Reconfigurable antenna systems

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Outline

- What is a reconfigurable antenna?
- Types of reconfigurable antennas
  - Frequency
  - Polarization
  - Pattern
  - Compound
- Main advantages and challenges
- Application - Wireless router with adaptive antenna system

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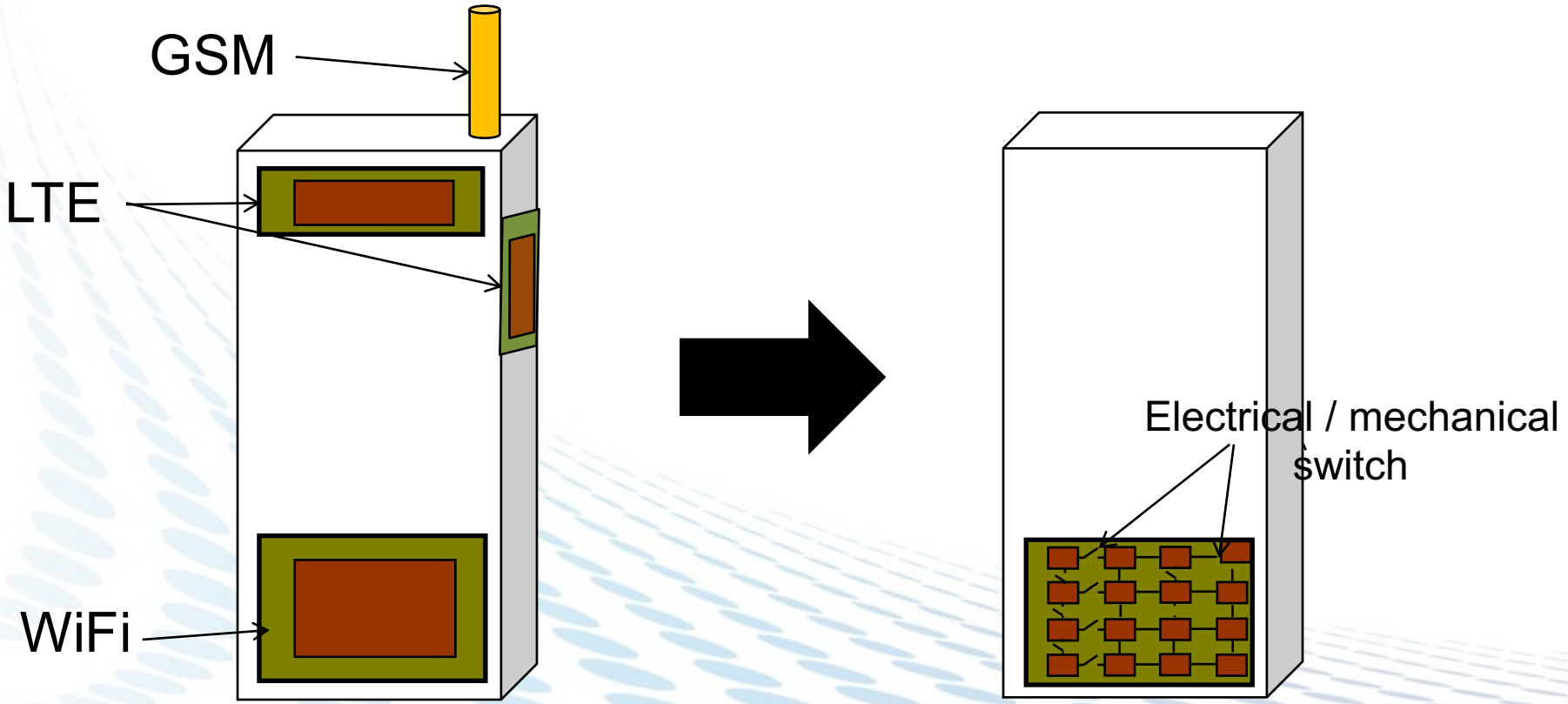
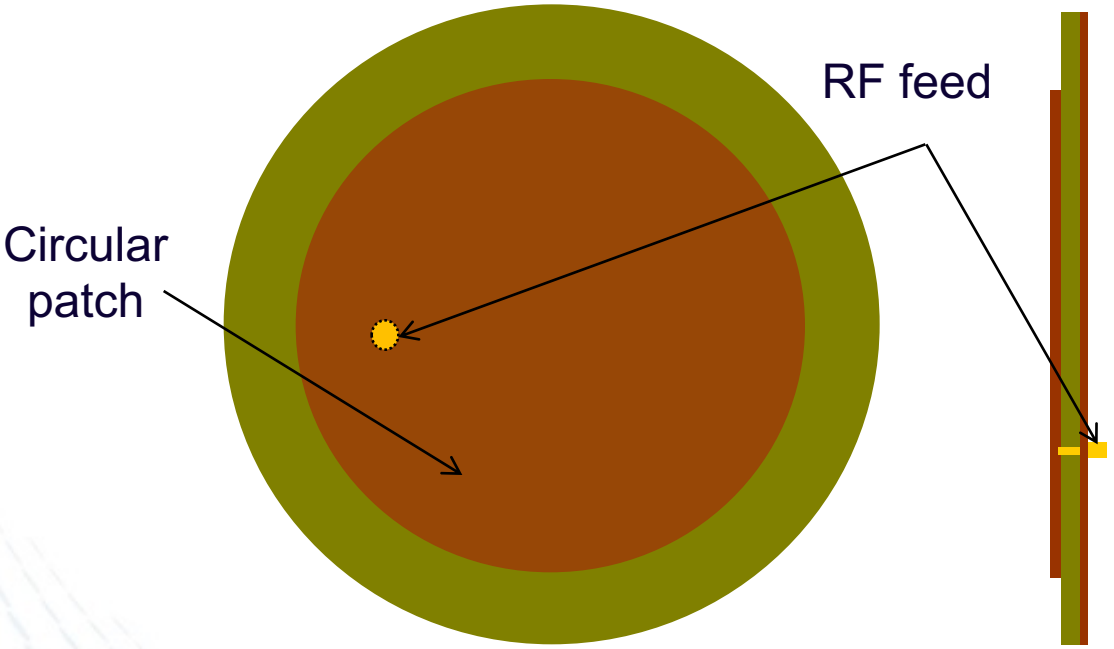
Reconfiugrable antennas

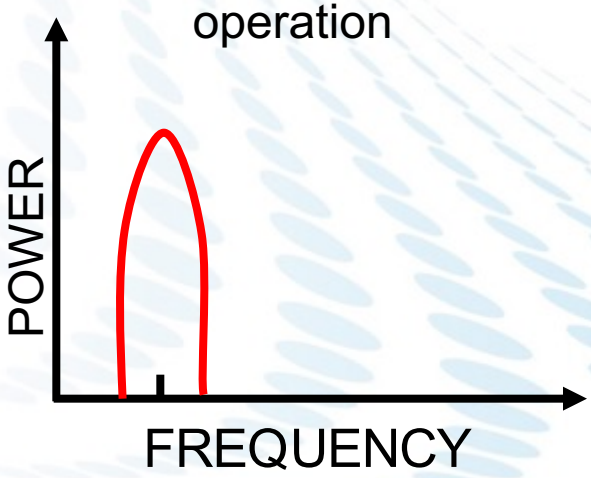
- Antennas that can reconfigure their radiation fundamental characteristics through electrical, mechanical or other means
- A single antenna element for multiple functions



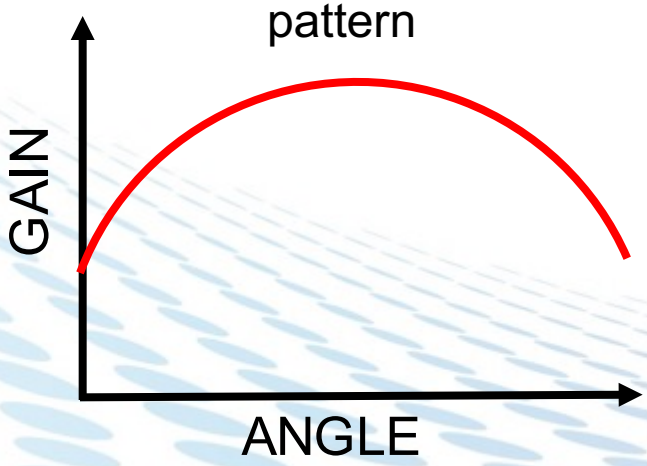
Patch Antenna



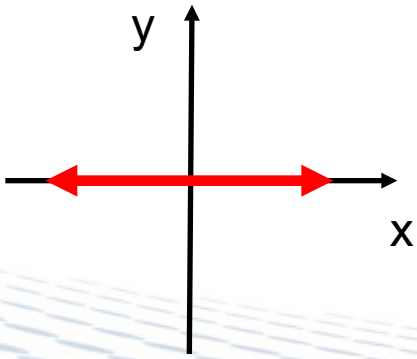
Frequency of operation



Radiation pattern



Polarization



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- What is a reconfigurable antenna?
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  - Pattern
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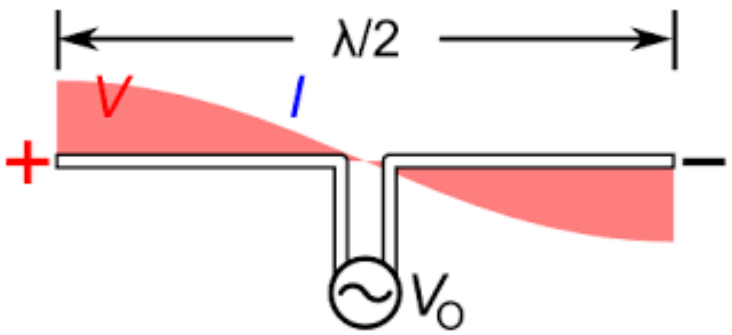
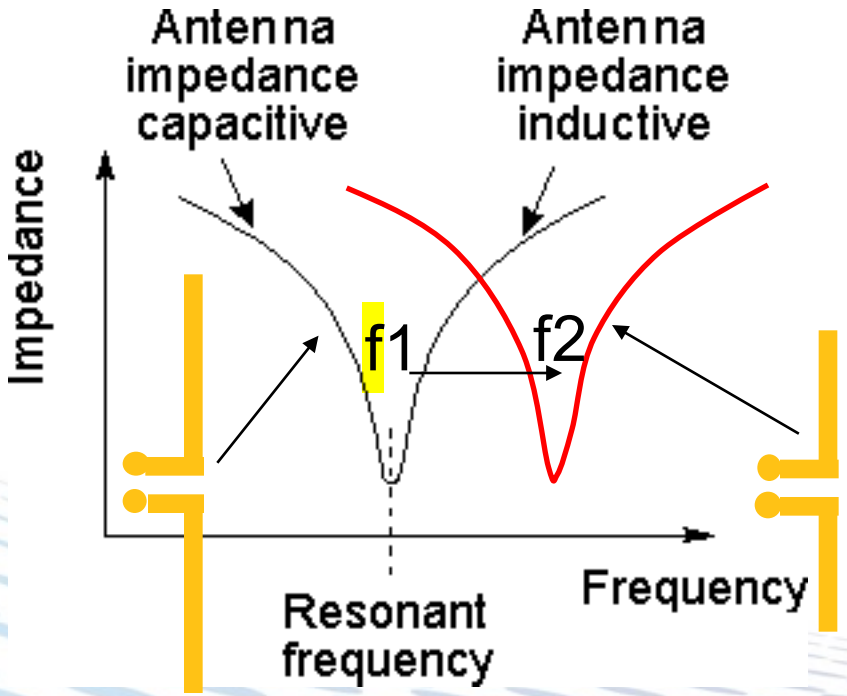
- Application - Wireless router with adaptive antenna system

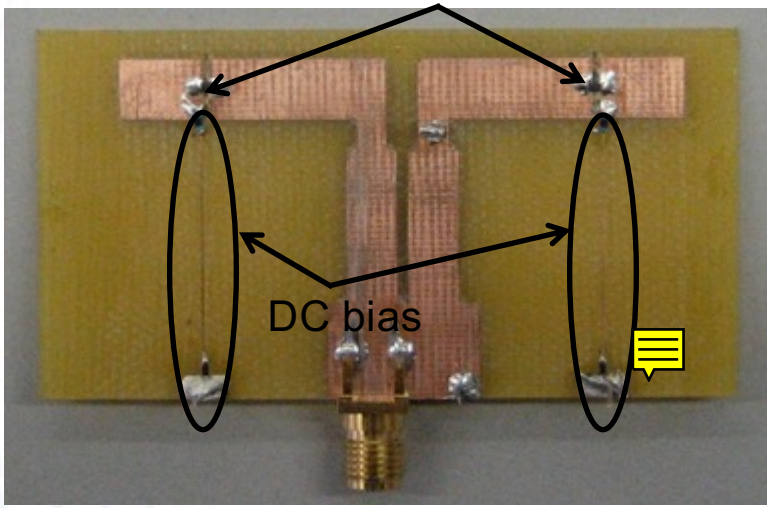
Frequency reconfigurability

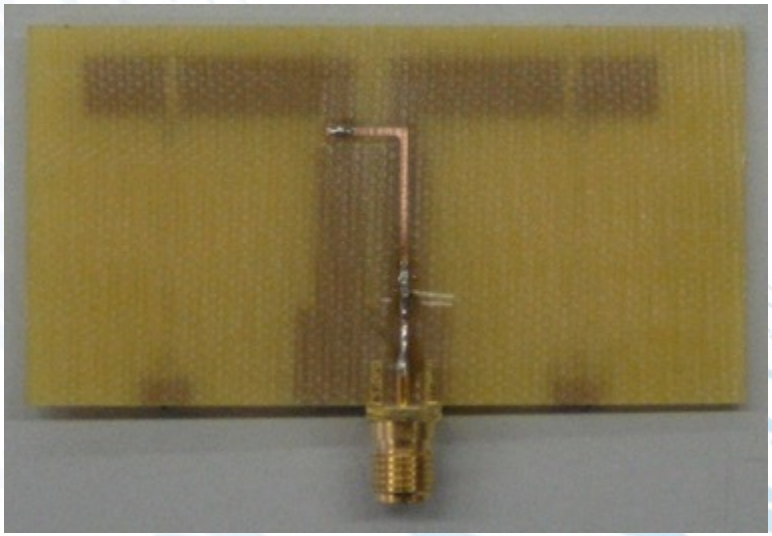
- Most of the antennas operate at resonance
- The electrical length of the antenna determines its resonant frequency
- By changing the electrical length of the antenna the resonant frequency of the antenna is changed



