Flex on Glass for mmWave Applications

Faculty: Prof. Swaminathan, Dr. Fuhan Liu **Student:** Sridhar Sivapurapu

Sponsors: Schott (Martin Lutz)
Taiyo Ink (Takenori Kakutani)

Outline

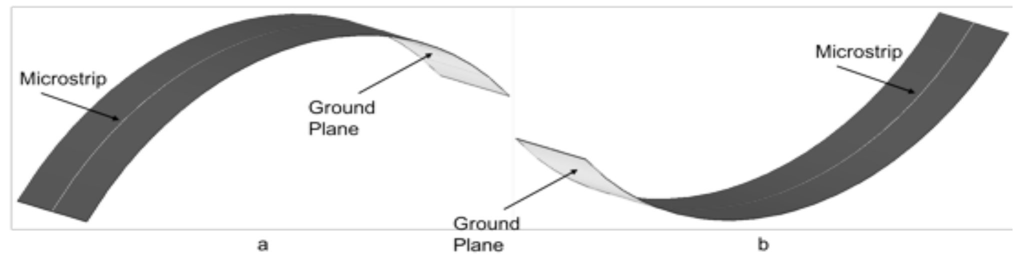
- Research Objectives
- Prior Work
- Application – Automotive Radar
- Individual Component Analysis
- Future Work
- Projected Timeline

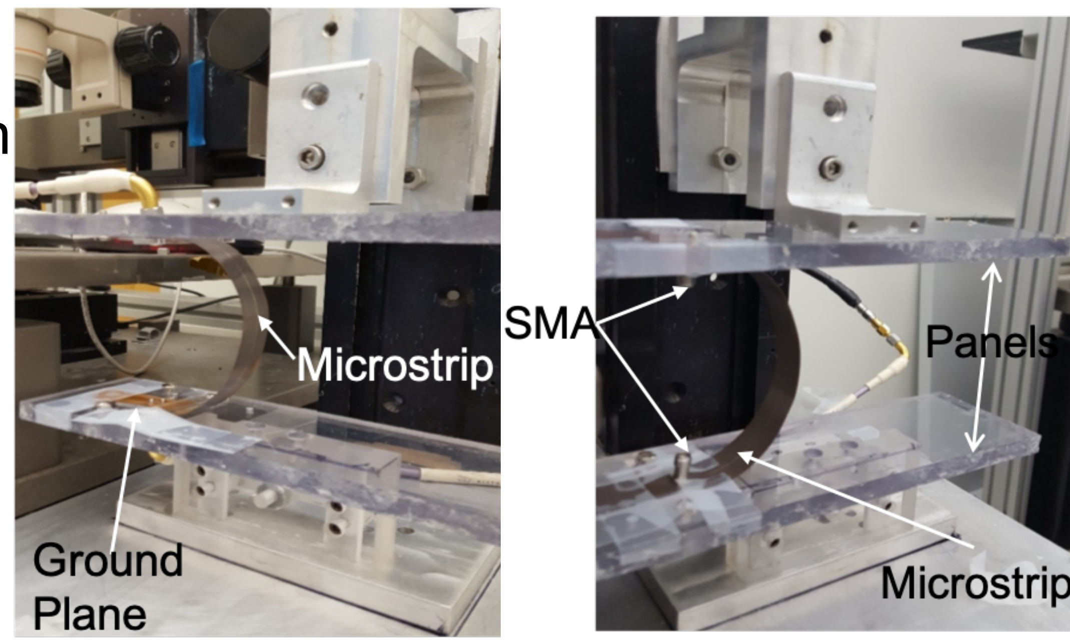
Research Objectives

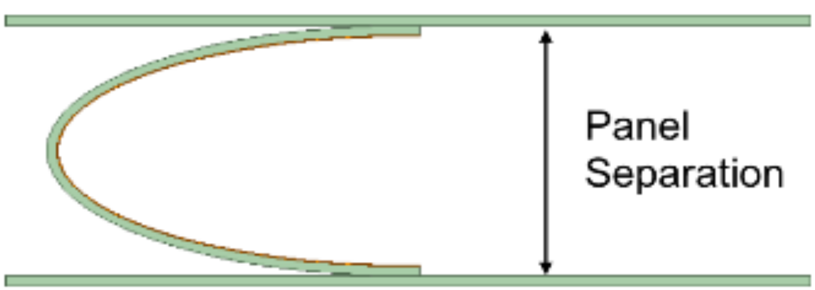
- Design, fabricate, and integrate passives (transmission line, antennas, couplers, etc.) and active components (ICs) onto flexible glass substrates (Schott AF32)
  - Stack-ups will include metallization (screen printing, inkjet printing, and aerosol jet printing) on bare glass as well as layers of build up materials to use subtractive etching and semi-additive processing
- Focus primarily on mmWave applications
  - Automotive
  - 5G

Prior Work

- ❑ Direct metallization (screen printing) onto Kapton polyimide (Pyralux AP and Kapton HF) and PET
  - ❑ Transmission Lines (Microstrip and CPW), Power Inductors, and Patch Antennas
- ❑ Components underwent both tensile (a) and compressive (b) bending using adaptive curvature bending



