



# Cognitive PMSE for Spectrum Sharing at UHF

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1. What is PMSE and what makes it so unique?
2. Spectrum Situation for PMSE at UHF
3. Activities ETSI STF386 and BMWI C-PMSE
4. C-PMSE concepts for spectrum sharing
5. Demonstration at Messe Berlin
6. Conclusions

# Speakers Background

## Experience

### Prof. Georg Fischer (geb. 1965)

- 1986-1992 Study of Electrical Engineering at RWTH Aachen (Aix La Chapelle)  
Focus on Communications , Radio Technology, Field Theory
- 1993-1996 Research assistant at University of Paderborn
- 1997 Dr.-Ing. (summa cum laude),  
Thesis „Adaptive Antenna Arrays for mobile satellite reception“
- 1996-2008 Lucent, later Alcatel-Lucent, Bell Labs Research  
Research on Basestation RF Technology  
2000 Bell Labs DMTS (Distinguished Member of Technical Staff)  
2001 Bell Labs CMTS (Consulting Member of Technical Staff)  
Chairman of ETSI SMG2 WPB EDGE
- 2001-2007 Part time Lecturer at University of Paderborn
- April 2008 University of Erlangen-Nürnberg Prof. for Electronics Engineering  
Research on Cognitive Radio, Frequency Agile Radio, Analog-Digital Balance
- Since 2010 ETSI STF 386 Chairman „*Methods, parameters and test procedures for cognitive interference mitigation techniques for use by PMSE devices*“
- Since 2010 Reviewer for EC FP7, COST, DFG, NSERC, IWT Flanders, Helmholtz Society





# 1. What is PMSE and what makes it so unique?

# What is PMSE and what makes it so unique?

## Definitions

### Definitions

- PMSE = Program Making and special events  
(Wireless Audio, Video and effect control)
- PWMS = Professional wireless Microphone system
- IEM = In Ear Monitor
- SAB = Services Ancillary to Broadcasting
- SAP = Services Ancillary to Programme making
- ENG = Electronic News Gathering



Wireless Microphone



Camera receiver

### PMSE Includes

- Wireless Audio (*focus today*)
- Wireless Video
- Wireless Effect control

PMSE is a  
production  
tool



Wireless instrument  
transmitter



8 channel receiver



Bodypack for ENG



Wireless Microphone



# What is PMSE and what makes it so unique?

## Applications

### Professional applications

- Cultural and Creative Industry
- Opera, Theatre
- Musical, Shows
- Concert halls, event halls
- Live events, music, festivals
- Cabaret, clubs, bars, casino
- TV production, broadcast TV/Radio
- News gathering, Outside Broadcast
- Recordings CD/DVD/Internet distribution



### Business

- Congress and conference centres
- Press centres, Presentations



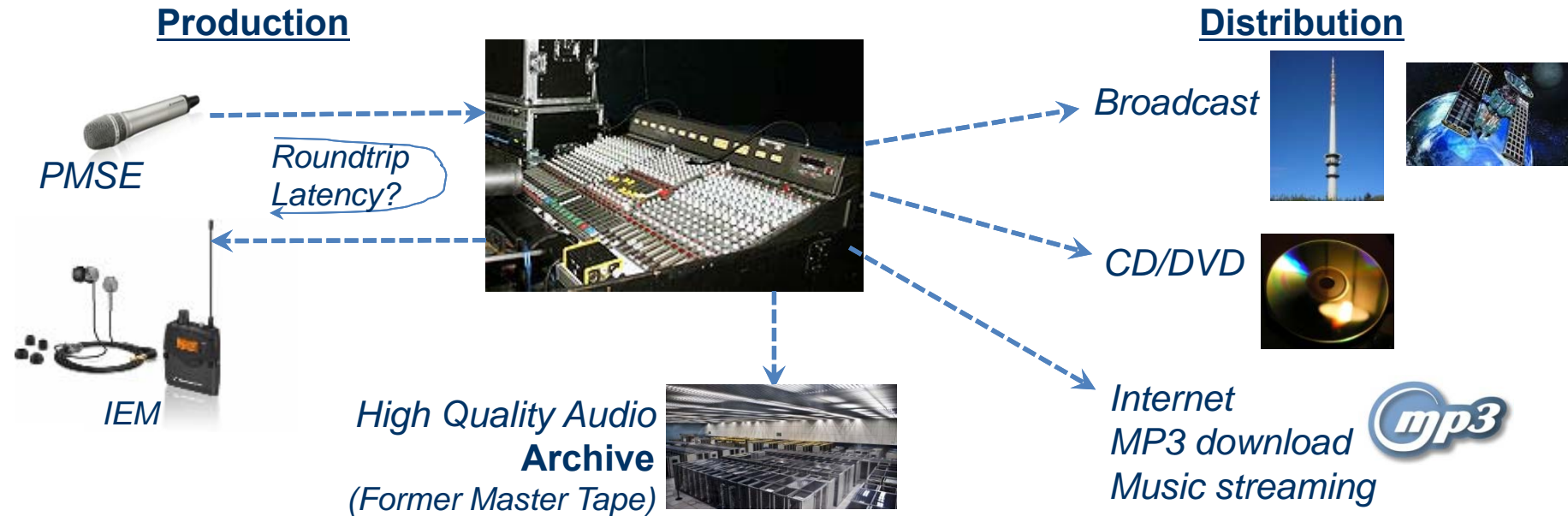
### Non-Profit

- Churches, religious societies
- Associations, unions
- Intercultural life, integration



# What is PMSE and what makes it so unique?

Production – Distribution - Archive



## Findings

- Production and distribution both use wireless technologies
- Large variety of distribution channels (wireline and wireless)
- Live productions – it must work reliable!

## Archive

- In most cases captured in an archive
- What's not captured in the archive cannot be distributed later
- Archive must be high quality to derive any level of quality in distribution

**Concatenation of  
two wireless links!**

# What is PMSE and what makes it so unique?

## Uniqueness

### Availability

- Drop-outs not acceptable, 100% reliable(!?)  
*cellular networks intentionally designed for 95% availability*
- Historic events cannot be repeated “Daß Ihre Ausreise...(Genscher)”

### Quality

- High quality must be captured in production as otherwise it is not possible to derive the various quality levels in distribution
- Large compression is thus not possible on production, only on distribution

### Latency

- The “drummer problem”, roundtrip from wireless mic to wireless IEM should be < 5ms  
*Telephone 200ms, Cellular 20ms, Satcom 500ms*
- Communication theory wise: Information source and information sink are colocated!



### Consequence

- Spectrum consumption by PMSE cannot be massively reduced by digitization
- Safety margins, headroom needed
- Expectations regarding spectrum savings from digitization of PMSE too high





