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WIRELESS INNOVATION FORUM™

FULLY RECONFIGURABLE FPGA-BASED COGNITIVE RADIO PLATFORM FOR RELIABLE COMMUNICATIONS

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OUTLINE

- Motivation
- Platform Description
  - Baseband Processing
  - RF Front-End
  - Antenna
- Measurements
- Conclusions and Future Work

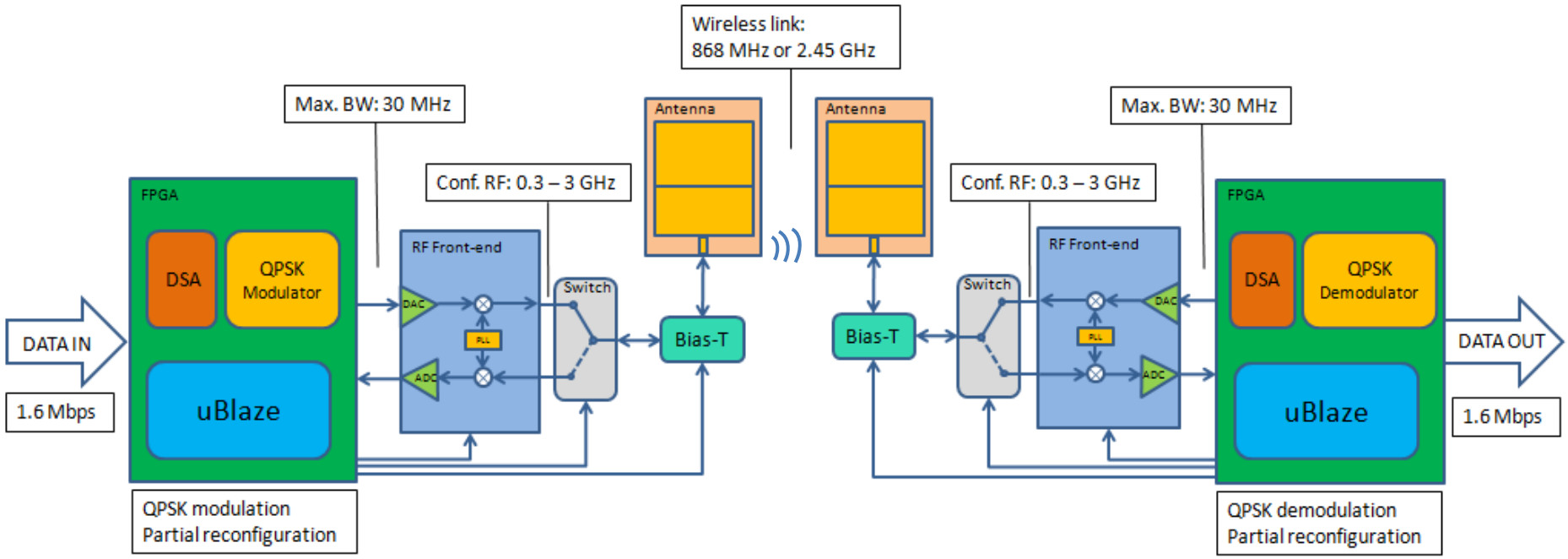
MOTIVATION

- New requirements in communications in industrial environments:
  - Bandwidth, size, compatibility, update capability, cost, robustness, no-new-wires...
- New technological possibilities
  - Software Defined Radios (SDR), Cognitive Radios, FPGAs, DSA... [1]
- Typical issues
  - Wide band interferences, multipath fading, attenuation...

