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TECHNICAL REPORT

**Electromagnetic compatibility
and Radio spectrum Matters (ERM);
Methods, parameters and test procedures for cognitive
interference mitigation techniques for use by PMSE devices
(Programme Making and Special Events)**

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The present document is the deliverable of phase 3 work by ETSI STF 386. It is a refinement of the concepts and methods depicted in earlier documents by phase 1 and phase 2. Phase 1 has generated document ETSI TR 102 799 [i.2] and phase 2 document ETSI TS 102 800 [i.6].

The refinement is based on the experience and lessons learnt during the course of a German national research project called "C-PMSE" funded by the German Federal Ministry of Economics and Technology (BMWi). This project had the aim of ensuring the high quality of productions with PMSE under a dynamically changing interference situation.

The present document therefore reflects several modifications to the originally proposed architecture of a cognitive interference mitigation system and spectrum access for PMSE and to the methods of operating it.

As the majority of partners and experts participating in STF 386 were also partners on the German Research project, a smooth transfer of public information gained in the research project to the STF 386 work was ensured.

The present document will highlight the changes made to the architectural concepts and operation methods for cognitive interference mitigation with PMSE over the phase 1 and phase 2 deliverables as a consequence of the findings by the German research project.

The present document provides recommendations on the interfaces that need to be standardized to ensure proper functionality of interference mitigation techniques.

As the german research project ran a large demonstration tested at Messe Berlin, several tests of cognitive behaviour have been conducted there and a deep understanding of necessary tests has been developed which serves as the basis for defining recommended test cases in the present document. The aim is to recommend test cases that should be incorporated in the relevant standards.

C-PMSE technology and measurement procedures should be incorporated in ETSI EN 300 422-1 [i.1] and ETSI EN 301 489-1 [i.4] and ETSI EN 301 489-9 [i.7] as soon as practicable in order to encourage the development and widespread use of cognitive PMSE systems in the market.

Although the testings and demonstrations with the German research project have focussed on UHF TV Band, the findings on refinement of architecture and operation method are applicable to other bands.

During Phases 1 and 2, the STF 386 has accomplished the following work:

- Investigated methods, principles and techniques for spectrum access systems for PMSE technologies and for the guarantee of a high sound production quality on selected frequencies utilizing cognitive interference mitigation techniques.
- Delivered an ETSI Technical Report ETSI TR 102 799 [i.2] on "Operation methods and principles for spectrum access systems for PMSE technologies and for the guarantee of a high sound production quality on selected frequencies utilizing cognitive interference mitigation techniques".
- Delivered an ETSI Technical Specification on the recommended spectrum access technique, defined in ETSI TS 102 800 [i.6] on "Electromagnetic compatibility and Radio spectrum Matters (ERM); Cognitive Programme Making and Special Events (C-PMSE); Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques".

During Phase 3, the STF 386 performed the following work:

- Specified test procedures based on experience gained during the BMWi research project. Please note that although the technology demonstrator at Messe Berlin concentrated on one particular PMSE application and frequency band, the theory is applicable to all PMSE applications.
- Delivered the present document containing the defined compliance tests for the proposed spectrum access mechanism evolved from ETSI TR 102 799 [i.2] and ETSI TS 102 800 [i.6]. STF 386 by the present document proposes the type of compliance required, which will be different from the current ETSI EN 300 422-1 [i.1] specifications.

1 Scope

The present document proposes an architecture for C-PMSE. This includes e.g. procedures, protocol, elements and interfaces.

The goal is to ensure high production quality with PMSE while raising efficiency of spectrum use.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 300 422-1 (V1.4.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 1: Technical characteristics and methods of measurement".

[i.2] ETSI TR 102 799: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Operation methods and principles for spectrum access systems for PMSE technologies and the guarantee of a high sound production quality on selected frequencies utilising cognitive interference mitigation techniques".

[i.3] Recommendation ITU-R SM.2152, (09/2009): "Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS)".

[i.4] ETSI EN 301 489-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements".

[i.5] Recommendation ITU-R BT.2069-5 (05/2011): "Tuning ranges and operational characteristics of terrestrial electronic news gathering (ENG), television outside broadcast (TVOB) and electronic field production (EFP) systems".

[i.6] ETSI TS 102 800: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Cognitive Programme Making and Special Events (C-PMSE); Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques".

[i.7] ETSI EN 301 489-9: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 9: Specific conditions for wireless microphones, similar Radio Frequency (RF) audio link equipment, cordless audio and in-ear monitoring devices".

[i.8] ECC Report 002: "SAP/SAB (Incl. ENG/OB) spectrum use and future requirements".

[i.9] 2013-12-02-IETF-PAWS Protocol to Access White-Space Databases (Internet-draft).

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

audio base station: audio PMSE equipment that is fixed and part of C-PMSE Device

audio terminal: audio PMSE equipment that is moving

C-PMSE system: constituted out of information acquisition and C-PMSE

CENbase: radio resource management including all time critical processes of CEN

content plane: contains audio and/or video information, analogue or digital

control plane: plane which contains only control information (signalling), e.g. Radio Resource commands, battery status, etc.

NOTE: The term data plane/data channel is not used in the present document due to potential irritations. Instead control and content plane are used.

ePMSE: evolved PMSE, a combination of content and control plane whose radio parameters of content plane can be altered electronically simultaneously on both ends of radio link

information acquisition: acquires information about actual spectrum use and assignments

PMSE link: describes the content-plane only

shared infrastructure: C-PMSE information acquisition can be shared among multiple C-PMSE, regardless of mobile, nomadic or fixed use

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AMC	Adaptive Modulation and Coding
AMCT	Adaptive Modulation and Coding Table
ASQ	Action Sequencer
BER	Bit Error Rate
BMWi	German Ministry of Research and Education
CDMA	Code Division Multiple Access
CEN	Cognitive Engine
CENbase	Time critical processes of CEN
CPC	Cognitive Pilot Channel
cpi	Interface between co-located Radio Resource Managers
C-PMSE IA	C-PMSE Information Acquisition
C-PMSE	Cognitive PMSE
CR	Cognitive Radio
CRS	Cognitive Radio System
DAT	Device Allocation Table
DBC	Internal Database of CEN
DBS	Database
DMO	Demonstration Monitor

DUT	Device Under Test
DVB-T	Digital Video Broadcasting - Terrestrial
ECC	Electronic Communication Committee
ePMSE	Evolved PMSE
EVM	Error Vector Magnitude
FAT	Frequency Allocation Table
fci	Interface between CEN and LSPM
FCO	Frequency Coordinator
FM	Frequency Modulation
GLDB	Geolocation Database
gli	Interface between Local Spectrum Database and Gelocation Database
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile Communication
GUI	Graphical User Interface
HAL	Hardware Abstraction Layer
HW	Hardware
IA	Information Acquisition, combines Scanning System and Frequency Booking
IEM	In Ear Monitor
IETF	Internet Engineering Task Force
IM	Intermodulation
IRT	Institut für Rundfunktechnik GmbH
ITU-R	International Telecommunication Union - Radio
LAT	Link Allocation Table
LQI	Link Quality Indicator
LSDB	Local Spectrum Database
lsi	Interface between Local Spectrum Database and CEN
LSPM	Local Spectrum Portfolio Manager
LTE	Long Term Evolution
MIMO	Multiple In Multiple Out
NRA	National Regulatory Authority
OTA	Over the Air
P2MP	Point to Multipoint
P2P	Point to Point
PAT	Power Allocation Table
PAWS	Protocol to Access White Space Database
PLL	Phase Lock Loop
PMO	Performance Monitor
PMSE	Program Making and Special Events
PSME	Program Making and Special Events
PWMS	Professional Wireless Microphone System
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
REM	Radio Environment Map
RF	Radio Frequency
rli	Interface between Hardware Abstraction Layer and CEN
RRM	Radio Resource Manager
RSSI	Radio Signal Strength Indicator
SCA	Scanning Antenna
SCC	Scanning Controller
sci	Interface between Scanning System and CEN
SCR	Scanning Receiver
SCS	Scanning System
SINR	Signal to interference plus noise ratio
SLE	Service Level Entry
SNR	Signal to noise ratio
STF	Special Task Force
TCP/IP	Transmission Control Protocol / Internet Protocol
TV	Television
UHF	Ultra High Frequency
WSD	White Space Device

4 Specialities of PMSE

4.1 Overview

PMSE especially PWMS have specific requirements that differ from other wireless systems. In the following some aspects are discussed.

4.2 Latency of service

PMSE has to serve very stringent latency requirements. The difference to most other wireless systems is that with PMSE the information source is co-located with the information sink, e.g. an artist is using a wireless microphone and simultaneously an In Ear Monitor.