## 2. Spectrum Situation for PMSE at UHF



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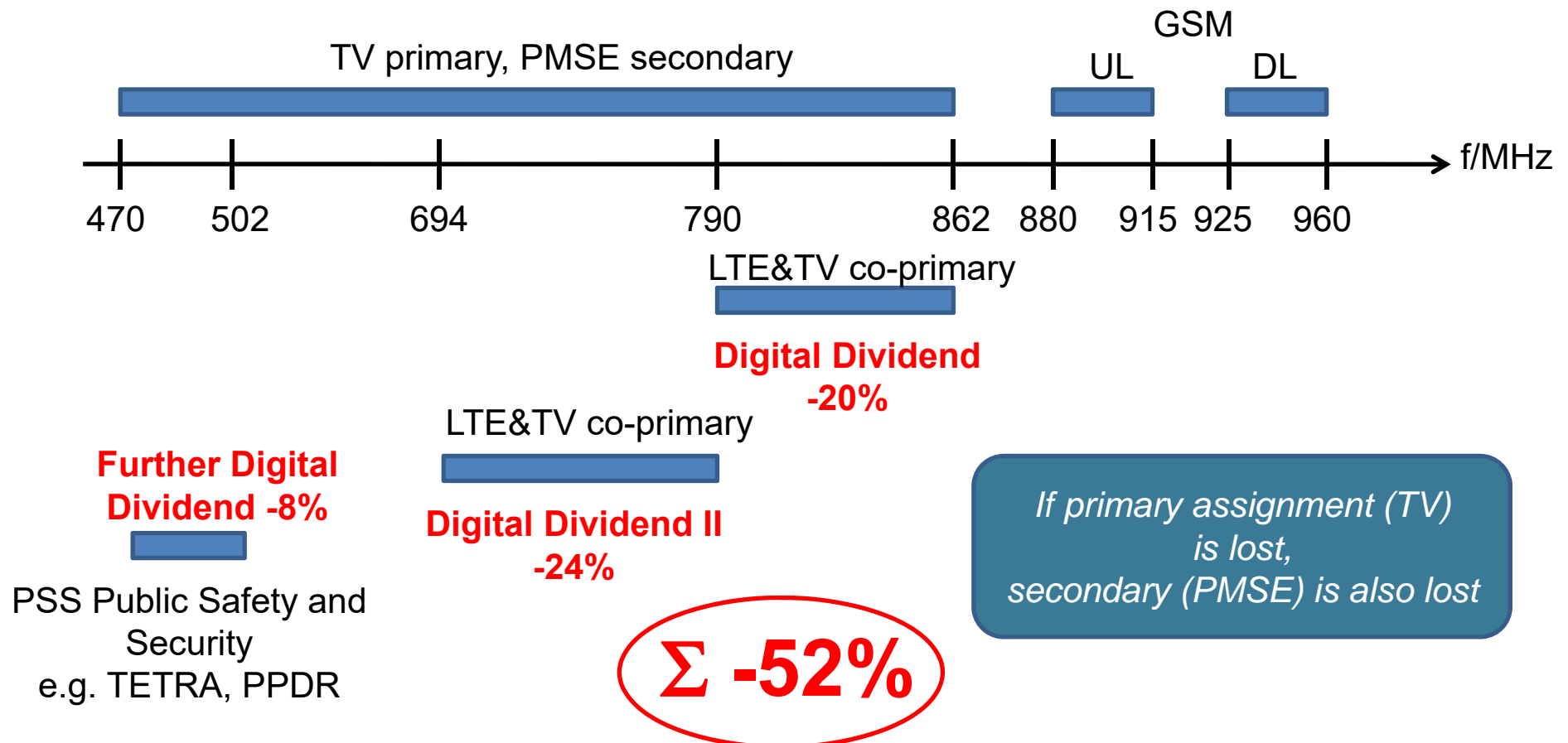
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# Spectrum Situation for PMSE at UHF

Changes going on

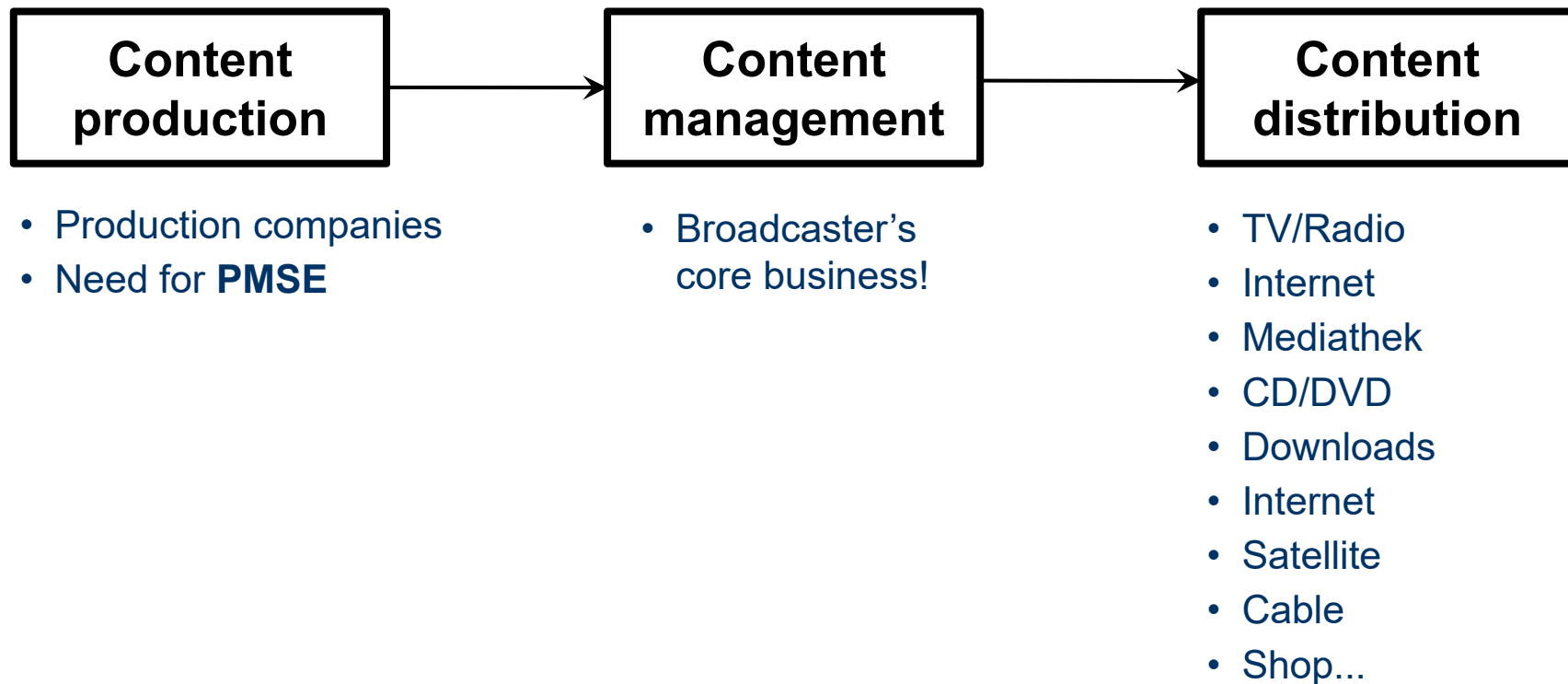
## What's going on?

- Digital dividend means that TV spectrum is moved to cellular
- It is imagined that in future 400...6000 MHz could all be Cellular



# Spectrum Situation for PMSE at UHF

PMSE in the back of TV no longer works



## Situation has changed

- Broadcasters no longer are present throughout the whole chain
- Broadcasters focus on core business content management
- Broadcasters no longer represent PMSE and Broadcast spectrum inside one institution



