The University of Puerto Rico, Mayagüez Campus - College of Engineering

National Aeronautics and Space Administration

Reconfigurable Wideband Circularly Polarized Stacked Square Patch Antenna for Cognitive Radios

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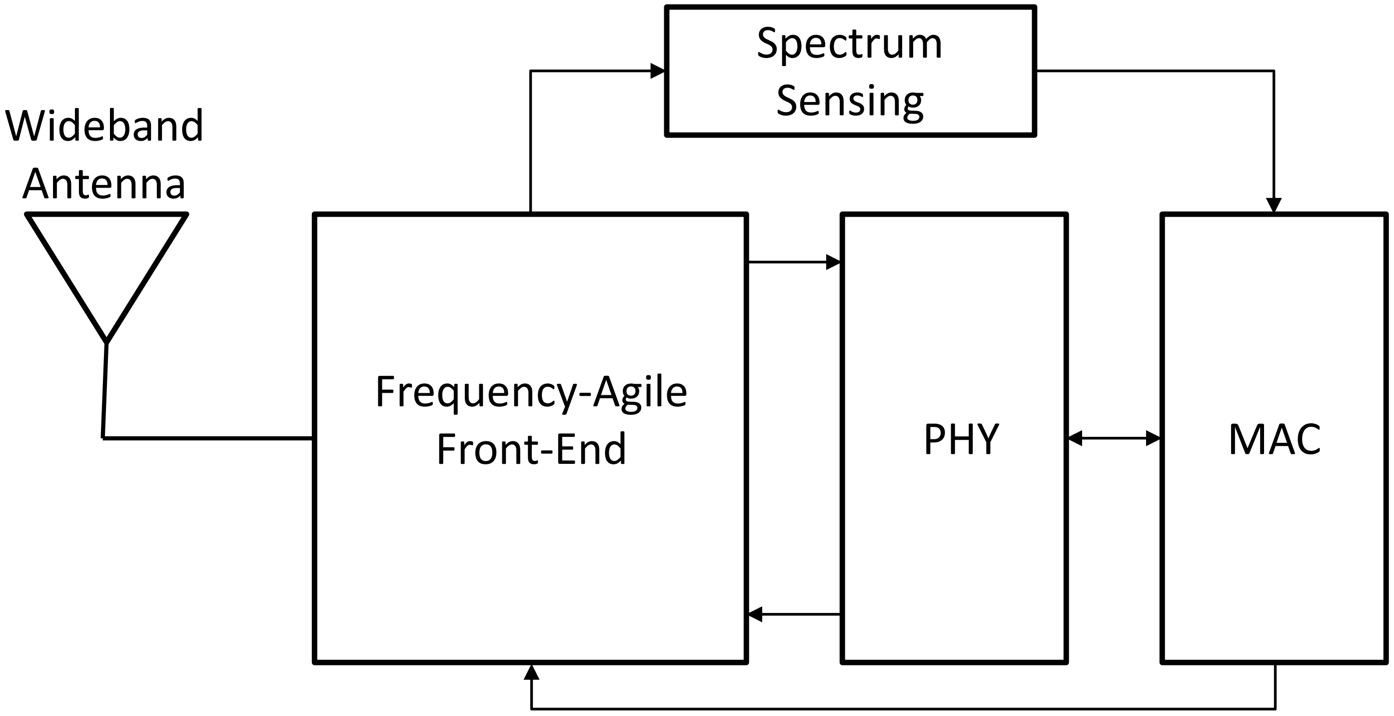
Outline

- Introduction
  - Motivation
    - Cognitive Radio
    - Advantages
- Desired Features of Cognitive Radio
  - Antenna Reconfiguration Advantages
- Antenna Design and Modeling
  - Standalone Geometries
  - Stacked Geometry
- Fabrication and Characterization
- Summary of Results
- Future Work
- Conclusion
- Acknowledgements

Objective

- Design a microstrip patch antenna element for Cognitive Radios for frequency reconfiguration at NASA X-Band frequencies (8.0 – 8.5GHz)

The Cognitive Radio*



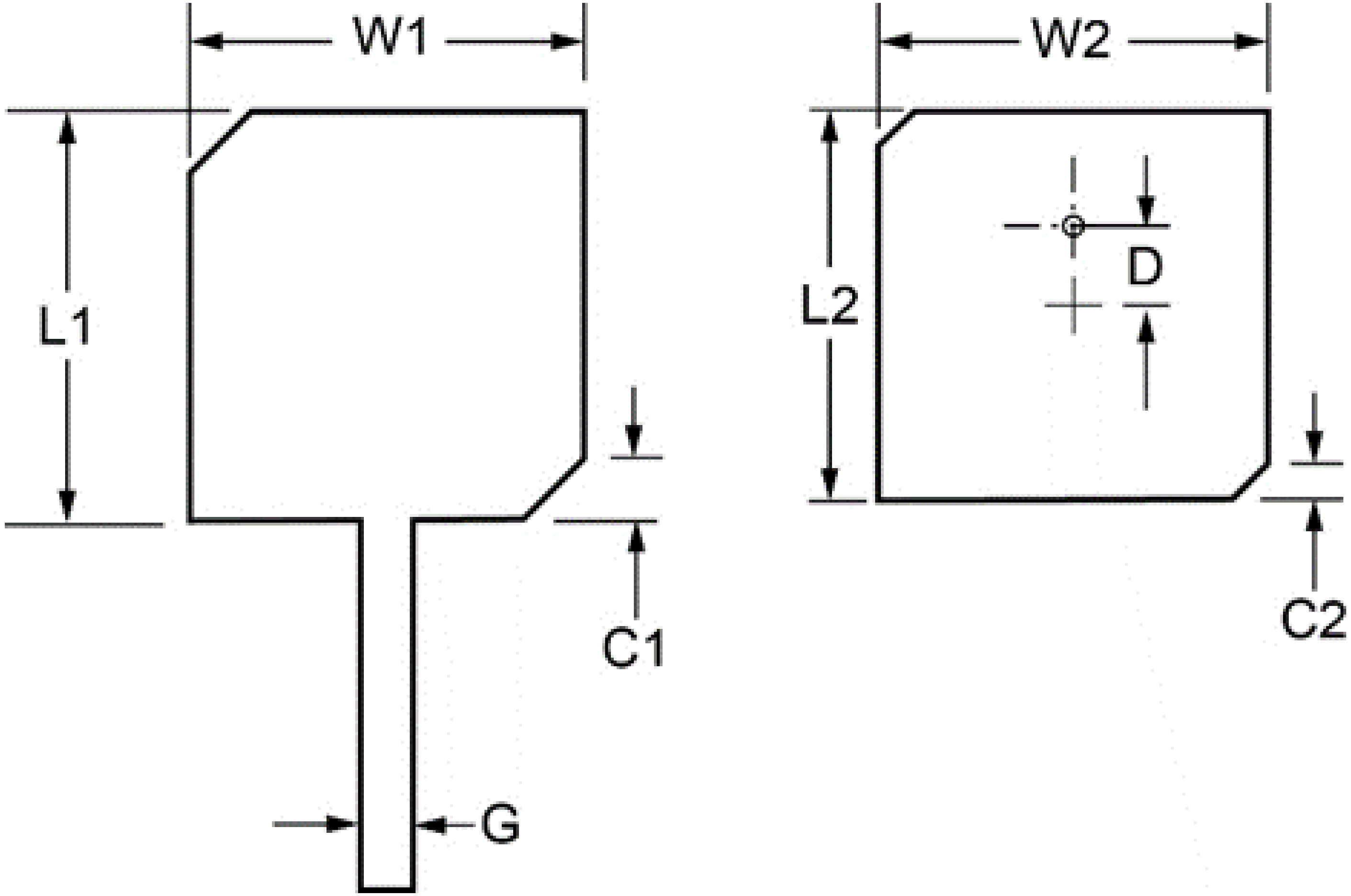
- Advantages of Cognitive Radios
  - It has knowledge of external environment
  - Can use this knowledge to exploit internal parameter tuning (carrier frequency, transmit power, etc.)
- Software Enabled Reconfiguration
  - Frequency-Agile Front-End module
  - Physical Layer Signal Processing (PHY)
  - Medium Access Control (MAC)
- Physical Layer
  - Wideband antennas are required
  - Conventional microstrip patch antennas are narrowband
  - Hence, antenna reconfiguration is desirable

**J. Laskar, R. Mukhopadhyay, Y. Hur, C. –H. Lee, and K. Lim, "Reconfigurable RFICs and Modules for Cognitive Radio," 2006 Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems, San Diego, CA, 18-20 Jan. 2006.*

