Hardware Design of Spectrum Sensing Nodes for Collaborative Sensing Networks

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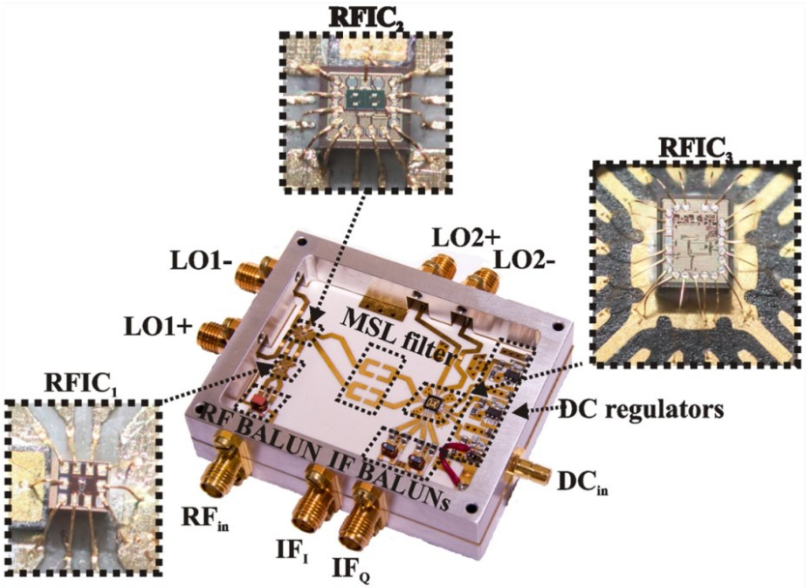
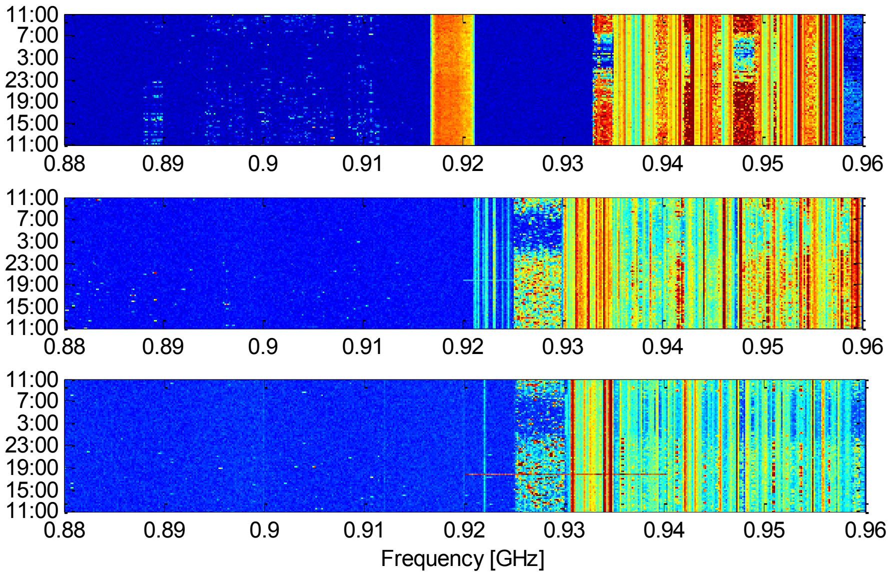


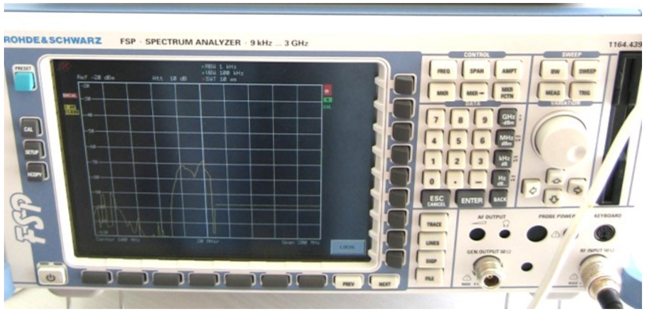


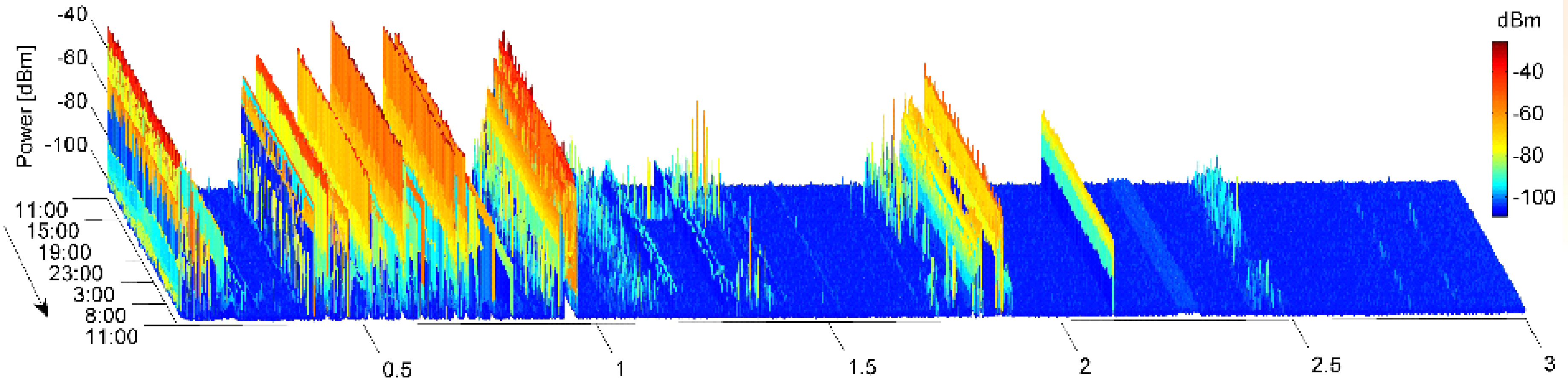
Outline

- Motivation
- DFG project overview
  - Collaborative spectrum sensing
  - Hardware implementation (RFIC + baseband)
  - Preliminary trials

