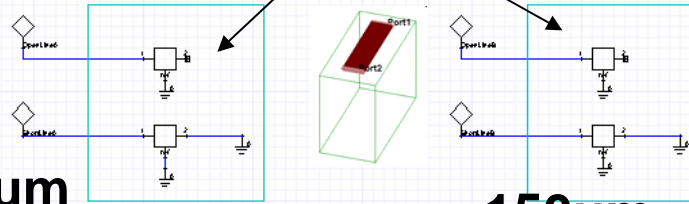
Case A

Case B

Step 1) Calculate Z_{oHalf} and Z_{oShort} using Fieldsolver

Assumption is this is a known Line

from HFSS



Use this to identify the known TRL to be characterized

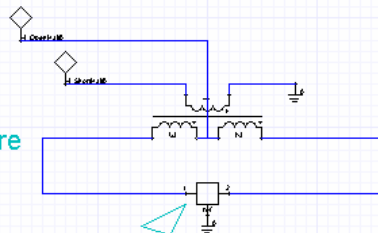
100um

150um

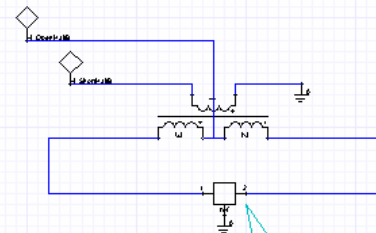
Step 2) Read in Measured S-parameters

User Bartlett Principle

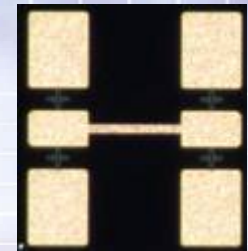
Bartlett Principle to realize ideal Short and Open for 2 different lines and test fixture



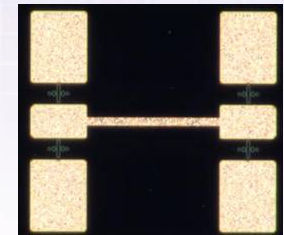
Measured Data A



Measured Data B



Case A 200um

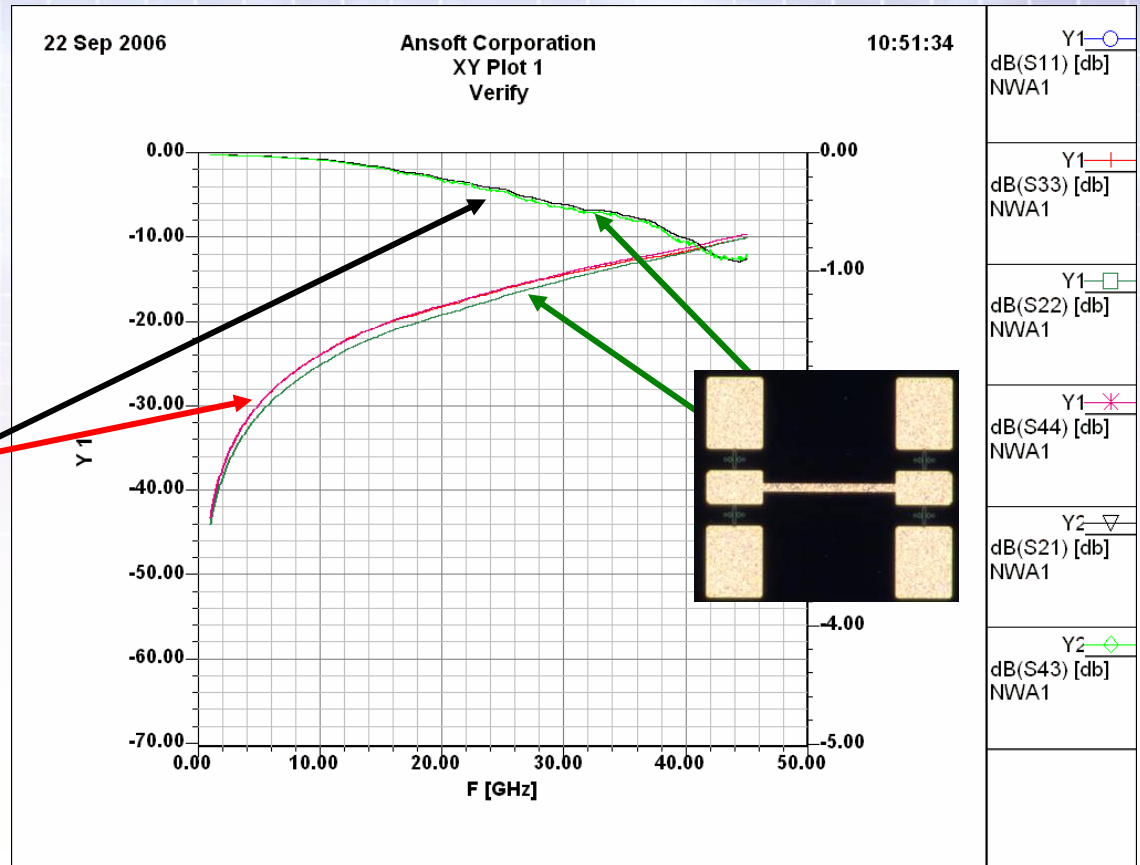
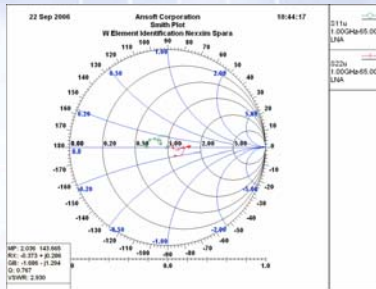


Case B 300um

Measured Data (two different length lines with pads)

Algorithm integration in AD project

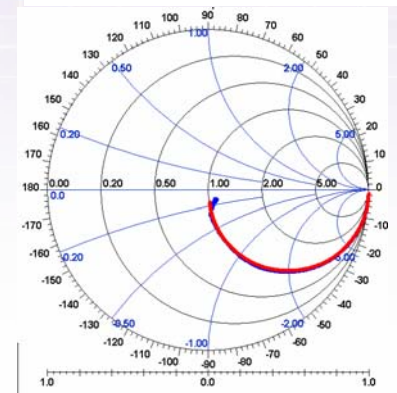
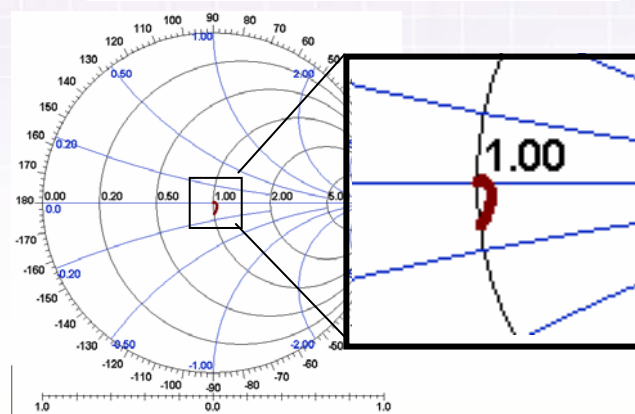
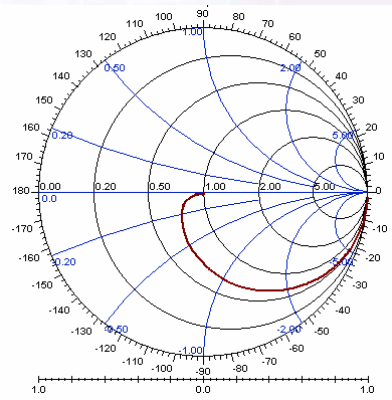
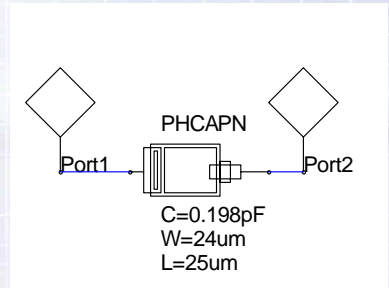
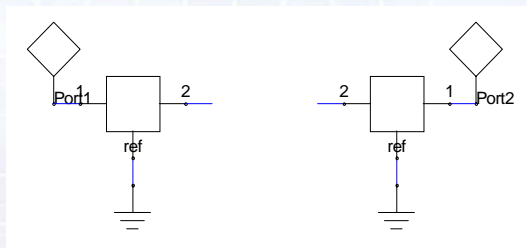
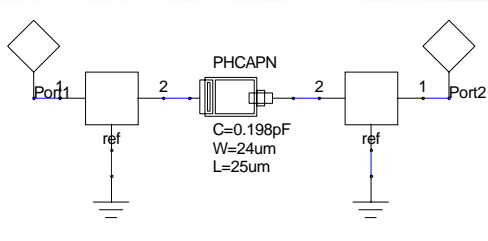
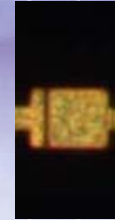
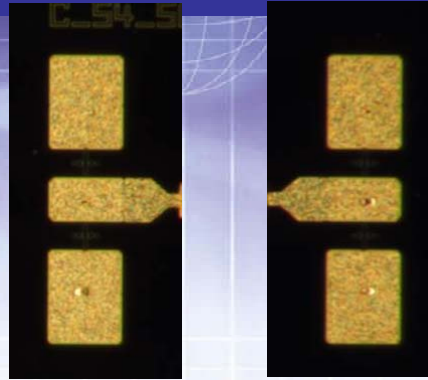
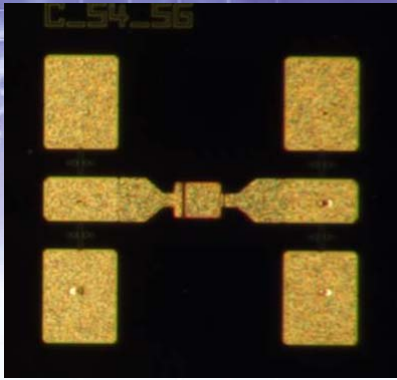
Verifying the Connector Extraction with Measured Results





