On the Variations of Shunt Characterization Technique of Decoupling Transmission Line for Millimeter-Wave CMOS

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Outline

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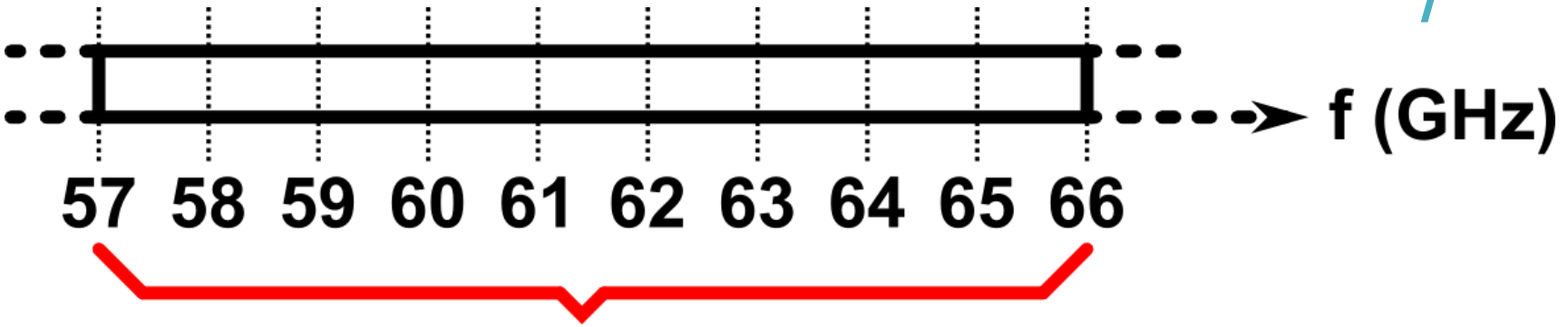
- Background
- Motivation
  - Example Millimeter-Wave Amplifier
  - Decoupling Transmission Line
  - Issues of MIM-TL Measurements and Characterization
- Proposed MIM-TL Characterization
  - Method
  - Variations
  - Measurement Results
- Application on One-Stage Amplifier
- Conclusion