Motivation

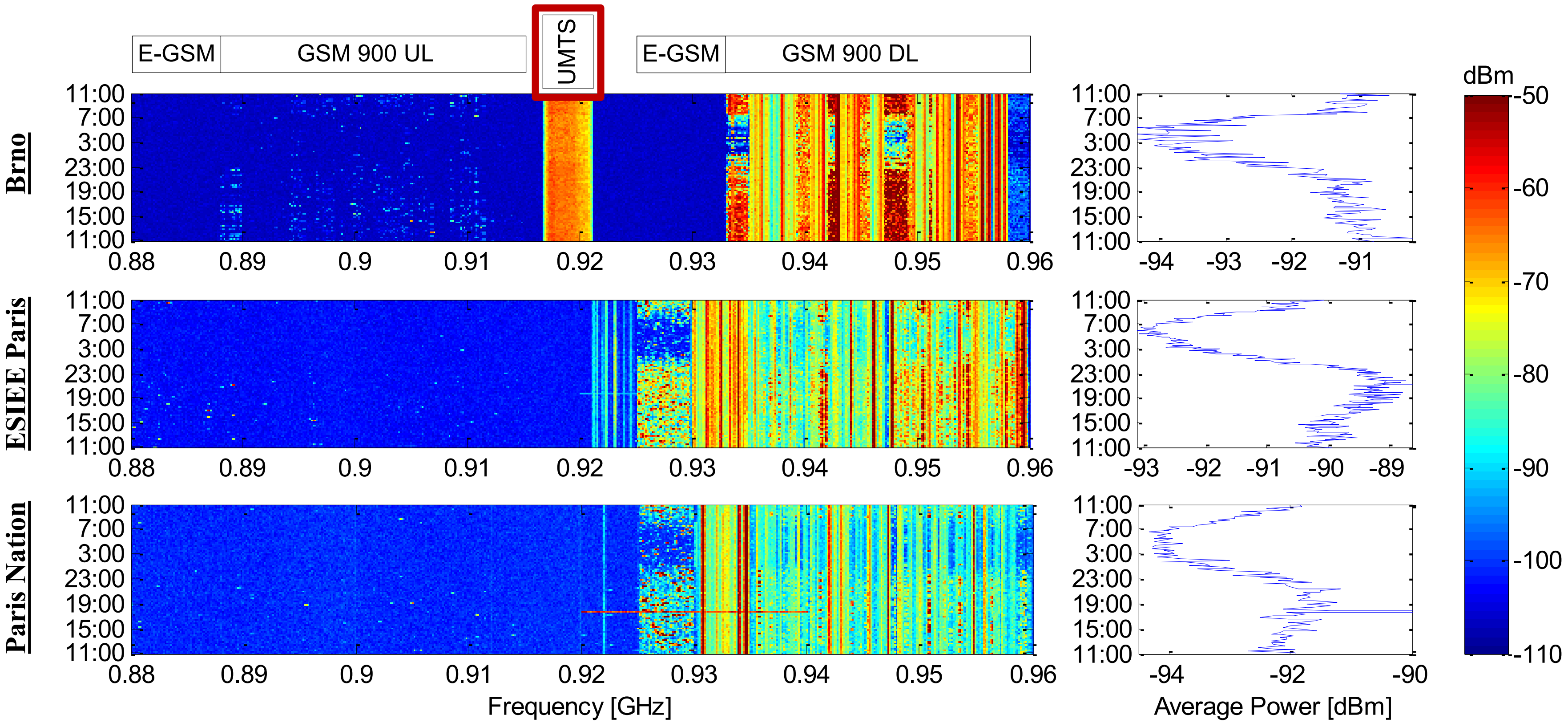
….you can't manage what you don't measure





* V. Valenta et al., Survey on spectrum utilization in Europe: Measurements, analyses and observations, IEEE CrownCom'10

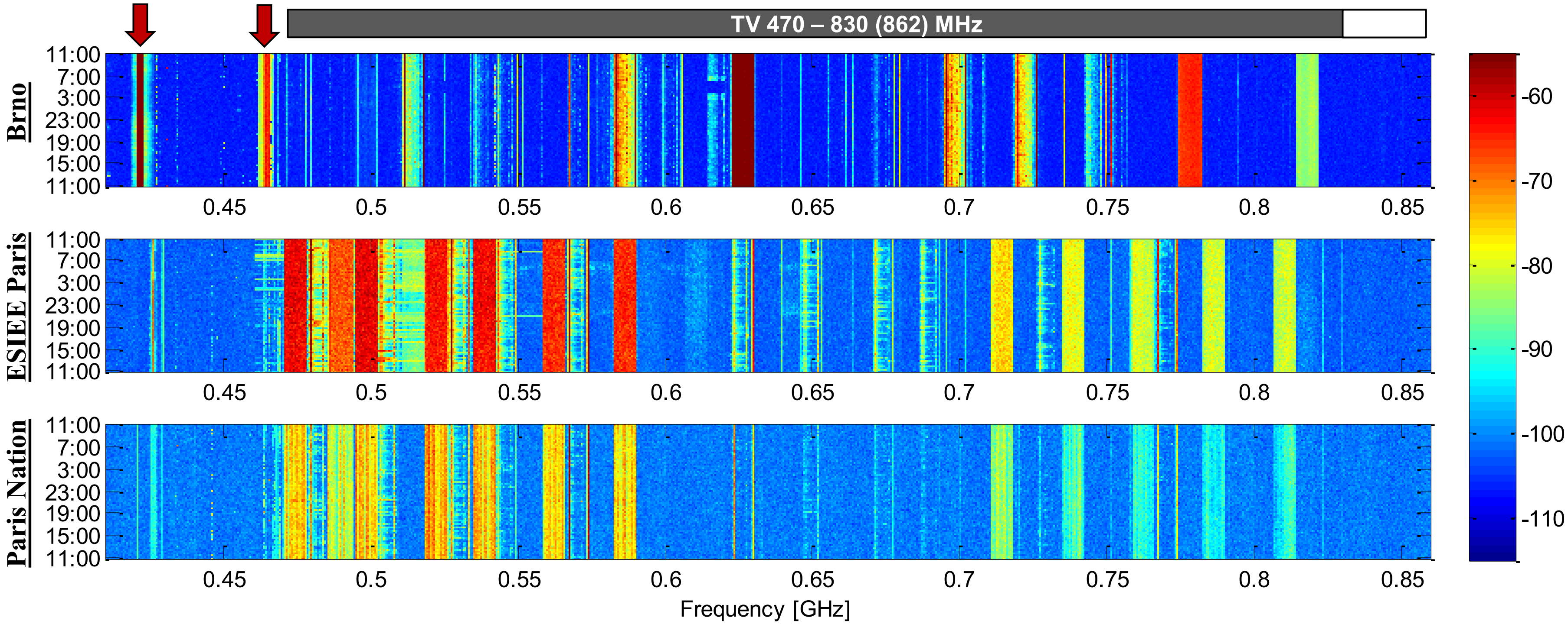
Motivation (cont'd)



