

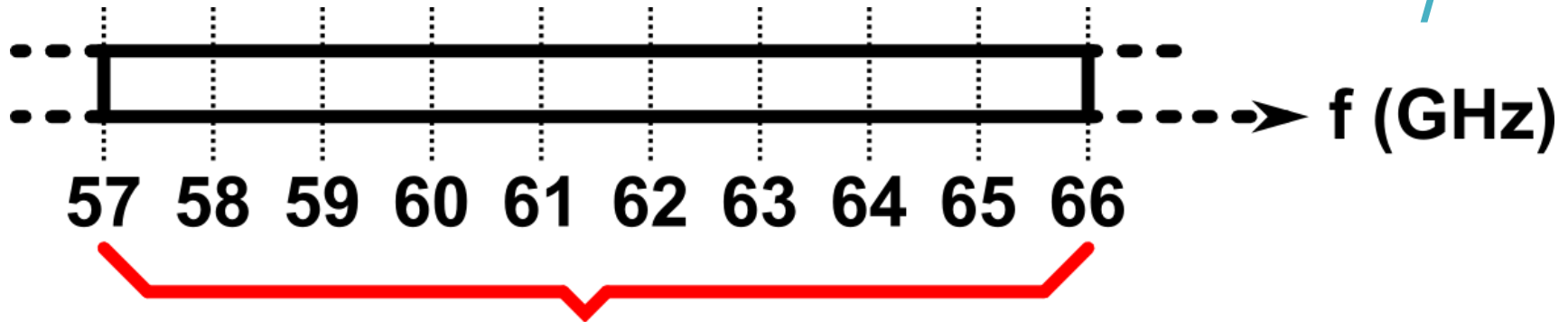
A Characterization Method of On-Chip Tee-Junction for Millimeter-Wave CMOS Circuit Design

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- **Background**
- **Motivation**
 - **Example Millimeter-Wave Amplifier**
 - **Common Characterization Structures**
 - **Issues of Multi-Port Measurements**
- **Proposed Tee-Junction Characterization**
 - **Method**
 - **Measurement Results**
- **Application on One-Stage Amplifier**
- **Conclusion**

