<WE1B>-<319-YG300>

Stub-loaded Via Transition for Wideband Impedance Matching of Sub-THz 6G Antenna-in-Package

Dongjin Jung, Chan Ju Park, Taek Sun Kwon, ByungKuon Ahn, Jung Woo Seo, Sang-Hyuk Wi, Hwan-joon Kwon

Advanced Communications Research Center
Samsung Electronics, Seoul, Korea

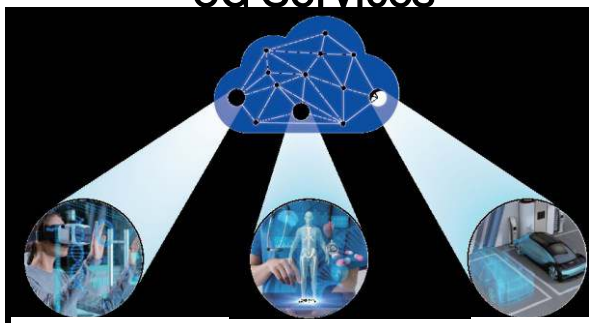
Outline

- Motivation
- Dk and Df of PCB at D-band
- Proposed via transition design
- Design and fabrication
- Calibration and measurement
- Measured results and summary
- References

Motivation

- **Sub-THz band for 6G**
  - 6G frequency spectrum along with upper-mid band
- **Three key 6G services**
  - Real time data processing, extremely lower latency, hyper-fast data rate (100 Gb/s – 1 Tb/s)[3]
  - FCC released 95 GHz to 3 THz for the next generation's communication research and experiment.
- **Samsung's white paper regarding 6G**
  - "Spectrum Expanding the Frontier"
  - "The Next Hyper – Connected Experience for All"

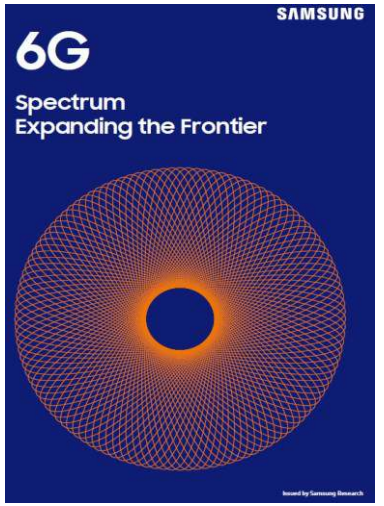
6G Services

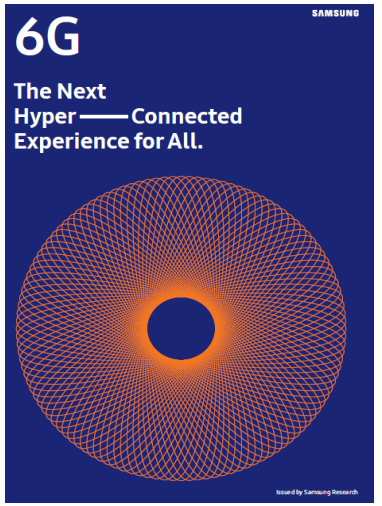


Truly Immersive XR

High-fidelity Mobile Hologram

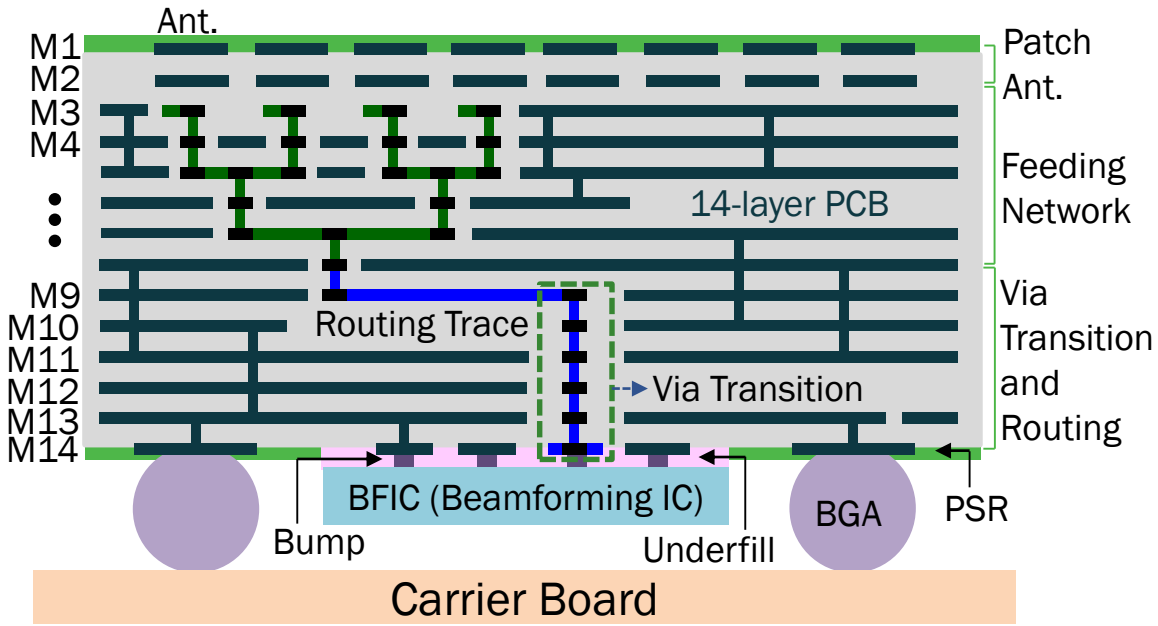
Digital Replica



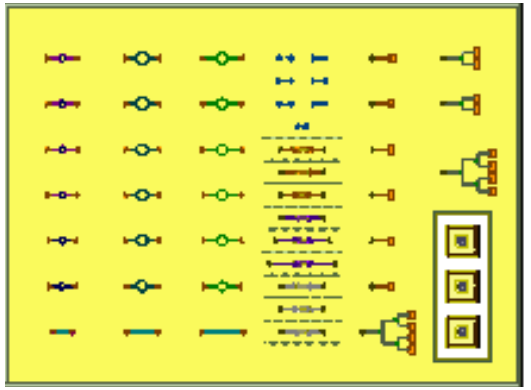


Dk and Df of PCB at D-band

- **Unknown Dk (ε_r) and Df (tanδ) at D-band**
  - Design constraints of RF circuits (antenna, power divider, etc,.)
- **Challenges:**
  - precise calibration/measurement, fabrication tolerance → incorrect Dk and Df