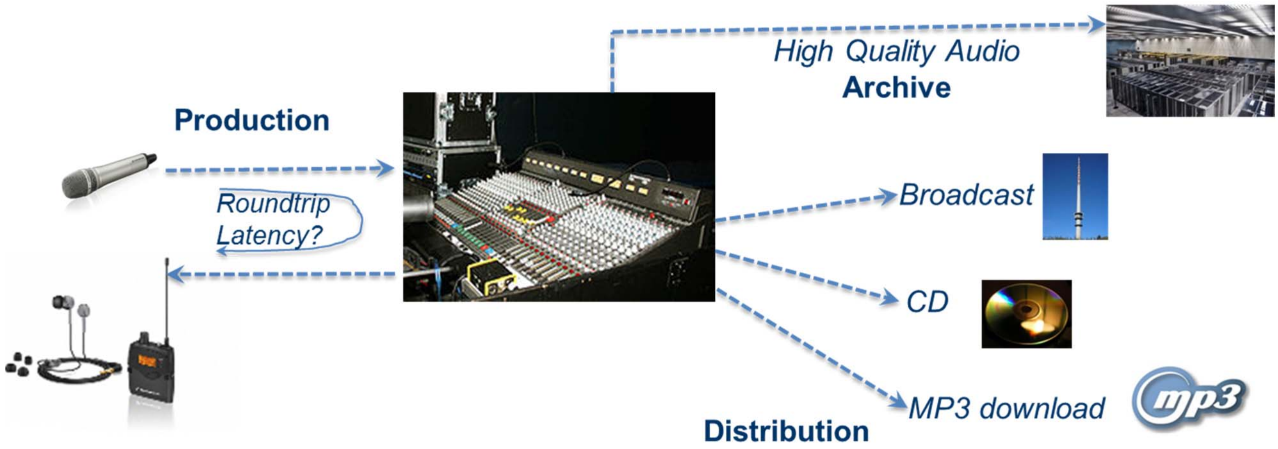

Figure 1: Roundtrip Problem scenario

The loopback from the artist back to the artist is enriched by the mixing console, where the information from other artists are added.

Experience from drummer artists tells that a roundtrip of smaller than 5 ms is needed for a high quality artistic performance. Assuming 1 ms for the mixing console, one PMSE link would be allowed to have maximum 3 ms latency.

If with an event multiple microphones are used there is also a further requirement on the latency differences between the links as this may lead to acoustic holes (comb filtering) in spatial sound production or loss of synchronization between audio and video production.

4.3 Availability of service

PMSE applications have high requirements in terms of availability of service. Availability should be 100 %. In a high quality production loss of a wireless link, leading to interruptions of the audio link, called drop-outs, are not acceptable. In general no perceived interruption whatever root cause can be tolerated. As variations of received signal strength due to fading may easily reach 30 dB, typically a high margin and diversity gains are implemented on the link budget.

An event or performance cannot be repeated. Mostly these are unique events, so information would be lost totally. In other communication systems lost data can be repeated, which of course adds latency.

Robustness of transmission cannot be gained by wide temporal interleaving as this would introduce unacceptably large latency.

4.4 Mobility

Some artistic performances and ENG applications involve high speed by mobile terminals, like wireless microphones with singers on skates e.g. with Musicals Cats and Holiday on Ice or reports from cars. Therefore typically speeds up to 80 km/h have to be supported, i.e. PMSE need to support mobility.

4.5 SNR operational conditions

RF SINR operational conditions for analogue FM links are higher than for other systems. As the 20 kHz audio bandwidth is typically expanded to 200 kHz wide RF channels, there is only a 10 dB bandwidth expansion gain by FM. This means that audio SNR is only 10 dB better than the RF SNR. So if an non-companded audio SNR of 60 dB is demanded, the SINR at RF has to be 50 dB. For reference GSM could work successfully with 7 dB to 9 dB SINR and CDMA systems may also work with negative SINR.

4.6 Intermodulation

In PMSE deployments one may face not only strong receiver, but also strong transmitter intermodulation. If for example an artist carries a wireless microphone and an instrument transmitter or if two singers stand close with their wireless microphones, reverse intermodulation can happen, meaning that part of the transmitter power from one wireless microphone enters the output stages of the other wireless microphone. Intermodulation's products will be generated due to non-linear behaviour of the output stage. As the operational RF SINR values are typically much higher than in other systems, PMSE is more vulnerable to transmitter and receiver intermodulation. This is the reason why intermodulation products are carefully planned up to IM5 products.

5 Terminology on spectrum use

5.1 Overview

For performing an optimization in terms of spectrum use, it is important to have a clear understanding of the metrics to be improved. In the following various metrics are presented. As there is also a lot of confusion in the definition of the term "spectral efficiency" the terminology is revisited here.

5.2 Definitions

5.2.1 Spectral efficiency of a point to point connection

The term "spectral efficiency of a P2P connection" describes the properties of a transmission scheme for a point-to-point link. It reflects the number of bits transported per second within a given bandwidth. It is measured bit/s/Hz. It can be increased by several options:

a) Increasing the order of modulation, e.g. from QPSK to 256 QAM.

b) Applying Source coding. With digital transmission e.g. MP3 could be used to reduce the amount of data to be transmitted. With analogue transmission an analogue compander reduces the dynamic range and which is a way of increasing spectral efficiency. Source coding is not only applicable to digital transmission, it is applicable to analogue transmission as well.

c) MIMO. This means multiple antennas at the transmitter and multiple antennas at the receiver. If the propagation channel offers a lot of reflections, the spectral efficiency more or less scales linearly with the number of antennas.

5.2.2 Spectral efficiency of a wireless communication system

The term "Spectral efficiency of a wireless communication system" describes the number of bits transported within a second and within a given bandwidth summed over all users normalized to served area. It is measured bit/s/Hz/km^2 . It therefore reflects an aggregation over all users, thus multiple links, versus above definition which reflects only one link.

This spectral efficiency of a wireless communication system can be increased by smaller cells, i.e. smaller cell radius equivalent to more dense placing of communication nodes. Small cell base stations with cellular networks are a good example for this approach.

5.2.3 Efficiency of spectrum use, sometimes also called short "spectral efficiency"

The term "Efficiency of spectrum use" describes the number of bits transported within a second and within a given bandwidth summed over all users normalized to area regardless what communication system the link belongs to. It is measured bit/s/Hz/km^2. It therefore reflects an aggregation over all users and all communication systems that share a spectrum.

It can be increased by implementation of co-primary and secondary systems, that make use of resources actually not in use by primary systems. So it is an opportunistic access by the secondary users.

As sometimes the "efficiency of spectrum use" is also named spectral efficiency, a conflict with the first definition arises. The present document is using the terms as described in clauses 5.2.2 and 5.2.3.

5.3 Objective in the context of a C-PMSE system

The objective with running a C-PMSE plus infrastructure is to increase the metric "efficiency of spectrum use". This optimization is different from the activities on digitizing PMSE which mainly is related to the first definition "spectral efficiency" of the individual PMSE link. A C-PMSE system does identify and use available spectrum pieces for transmission, while still ensuring a high quality audio link at high availability level (no drop-outs).

5.4 Spectral efficiency of a PMSE link

There is large expectation that digitizing PMSE would increase "spectral efficiency" per se. This is not the case. Instead digital transmission implies additional overhead by e.g. signalling and channel training.

Spectral efficiency increase is not the primary scope of a C-PMSE system, but ensuring high quality, robustness and availability of PMSE links.

6 Cognitive properties

6.1 Overview

The following clauses provide general definitions of terms, general concepts, and high-level functionalities to be implemented by a cognitive PMSE.

6.2 General description of cognitive functionality

Cognitive functionality includes at least following sequence of stages:

- Acquisition of context-awareness (Orient, Observe):
  - Gathering information about geo-location, radio spectrum environment, operational goals and parameters.
  - Understanding and translating acquired information into suitable assessment criteria (e.g. rating of radio spectrum resources, definition of a suitable cost function for resource usage).
- Autonomous dynamic system reconfiguration (Plan, Decide, Act):
  - Planning and decision-making in order to achieve goals of operation, usually involving reasoned judgment of acquired knowledge and some optimization procedures.
  - Implementation of decisions through reconfiguration and adaptation of operational parameters.

Additional cognitive functionality may include learning from past actions and reoccurring situations. Learning functionality implies in general following system capabilities:

- Recognizing patterns of behaviour.
- Evaluation of risks and prediction of future events.

6.3 Definition of Cognitive PMSE

Cognitive PMSE is built of a Cognitive Radio System (CRS) designed for the purpose and the specific requirements of PMSE applications (ECC Report 002 [i.8]).