Region	Frequency allocation [MHz]	Utilization [%]
No.1 Brno	E-GSM + GSM 900: 880 – 915 (UL) / 925 – 960 (DL) GSM 1800: 1710 – 1785 (UL) / 1805 – 1880 (DL)	38.0 / 20.0
No.2 ESIEE Paris		47.9 / 29.3
No.3 Paris Nation		44.4 / 15.6

* V. Valenta et al., Survey on spectrum utilization in Europe: Measurements, analyses and observations, IEEE CrownCom'10

Motivation (cont'd)



Region	Utilization in 400-470 MHz [%]	Freq. allocation [MHz]	No. of TV channels	No. of "occupied" TV channels	Utilization (Method 1) [%]	Utilization (Method 2) [%]
Brno	19.71	470 – 862	49	20	21.2	40.8
ESIEE Paris	9.83	470 – 830	45	28	44.9	62.2
Paris Nation	6.37			23	29.9	51.1

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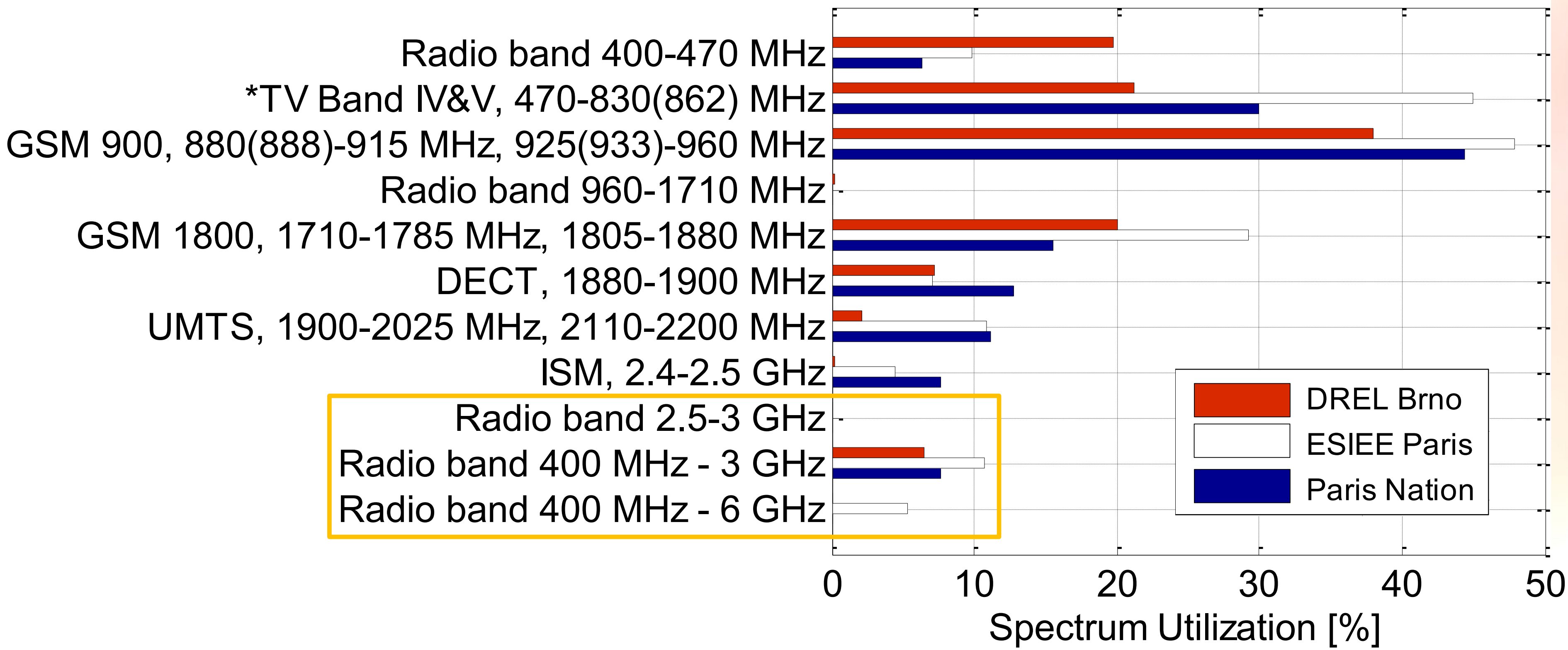
Motivation (cont'd)

- Low spectrum utilization across licensed bands < 6 GHz
- Fixed spectrum assignment inefficient



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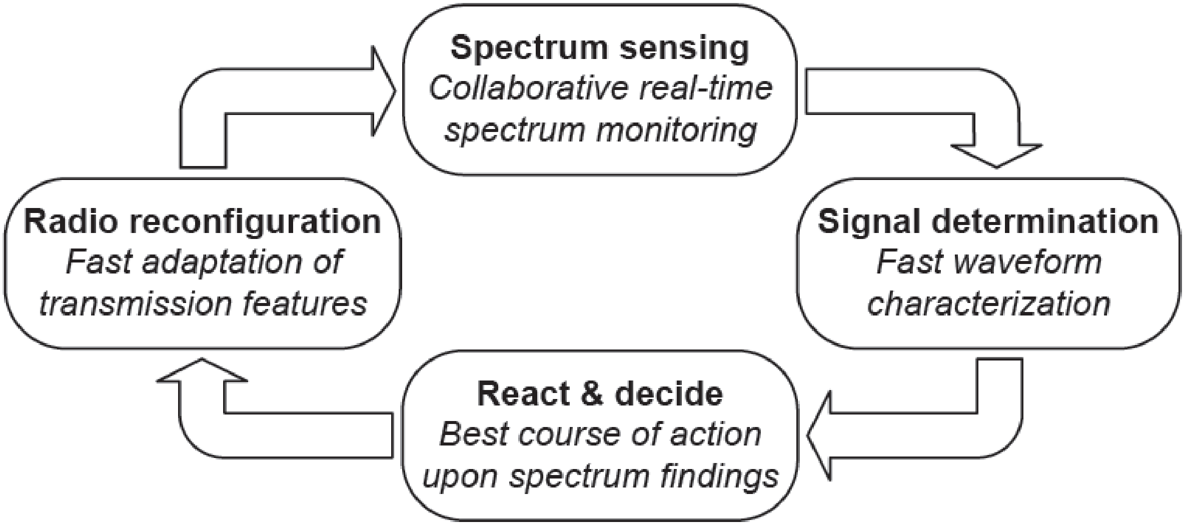
Dynamic Spectrum Access as a solution ??



