mm-Wave and sub-Terahertz Antennas for 5G and 6G Applications

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Acknowledgements

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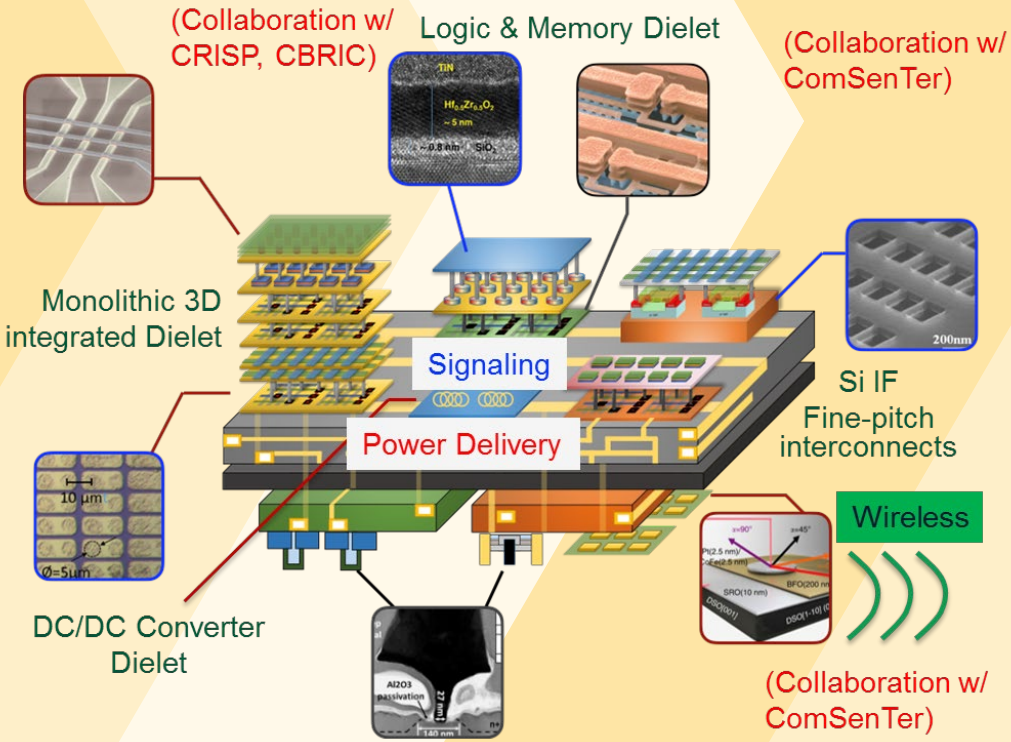
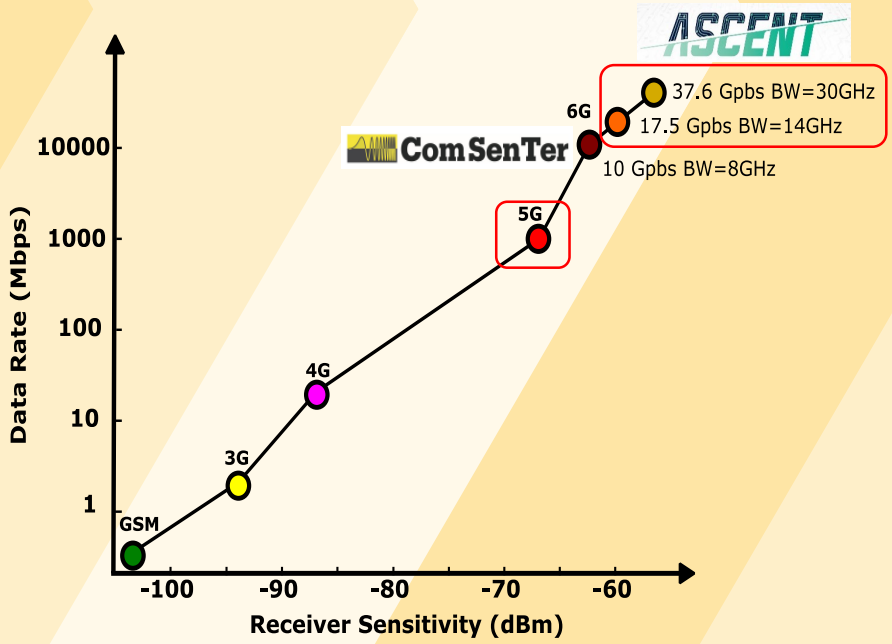
Task Statement

- ASCENT task — Antenna integration and miniaturization
  - Antenna as a key component of integrated RF front-end dielets
  - Interface of a high-performance microsystem to the space
  - mm-Wave to THz bands for 5G/6G+ wireless communications
  - High-gain antenna solution integrated on glass-based panels