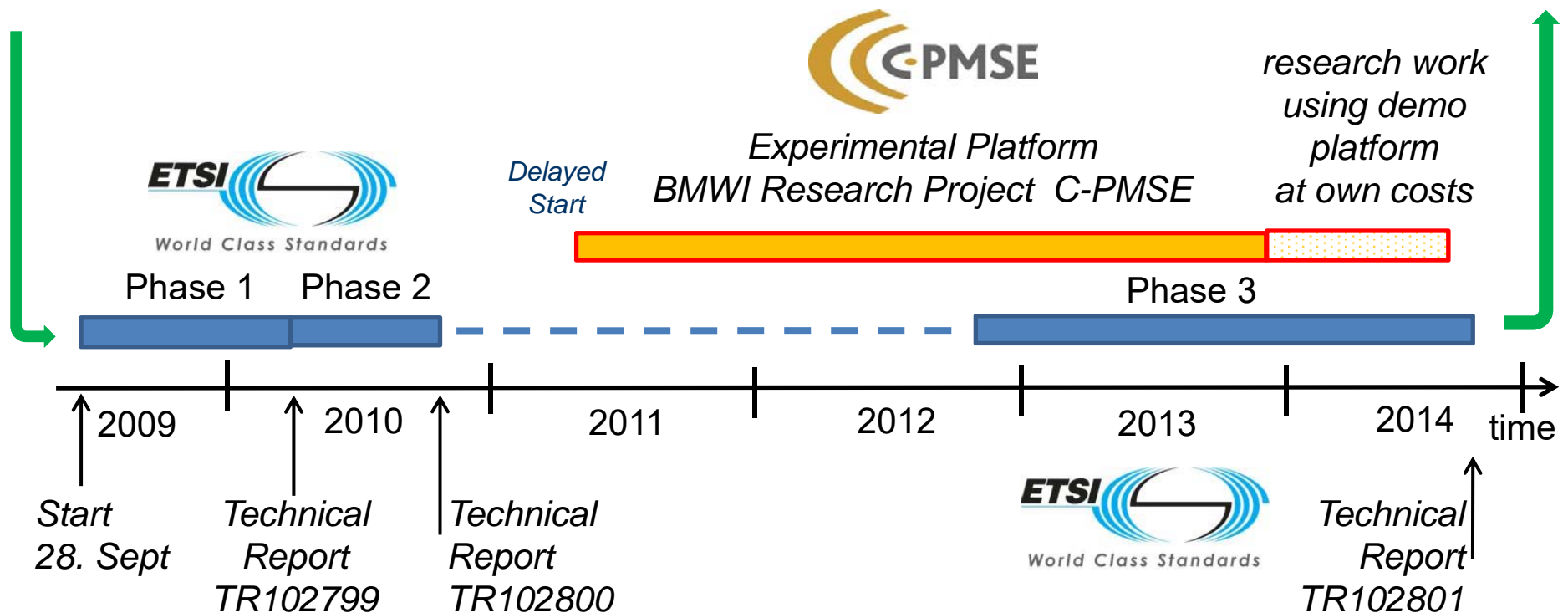
### **3. Activities ETSI STF386 and BMWI C-PMSE**

# Activities ETSI STF386 and BMWI C-PMSE

## Time Lines

Industry identified need  
for new research and  
standardisation work

ETSI full  
standardisation

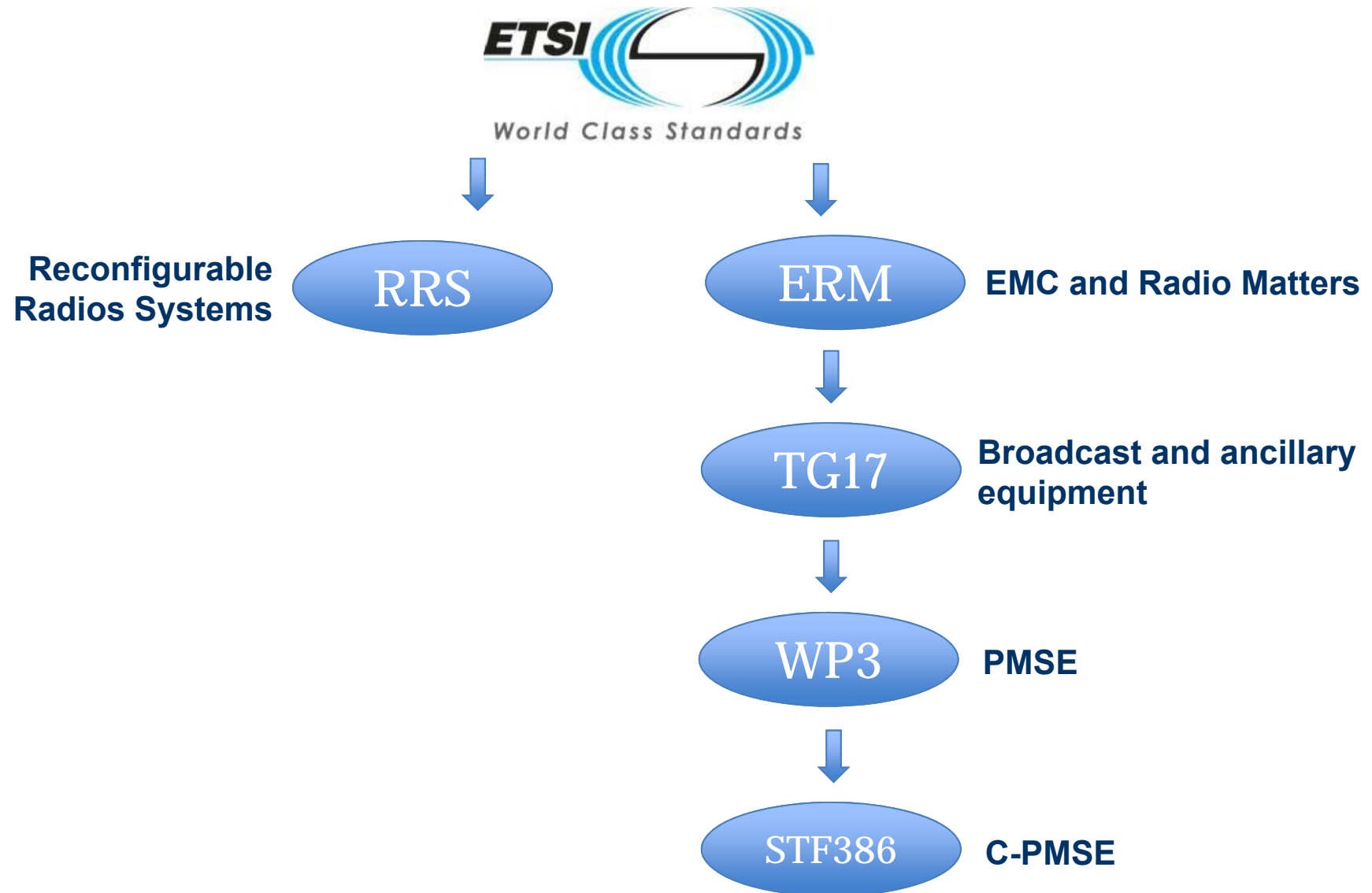


Industry trigger - research - proof - standardisation



# Activities ETSI STF386 and BMWI C-PMSE

## Group in ETSI



### Scope of STF386

- Set by ToR (Terms of reference): “***Methods, parameters and test procedures for cognitive interference mitigation techniques for use by PMSE devices (Programme Making and Special Events)***”
- Purpose: ***Achieve co-existence of high audio quality PMSE devices using often a 100% transmitter duty cycle emission profile with victim radio services such as Services in L-Band or Broadcast Services and future Land Mobile Services and applications in the UHF frequency range that is currently under investigation under the “Digital Dividend” discussions in EC, ECC and ETSI fora.***

### Aims

- Understand potentials of CR (Cognitive Radio) Technology for PMSE
- Assess benefits of CR technology in light of PMSE specifics
- Study spectrum impact

### Phase 1 deliverable - Technical Report ETSI TR 102 799

- “Operation methods and principles for spectrum access systems and quality control of used spectrum for PMSE technologies utilising cognitive interference mitigation techniques”
- Describes main architectural concepts and procedures



### Phase 2 deliverable - Technical Report ETSI TS 102 800

- “Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques”
- Describes recommended spectrum access technique



### Phase 3 deliverable - Technical Report ETSI TR 102 801

- “Methods, parameters and test procedures for cognitive interference mitigation techniques for use by PMSE devices”
- Contains architecture and interface definitions and test procedures



### Project Overview

- Duration 26 month, April 2011 - May 2013.
- 9 partners from industry, research institutes and universities.
- Budget about 7.5 million EUR.
- funded by the German Federal Ministry of Economics and Technology (BMWi)
- Project keeper German Aerospace Center (DLR) in Cologne
- Goal: The project goal is the design, development, test and research on a cognitive PMSE system which provides cooperative coexistence with other C-PMSE systems, white space devices, broadcasting and mobile radio
- Basic requirements are automation of the frequency utilization within the assigned frequency spectrum, securing a coordinated coexistence of different user in the same frequency range and efficient frequency utilization.