A fully reconfigurable platform is required

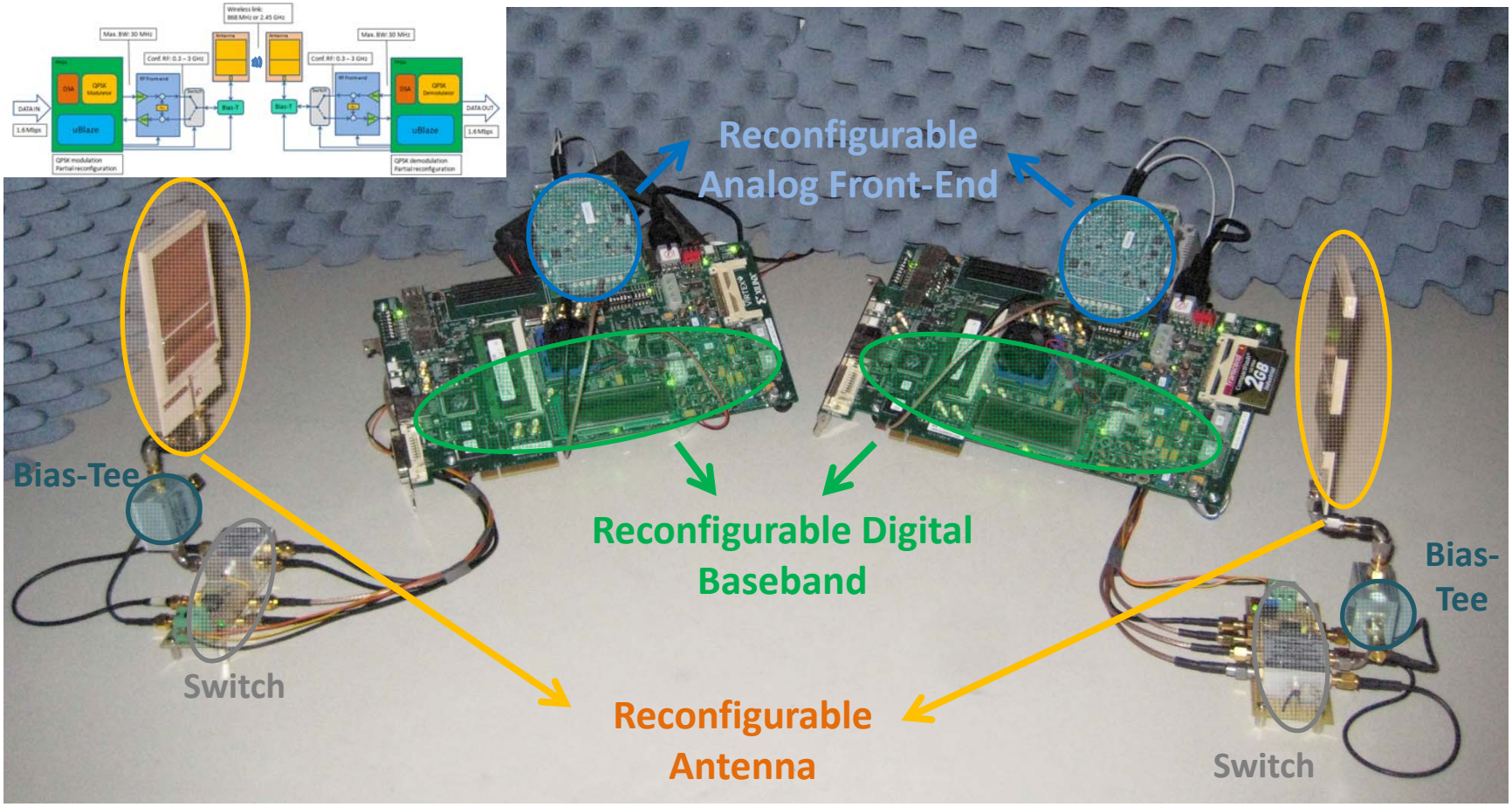
[1] Torrego, R., Val, I., and Muxika, E.: "Small-form-factor cognitive radio, implemented via FPGA partial reconfiguration, replacing a wired video transmission system" SDR13, Washington

PLATFORM DESCRIPTION



- Basic characteristics:
  - QPSK modulation
  - 1.6 Mbps
  - F: 2.45 GHz or 868 MHz
  - FPGA with partial reconfiguration
  - Reconfigurable Front-end
  - Reconfigurable Antenna