Millimeter-Wave Band: 60 GHz



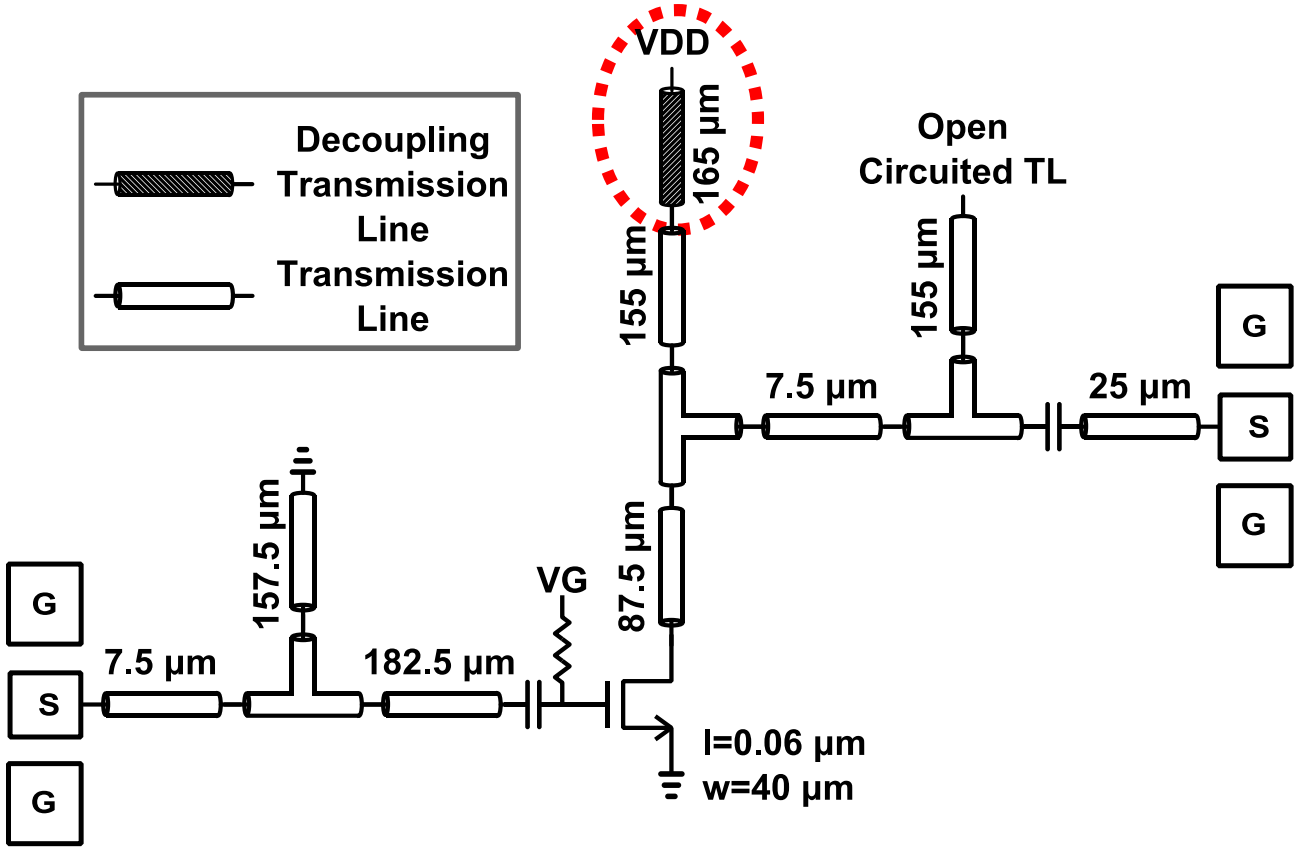
***57-66 GHz Unlicensed Frequency Band**

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

*http://www.tele.soumu.go.jp/resource/e/search/share/2008/t3.pdf

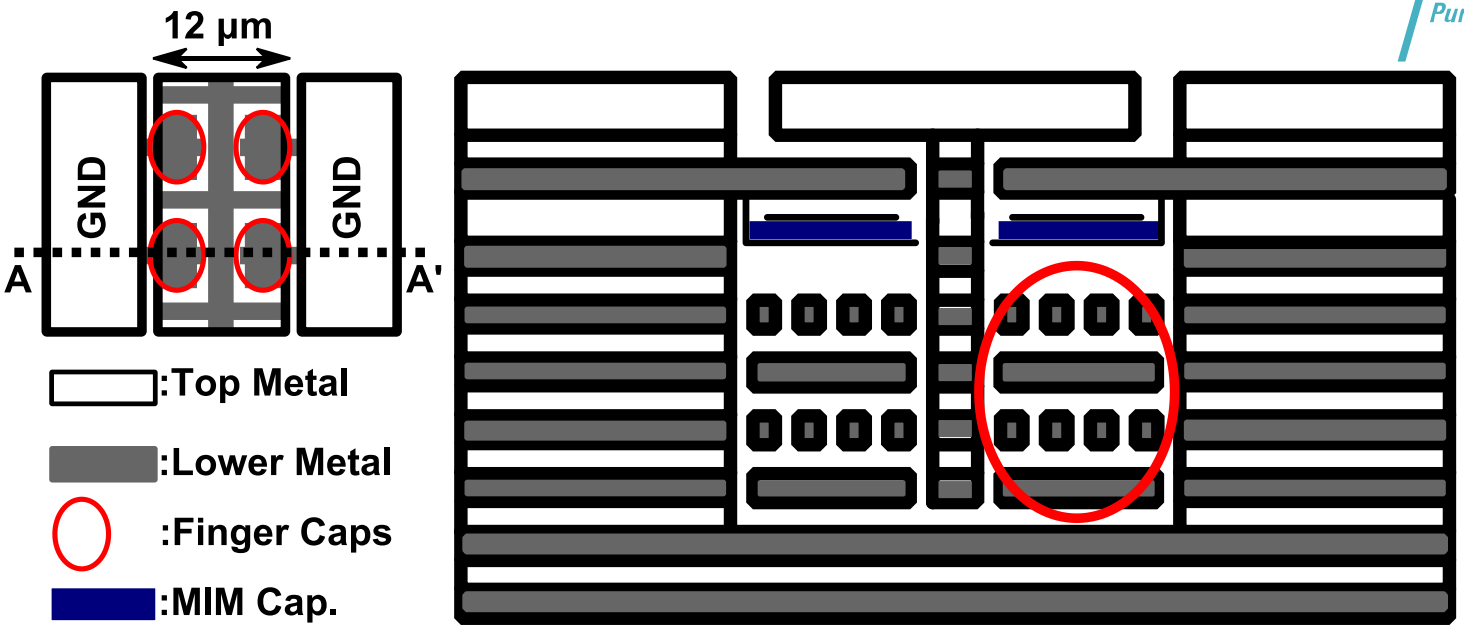
An Example Millimeter-Wave Amp.