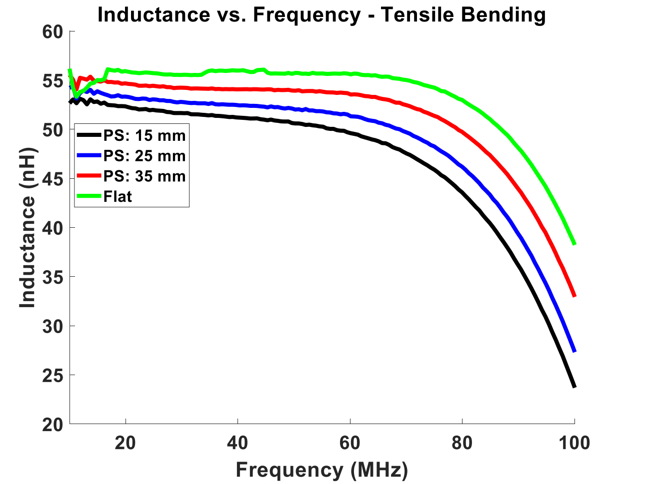


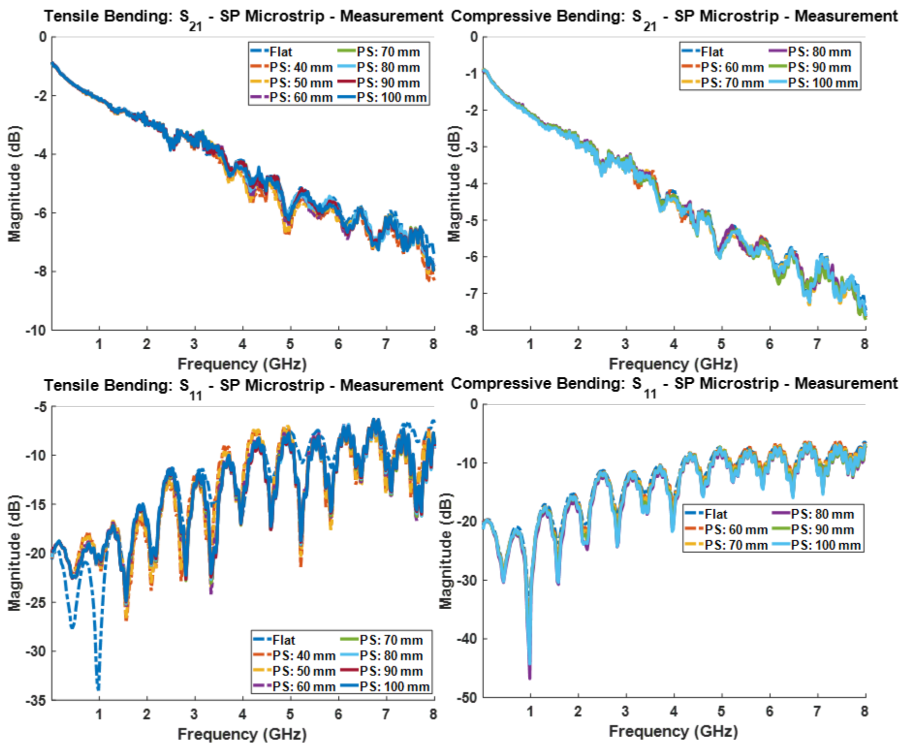


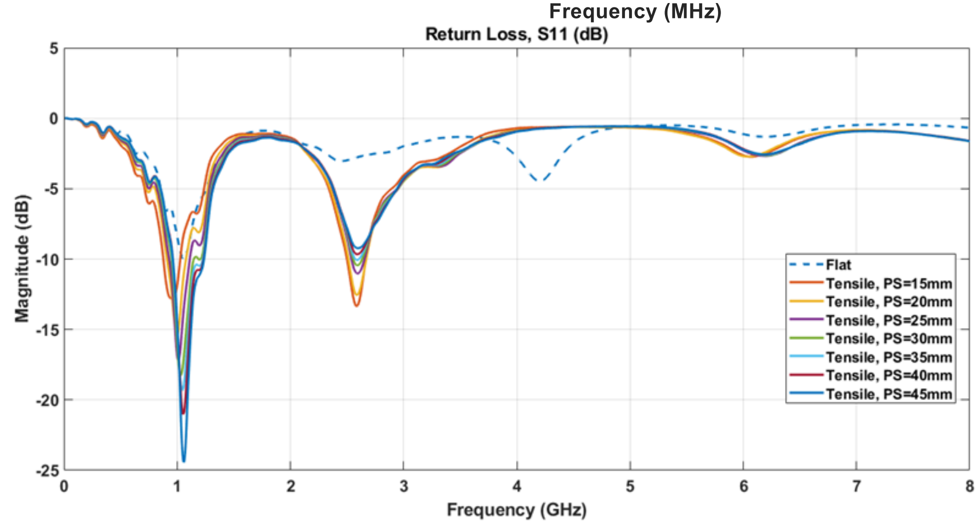
Ref: S. Sivapurapu, C. Mehta, R. Chen, Y. Zhou, X. Jia, M. Bellaredj, P. Kohl, S. Sitaraman, M. Swaminathan, “Multi-physics Modeling Characterization of Aerosol Jet Printed Transmission Lines”

Prior Work (cont.)

- ❑ Depending on the component, the impact of bending varies
  - ❑ Microstrip Transmission Line: No Impact
  - ❑ Power Inductor: Significant
  - ❑ Patch Antenna: Small Frequency Shift



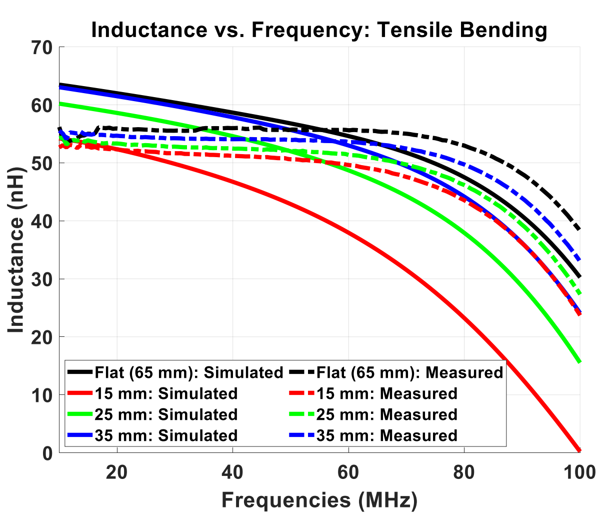


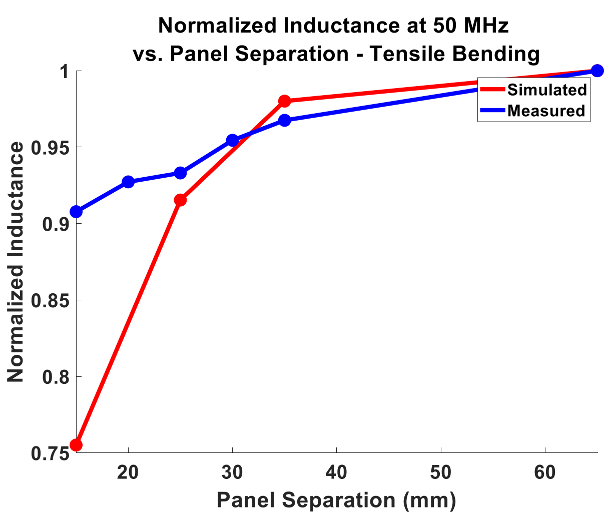


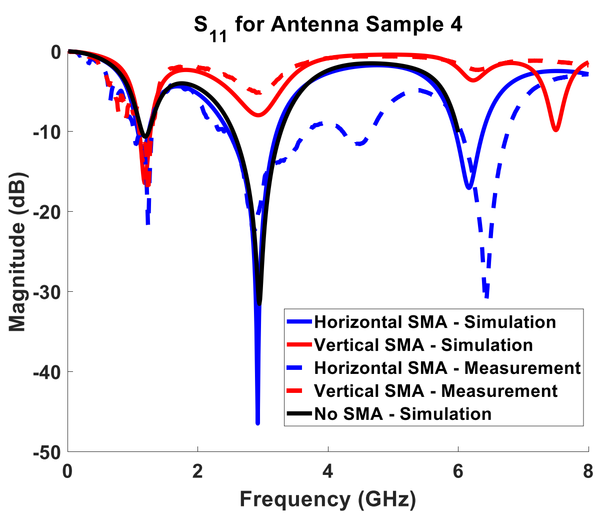
Ref: S. Sivapurapu, C. Mehta, R. Chen, Y. Zhou, X. Jia, M. Bellaredj, P. Kohl, S. Sitaraman, M. Swaminathan, "Multi-physics Modeling and Characterization of Components on Flexible Substrates"

Prior Work (cont.)