Millimeter-Wave Band: 60 GHz



*57-66 GHz Unlicensed Frequency Band

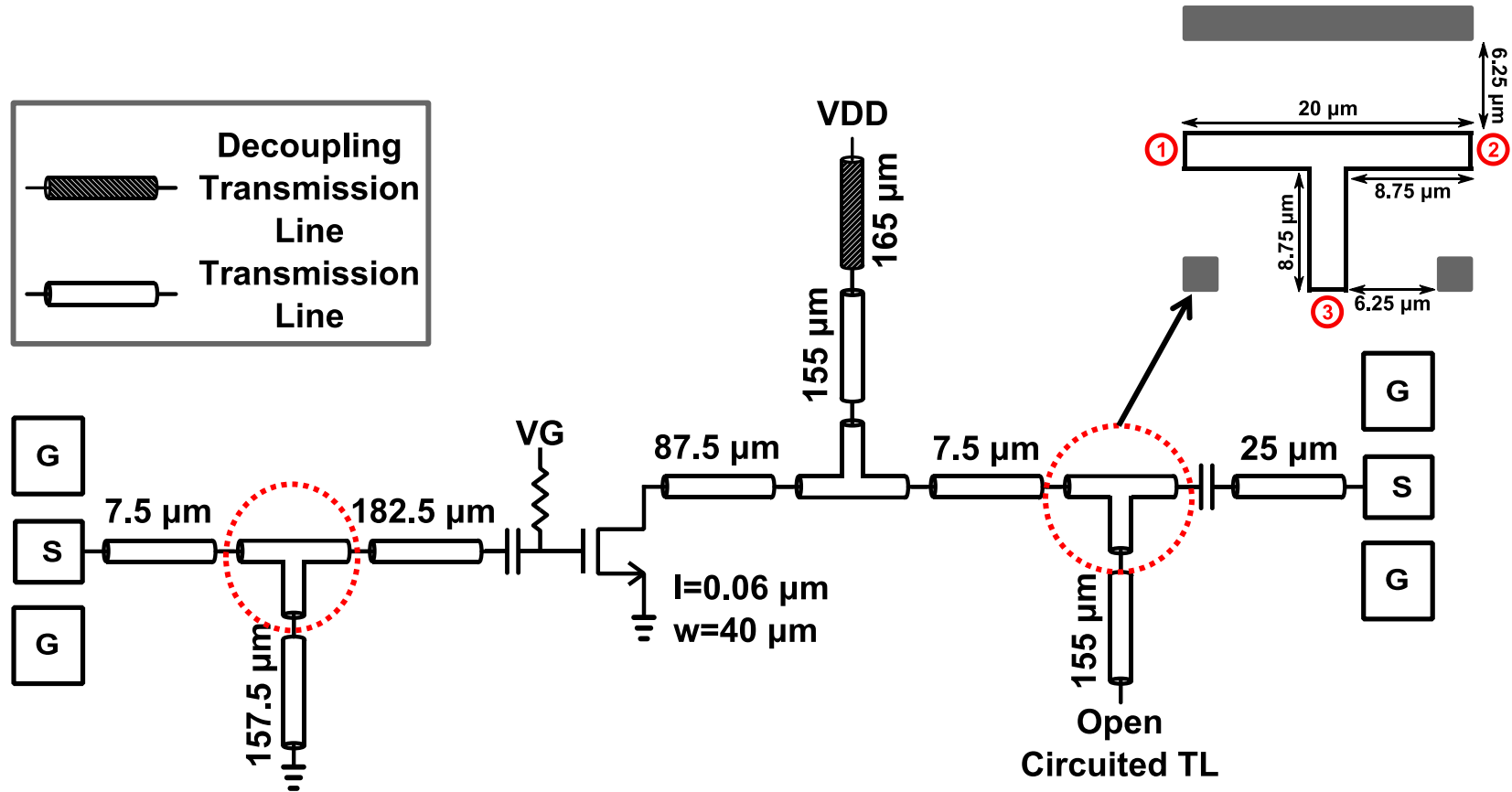
- **9 GHz Unlicensed band**
 - Data rates up to 40 Gbps
- **Large atmospheric attenuation**
 - 😊 **Secure Communication**
 - 😞 **Limited Communication Range**

An Example Millimeter-Wave Amp.

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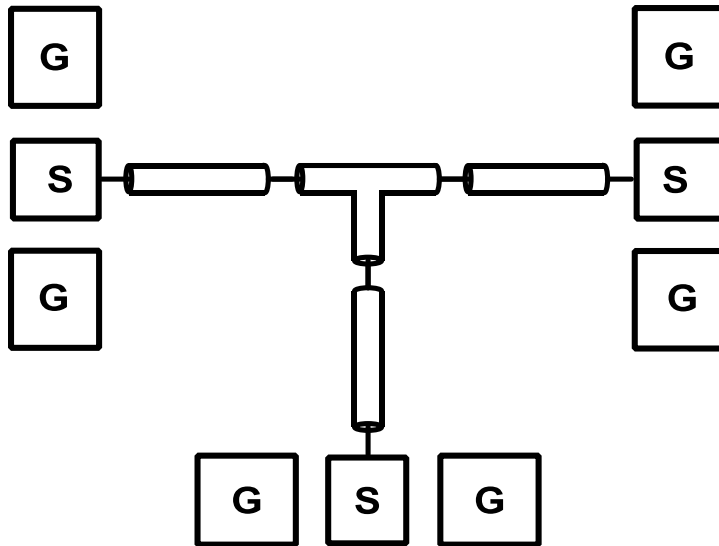
- Several active and passive devices



