PAR4CR: THE DEVELOPMENT OF A NEW SDR-BASED PLATFORM TOWARDS COGNITIVE RADIO

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Where innovation starts

Outline

- Introduction
- System Requirements
- Methodology
- System Analysis
  - General Architecture
  - Building Elements
- Discussions and Future work

Introduction. Par4CR: Consortium & Goal

ACADEMIA PARTNERS

- TU/e Technische Universiteit Eindhoven University of Technology
- ESIEE ENGINEERING
- ITE Instytut Technologii Elektronowej, Al. Lotników 32/46, 02-668 Warszawa
- TNO

KNOWLEDGE EXCHANGE

INDUSTRY PARTNERS

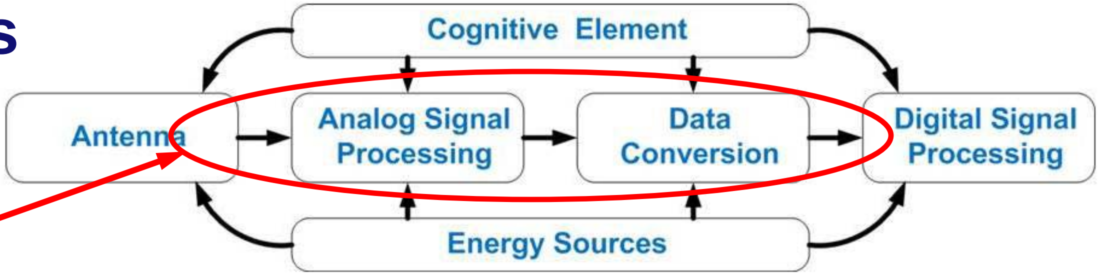
- NXP
- IMST
- CATENA

GOAL

Implementation of available SDR and CR **knowledge** and **technologies** in order to achieve the **best performance** on the stage of ***flexible*** system in the **heterogeneous** wireless environment.

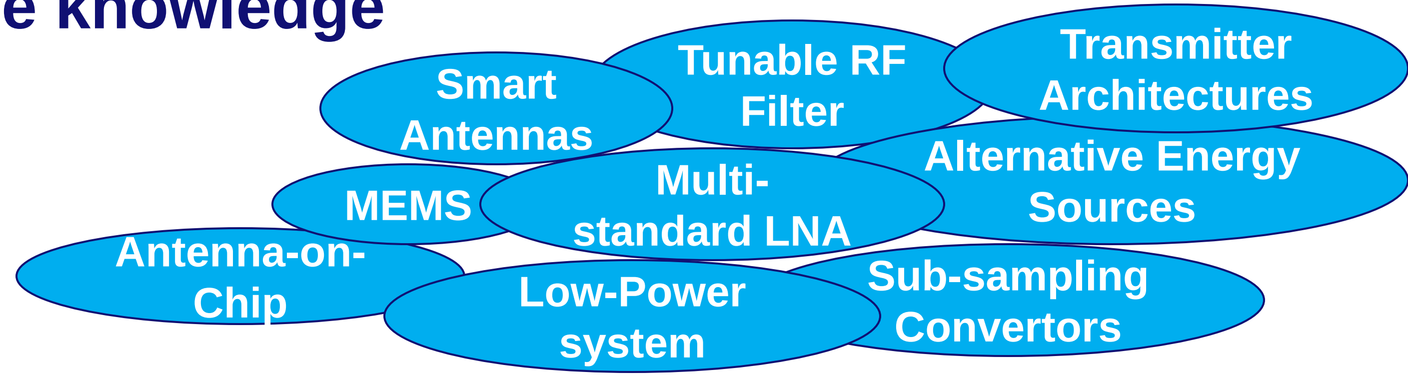
Introduction. Strategy

Define main focus points



Main area of partners expertise

Analyze available knowledge



Apply these knowledge on the system skeleton

Evaluate system performance accordingly

FOM_1, FOM_2 … FOM_N

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System Requirements

Definition of the Cognitive Transceiver:

A Cognitive Transceiver is a flexible radio system that transmits and /or receives (and fully processes) a number of ***N*** *wireless links in a wideband frequency range, and performs the cognition of the frequency spectrum environment in order to adjust itself accordingly*

Flexibility related

- Modulation type
- Bandwidth
- System selectivity
- Noise figure
- Gain

Cognitivity related

- Sensing time
- Modulation type and order
- Pulse shaping
- Packet format
- User identification
- Direction/angle of arrival

System Requirements. Overview

- **Wireless Radio technologies:**
  - Broadcast DAB, DVB, DECT;
  - Cellular GSM900/1800, UMTS/LTE;
  - Data and connectivity IEEE 802.11, 15.3, 16;
- **User Equipment → size and power matter**
  - Max TX Power 33 dBm
  - Lowest Sensitivity -117 dBm
  - Widest Allocated BW 400 MHz
  - Frequency range from 174 MHz to 5850 MHz

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Methodology

- Results from knowledge exchange integrated into generic/abstract system level model
- Merging top-down and bottom-up approach