Design and Evaluation of Millimeter-Wave MMICs

Capacitors

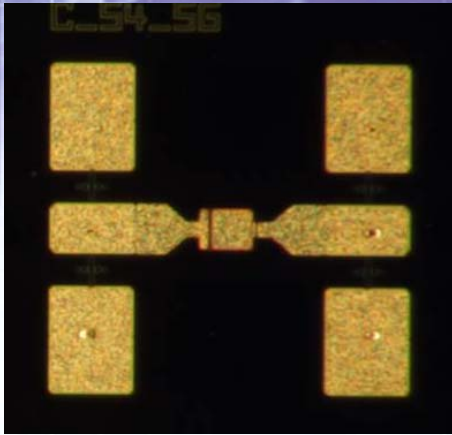


Measurement

Pad Equivalent
Circuit

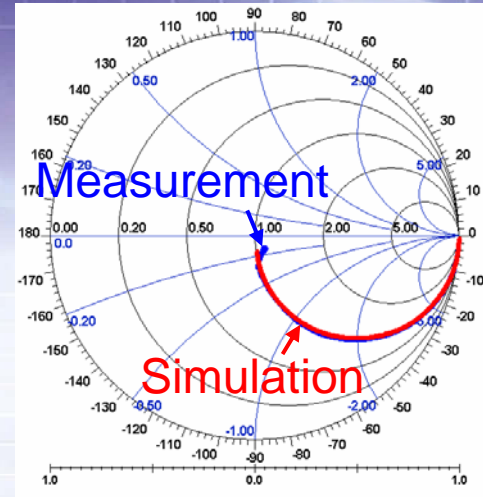
Capacitor

Capacitors

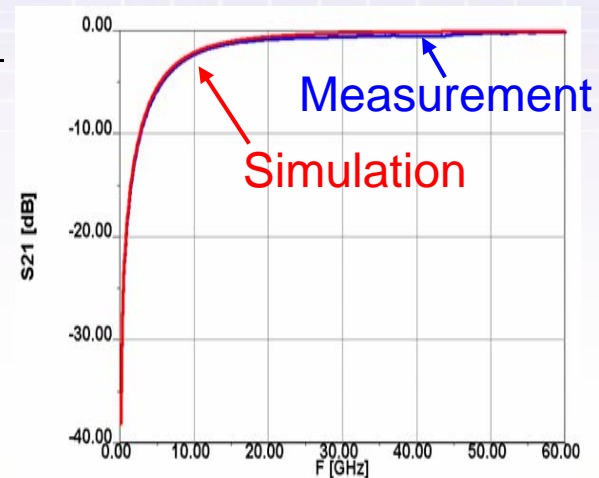


Capacitor Photograph

S11

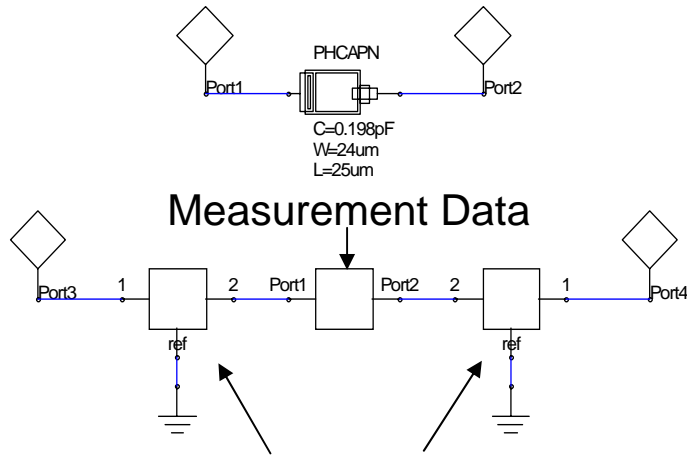


S21



Measurement and Simulation agree well.

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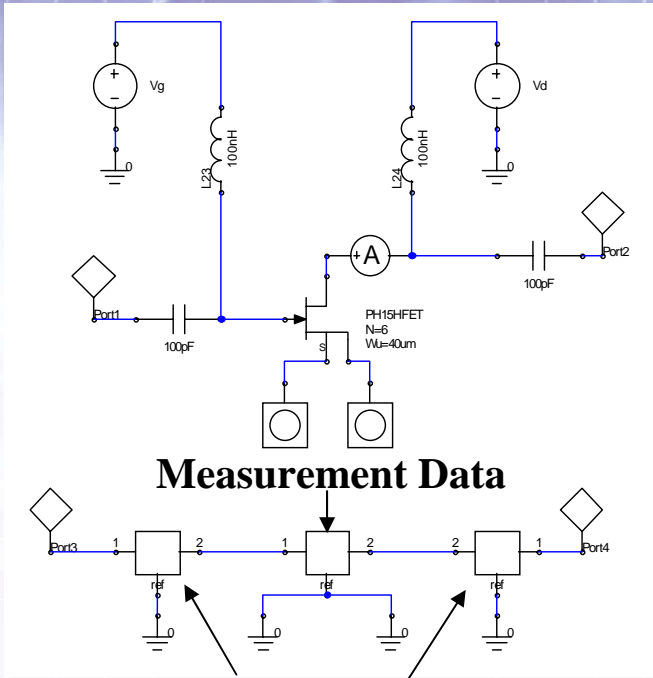