Cognitive radio as a DSA enabling technology

* J. Mitola, Cognitive radio: making software radios more personal, IEEE Personal Communications 1999

Dynamic Spectrum Access as a solution ??

…good idea but

- how to guarantee absolute protection for primary users?
- and effective and fair sharing of resources among secondary users?

Motivation (cont’d)

Common requirement: <u>Spectrum Awareness</u>

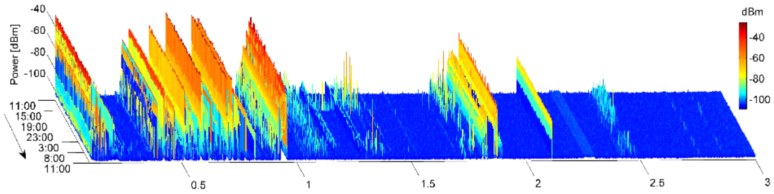
- Geolocation based databases
- Sensing nodes in user terminals
- Sensing nodes in base station

…. sensing nodes simply everywhere

* E.S. Sousa, Spectrum sensing in cognitive radio networks: requirements, challenges and design trade-offs," *Comm. Mag.*, 2008
** T. Yucek, H. Arslan, A survey of spectrum sensing algorithms for cognitive radio applications, 2009

Current Initiatives

Towards Collaborative Spectrum Sensing



- Drawbacks of the sensing method:
  - Single node & inflexible platform
  - Noise uncertainty problem, bad performance at low SNR
  - No “feature” information (modulation, time slot lengths, etc.)

Development of a flexible multi-nodal sensing network

…why?

- To mitigate the “hidden node problem” and increase sensing reliability
- Relax HW requirements by means of multiple reception
- Exploitation of cooperation principles

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DFG Project Summary

Opportunistic radio spectrum access: Collaborative spectrum sensing using custom RFICs and digital signal processing

Three project phases:

T0-24

Development of highly reconfigurable spectrum sensing platforms
(customized RFIC and a flexible baseband DSP)

Follow-up

Deployment of multiple spectrum sensing units

Definitions of decision strategies, noise analyses, dynamic threshold optimization (all based on experiments)

http://gepris.dfg.de/gepris/projekt/254393704

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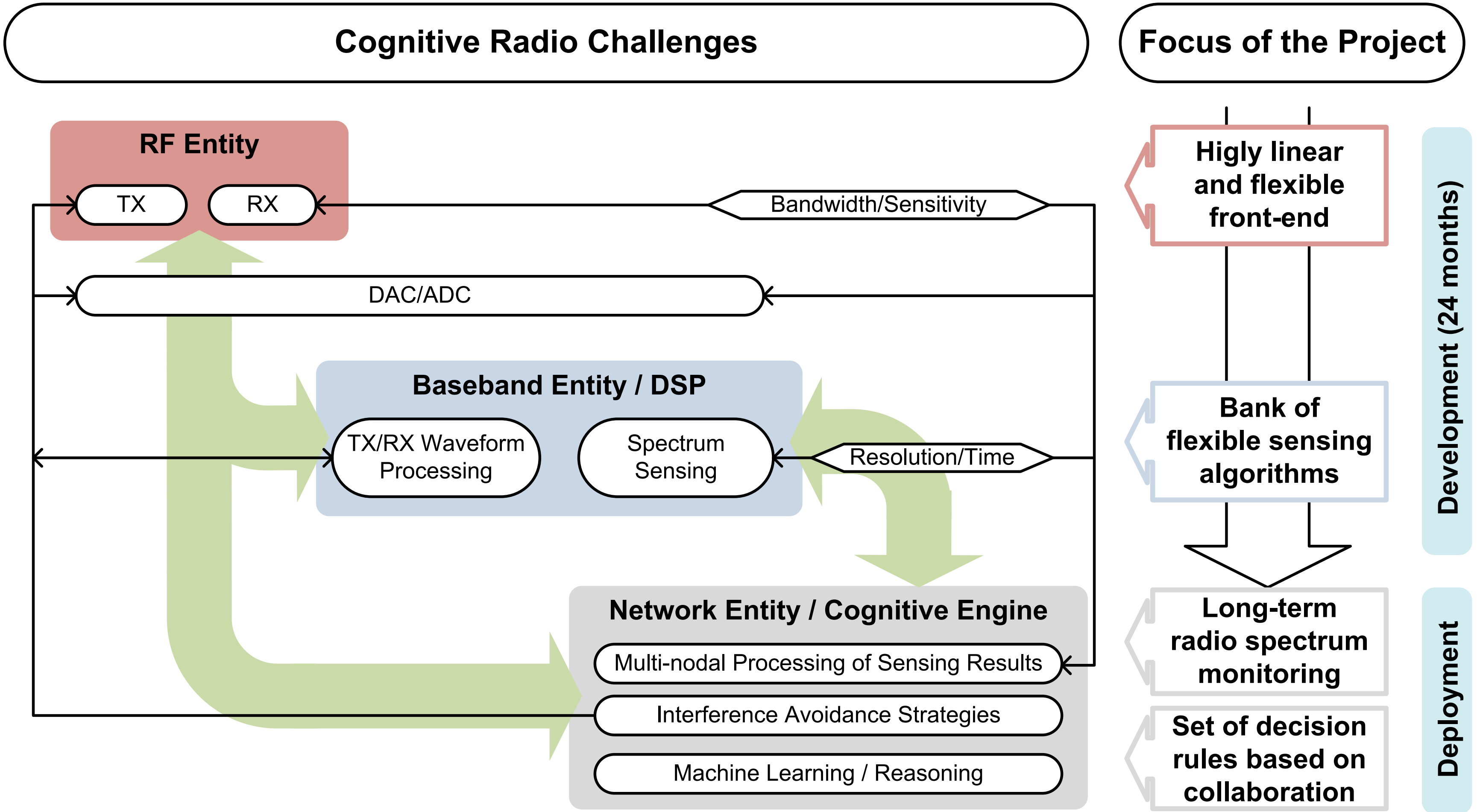
DFG Project Summary (cont‘d)