- Given the type of component and amount of bending, good correlation can be found
- Mismatch between measurement and simulation occurs to tool limitation to account of positional strain inside of EM simulation
  - Occurs at small panel separation (maximum bending)

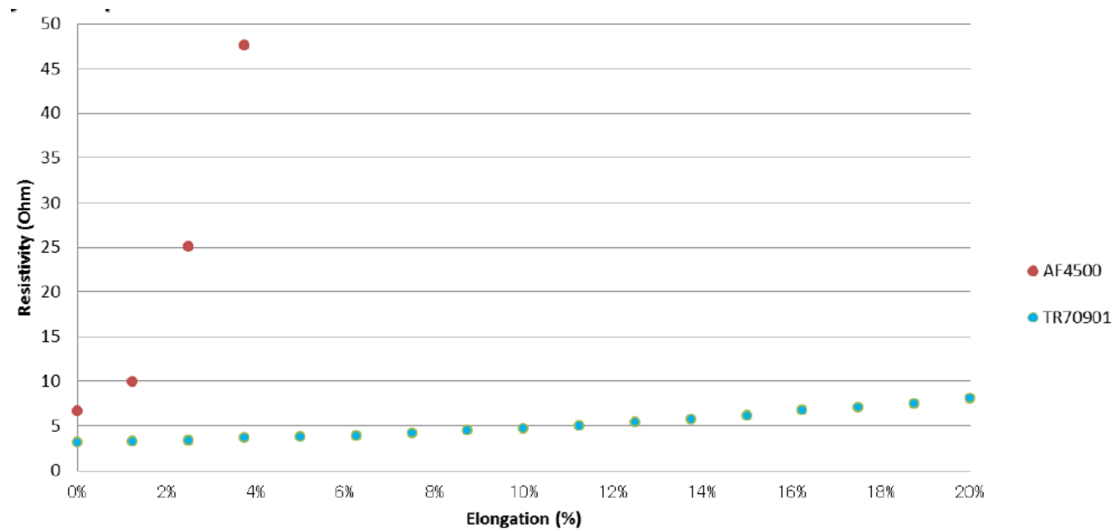






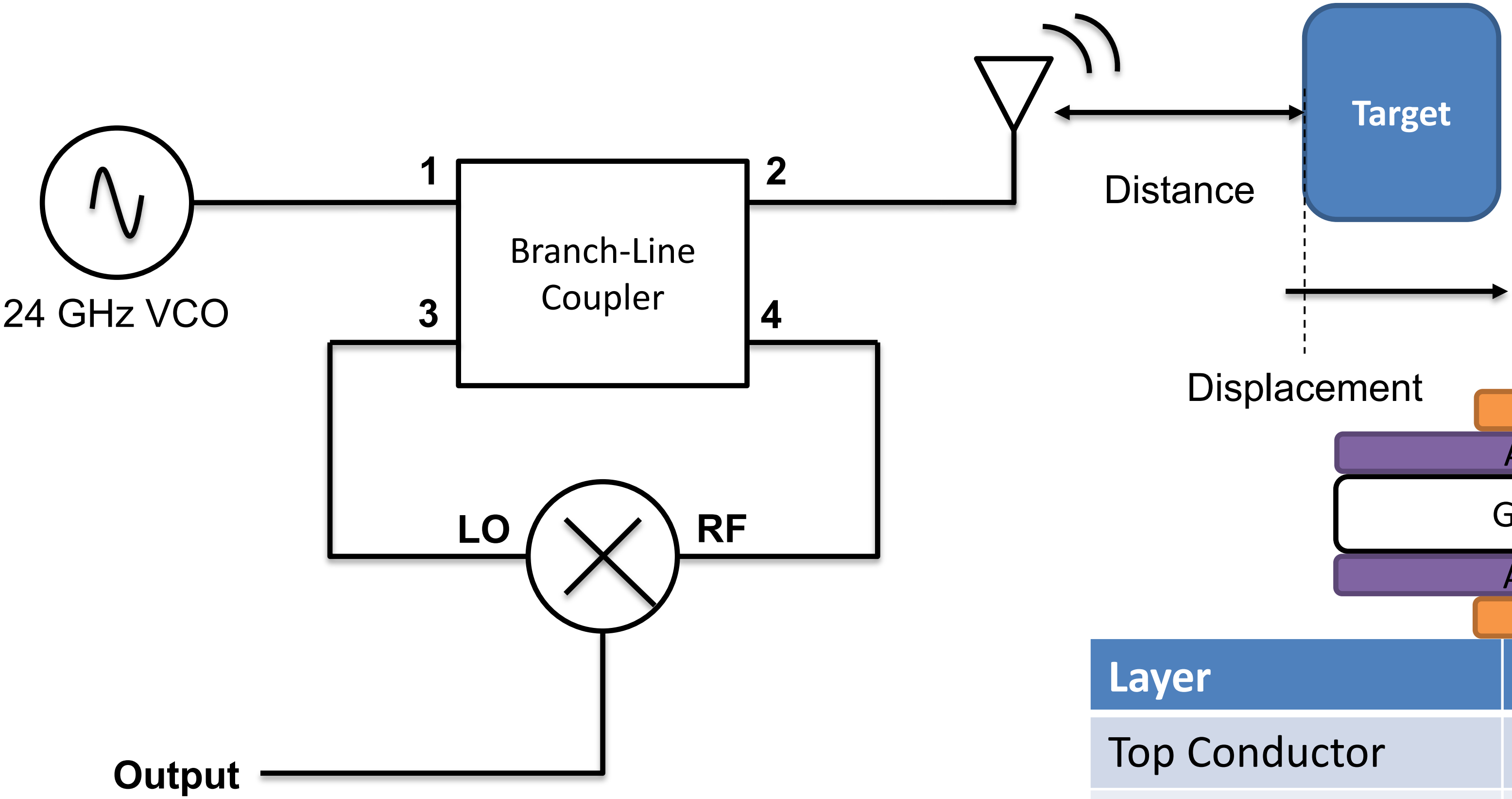
Ref: S. Sivapurapu, C. Mehta, R. Chen, Y. Zhou, X. Jia, M. Bellaredj, P. Kohl, S. Sitaraman, M. Swaminathan, “Multi-physics Modeling and Characterization of Components on Flexible Substrates”

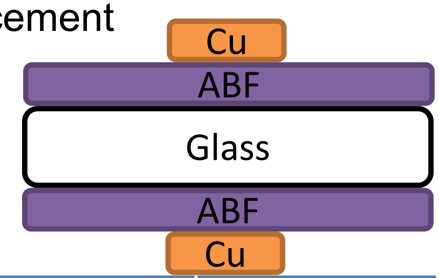
Direct Metallization on Glass



- Begin with Taiyo Stretchable Ag Conductive Paste both directly on glass using Screen Printing
- Low temperature processing (90°C)
- Major advantage compared to other Ag Conductive Pastes is minimizing change in resistance while stretching compared to other products
  - Stretch testing completed up to 20% elongation without fracture