### Project Objectives

- R&D on the cognitive system and procedures for PMSE by development of system components, like antennas, scan receiver, scan controller, cognitive engine, data base and so on, measurement- and test procedures as well as channel-, interference- and coexisting models as reference for the standardization and regulation activities.
- Setting up a field trial platform for cognitive PMSE applications at the fair grounds of Messe Berlin, technical and economical proof of concept of the cognitive methods for PMSE and realizing an open and modular R&D platform for future research.
- Supporting frequency regulation and standardization by setting up a forum to discuss and prioritize necessary actions concerning cognitive PMSE on national, European and worldwide level as well as active collaboration with ITU, ETSI, CEPT and Bundesnetzagentur by using the project results and the preparatory work of the Special Task Force ETSI STF 386.




Bundesministerium  
für Wirtschaft  
und Technologie



# Activities ETSI STF386 and BMWI C-PMSE

Experts working for ETSI



Wolfgang Bilz  
(Shure EU)  
**Chairman**

Prof.Dr. Georg Fischer  
(UNI Erlangen-  
Nürnberg)  
**Chairman**

Matthias Fehr  
(APWPT)

Johannes Brendel  
(UNI Erlangen-  
Nürnberg)

Dr. Axel Schmidt  
(Sennheiser)

Dr. Maria Dolores  
Perez-Guario  
(UNI Hannover)

Dr. Sven Dortmund  
(UNI Bochum)

Edgar Reihl P.E.  
(Shure US)

Clemens Kunert  
(IRT)

Dr. Radu Circa  
(Bosch conference  
systems)

Artur Nalobin  
(UNI Bochum)

Dr. Andreas Wilzeck  
(Wisesense)

*WlnnComm, Erlangen, 6. October 2015*

# Activities ETSI STF386 and BMWI C-PMSE

## BMW project partners

### Industry

- Shure: Wolfgang Bilz (EU), Edgar Reihl (US)
- Sennheiser: Dr. Axel Schmidt
- Bosch: Dr. Radu Circa



### SME

- WiseSense: Dr. Andreas Wilzeck



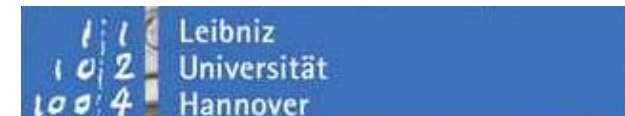
### Research Institute

- IRT: Clemens Kunert



### Academia

- University of Hannover:  
Dr. Maria-Dolores Perez-Guario
- Ruhr University Bochum:  
Dr. Sven Dortmund, Artur Nalobin
- FAU, University of Erlangen Nürnberg:  
Prof. Dr. Georg Fischer, Johannes Brendel,  
St. Riess



### Association

- APWPT: Matthias Fehr





## 4. C-PMSE concepts for spectrum sharing



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# C-PMSE concepts for spectrum sharing

## Spectrum users at UHF

### PMSE

- Area of movement known
- Very special requirements (highest availability, low latency, high operational SNR)
- Vulnerable to TX Intermodulation

### DVB-T

- Transmitter locations well known
- Don't move
- Seldom changes of parameters

### Cellular LTE

- Mobiles move around, Basestations don't move
- Dynamic changes of power and frequencies due to RRM/Scheduler
- Pulsed characteristics, wide sideband emissions, peaky interference

### WSD (White Space Devices)

- A sole LBT scheme cannot cope with the hidden node problem
- ABT - consulting GLDB is necessary
- Movement totally unknown

### Actions performed so far manually

- Finding by STF: Cognitive behaviour not totally new, already cognitive manual actions by today
- Initial frequency plan by calculating IM products up to IM5..7
- Spectrum supervision by handheld scanning receivers
- Link Quality supervision by audio engineers listening
- Frequency change by handing new microphone to artist
- Power set in static manner
- Consequence: Move manual actions to automatic ones

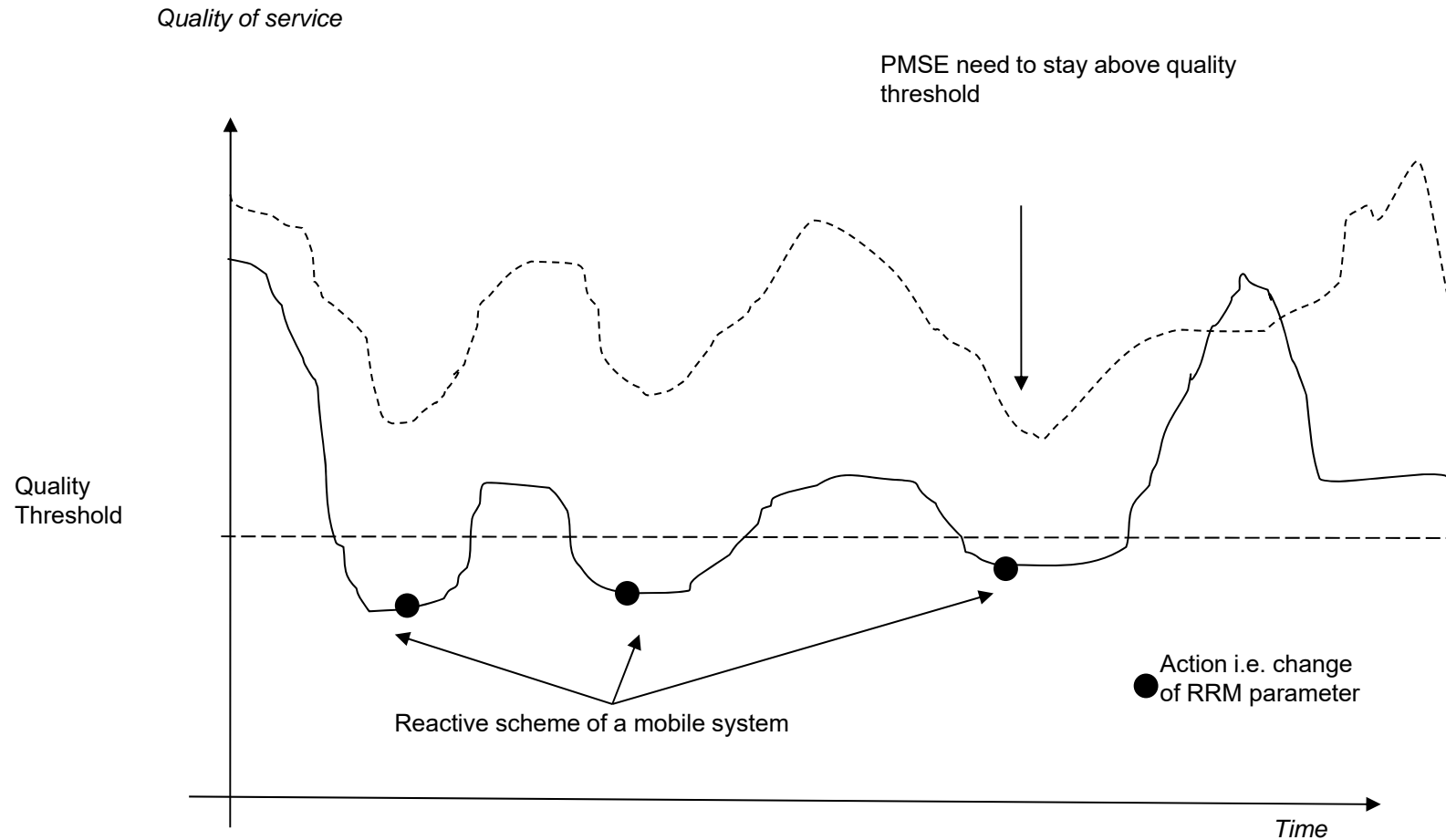
### Technology assets

- Cognitive engine, proactive behaviour, analyse trends
- Link to geolocation database
- Local spectrum sensing grid
- Automatic link quality supervision, also for analogue FM ! (C/I equivalent, not signal strength), digital PMSE is not a must for C-PMSE
- Automatic frequency changes and transmit power control
- Cognition not necessarily mandates digital transmission, separation of Content and Signalling plane is possible