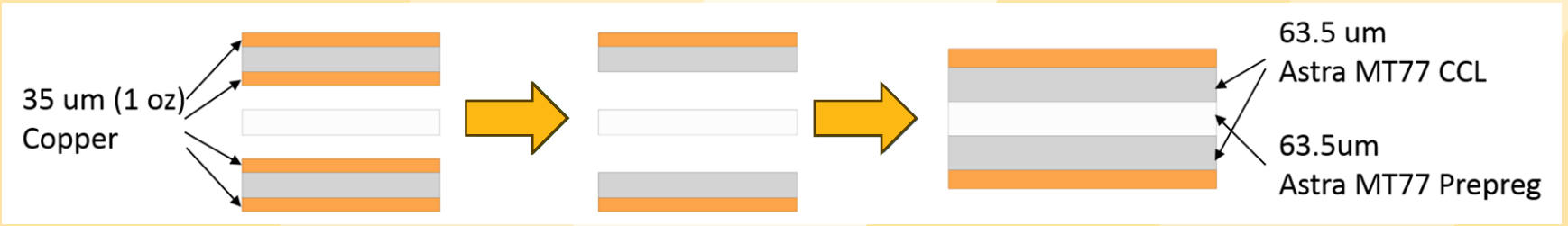
Objectives

- Design, fabricate, and prototype antennas that:
  - Work at mm-wave to sub-terahertz frequency bands for 5G/6G wireless applications
  - Support >15% bandwidth at 140 GHz band
  - Provide high gain
  - Have 20% reduced antenna size compared to typical designs
  - Have high efficiency



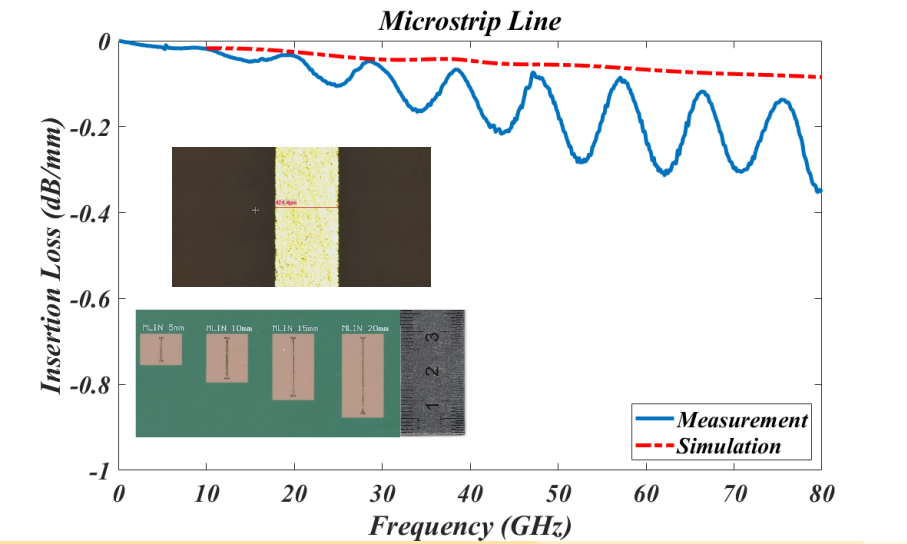
Antenna Implementation

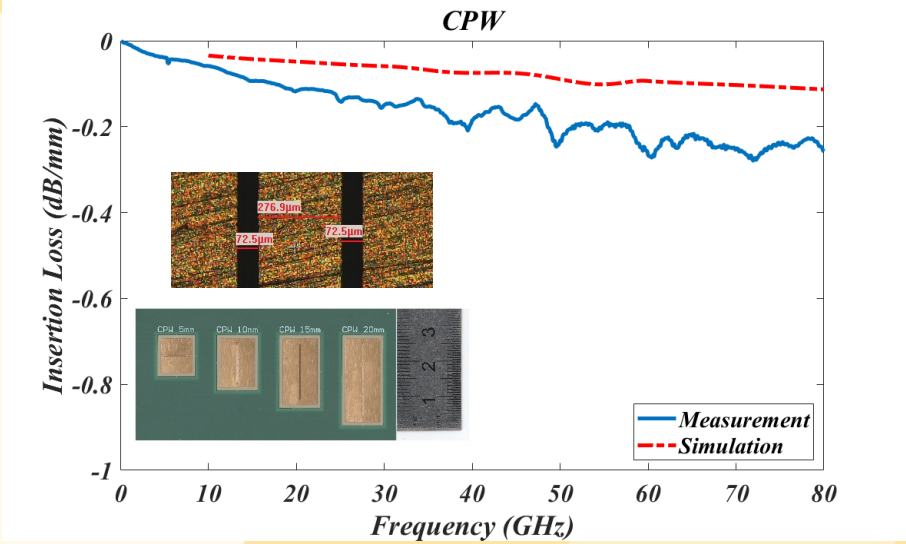
- Laminate substrate
  - For <200GHz applications
  - Low and stable permittivity Dk=3.0
  - Low loss tangent Df=0.0017
  - Vendor fabrication and Georgia Tech (process being developed)
- Fan-Out Panel-Level Packaging (FOPLP)
  - For >100GHz applications
  - Moderately low permittivity and loss tangent Df~0.005
  - Fabrication process being developed