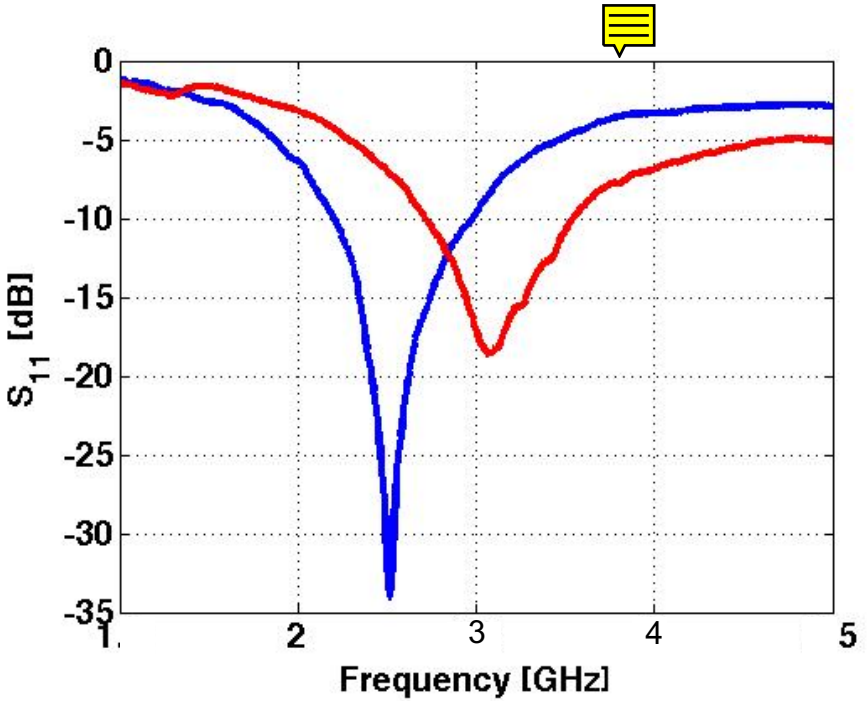


Frequency reconfigurable antenna





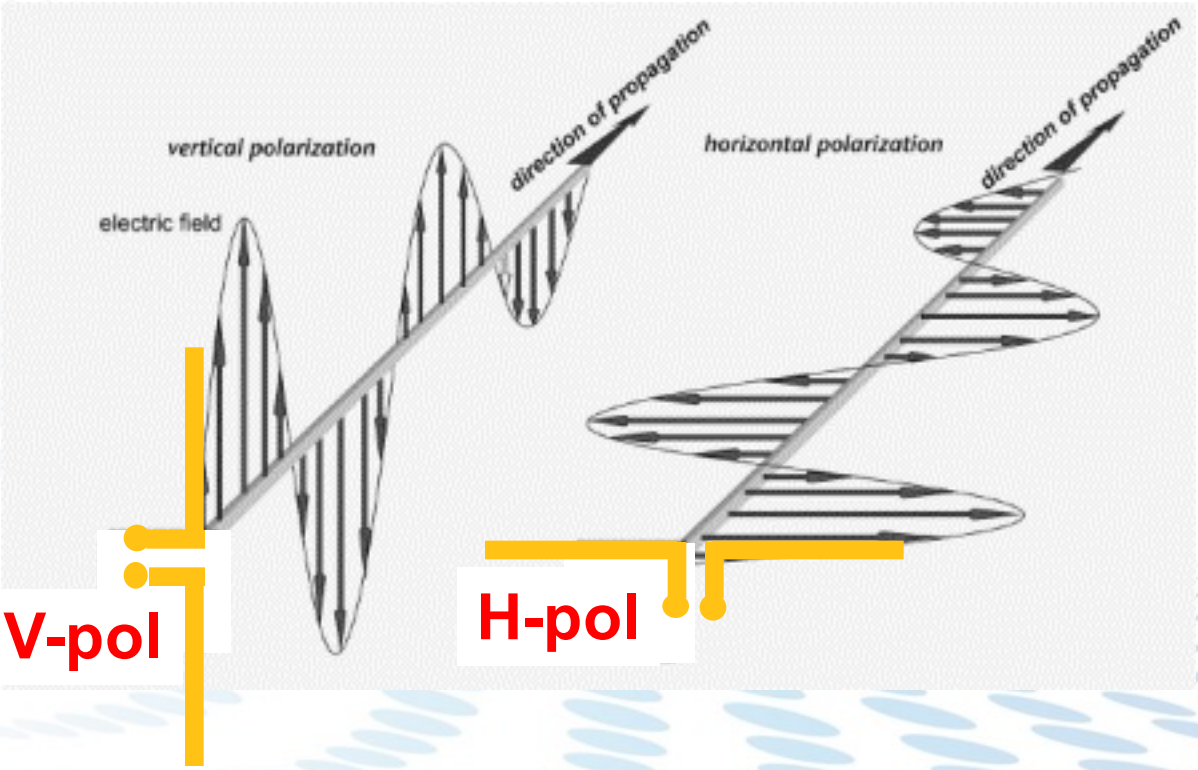
- Switches are used to change the electrical length of the antenna and therefore the operating frequency
- MEMS, PIN diodes, FET are used as switches

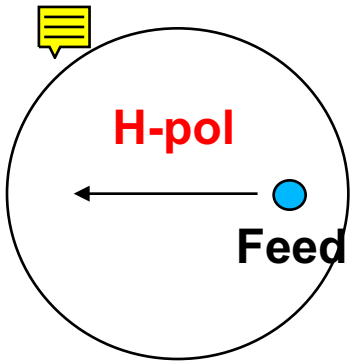


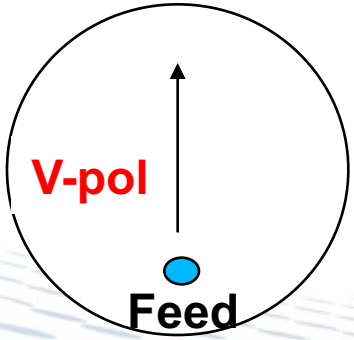
D. Piazza, N.J. Kirsch, A. Forenza, R.W. Heath, Jr., and K.R. Dandekar, " Design and evaluation of a reconfigurable antenna array for MIMO systems ," IEEE Transactions on Antennas and Propagation, vol. 56, no. 3, pp. 869 - 881, March 2008.

Polarization reconfigurability

- The direction of current flow on the antenna translates directly into the polarization of the electric field in the far field of the antenna
- Current flow can be changed through changes in
  - Structure of the antenna
  - Feed location

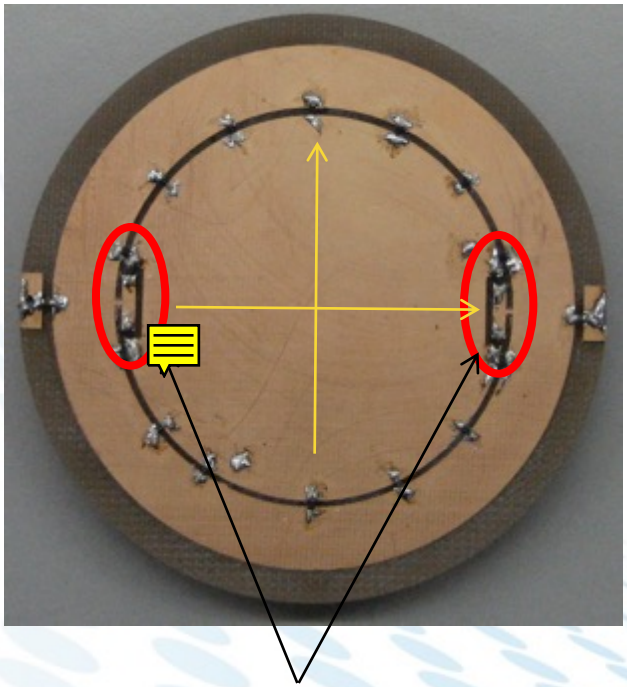


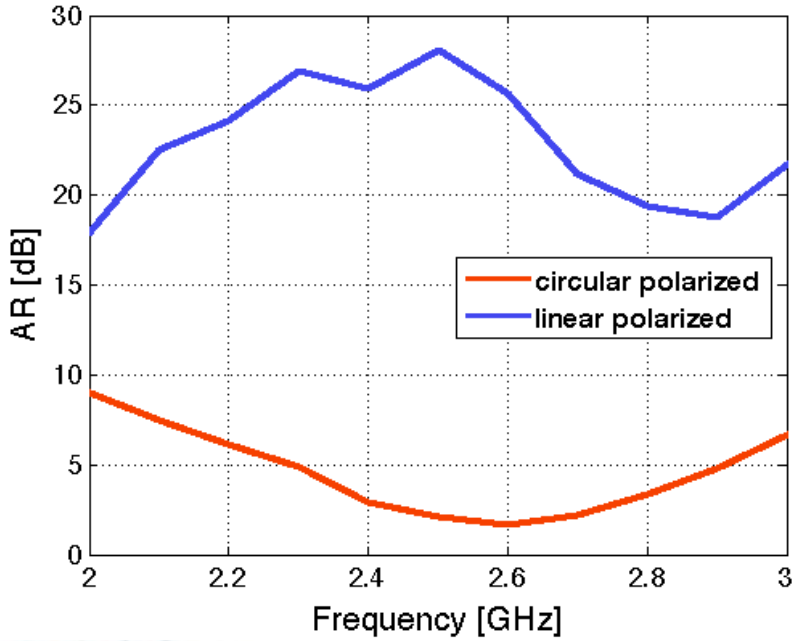




Polarization reconfigurable antennas

- Switches are used to activate/deactivate perturbation segments used to excite two degenerate modes with different phase offsets
- MEMS, PIN diodes, FET are used as switches

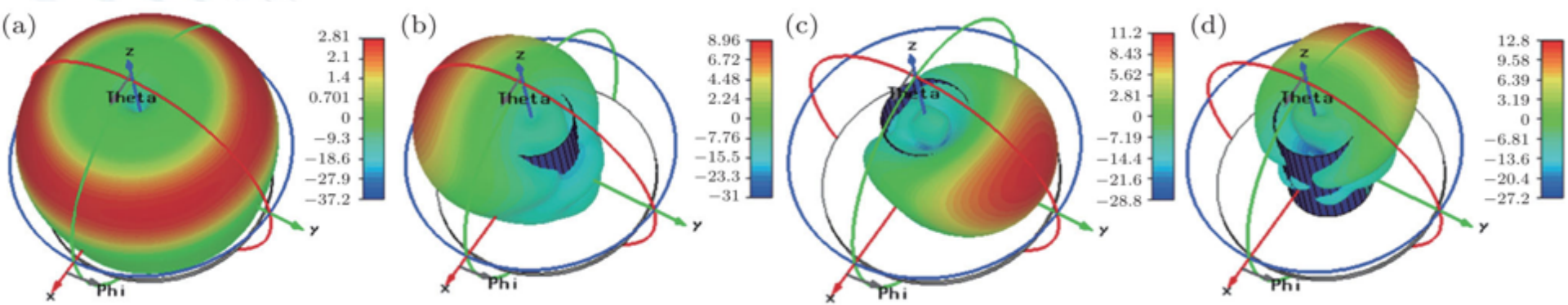




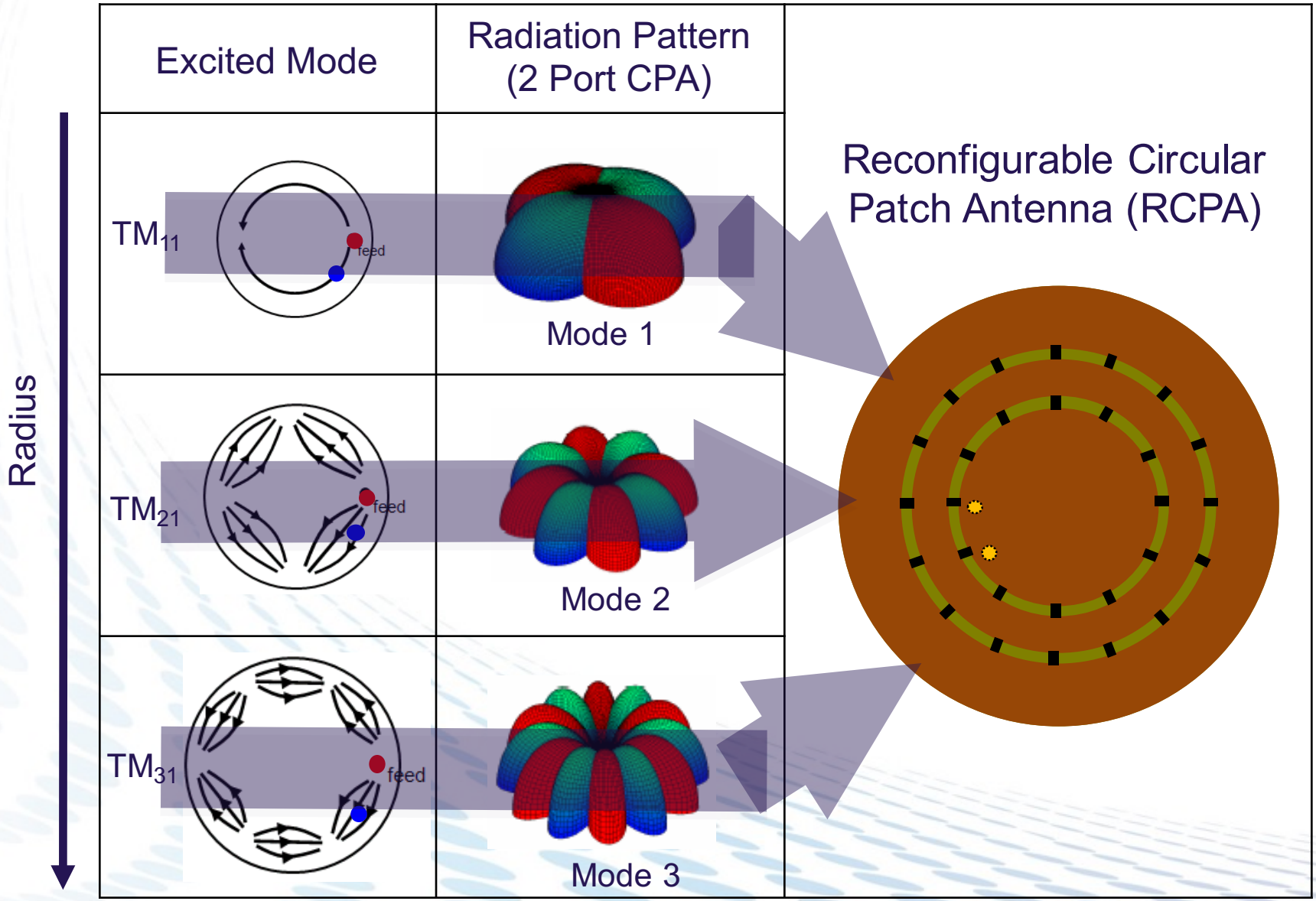
D. Piazza, P. Mookiah, M. D`Amico and K.R. Dandekar, "Pattern and polarization reconfigurable circular patch for MIMO systems," Proceedings of the 2009 European Conference on Antennas and Propagation (EuCAP), 2009.

Pattern reconfigurability

- The distribution of currents on the antenna translates directly into the spatial distribution of radiation from the structure
- The arrangement of currents on the antenna can be changed through
  - Variation in the radiation structure
  - Variation in the structures surrounding the main radiation structure
  - Feed location

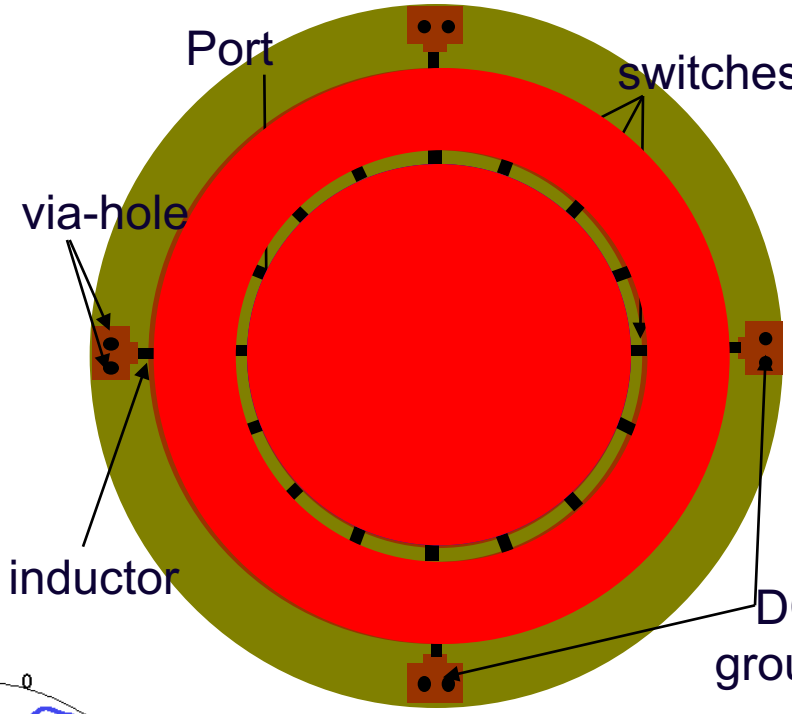


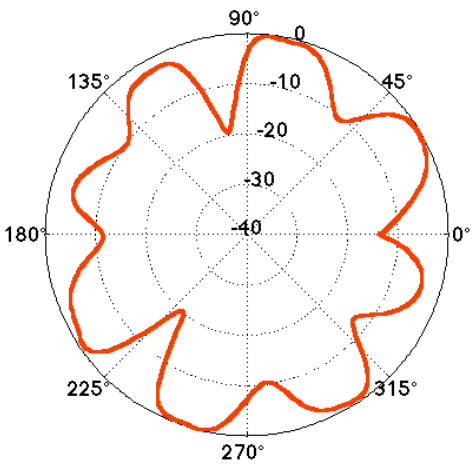
Pattern reconfigurability - multimode

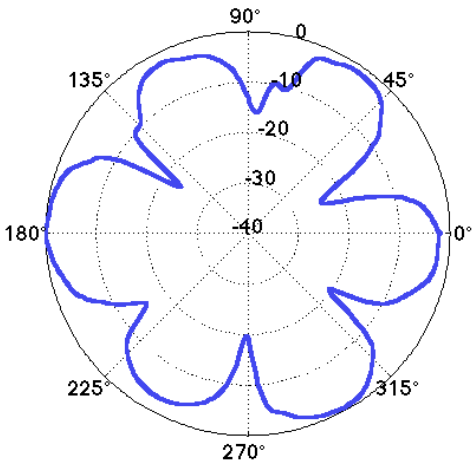


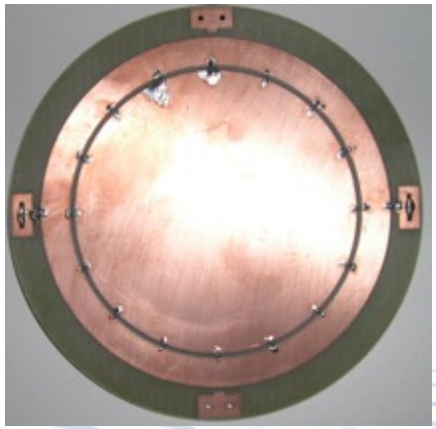
Pattern reconfigurable antennas: multimode