Cross-sectional View of Antenna-in-Package (AiP)



Test patterns for PCB characterization

- PPG and core material: DS-7409DV(N)
- # of metal layers: 6
- metal thick: 15 um
- Core and PPG thick: 50 um

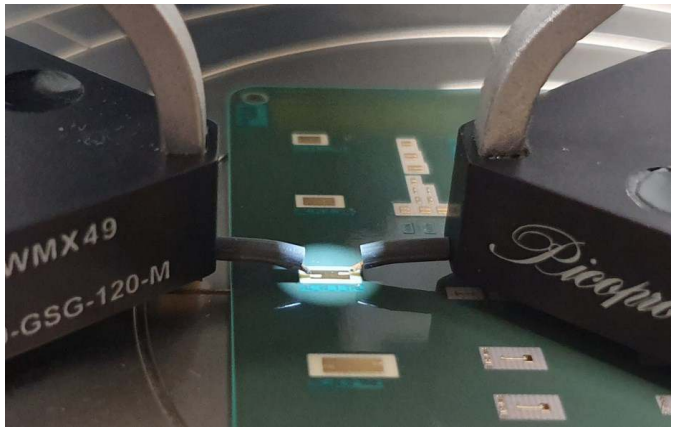
PCB Material Properties at D-band

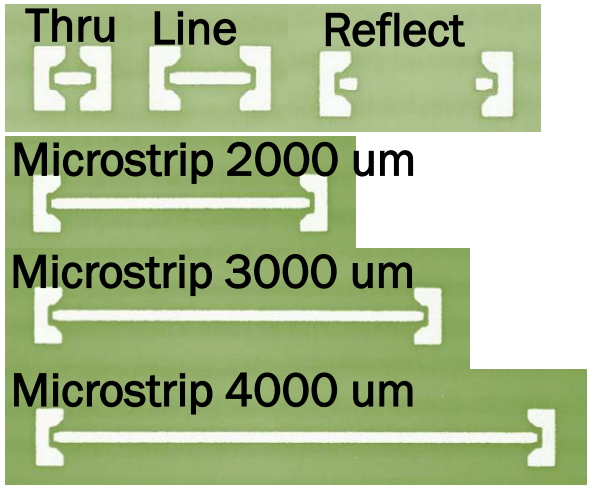
- **Calibration Method for Measurement**
  - SOLT / TRL Calibration
- **Dk/Df extraction from measurement**
  - Two microstrip line method [4],[5]

$$\theta = \beta l = 2\pi f \frac{\sqrt{\varepsilon_{eff}}}{c} L \quad , \quad \Delta\theta = 2\pi f \frac{\sqrt{\varepsilon_{eff}}}{c} \Delta L \quad , \quad \varepsilon_{eff} = \left[\frac{\Delta\Phi c}{2\pi f \Delta L}\right]^2$$

  - Ring resonators and patch antennas

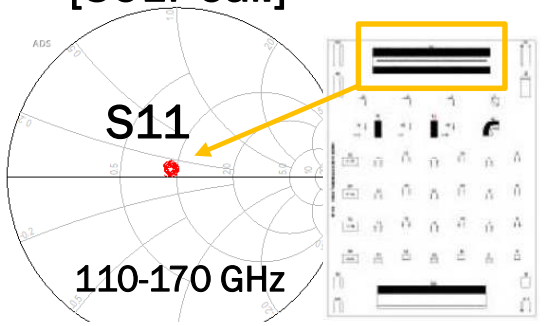
Probe Measurement



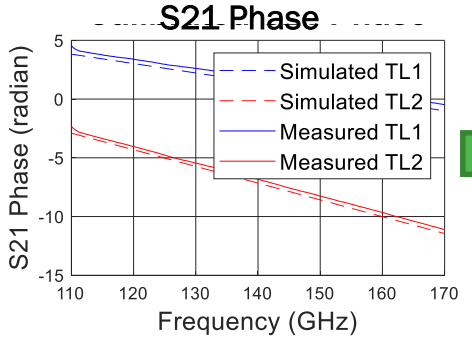


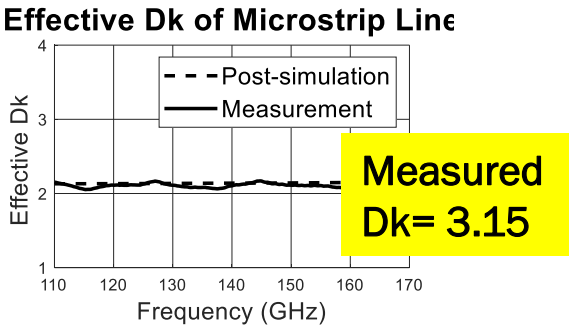
[TRL Cal.]

[SOLT Cal.]

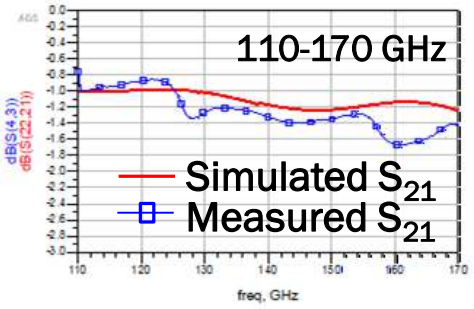


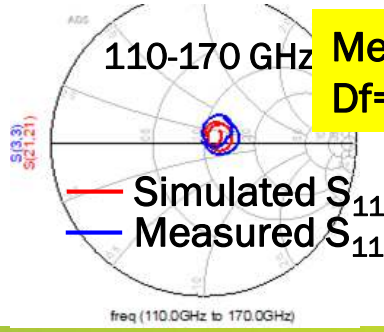
Verification of calibration using a long thru line