System modeling via behavioral functionality description and general architecture selection

Detailed studies on the particular elements within available knowledge from the partners

Optimization tasks: best performance & low power

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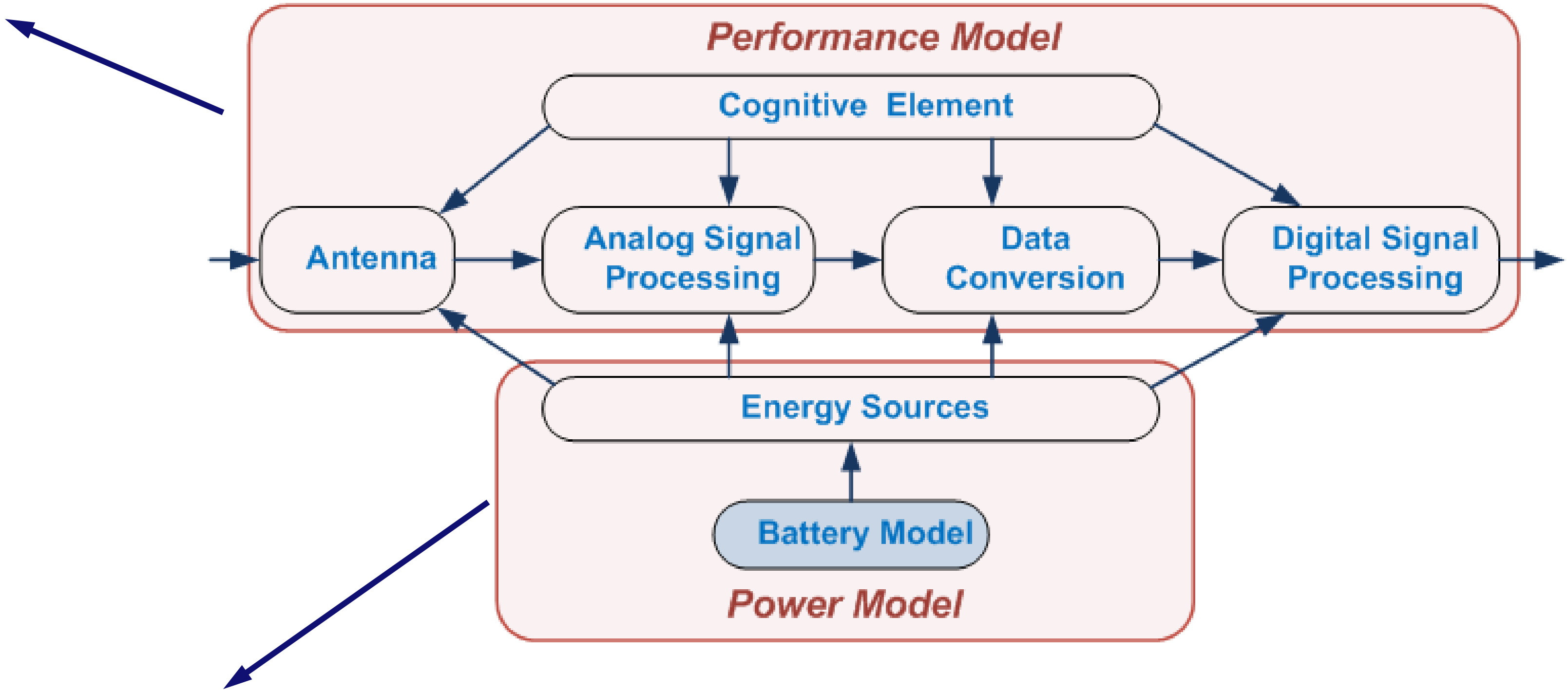
Methodology. System modeling

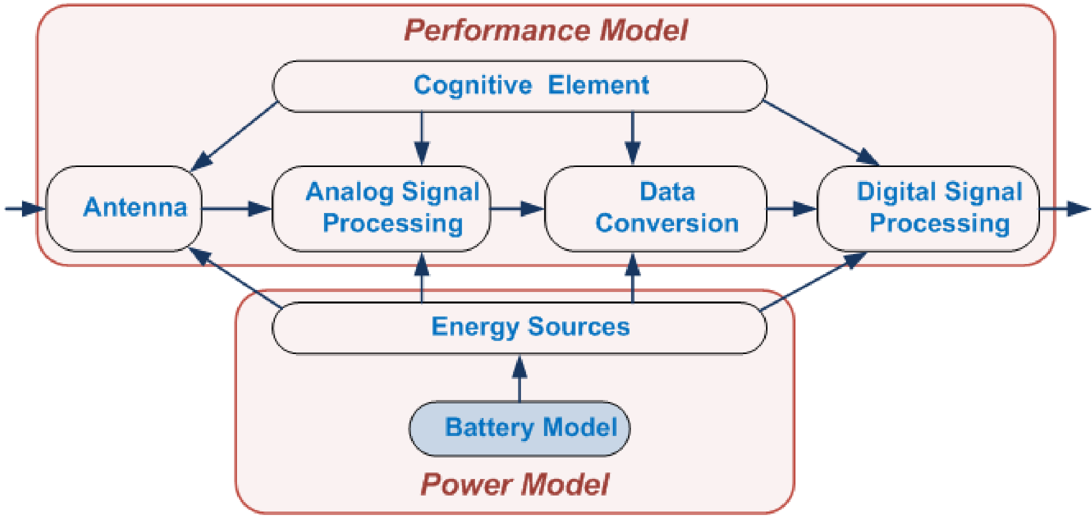
Takes into account all issues related to the general system performance optimization