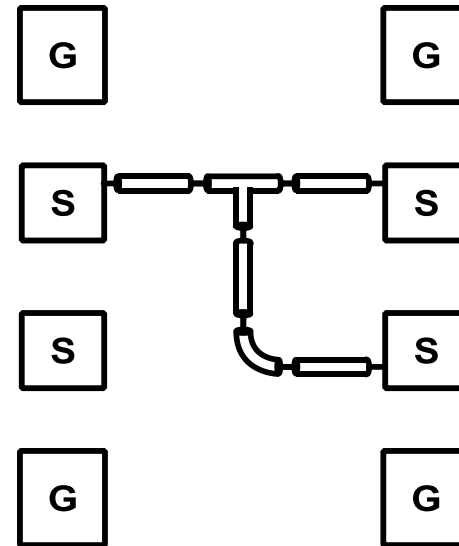
- This work focuses on **Tee-Junction** characterization

- Three-port passive device

◆ Three probes (GSG)



◆ GSSG configuration



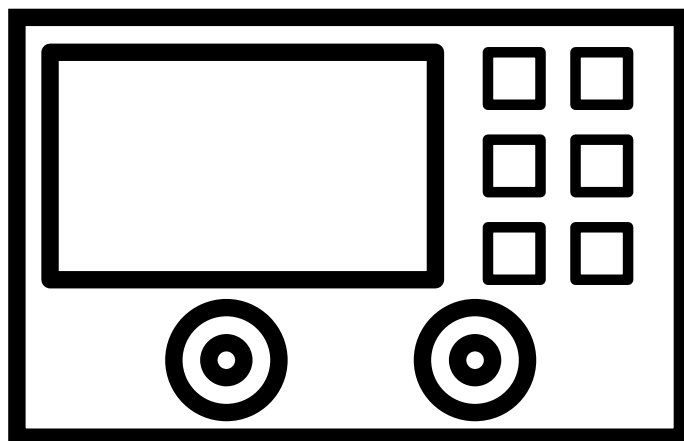
◆ **Calibration** problem

◆ **Decreased** accuracy

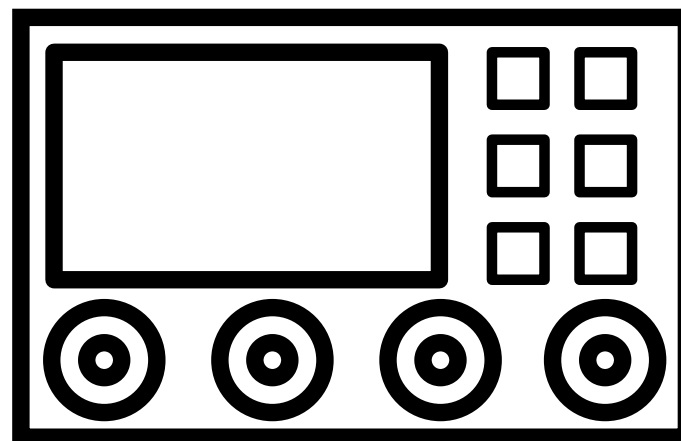
◆ De-embedding

◆ Unwanted **crosstalk**
and **coupling**

◆ **More** structures



Port 1 Port 2



Port 3 Port 1 Port 2 Port 4

□ Most common VNAs **Two-Port**

□ Four-Port Measurements

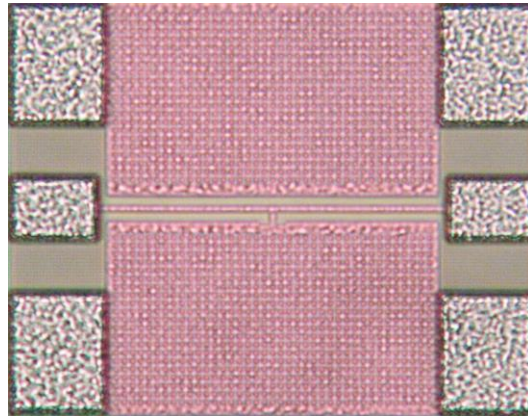
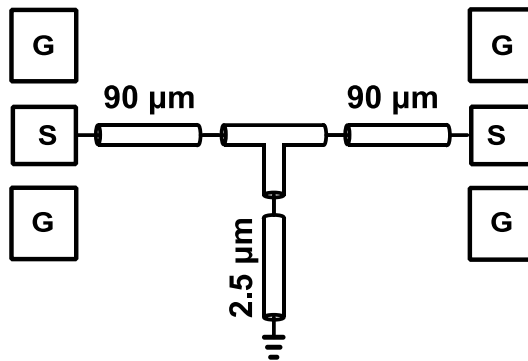
◆ **Decreased** Dynamic Range of Instrumentations*