Antenna Reconfiguration

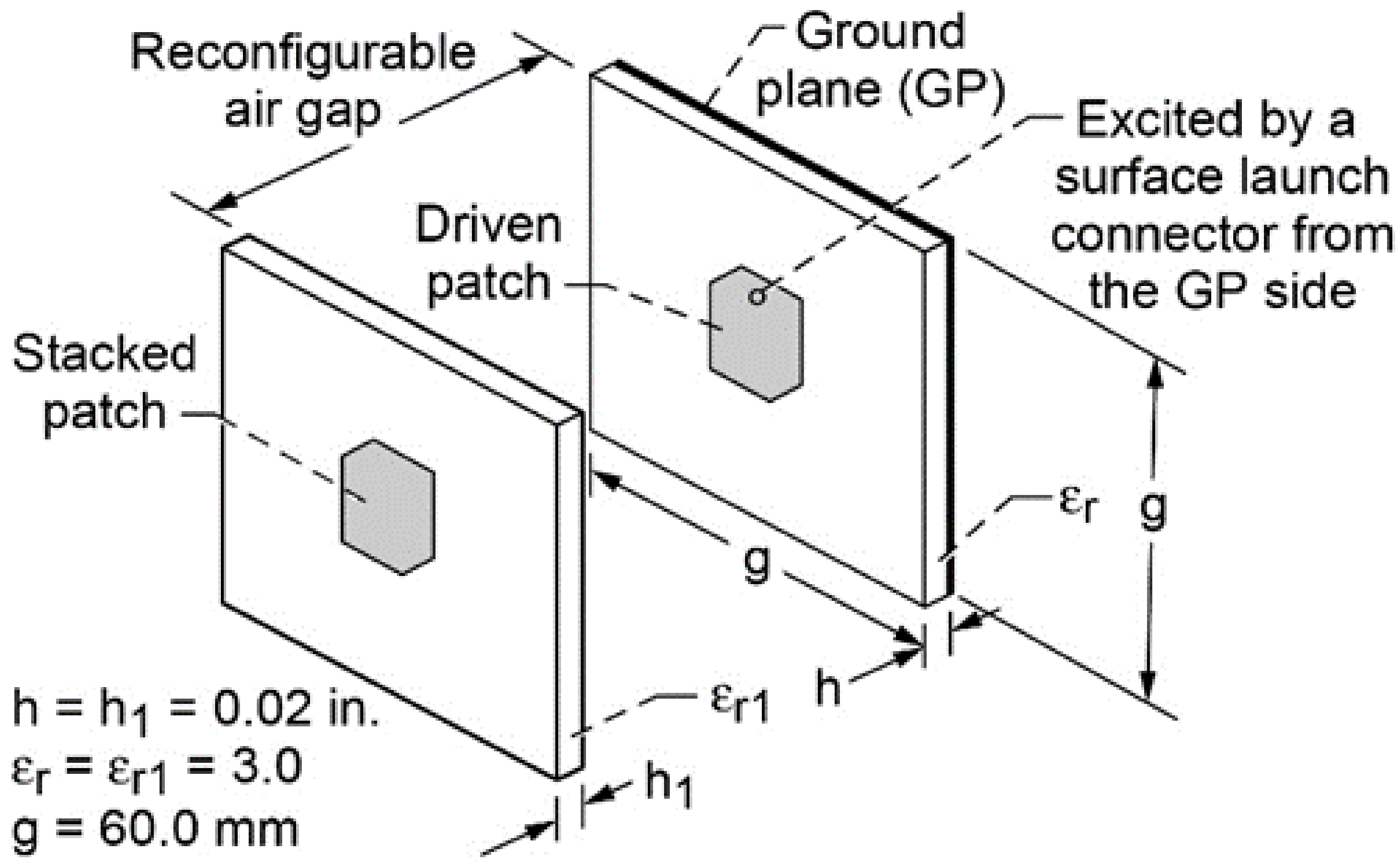
- The Microstrip Patch Antenna
  - It is lightweight, easy to fabricate and has a low cost
  - These features make fast prototyping feasible
  - Its biggest downside is narrow bandwidth
- Microstrip Patch Antennas have the potential for reconfiguration in frequency, polarization and radiation pattern
- They can further expand the added reconfiguration capabilities of the physical layer in a Cognitive Radio

Standalone Geometries



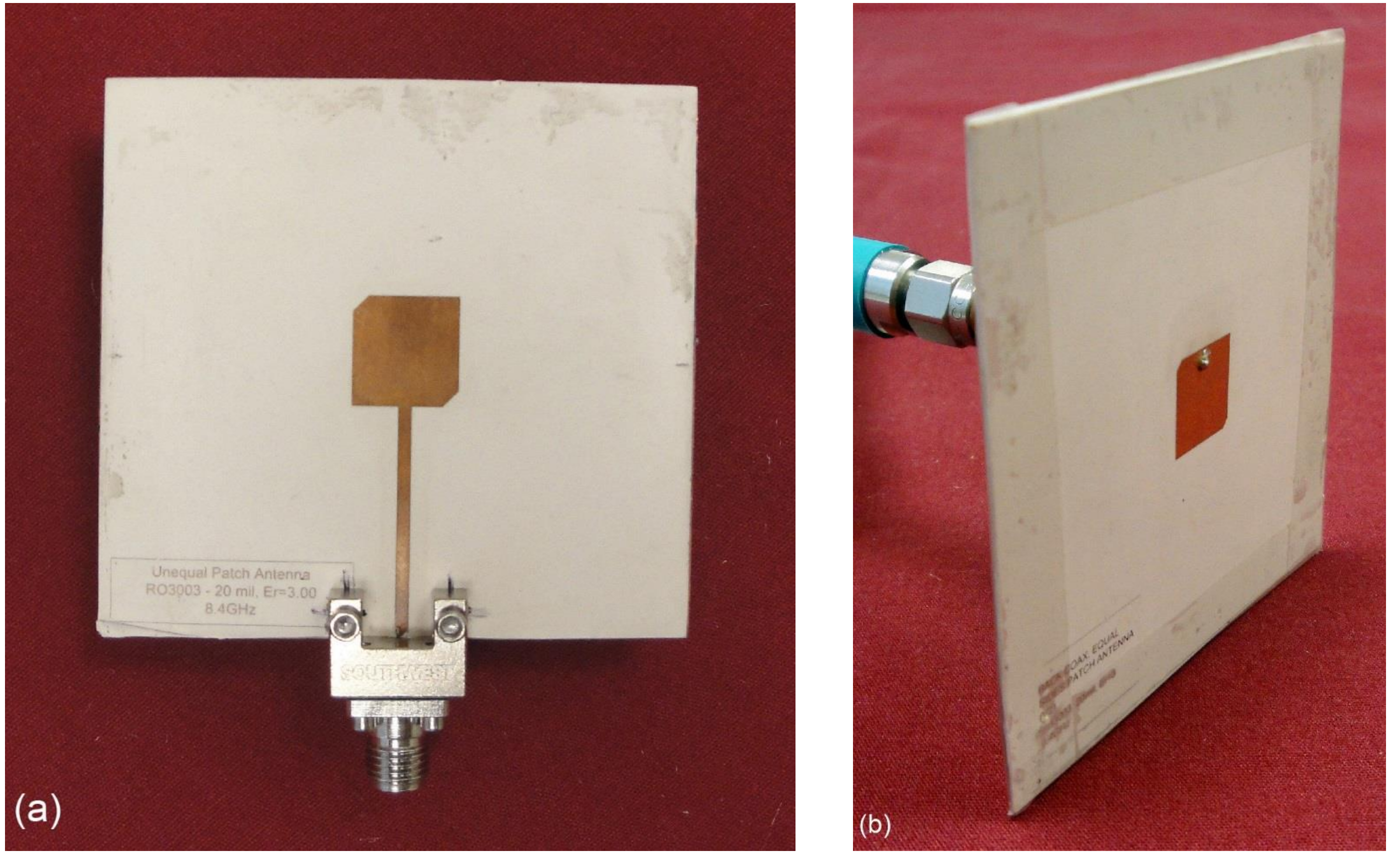
Dimensions (mm)	
L_1	10.337
W_1	10
C_1	1.487
G	1.277
L_2	9.856
W_2	9.856
C_2	0.873
D	2