Test Structures

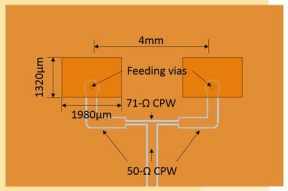
Astra Substrate

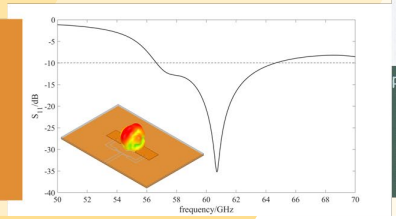


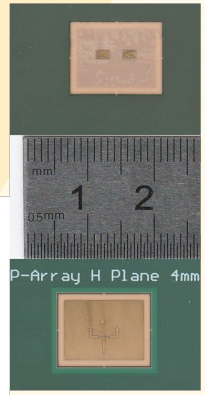


Patch Antennas

- Example: Patch Array
  - Patch size: 1380µm(L) x 2070µm(W)
  - Element distance: 4mm
  - Resonance frequency: 60.07GHz
  - Bandwidth: 8.11GHz (13%)
  - Broadside gain: 9.3dBi

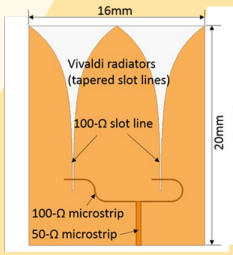


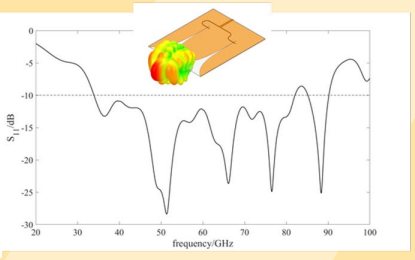


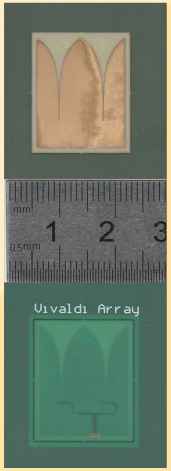


Vivaldi Antennas

- Example: Vivaldi Array
  - Size: 16mm x 20mm
  - Bandwidth: 33.9GHz – 82.1GHz
  - Gain: 11.5dBi @ 60GHz