- Several active and passive devices



- This work focuses on Decoupling Transmission Line characterization
  - Near zero characteristic impedance

Decoupling Transmission Line



- Metal-Insulator-Metal (MIM) Transmission Line
- Decoupling of DC and RF
- More reliable in millimeter-wave frequencies
  - Lumped RF choke and Decoupling capacitor lacks accuracy

Issues with MIM TL Characterization

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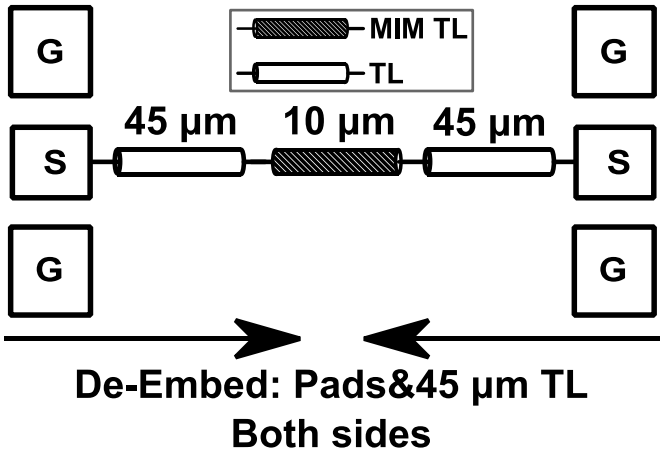