Stacked Square Patch



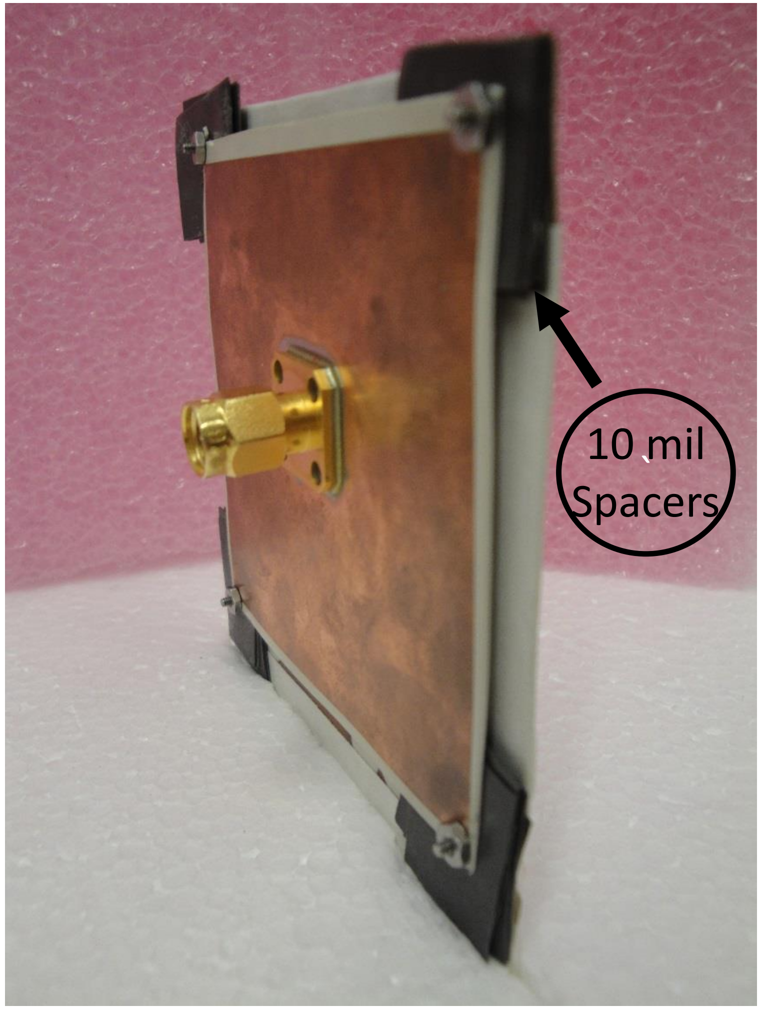
- Identical antenna geometry and substrate properties
- No ground plane on the second substrate
- Fixed 0.254 mm initial air gap between both substrates

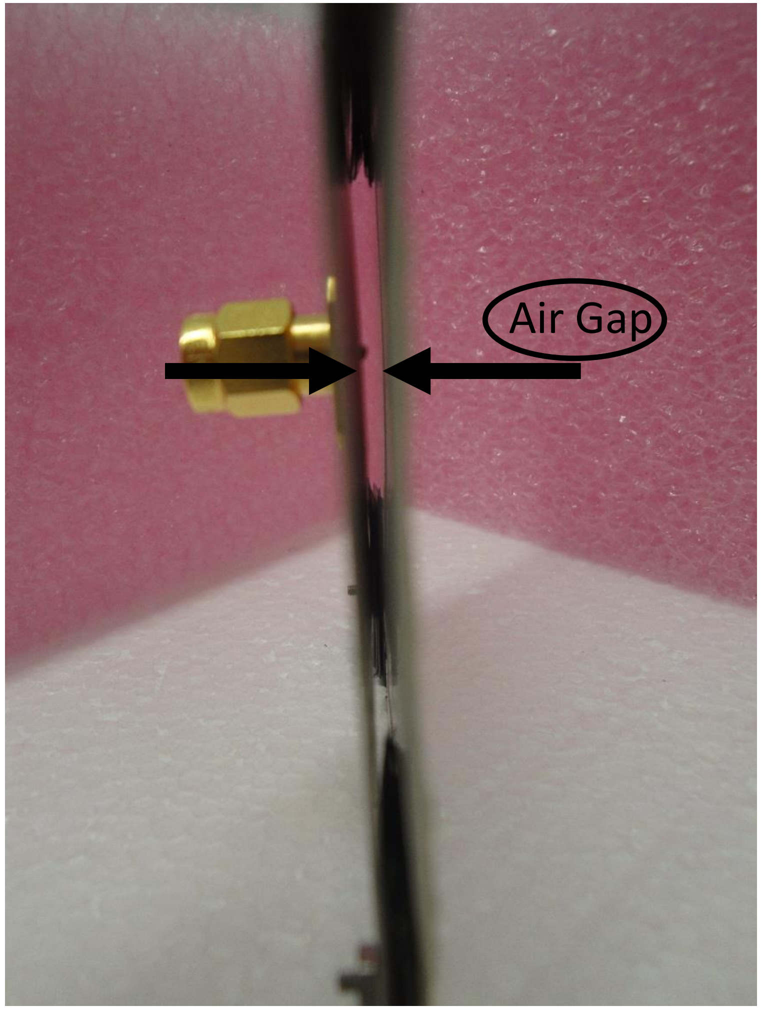
Standalone Geometries



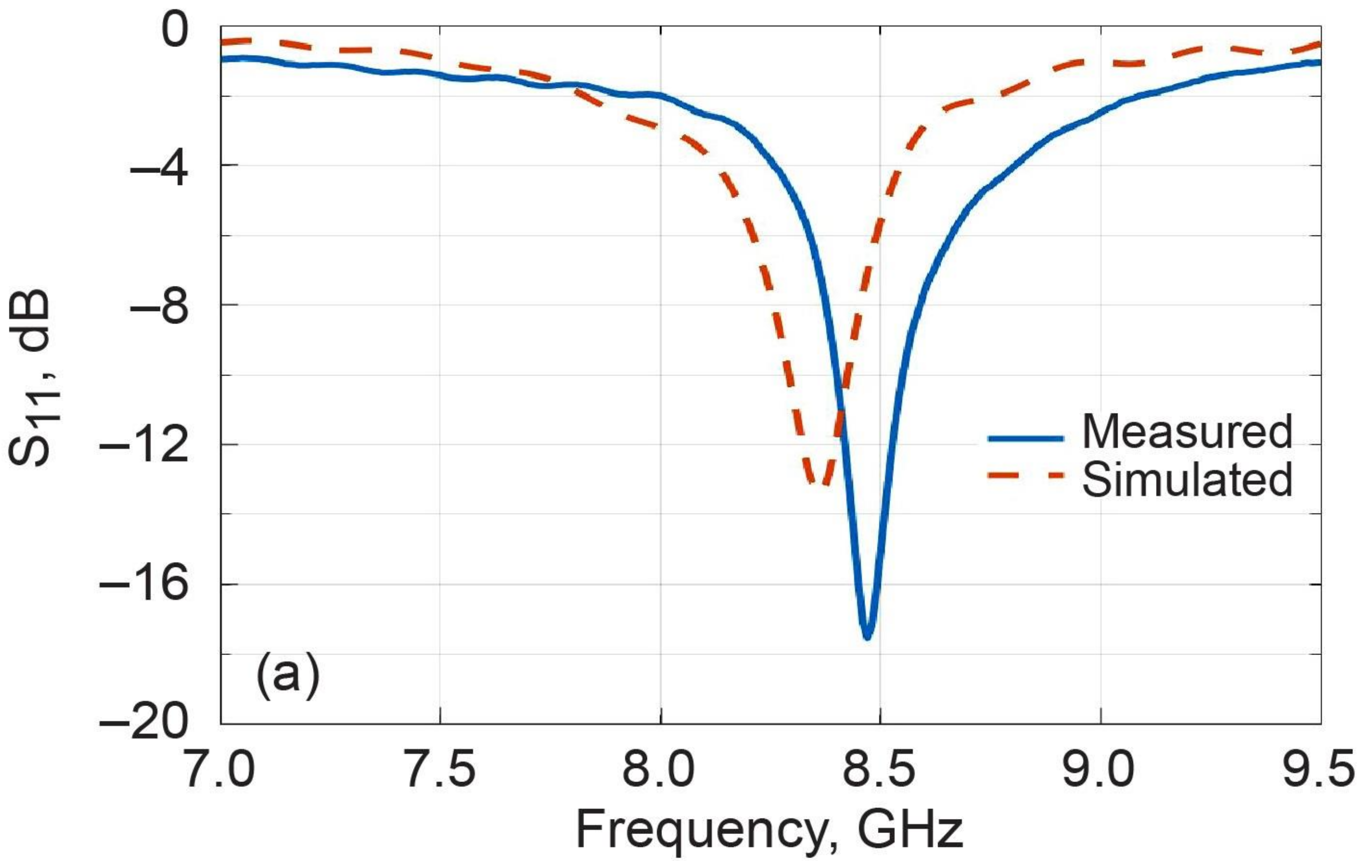
- The CST designs were exported to AutoCAD for the creation of a mask
- The antennas were fabricated using a photolithography process at NASA Glenn Research Center
- Roger's Corporation RO3003 Substrate
  - h = 20 mil (0.508 mm)
  - $\varepsilon_r = 3$