Possible Application: Automotive Doppler Radar

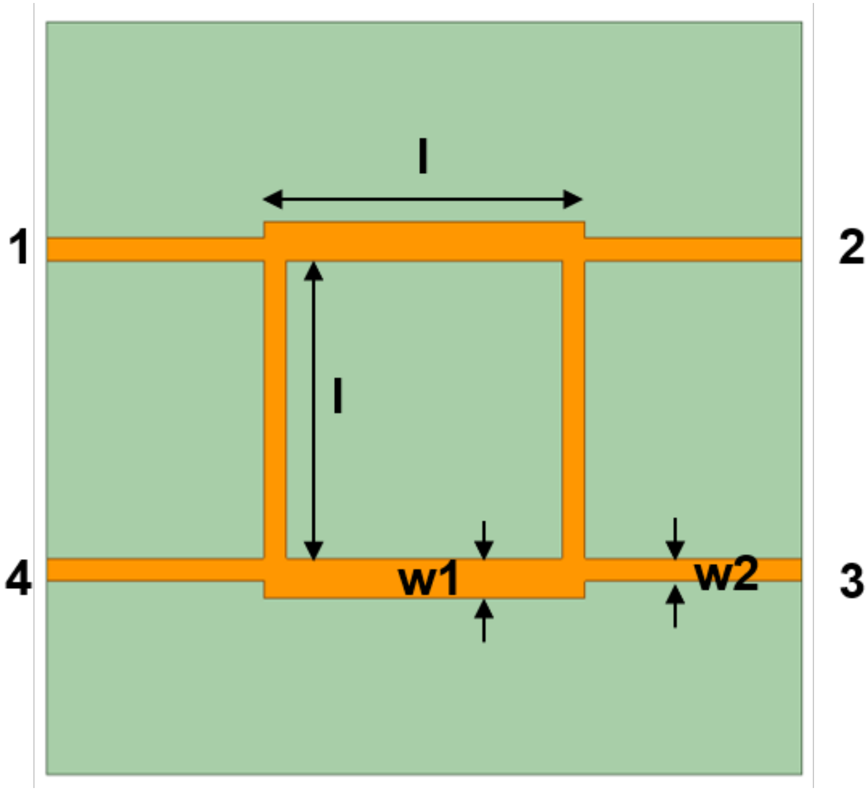


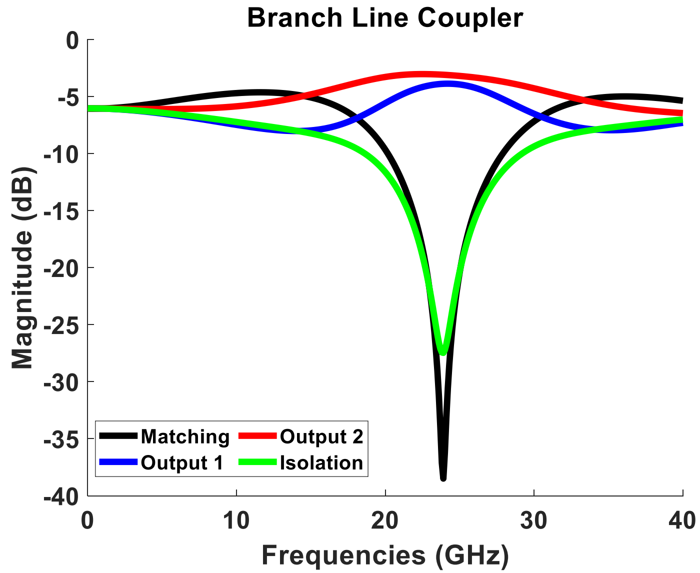


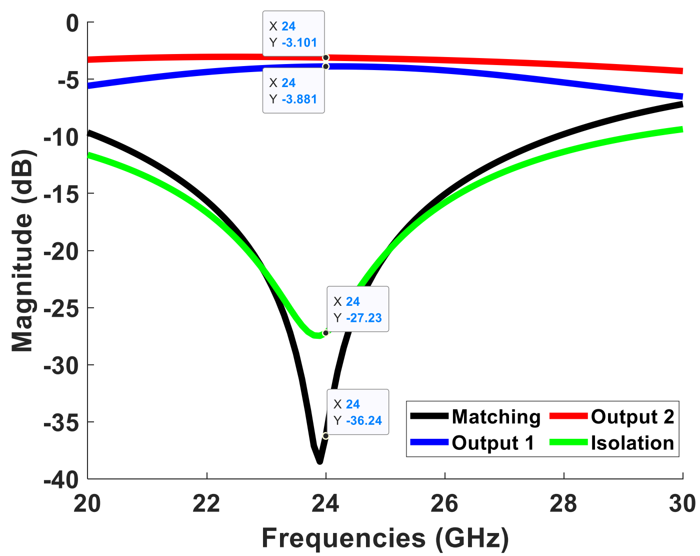
Layer	Thickness
Top Conductor	6 µm
ABF (GX-92)	15 µm
Glass (Schott AF32)	30 µm
ABF (GX-92)	15 µm
Bottom Conductor	6 µm

- ❑ Full system would be integrated onto glass substrate and should be flexible
- ❑ Targets for Branch-Line Coupler, Mixer, and Antenna shown in upcoming slides
- ❑ All of the designs use the stack up on the right