PLATFORM DESCRIPTION



PLATFORM DESCRIPTION

- Baseband processing
  - FPGA based (Xilinx Virtex 6)
  - Tasks
    - Data modulation/demodulation (Baseband or Low IF)
    - Dynamic Spectrum Access
    - Front-end and Antenna control
  - Use of Dynamic Partial Reconfiguration
    - In-band channel changes (< 10 MHz)
    - Any other change (modulation, waveform...)
  - Use of rapid prototyping tools
    - System Generator

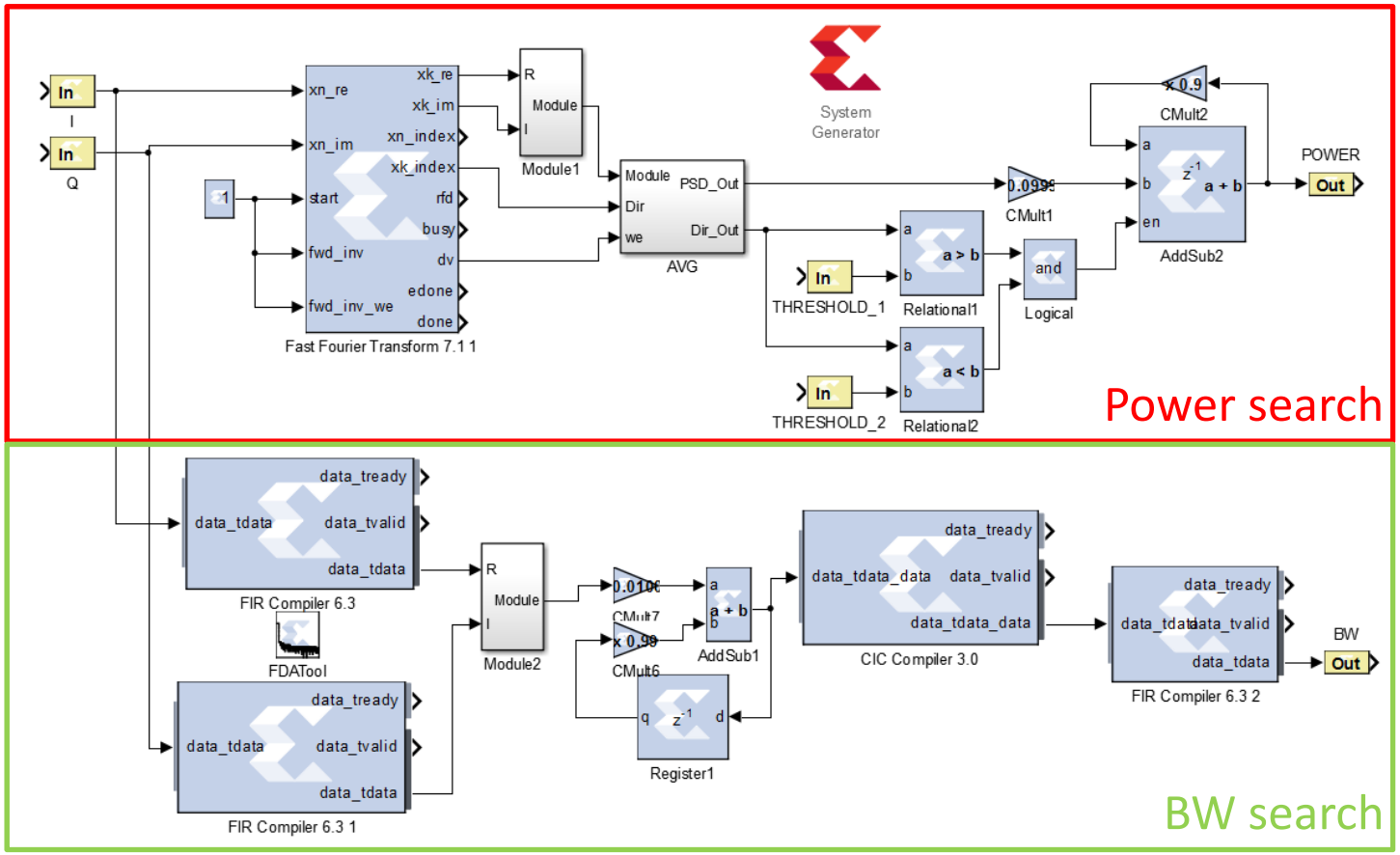
PLATFORM DESCRIPTION

- Baseband processing
  - Dynamic Spectrum Access
    - Transmission
      - Look for channel availability
        - » Free ⟶ Transmit
        - » Occupied ⟶ Look for new in-band (<10 MHz) channel
          - Free ⟶ Change to new channel (FPGA reconfiguration)
          - Occupied ⟶ Change to new band (Front-end and antenna reconfiguration)
    - Reception
      - Look for correct transmitted signal (BW based search)
        - » In-band search (FPGA reconfiguration)