Stacked Square Patch





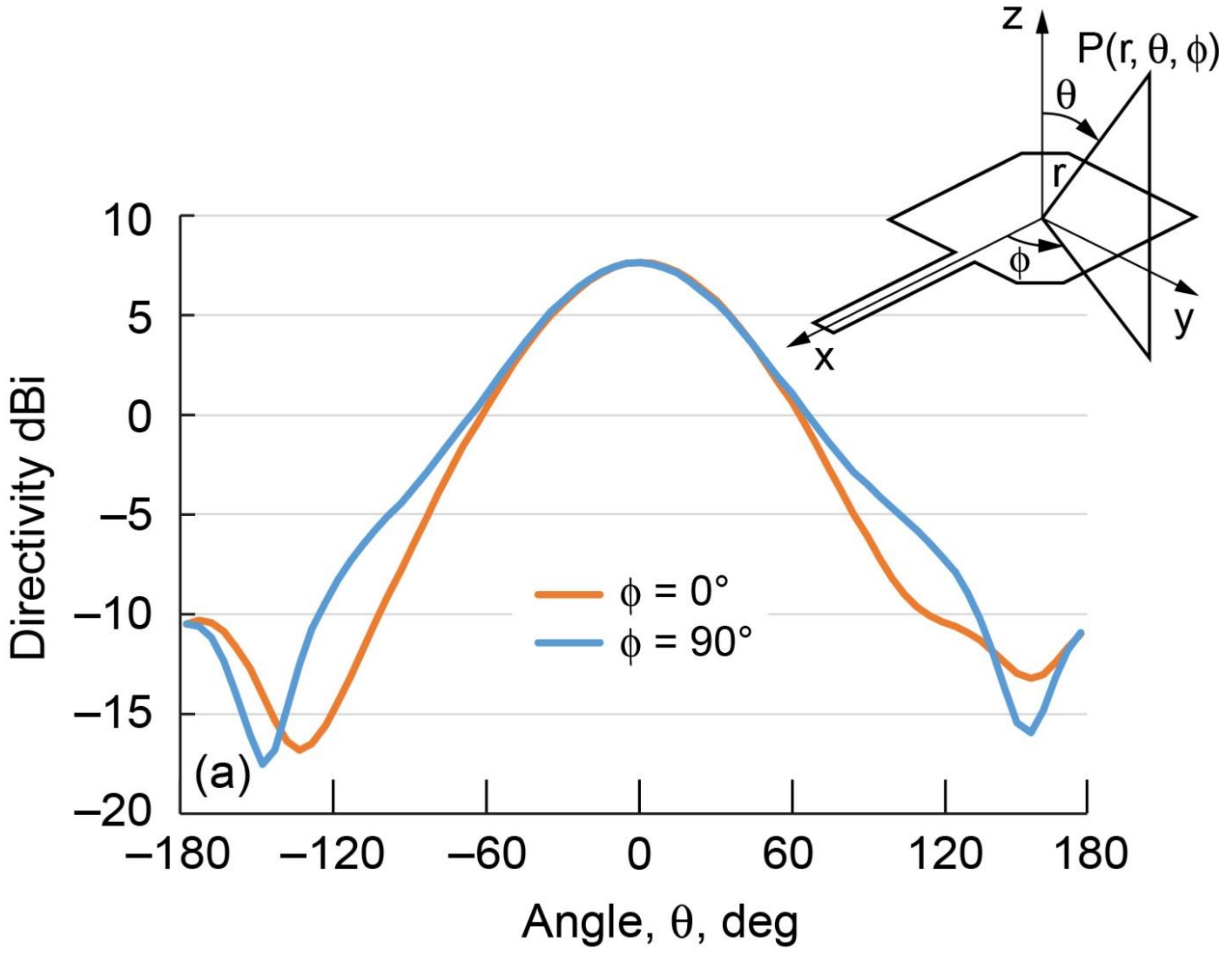
Standalone Almost Square Patch



CST SIMULATED RESULTS					
f_0 (GHz)	**Return Loss (dB)**	**f_L (GHz)**	**f_H (GHz)**	**BW = f_H - f_L (MHz)**	**BW/f_0 (%)**
8.356	13.460	8.2888	8.4203	131.5	1.57

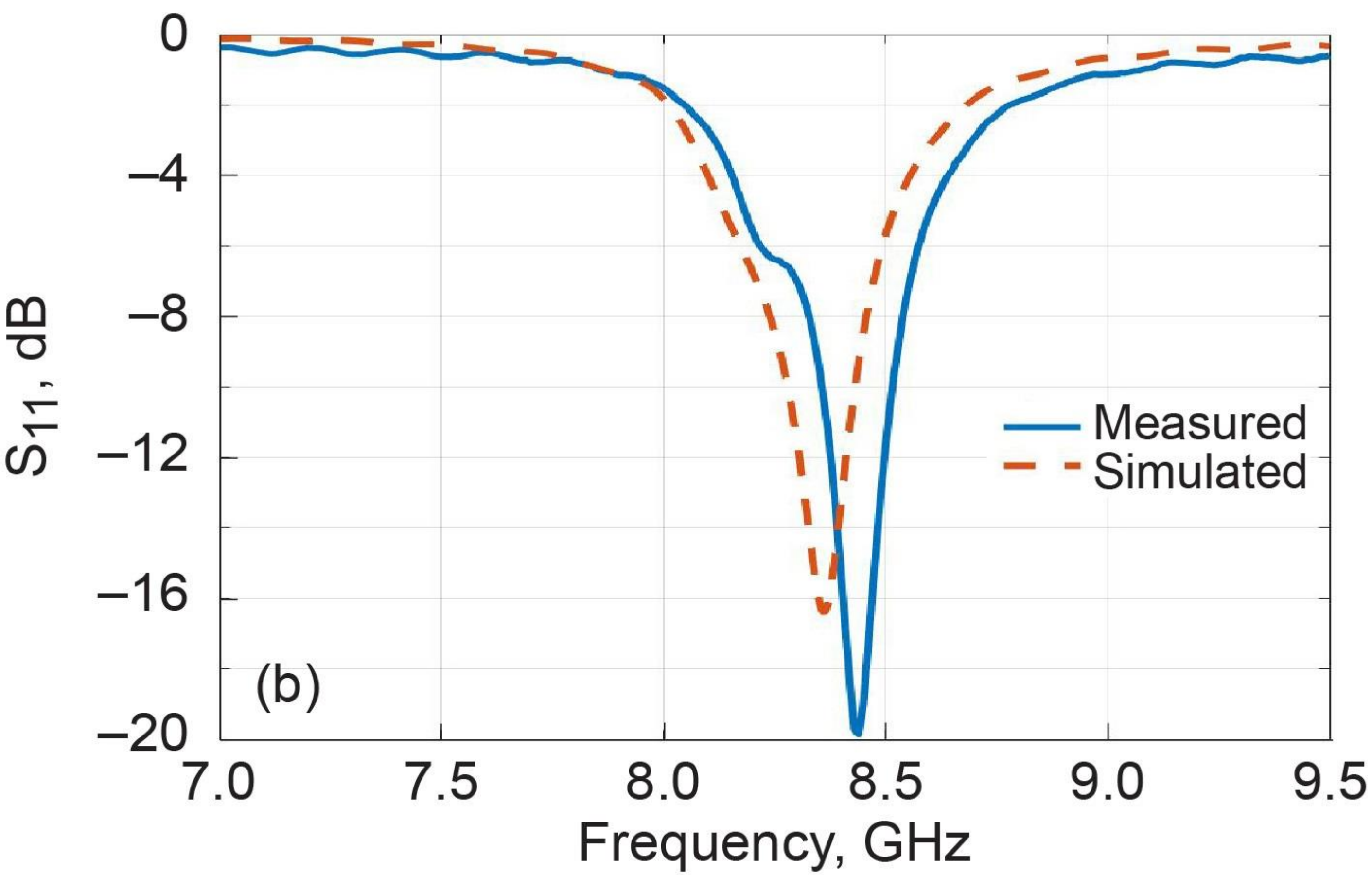
MEASURED RESULTS					
f_0 (GHz)	**Return Loss (dB)**	**f_L (GHz)**	**f_H (GHz)**	**BW = f_H - f_L (MHz)**	**BW/f_0 (%)**
8.46	17.5402	8.385	8.529	144	1.7

Standalone Almost Square Patch



CST SIMULATED RESULTS			
	Directivity (dBi)	**Realized Gain (dB)**	**3 dB Angular Width (Deg.)**
Phi = 90	7.65	6.7	76.4
Phi = 0	7.65	6.7	75