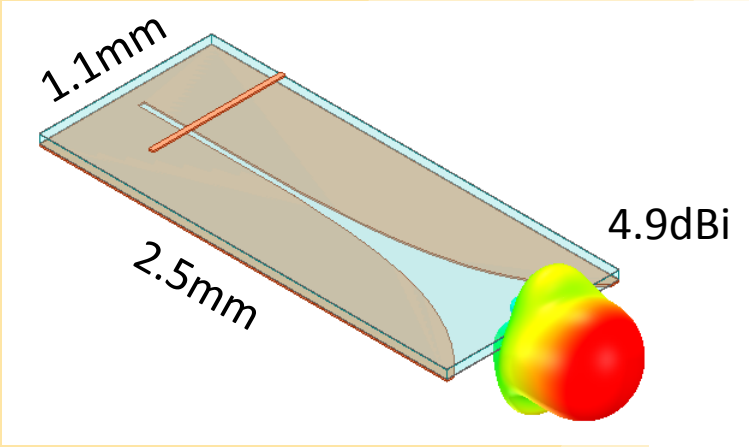


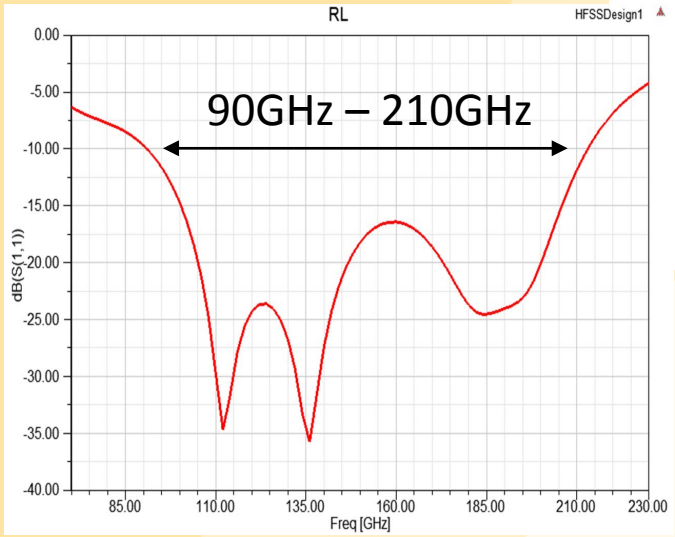


Antenna Design

Vivaldi Antennas on Glass

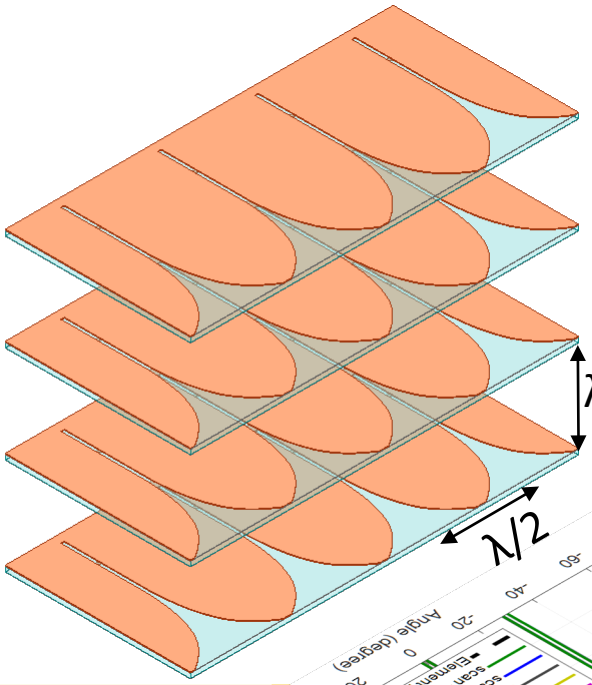
❑ Antenna element

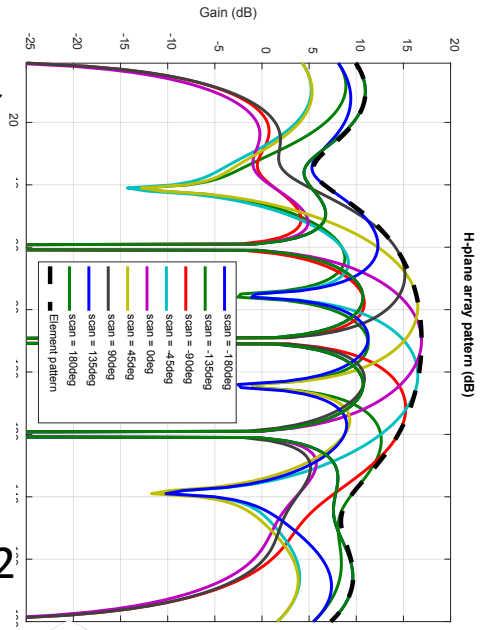


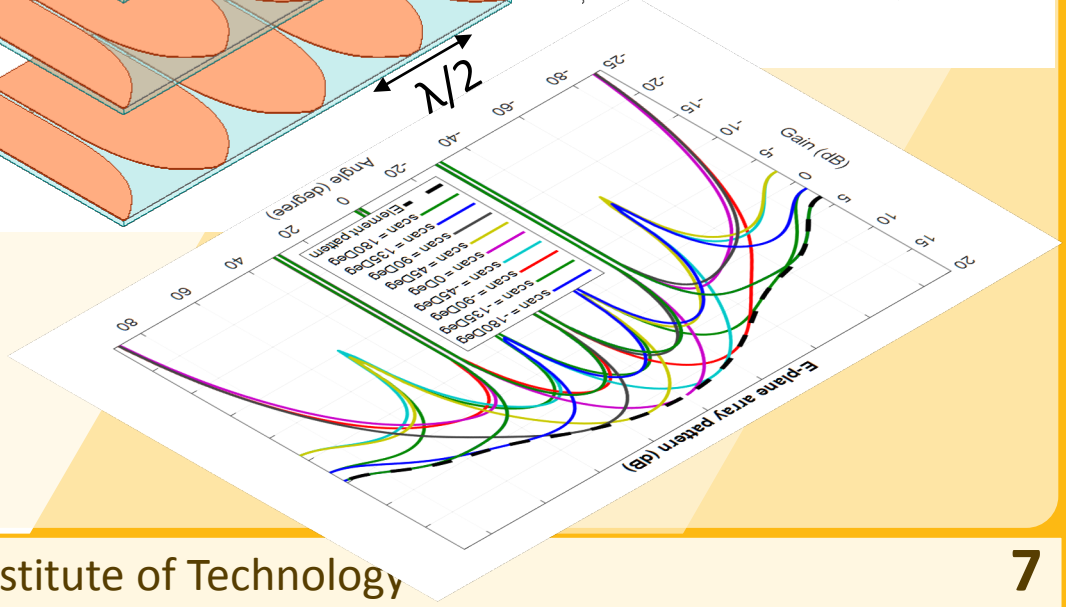


❑ 4x4 Array

$\lambda/2 \cong 1.1mm$ @$140GHz$