Measured Dk= 3.15

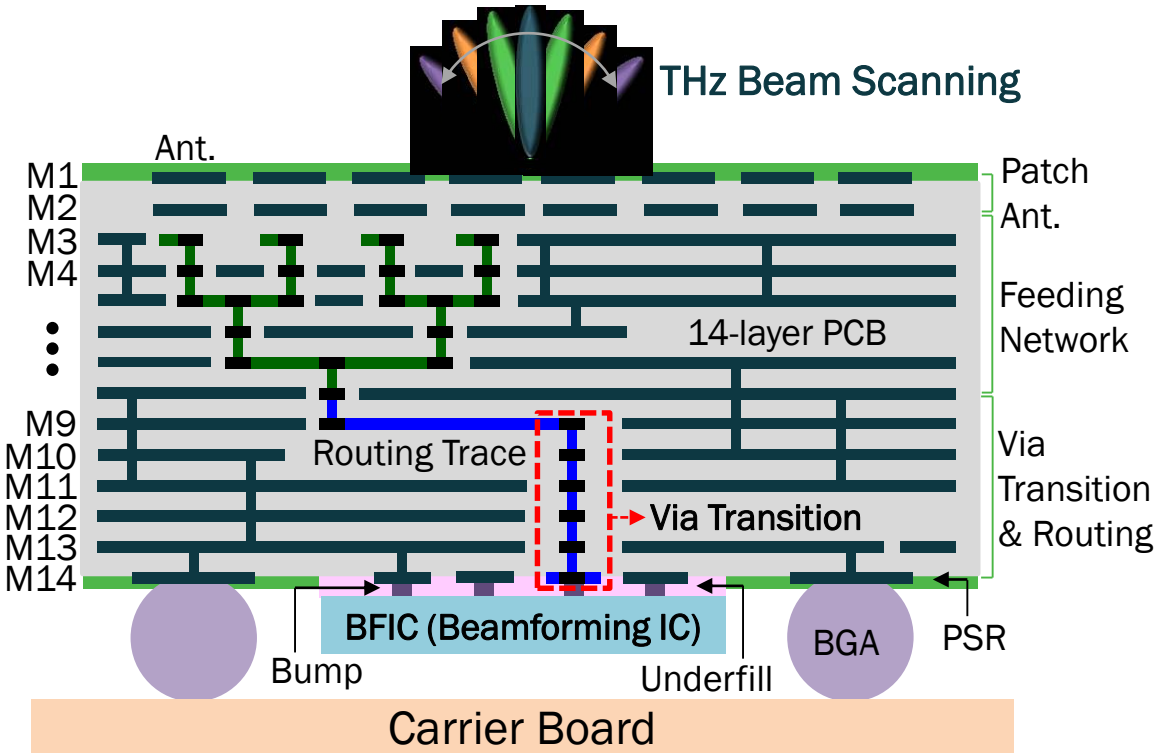


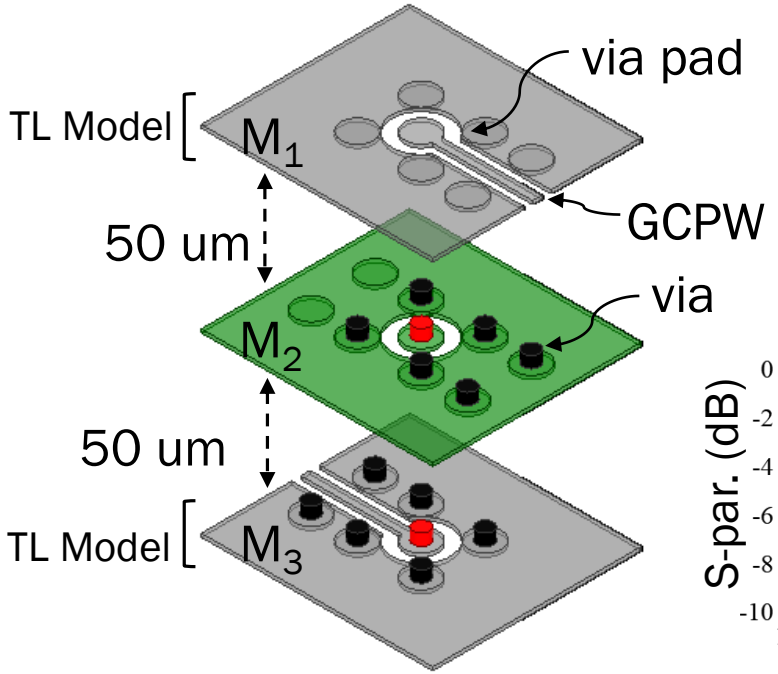


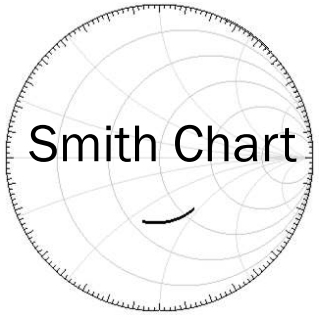
Measured Df= 0.014

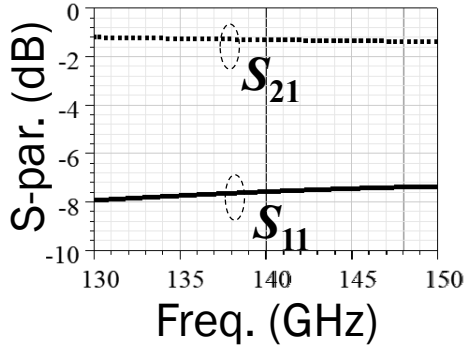
Via Transition and Sub-THz AiP

- **Via transition as key component of signal path**
  - Sub-THz frequency response characteristic
- **Challenges:**
  - Electrically large via size, rough design rule of conventional PCB fab