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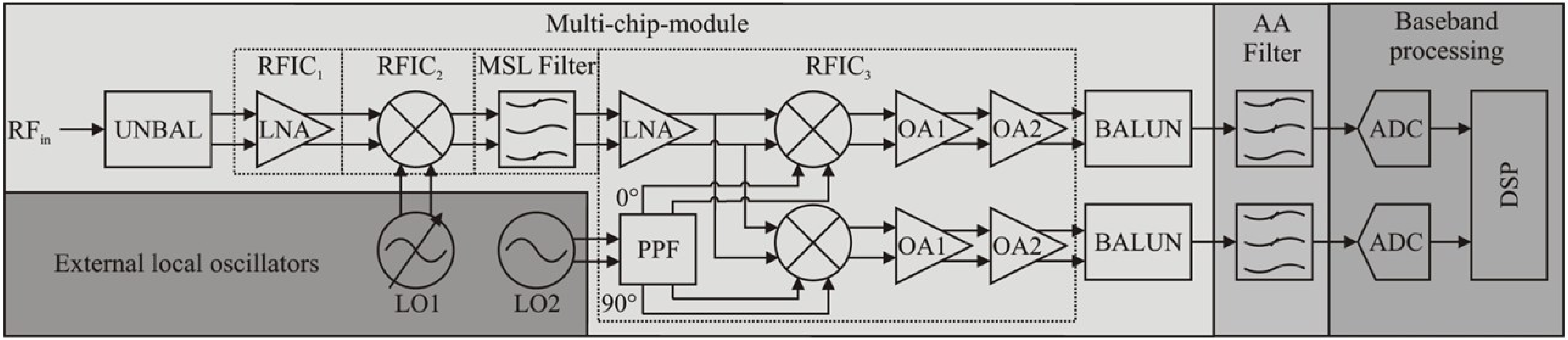
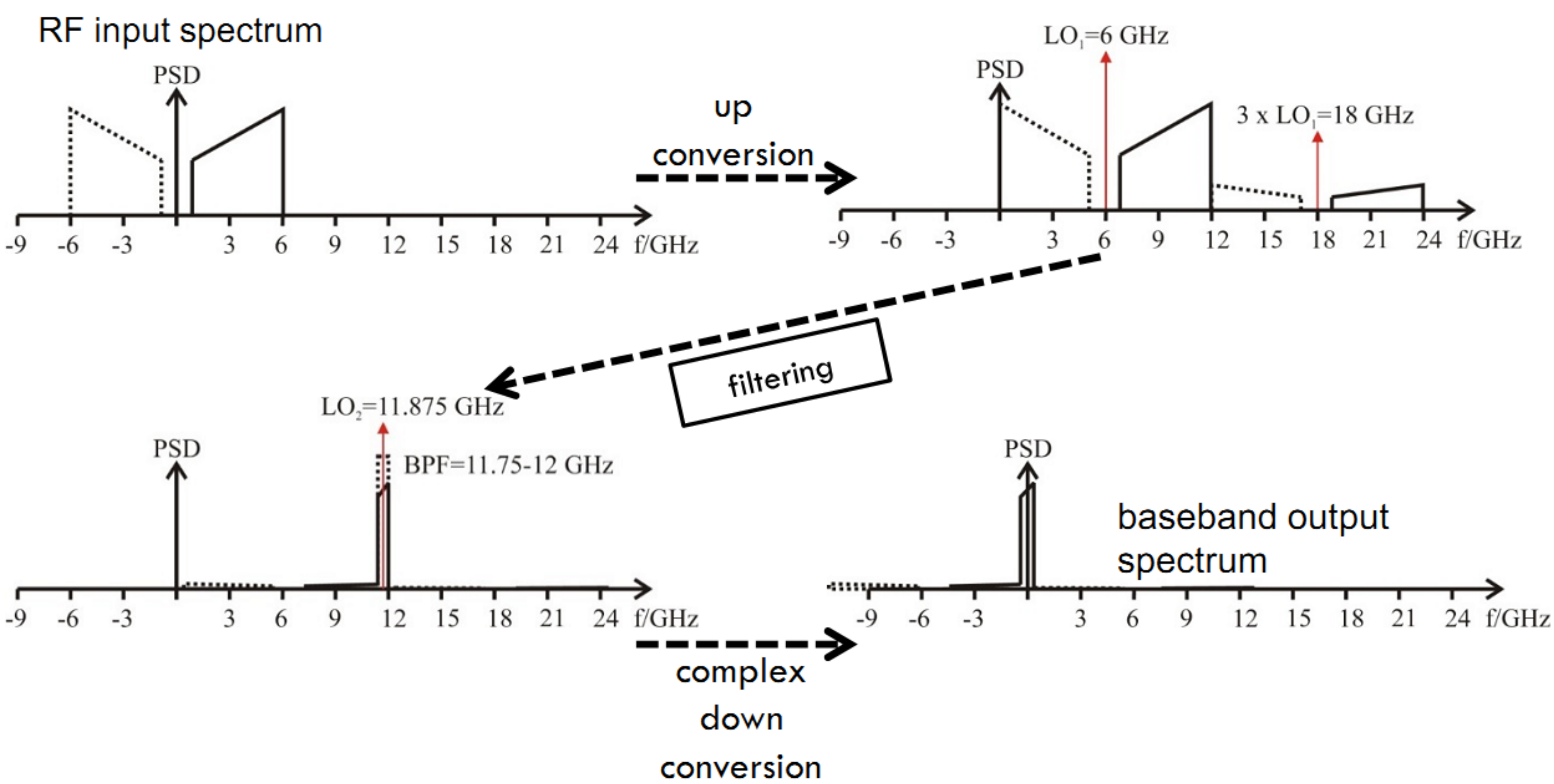
Development Phase: RF Front-End

- Double frequency conversion scheme, with up-conversion to a high IF and down-conversion to 0 IF
- Customized SiGe 0.25 µm BiCMOS:C ICs (IHP SG25H3, F_T/F_{max} = 110/180 GHz)
- Off-chip microstrip filter
- IF detection bandwidth is 245.76 MHz
- External local oscillators determine the detected frequency band