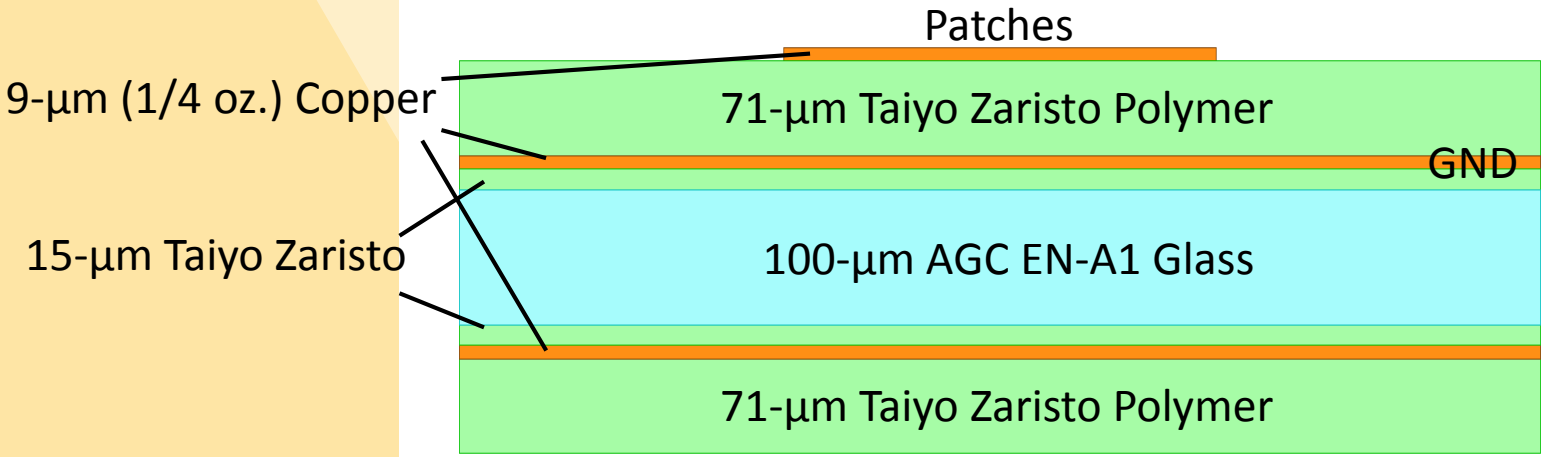




Test Structures

Test Vehicle Stack-up

- Stack-up of the test vehicle



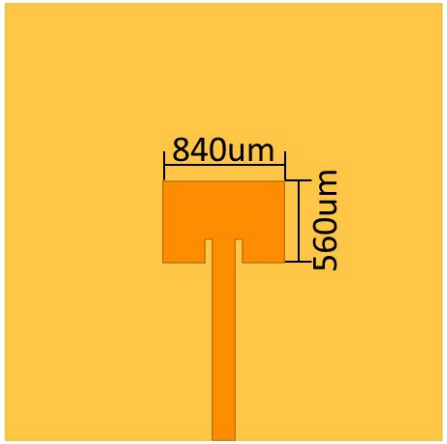
- Material properties

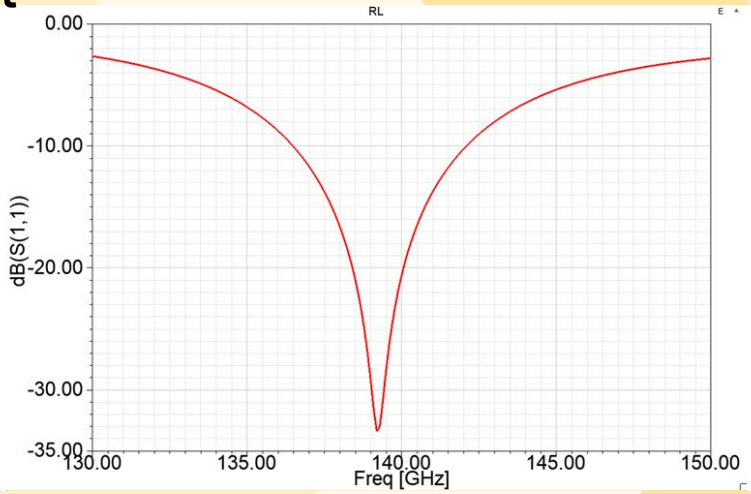
Material	Dk	Df
Glass (AGC EN-A1)	5.4	0.005
Polymer (Taiyo Zaristo)	3.3	0.0025