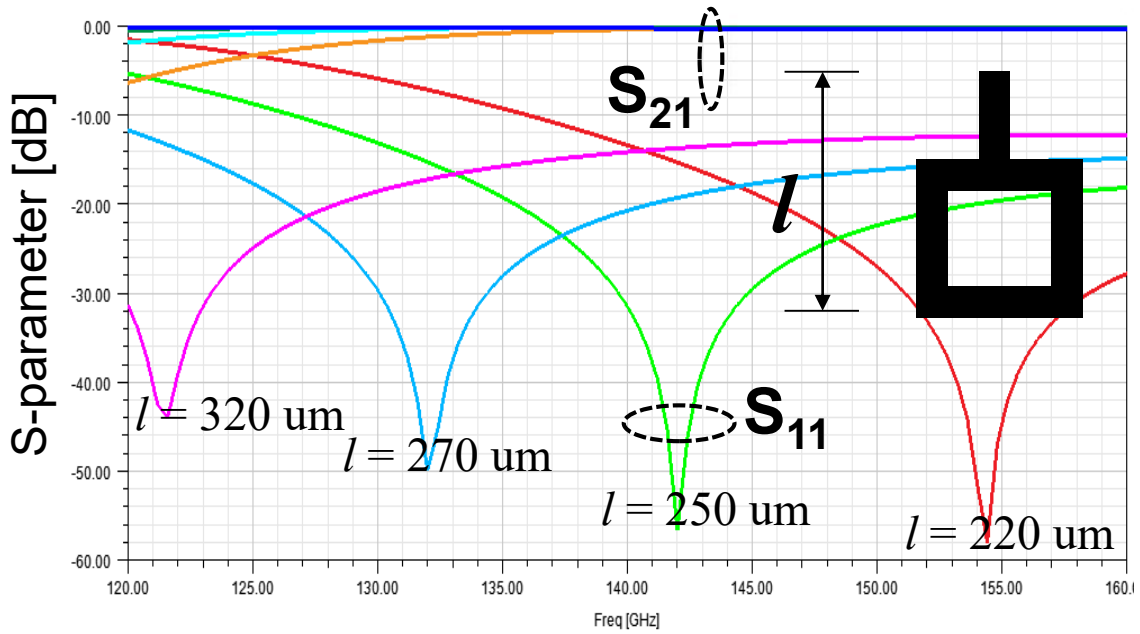


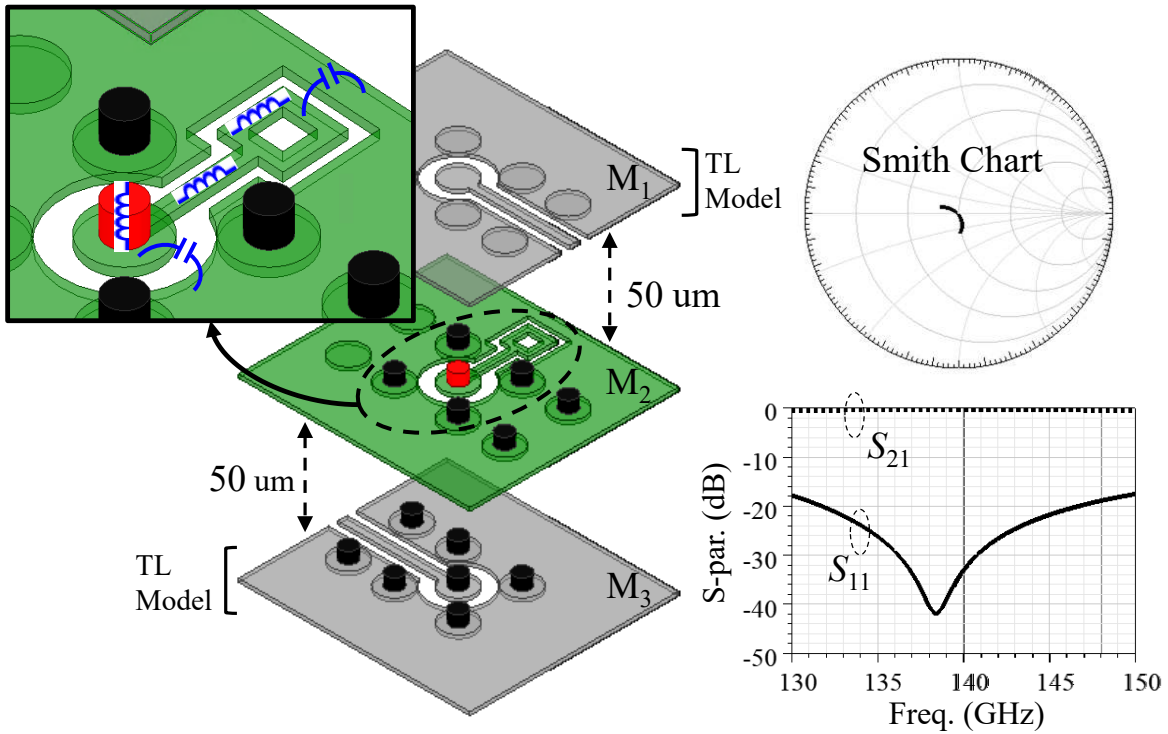




Proposed Stub-loaded Via Transition

- How to improve impedance degradation of via transition?
- Requirements: compact size and wideband
- Stub-loaded via transition as solution