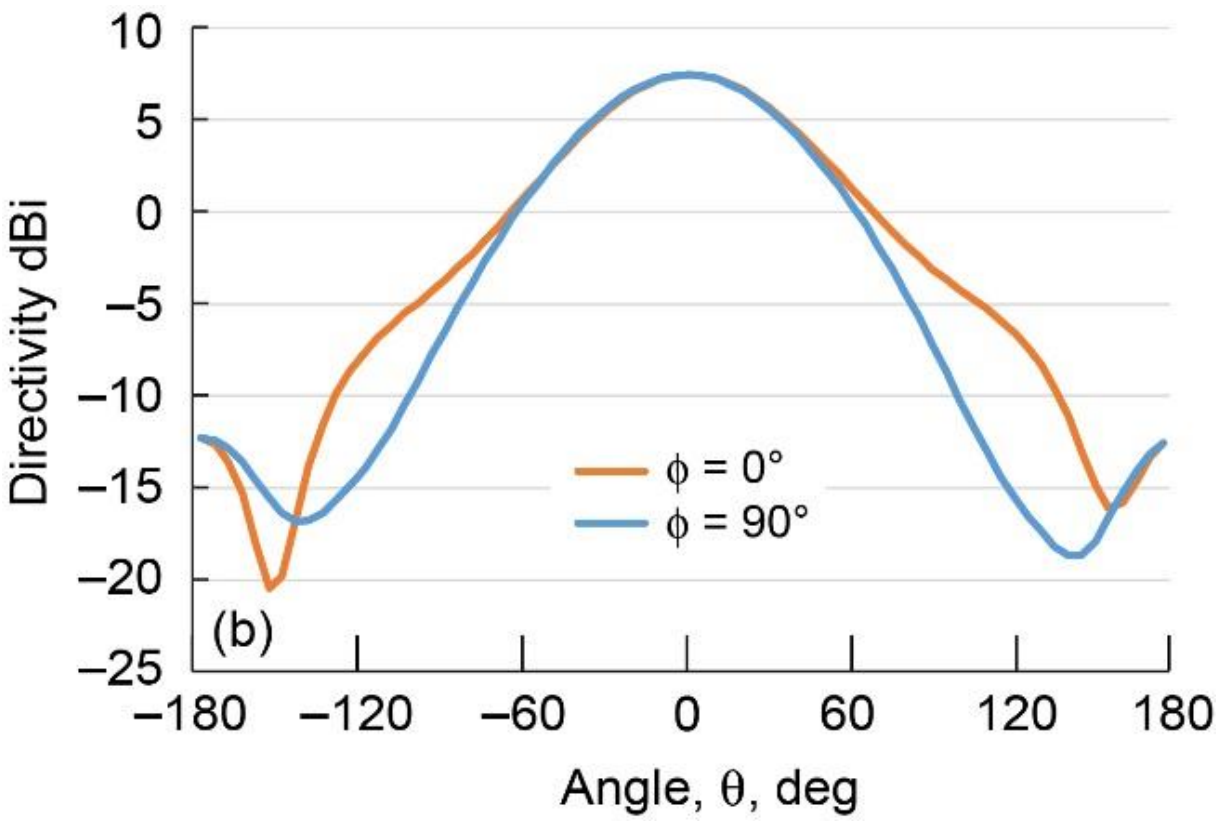
Standalone Square Patch



CST SIMULATED RESULTS					
f_0 (GHz)	Return Loss (dB)	f_L (GHz)	f_H (GHz)	BW = f_H - f_L (MHz)	BW/f_0 (%)
8.364	16.375	8.2797	8.4314	151.7	1.81

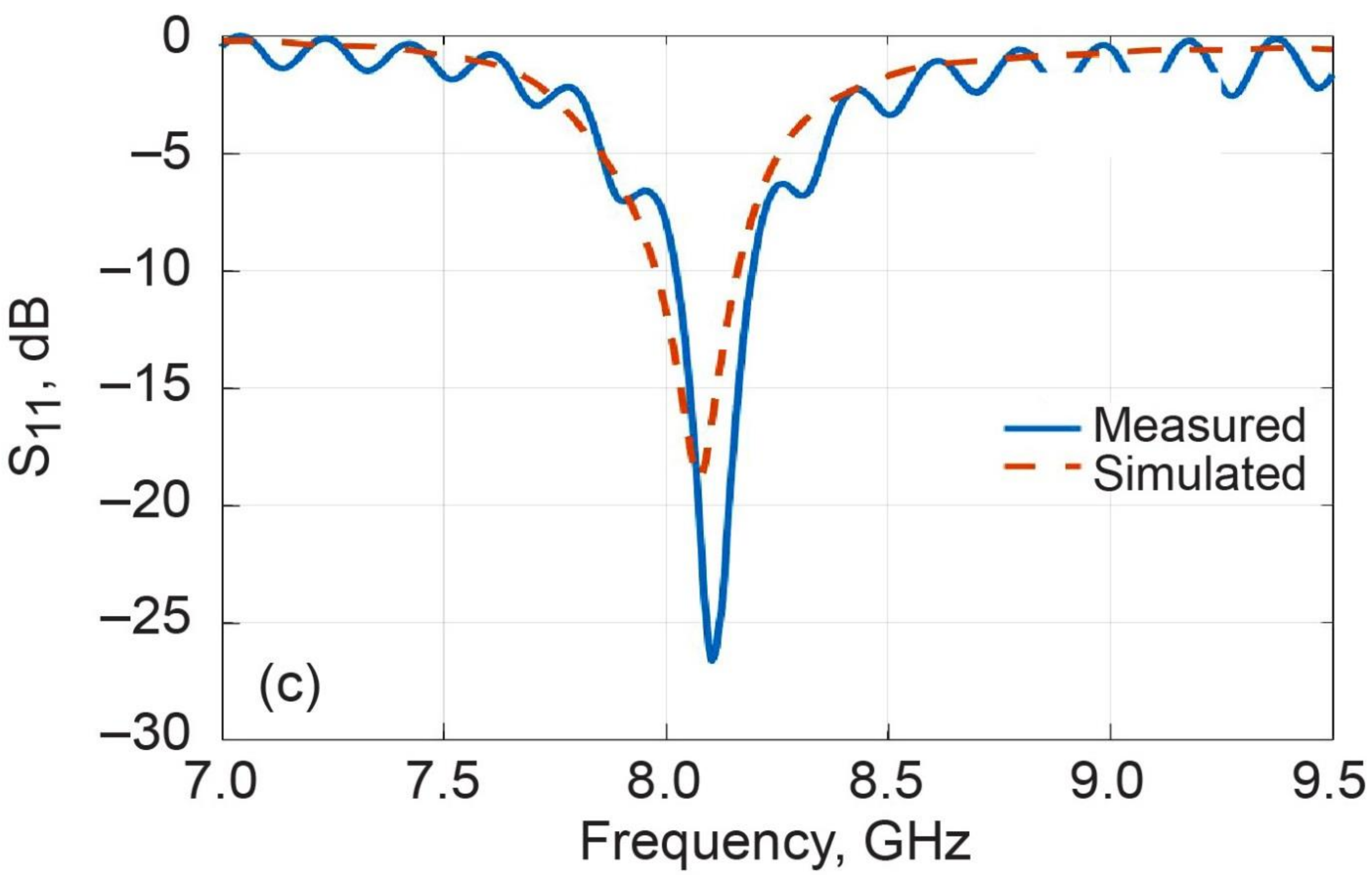
MEASURED RESULTS					
f_0 (GHz)	Return Loss (dB)	f_L (GHz)	f_H (GHz)	BW = f_H - f_L (MHz)	BW/f_0 (%)
8.45	19.7545	8.3675	8.5255	158	1.87

Standalone Square Patch



CST SIMULATED RESULTS			
	Directivity (dBi)	**Realized Gain (dB)**	**3 dB Angular Width (Deg.)**
Phi = 90	7.45	6.75	76.6
Phi = 0	7.45	6.75	77

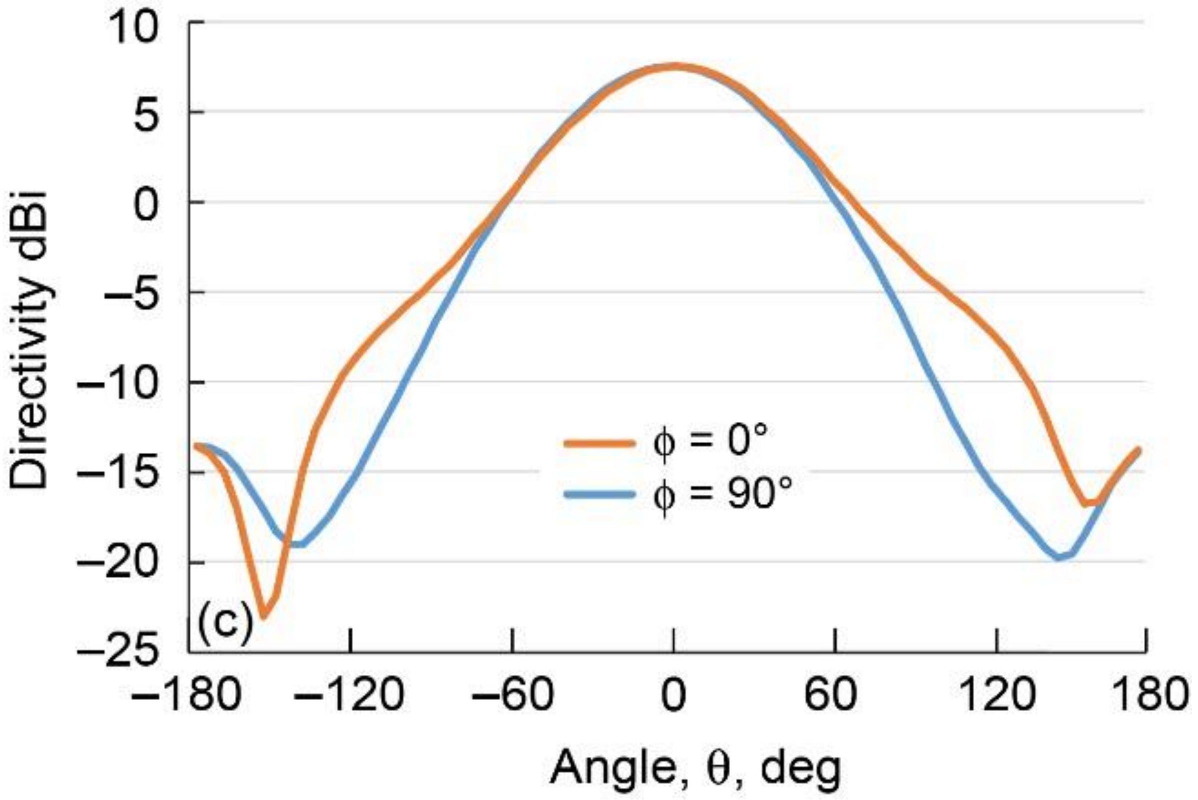
Stacked Square Patch



CST SIMULATED RESULTS					
f_0 (GHz)	Return Loss (dB)	f_L (GHz)	f_H (GHz)	BW = f_H - f_L (MHz)	BW/f_0 (%)
8.076	18.869	7.9755	8.1625	187	2.31