Branch-Line Coupler Design



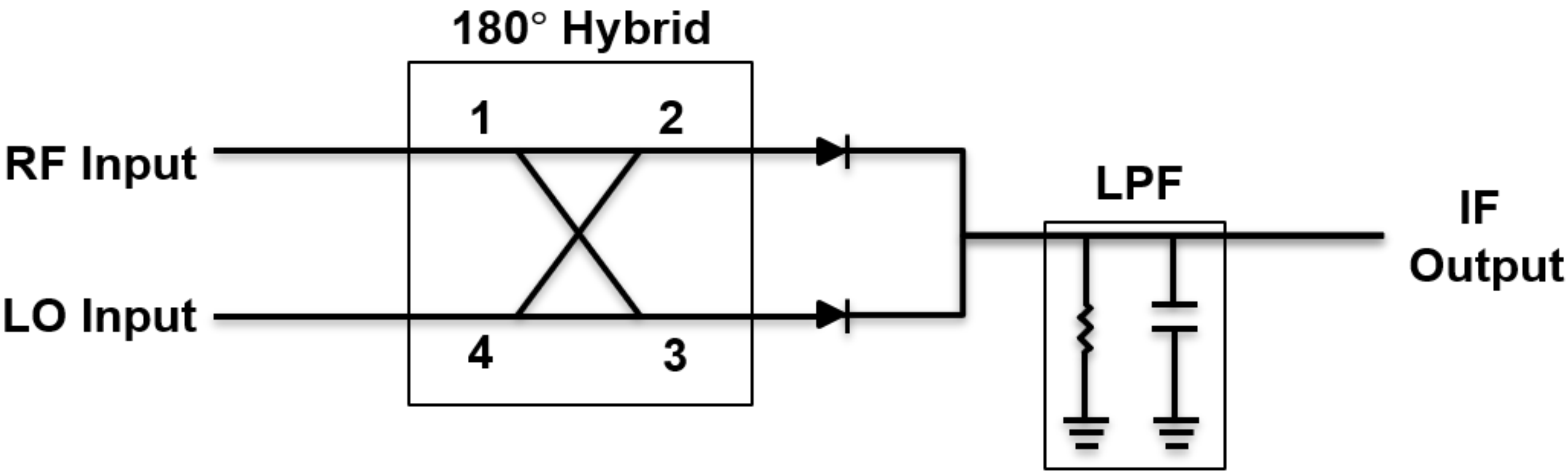




Parameter	Size
l (mm)	1.7
w1 (um)	150
w2 (um)	90

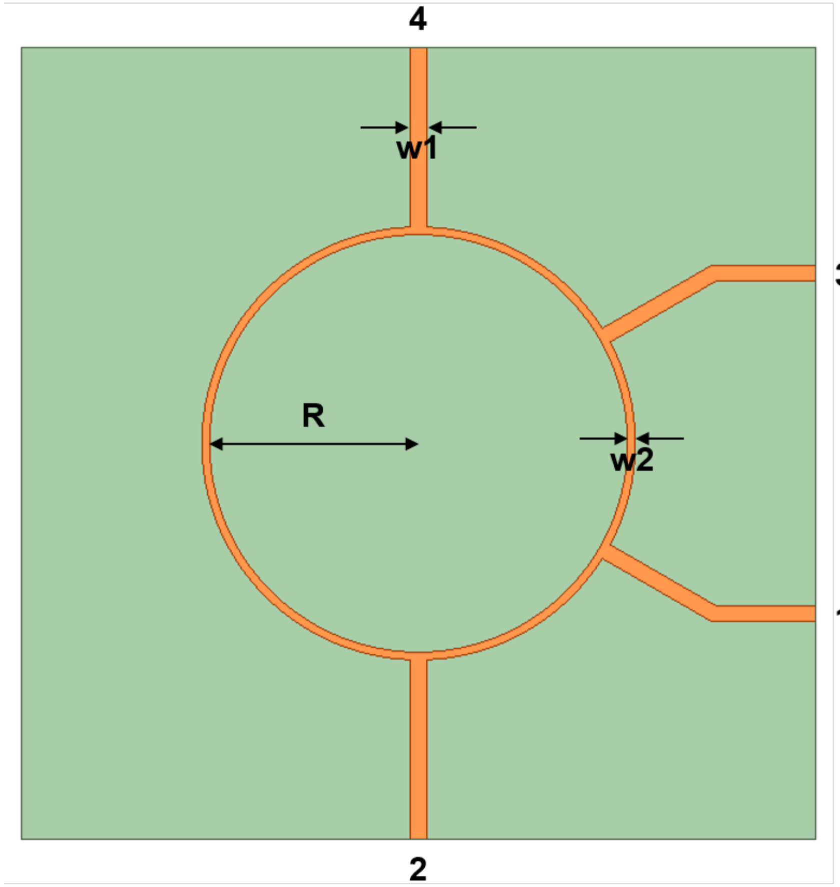
- ❑ Output 1 and Output at 24 GHz > -4 dB
- ❑ Matching and Isolation at 24 GHz < -20 dB

Passive Mixer Design



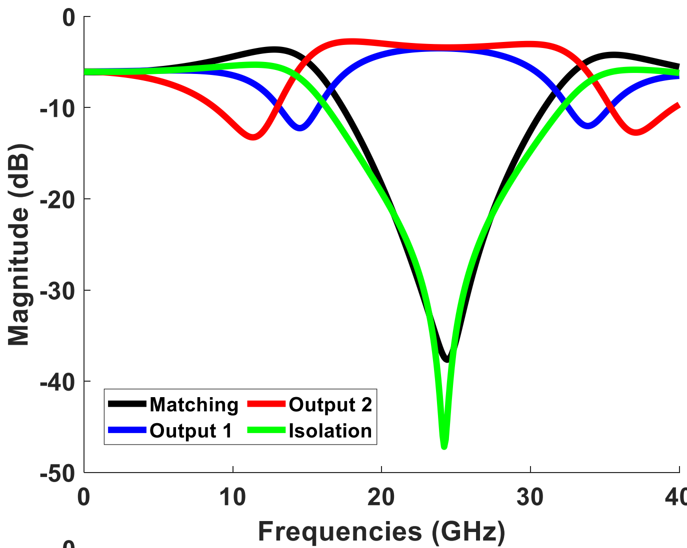
- Expected Conversion Gain: -5 dB at 150 MHz (cutoff frequency for baseband processing)
- R is 200Ω and C is 5 pF
- Diodes will be off-the-shelf Schottky Diodes
- RF Input expected to be -30 dBm