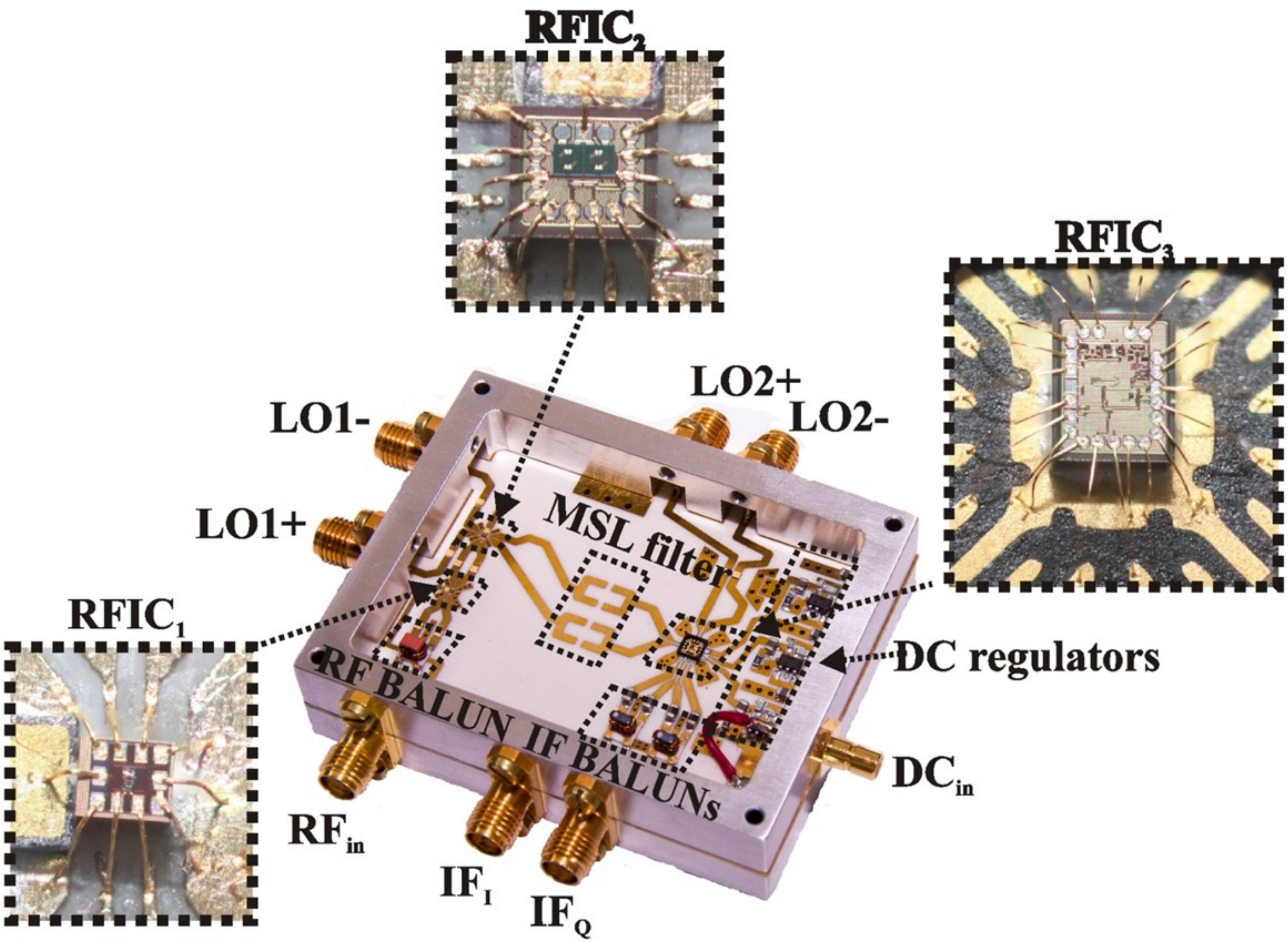


* A. Elsokary et al., A Hardware Prototype of a Flexible Spectrum Sensing Node for Smart Sensing Networks, IEEE CrownCom'15

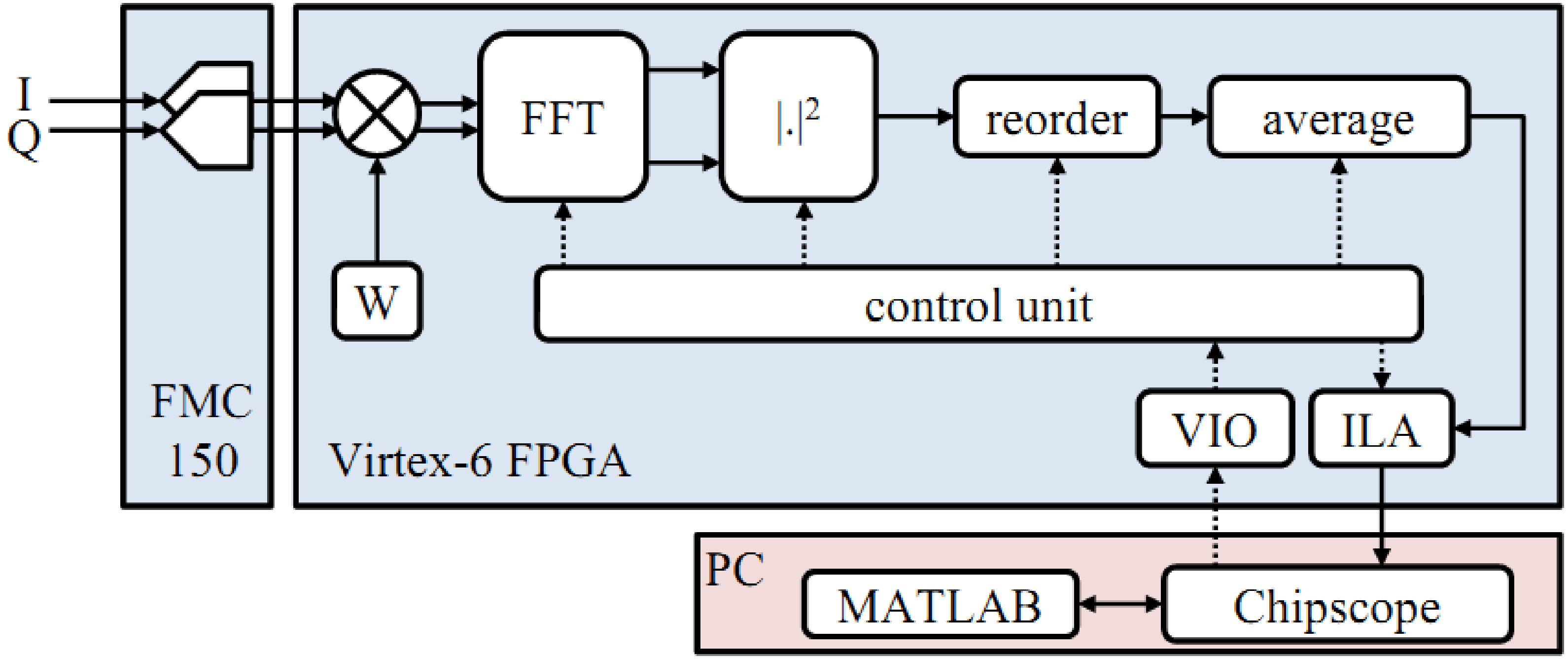
Up/Down Conversion Frequency Plan



Realized RF Front-End



Development Phase: Digital Baseband



- FMC150: Dual channel A/D converter, 245.76 MSPS, 14 bits
- ILA: Internal logic analyzer
- VIO: Virtual I/O port
- MATLAB : Data visualization and platform control