        - » Change of band (Front-end and antenna reconfiguration)

PLATFORM DESCRIPTION

Baseband processing

- Dynamic Spectrum Access



PLATFORM DESCRIPTION

RF Front-end

- Nutaq Radio420S commercial front-end
- Characteristics:
  - Frequency: 300 MHz – 3 GHz
  - Bandwidth: 1.5 MHz – 28 MHZ
  - Output Power: from -21.5 dBm to 10 dBm
  - Sensitivity: -90 dBm @ (0.3 – 1.5 GHz)
    -103 dBm @ (1.5 – 3 GHz)

PLATFORM DESCRIPTION

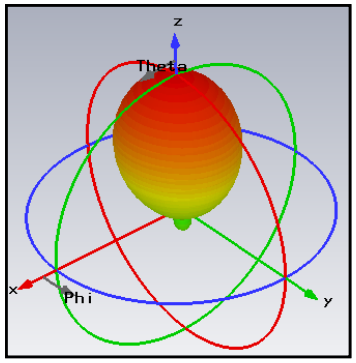
- Antenna:
  - Basic antenna parameters:
    - Return loss:

$$Z_i = R_i(w) + X_i(w)$$

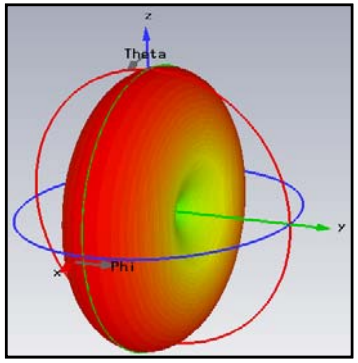
$$\Gamma = \frac{Z_i - Z_0}{Z_i + Z_0}$$

$$\mathrm{RL} = -20\log|\Gamma| \ (\mathrm{dB})$$

    - Radiation pattern:



Directional Pattern

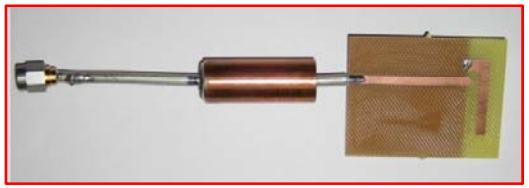


Omnidirectional Pattern

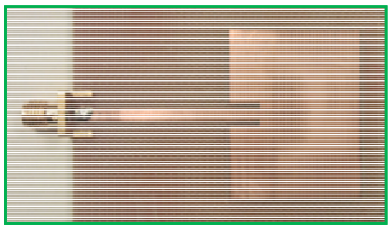
PLATFORM DESCRIPTION

– Antenna topology:

- Monopole-like:
  - Wide impedance matching
  - Omnidirectional radiation pattern