- Two-port → 110 to 120 dB Dynamic Range up to 110 GHz
- Four-port → 80 dB after 67 GHz to 110 GHz

*Agilent Technologies, Network Analyzers' Data Sheets
<http://www.home.agilent.com/agilent/>

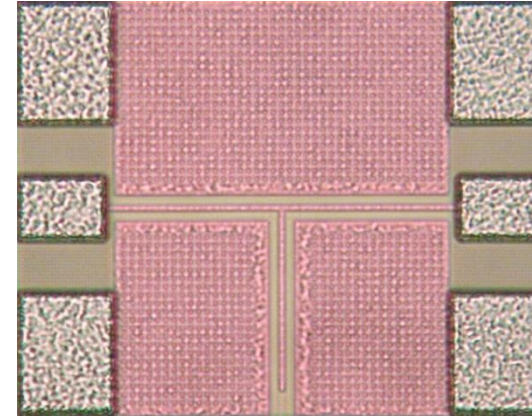
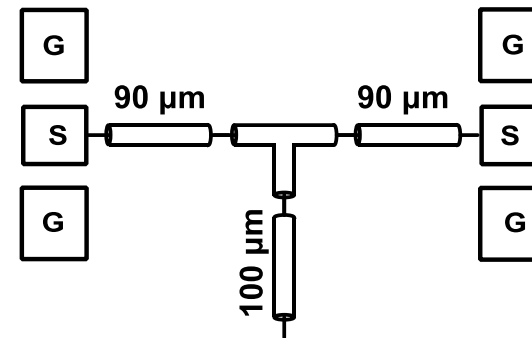
● Short Structure