- Responsible for the best power configuration according to the chosen environment/system parameters
- Valuable for mobile terminal

Methodology. System modeling

Antenna Model
- General design parameters
- Specific antenna parameters



Analog Signal Processing Model
- Core of the model
- Passband behavioral modeling approach with complex scenario
- Common system specs

Data Conversion Model
- Main parameters
- System trade-off point

Digital Signal Processing Model
- Complex multi-engine architecture
- General processing parameters

Battery Model
- Operation modes consideration
- Elements modeling

Cognitive Element Model
- Connects to every element
- General parameters must be defined

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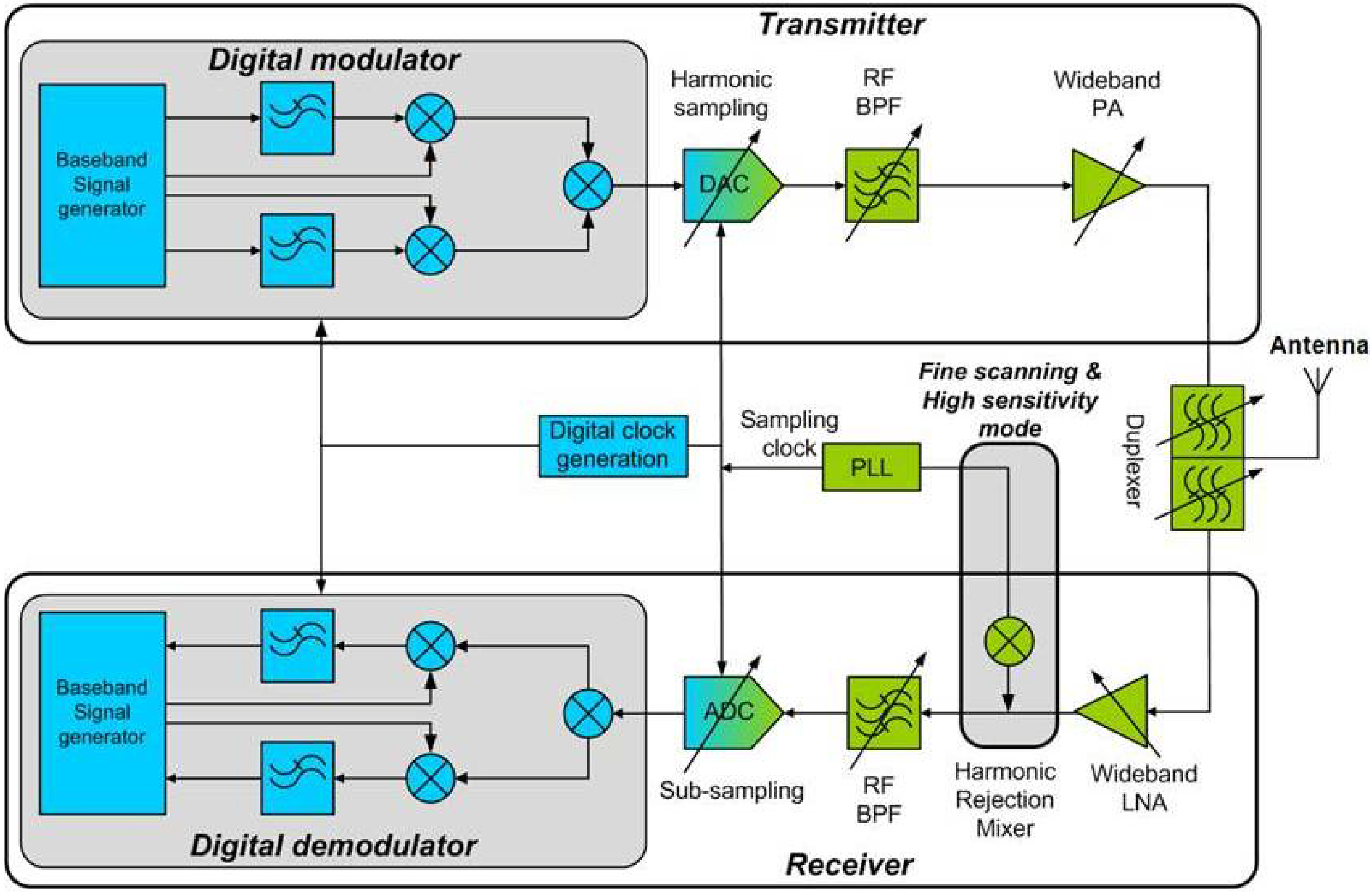
System Analysis