- Patch-like:
  - Narrow impedance matching
  - Directional radiation pattern



Performance in presence of metallic objects

→ High impedance variation

→ Significant reduction in the radiation efficiency

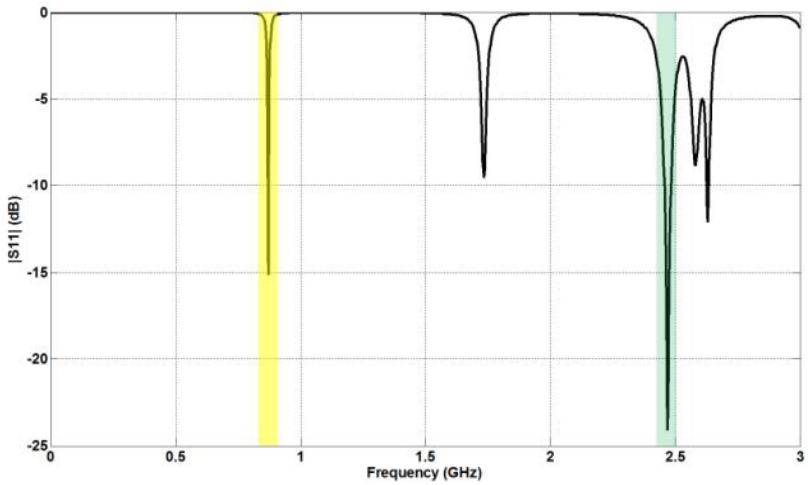
→ Slight impedance variation

→ No reduction in the radiation efficiency

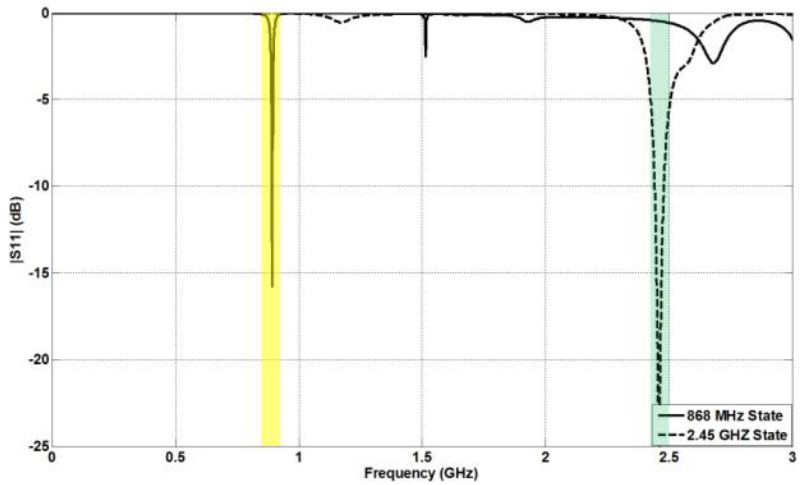
PLATFORM DESCRIPTION

- Reconfigurable vs Multiband Microstrip Patch-like antenna:
  - Impedance:
    - *Multiband antennas* cover both bands at the same time
    - *Reconfigurable antennas* cover the working band