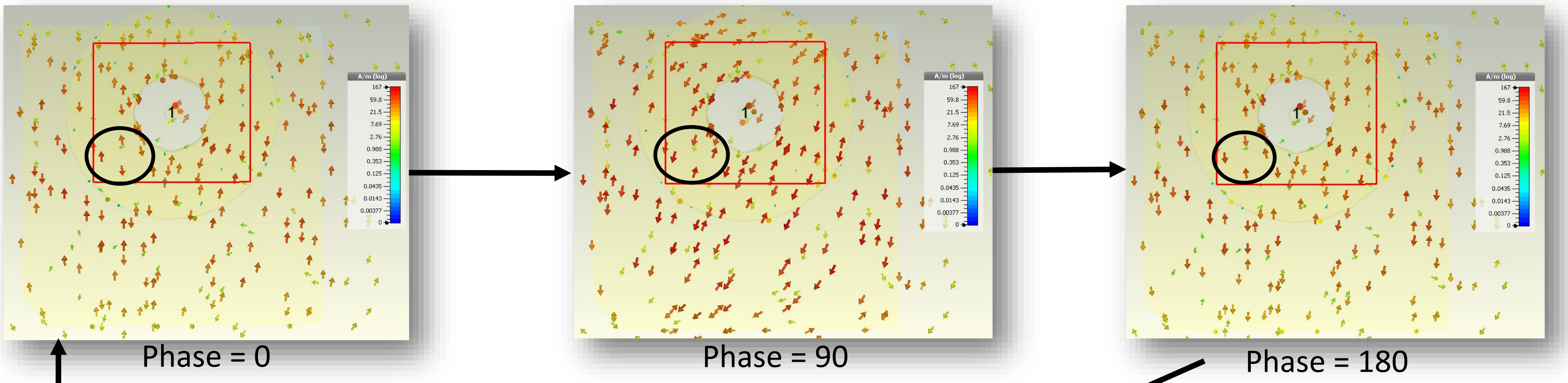
MEASURED RESULTS					
f_0 (GHz)	Return Loss (dB)	f_L (GHz)	f_H (GHz)	BW = f_H - f_L (MHz)	BW/f_0 (%)
8.1017	25.7	8.0204	8.2005	180.1	2.22

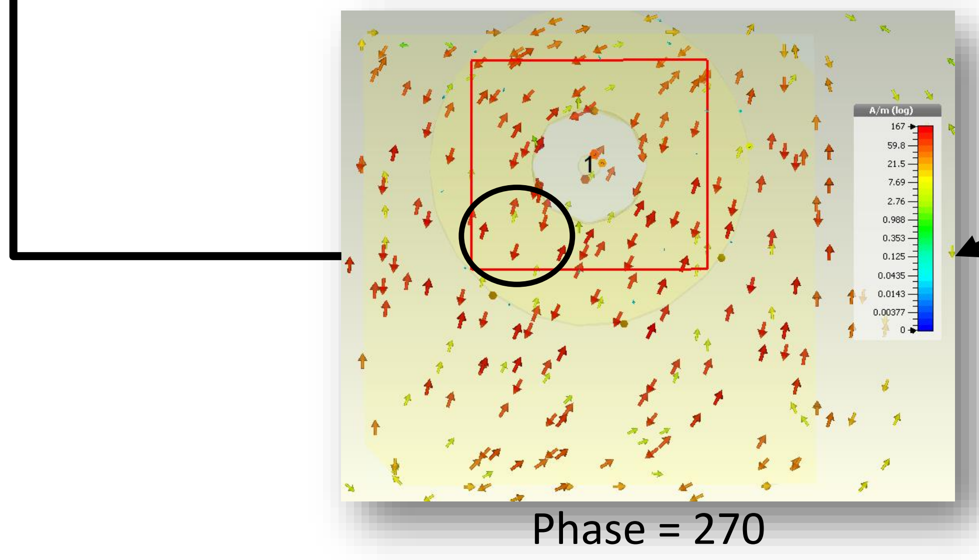
Stacked Square Patch



CST SIMULATED RESULTS			
	Directivity (dBi)	**Realized Gain (dB)**	**3 dB Angular Width (Deg.)**
Phi = 90	7.53	7.1	76.1
Phi = 0	7.53	7.1	76.7