General Requirements:

- **Flexibility –** ability to process any required modulated signal
- **Agility –** obliges for the fast switching
- **Ruggedness –** robust response on power dynamics
- **Linearity –** critical in wideband multi-signal environment
- **Selectivity –** to relax convertors performance
- **Power efficiency –** no need to process unwanted signals
- **Sensitivity –** to recognize wanted signal in the noisy environment

System Analysis. General Architecture

Two modes system: Spectrum Sensing and Data Connection



System Analysis. Building Elements

Recently considered building blocks

- RF filters
- Flexible matching networks
- Antenna functionalities

Flexible Matching Networks

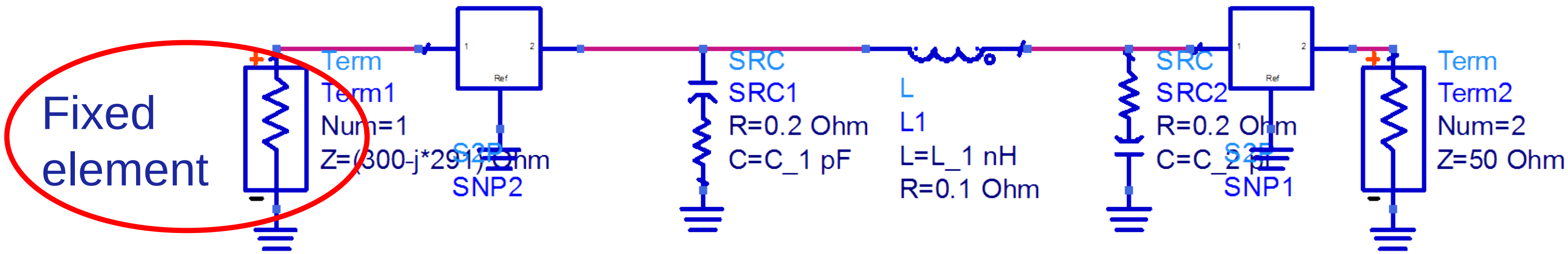
- To provide continuous matching of power for the transmitter side and impedance for the receiver side
- Guarantee high isolation between receiver and transmitter
- Available solutions: varactors, switches, capacitors, transmission lines
- Possible technologies: GaAs HEMT, SOI/SOS CMOS, RF MEMS, Ferroelectrics/BST, PIN diodes
- Main parameters for the design process: effective capacitance tuning range, control voltage, insertion loss, isolation, and linearity.

Diodes for the simulations

Parameters/Switch	SP4T PIN Diode	SPST PIN Diode	GaAs PHEMT MMIC (SPDT)
Frequency range	50 MHz – 26.5 GHz	1 MHz – 6 GHz	DC – 5 GHz
Insertion loss, dB	0.3@ 1 GHz 0.4@ 5 GHz	0.1@ 1GHz 0.85@ 5GHz	0.25@ 1GHz 1.1@ 5 GHz
Switching time, ns	50	1600	70 – 100
Isolation, dB	30@ 1G Hz 30@ 5 GHz	7.7@ 1 GHz 3@ 5GHz	25@ 1 GHz 11@ 5 GHz
Harmonics, dBm	40@ 500 MHz	37@1.8 GHz	56@825 MHz

Acknowledgment to IMST and particularly to Tassilo Gernandt who has performed simulations during his exchange program between IMST and TU/e