de-embedding Pad Data

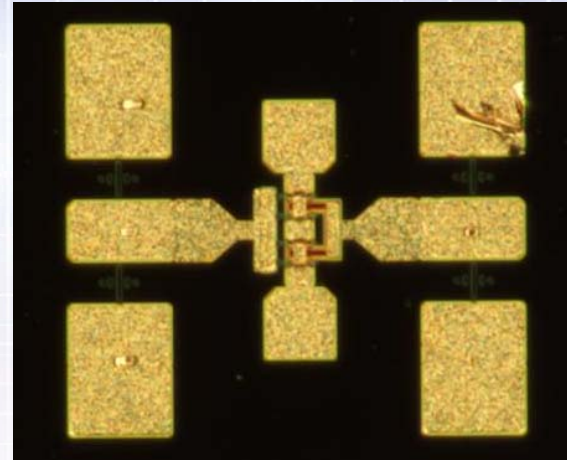
LeadingInsight

Application Workshops for High-Performance Design



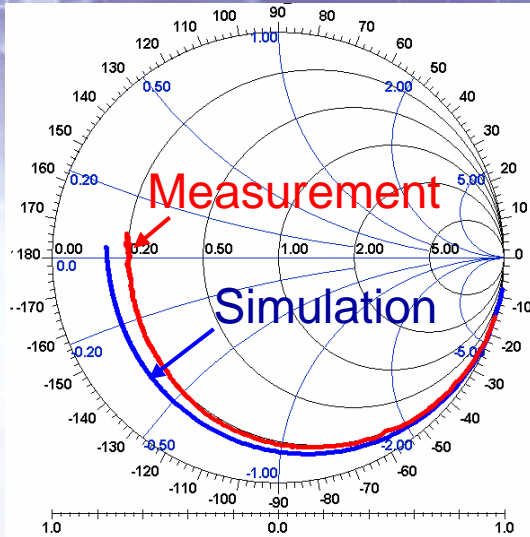


de-embedding Pad Data

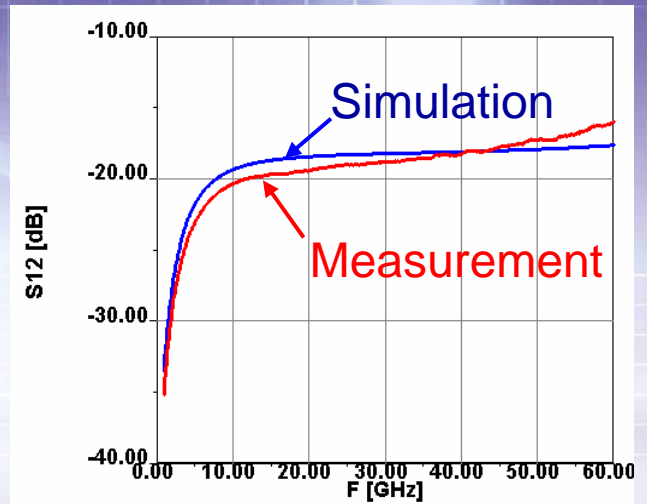


FET Photograph

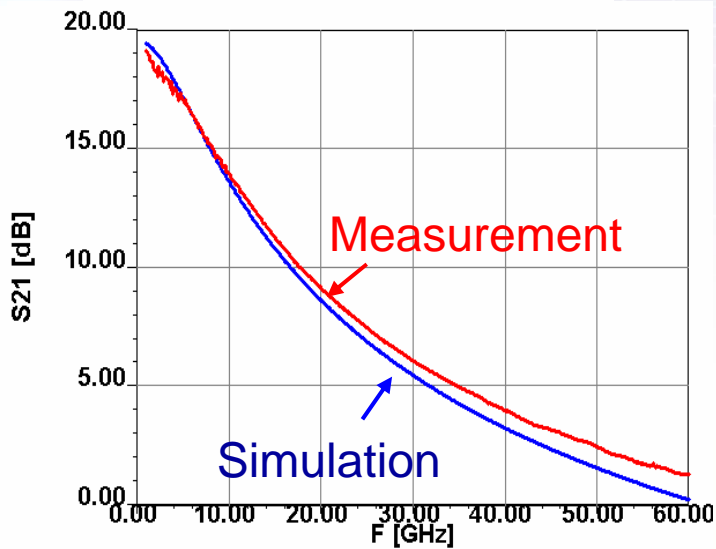
S11



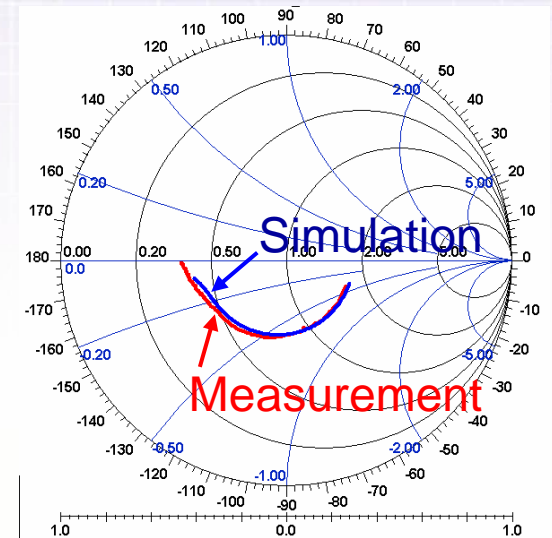
S12



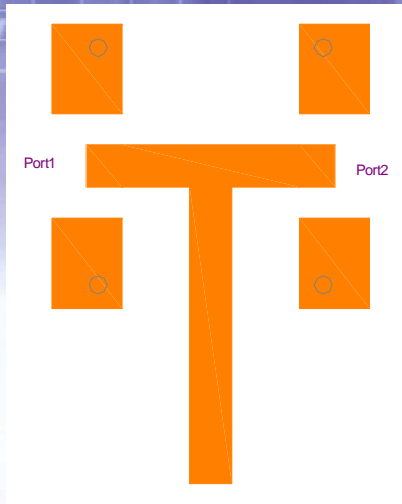
S21



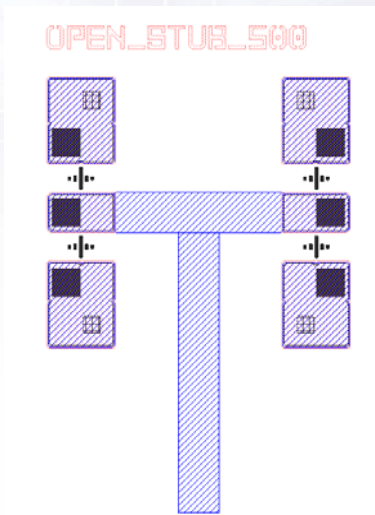
S22



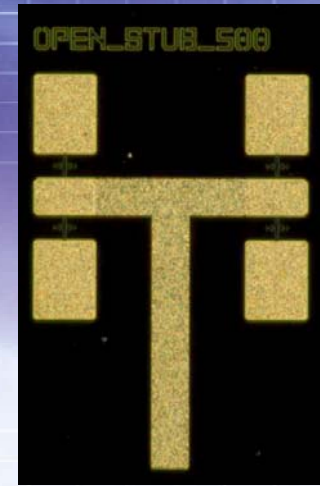
Open Stub



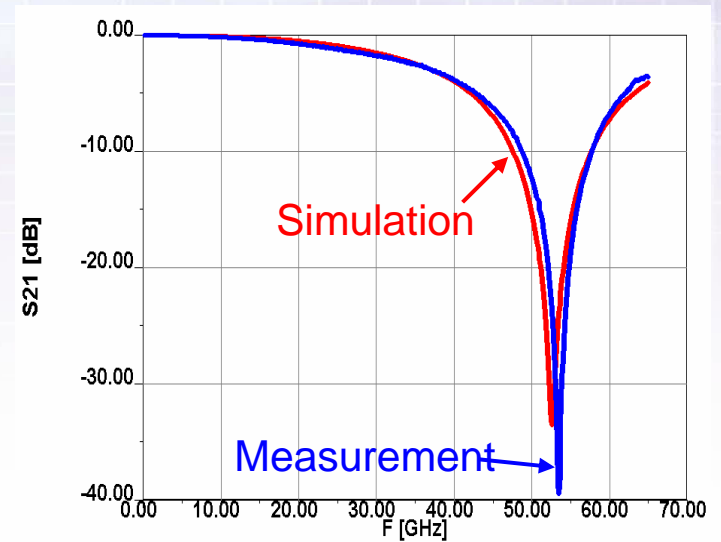
EM model



Layout



Open Stub Photograph

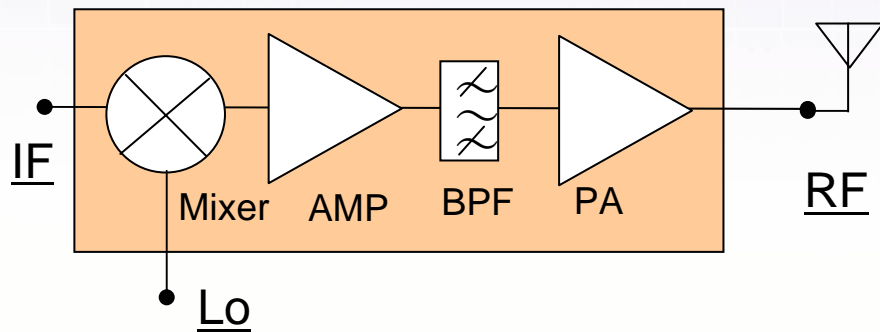


Measurement corresponds with Simulation.