EXTRA FILTERING



Multiband antenna

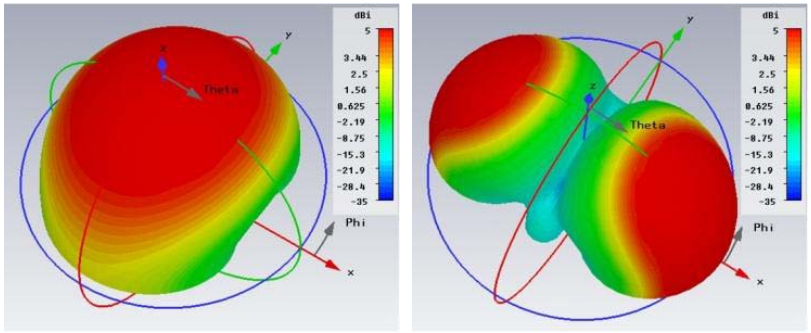


Reconfigurable antenna

PLATFORM DESCRIPTION

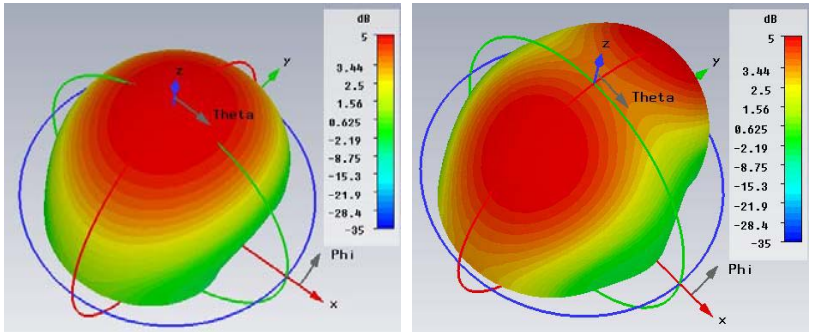
- Radiation:
  - *Multiband antennas*: different radiation pattern at both bands
  - *Reconfigurable antennas*: both radiation patterns alike

BETTER DISTANCE RANGE AND ALIGNMENT



f = 0.868 GHz **f = 2.45 GHz**

Multiband antenna



f = 0.868 GHz **f = 2.45 GHz**

Reconfigurable antenna

PLATFORM DESCRIPTION

- Antenna's features:
  - Reconfiguration : done by PIN Diodes
  - f = 868 MHz
    - Matching Bandwidth: 6 MHz
    - Radiation efficiency: 50 %
  - f = 2.45 GHz
    - Matching Bandwidth: 100 MHz
    - Radiation efficiency: 94 %

→ **Using a Reconfigurable Matching Network (RMN)**

		ISM 868 MHz	ISM 2.45 GHz
Antenna's PIN Diodes	#1	ON	OFF
	#2	ON	OFF
RMN's PIN Diodes	#1	OFF	ON
	#2	OFF	ON

MEASUREMENTS

– FPGA resources

	SLICE	Flip-Flop	LUT	BRAM	DSP48
Transmitter	7180 (20%)	13943 (4%)	14410 (4%)	97 (23%)	630 (82%)
Receiver	8834 (23%)	23902 (6%)	22765 (15%)	98 (23%)	368 (47%)