The ITU definition of Cognitive Radio Systems (CRS) (Recommendation ITU-R SM.2152 [i.3]) is as given in table 1:

Table 1

Definition	Actions
"A radio system employing technology that allows:	
• the system to obtain knowledge of its operational and geographical environment, established policies and its internal state;	Orient, Observe
• to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives;	Plan, Decide, Act
• and to learn from the results obtained."	Learn
NOTE: The implementations to obtain knowledge of its operational and geographical environment, and established policies (Orient, Observe) can include technology approaches such as geolocation database, sensing of the radio environment or cognitive pilot channels (CPC).	

7 Functionality of a Cognitive PMSE System

7.1 Overview

This clause describes the general concept of cognitive PMSE systems and provides an overview of their functionality.

7.2 General Concept of Cognitive PMSE

In the light of the definition of cognitive PMSE, herein after called C-PMSE, C-PMSE is able to acquire and use appropriate radio spectrum and autonomously avoid or minimize harmful interference while ensuring high audio quality by:

- obtaining knowledge about legally appropriate operating frequency ranges at the system's geographic location as well as at a certain time;
- sensing the radio environment;
- measuring the radio link quality;
- switching the wireless audio links to (alternative) operating frequencies and/or adapting their link parameters;
- learning from past system behaviour and from reaction on different system interference situations.

For that, an example C-PMSE may consist of:

- a remote controllable wireless audio link;
- a mechanism to obtain knowledge about appropriate operating frequency ranges (e.g. by contacting the administration, by access to a suitable database);
- access to a sensing system and/or a geo-location database;
- a mechanism to assess the wireless audio link quality or possible interferences (internal measuring capability).

7.3 Features of BMWi C-PMSE demonstrator

7.3.1 General

BMWi C-PMSE demonstrator is the outcome of the BMWi C-PMSE project, which aims to develop a research platform for the evaluation and validation of cognitive radio to improve the frequency utilization and coexistence for PMSE systems by cognitive methods. It considers only professional wireless microphone systems with state of the art analogue transmission scheme (FM). Digital audio transmission schemes are not in the focus of the BMWi C-PMSE demonstrator.

BMWi C-PMSE demonstrator consists of three main blocks (figure 2):

- C-PMSE master including cognitive engine, and the wireless audio links.
- Scanning System (SCS) with scanning receivers (SCR) and scanning controller (SCC).
- Local Spectrum Portfolio Manager (LSPM) maintaining the local available spectrum portfolio for operation.

Not the complete concept of clause 7.2 but a subset of its functionality is implemented in the BMWi C-PMSE demonstrator.

The implemented features are:

- Ask before talk.
- Spectrum sensing (Listen before talk) and spectrum rating.
- Reaction on changes in spectrum environment and in transmission quality respectively.

7.3.2 Ask before talk

At start-up C-PMSE negotiates with local spectrum portfolio manager (LSPM) a spectrum range for operation at a certain time, whereby LSPM obtains knowledge from geolocation database (GLDB). Without the LSPM having obtained knowledge about legally appropriate spectrum C-PMSE should not start wireless audio transmission.

LSPM periodically obtains knowledge about legally appropriate spectrum.

7.3.3 Spectrum sensing (listen before talk) and spectrum rating

The SCS is used for spectrum observation matters. It allows continuous sensing of the used spectrum range not only at system start-up but also during operation. To overcome hidden node and fading problems a grid of small, low cost scanning receivers (SCR) is employed.

The spectrum rating process continuously translates measurement data of SCS into two assessment criteria:

- risk: expressing the potential for getting interfered;
- quality: expressing the expected noise plus interference level of free spectrum;
- expressing the measured signal-to-noise plus interference-ratio SINR at the working frequencies.

7.3.4 Reaction

If SCS or C-PMSE master detect a decrease in spectrum quality and/or transmission quality respectively, C-PMSE master has to initiate proper reaction. Reaction differs depending on system operational phase.

During initialization:

- C-PMSE rates the spectrum range provided by LSPM by means of measurement data coming from SCS to perform an initial frequency planning. The resulting frequency list is executed at C-PMSE operation start.

During operation:

- C-PMSE continuously rates the possible useable radio spectrum using measurement data from SCS. This includes occupied by wireless audio links and non-occupied radio spectrum.
- In addition radio spectrum occupied by wireless audio links is rated by means of link quality indicator (LQI) data.
- The outcomes of rating processes can trigger related actions.

8 The Demonstrator in the BMWi C-PMSE Project

8.1 Overview

The following clauses provide a detailed overview on the BMWi C-PMSE project and its demonstrator including architecture overview, elements, functionalities, and limits of the realized demonstrator. Furthermore, the interfaces to its LSPM and its distributed Scanning Subsystem (SCS) are provided as initial input for standardization.

8.2 BMWi C-PMSE Project Overview

The C-PMSE project was started on April 1st, 2011 and will run in three phases for 32 month until November 30th, 2013.

The consortium of the BMWi C-PMSE project consists of five partners from industry, one research institute, and three universities.

Within the consortium Robert Bosch GmbH and Sennheiser electronic GmbH & Co. KG are representing the PMSE industry. The Institut für Rundfunktechnik GmbH (IRT), a research institute serving German, Austrian, and Swiss public broadcasters, represents the broadcasters as users of PMSE technology and the broadcasting services (like DVB-T) as primary user of radio spectrum in the UHF-TV bands. eesy-id GmbH is involved to develop sensor nodes, wiseSense GmbH for wireless coexistence and related standardization & regulation activities, and RFmondial GmbH develops monitoring software and data base infrastructures. The universities Friedrich-Alexander-Universität Erlangen-Nürnberg, Gottfried Wilhelm Leibniz Universität Hannover, and Ruhr Universität Bochum provide the practical and scientific expertise in electronics, signal processing, software defined radio, cognitive radio, radio resource management, signal classification, measurements, channel modelling, and link and system level simulation.

The C-PMSE project has two main objectives:

1) Setting up a research platform for lab and field trials; and
2) Driving standardization and regulation for cognitive PMSE systems.

Beside of the realization and setup of the lab and field trial platforms, the main goals include the development of all-necessary hardware and software components, the development and installation of a distributed scanning system with signal processing, network and data base infrastructure, and the verification of feasibility. Finally functional demonstrations and test operations on the lab and field trial platforms, which may include activities of the working group ETSI STF 386, will be performed. Coexistence investigations with other wireless services and devices, like white space devices, mobile communications, digital video broadcasting terrestrial (DVB-T), will be executed.

Standardization and regulation activities of the project consider cognitive radio (CR)-enabled approaches for PMSE applications in worldwide regulatory frameworks. The BMWi C-PMSE project aims therefore, to provide appropriate and validated inputs for standardizations and frequency regulations.

8.3 Architecture of BMWi C-PMSE Demonstrator

8.3.1 General

C-PMSE demonstrator is built up by three main system blocks including all necessary functionality. Figure 2 shows the block diagram of the C-PMSE demonstrator.

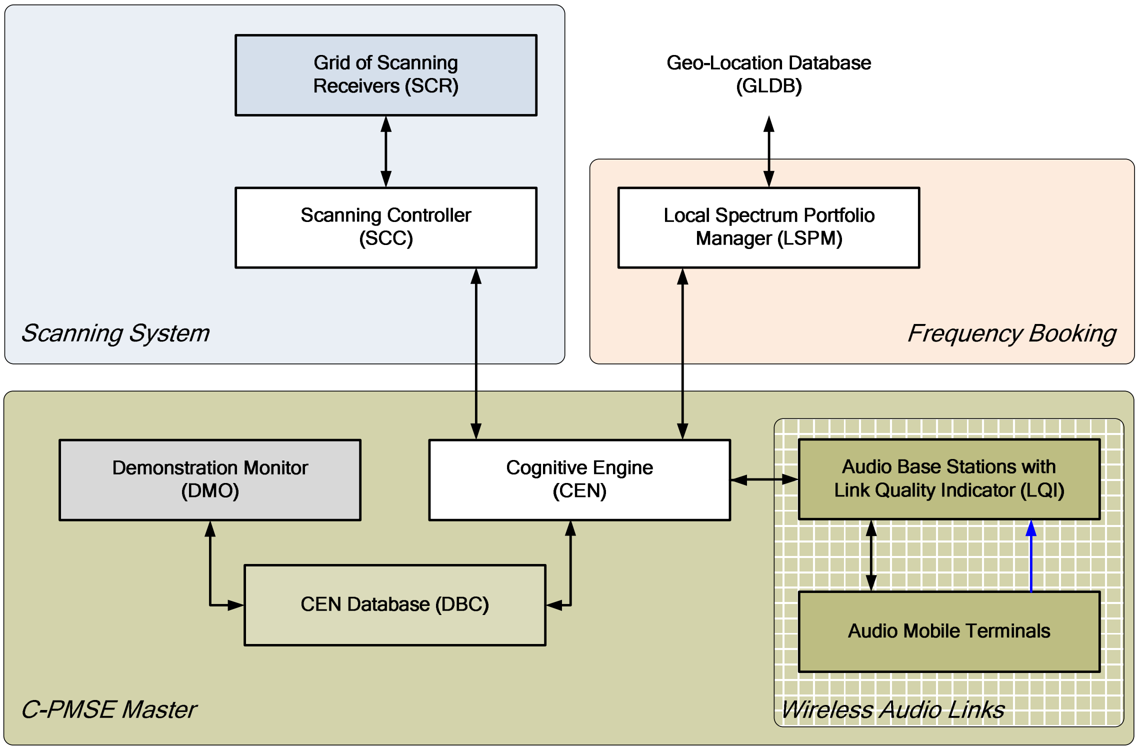

Figure 2: Block diagram of BMWi C-PMSE demonstrator

The three main blocks and their tasks are:

- Local spectrum portfolio manager (LSPM) with interface to C-PMSE master and to the geo-location database (GLDB):
  - Lowest level of hierarchical GLDB.
  - Task: Radio spectrum assignment to C-PMSE.
- Scanning system (SCS):
  - Scanning grid with low cost scanning receivers (SCR) and scanning controller (SCC) for managing scanning jobs and controlling SCRs.
  - Task: Continuous, and dedicated grid sensing of radio spectrum.
- Cognitive PMSE (C-PMSE):
  - C-PMSE master with cognitive engine (CEN), internal database (DBC), demonstration monitor (DMO), and wireless audio links consisting of one audio base station, one audio mobile terminal, one audio channel (blue arrow) and one control channel (black arrow) per link.
  - Task: Maintaining high quality and availability of the wireless audio links.

8.3.2 Functional Blocks of BMWi C-PMSE Demonstrator

Functional blocks depicted in figure 2 are as follows:

- Local Spectrum Portfolio Manager (LSPM):
  - LSPM is the project's realization of the lowest level of a geo-location database (GLDB) hierarchy. It tells C-PMSE, which radio frequency ranges are allowed for operation. LSPM can also connect to GLDB to get information from NRA.
  - In ETSI TS 102 800 [i.6] LSPM is called frequency coordinator (FCO).

- Scanning System (SCS):
  - SCS comprises one scanning controller (SCC) and several scanning receivers (SCR). SCC is in charge of managing all SCR connected to it.
  - The internal database (DBS) within SCC is used for data exchange and act as a common interface within SCS to CEN of C-PMSE master.
  - Following a request from CEN, SCC schedules scanning jobs among its SCR, performs pre-processing (e.g. signal detection, parameter extraction) of data acquired and provides essential information to CEN. Allowing data pre-processing in SCC serves to distribute the computational load of the required signal processing and to significantly reduce the load on the interface between SCS and CEN.
- C-PMSE master:
  - C-PMSE master consists of a cognitive engine (CEN), an internal database (DBC), a demonstration monitor (DMO), and remote controllable wireless audio links (audio base station + audio mobile terminal).
  - CEN constitutes the central control unit of the C-PMSE master and embodies the cognitive functionalities described in clause 7. CEN has the aim to guarantee interference-free high audio quality transmission of the reconfigurable wireless audio link.
  - Therefore:
    - it connects to LSPM in order to negotiate suitable radio frequency ranges for operation;
    - it continuously merges and analyses all information acquired via SCS with link quality indicators of the individual wireless audio links; and
    - it performs adequate dynamic resource allocation and transmit power control.
  - CEN is built up by different layers (see figure 3), of which the higher layers are named CEN and the lower layers CENbase, which contains all time critical processes. CENbase is the equivalent to the radio resource manager (RRM) depicted in ETSI TS 102 800 [i.6] without ASQ and AMCT. ASQ is not necessary in the current implementation anymore, because every system's reaction is based on the current rating of the given solutions independent on the kind of interference scenario. AMCT is not implemented, because supported wireless audio links are frequency modulated, which means, that frequency and power are adjustable only (FAT/PAT).
  - The internal database (DBC) is used for data exchange and as a common interface for all available components within C-PMSE Master.
  - DBC contains FAT/PAT, DAT, LAT, REM (see ETSI TS 102 800 [i.6]) and the solution pool of the genetic algorithm.
  - DMO allows visualization, tracing, and control of the behaviour and status of C-PMSE master operation. It also provides advanced storage capabilities to store measurement traces and log files. It combines the functionality of the performance monitor (PMO) and the service level entry (SLE) described in ETSI TS 102 800 [i.6] and ETSI TR 102 799 [i.2] respectively. SLE is realized as a lookup-table read in at system start-up. SLE cannot be adjusted during operation.
  - Remote controllable wireless audio links with following functionality:
    - frequency agility;
    - transmit output power agility;
    - link quality indicator.

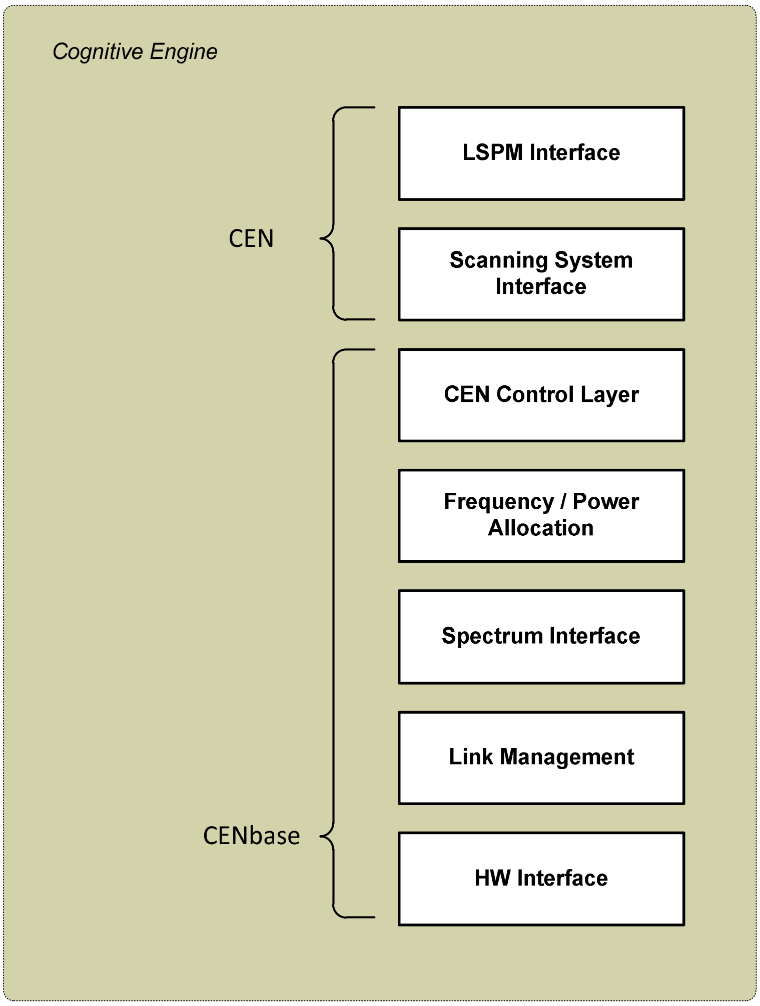

Figure 3: Layer model of cognitive engine

8.3.3 Interfaces of realized demonstrator

Two interfaces are realized:

- sci: interface between CEN and SCC.
- fci: interface between CEN and LSPM.

Original fci descript in ETSI TS 102 800 [i.6] is between RRM and FCO. Now it is rearranged and placed between CEN and LSPM. It is shifted from RRM (now CENbase) to higher layer CEN due to its less time critical character.

Original cpi (interface between RRMs of collocated C-PMSE) is omitted in the realization. Every inter C-PMSE communication should be done via LSPM.

A more detailed view on the interfaces can be found in clause 9.2.

8.3.4 Limits of realized demonstrator

There are several limits in the implementation of the BMWi C-PMSE demonstrator:

- Control plane is limited to a maximum of seven links.
- LQI measurement hardware supports a maximum of eight links.
- Six frequency agile wireless microphones are available.
- Four RF output power agile microphones are available.

- CEN handles either reconfigurable frequency or reconfigurable output power mode but not both simultaneously.
- HW Management layer of CENbase supports Sennheiser or Electro-Voice products only.
- DBC causes time delay when acquiring measurement data from a high number of SCR.
- CEN expects technology and feature homogenous wireless audio links.
- FM wireless audio links need long time for settling after frequency switching caused by the very low phase noise PLL.
- Frequency range of frequency agile wireless audio links is limited from 718 MHz to 790 MHz.
- Output power range of transmit power controlled links is limited to approx. 20 dB.
- SLE is fixed during operation.

General concept of BMWi C-PMSE is open for more links and frequency resources.