# C-PMSE concepts for spectrum sharing

## Behaviour according to specialities of PMSE

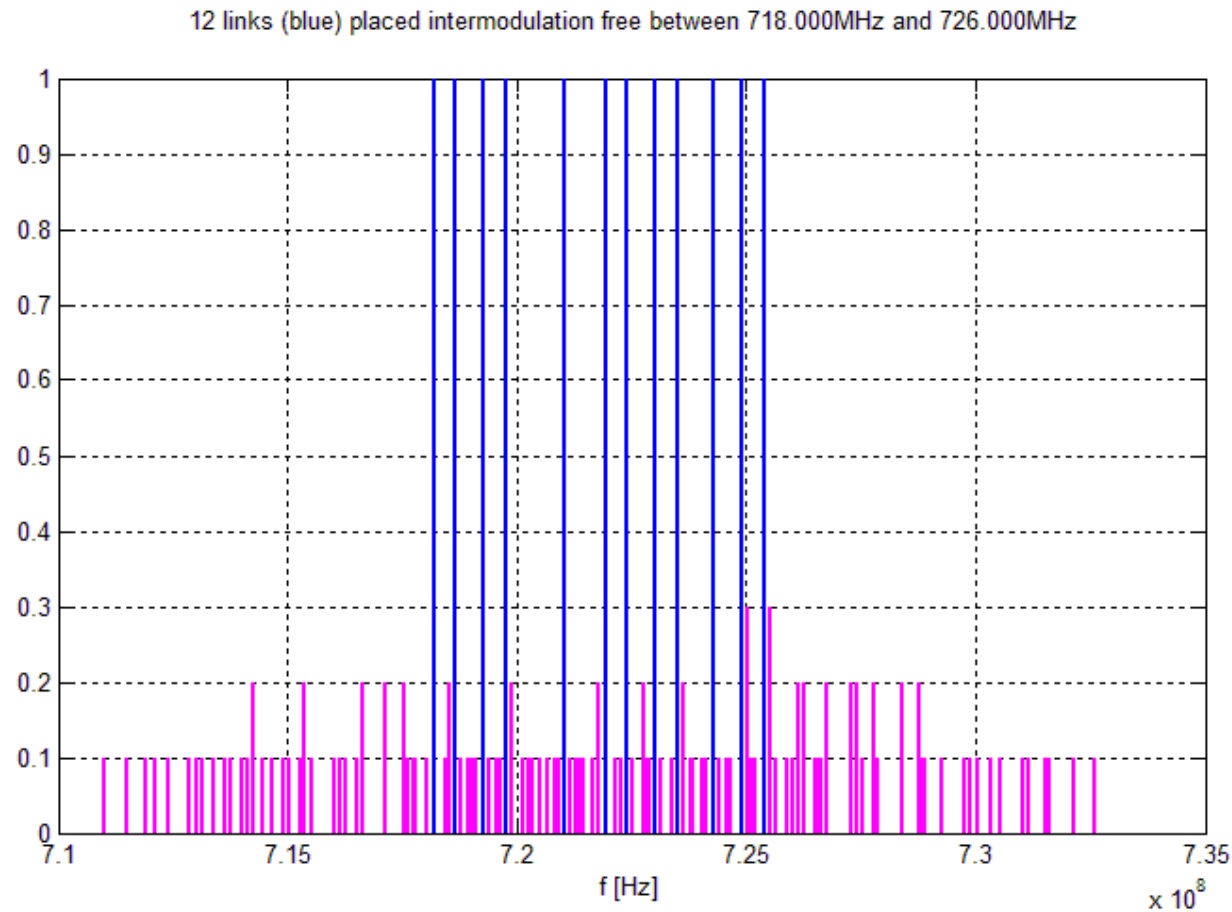


Proactive rather than reactive behaviour as in cellular

# C-PMSE concepts for spectrum sharing

## Nonlinear behaviour

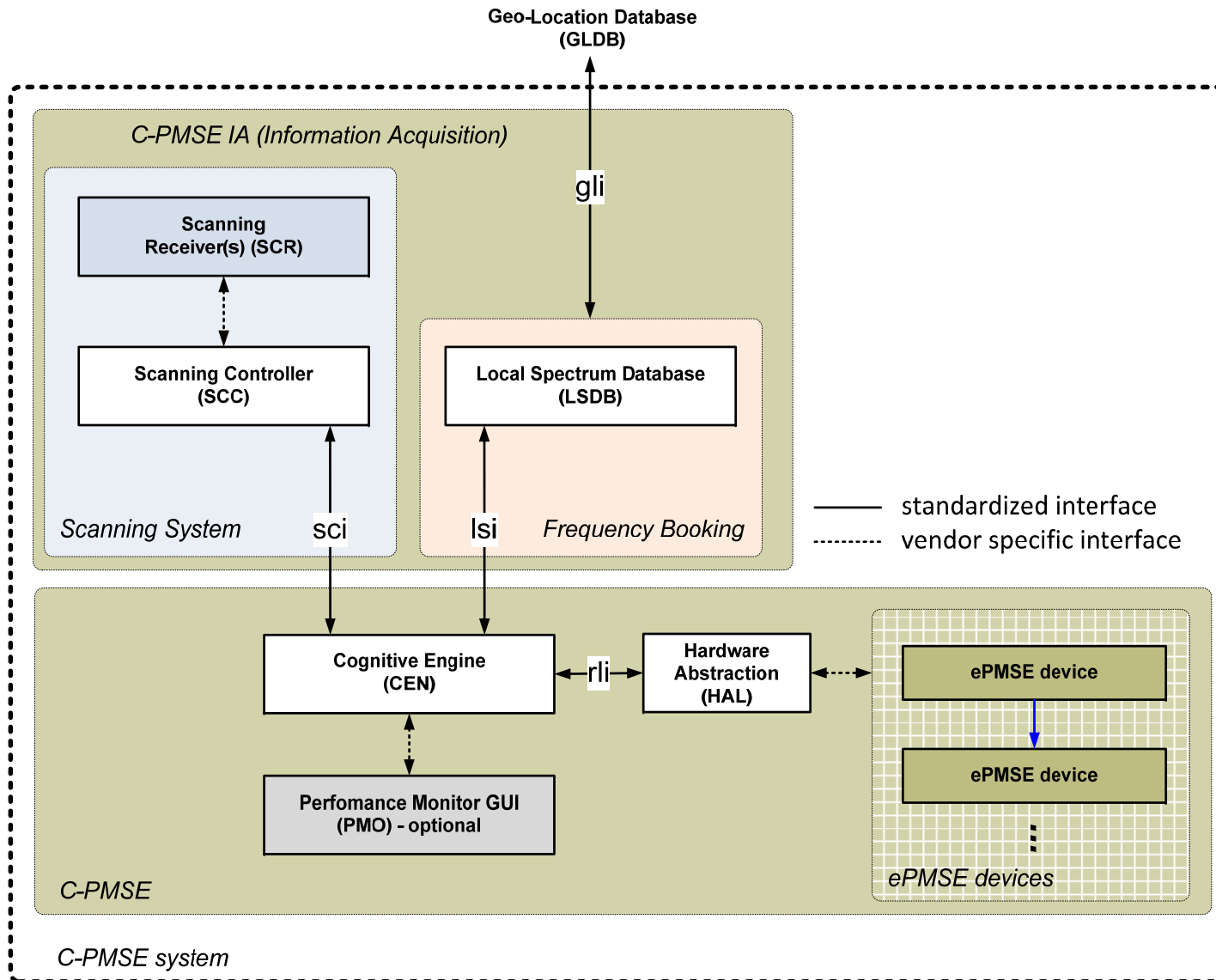
*N* audio channels generate  $N*(N+1)$  IM3 products