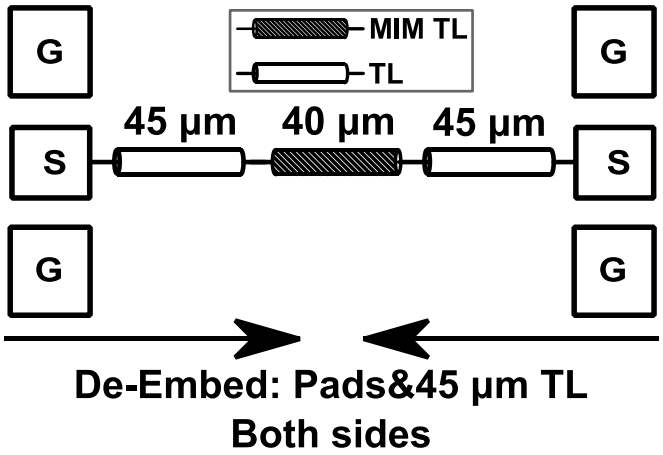
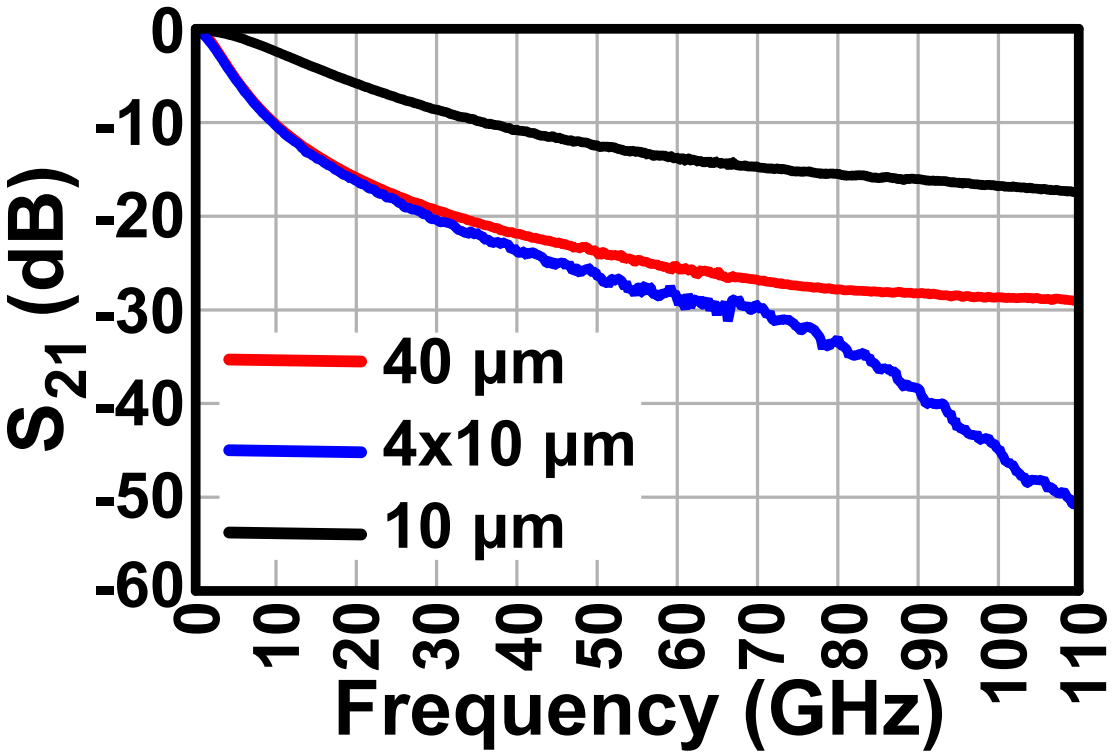
- Extremely low characteristic impedance
- Accuracy of direct S-parameters degrade







Overview of Proposed Method

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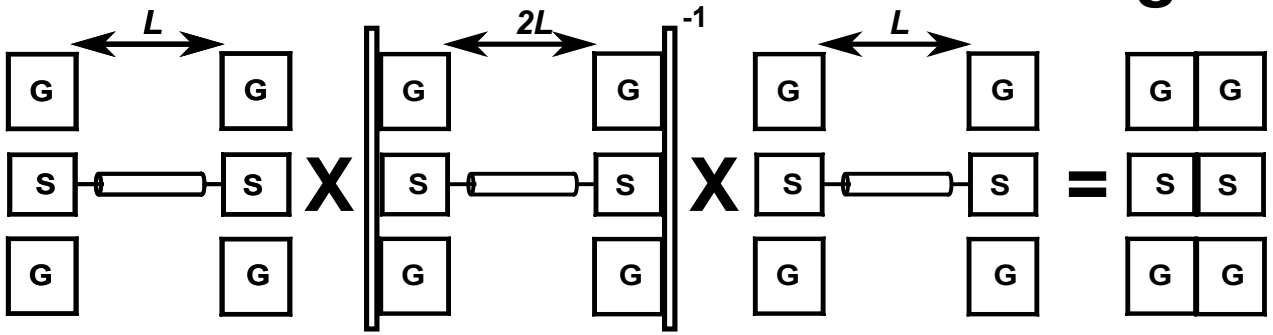
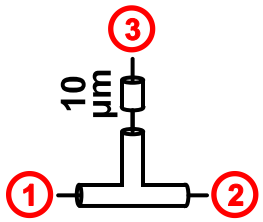
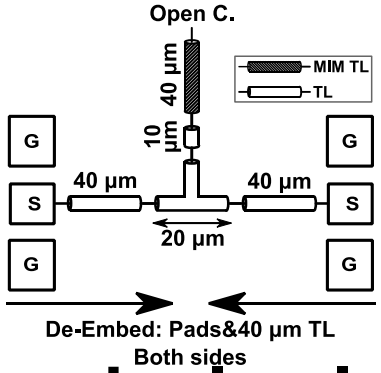
1) Pad and transmission line modeling