9 Generalized C-PMSE system architecture

9.1 Elements of the architecture

9.1.1 General

Figure 4 depicts the generalized logical C-PMSE system architecture. The physical structure does not have to be identical with the logical structure.

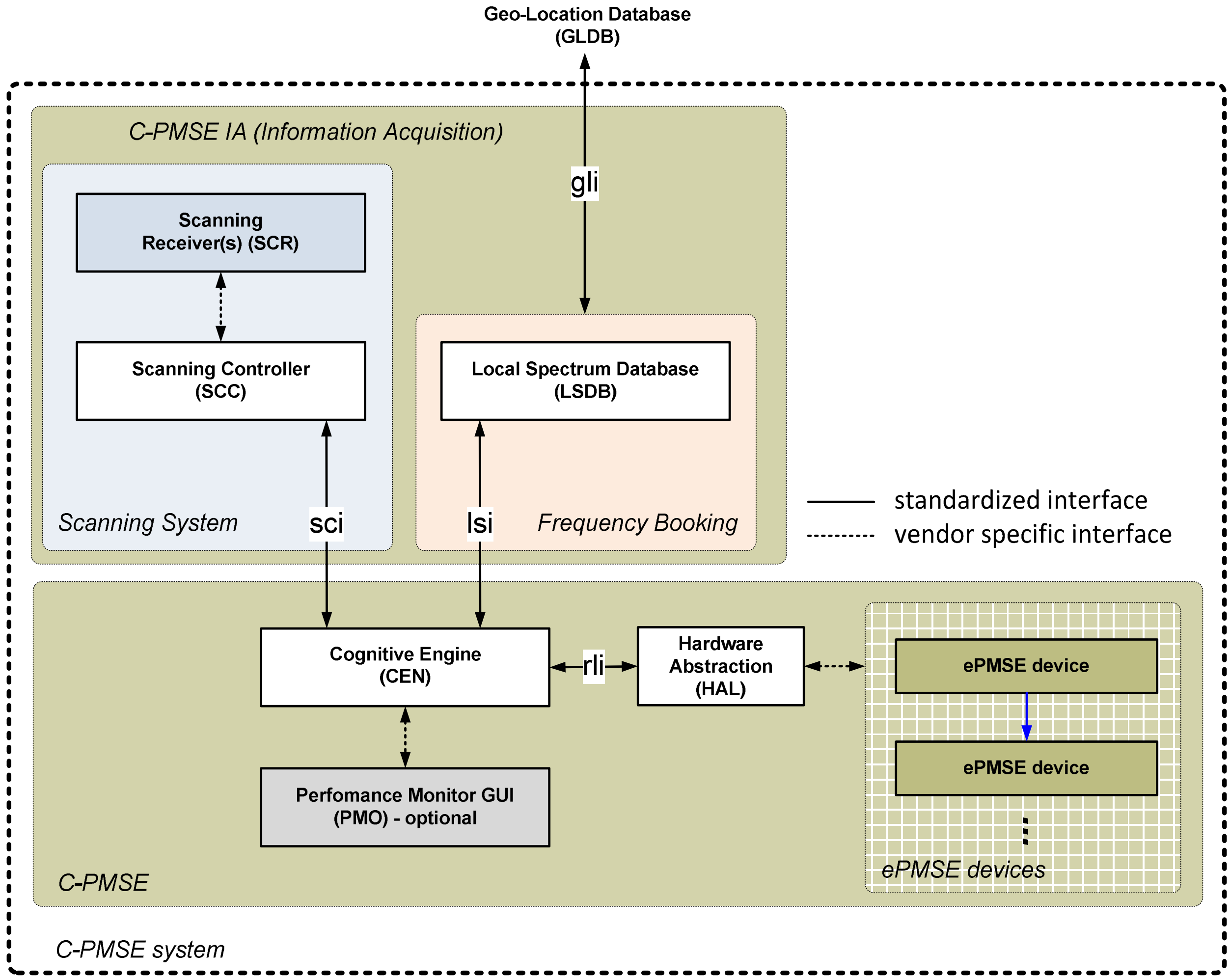

Figure 4: Generalized logical C-PMSE system architecture

9.1.2 Functionality of SCS

The SCS consist of one SCC and one or more SCRs connected to the SCC. With the help of the connected SCRs the SCC generates a radio environment map which is power over frequency and time of the SCS installation location. The location can be divided into multiple zones. For each zone a separate radio environment map is generated. In the case that the SCS is part of shared infrastructure, the SCS is connected to the C-PMSE over the sci interface. The SCC provides the radio environment map of one or more zones upon request of the C-PMSE. Optional features of the SCS include classification or localization capabilities.

Furthermore, the SCC delivers information about capabilities, location and zone configuration of the SCS to the C-PMSE.

9.1.3 Functionality of LSDB

The LSDB is a database which contains a list of regional usable frequency ranges for the C-PMSE. The list is entered manually or could be granted from the GLDB automatically. The LSDB delivers the list of available frequencies to connected C-PMSE upon request. In the case that the LSDB is part of shared infrastructure, the SCS is connected to the C-PMSE over the lsi interface.

As an optional feature the LSDB contains a list of the currently used frequencies. Therefore, each connected C-PMSE can deliver its current link allocation to the LSDB. The LSDB distributes the list of the used frequencies to all connected C-PMSEs. There is no guarantee that the list of used frequencies is complete or consistent.

9.1.4 Functionality of C-PMSE

The C-PMSE provides the functionality to transmit the content of a production (e.g. audio) over the air. Therefore, it uses at least two ePMSE devices. These devices are configured according to the information from the ePMSE devices, the LSDB and the SCS.

9.2 Interfaces

9.2.1 Scanning Interface (sci)

9.2.1.1 Overview

The interconnection of a shared Scanning System (SCS) and one or more C-PMSE is realized with the bidirectional Scanning Interface (sci) based on Ethernet and TCP/IP (figure 5). After an initial login and authentication procedure (which is not part of this interface description) the C-PMSE basically requests power spectral density and/or signal identification information for a certain frequency range from the SCS. The SCS answers which the corresponding measured data.

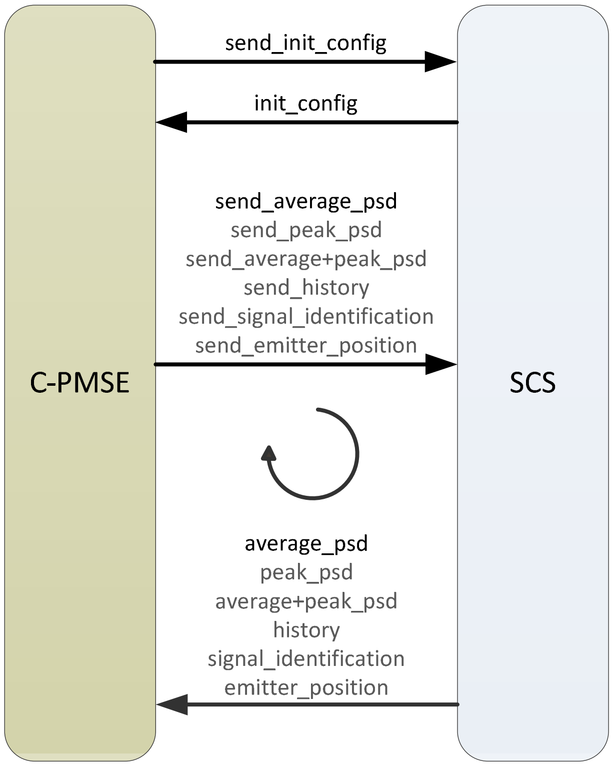

Figure 5: sci communication

9.2.1.2 Commands on sci interface

Table 2 summarizes all mandatory (M) and optional (O) commands which could be send over the sci interface from C-PMSE to SCS.

Table 2

sci Command	Parameters
'send_init_config' (M)	-
'send_average_psd' (M)	*f_range* (f_start, f_stop)[Hz, Hz](M), *f_res* [Hz](O), *avg_nmb* [-](M), *zone* [-](M)
'send_peak_psd' (O)	*f_range* (f_start, f_stop)[Hz, Hz](M), *f_res* [Hz](O), *avg_nmb* [-](M), *zone* [-](M)
'send_average+peak_psd' (O)	*f_range* (f_start, f_stop)[Hz, Hz](M), *f_res* [Hz](O), *avg_nmb* [-](M), *zone* (array{zone_number})[-](O)
'send_history' (O)	*f_range* (f_start, f_stop)[Hz, Hz](M), *time_range* (time_start, time_stop)[timestamp,timestamp](O), *f_res* [Hz](O), *zone* [-](M)
'send_signal_identification' (O)	*f_center* [Hz](M), *bw* [Hz](M), *zone* [-](M)
'send_emitter_position' (O)	*f_center* [Hz](M), *bw* [Hz](M), *zone* [-](M)

'send_init_config'

A 'send_init_config' command includes no parameters. This mandatory command requests the initial configuration of the SCS.