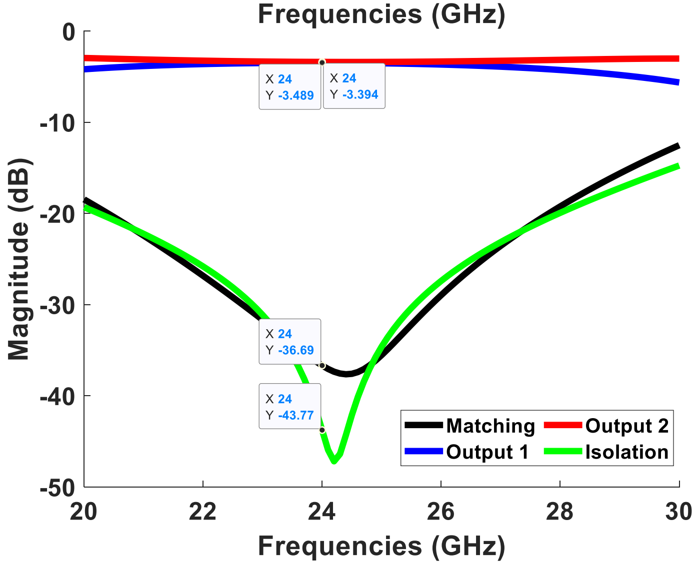
180° Hybrid



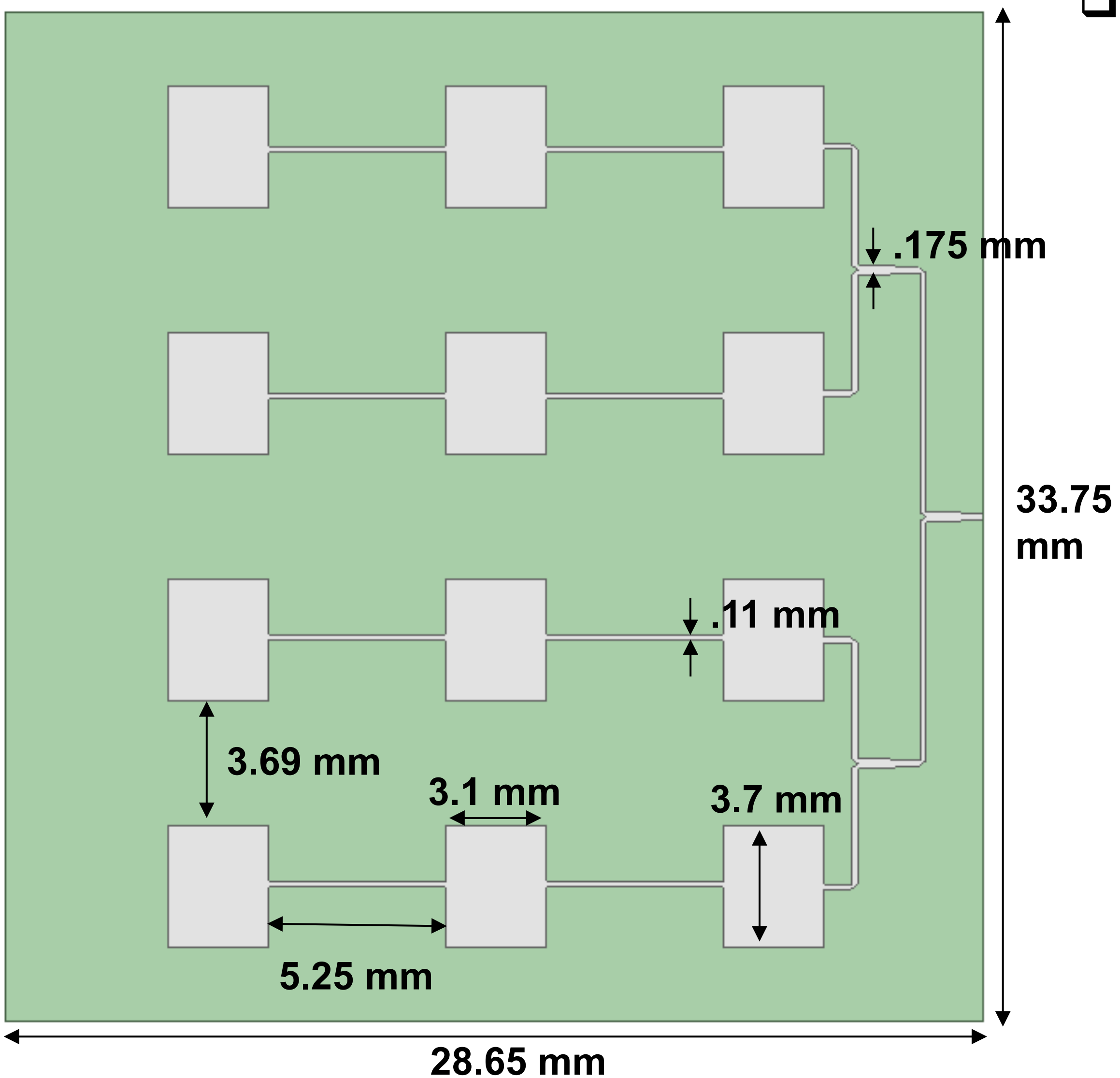
Parameter	Size
R (mm)	1.7
w1 (um)	150
w2 (um)	90

- Output 1 and Output at 24 GHz > -4 dB
- Matching and Isolation at 24 GHz < -20 dB