2) Tee-Junction Modeling



3) De-embedding from the structures used



4) Performing numerical calculations for model

Proposed Characterization Method

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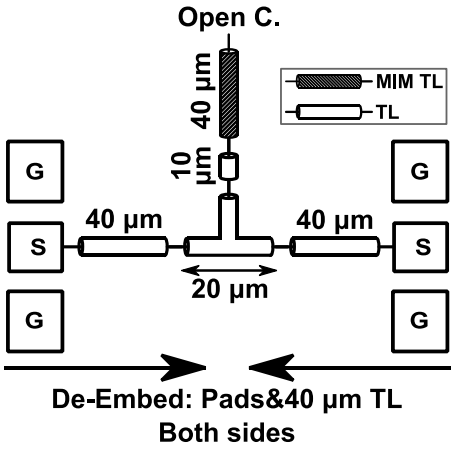
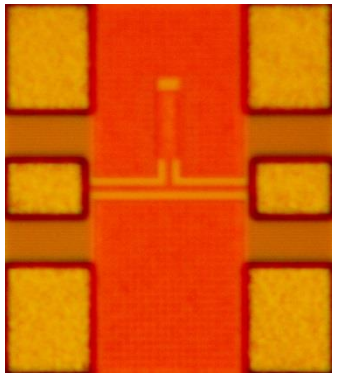
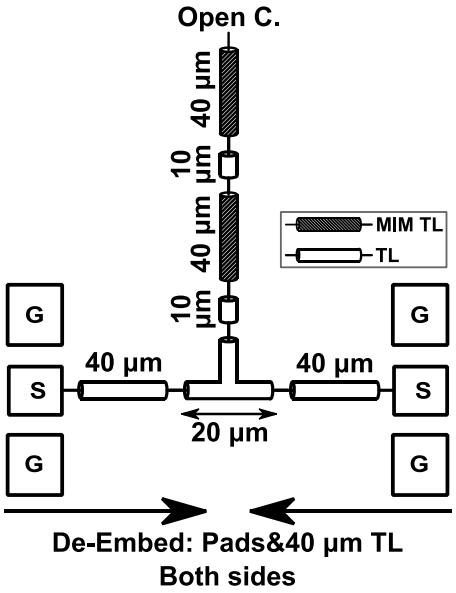
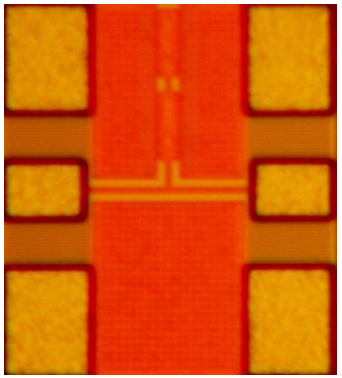
- One MIM TL