'send_average_psd'

A 'send_average_psd' command includes the frequency range *f_range*, the frequency resolution *f_res* in Hz with a typical value of 25 kHz, the number of averaged measurements *avg_nmb* and a *zone* number as parameters. This mandatory command requests the average power spectral density for a certain frequency range and resolution in the requested zone.

'send_peak_psd'

A 'send_peak_psd' command includes the frequency range *f_range*, the frequency resolution *f_res* in Hz with a typical value of 25 kHz, the number of measurements *avg_nmb* over which the peak value is calculated and a *zone* number as parameter. This optional command requests the peak power spectral density for a certain frequency range and resolution in the requested zone.

'send_average+peak_psd'

A 'send_average+peak_psd' command includes the frequency range *f_range*, the frequency resolution *f_res* in Hz with a typical value of 25 kHz, the number of average cycles *avg_nmb* and a *zone* number as parameters. This optional command requests the average as well as peak power spectral density for a certain frequency range and resolution in the requested zone.

'send_history'

A 'send_history' command includes the frequency range *f_range*, the frequency resolution *f_res* in Hz with a typical value of 25 kHz and a *zone* number and a *time_range* as parameters. This optional command requests the SCS history for a certain frequency range and resolution in the requested zone over the requested *time_range*.

'send_signal_identification'

A 'send_signal_identification' command includes the center frequency *f_center* in Hz, the bandwidth *bw* in Hz and a *zone* number as parameters. This optional command requests the signal identification inside of a certain frequency range in the requested zone.

'send_emitter_position'

A 'send_emitter_position' command includes the center frequency *f_center* in Hz, the bandwidth *bw* in Hz and one *zone* number as parameters. This optional command requests an estimation on the emitter position inside of a confidence radius in the requested zone.

Table 3 summarizes all mandatory (M) and optional (O) reports which could be send over the sci interface from SCS to C-PMSE.

Table 3

sci Command	Parameters
'init_config' (M)	*time* [timestamp], *scs_name* [verbose], *zone_config* (array{zone_number, zone_loc}[array{-,GNSS}], *f_range* (start_freq, stop_freq) [MHz, MHz], *f_res* (array{f_res}) [array{Hz}], *supported_commands* (array{cmd}) [array{verbose}]
'average_psd' (M)	*time* [timestamp], *spectrum* (array{freq_bin, psd_rms})[array{Hz, dBm}]
'peak_psd' (O)	*time* [timestamp], *spectrum* (array{freq_bin, psd_peak})[array{Hz, dBm}]
'average+peak_psd' (O)	*time* [timestamp], *spectrum* (array{freq_bin, psd_rms, psd_peak})[array{Hz, dBm, dBm}]
'history' (O)	*time* [timestamp], *spectrum* (array{freq_bin, hx_rms, hx_peak, hx_dev})[array{Hz, dBm, dBm, dBm}]
'signal_identification' (O)	*time* [timestamp], *signal_type* [*verbose*]
'emitter_position' (O)	*time* [timestamp], *location* (em_loc, conf_r) [GNSS, m]

'init_config'

An 'init_config' report includes a *time* stamp taken when the report is processed in the SCS, verbose *name* information of the SCS, the *zone_configuration* which is the zone_number and the corresponding zone location zone_loc in GNSS format, the frequency range *f_range* covered by the SCS, a vector of available frequency resolutions *f_res* as well as a list of *supported_commands*. This is a response to the mandatory 'send_init_config' command.

'average_psd'

An 'average_psd' report includes a *time* stamp taken when the report is processed in the SCS and the *spectrum* dataset with the frequency bins and the average values of the power spectral density psd_rms in the requested zone as a response to the mandatory 'send_average_psd' command.

'peak_psd'

A 'peak_psd' report includes a *time* stamp taken when the report is processed in the SCS and the *spectrum* dataset with the frequency bins and the average values of the power spectral density psd_peak in the requested zone as a response to the optional 'send_peak_psd' command.

'average+peak_psd'

An 'average+peak_psd' report includes a *time* stamp taken when the report is processed in the SCS and the *spectrum* dataset with the frequency bins and the average and peak values of the power spectral density psd_rms and psd_peak in the requested zone as a response to the optional 'send_average+peak_psd' command.

'history'

A 'history' report includes a *time* stamp taken when the report is processed in the SCS and the *spectrum* dataset with the frequency bins in Hz, the average and peak values of the SCS scanning history, hx_rms and hx_peak, and the deviation of the SCS scanning history over time hx_dev. These statistics are calculated over the requested time range with the data from the requested zone. This is a response to the optional 'send_history' command.

'signal_identification'

A 'signal_identification' report includes a *time* stamp taken when the report is processed in the SCS and a verbose *signal type* identification information (e.g. 'DVB-T', 'LTE', 'PMSE', etc.) as a response to the optional 'send_signal_identification' command.

'emitter_position'

An 'emitter_position' report includes a *time* stamp taken when the report is processed in the SCS and an estimation of the emitter *location* which is a GNSS coordinate em_loc and a confidence radius conf_r as a response to the optional 'send_emitter_position' command.

9.2.2 Local Spectrum Database Interface (lsi)

9.2.2.1 Overview

The interconnection of the Local Spectrum Database (LSDB) and one or more C-PMSE is realized with the bidirectional Local Spectrum Portfolio Interface (lsi) based on Ethernet and TCP/IP (figure 6). After an initial login an authentication procedure (which is not part of this interface description) the C-PMSE requests available spectrum from the LSDB which offers available local spectrum resources over the lsi interface. During operation the C-PMSE can update its current frequency allocation to the LSDB. On the other hand, the LSDB notifies the C-PMSE about changes in spectrum usage which is optional.

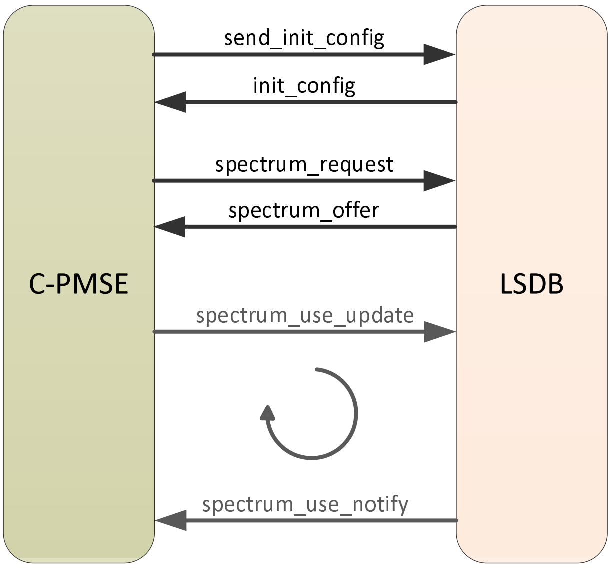

Figure 6: lsi communication

9.2.2.2 Commands on lsi interface

Table 4 summarizes all mandatory (M) and optional (O) commands which could be send over the lsi interface from C-PMSE to LSDB.

Table 4

lsi Command	Parameters
'send_init_config' (M)	-
'spectrum_request' (M)	*location* [GNSS coordinates] (M), *operation_radius* [m] (M), *duration* (start_time, stop_time)[timestamp, timestamp] (M), *freq_range* (start_freq, stop_freq)[Hz, Hz] (O)
'spectrum_use_update' (O)	*spectrum_usage* (array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (M), *potential_generated_imd* (array{center_freq, bandwidth}) [array{Hz, Hz}](O)

'send_init_config'

A 'send_init_config' command includes no parameters. This mandatory command requests the initial configuration of the LSDB.

'spectrum_request'

The 'spectrum_request' command requests available spectrum from the LSDB. Beside the information where (*location*) and when (*duration*) the spectrum should be used, the parameter *radius* gives the spatial extend of the intended spectrum usage. With the parameter *freq_range* the requested frequency range could be limited.

'spectrum_use_update'

The current spectrum usage of the C-PMSE can be signalled to the LSDB via the 'spectrum_use_update' command. The *spectrum_usage* dataset contains the current link allocation of the C-PMSE which is an array containing all center frequencies (center_freq), the corresponding bandwidth which should be kept free by other devices (keep_free_bandwidth) and the used output power (output_power). The optional dataset *potential_generated_imd* contains a list of potential disturbed frequencies by intermodulation products.

Table 5 summarizes all mandatory (M) and optional (O) commands which could be send over the lsi interface from LSDB to C-PMSE.