➤ Characterization



● Open Structure

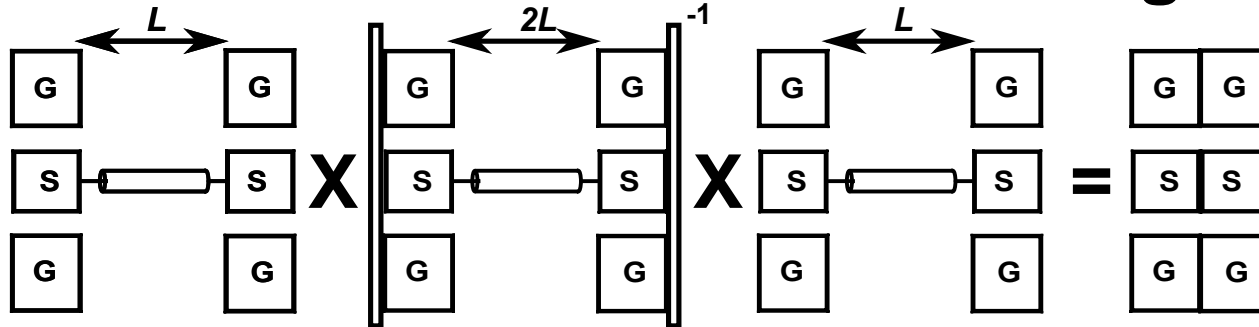
➤ Verification



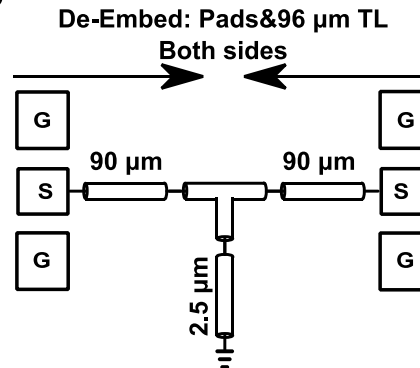
□ Based on **two-port** measurements

□ Up to 110 GHz

1) Pad and transmission line modeling



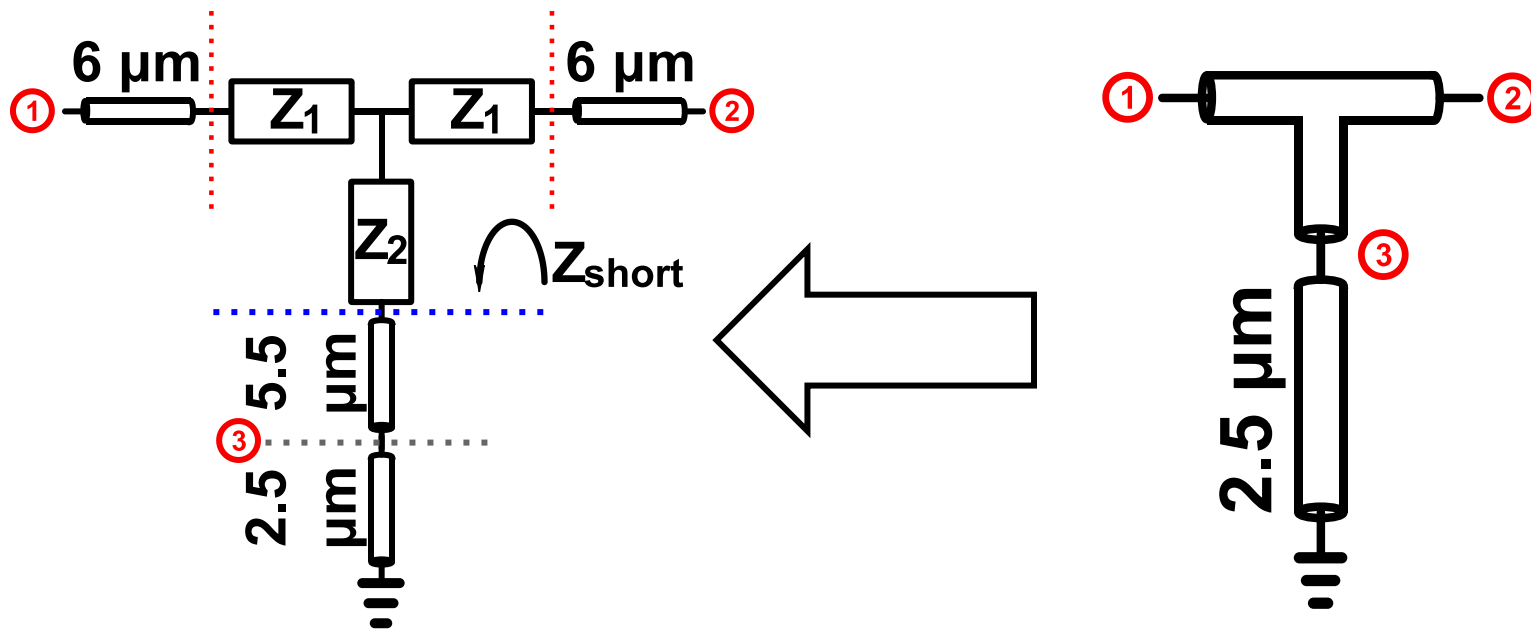
2) De-embedding from short structure



3) Performing numerical calculations for model

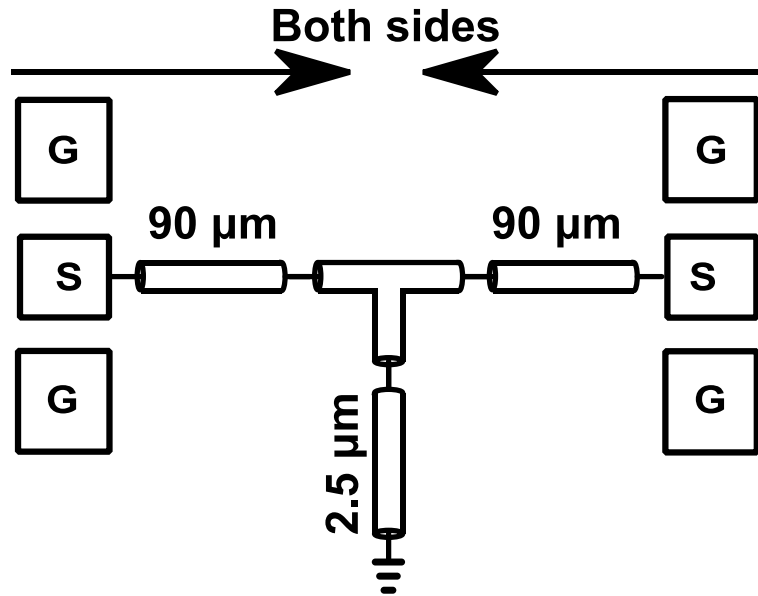
4) Verification with open structure measurement results