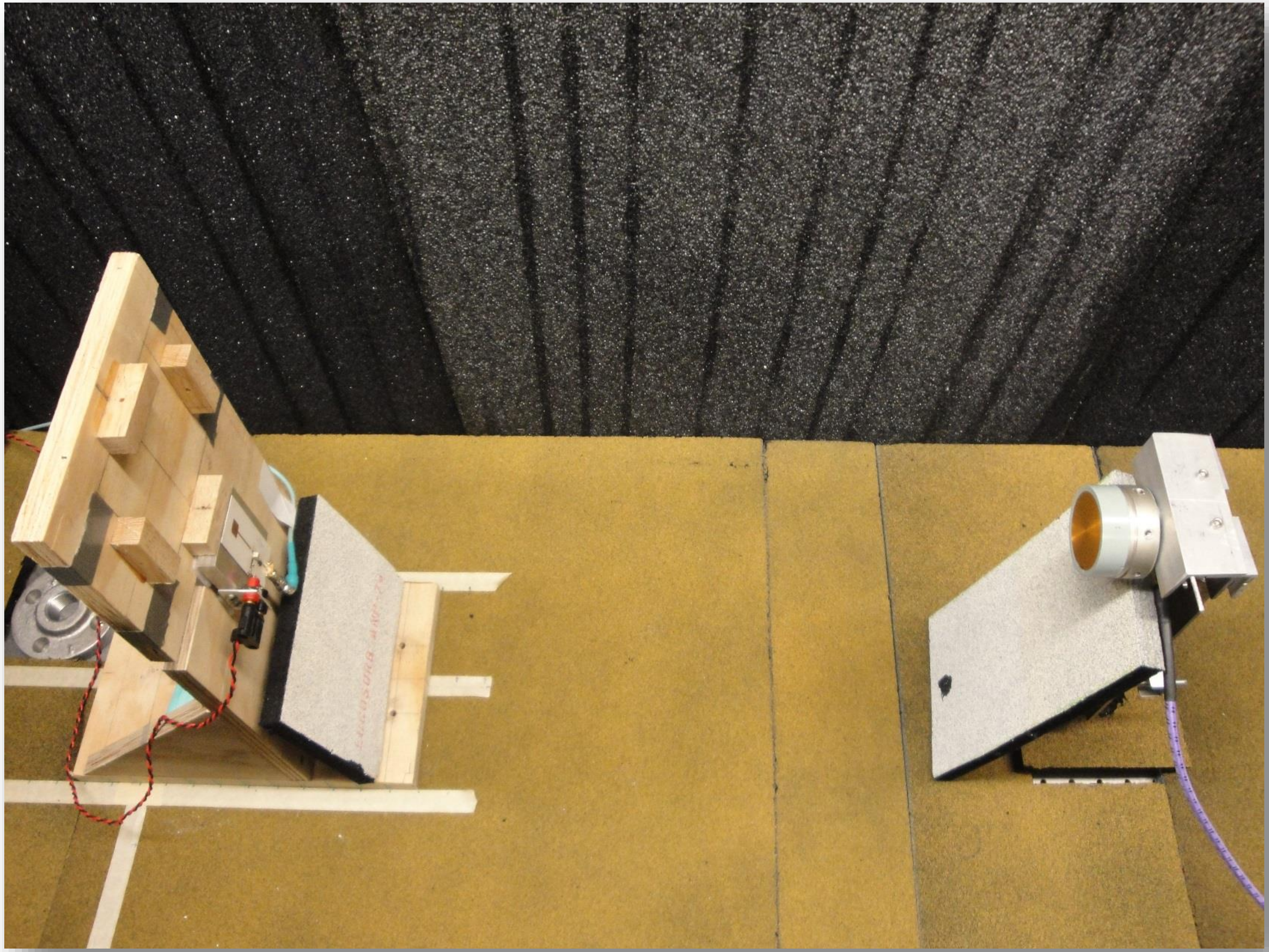
Simulated Surface Currents



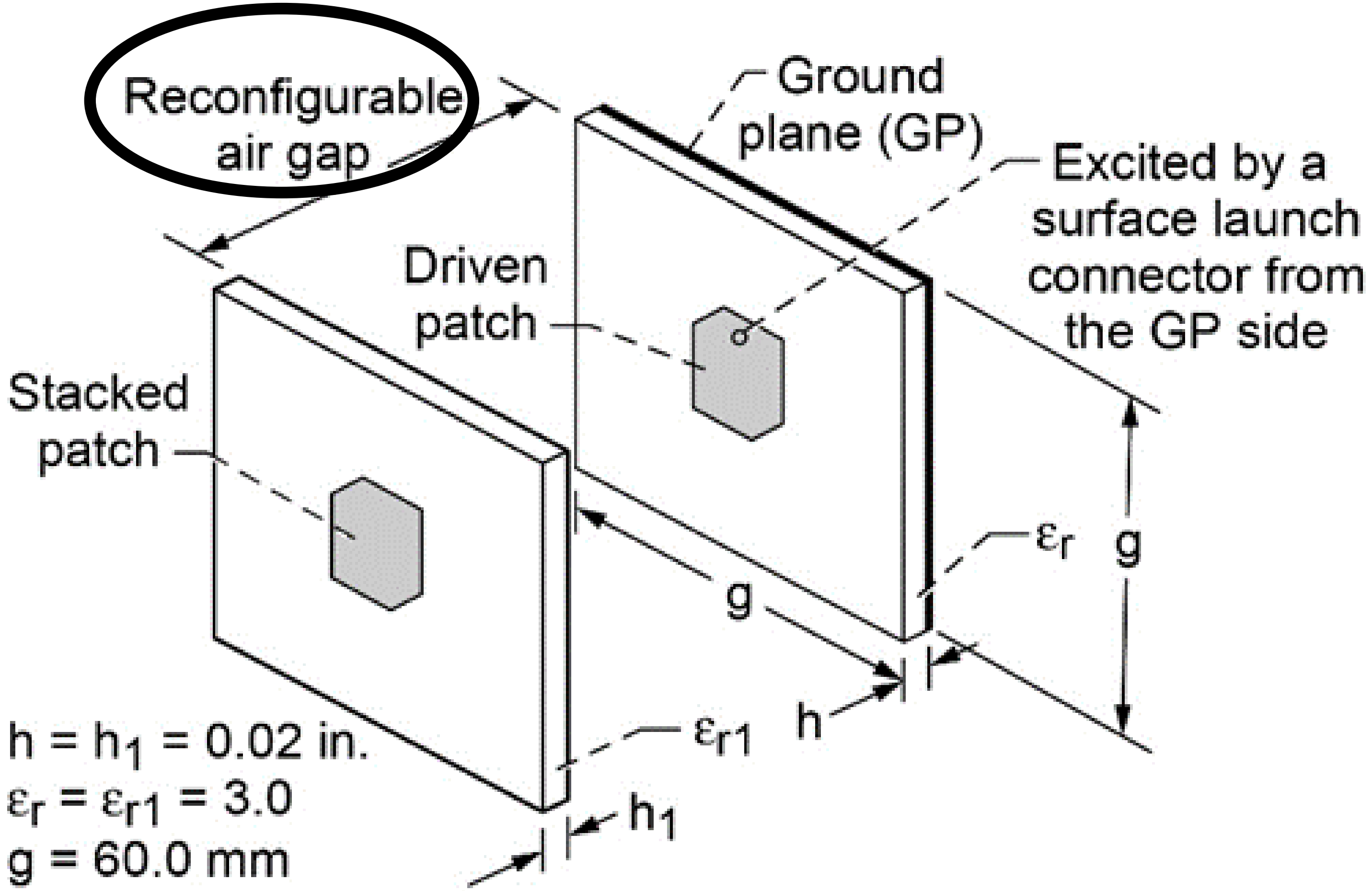


- When looking through the feed side, the surface currents show a counter clock wise pattern
- This proves LHCP through simulation

- Set up of microstrip patch antenna with a LHCP reference spiral antenna to prove polarization
- A LHCP signal was received from the spiral antenna



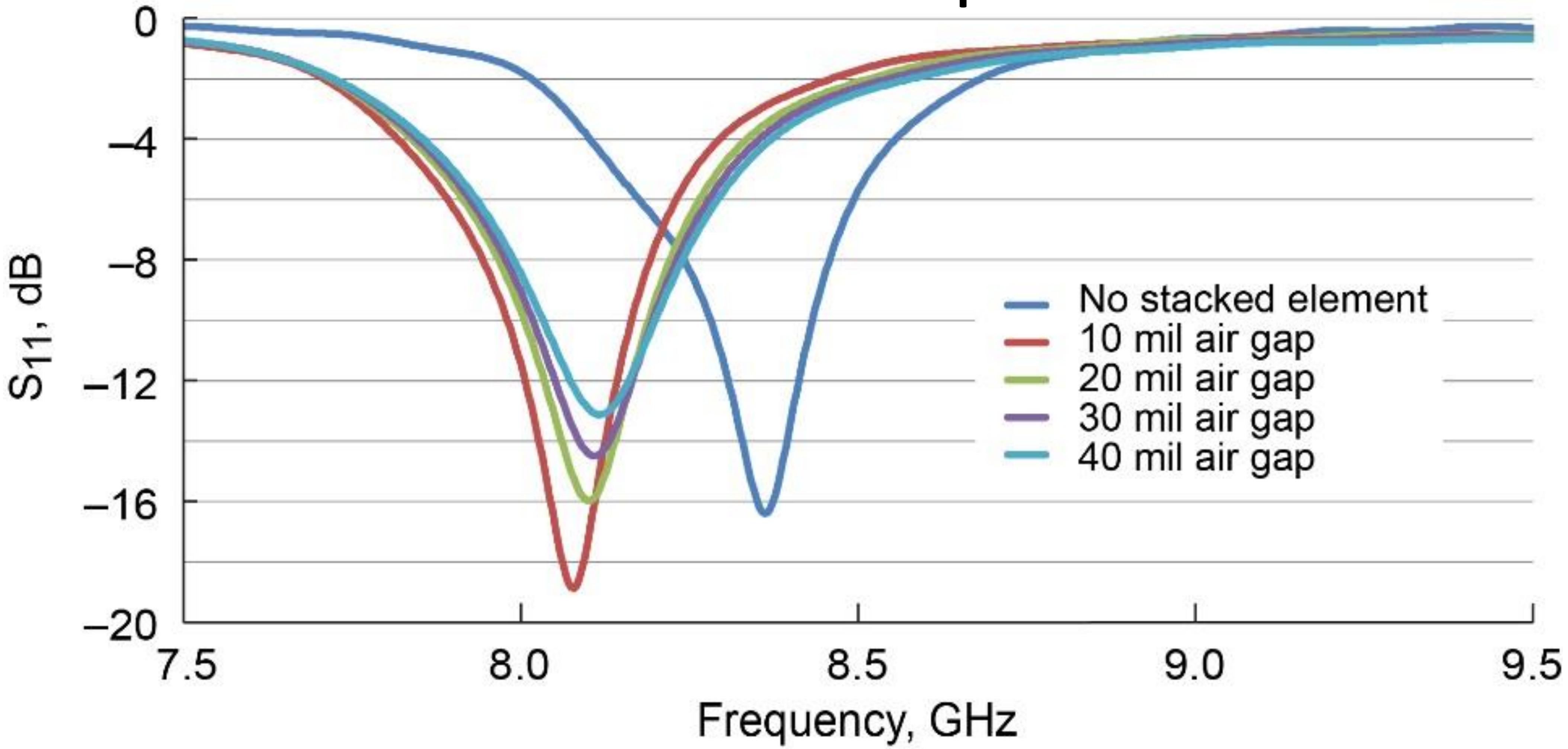
Frequency Reconfiguration



- Adding a stacked patch causes a center frequency shift due to added capacitance
- This center frequency shift is part of the frequency reconfiguration features of this antenna
- Air gap reconfiguration:
  - The initial air gap is 0.254 mm
  - The air gap can be incremented in steps of 0.254 mm
  - Experimentally, a shift in center frequency is observed in the order of 13.12 MHz per 100 microns