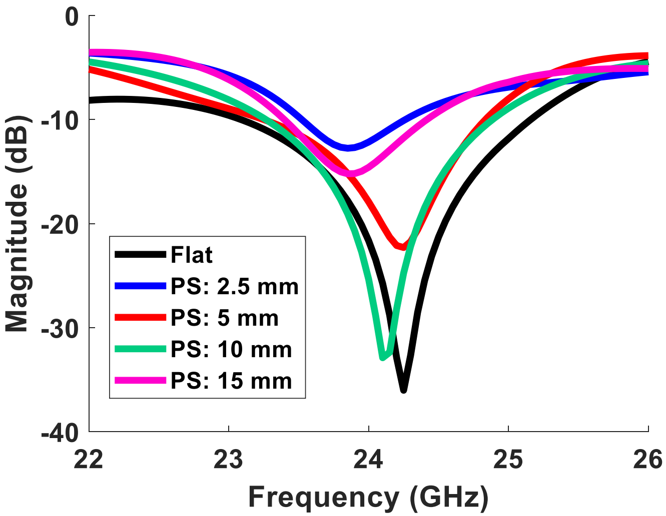


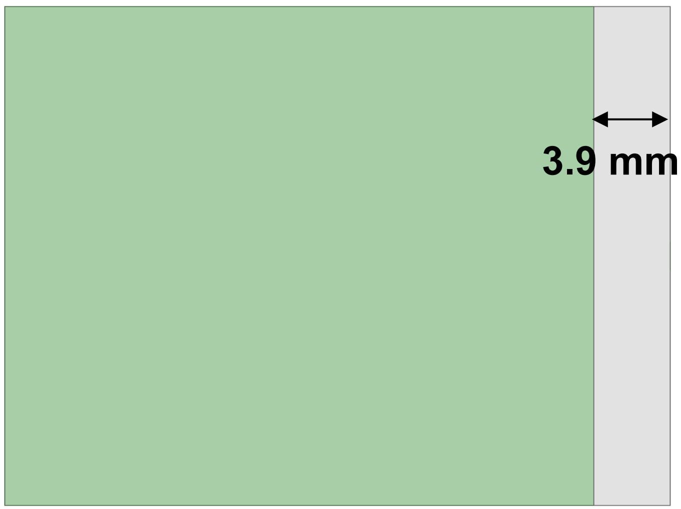


Antenna Design – Patch

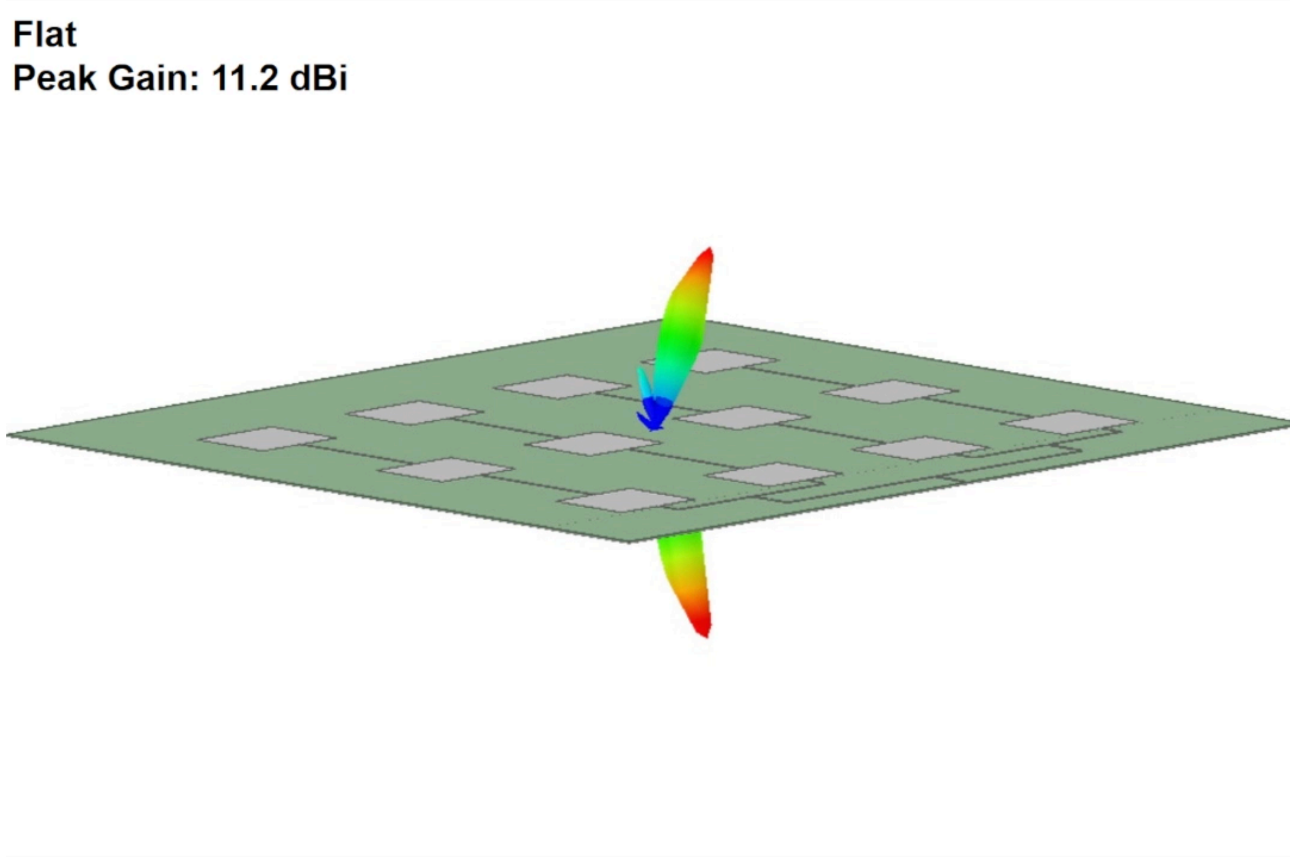


- Expected Gain > 10 dB



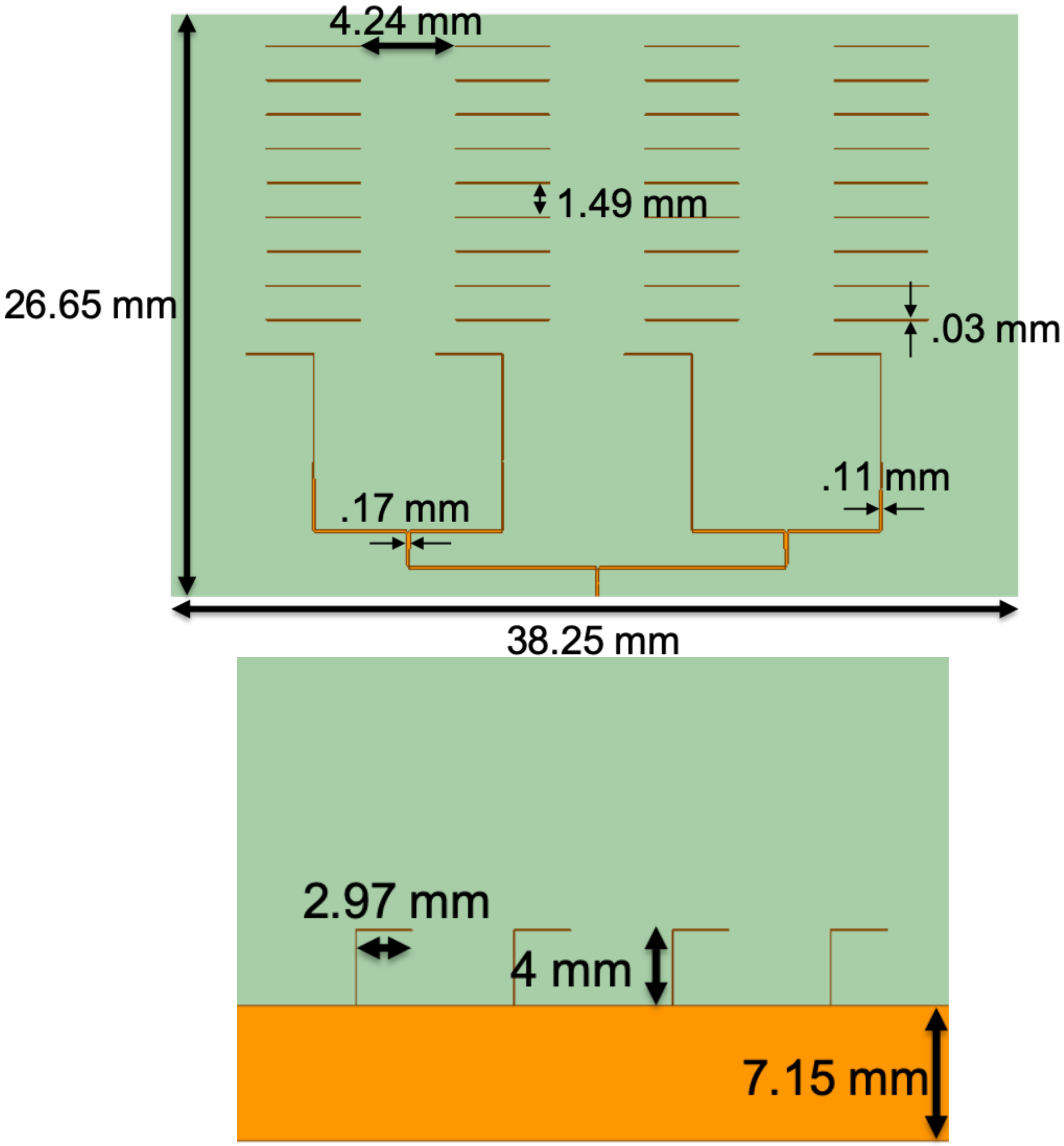


Patch Antenna – Adaptive Curvature Bending – Radiation Pattern

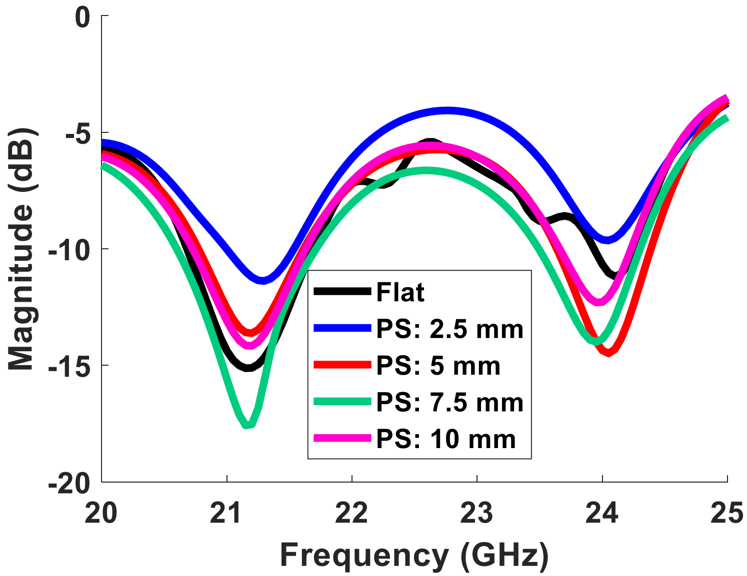


- ❑ Changing the panel separation significantly changes the radiation pattern

Antenna Design – Yagi Uda Array

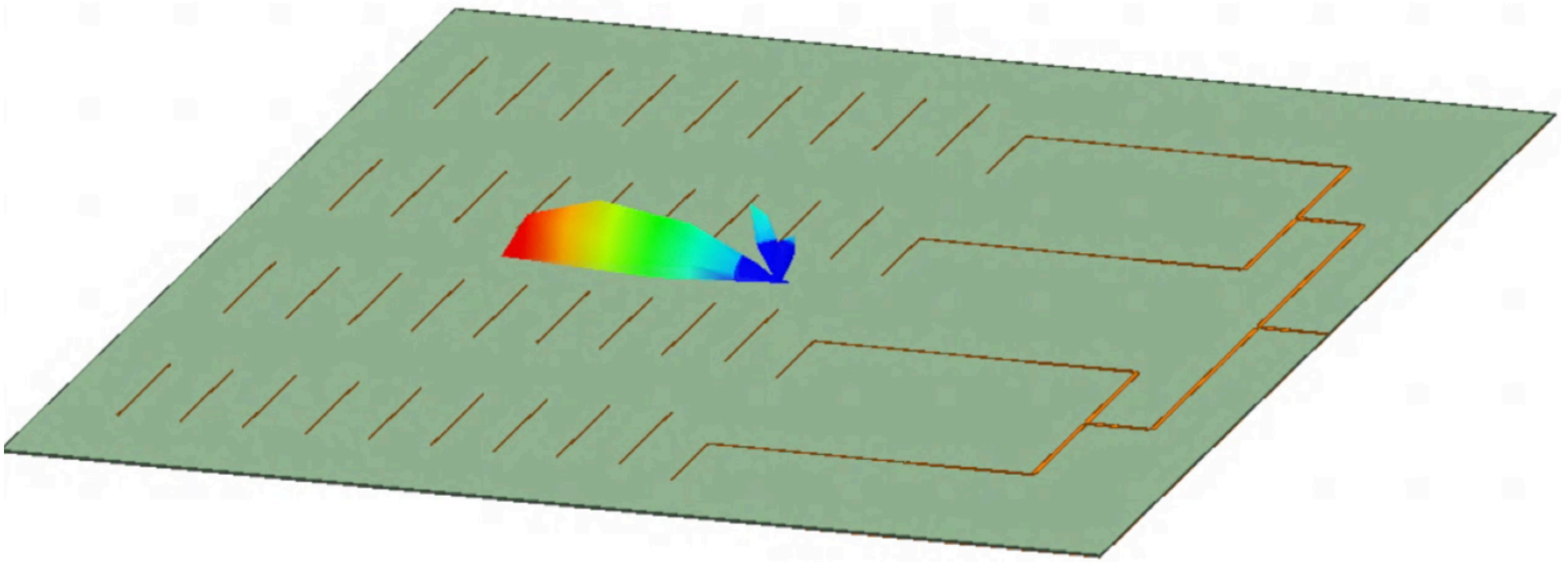


- ❑ Expected Gain > 10 dB



Patch Antenna – Adaptive Curvature Bending – Radiation Pattern

Flat
Peak Gain: 11.1 dB