- Tee-junction model based on
 - Pre-modeled transmission lines
 - Lumped constants: Z_1 and Z_2

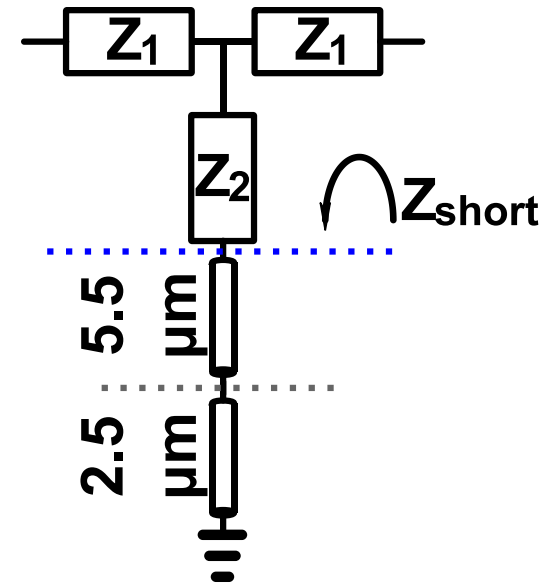


● From the measurement results of;

De-Embed: Pads & 96 μm TL



Remaining Response



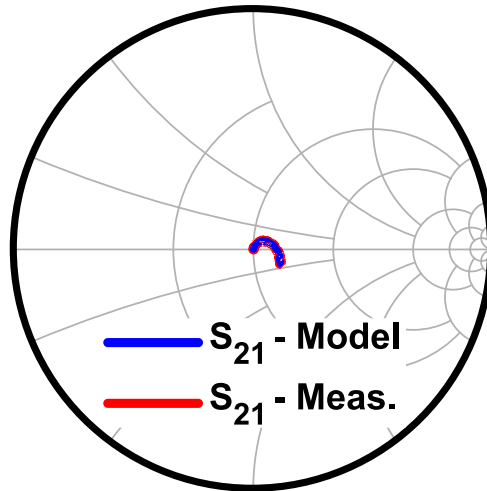
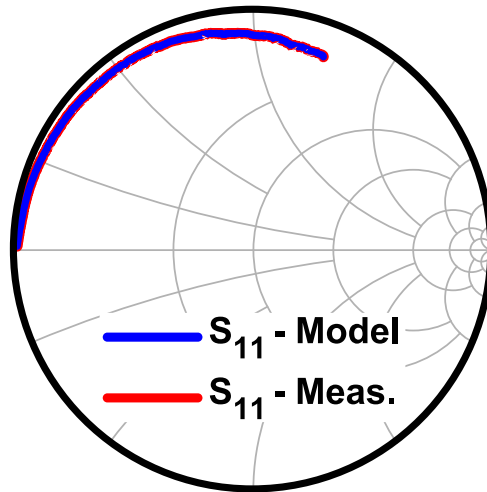
$$Z_{\text{de-embed}} = \begin{bmatrix} Z_{11} & Z_{21} \\ Z_{21} & Z_{11} \end{bmatrix} = \begin{bmatrix} Z_1 + Z_2 + Z_{\text{short}} & Z_2 + Z_{\text{short}} \\ Z_2 + Z_{\text{short}} & Z_1 + Z_2 + Z_{\text{short}} \end{bmatrix}$$