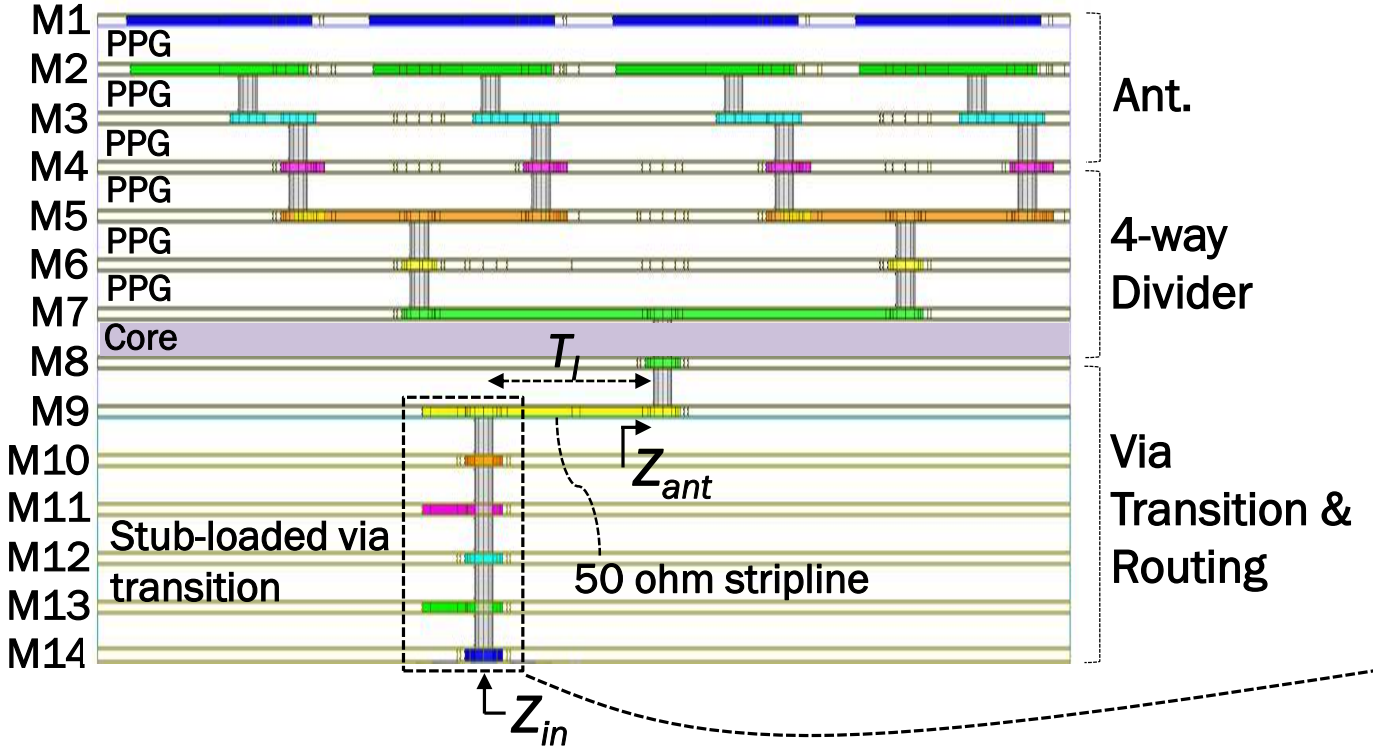




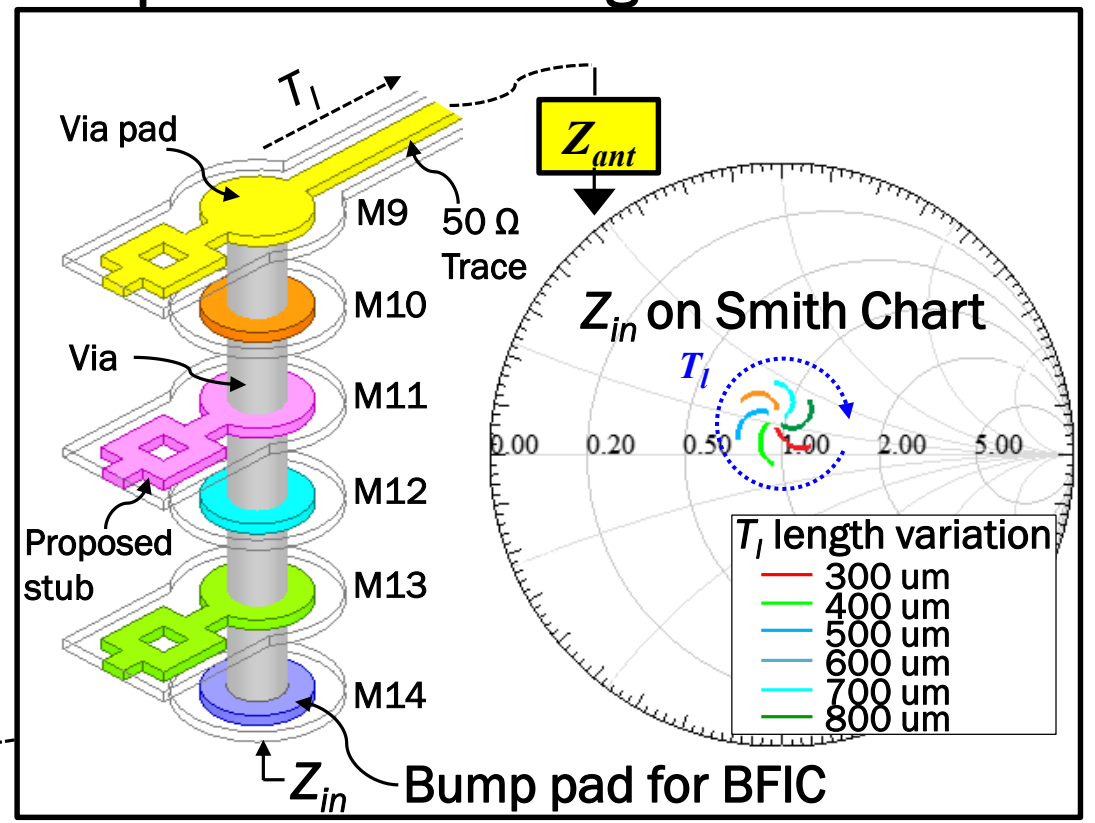
Proposed Stub-loaded Via Transition

- Design and implementation
  - 4x1 linear array on 14-layer PCB
  - Multiple stub-loaded via transition