- Two Cascaded MIM TL





Details: Tokgoz *et. al.*, APMC 2014

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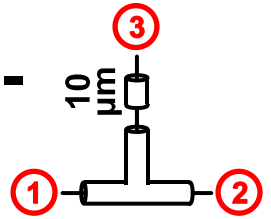
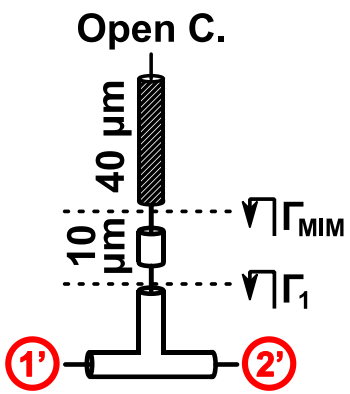
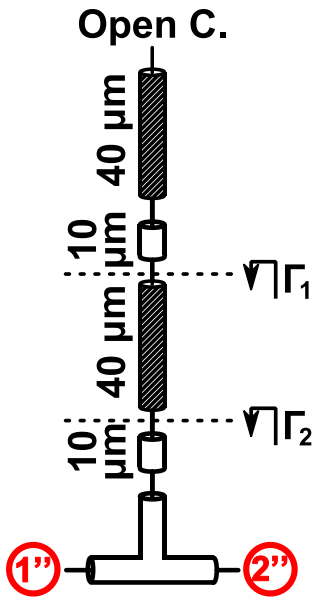
Proposed Method

- S-parameters of MIM TL calculated from the reflections
- Reflections are calculated from the de-embedded measurement results and pre-characterized Tee-junction, TLs







$$S_{\mathrm{MIMTL11}} = \frac{(\Gamma_2 - \Gamma_{\mathrm{MIM}}\,\Gamma_1)}{1 + (\Gamma_2 - \Gamma_{\mathrm{MIM}} - 1)\Gamma_1}$$

$$S_{\mathrm{MIMTL21}} = \sqrt{(\Gamma_{\mathrm{MIM}} - S_{\mathrm{MIMTL11}})(1 - S_{\mathrm{MIMTL11}})}$$

$$\Gamma_{\mathrm{MIM}} = 1/\left(S_{33} + S_{13}^2/\left(S_{\mathrm{Meas},11}^{\Gamma_{\mathrm{MIM}}} - S_{11}\right)\right)$$