$$Z_1 = Z_{11} - Z_{21}$$

$$Z_2 = Z_{21} - Z_{\text{short}}$$

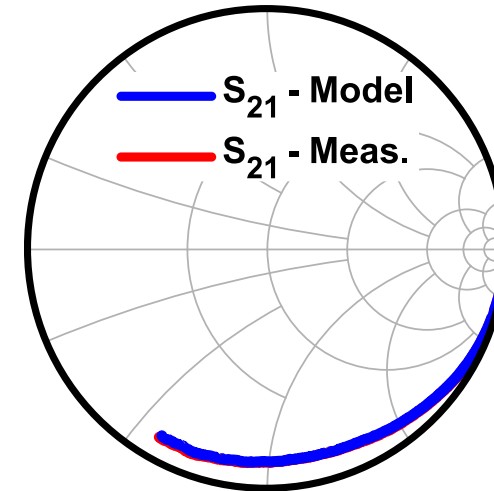
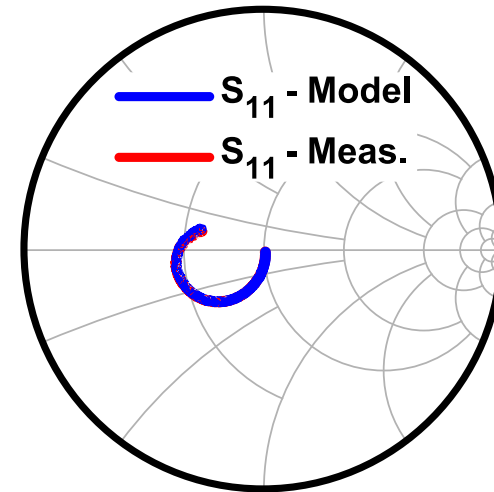
- Short Structure