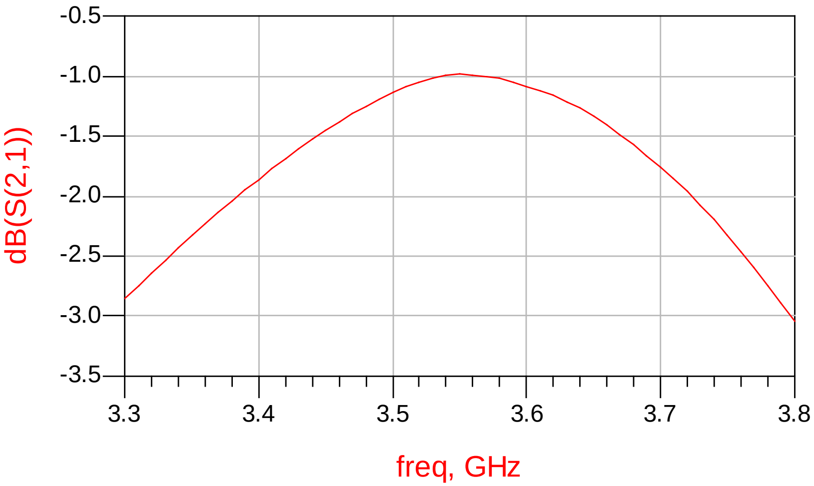
Possible FMN Architecture. PI-case



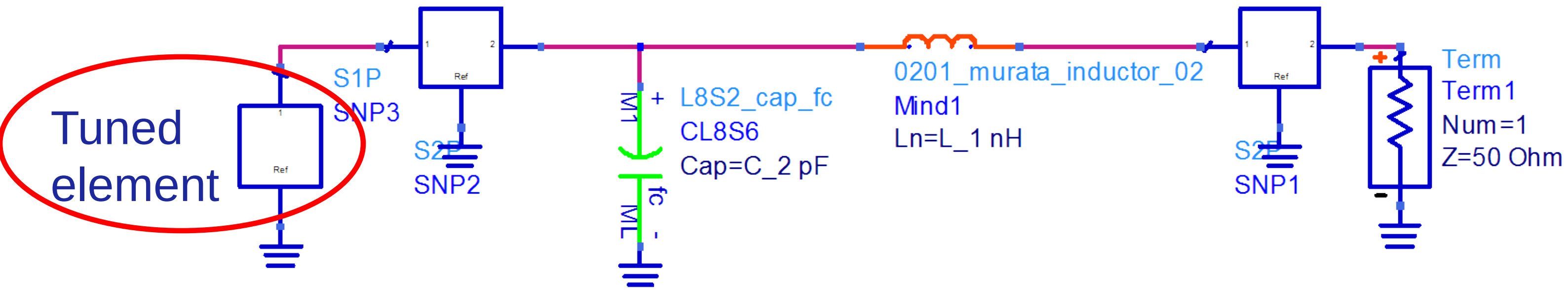
S21 for Complete coupling Element

Type	GSM	WLAN
SPDT	-2.3 dB@1.850 GHz	-1.823 to -1.845@ 2.4 to 2.485 GHz
SP4T	- 1.93 dB@1.850 GHz	-1.852 to - 1.886 dB @ 2.4 GHz to 2.485 GHz

SP4T switches for WiMAX



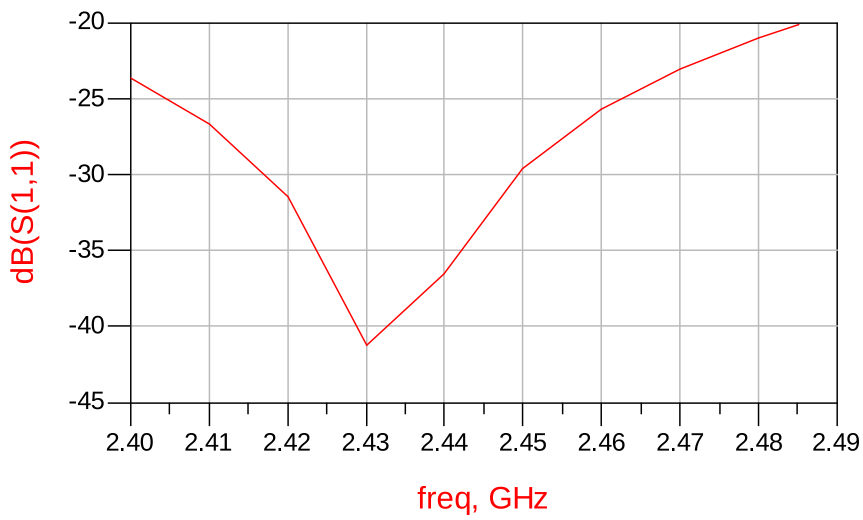
Possible FMN Architecture. L-case



Complete coupling Element

Type	GSM	WiMAX
SPDT	S11: -24 dB @1.850GHz S21: below -2 dB	S11: -8.8@ 3.48 GHz
SP4T	S11: -8.57 dB @1.850 GHz S21: below -2 dB	S11: -19.8@ 3.58GHz
SPST	S11: -7.4 dB @1.850 GHz S21:-1.4 dB @1.850GHz	S11: -9.8@ 3.55GHz

SPDT switches for WLAN



Filtering Requirements

From Multi-standard Architecture Point of view

- High output power handling at the transmitter
- High out of band rejection
- At some frequencies very short transition band
- High carrier frequencies
- High relative bandwidth
- Low insertion losses
- Integrated on-die
- Low cost

Cognitivity related

Flexibility related

- Limit the noise bandwidth
- Reduce requirements of other blocks in the architecture
- Prevent aliasing during the ADC process
- Relax power requirements of ADC (due to high dynamic range)

RF Filtering Technologies

- **LC Filters :**
  - Frequencies (< 3 GHz)
  - *(-) Limited quality factor*
  - (-) Size
  - Evolution CMOS-SOI (>Q)

- **Ceramic Filters :**
  - Frequencies (400 MHz – 6 GHz)
  - Low IL (1.5 dB – 2.5 dB)
  - Low cost
  - Power handling (< 5W)
  - *(-) Integration , Size ($f(\varepsilon_r)$)*

- **SAW Filters :**
  - Size
  - *(-) Frequency (< 3GHz)*
  - (-) Power (< 1W)
  - (-) IL (>2.5dB)
  - (-) Integration IC

- **BAW Filters:**
  - Significant band rejection (~40 dB)
  - Low IL (1.5 – 2.5 dB)
  - Frequency (< 12GHz).
  - Power handling (< 3W)
  - Integration "*above IC*" / Size reduction.