- Switches are used to change the current distribution on the antenna structure
- MEMS, PIN diodes, FET are used as switches



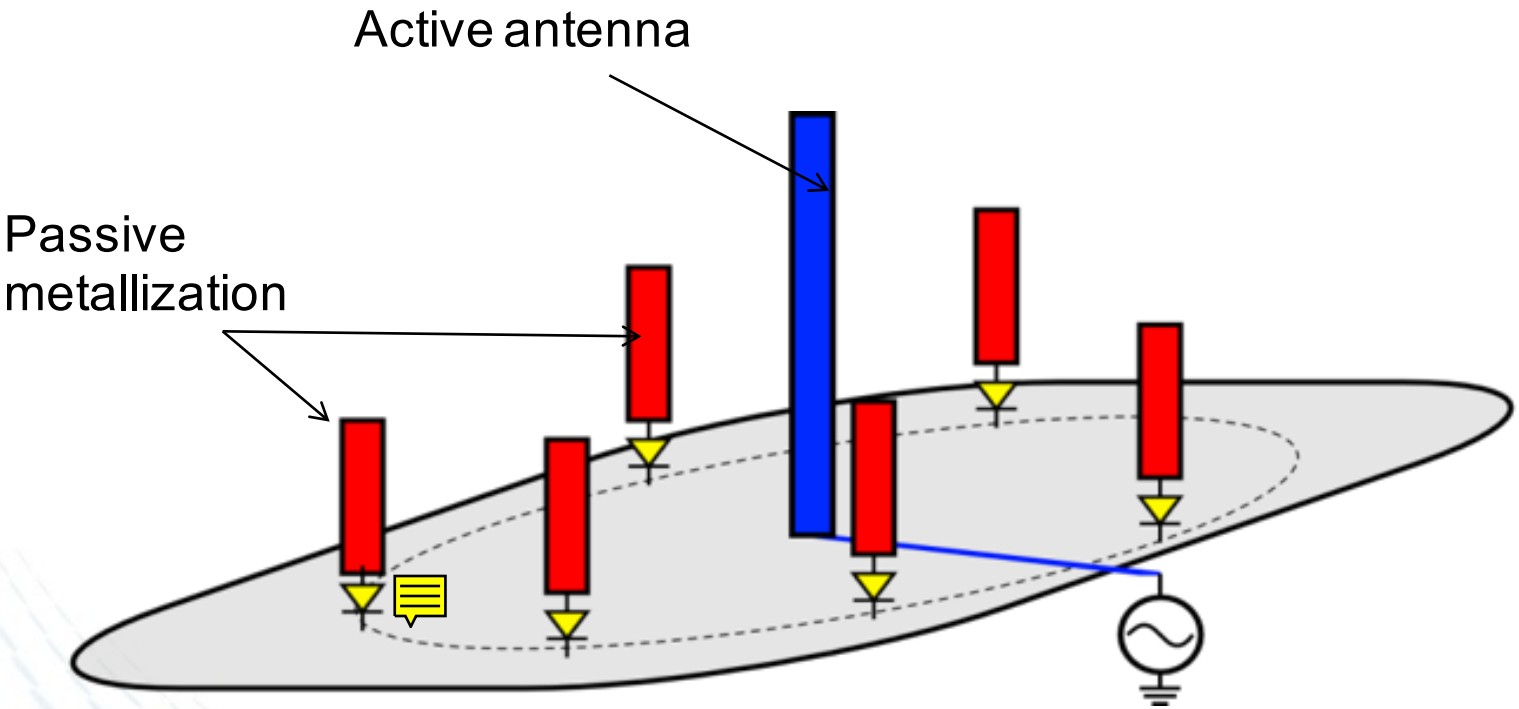






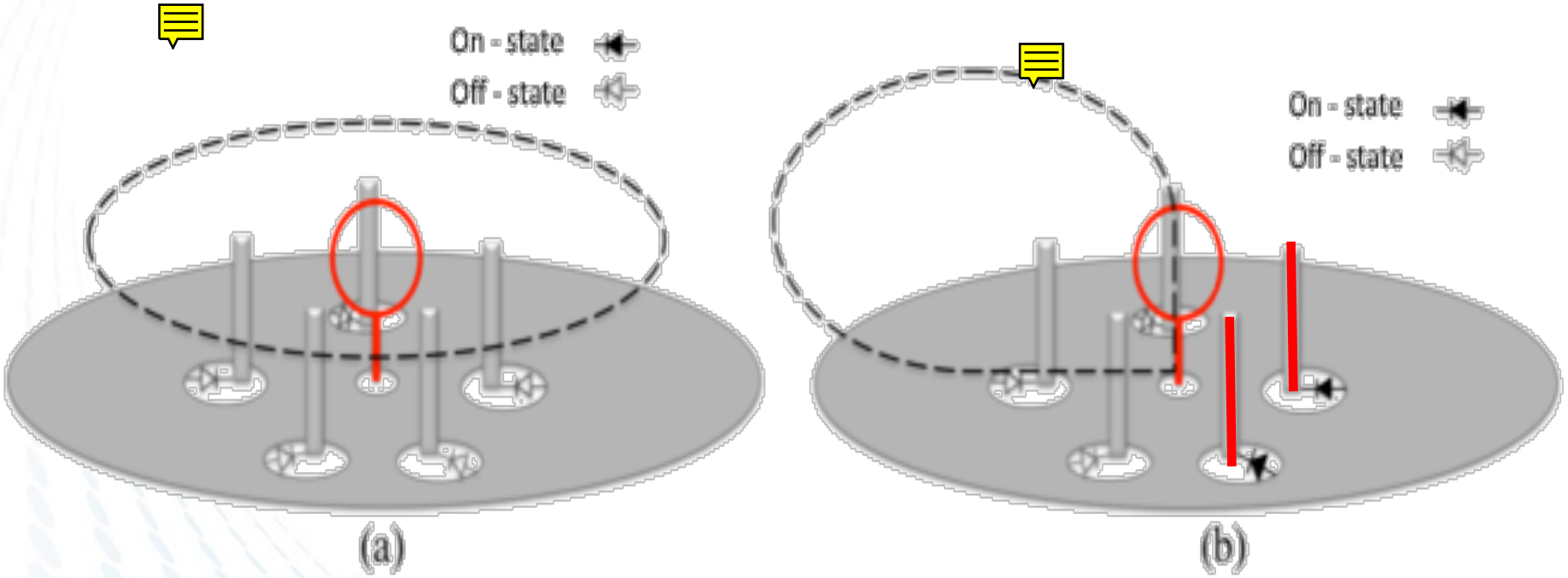
D. Piazza, P. Mookiah, K.R. Dandekar, and M. D`Amico, "Two port reconfigurable circular patch antenna for MIMO systems," Proceedings of the 2007 European Conference on Antennas and Propagation (EuCAP), 2007

Pattern reconfigurable antennas parasitic elements



- The active element radiates as standard monopole with omnidirectional radiation
- The electrical length of the parasitic elements can be changed through switches to change their behavior

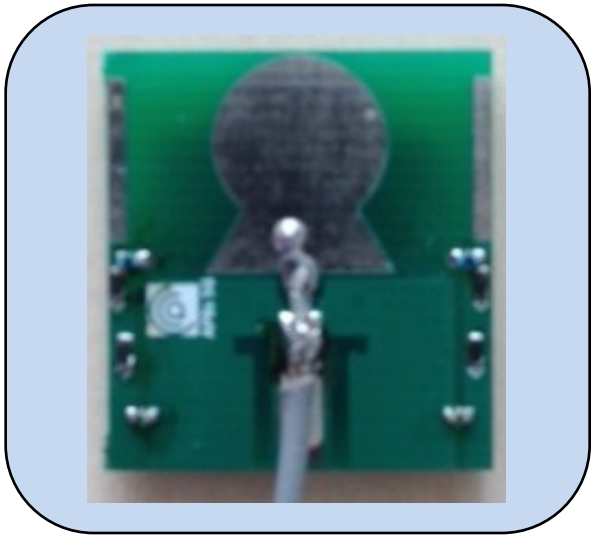
Pattern reconfigurable antennas parasitic elements (2)



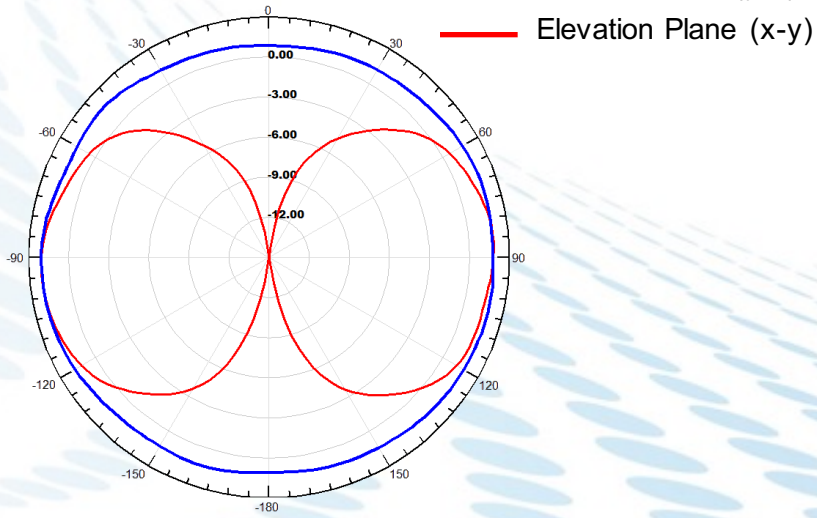
- If L_e_parasitic << L_e_active – no effect of the parasitic elment on the radiation of the active element
- If L_e_parasitic ~ L_e_active – the parsitic element can act as director or reflector for the active element and it participates in the formation of a directional radiation pattern

APB 5 GHz

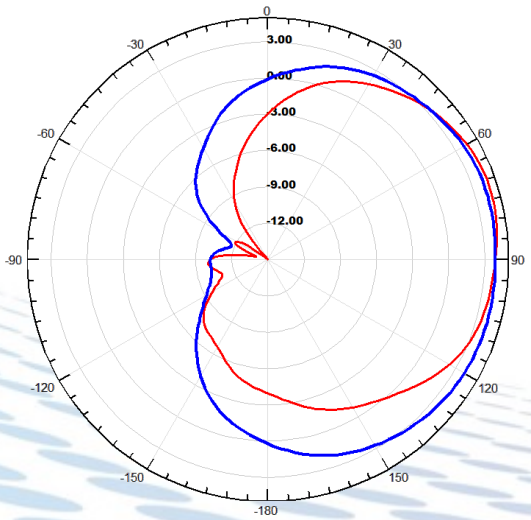
Key Features of Adant APB antenna	
Frequency	5.15 – 5.85 GHz
Polarization	Vertical
Input Impedance	~50 Ohm
Material	FR4
Dimensions	20 x 22 mm @ 5 GHz
Gain directional mode	4.5 dBi @ 5GHz
Gain omni mode	1.5 dBi
Efficiency	~75%
Bias voltage	0-1 V



OMNI MODE

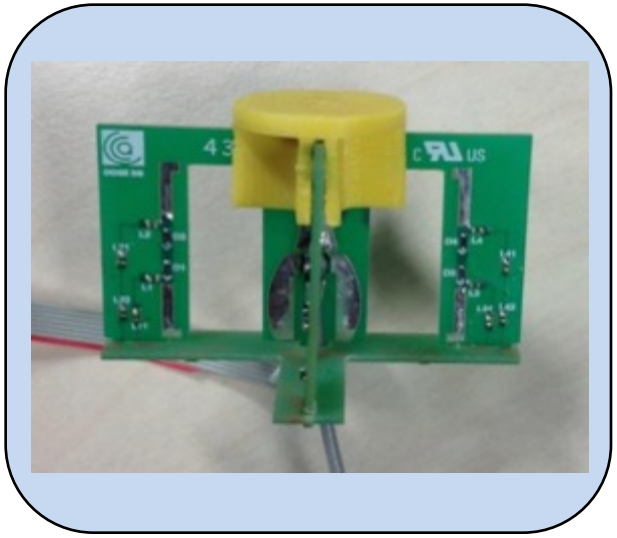


DIRECTIOINAL MODE

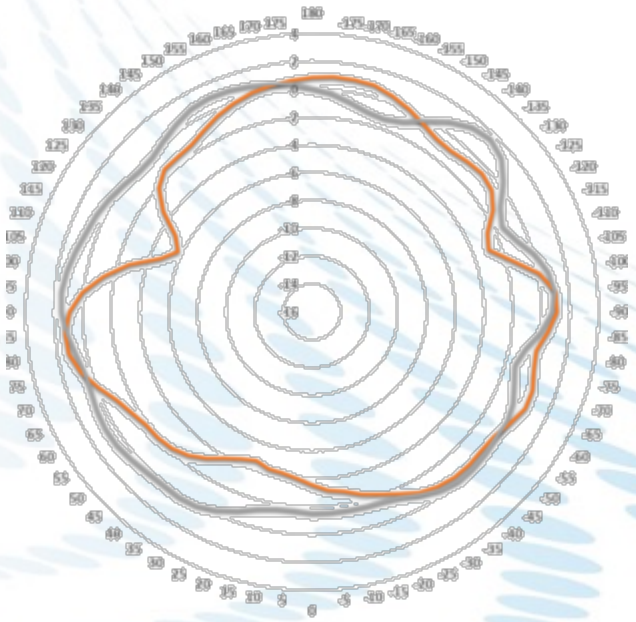


DOGE

Key Features of Adant DOGE antenna	
Frequency	5.15 – 5.85 GHz
Polarization	Vertical
Dimensions	35x35x26
Gain directional mode	up to 6 dBi @ 5GHz
Gain omni mode	1.5 dBi
Efficiency	~75%
Number of directional beams	8



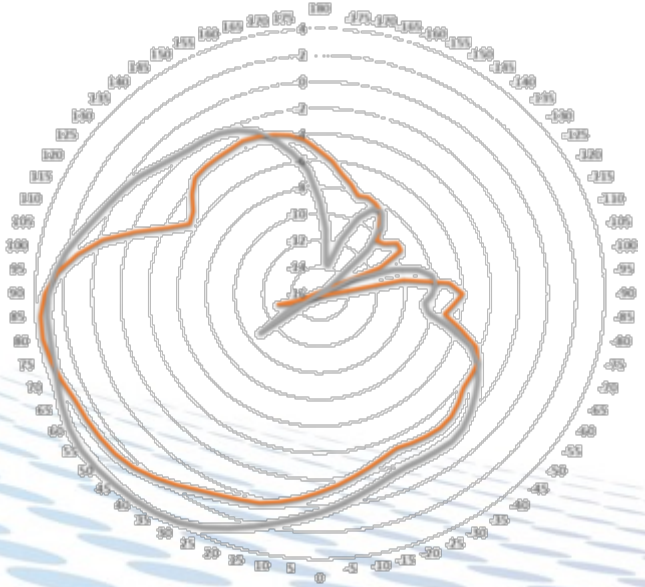
OMNI MODE



5.8 GHz

5.2 GHz

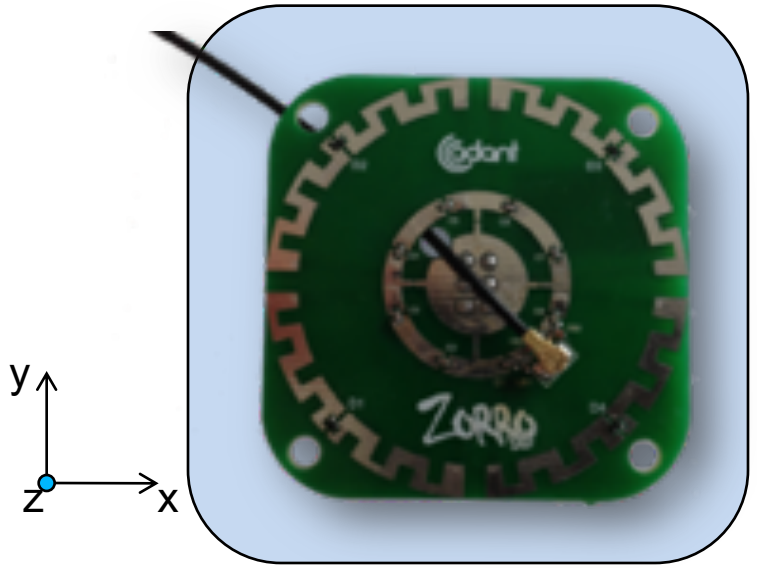
DIRECTIONAL MODE



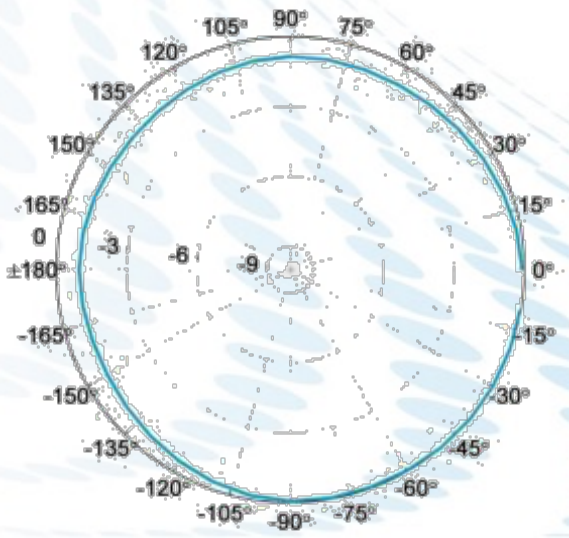
The beam can rotate over the whole 360 deg