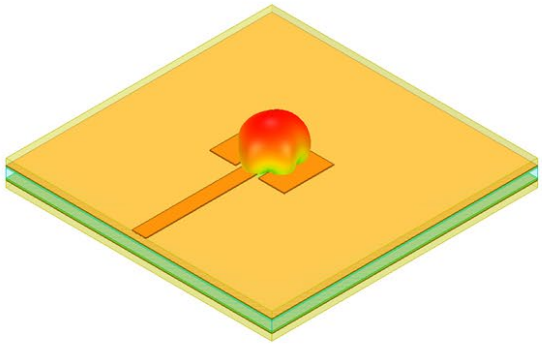
Antenna Design

Patch Antennas on Glass

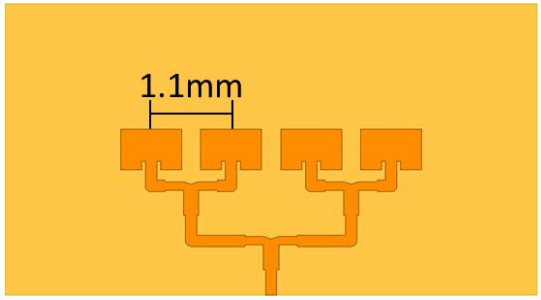
❑ Patch element

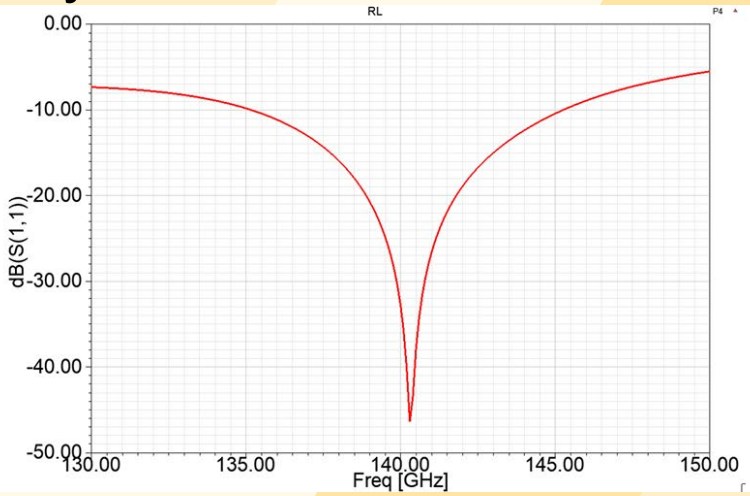


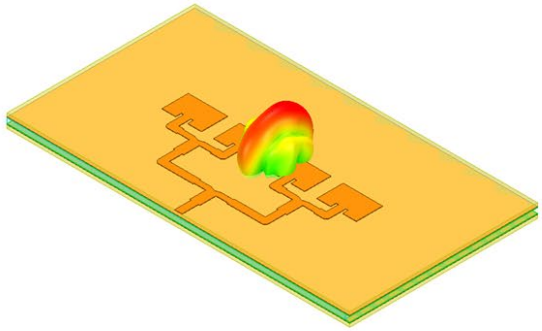




❑ Parallel-fed array



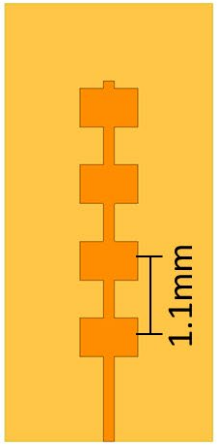


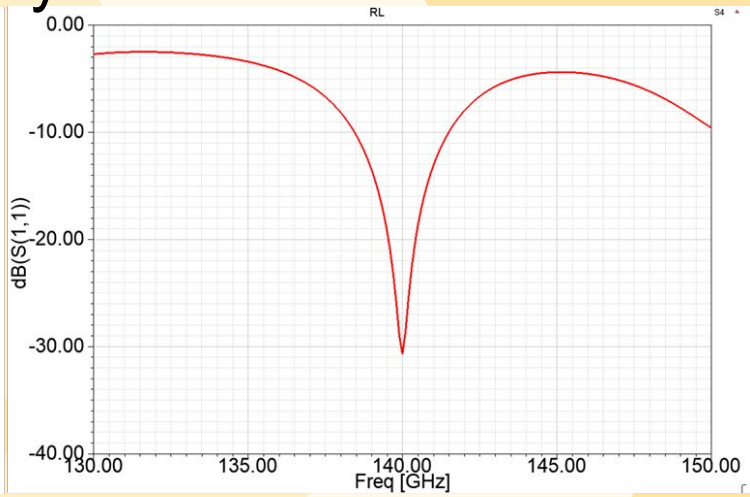


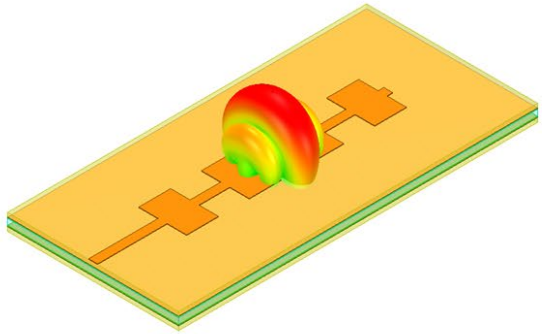
Antenna Design

Patch Antennas on Glass

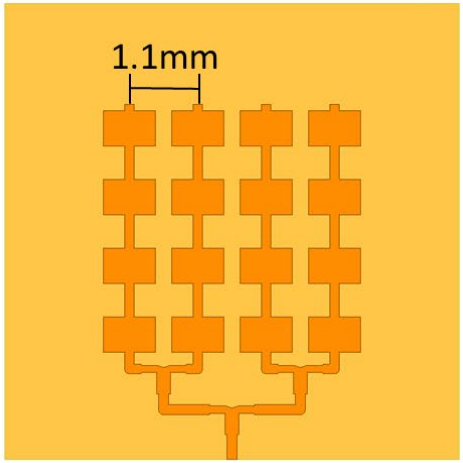
- Series-fed array

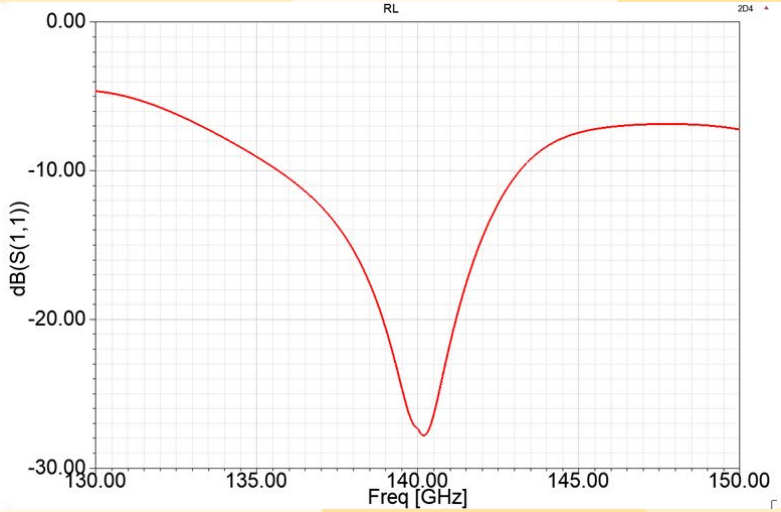


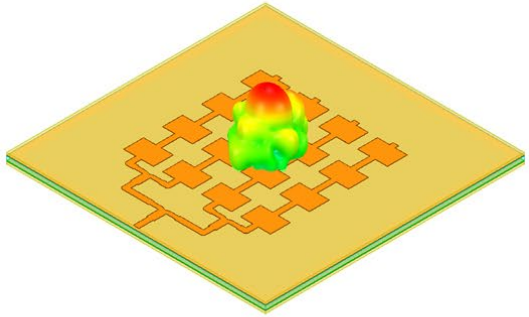




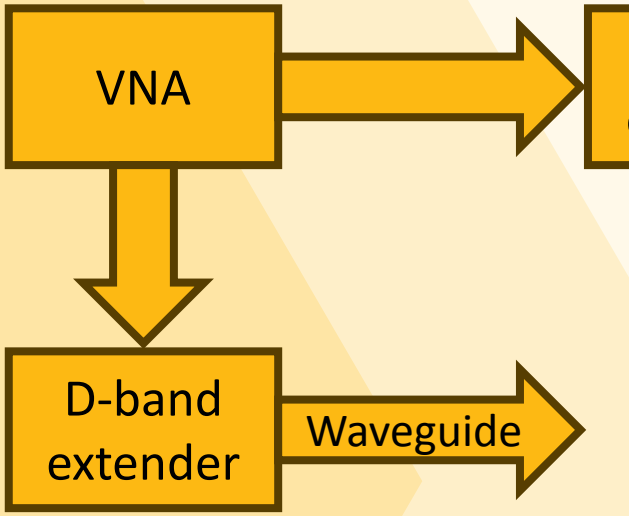
- 2-D array

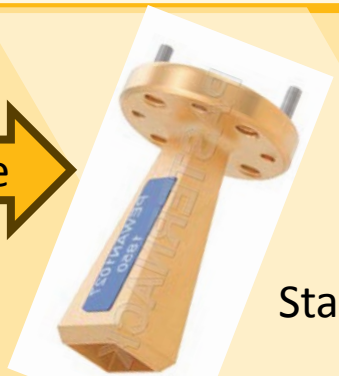






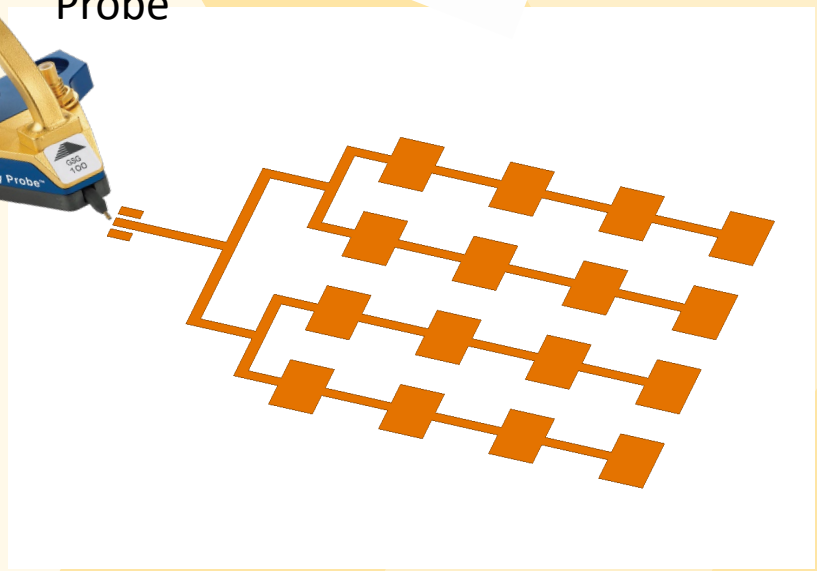