Table 5

lsi Command	Parameters
'init_config' (M)	*time [timestamp],* *lsdb_name [verbose],* *supported_commands (array{cmd}) [array{verbose}]*
'spectrum_offer' (M)	*available_frequency_ranges (array{start_freq, stop_freq, max_allowed_output_power, validity_period}) [array{Hz, Hz, dBm, timestamp}] (M),* *spectrum_usage(array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (O),* *potential_generated_imd (array{center_freq, bandwidth}) [array{Hz, Hz}](O)*
'spectrum_use_notify' (O)	*spectrum_usage (array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (M),* *potential_generated_imd (array{center_freq, bandwidth}) [array{Hz, Hz}](O)*

'init_config'

An 'init_config' report includes a *time* stamp taken when the report is processed in the SCS, verbose *name* information of the LSDB and a list of *supported_commands*. This is a response to the mandatory 'send_init_config' command.

'spectrum_offer'

After a 'spectrum_request' command from the C-PMSE, the LSDB answers with a 'spectrum_offer'. The *available_frequency_ranges* dataset contains an array of the potential usable frequency ranges (start_freq, stop_freq) with the maximum allowed output power in this range (max_allowed_output_power) and the validity of this spectrum grant (validity_period). Optionally, the already used and registered frequencies at the requested location are returned with the *spectrum_usage* dataset. The list of potential disturbed frequencies by intermodulation products is returned with the *potential_generated_imd* dataset.

'spectrum_use_notify'

Each time the link allocation list in the LSDB changes (e.g. another C-PMSE reallocates its links and signals this to the LSDB via the 'spectrum_use_update' command) it notifies all connected C-PMSE about this frequency change with the 'spectrum_use_notify' command. This is done via the *spectrum_usage* and *potential_generated_imd* dataset as described above.

9.2.3 Radio link management interface (rli)

9.2.3.1 Overview

Radio link management interface connects the hardware abstraction layer (HAL) with the cognitive engine (CEN) as depicted in figure 7.

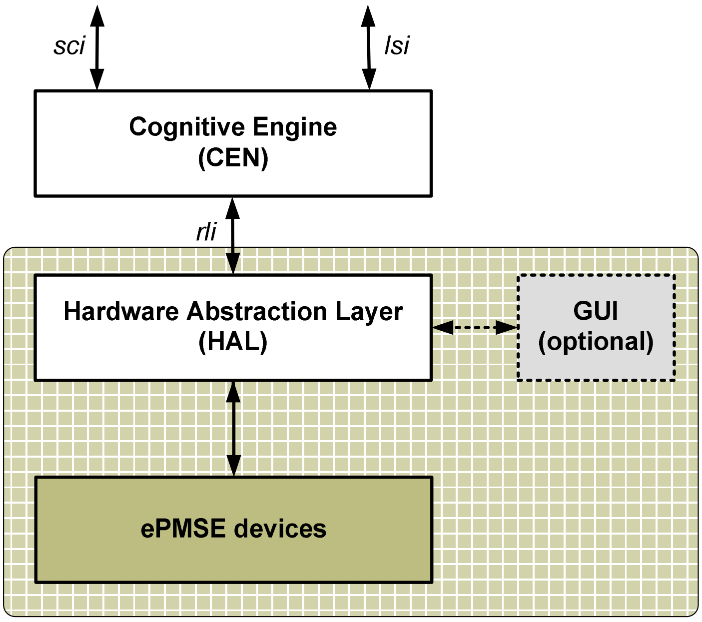

Figure 7: Architecture overview

rli is a bidirectional interface carrying commands, status and hardware information. It provides device capability information from ePMSE devices to CEN (e.g. RF bandwidth, minimum channel spacing, output power settings, etc.) and management commands from CEN to ePMSE devices. Status information like link quality indicator and battery state are communicated from ePMSE devices to CEN.

The hardware abstraction layer serves as vendor specific bridge to translate vendor specific hardware language to standardized commands for rli communication. For that reason HAL should be provided by the corresponding vendor of ePMSE devices.

To get access to HAL without a cognitive engine or any other higher layer software an optional GUI is provided.

If more than one kind of ePMSE devices is co-located, all devices can be managed by one CEN when connected to it via a specific HAL (figure 8). So it is possible to share one CEN with ePMSE devices of different vendors or with different command syntaxes.

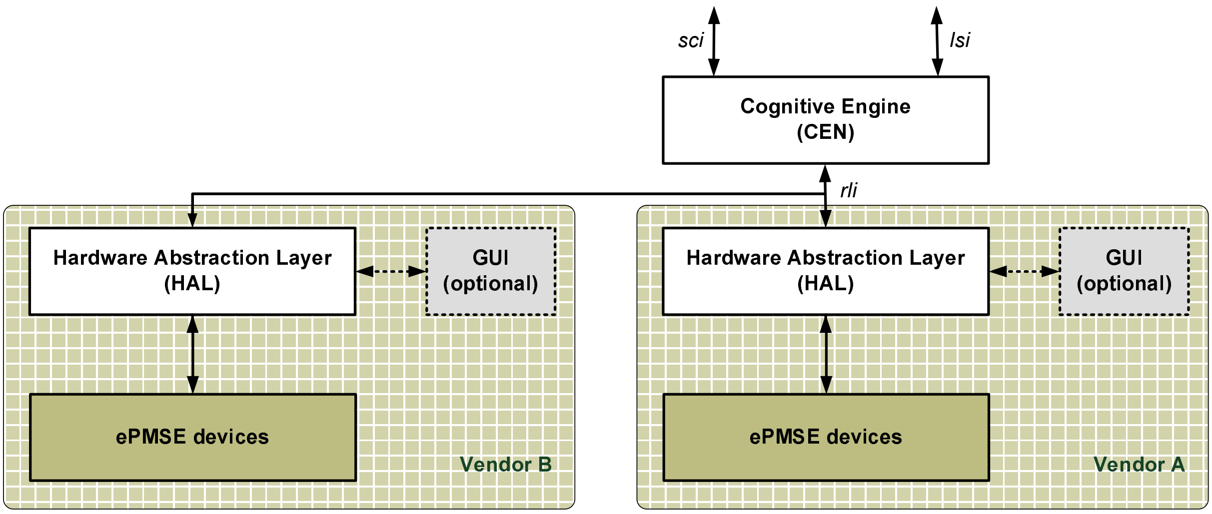

Figure 8: Two co-located C-PMSE connected to one CEN

Two processes are running. The Device Management Process is in charge of detecting what devices are connected and what capabilities they are having.

The Dynamic Link Management Process ensures that decisions by the CEN are immediately implemented in the ePMSE devices.

The Device Management process is less time critical than the Dynamic Link Management Process.

9.2.3.2 Device Management Process

The Device Management Process run by CEN includes detection of ePMSE devices that are connected to the Hardware Abstraction Layer (HAL) and passes their capabilities to the CEN. An example could be supported frequency range by a ePMSE device.

The detection could be a one time process during initialization of a C-PMSE or a continuous process supporting adding and removing ePMSE devices during operation. Such a Plug and Play scheme would support automatic configuration of the system.

As a minimum set a detection scheme during initialization should be supported.

Commands that interrogate and pass capabilities of connected ePMSE devices can be found in below clause.

9.2.3.3 Dynamic Link Management Process

Dynamic Link Management Process reflects the alteration of radio link parameters based on decisions by the CEN. The HAL translates commands on the rli into vendor specific commands to ePMSE devices. As drop-out time has to be minimized the Dynamic Link Management Process running in the CEN has to be conducted in real time. Decisions by the CEN signalled on rli have to be implemented at the ePMSE links with low latency.

Dynamic Link Management Process includes alteration of parameters like carrier frequency, transmit power or modulation and coding. As a minimum set, the commands for alteration of frequency should be supported.

The commands generated by the two processes have identical syntax.

9.2.3.4 Commands on rli interface

Below the necessary commands on rli interface are given. First the commands from CEN to HAL are given and then vice versa.

Table 6 summarizes all mandatory (M) and optional (O) commands which could be send over the rli interface from CEN to HAL.

Table 6

rli Command	Parameters	Notes
set_frequency_link (M)	*Link_number* #, *f_carrier* [Hz], Acknowlede mode (yes/no)	To allow also a mix of very narrowband and wideband transmission schemes, e.g. PMSE effect control Acknowledged mode is optional
set_power_link (M)	*link_number #,* *power* [dBm]	
set_AMC_link (O)	*link Number #,* *AMC#*	AMC modes are vendor specific
ask_capabilities_link (M)	*link Number #*	Returns link capabilities
set_RFpower_onoff_link (M)	*link_number #,* *on/off*	Switches transmit device on/off
ask_identity_link (M)	*link_number #*	
ask_quality_link (M)	*link_number #*	
ask_rssi_link (M)	*link_number #*	
ask_status_link (O)	*link_number #*	

Table 7 summarizes all mandatory (M) and optional (O) commands which could be send over the rli interface from HAL to CEN.