$S_{\mathrm{Meas},21}^{\Gamma_{\mathrm{MIM}}}$

Resultant Variations on MIM TL

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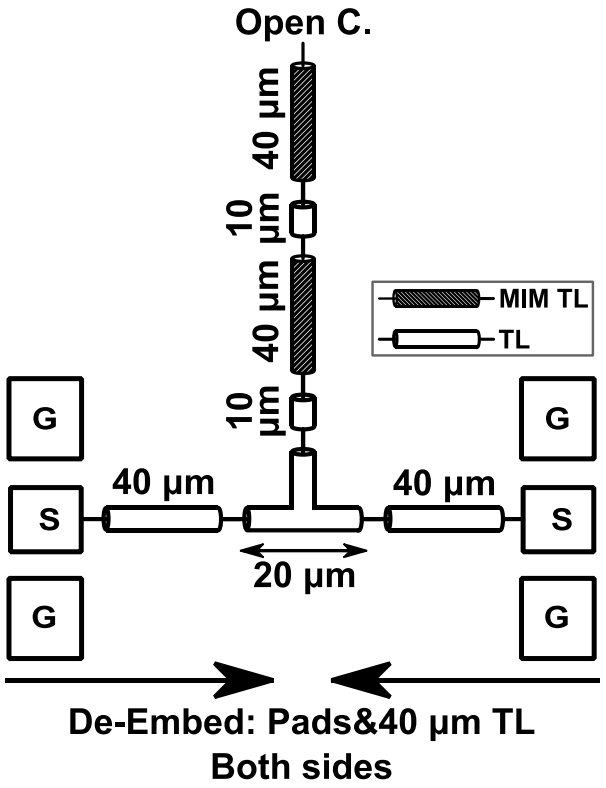
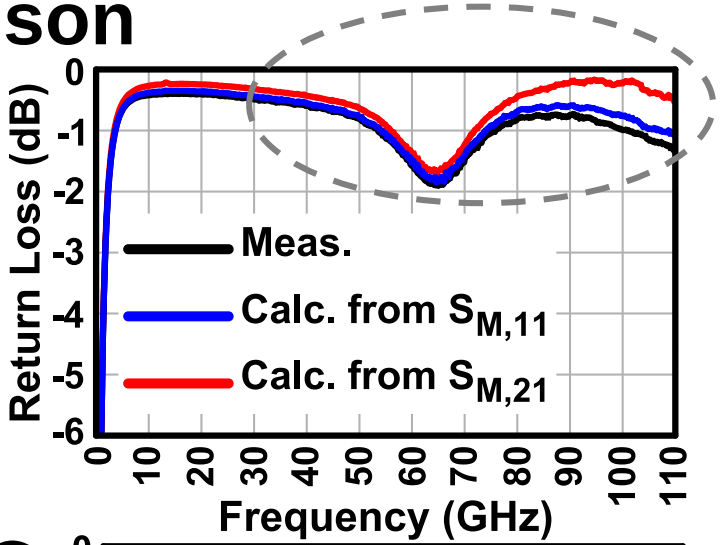
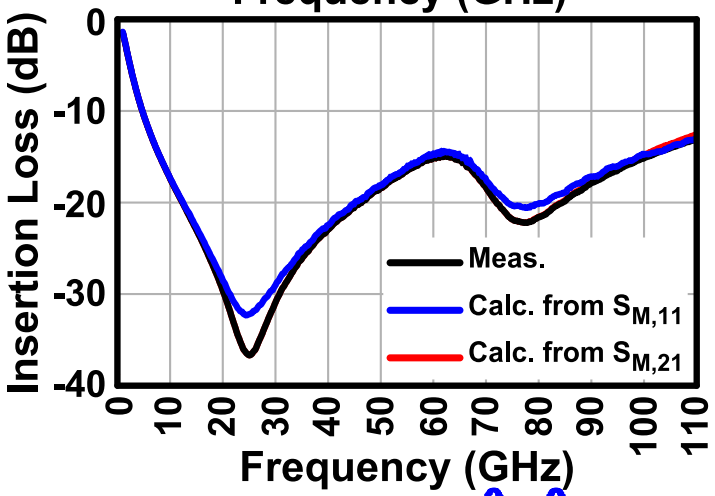
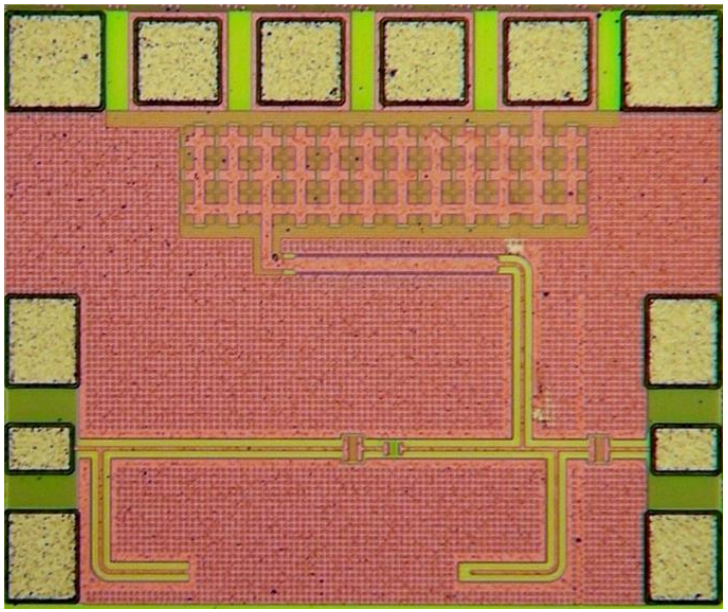
- Two cascaded MIM TL version model and measurement comparison