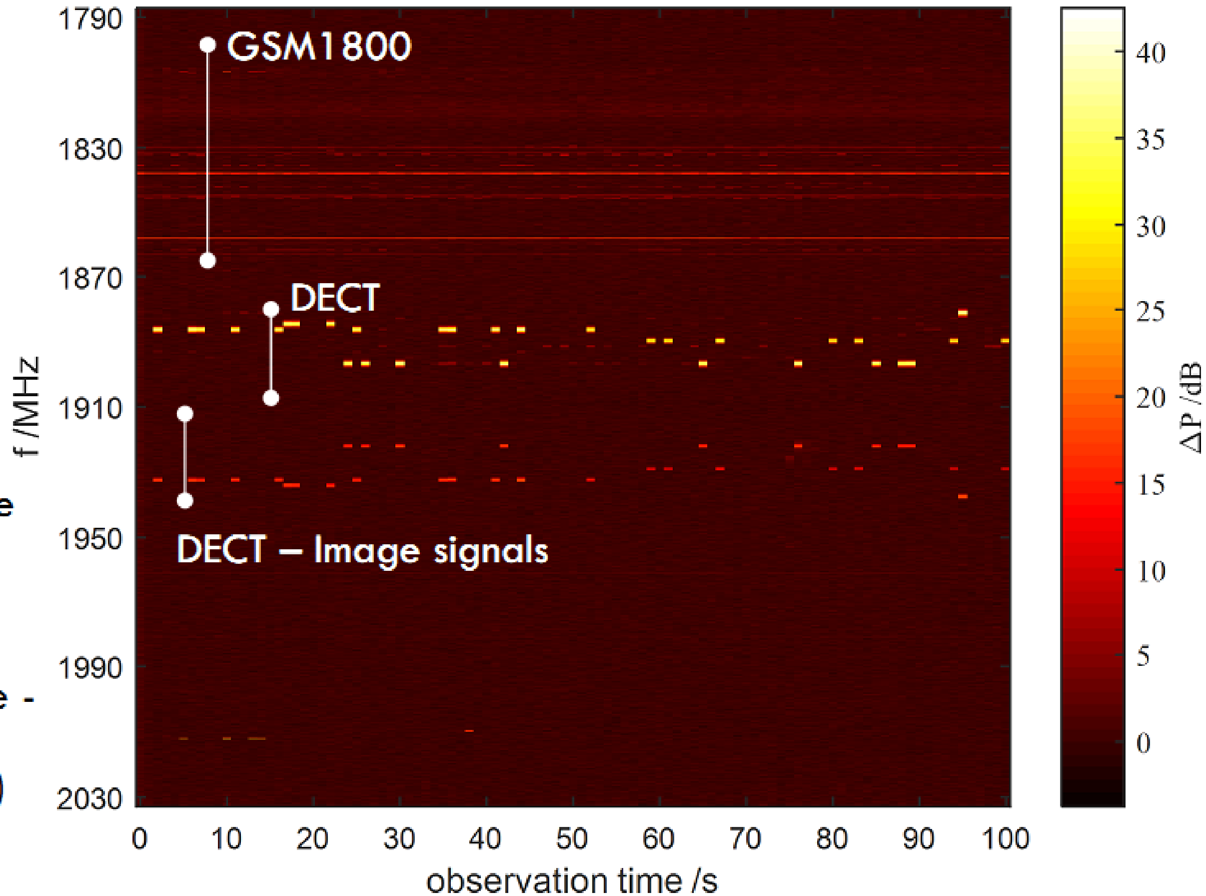
Trial Sensing Tests

Real-time performance

- Detector parameters
  - Averages: 100
  - Central frequency: 1910 MHz
  - Window: Blackman

- Observed signals
  - GSM and DECT
  - Frequency hops of DECT can be captured

- Limitation
  - Communication using Chipscope - low data rate.
  - Slow update rate (~1 frame/s) due to large frame size.



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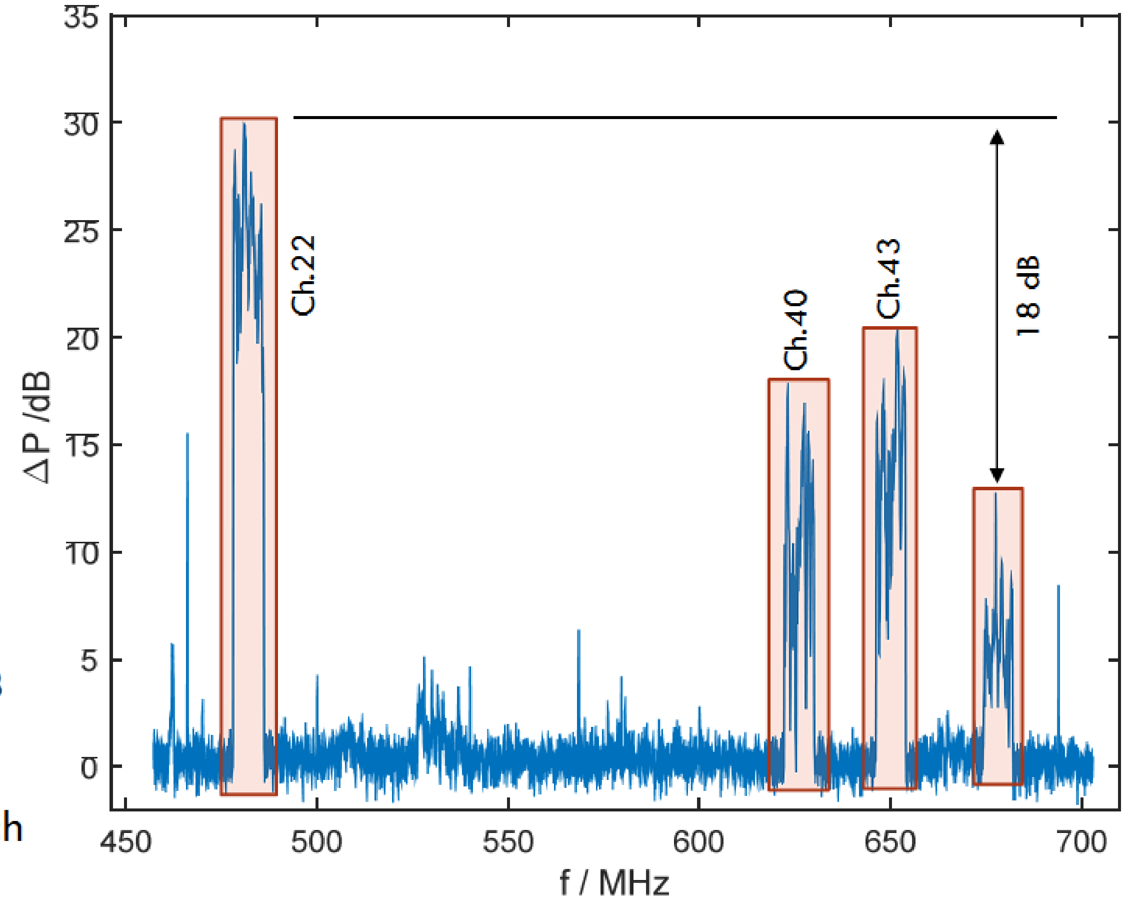
Trial Sensing Tests (cont’d)