ZORRO

Key Features	
Frequency	2.40 GHz -2.48 GHz (scalable for other frequency bands
Polarization	Horizontal
Input Impedance	~50 Ohm
Material	FR4
Dimensions	32x32 mm
Gain directional mode	4 dBi
Gain omni mode	1.5 dBi
Efficiency	75%
Bias voltage	0-1 V

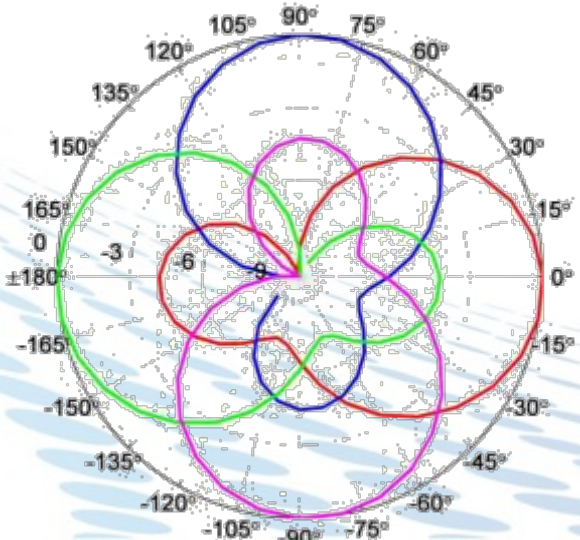


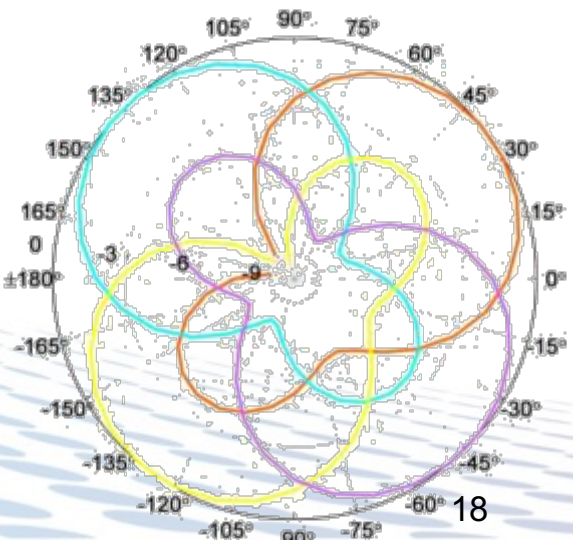
OMNI MODE



DIRECTIONAL MODE

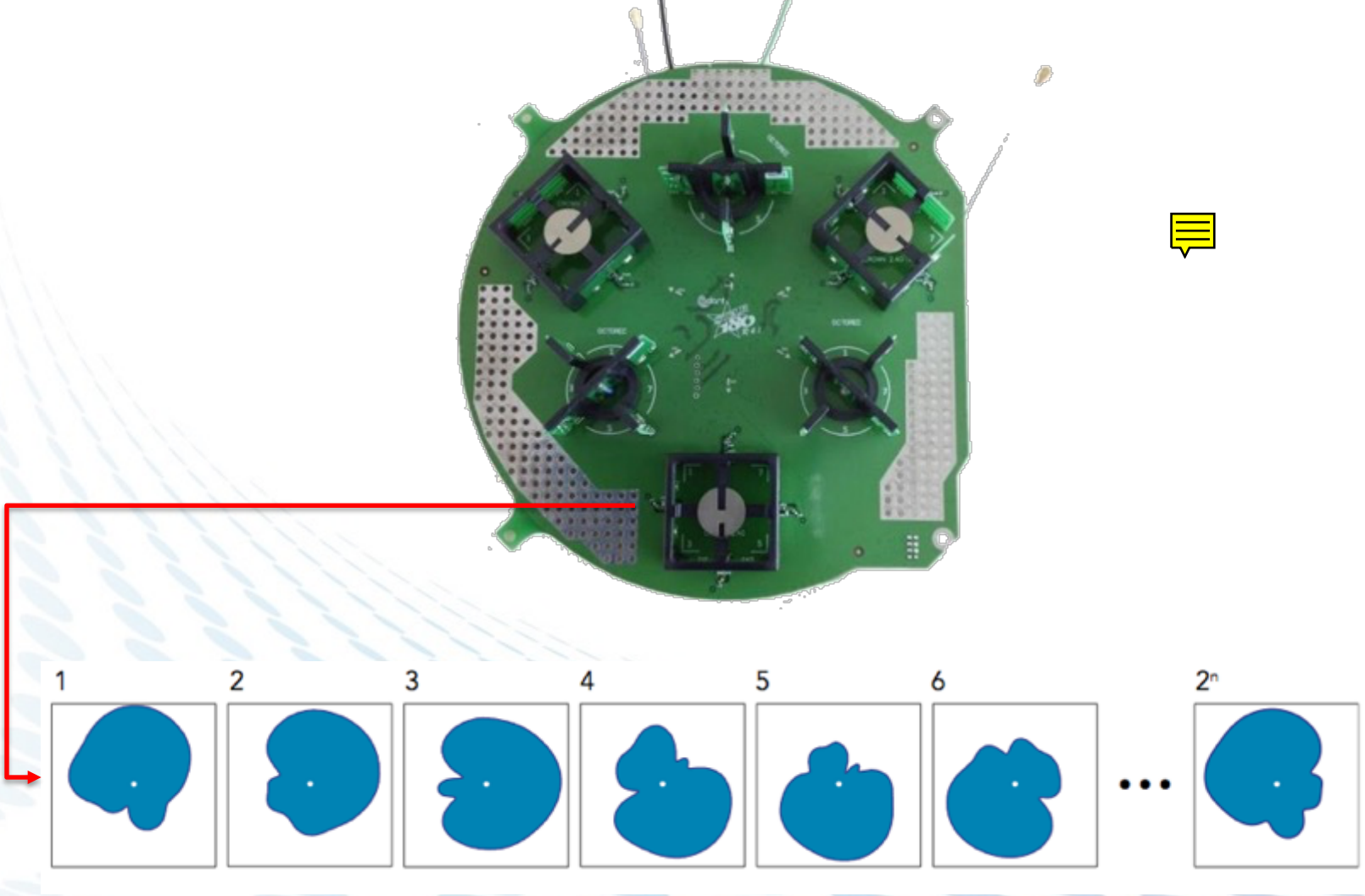
Config. 1 Config. 2 Config. 3 Config. 4
Config. 5 Config. 6 Config. 7 Config. 8





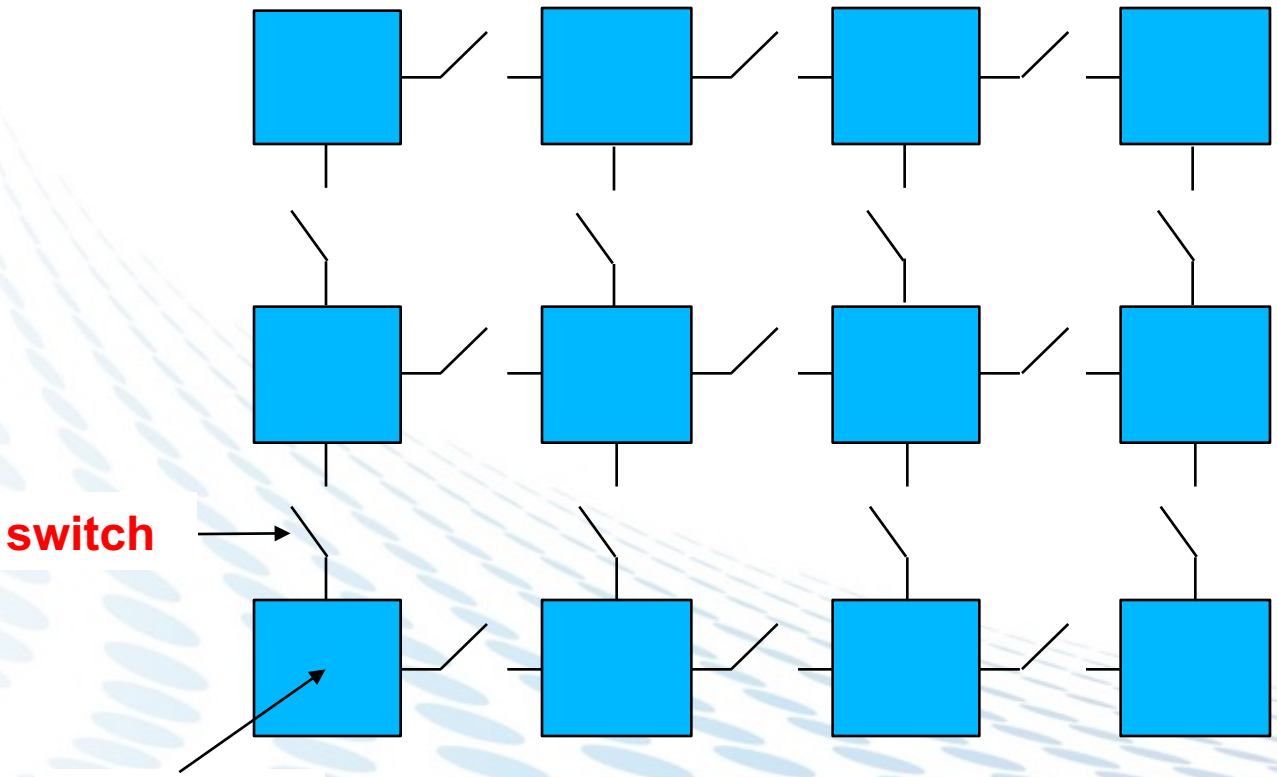
STAR antenna array

- Each antenna in the array can generate up to 2^N independent radiation patterns where N is the number of parasitic elements in the antenna



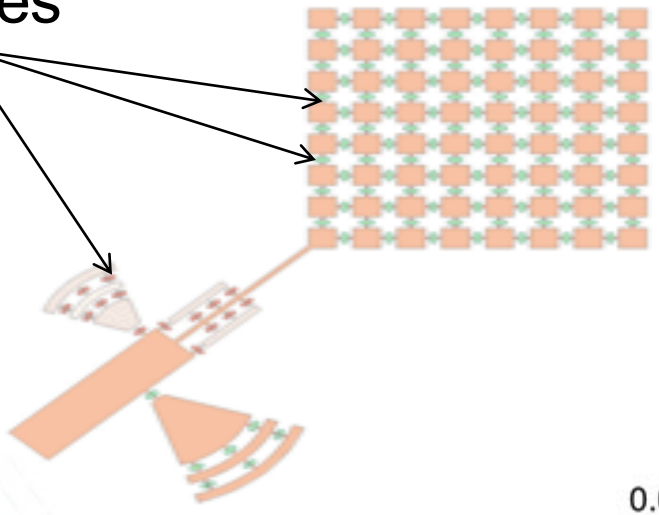
Compound reconfigurability

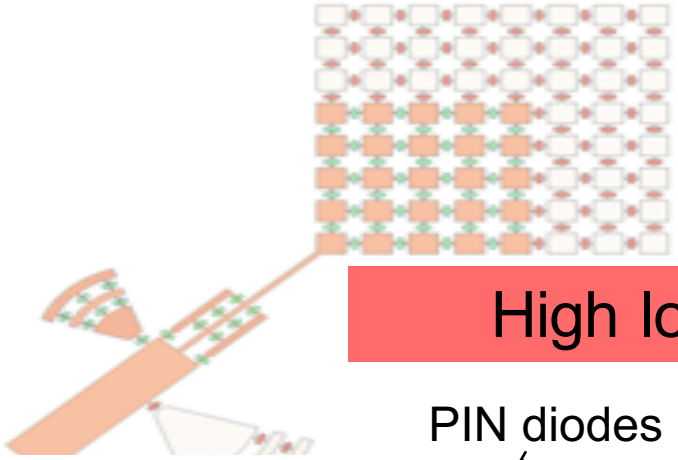
- Antennas that allow for independent tuning of frequency, polarization and radiation pattern
- Pixel antenna structures are the most common to achieve strong compound reconfigurability