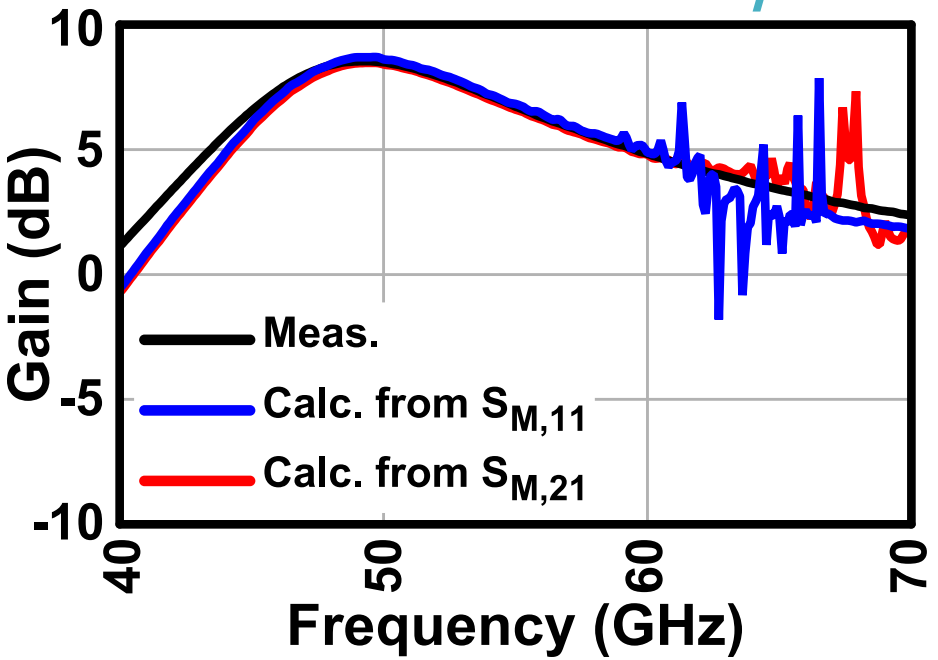


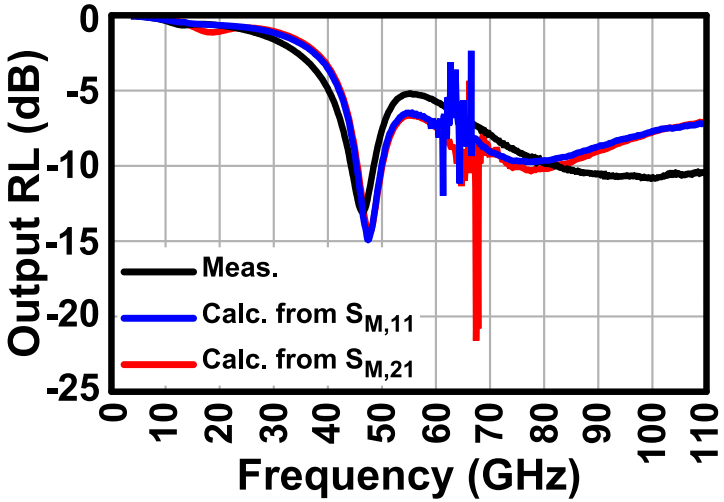




Application on One-Stage Amplifier







- **Difference between two separate calculations on a one-stage amplifier**

Conclusion

- Decoupling transmission line: MIM TL
  - Very low characteristic impedance
- Decreased accuracy in direct measurements
- An indirect shunt characterization method is introduced
  - S-parameters of a MIM TL calculated from reflections
- Variations from calculation procedure affect the results
  - Measurement results of a one-stage amplifier
- Still good agreement achieved on amplifier results