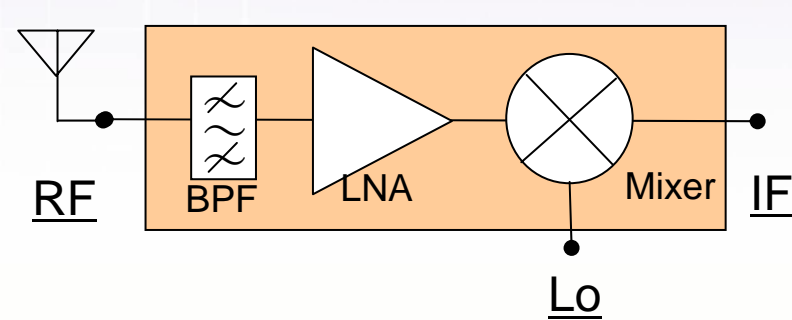
Evaluation of MMIC components

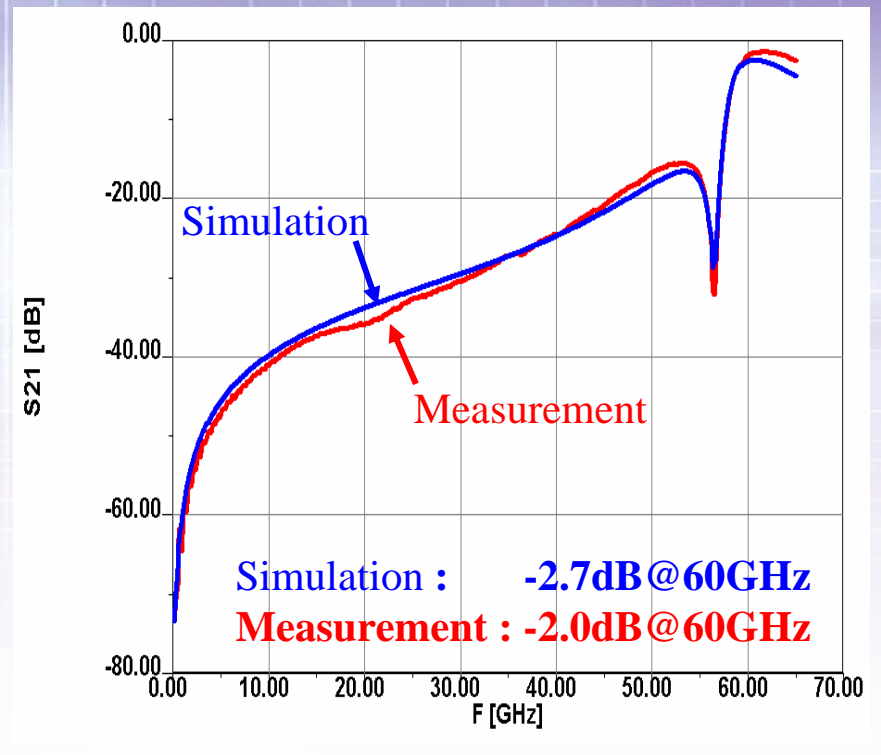
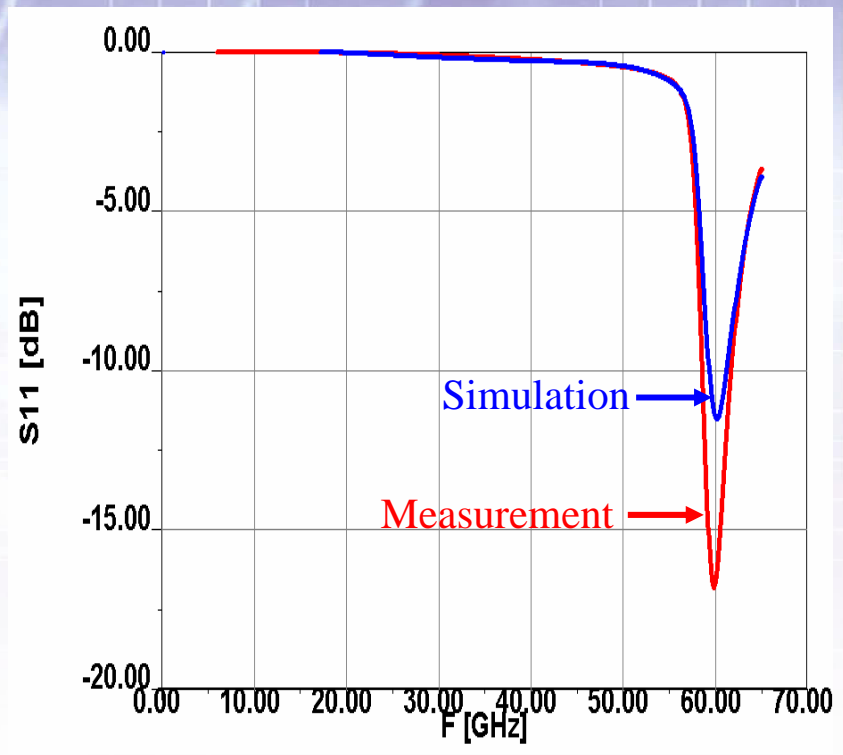
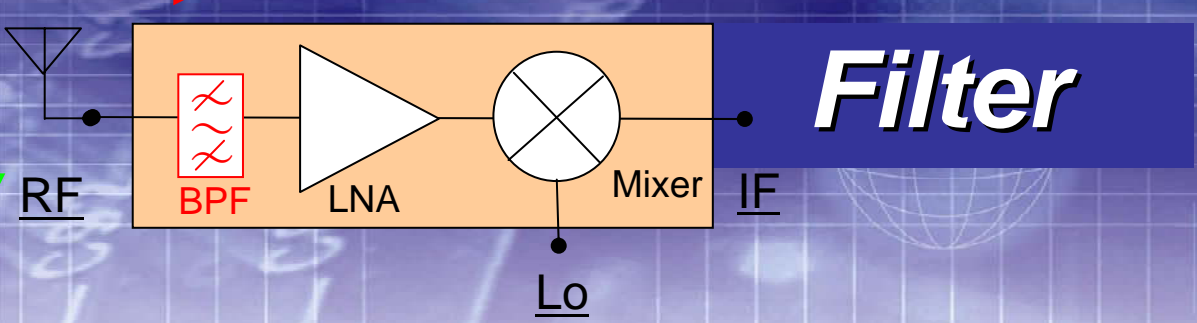
- Filter
- LNA
- PA
- Mixer