**We cannot assume independent orthogonal frequency resources!**

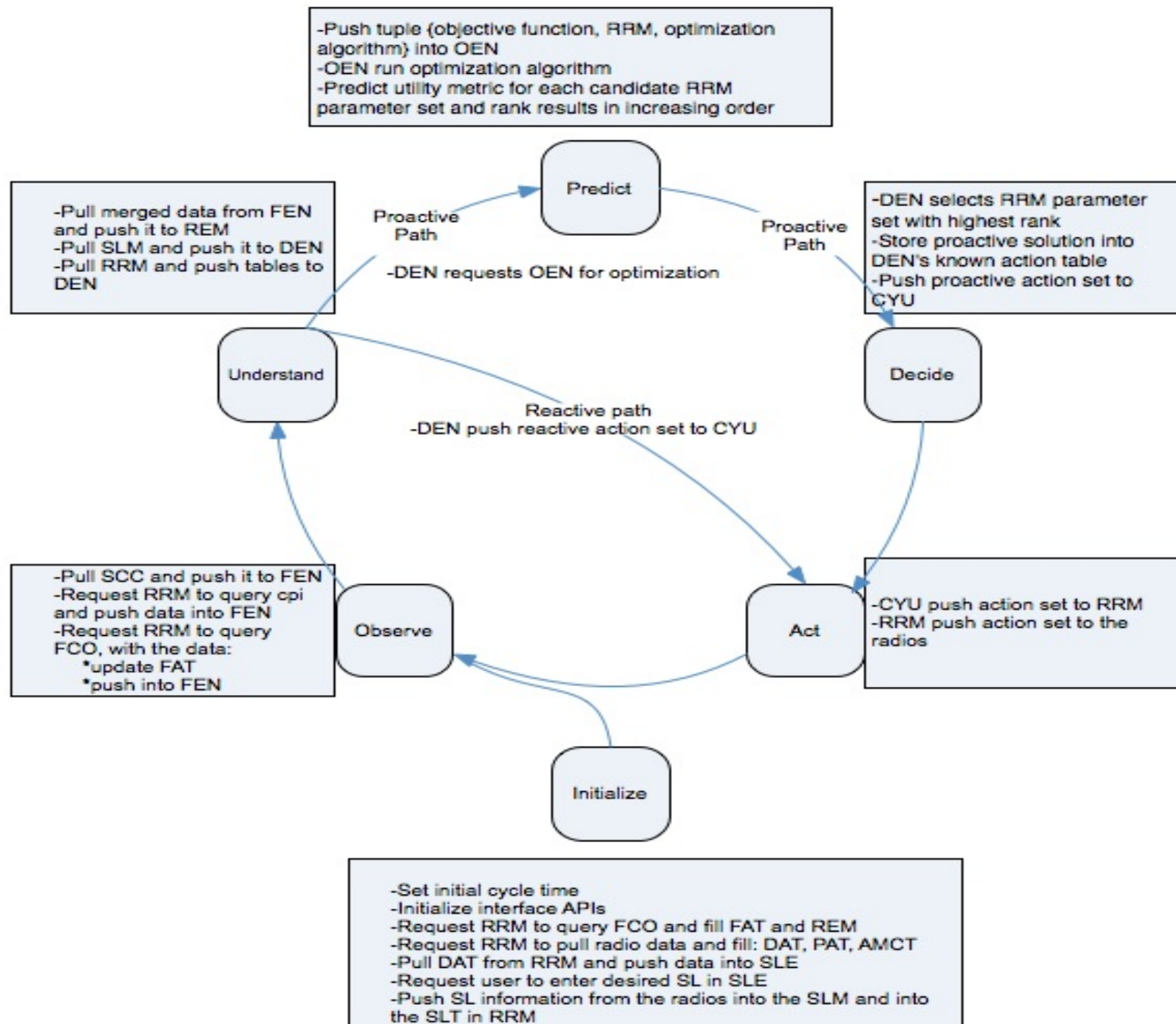
# C-PMSE concepts for spectrum sharing

## Overall Architecture



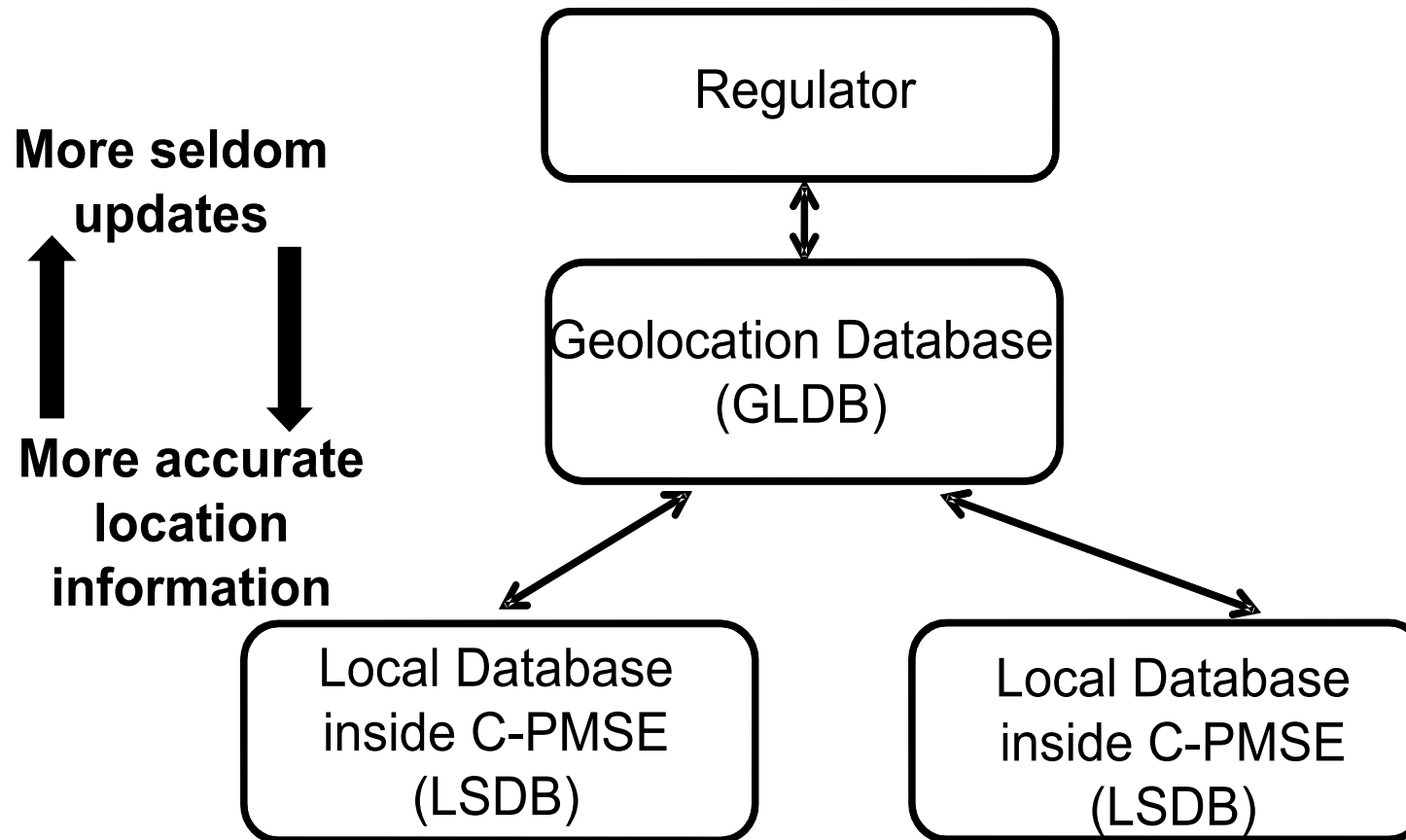
### Benefits

- Information acquisition may be a fixed installation at an event location
- C-PMSE may be different from event to event
- C-PMSE of different vendors may perform differently