Detection of UHF DVB-T signals

- Observed effects
  - Noise floor ripple
  - DC-Offset
- Noise floor ripple can be calibrated
- Observed signals
  - Three DVB-T channels observed.
  - Image of Ch.22 at approx.18 dB
- Main limitation: IQ mismatch



- Observed sensitivity limit -107 dBm

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Results - Hardware

FPGA usage

Component	Value
Logic slices	2137 (5%)
Block RAM (18kb)	30 (3%)
Block RAM (36kb)	42 (10%)
DSP slices	26 (3%)
Maximum clock frequency	250 MHz

Detection parameters

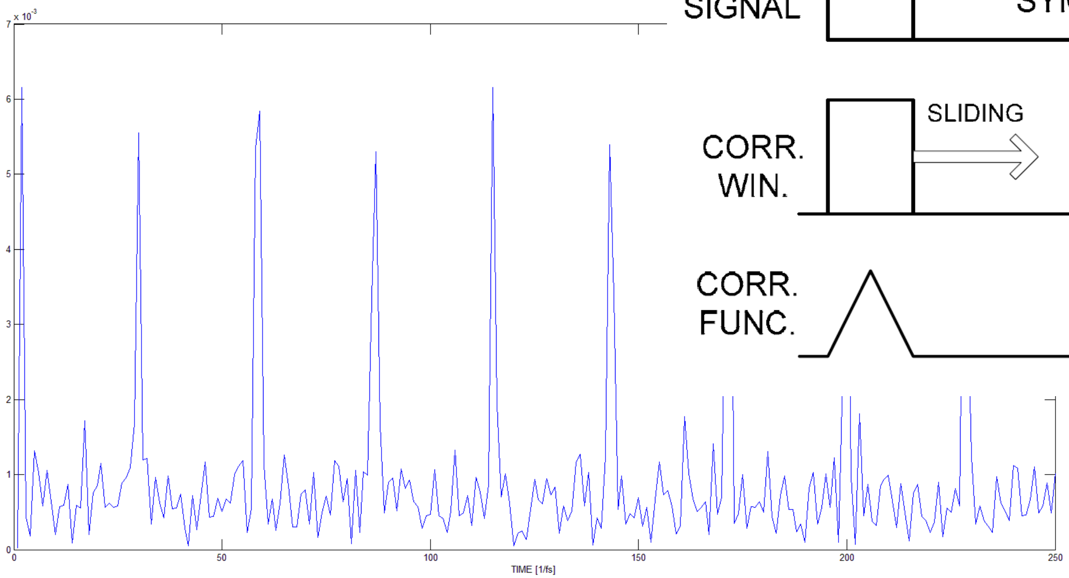
Parameter	Value
FFT length	4096
Detection BW	245.76 MHz
Detection time	$(42 + 17 \times N_{avg})$ µs
Resolution BW	60 kHz

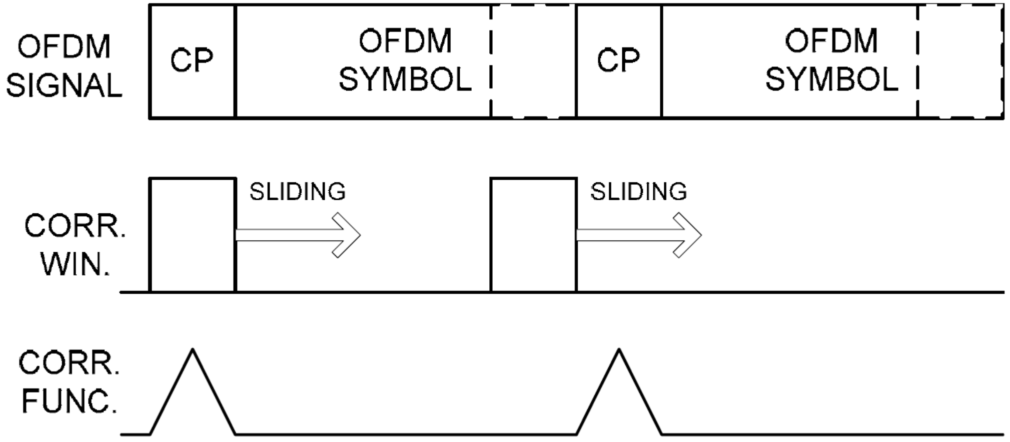
- DSP48 slices: Multipliers for twiddle factor multiplication, window function and magnitude evaluation.
- Block RAM: Twiddle factor storage, reordering and feedback shift registers.
- Logic slices: Adders and short length shift registers.

* A. Elsokary et al., A Hardware Prototype of a Flexible Spectrum Sensing Node for Smart Sensing Networks, IEEE CrownCom'15

Ongoing Efforts

- Frontend improvments
- Digital IQ mismatch compensation
- Design of different sensing algorithms
- Decision engine integration
- UHF TV deployment **





** OPINIONS FOR THE FUTURE USE OF THE UHF TV BROADCASTING BAND: THE LAMY REPORT – OUTCOME OF THE PUBLIC CONSULTATION

Summary

- Cooperation principles proven in succesfull resource sharing !

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couchsurfing

UBER

velib'
MAIRIE DE PARIS

CAR 2GO

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Acknowledgements

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Thank you for your attention !