- **LTCC Filters :**
  - Low IL.
  - Frequency (< 10 GHz).
  - Size reduction
  - *(-) Integration process*
  - (-) Elements precision

SAW: Surface Acoustic Wave BAW: Bulk Acoustic Wave LTCC: Low Temperature Co-Fired Ceramic

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RF Filtering Technologies

Enhanced-Q Resonators

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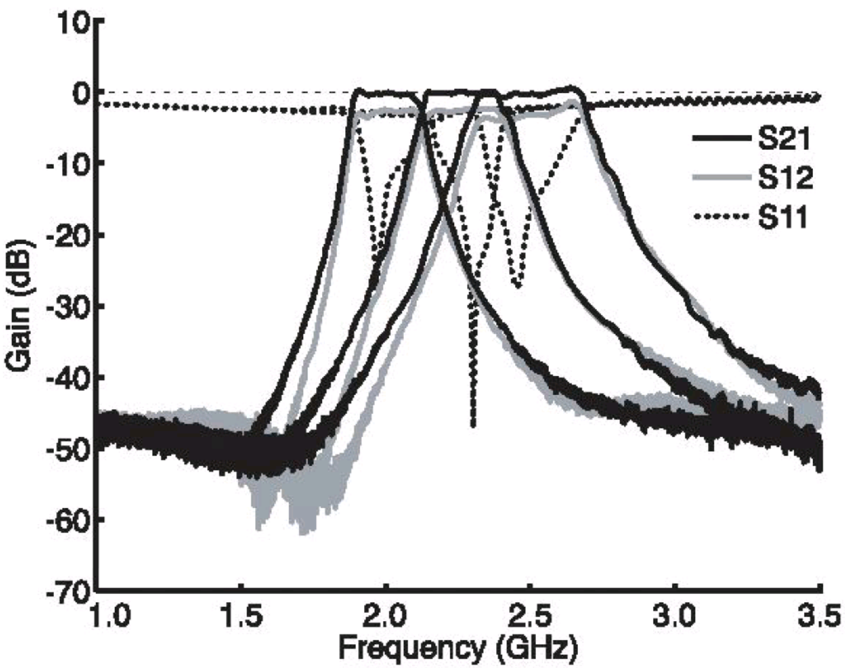
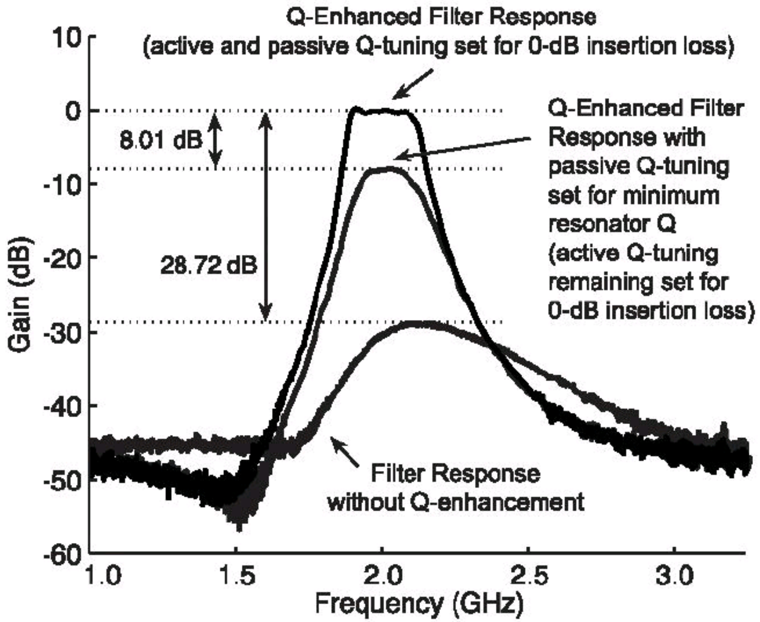
Perspectives on Filtering System

Examples of Q-Enhanced filters [1]