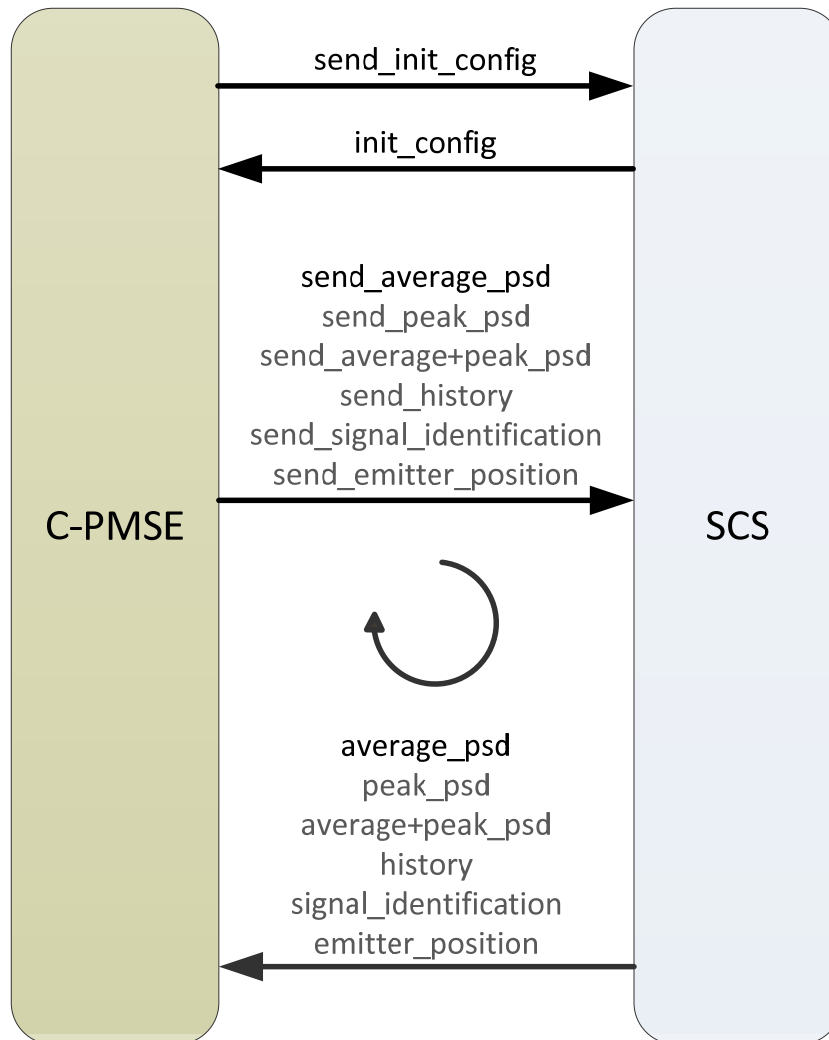
# C-PMSE concepts for spectrum sharing

## Hierarchy of databases



# C-PMSE concepts for spectrum sharing

## sci communication – spectrum scan



### Abbreviations

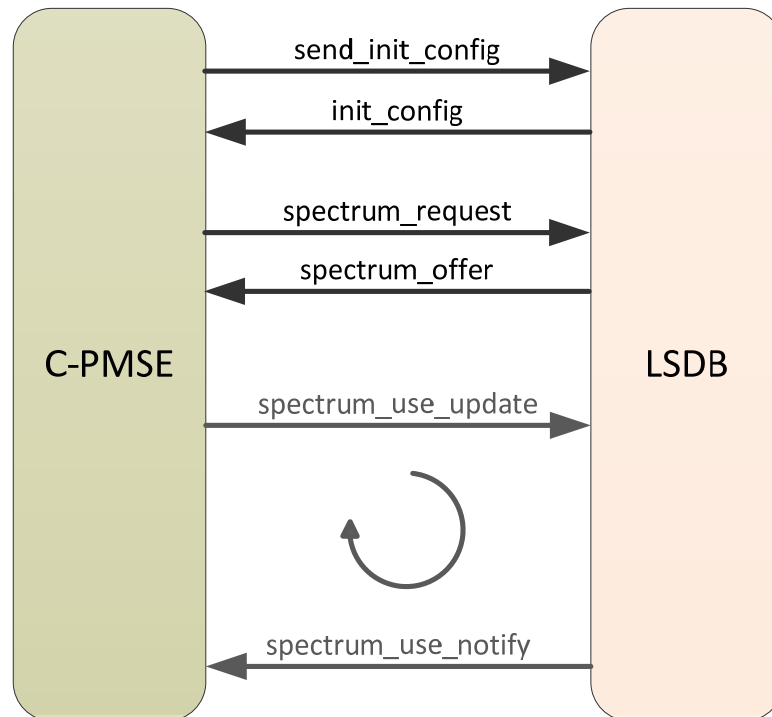
- Isi Local Spectrum Portfolio Interface
- C-PMSE Cognitive PMSE
- SCS Scanning System

### Benefits

- SCS monitors frequencies that are in use by C-PMSE and potential new ones
- Reasoning of what is known in LSDB
- Support for LBT (but hidden node problem may persist)

# C-PMSE concepts for spectrum sharing

## Isi communication – consulting LSDB



### Abbreviations

- Isi local spectrum database Interface
- LSDB Local Spectrum Database
- C-PMSE Cognitive PMSE

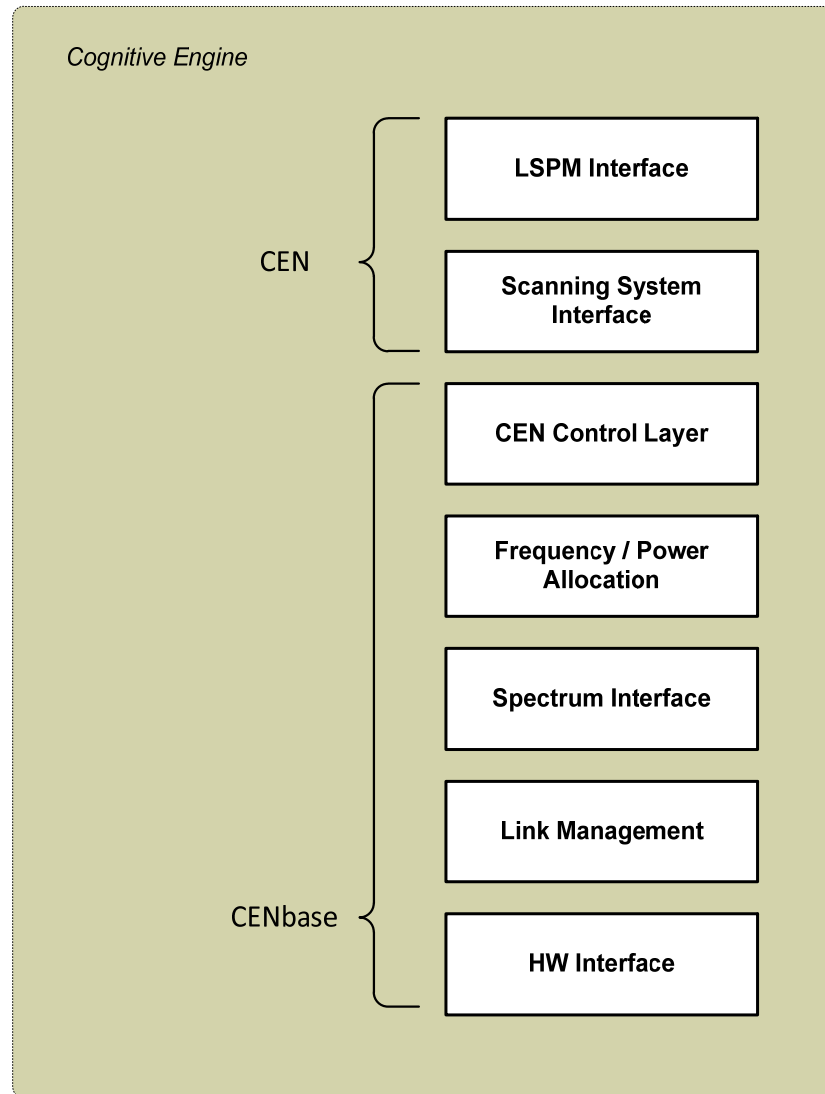
### Benefits

- LSDB has knowledge about allowed potential frequencies
- Isi communication avoids continuous and frequent access to GLDB
- LSDB may also host an offline copy
- Reflects ABT ask before talk