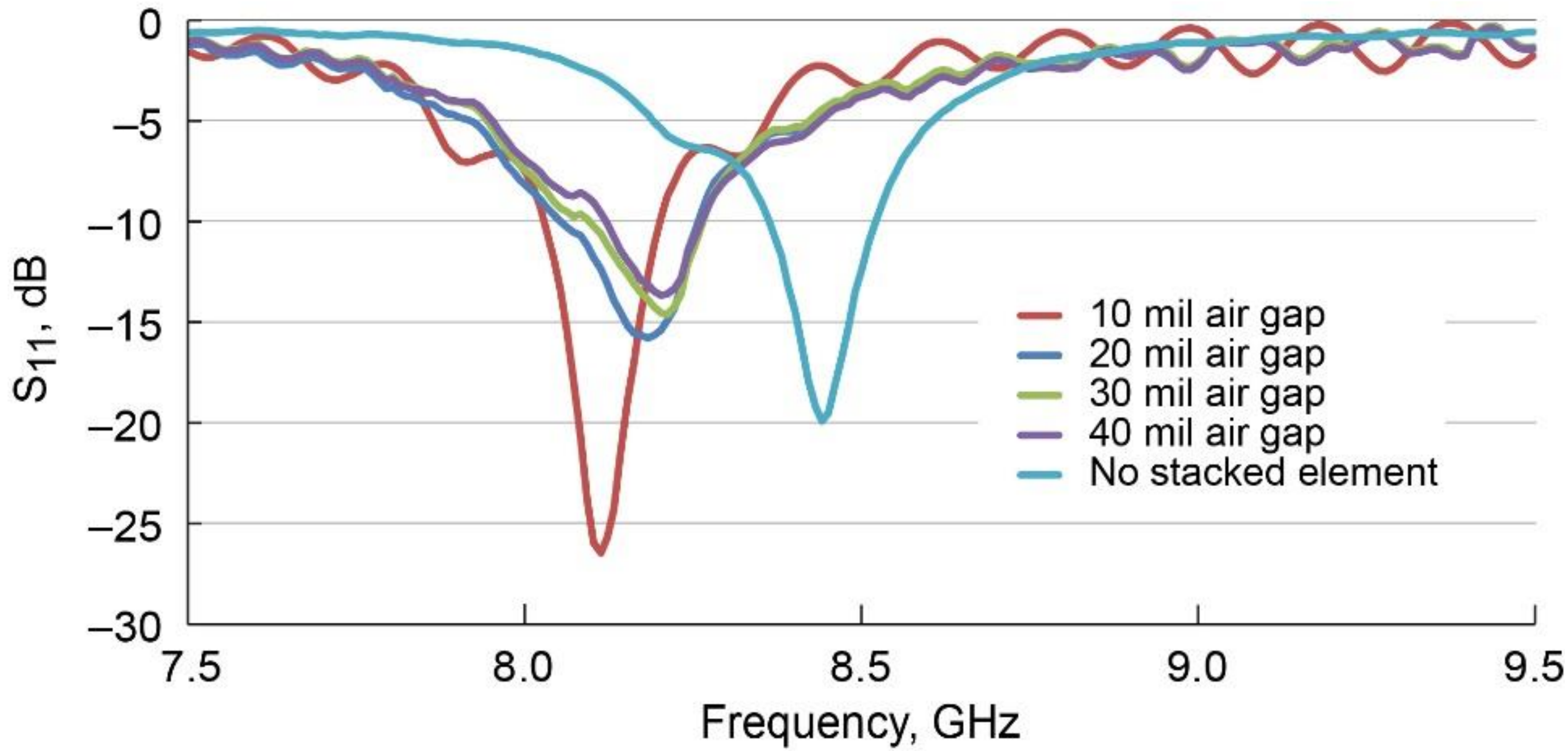
Frequency Reconfiguration

Simulated Air Gap Variant



Frequency Reconfiguration

Measured Air Gap Variant



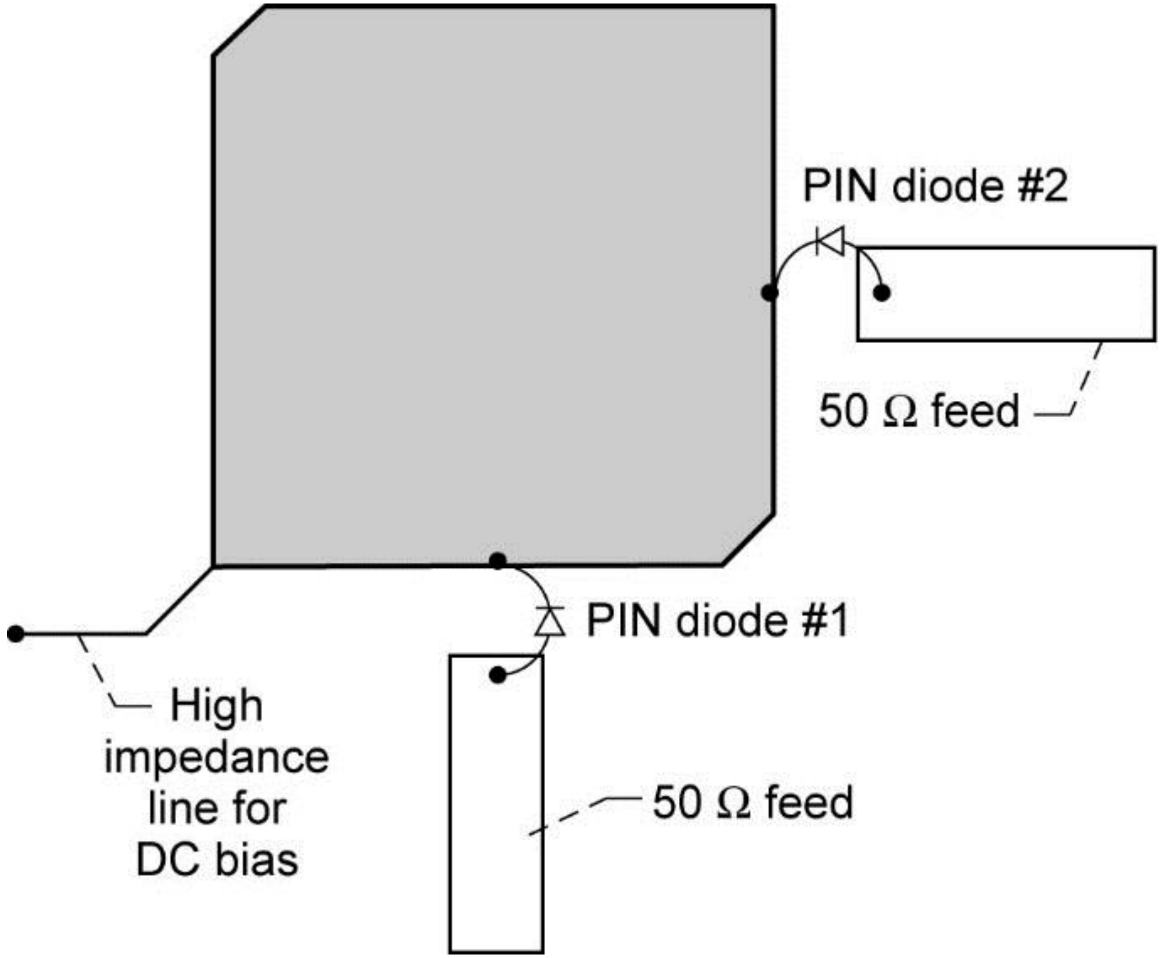
The main takeaway from this experiment is that the central frequency in a stacked square patch can be reconfigured by as much as 100MHz (Shifted from 8.1017 to 8.2017 GHz).

Summary of Results

MEASURED RESULTS SUMMARY						
	f_0 (GHz)	Return Loss (dB)	f_L (GHz)	f_H (GHz)	BW = f_H - f_L (MHz)	BW/f_0 (%)
Almost Square Patch	8.46	17.5402	8.385	8.529	144	1.7
Square Patch	8.45	19.7545	8.3675	8.5255	158	1.87
Stacked Square Patch	8.1017	25.7	8.0204	8.2005	180.1	2.22

	Air Gap (mil)	f_0 (GHz)	Return Loss (dB)	BW = f_H - f_L (MHz)	BW/f_0 (%)
Stacked SP Reconfiguration	∞	8.45	19.7545	158	1.87
	40	8.2017	13.68	140	1.70
	30	8.195	14.56	165	2.01
	20	8.18	15.81	205	2.51
	10	8.1017	25.7	180.1	2.22

Future Work



- Polarization Reconfiguration:
  - Ability to become LHCP or RHCP.
  - PIN diodes would work as switches.
  - Integration of semiconductor devices with antenna elements.

Future Work (Continued)

- Electronic Reconfiguration:
  - RF Microelectromechanical systems (MEMS)
    - Advantages
      - Electrostatically actuated MEMS devices consume insignificant amount of power during operation
      - Higher linearity when compared to semiconductor devices
  - Realization
    - Electro-active polymers/shape memory alloy actuators
    - Magnetic actuators
    - Displacement multipliers

Conclusions

- The impedance bandwidth of the CP square patch antenna excited from the ground plane side by a surface launch connector is superior to the case when excited from the edge by a 50 ohm line
- When an identical patch is stacked above the driven patch two things happen:
  - The impedance bandwidth further improves
  - A center frequency shift is observed, which can be exploited in a cognitive radio
- A varying air gap further expands frequency reconfiguration capabilities
- MEMS devices can be utilized to achieve efficient frequency tuning

Acknowledgements