- Characterization

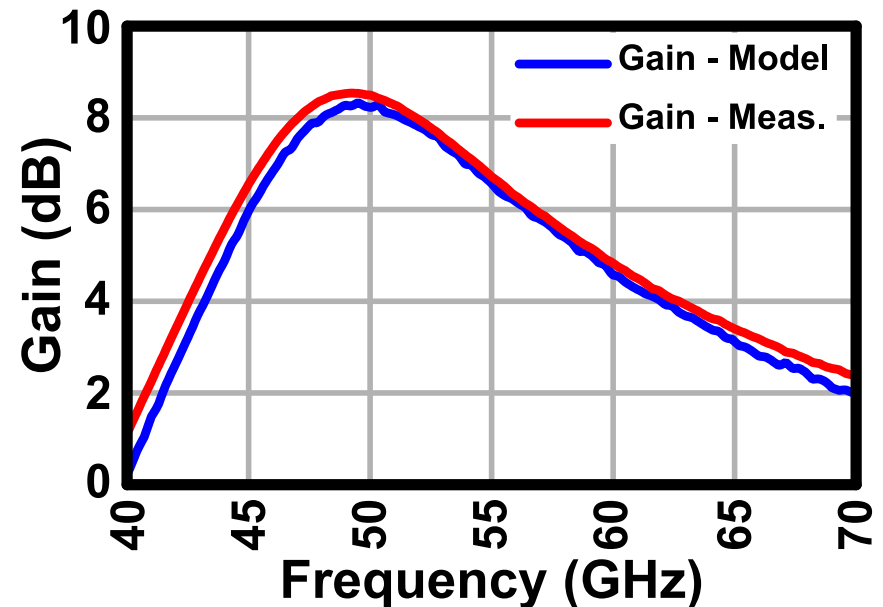
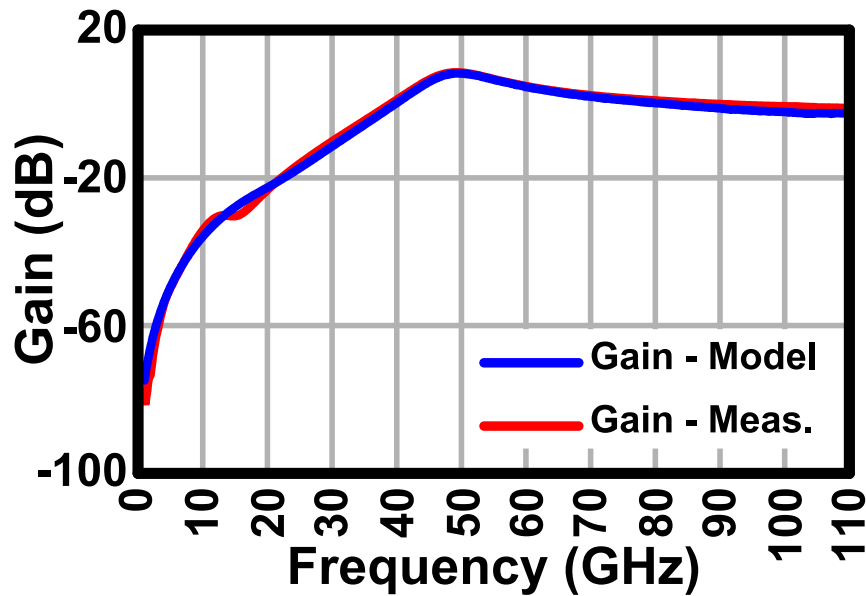
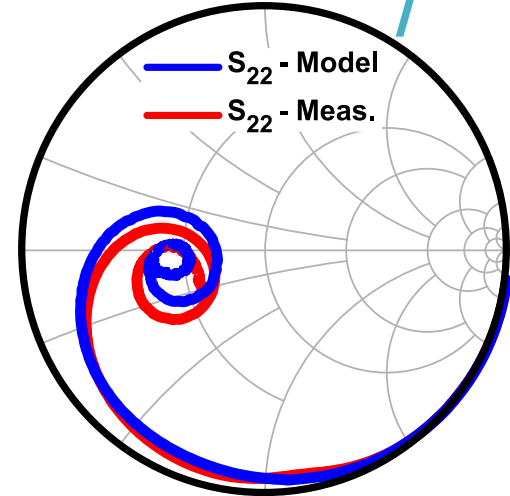
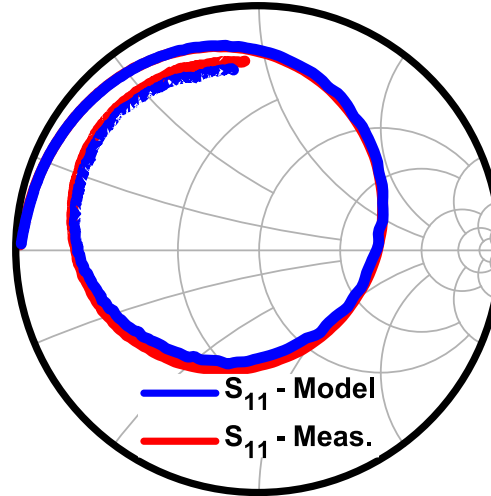
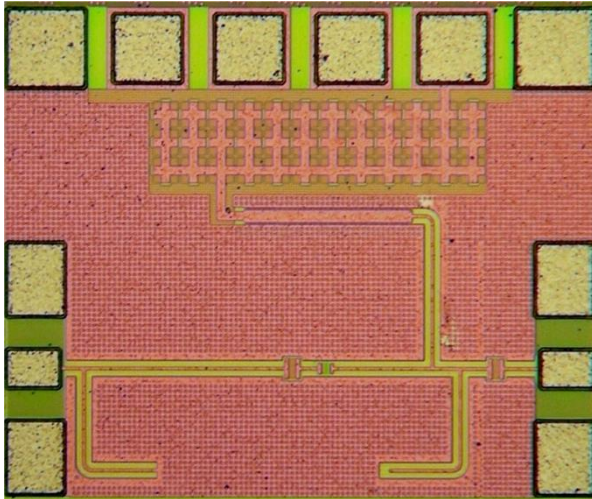


- Open Structure

- Verification



Application on One-Stage Amplifier



- **A simple** characterization approach
 - **Two-port** measurements
 - Model with transmission lines and **lumped constants**
 - Z-parameters used for calculations
- Model and measurements **agree well** up to 110 GHz
- One-stage amplifier **application**
 - Amplifier measurements and simulation model **agree well up to around 80 GHz**

**THANK YOU VERY MUCH
FOR YOUR ATTENTION!**