Antenna Measurements

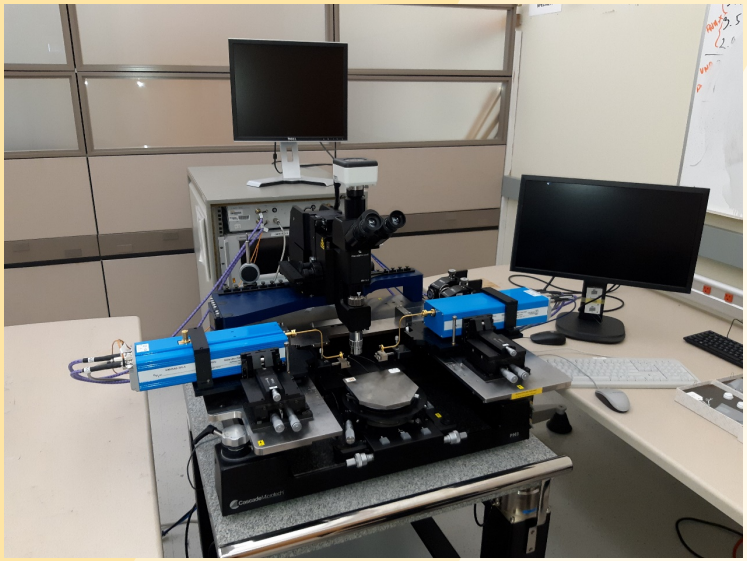




Standard horn

Probe





D-band measurement equipment at GEDC

Challenges

- Fabrication difficulties of 3-D fine structures
- Broadband matching of the antenna feeding network
- Substrate modes as the wavelength is comparable to substrate thickness at sub-THz frequency
- Coupling between elements is complicated in a large array consisting of numerous elements
- mm-Wave and sub-THz antenna measurement

Timeline

- Develop the complete fabrication process of laminate substrate and the FOPLP process on glass substrate
- Continuously design and fabricate new structures to test the concept and the process
- Design wide-band low-loss feeding network using SIW's
- Investigate the design and fabrication of 3-D high-gain antennas such as horn antennas
- Develop a reliable antenna measurement method beyond 100 GHz

'19 Q4	'20 Q1	'20 Q2	'20 Q3	'20 Q4
Fabrication Process				
Test Structure Tape-Out				
	SIW Antennas and Feeding Network			
				3-D Antennas
Measurement Method				

Summary

- Antenna at mm-wave and sub-terahertz bands for 5G/6G RF front-end
- Fabrication of antenna dielets using organic laminate substrate and glass FOPLP
- Test structures fabricated on Astra substrate for 5G applications at 60 GHz band
- Antenna design based on glass stack-up for 6G applications at 140 GHz
- mm-Wave and sub-THz antenna measurement