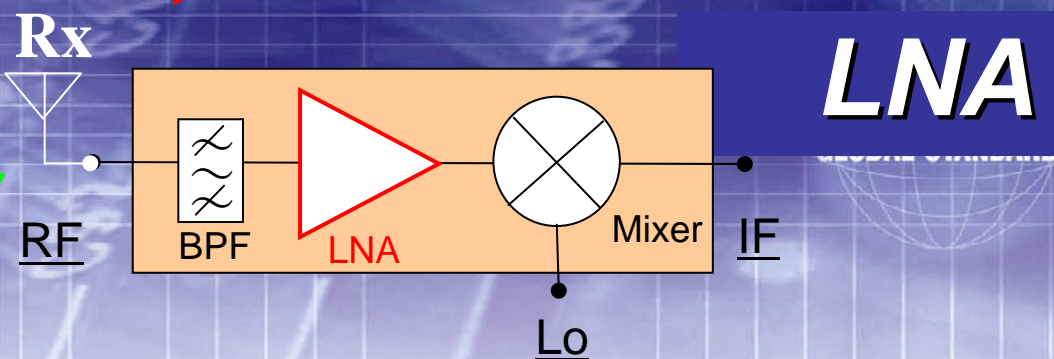
Tx



Rx



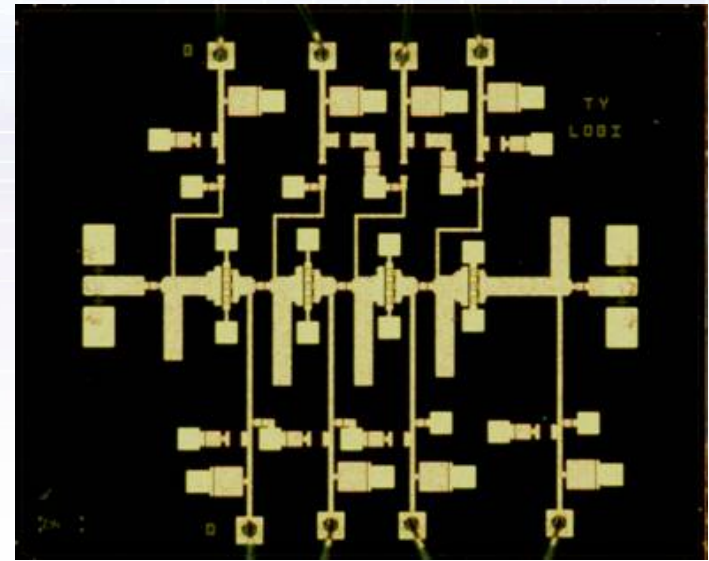
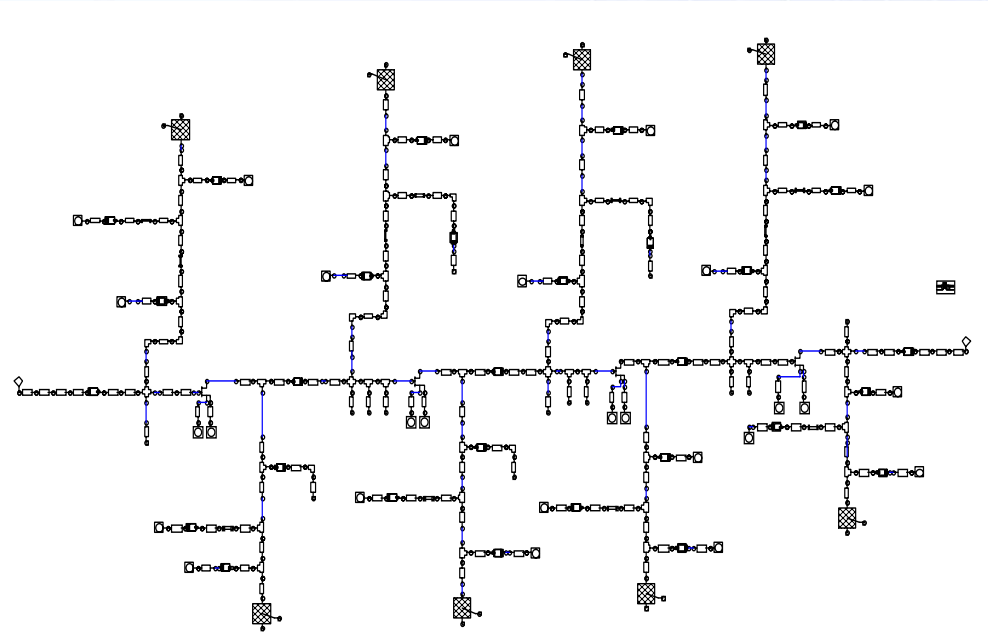




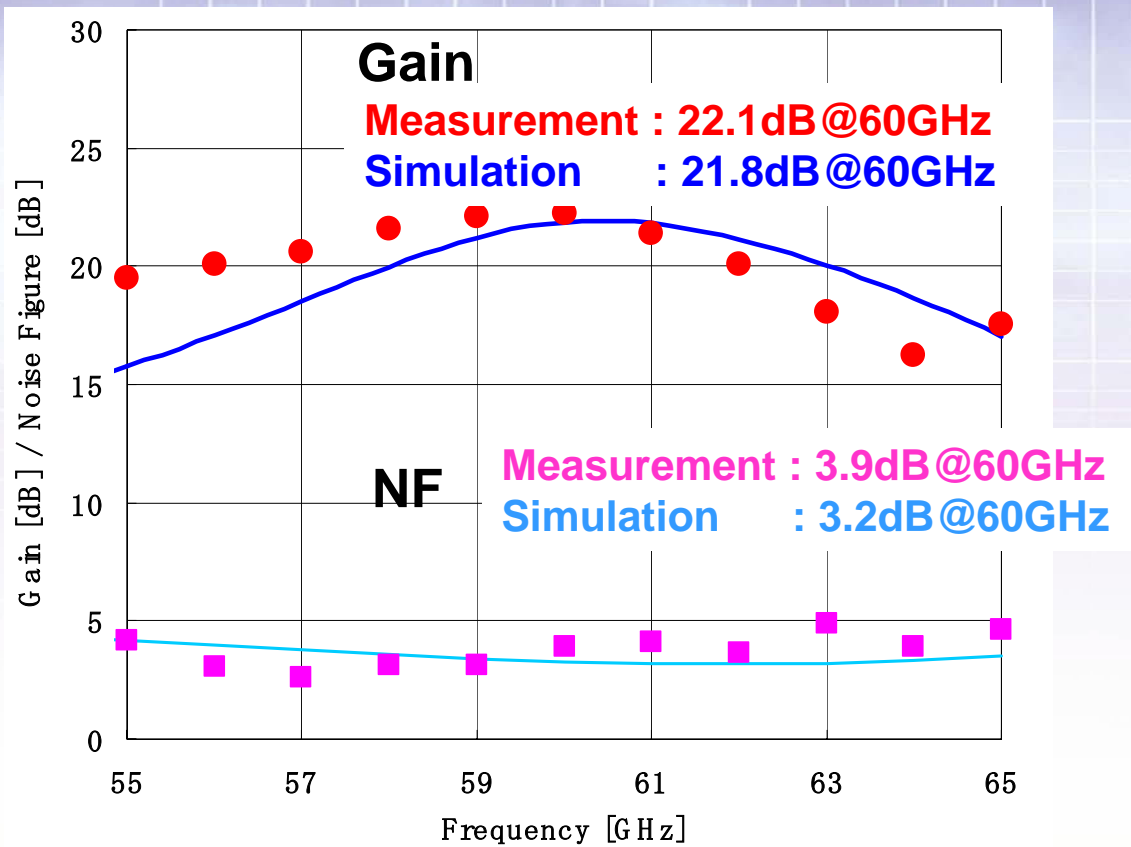
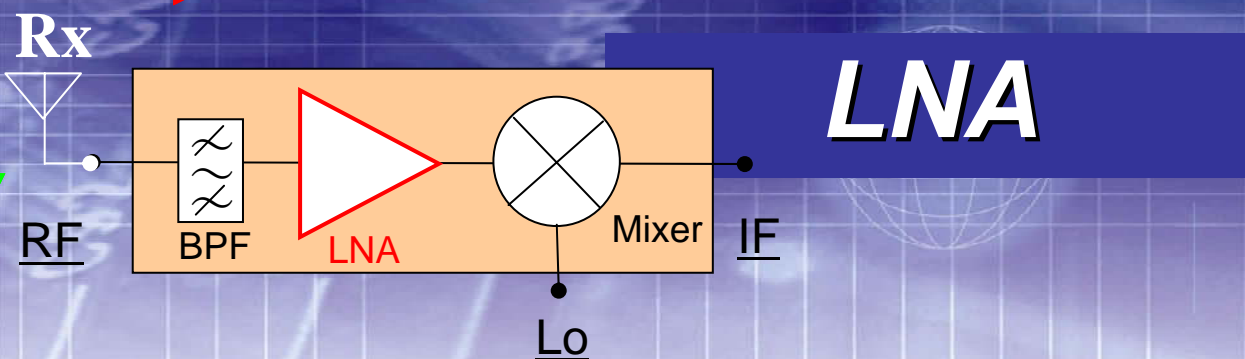
Four Stage LNA