4x1 linear array with stub-loaded via transition

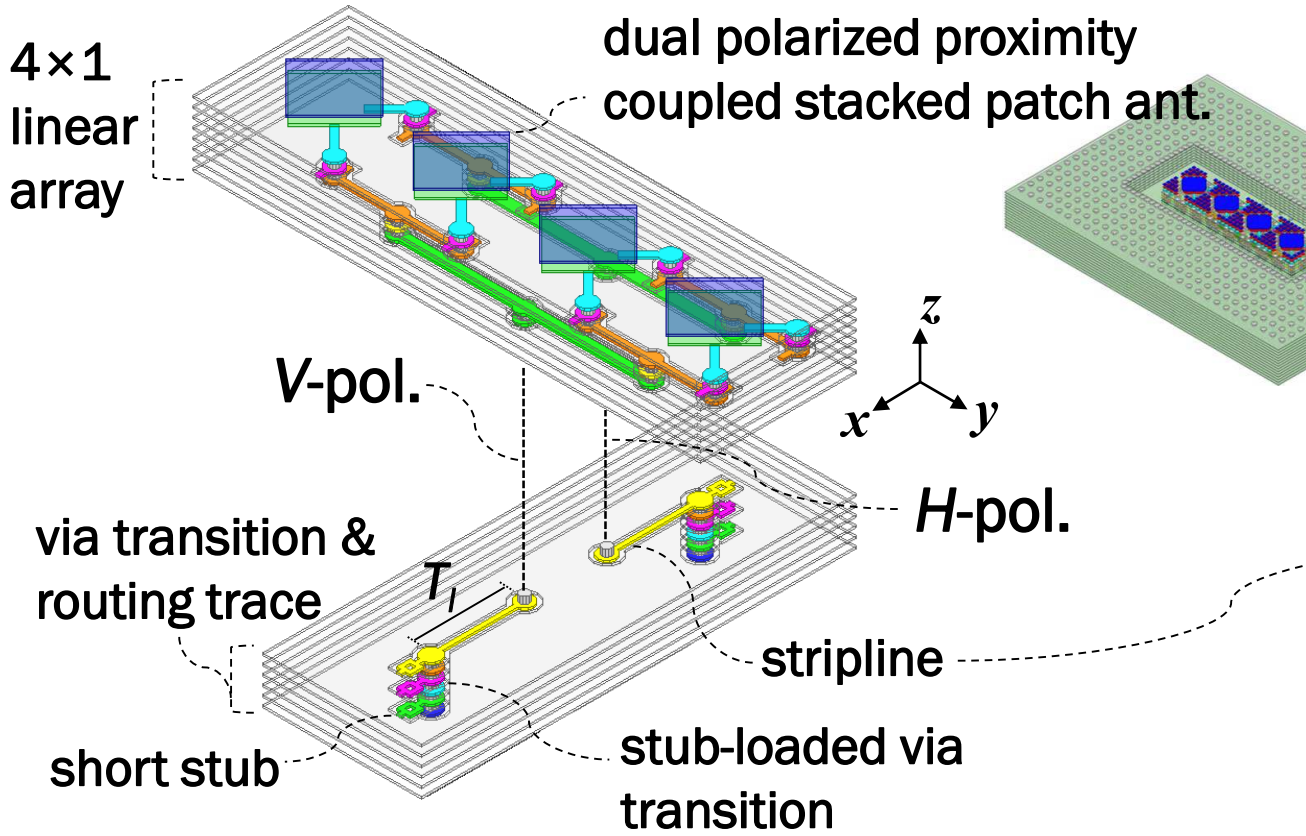


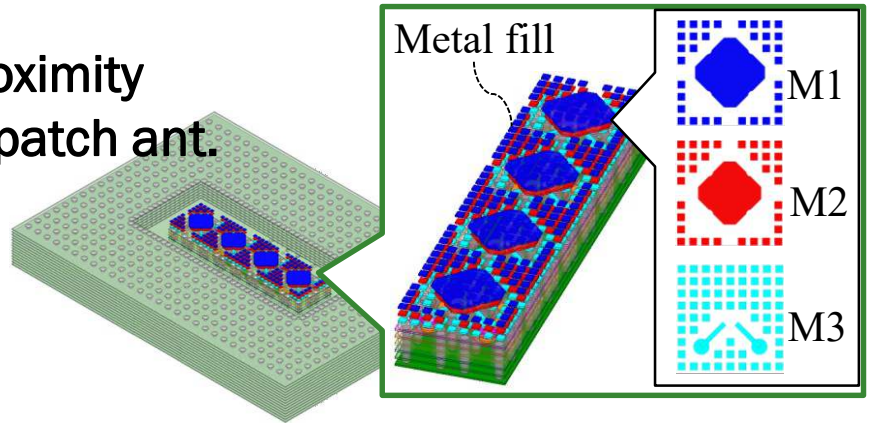
Impedance Matching Performance



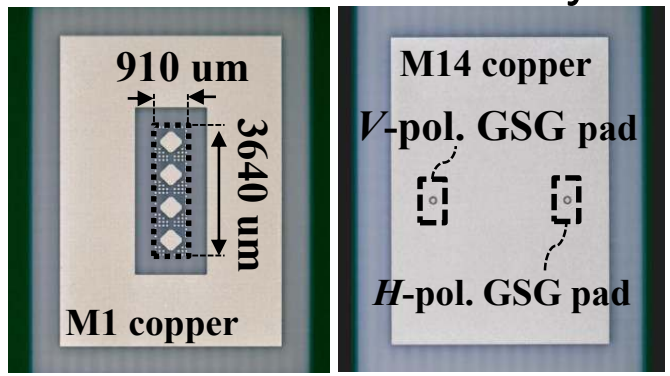
Design and Fabrication

- 4x1 linear array + stub-loaded via transition
  - Fabricated using conventional mSAP