Filter Frequency Response Measurement

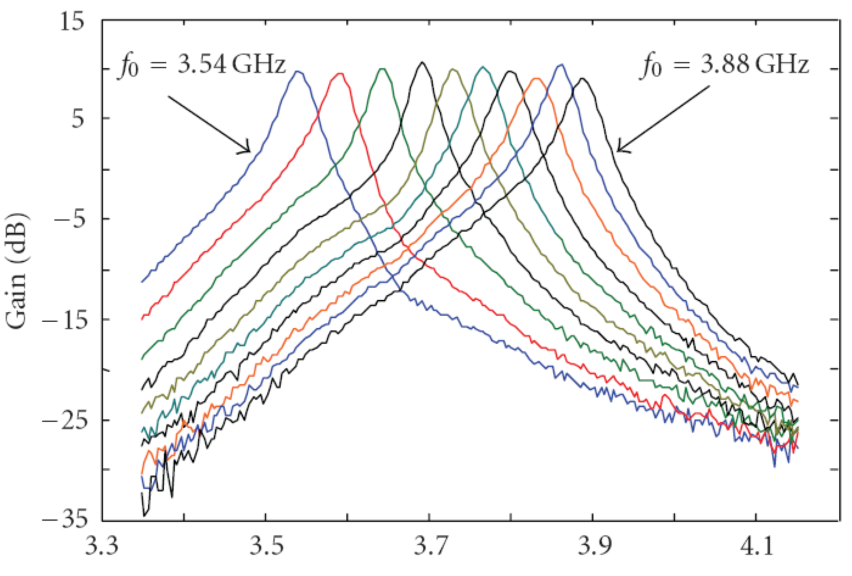


Measured Filter Response with Q-Tuning - active Q-tuning is held constant while passive Q-tuning is varied for the top two curves

Enhanced-Q resonators can be cascaded to form wide bandwidth filters and allow tuning in both center frequency and bandwidth.

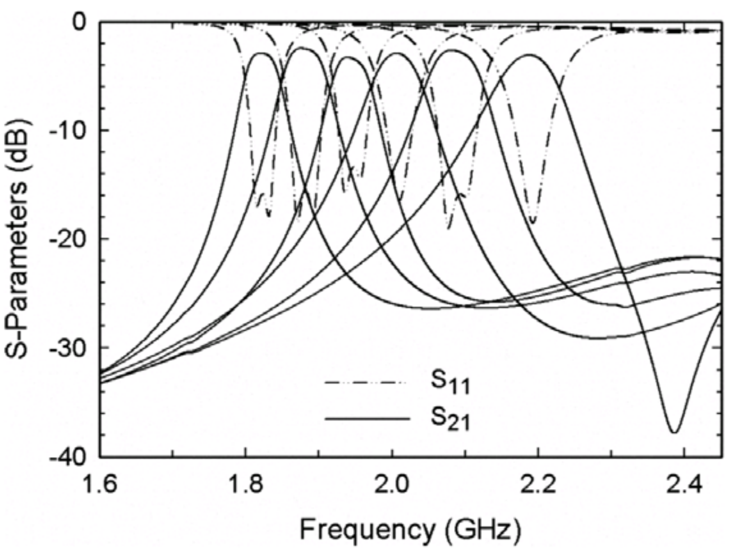
Perspectives on Filtering System

Example using LC RF CMOS [2]



Frequency tuning measurement.

Example using MEMs technology [3]



Simulated S-parameters for the proposed SIW RF MEMS tunable filter (tuning range: 1.8 – 2.2 GHz) tuning range.

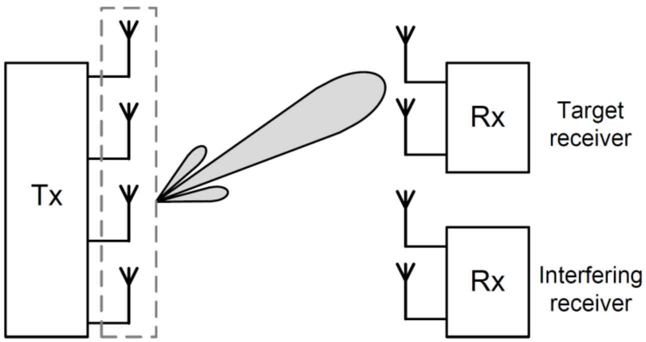
Antenna functionalities

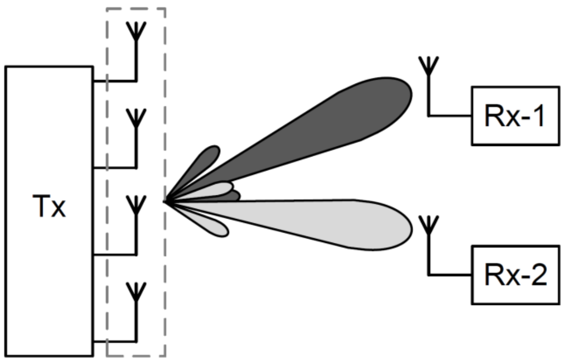
- **Interface to communications network**
- **Multi-mode characteristics**
  - **Operate in whole frequency range**
  - **Sufficient bandwidth and efficiency**

- **Support functionalities of multi-antenna techniques:**
  - **MIMO**
  - **Beamsteering**

Multi-antenna techniques

- Based on multiple antennas in array configuration
- MIMO and beamsteering foreseen in LTE specifications