Compound reconfigurable antenna: pixel antenna

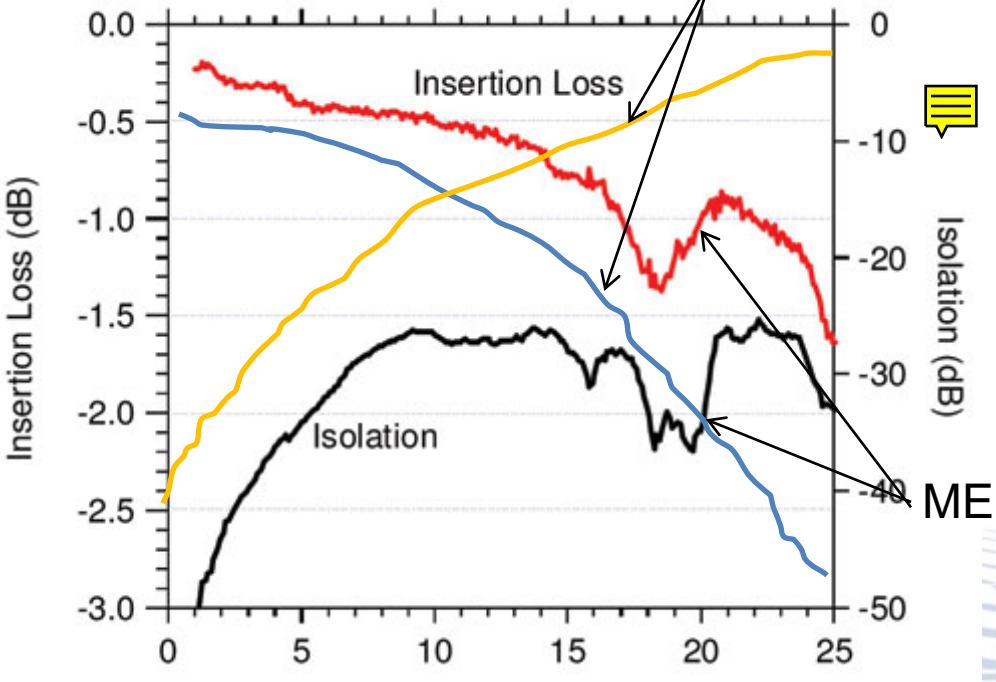
switches





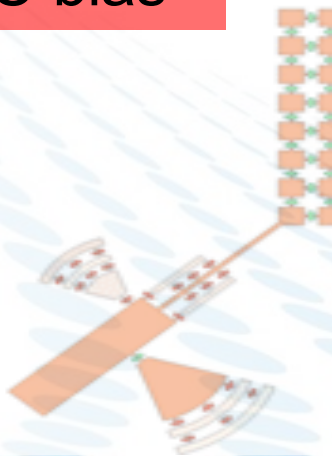
High losses

PIN diodes



MEMS

Complex DC bias



Adant pixelized antenna

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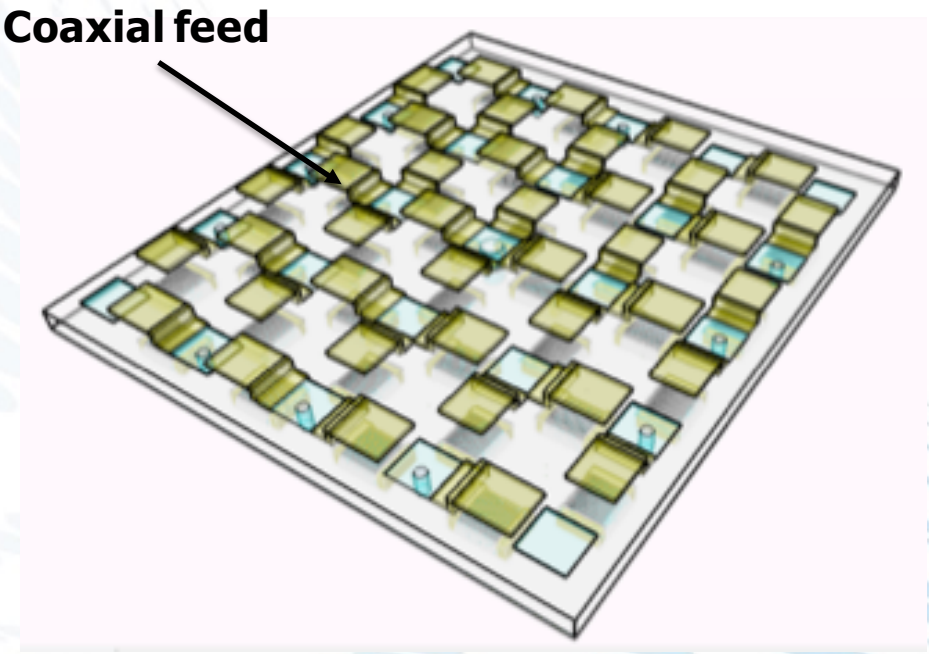
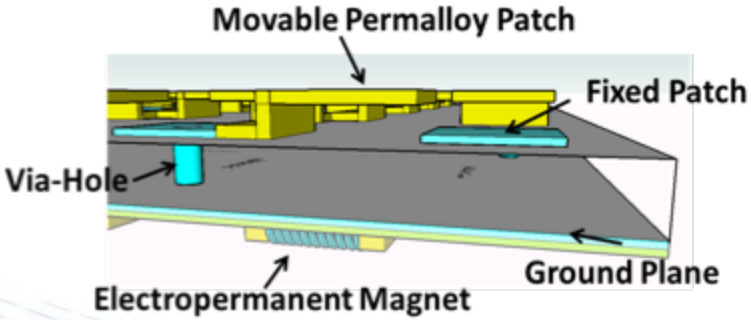
- Two layers patch antenna
  - Top layer: fixed patch + movable patches
  - Bottom layer: ground plane
- Duroid substrate to minimize losses at high frequencies
- Coaxial feedpoint through the ground plane of the antenna





Reconfigurability with High Efficiency

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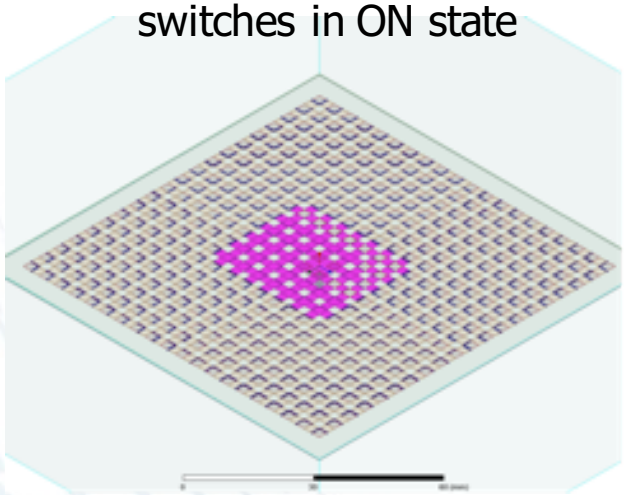
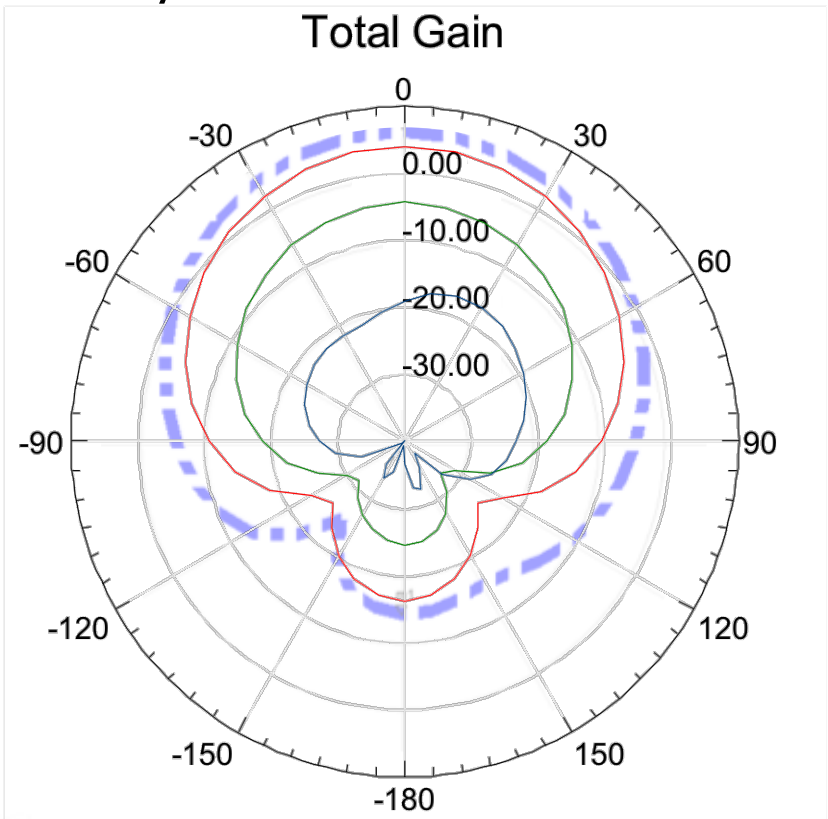
- Extremely low loss switch enables highly reconfigurable patch antennas with high radiation efficiency

Antenna at 2.5 GHz with 67 switches in ON state



Switch IL [dB]	Radiation efficiency @ 2.5 GHz
0	79%
0.02	56%
0.1	10%
1	1%



Frequency Reconfigurability

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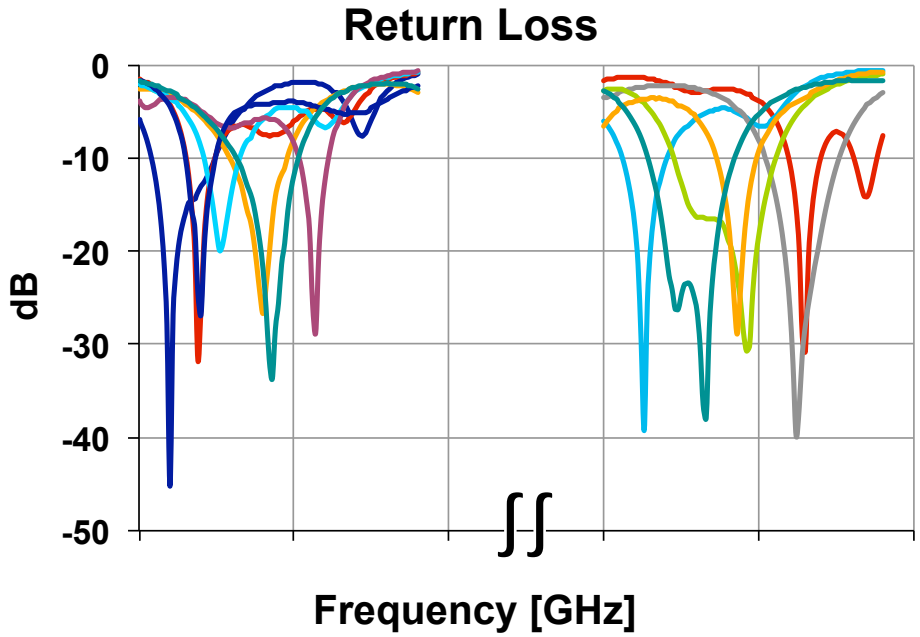
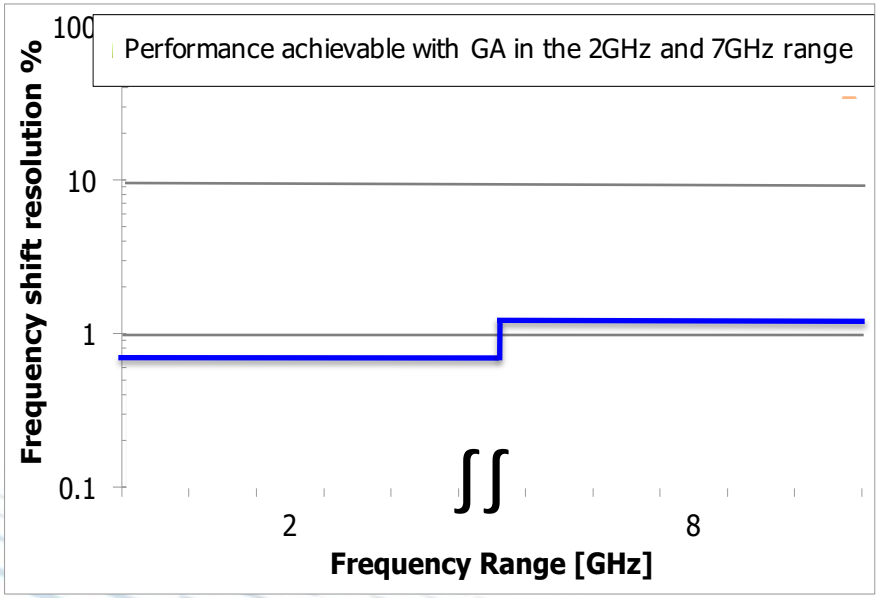
- Arbitrary patch shapes can be identified to change the resonant frequency of the main mode in the microstrip antenna
- Frequency reconfigurability resolution of ~ 1% across the whole bandwidth is possible

Example of frequency shift



Achievable frequency shift



Bandwidth Reconfigurability

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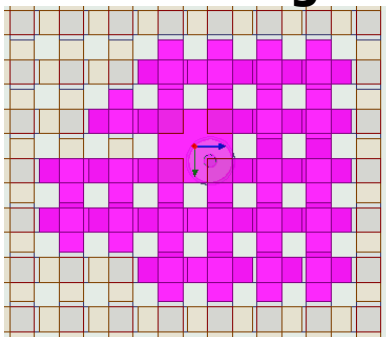
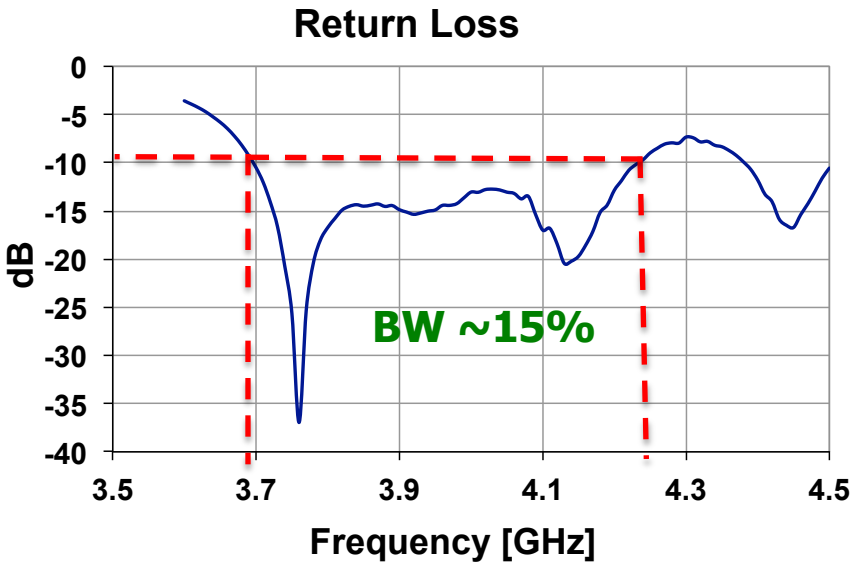
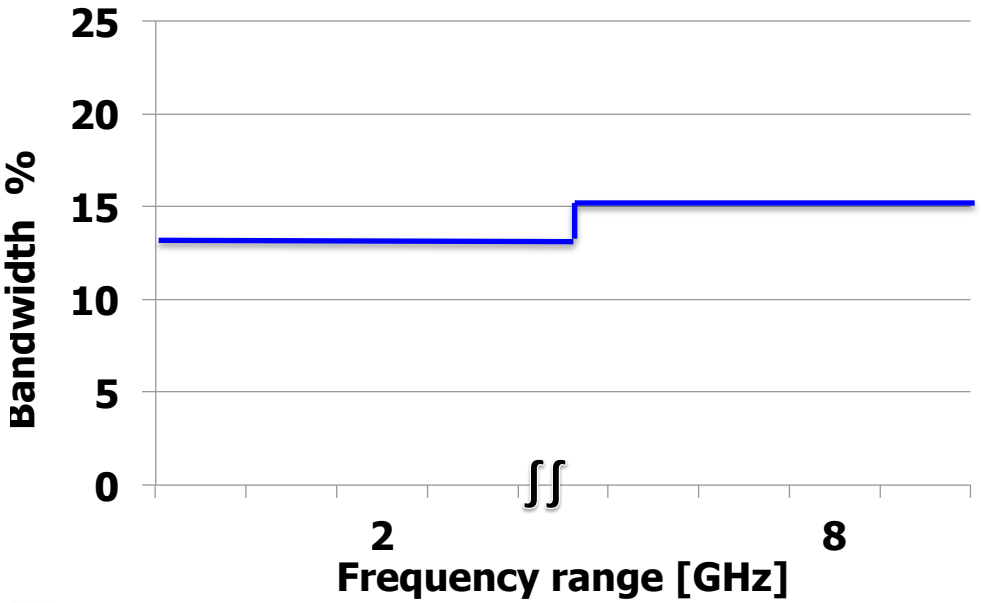
- Bandwidth can be enhanced up to 15%

Example of broad bandwidth configuration







Polarization Reconfigurability

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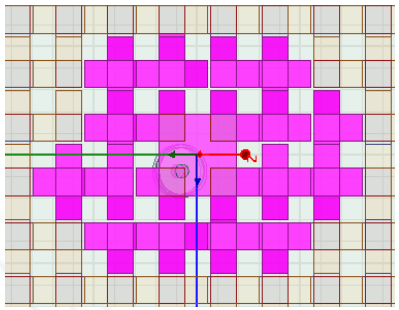
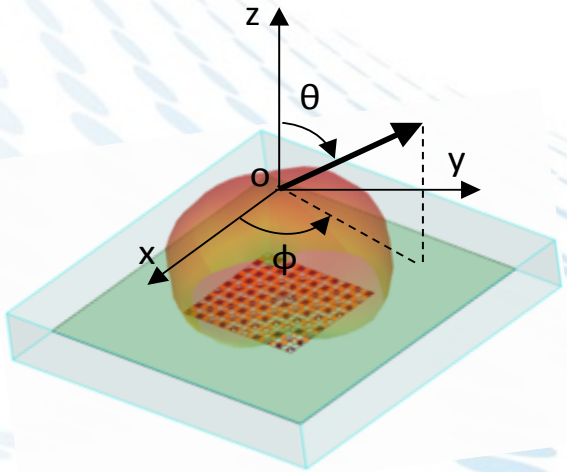
- Single feed point antenna with good circular polarization over a relatively wide bandwidth can be easily achieved

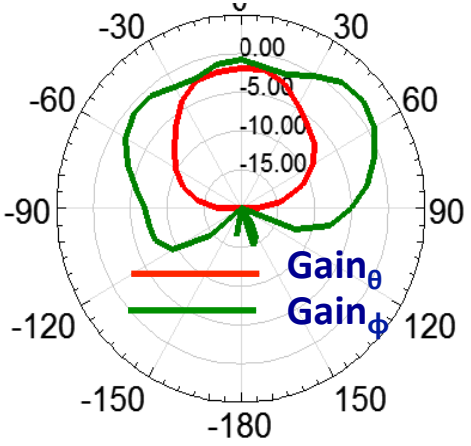
Example of circularly polarized configuration