Size 2.2mm × 2.8mm

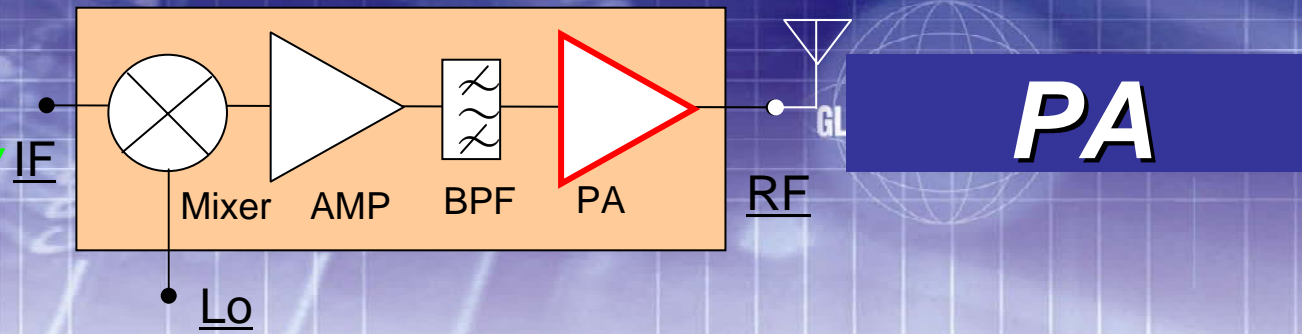
Vd = 2.5V Id = 130mA



LNA Photograph



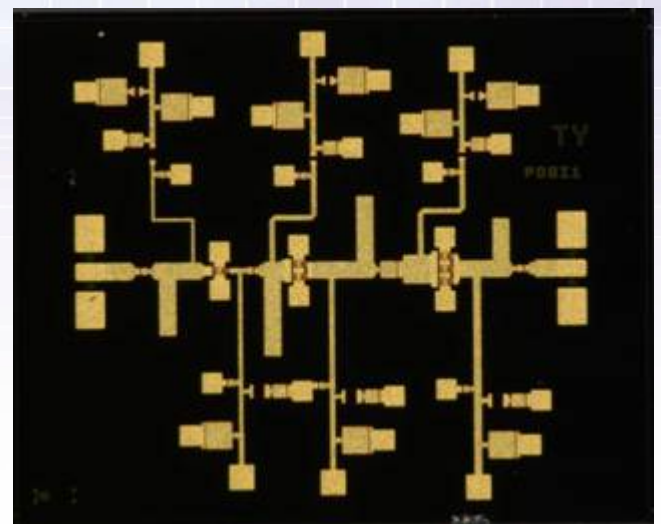
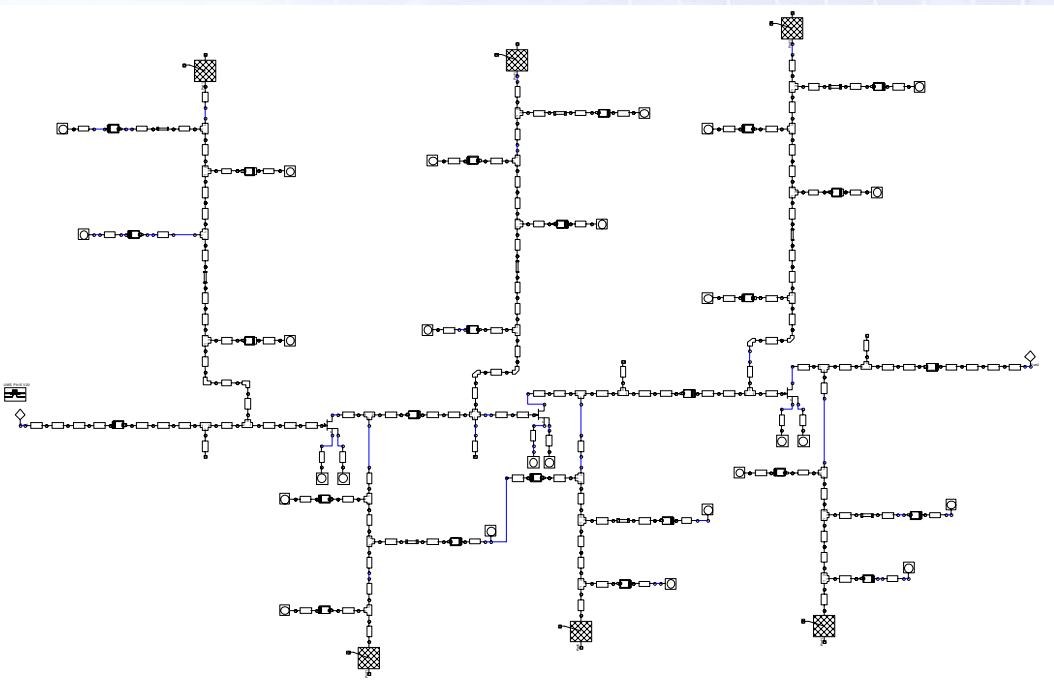
Measurement comparatively corresponds with Simulation.