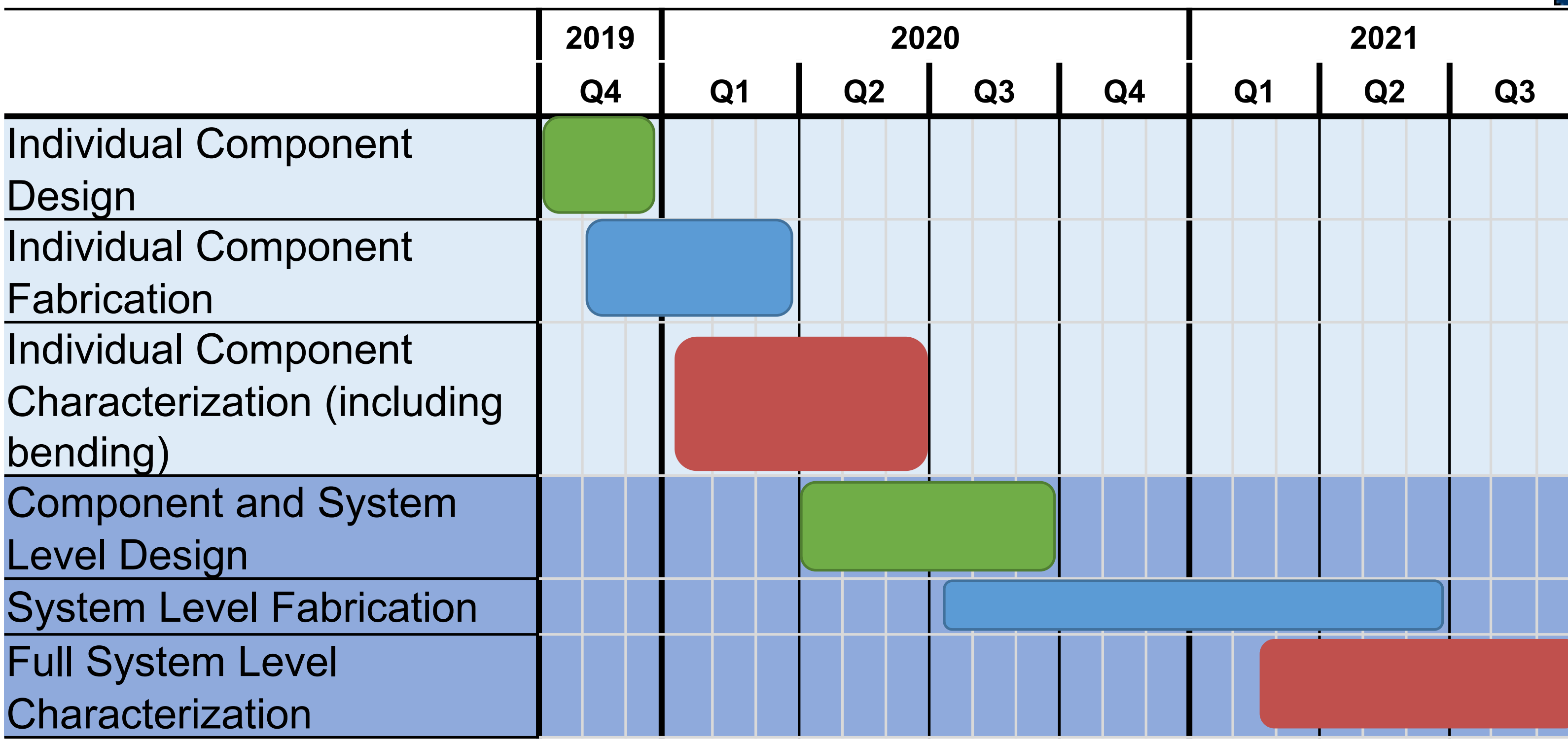


- At small enough panel separations, the Yagi Antenna changes from End-fire to Broadside

Future Work

- Begin fabrication on 30 um Schott AF32 glass with both direct metallization of glass (printing) as well as with build up layers
- Measure individual components (antenna, transmission line, coupler, etc.)
- Integrate components for full system analysis before chip attach
- Chip attach and integrate system (Chip last module)

Timeline for Proposed Work



Light Blue: Component Level Design
Dark Blue: System Level Integration (Chip Last)

- Electrical Design
- Fabrication
- Characterization