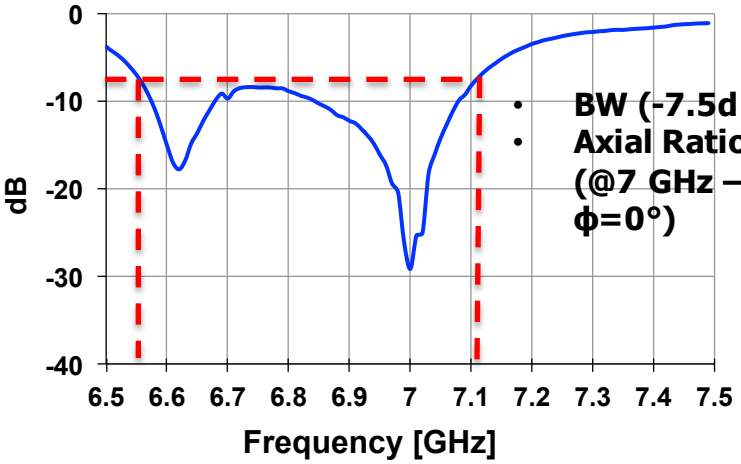
Active area



Composite Gain [dB]



Return Loss



- **BW (-7.5dB) ≈ 8%**
- **Axial Ratio = 1.7 dB (@7 GHz – θ=0°, ϕ=0°)**

Beam Scanning Reconfigurability

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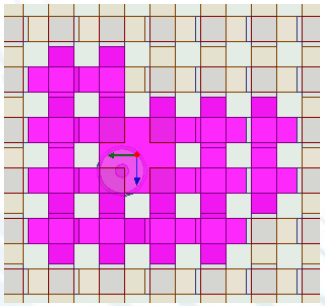
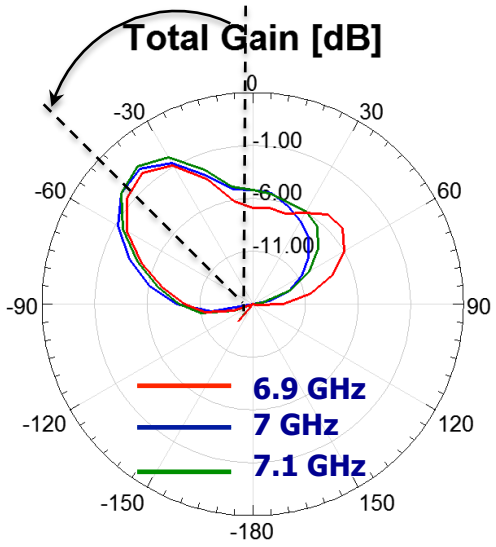
College of Engineering

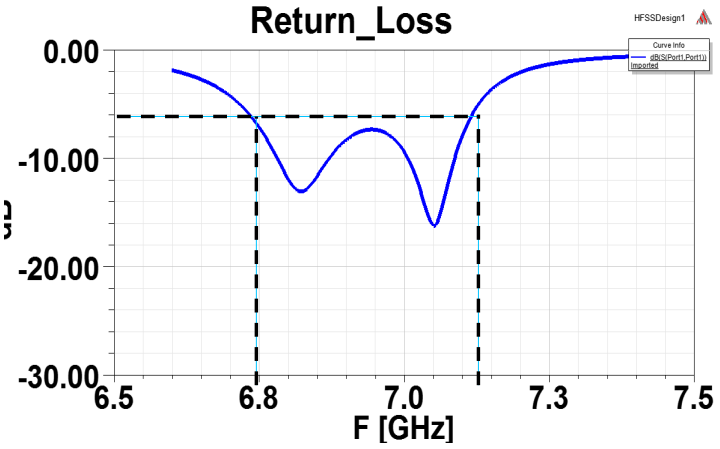
- Up to 50 deg of beam tilting in the elevation plane can be achieved using the proposed antenna structure

Example of beam-tilted configuration [6.7÷7.2] GHz



Active area





- **BW (-7.5dB) ≈ 5.5%**
- **Scan angle = [0 →50] deg**

Microfabricated Movable Pixel

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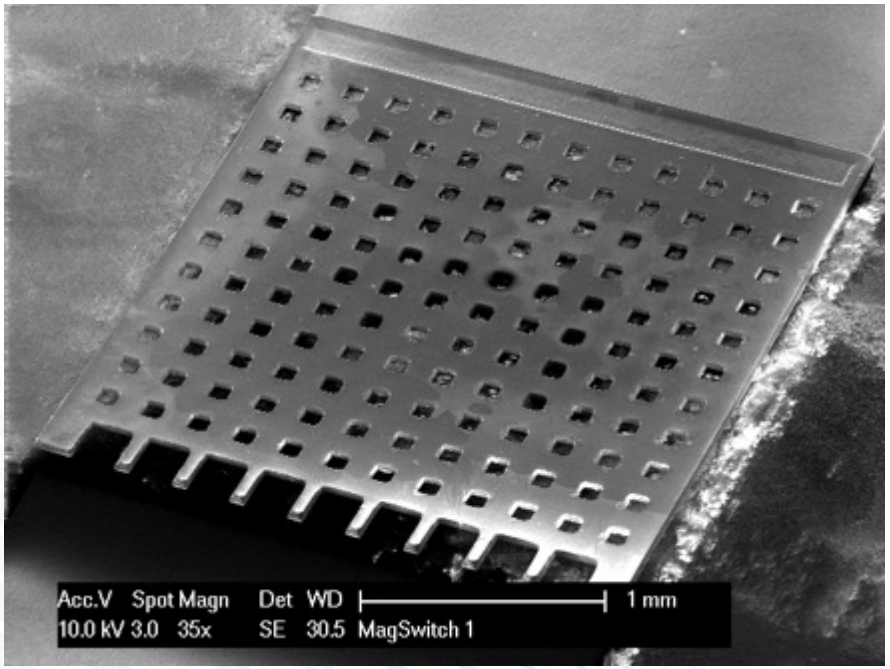
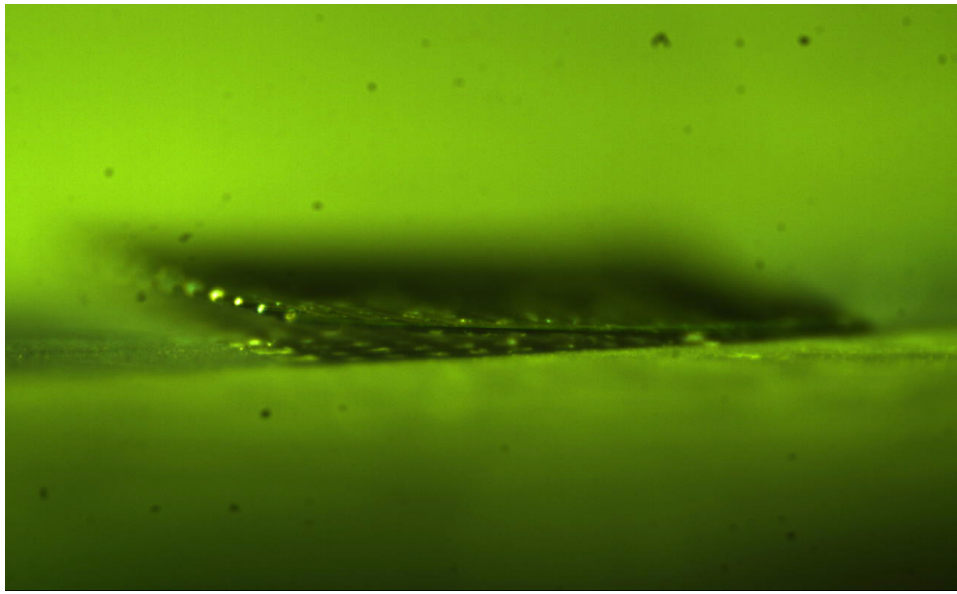
College of Engineering





Antenna Assembly

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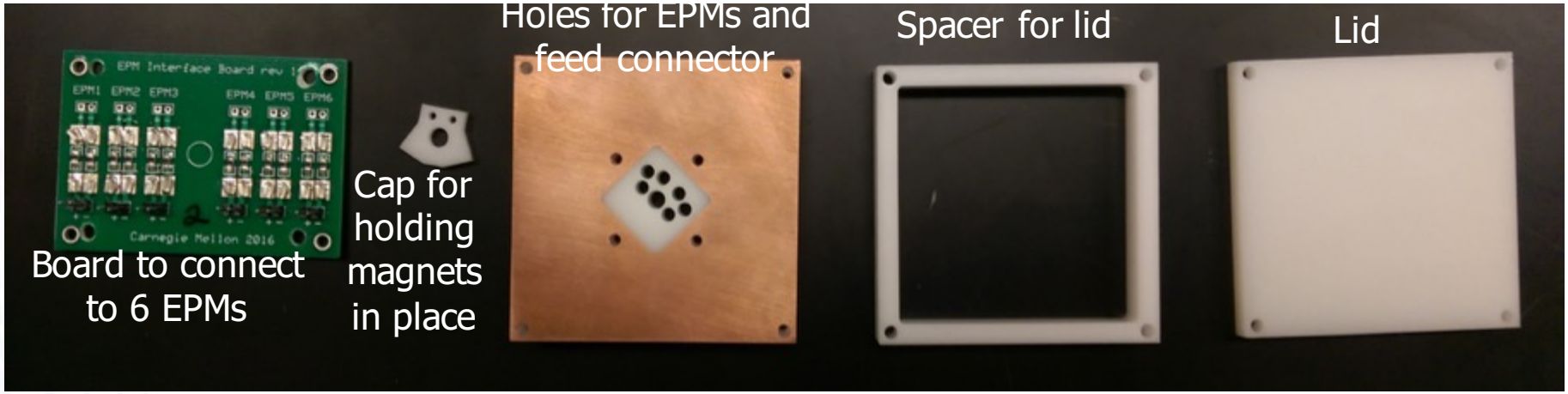
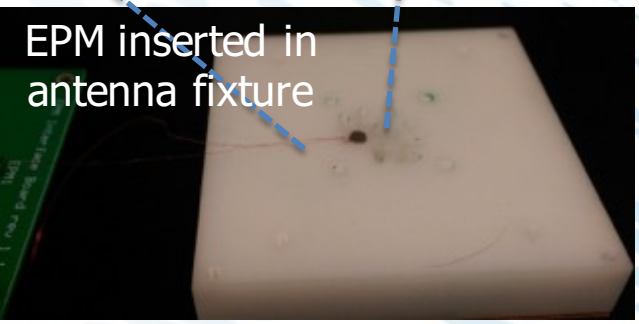
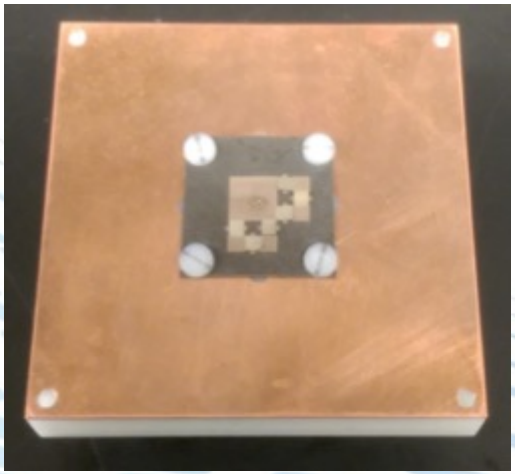
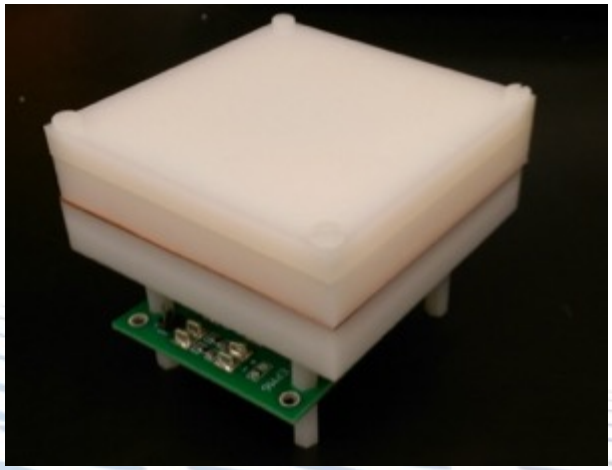
College of Engineering







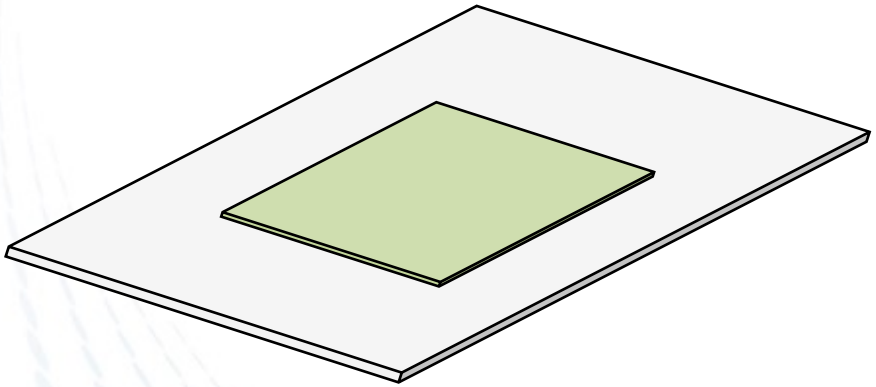


Outline

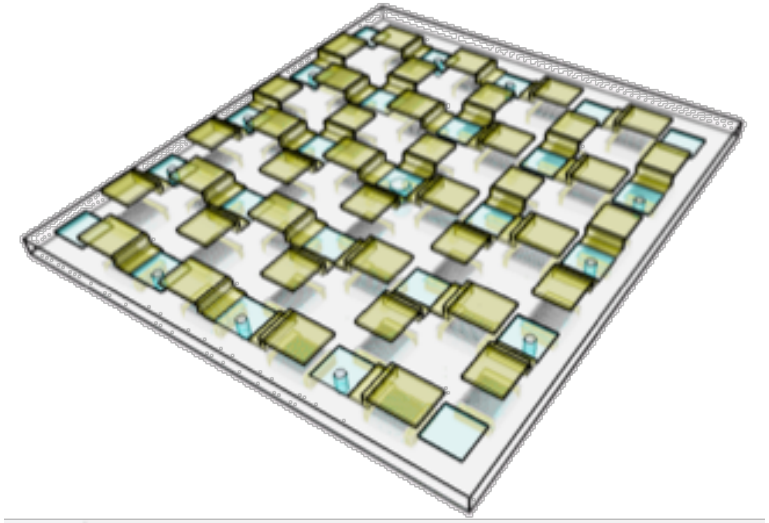
- What is a reconfigurable antenna?
- Types of reconfigurable antennas
  - Frequency
  - Polarization
  - Pattern
  - Compound
- Main advantages and challenges
- Application - Wireless router with adaptive antenna system

Reconfigurable antennas vs standard antennas

STATIC ANTENNA

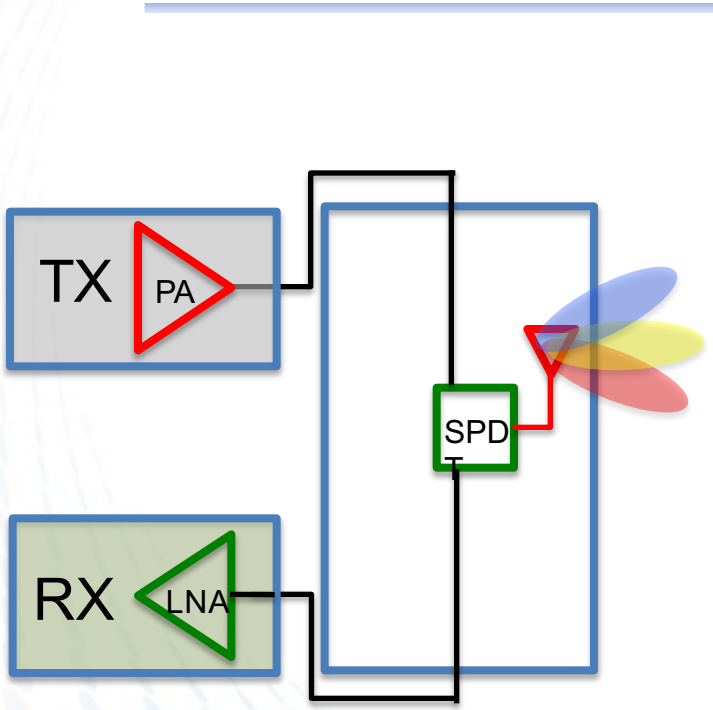


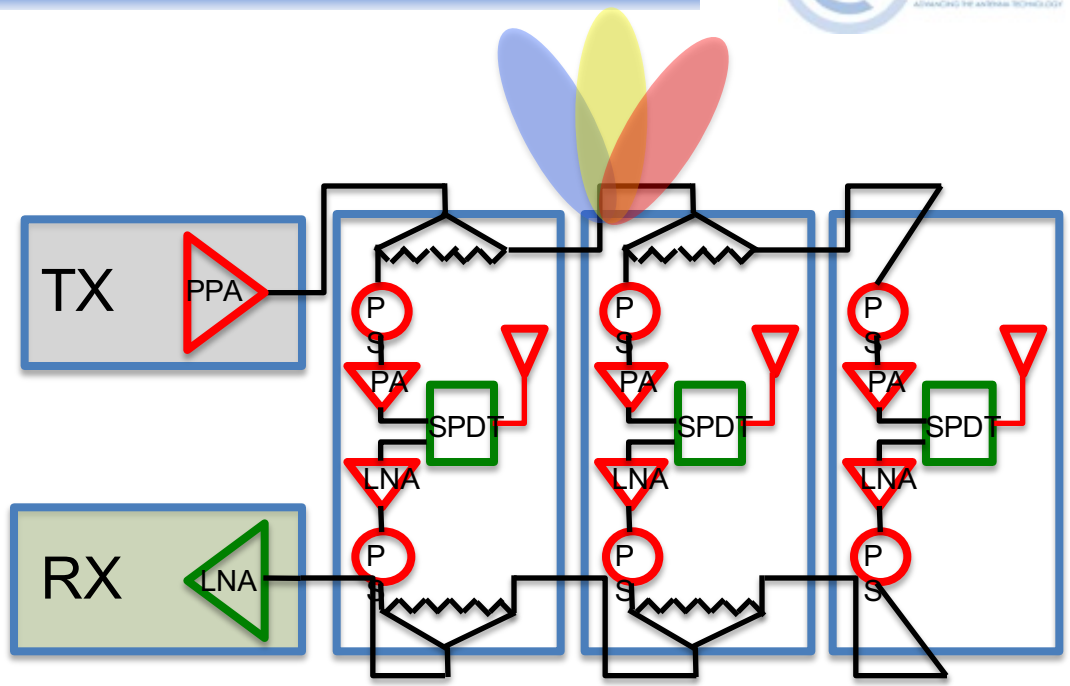
RECONFIGURABLE ANTENNA



	Multi pattern	Multi polarization	Multi frequency	Simple design	Cost
Reconfigurable antenna	✔	✔	✔	✖	✖
Standard antenna	✖	✖	✖	✔	✔