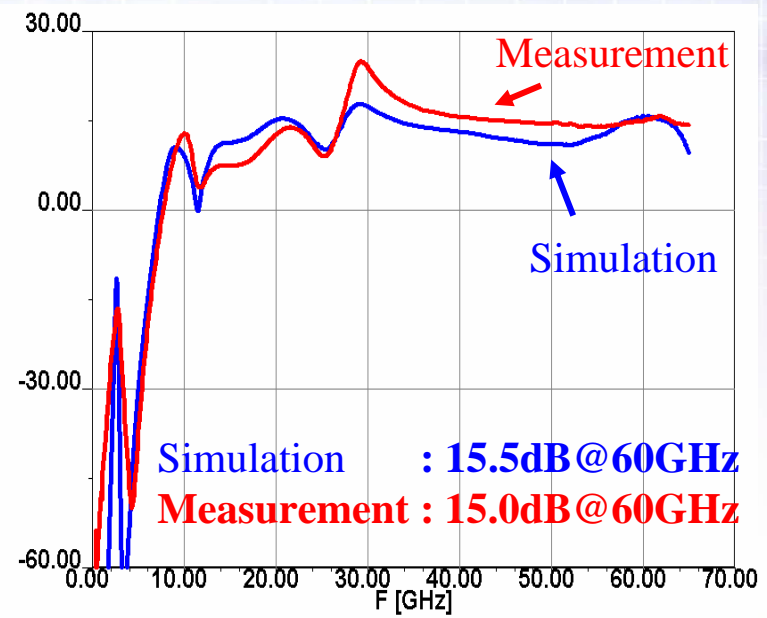
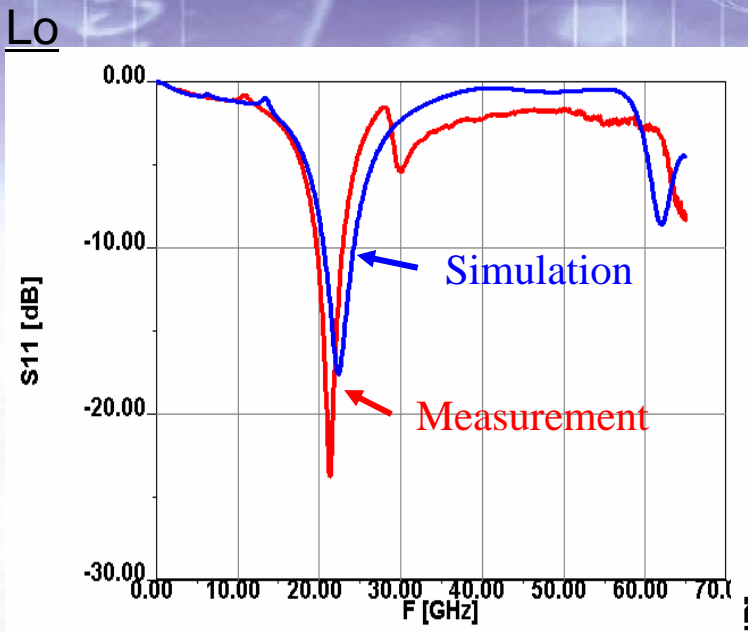
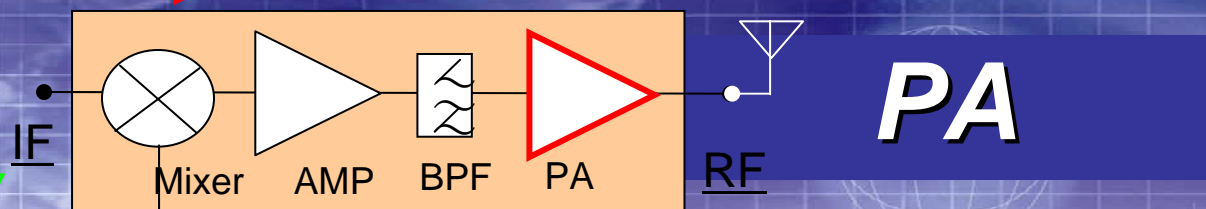
Three Stage PA

Size 2.2mm × 2.8mm

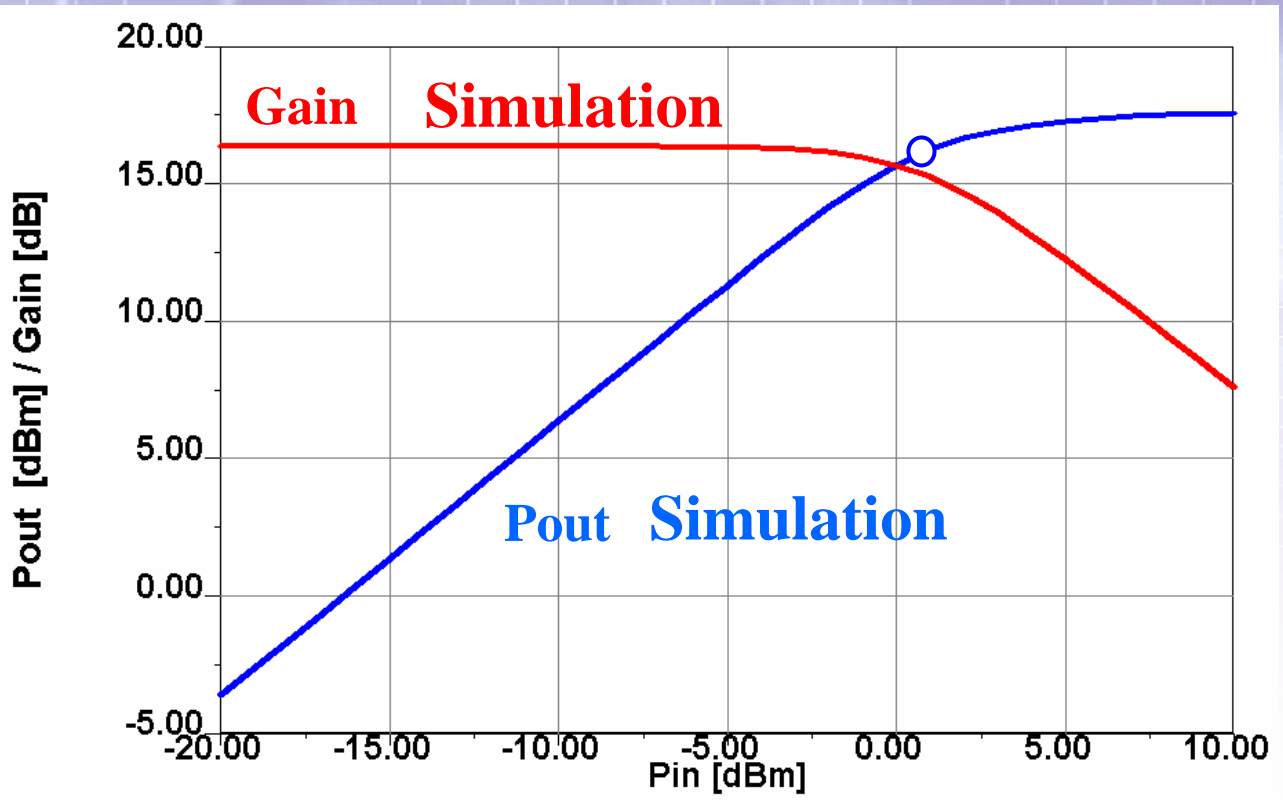
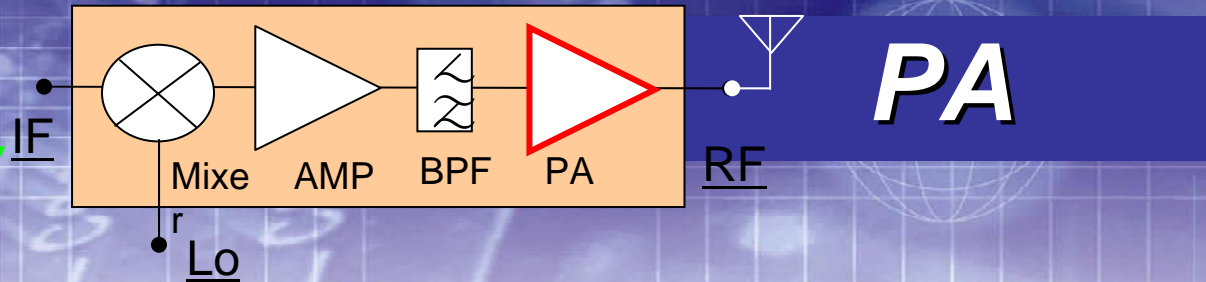
Vd = 2.5V Id = 85mA