- Small-form-factor: 20-23% of FPGA resources

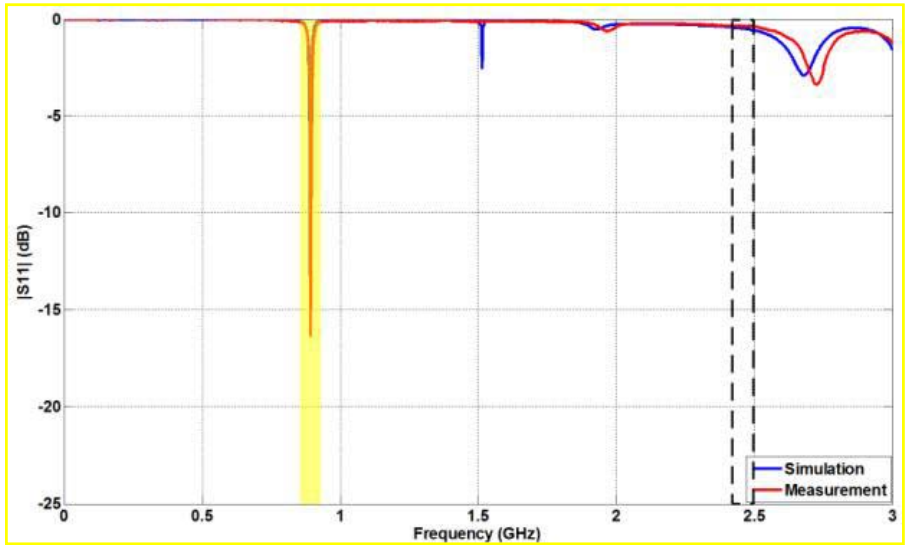
– Reconfiguration time

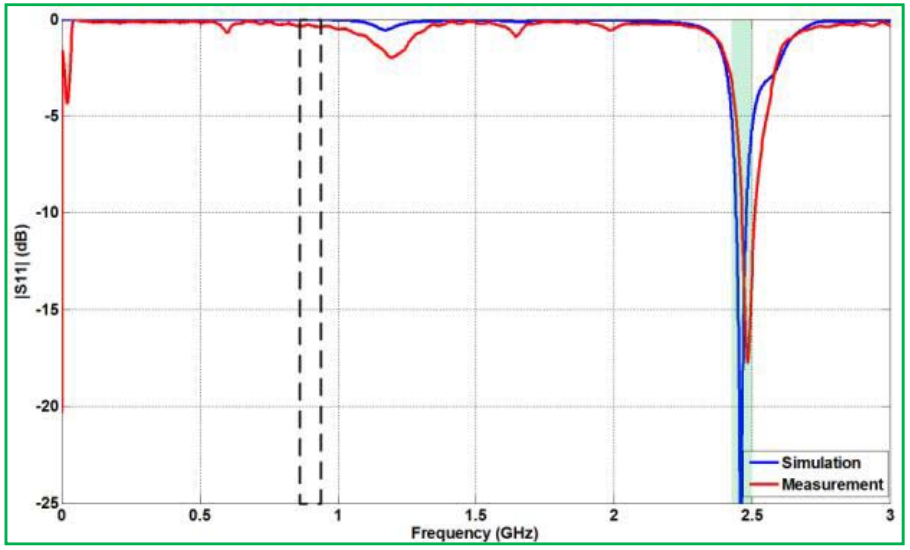
FPGA	Front-end	Antenna
94 µs	79 µs	53 µs

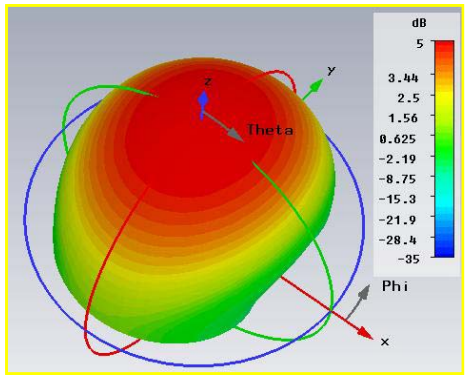
- In-band reconfiguration (only FPGA reconf.)
  - Slower but possible to reconfigure other characteristics
- Change of band (front-end and Antenna reconf.)
  - Faster

MEASUREMENTS

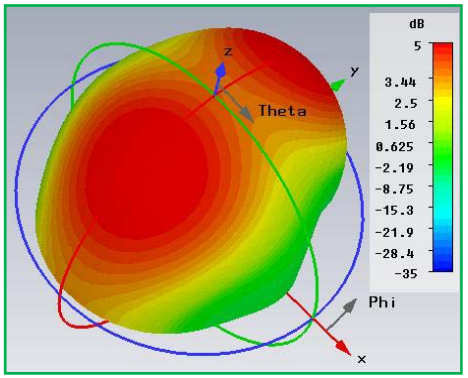
– Antenna's results:







		ISM 868 MHz	ISM 2.45 GHz
Antenna's PIN Diodes	#1	ON	OFF
	#2	ON	OFF
RMN's PIN Diodes	#1	OFF	ON
	#2	OFF	ON



CONCLUSIONS AND FUTURE WORK

- Conclusions
  - Fully reconfigurable cognitive radio platform presented
  - Necessity and feasibility of baseband, front-end and antenna reconfiguration demonstrated
  - PIN Diode-based frequency reconfigurable antenna features presented

- Future work
  - Improve DSA algorithm

QUESTIONS

THANKS FOR YOUR ATTENTION