Reconfigurable antennas vs phased arrays





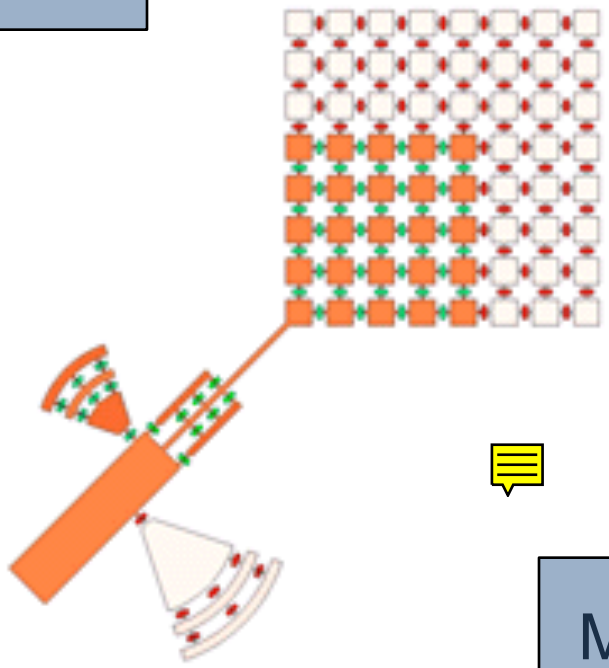
	Multi pattern	Multi polarization	Multi frequency	Simple design / Cost	Compactness
Reconfigurable antenna	✔	✔	✔	✔	✔
Phased array	✔	✖	✖	✖	✖

Main challenges

Minimize losses
- MEMS
- integrated CMOS

Maximize reconfigurability:
- pattern
- polarization
- frequency

Constant input impedance



Miniaturization

Simple DC bias

Outline

- What is a reconfigurable antenna?
- Types of reconfigurable antennas
  - Frequency
  - Polarization
  - Pattern
  - Compound
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Target applications

WIRELESS NETWORKING

MOBILE INTERNET

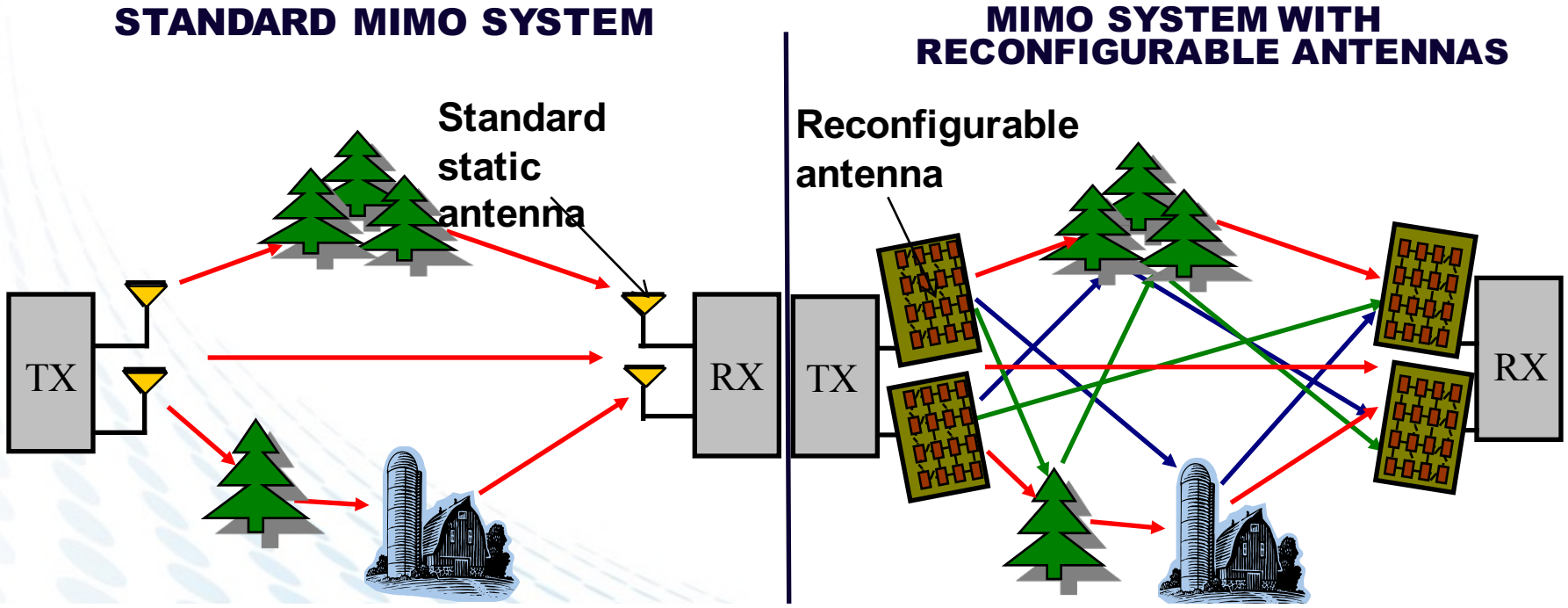
IoT/M2M

Wireless ISP

RFID

MIMO systems – adaptive antennas

The best wireless communication channel between TX/RX antennas is carefully selected among the large set of channels that can be generated by changing the antenna radiation patterns

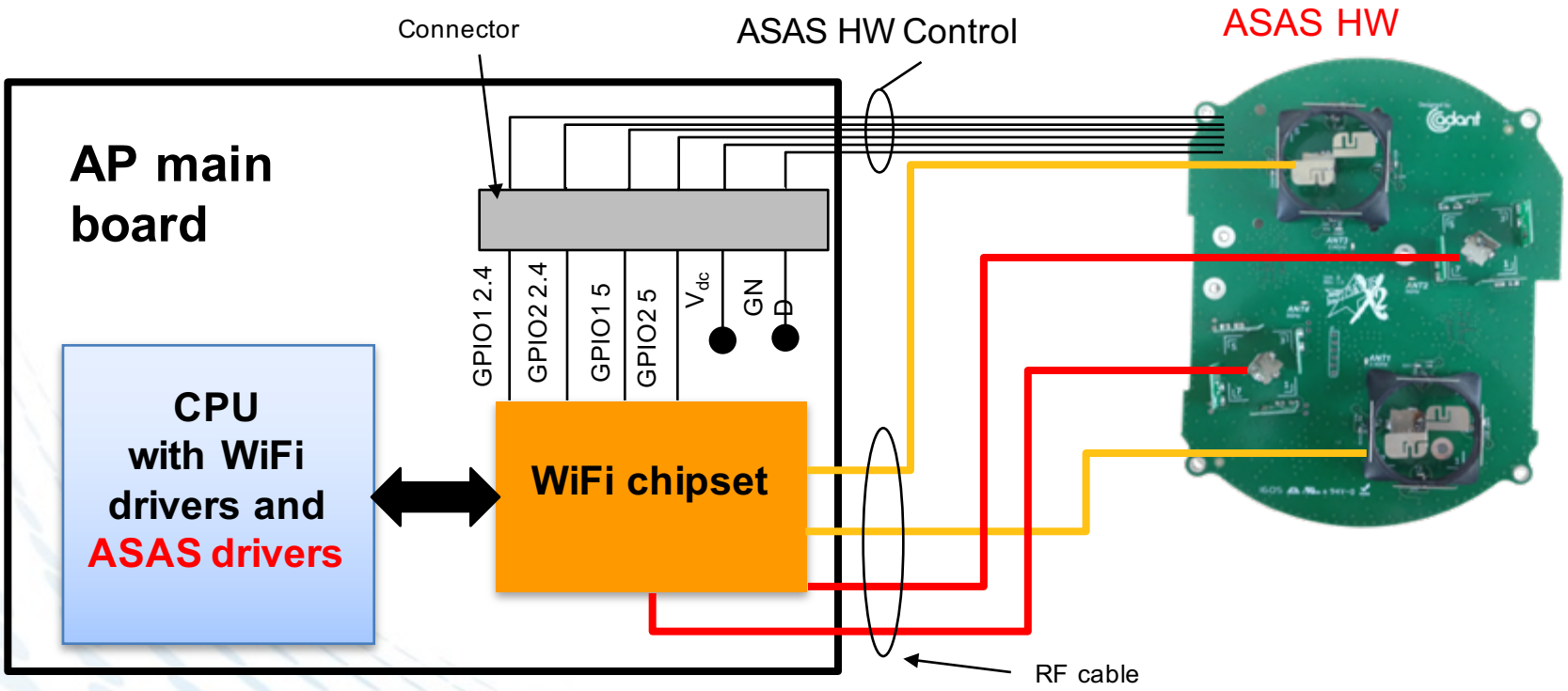


maximize channel diversity + SNR at receiver

suppress interference

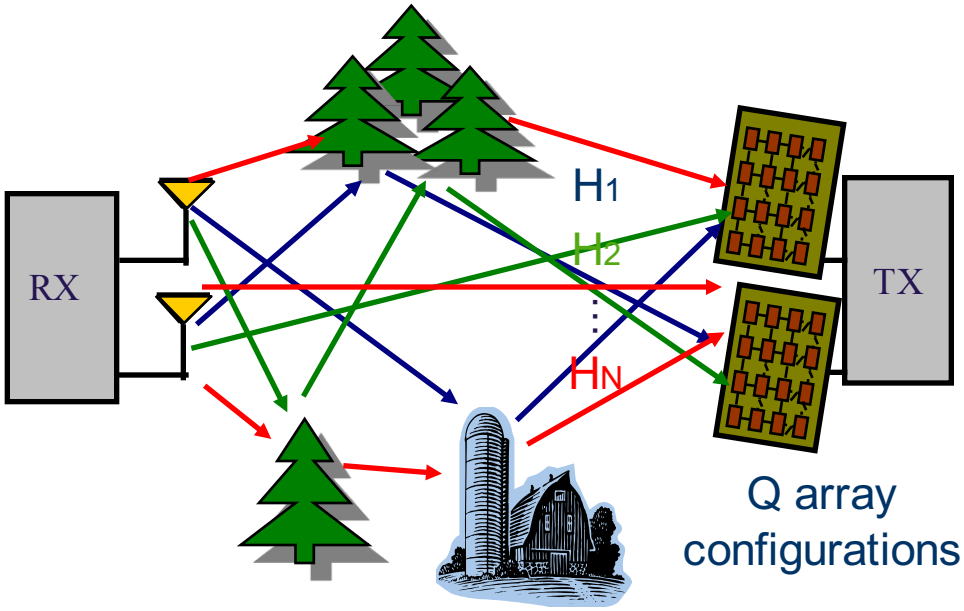
enhance pre-coding techniques

System Integration for Access Points



- Only two GPIOs needed for each band (2.4 and 5 GHz) to control the antennas
- Integrated with most QCA and Broadcom WiFichipsets

Maximum channel capacity



$$y = H x + n$$

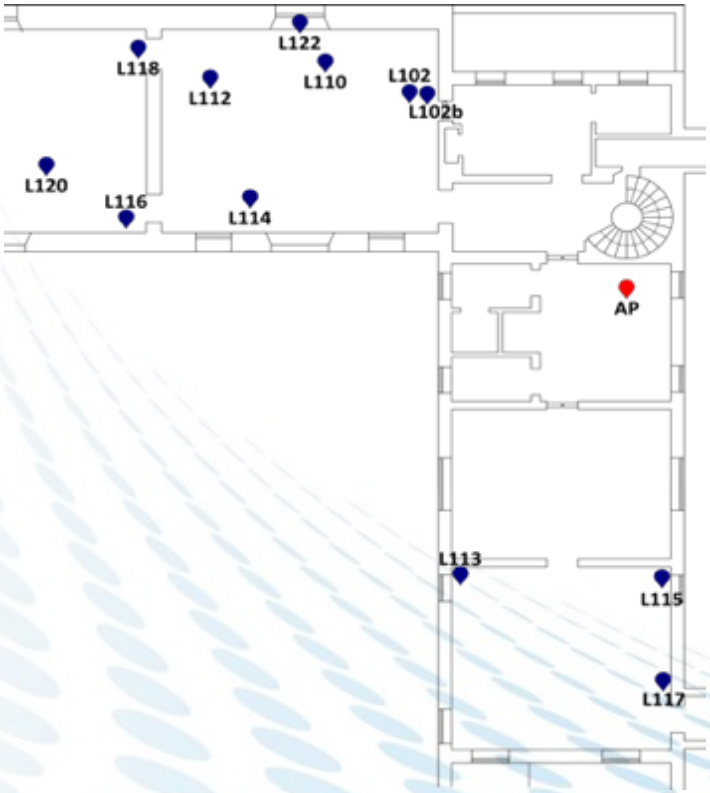
Optimal antenna selection

$$C = \max\left\{\log_2\left[det\left(\boldsymbol{I} + \frac{SNR_Q}{N_t}\boldsymbol{H}_Q\boldsymbol{H}_Q^*\right)\right]\right\}$$

Test setup

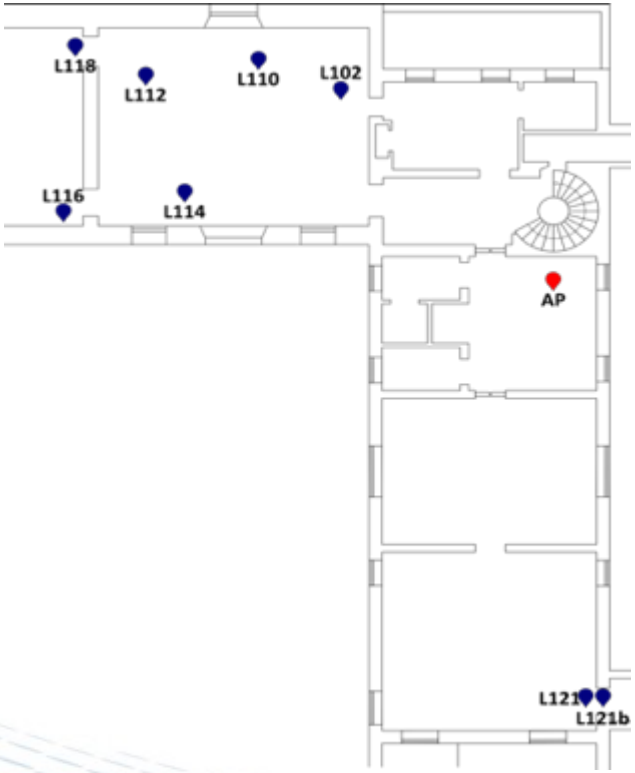
Indoor harsh environment with thick concrete walls