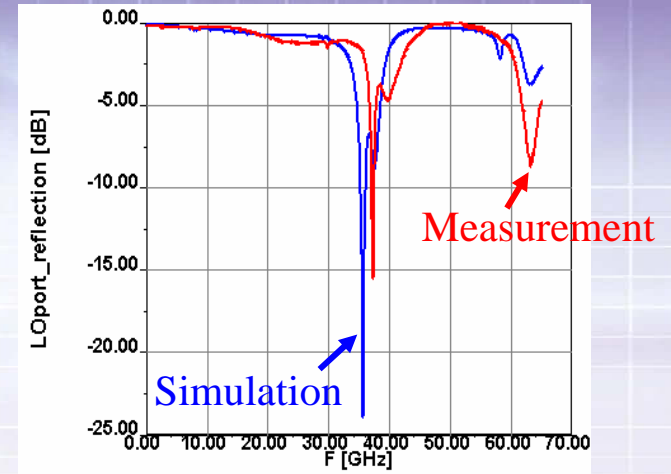
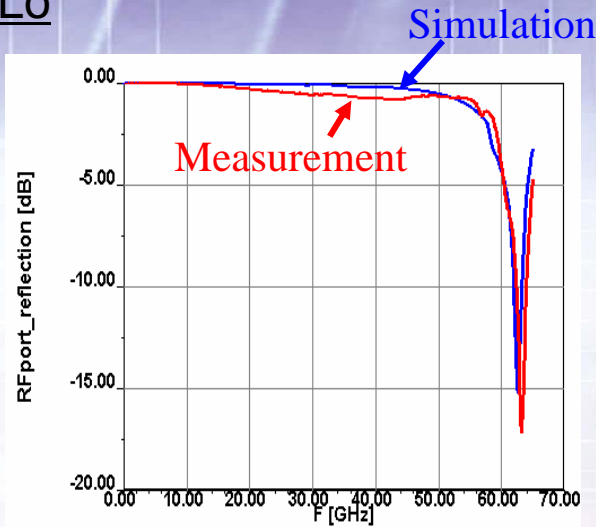
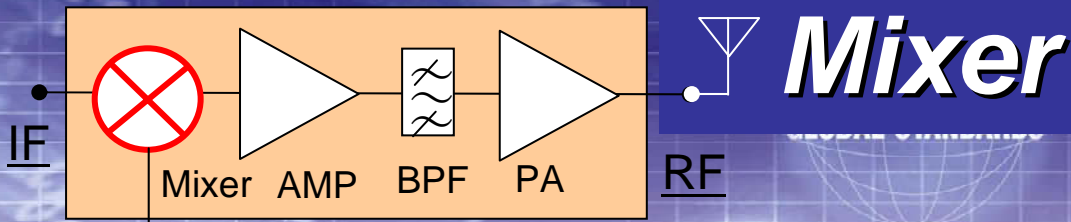
PA Photograph



Measurement comparatively corresponds with Simulation.



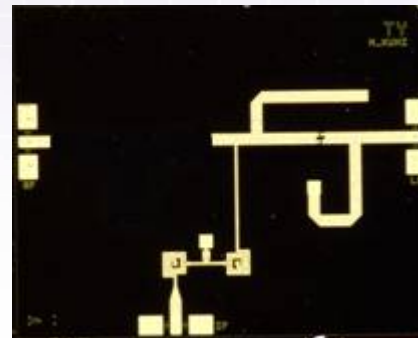
Simulation P1dB 16.3dBm @Pin=1dBm



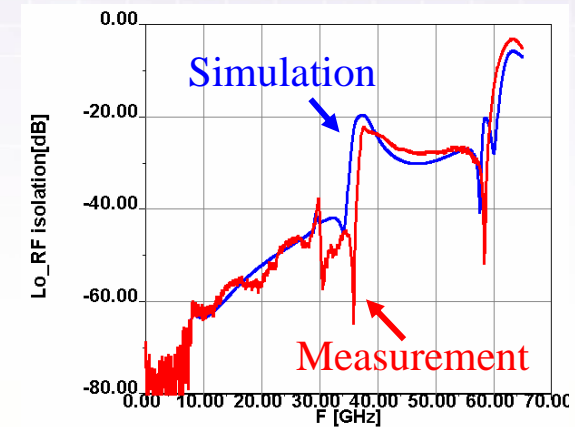
Size 2.2mm × 2.8mm

RF:60GHz

Lo:29.5GHz



Mixer Photograph



Measurement corresponds relatively well with Simulation.

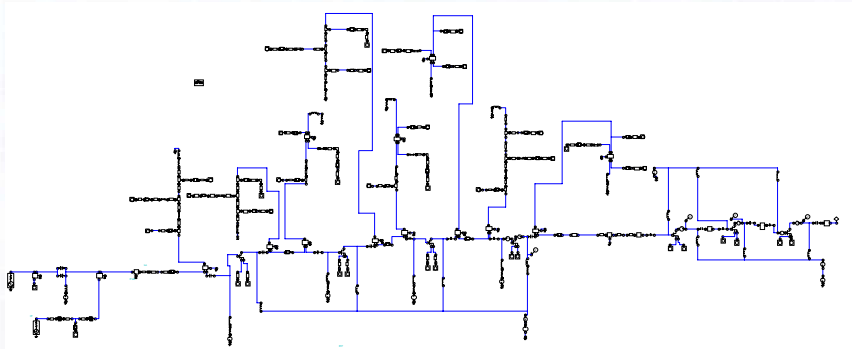
LeadingInsight

Application Workshops for High-Performance Design

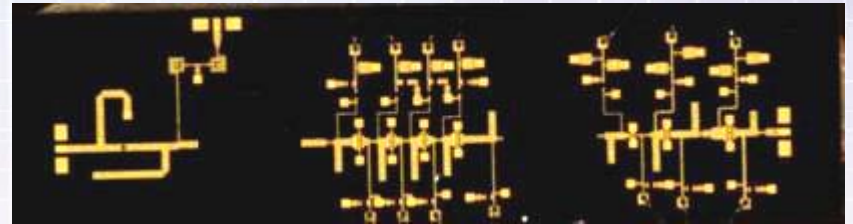
TAIYO YUDEN

Circuit Design of Transmitter and Receiver

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



Transmitter

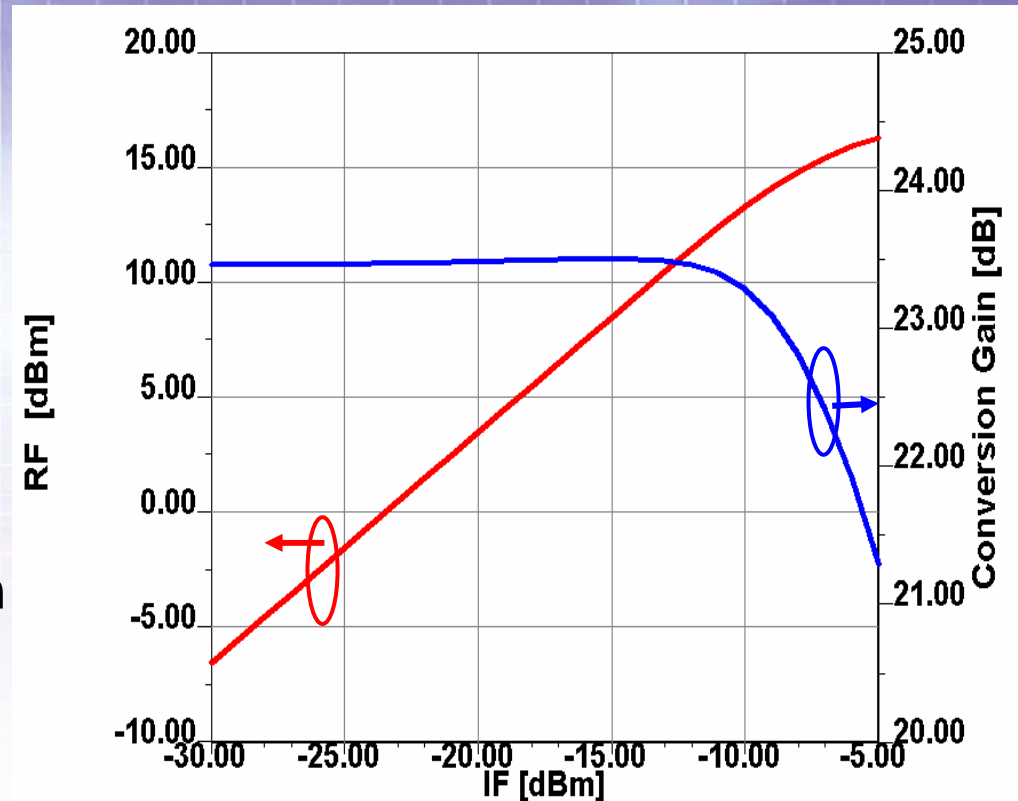


Tx Photograph

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

- ***About This Presentation and Taiyo Yuden Products:***
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