# C-PMSE concepts for spectrum sharing

## Cognitive Engine



### Abbreviation

- CEN Cognitive Engine

### Realisation

- CEN not standardized
- Graph shows exemplary realisation in BMWI C-PMSE
- A highly performant CEN should also conduct non-linear analysis by projecting IM products (partly done already at Berlin demo)



## 5. Demonstration at Messe Berlin



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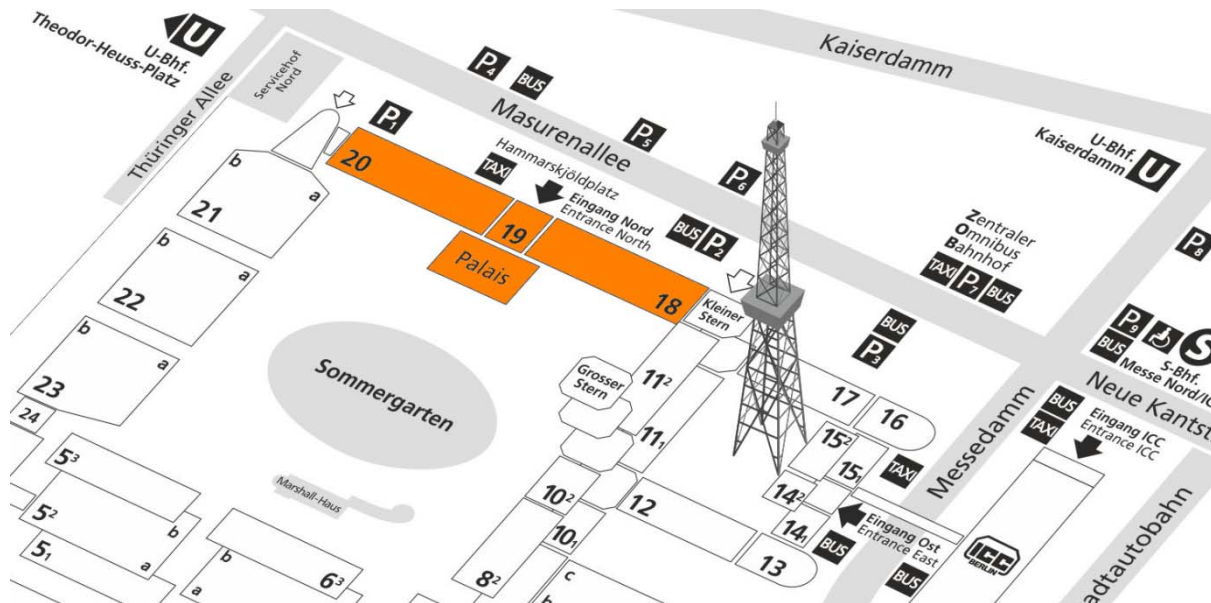
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# Demonstration at Messe Berlin

## Location

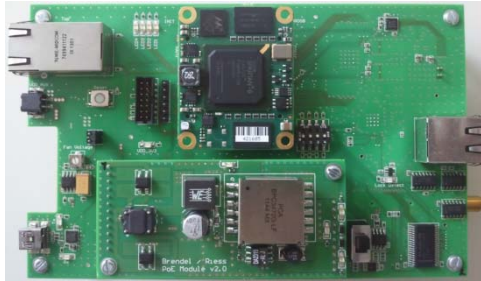
### Location

- Messe Berlin
- Installation date 15.-17. April 2013
- Scanning grid with 21 low cost scanners spread over halls 18/19/20/Palais

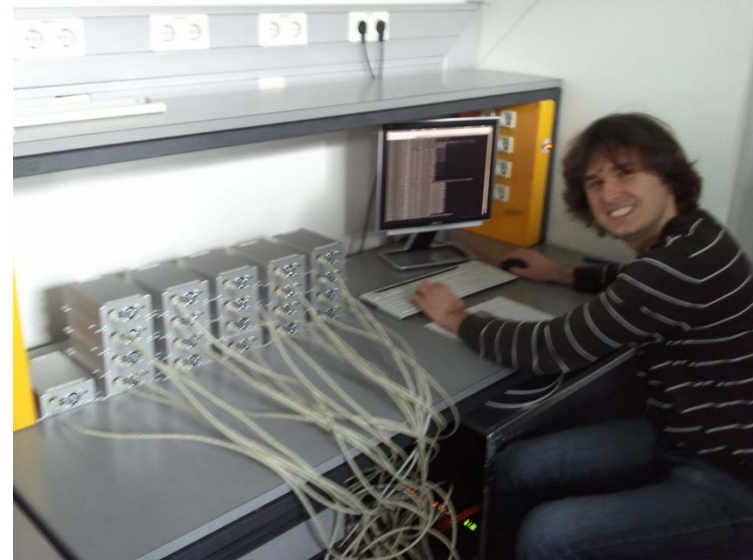


# Demonstration at Messe Berlin

## Scanning grid



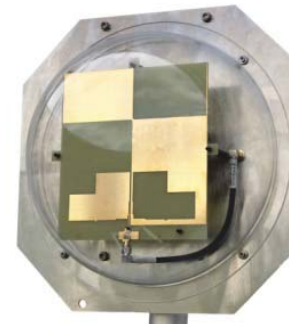
*Scanning receivers (SCR)*



*J. Brendel testing Scanning receivers*

### Scanning subsystem (SCS)

- 21 Scanning Receiver with antennas,
- 1 Scanning controller with database
- Demonstration Monitor
- Scanning band 718-790 MHz every 800ms



*Broadband  
Scanning antennas*



*Scanning controller (SCS)*

# Demonstration at Messe Berlin

## What was demonstrated?

### Public Demonstrations

- Public demo on 29<sup>th</sup> April 2013
- Presentation of the C-PMSE Research Platform
- Short presentation on components and functions

### Functionalities demonstrated

- Automatic System Setup and Configuration
- Spectrum Scanning
- Signal Classifications
- Operation Modes (legacy versus cognitive)
- Performance Monitor
- Link Quality Indicator for Analogue FM links



### What was demonstrated?

- Walk around equipped halls with PMSE Microphone
- Change of frequency due to interference
- Change of transmit power due to Interference



# Demonstration at Messe Berlin

## Cognitivity in Space?



**Hemispherical Scan Antenna by  
Prof. Jan Hesselbarth, UNI Stuttgart  
L-Band**



**Measurement Campaign on roof of  
Cauerstrasse 9, FAU**

**Can we coordinate with MSS?**





## 6. Conclusions



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## PMSE

- Unique requirements (high operational SNR)
- What is not produced cannot be distributed ... in the beginning of the food chain...

## Spectrum situation at UHF

- Low frequencies are very attractive due to good propagation and low Doppler
- PMSE has massively lost spectrum due to digital dividend
- Multiple users: PMSE, DVB-T, Cellular, WSD

## Research and Standardisation on Cognitive PMSE

- Aligned work in ETSI STF386 and BMWI C-PMSE research project

## C-PMSE

- Architecture being researched and practically demonstrated
- Cognitive engine takes into account TX Intermod, so it is a nonlinear optimization
- Frequency resources cannot be assumed to be orthogonal and thus independent of each other
- Dynamic change off frequeuncy and power, future also AMC

## Outlook

- Cognitionity in spatial domain, hemispherical scan for coordination of PMSE with MSS