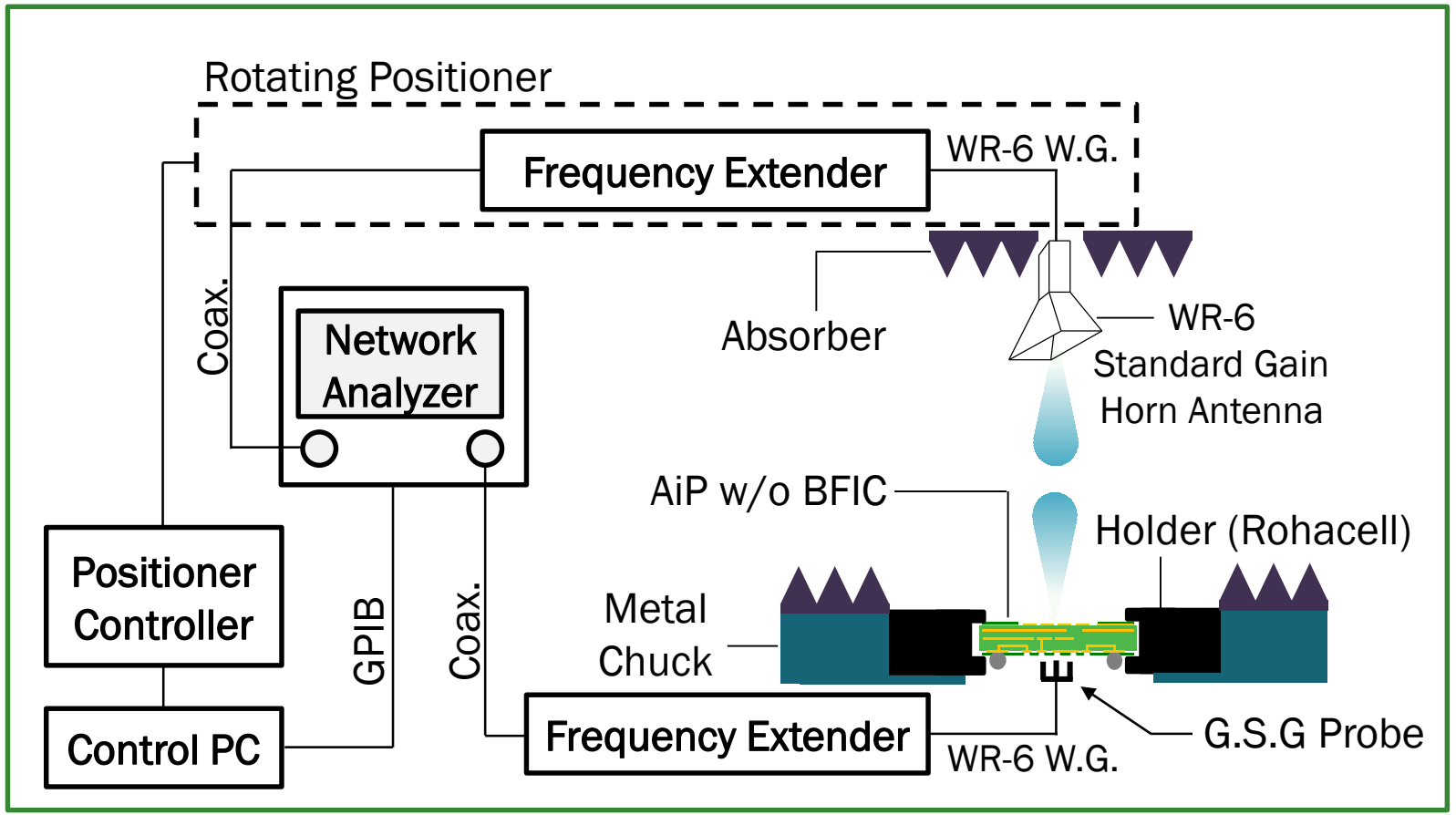
Fabricated 4x1 linear array

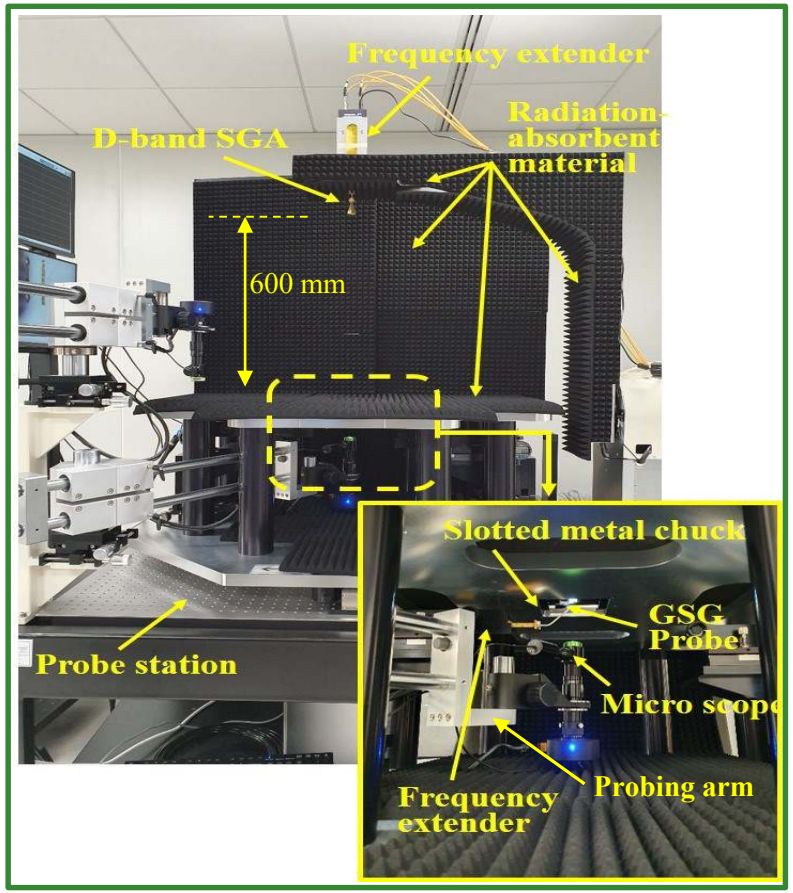


X-ray images of internal metal layers

Calibration and Measurement

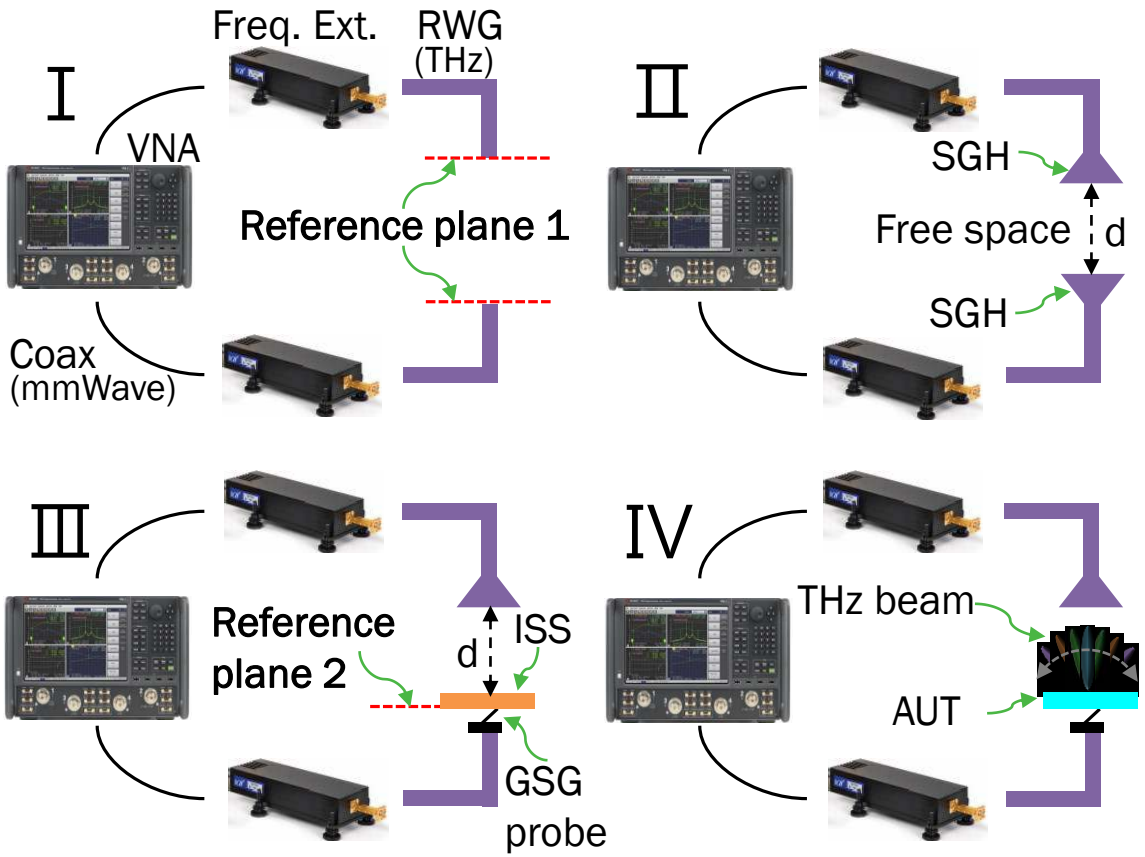
- Custom-built D-band antenna probe measurement system
  - Allows accurate characterization of AiP