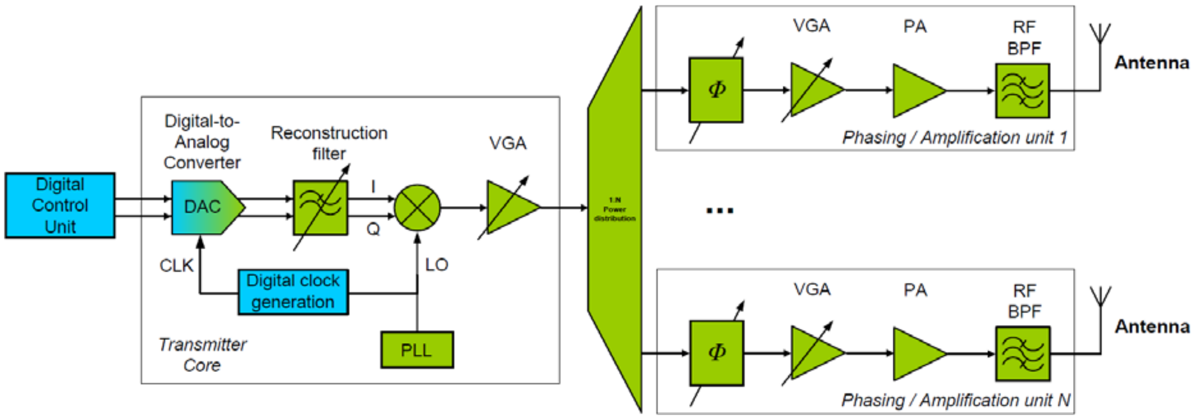




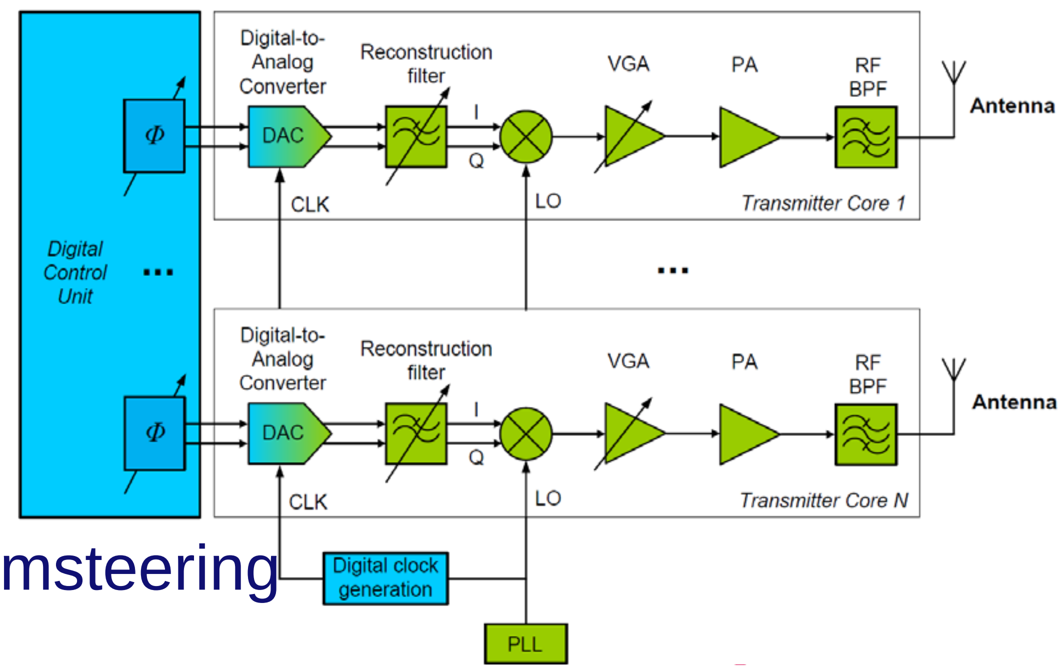
- Focus on beamsteering for base stations
- Benefits of beamsteering:
  - Interference reduction
  - Increased spectrum re-use (higher spatial density)
  - Lower radiated power
  - Reduced power requirements (distributed approach in architecture)

Beamsteering/beamforming for CR

Implications on TX architecture under investigation



RF beamsteering



Digital beamsteering

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Discussion

- Project overview: consortium description, main goals and strategy
- System requirements for the cognitive transceiver specified
- Overview of general system model
- Choice for possible architecture motivated
- Recent work presented through building elements descriptions

Future work

- **Precise specifications and requirements for the filters according to architectures**
- **Detailed study of the cognitive transceiver model**
- **Implementation of the system with available technologies**
- **Proof of concept through software simulations and some hardware demonstrations**

References

1. J. Nakaska, J. Haslett. “2 GHz Automatically Tuned Q-Enhanced CMOS Bandpass Filter”, Microwave Symposium, 2007. IEEE/MTT-S International, pp. 1599–1602, 03–08 June. 2007.
2. A. Dinh and Jiandong Ge. “A Q-Enhanced 3.6 GHz, Tunable, Sixth-Order Bandpass Filter using 0.18 um CMOS”, Hindawi Publishing Corporation. VLSI Design. Volume 2007, 9 pages. 2007.
3. Entesari K. Advanced modeling of packaged RF MEMS switches and its application on tunable filter implementation. 2010 IEEE 11th Annual Wireless and Microwave Technology Conference (WAMICON). 2010.

THANK YOU FOR YOUR ATTENTION!

ANY QUESTIONS?