LOCATIONS AT 5 GHZ



7 m

LOCATIONS AT 2.4 GHZ



STARX3 and Link Speed

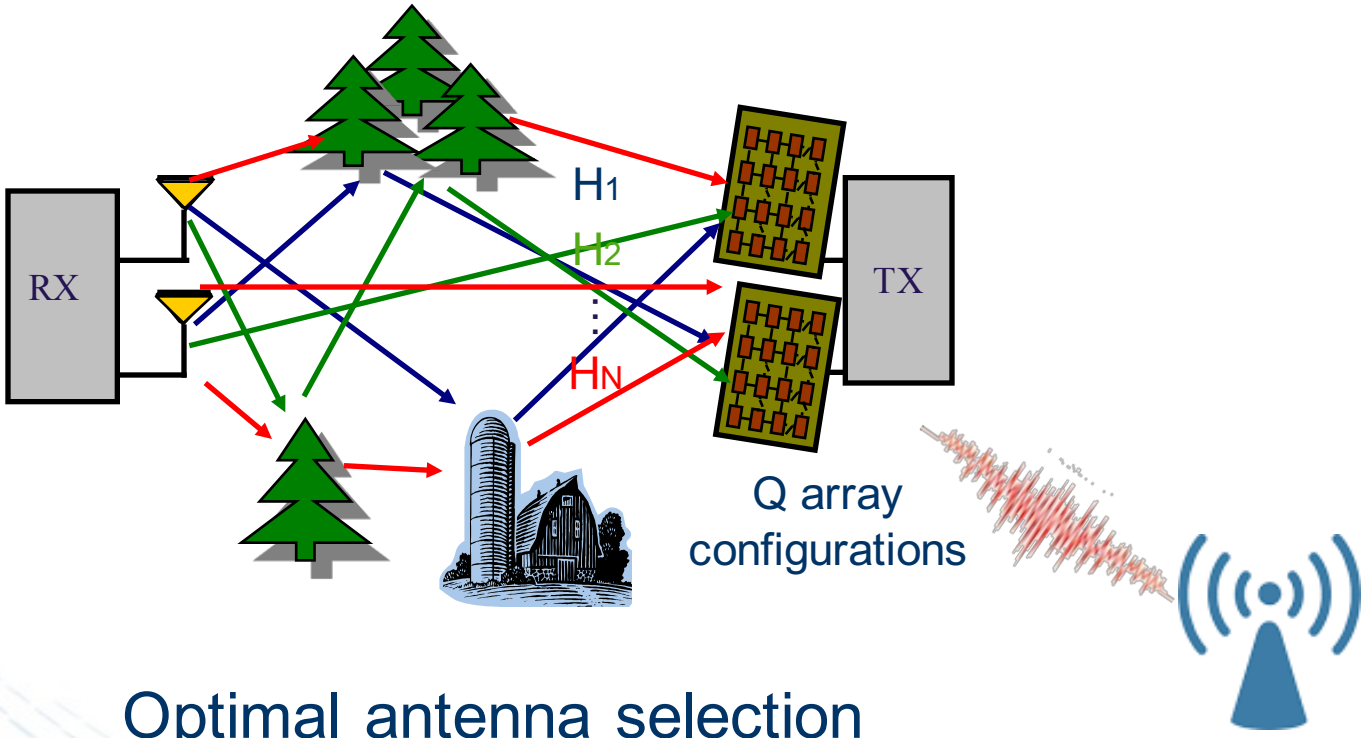
Adant STARX3 offers 30% faster link speed with respect to standard antenna systems

Adant

PIFA

Average Throughput Improvement vs. PIFA internal antenna				
	5 GHz		2.4 GHz	
	DOWNLINK	UPLINK	DOWNLINK	UPLINK
ALL THROUGHPUT RANGES	**1.31x**	**1.37x**	**1.37x**	**1.30x**
LOW THROUGHPUT	**1.54×**	**1.70×**	**1.89x**	**1.55x**
% OF TIMES ADANT OUTPERFORMS PIFA	**70%**	**65%**	**60%**	**75%**

Reconfigurable antennas for interference mitigation

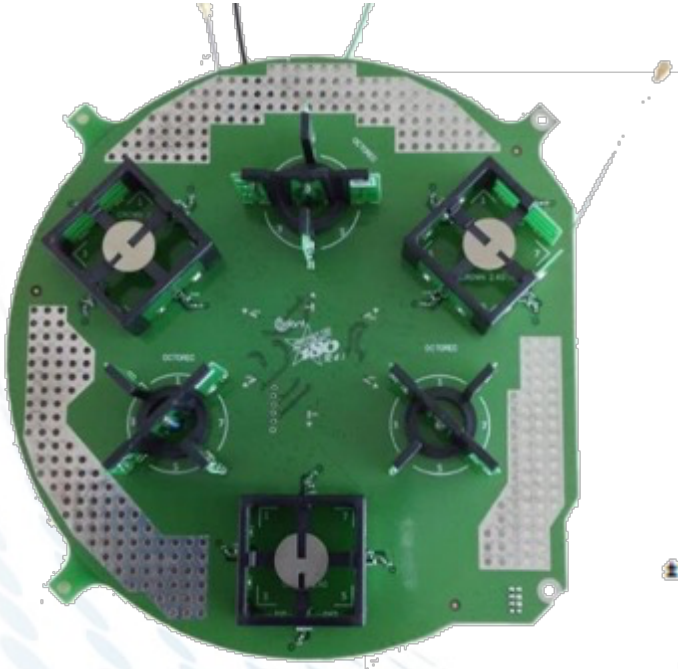


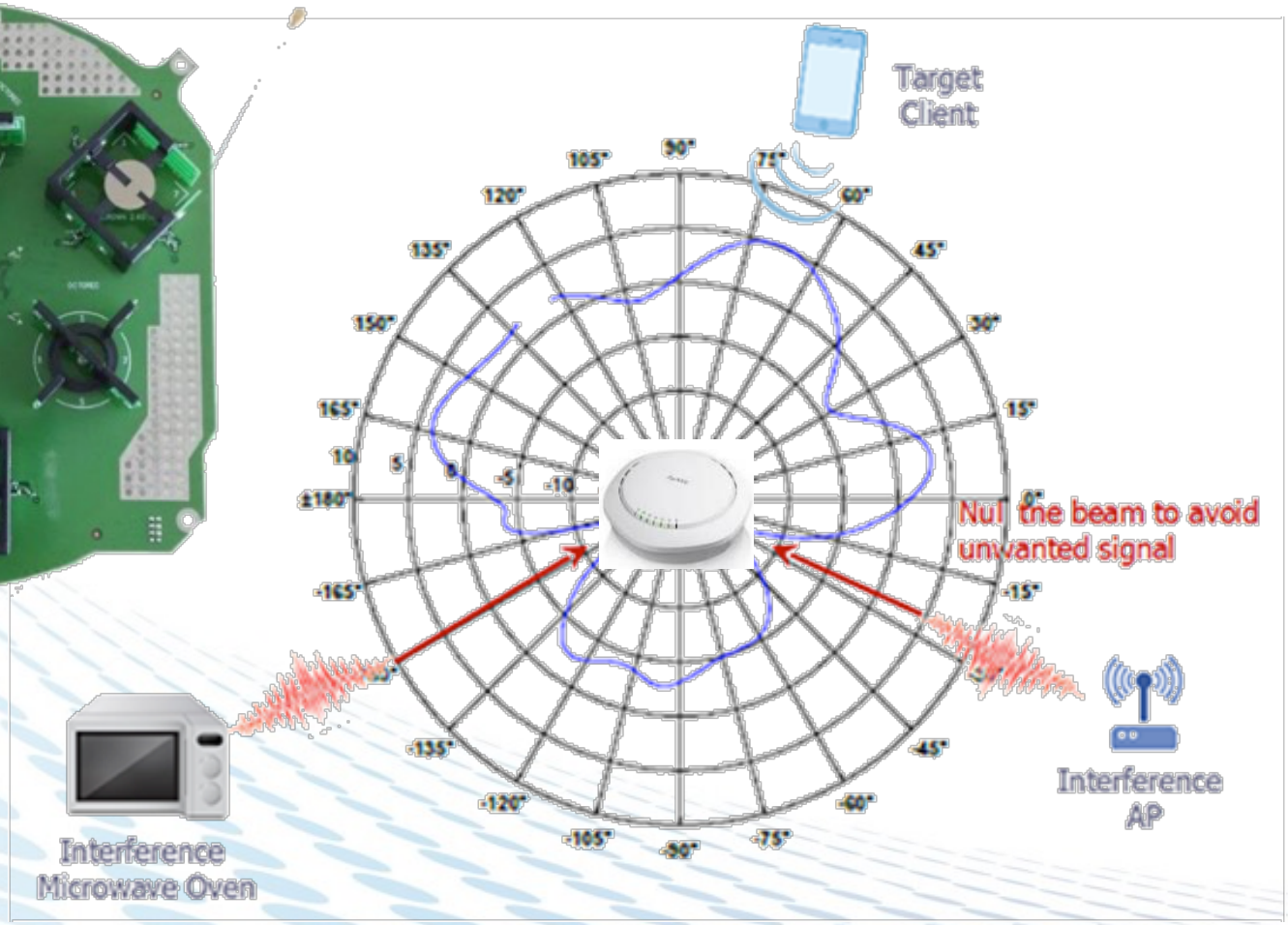
Optimal antenna selection

$$C = \max\left\{\log_2\left[det\left(\boldsymbol{I} + \frac{SNR_Q}{N_t}\boldsymbol{H}_Q\boldsymbol{H}_Q^*\boldsymbol{W}_Q^{-1}\right)\right]\right\}$$

Adant interference mitigation

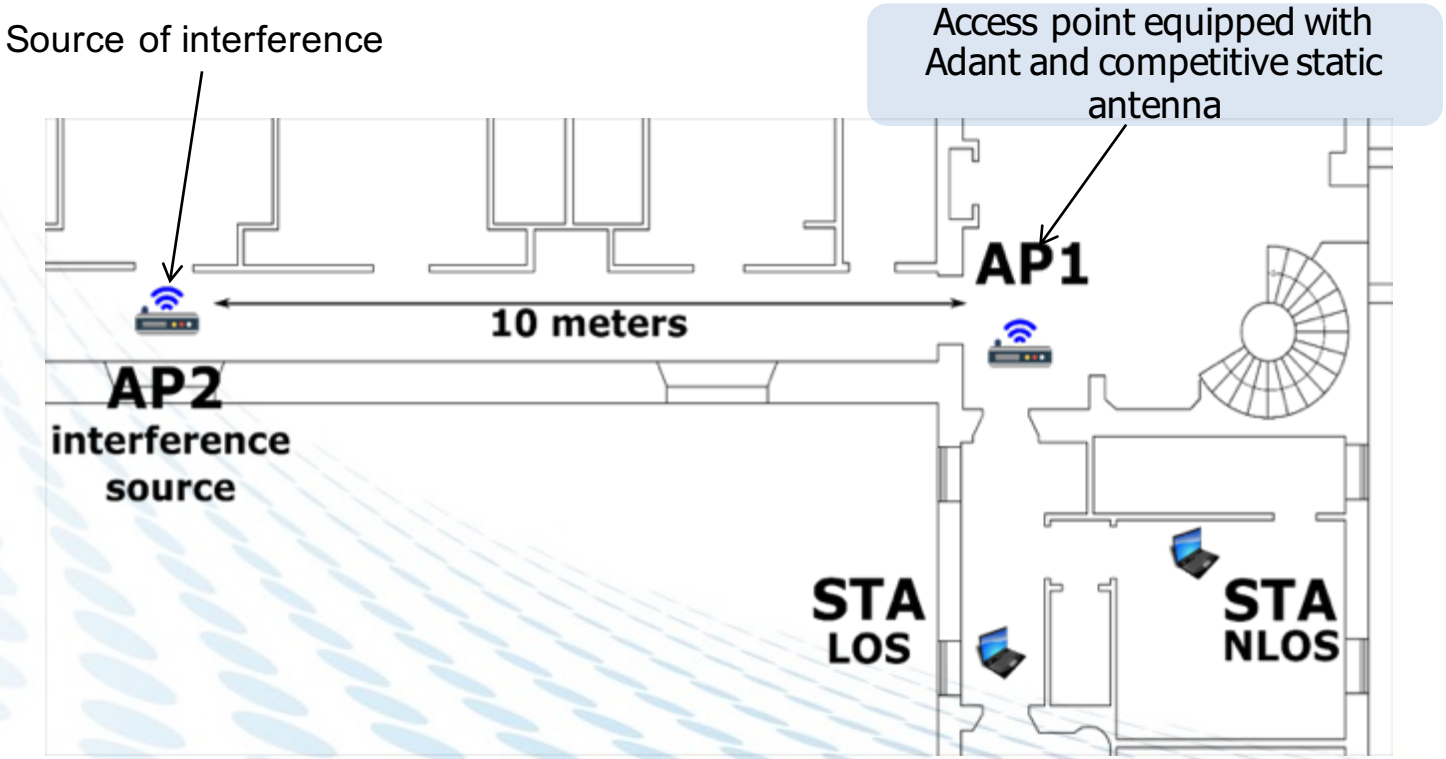
Dynamically change direction of radiation to maximize power at the receiver while minimizing interference





Interference mitigation – setup

- Indoor harsh environment with thick concrete walls
- STA placed in two different locations (LOS and NLOS)

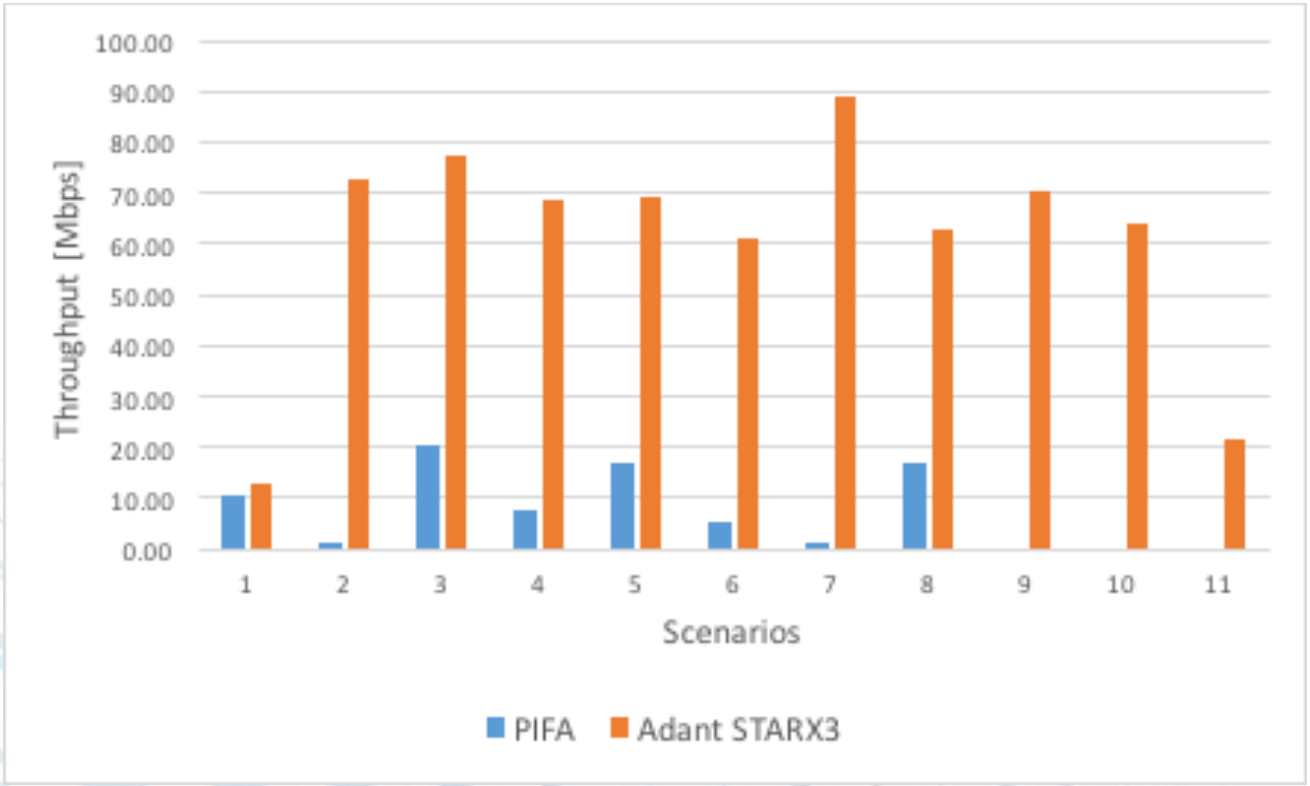


Interference mitigation

- Much Bigger WAP throughput gain with ASAS in presence of interference in the environment
- More than 5× median improvement (>10x average)

Adant

PIFA



ADVANCING THE ANTENNA TECHNOLOGY

Thank You