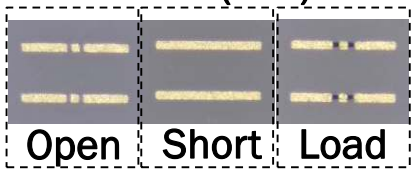
Calibration and Measurement

- Two-step calibration procedure

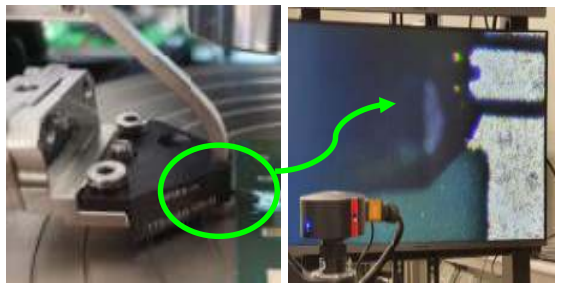


Waveguide SOL Cal. Kit

Impedance Standard Substrate (ISS)

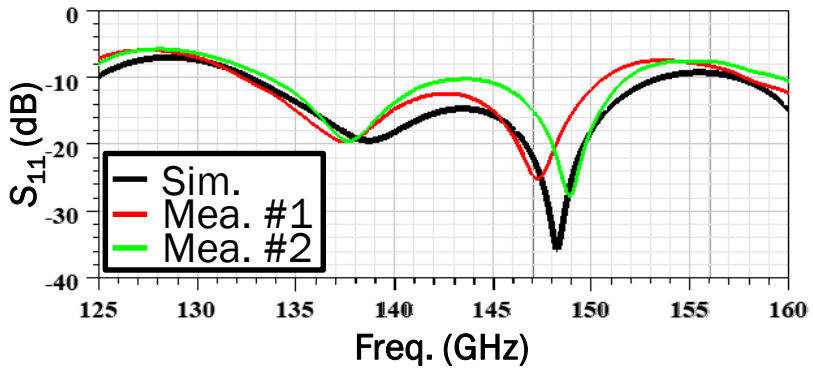


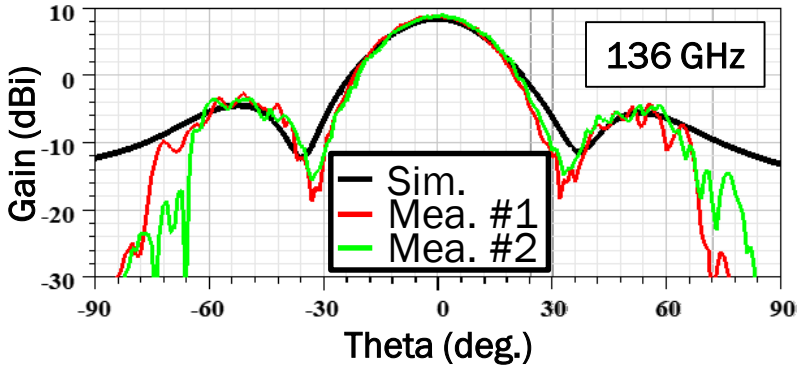
Probe Measurement

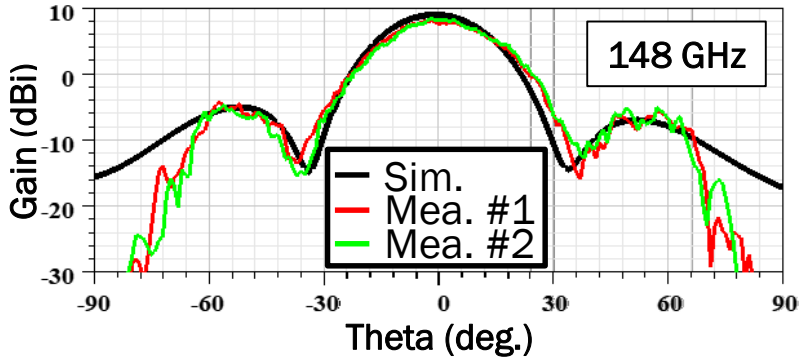


Measured Results and Summary

Measured Return Loss and Radiation Patterns (ϕ=90˚)







- Proposed stub-loaded via transition for D-band AiP
- Showed good correlation between mea. and sim.
- Gain of greater than 8.9 dBi with 13.2% of 10 dB FBW
- Provided sub-THz AiP design with conventional PCB process

Thank You

References

[1] Samsung white paper, “The next hyper-connected experience for all”

[2] Samsung white paper, “spectrum expanding the frontier”

[3] A. O. Watanabe et al., "A Review of 5G Front-End Systems Package Integration,“ *IEEE Transactions on Components, Packaging and Manufacturing Technology*, vol. 11, no. 1, pp. 118-133, Jan. 2021.

[4] N. K. Das, et al, "Two Methods for the Measurement of Substrate Dielectric Constant," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 35, no. 7, pp. 636-642, Jul 1987

[5] J. Coonrod, et al., “Characterizing circuit materials at mmWave frequencies,” Microwave Journal, May 2019