Table 7

rli Command	Parameters	Notes
confirm_set_frequency_link (O)	*link_number #*	This acknowledge reflects that a frequency change was successfully implemented on ePMSE link and the link is up and running again
capabilities_link (M)	*link number #, f_start [Hz], f_stop [Hz], stepsize [Hz], channel_bandwidth [Hz] min_channel_spacing [Hz], min_IMD_spacing [Hz], output_power [dBm], X_IMD_performance [dBc] RX_IMD_performance [dBc]*	Channel_bandwidth and output_power are lists of possible discrete settings; RX_IMD_performance may be set to infinity if not relevant; dBc-values are always positive
identification_link (M)	*link_number #, PMSE type (Audio/Video/Effect/Safety/Others), text string*	Text string may contain equipment code
quality_link (M)	*link_number #, LQI [SNR dB]*	EVM and BER figures can be converted to SNR
rssi_link (M)	*link_number #, RSSI [dBm]*	
status_link (O)	*link_number #, yes/no*	"yes" implies that content plane and bidirectional control plane works

NOTE: In a P2MP environment like conference systems a link is comprised out of all links to all paired devices. In such scenarios the weakest RSSI and the lowest SNR are returned from HAL to CEN.

10 Recommended test procedures for individual elements of SCS, LSDB and C-PMSE

10.1 Technical requirement specification

10.1.1 Scanning system (SCS)

Definition:

A scanning system (SCS) is a component of the C-PMSE IA.

NOTE: The C-PMSE IA can be part of a C-PMSE (single device including all).

The scanning system (SCS) is composed of one or more scanning receivers (SCR) with scanning antennas (SCA) and one scanning controller (SCC).

Multiple SCR can be distributed within areas of interest.

10.1.2 Scanning antenna (SCA)

10.1.2.1 Definition

A scanning antenna (SCA) is an integral or non-integral antenna connected to the scanning receiver (SCR). SCA may include antenna systems, e.g. multi-antenna systems, beamforming systems, or multi-beam.

10.1.2.2 Requirements

The SCA should be built for a radio frequency range including the radio frequencies of interest.

Further information on the antenna should be available for testing and calibration purposes.

10.1.2.3 Conformance

Requirements should be fulfilled by the manufacturer via product specification and user manual.

10.1.3 Scanning receiver (SCR)

10.1.3.1 Definition

An SCR is a device able to acquire measurements or information on the radio spectrum and its usage.

An SCR may have integral or non-integral SCA.

10.1.3.2 Requirements

The scanning receiver (SCR) should be built for a radio frequency range including the radio frequencies of interest.

Calibration information on the SCR should be provided by the manufacturer.

The SCR should provide an interface and protocol supported by SCC.

10.1.3.3 Conformance

Requirements should be fulfilled by the manufacturer via product specification and user manual.

10.1.4 Scanning controller (SCC)

10.1.4.1 Definition

An SCC is built to cope with one or multiple SCR using a protocol for control and data exchange.

NOTE: A multitude of standardized or vendor-specific protocols could be supported by SCC.

An SCC is built to cope with one or multiple C-PMSE using a protocol for control and data exchange.

10.1.4.2 Requirements

The interface and protocol as specified in clause 9.2.1 should be used for communication between SCC and C-PMSE, if the sci is provided to attach shared infrastructure. Shared infrastructure, means C-PMSE IA can be shared among multiple C-PMSE, regardless of mobile, nomadic or fixed use.

10.1.4.3 Conformance

Appropriate protocol tests should be used to verify the communication between SCC and C-PMSE, if sci is provided.

10.2 Local Spectrum Database (LSDB)

10.2.1 Definition

The LSDB is part of the C-PMSE IA.

The LSDB holds information on the frequencies legally appropriate for usage by C-PMSE.

NOTE: There are several ways to provide this information:

1) Manual license entering in case of written frequency grants by NRA.

2) Automatic or manual license entering derived from a GLDB operated by or on behalf of an NRA.

3) Manual or automatic entering of frequency bands allowing license exempt operation by C-PMSE.

In addition, the LSDB can be used to share information on spectrum usage among co-located C-PMSE.

10.2.2 Requirements

The LSDB should provide an interface and protocol corresponding to clause 9.2.2 to interact with C-PMSE, if the LSDB is part of shared infrastructure (lsi).

NOTE: The LSDB should also support corresponding interfaces and protocols to frequency information databases/GLDB. This note gets a requirement, if access to GLDB is required by NRA.

10.2.3 Conformance

- It is recommended to use an adequate protocol tester to verify the communication between LSDB and frequency information databases/GLDB.
- It is mandatory to test the communication between LSDB and C-PMSE, if lsi is provided.

10.3 C-PMSE

10.3.1 Definition

A C-PMSE consists of a cognitive engine (CEN) and ePMSE devices.

A performance monitor (PMO) could be included.

The ePMSE devices are dynamically adjustable concerning their radio link parameters and should report link quality indicator (LQI) to CEN.

NOTE: Radio link parameters can include: RF carrier frequency, RF output power, Occupied RF bandwidth, Adaptive Modulation and Coding.

10.3.2 Requirements

A C-PMSE should provide lsi and/or sci, if the C-PMSE can be attached to shared infrastructure.

10.3.3 Conformance

- It is mandatory to test the communication between C-PMSE IA and C-PMSE, if lsi and/or sci is provided.

10.4 Cognitive Engine (CEN)

10.4.1 Definition

A cognitive engine (CEN) is an entity that is part of C-PMSE.

A CEN performs tasks required for information rating, decision making, and optional learning based on C-PMSE IA input and ePMSE device information.

A CEN is capable of configuring radio link parameters to be used by attached ePMSE devices according to its decisions. A CEN can communicate with ePMSE devices via a hardware abstraction layer (HAL) and rli interface as specified in clause 9.2.3 for their dynamic management.

10.4.2 Requirements

The radio link parameters defined by CEN should not result in harmful interference to other systems.

NOTE: The operation of CEN should lead to a stable and efficient coexisting utilization of the radio spectrum.

A CEN should employ the hardware abstraction layer (HAL) as specified in clause 9.2.3 for dynamic management of ePMSE devices, if the CEN is shared for the purpose of different (e.g. multi-vendor) ePMSE and legacy PMSE device support.

10.4.3 Conformance

- Radio link parameter sets definable by CEN should exclude sets locally disallowed for usage by C-PMSE systems based on LSDB information.
- Radio link parameters sets definable by CEN should exclude sets, which include frequencies already in-use by others based on LSDB information.
- It is recommend to use adequate protocol tests to verify the communication between CEN and both C-PMSE IA and ePMSE devices.

11 Testing for compliance with technical requirements

11.1 Test suites applied to SCS

An adequate protocol tester should be used to verify proper sci communication.

11.2 Test suites applied to LSDB

An adequate protocol tester should be used to verify proper lsi communication.

11.3 Test suites applied to C-PMSE

11.3.1 LSDB related tests

The following test aims at verification that C-PMSE follows LSDB restrictions on operational frequency range.

A test LSDB is used to enable testing of a device under test (DUT), e.g. a C-PMSE.

Test 1: Test LSDB is not available or deactivated.

Verify that there are no RF transmissions by DUT, which ever state it is in.

Test 2: Test LSDB is configured in such a way that it disallows operation on all previously allowed frequencies.

Verify that there are no RF transmissions by DUT, which ever state it is in.

Test 3: Test LSDB is configured in such a way that it allows only a specific frequency range supported by DUT.

Step 1 - The frequency range should be randomly drawn between the minimum and maximum frequencies supported by DUT.

Step 2 - There should be no RF transmission by DUT outside the allowed frequency range, which ever state it is in.

Step 1 and Step 2 should be repeated several times.

Test 4: Test LSDB is configured in such a way that it disallows a previously allowed frequency range.

Verify that the DUT stops transmission in the disallowed part of spectrum within a given time.

11.3.2 C-PMSE dynamic reaction tests

The following tests are applied to verify that C-PMSE shows a dynamic reaction when interference occurs.
Test-LSDB is configured in such a way that it allows a frequency range, which is N x 8 MHz wide. where N is an integer equal or greater than 1.

For test 1 N is chosen to 1 that all ePMSE links can be placed successfully.

Test 1: Reaction to PMSE-like interferer

N is set to 1, at least 1 ePMSE link is up and running.

Step 1 - Place narrowband interferer (e.g. PMSE like signal) on one ePMSE link. The power of interferer is the maximum allowed RF output power for ePMSE links.

Step 2 - Verify, that the DUT adjusts frequency utilization and that there are no transmissions outside Test-LSDB allowed frequency range.

Test 2: Reaction to WSD-like interfere

N is set to 2, at least 1 ePMSE link is up and running. If more than one ePMSE link is active, all ePMSE links should be placed in one 8MHz TV channel.

Step 1 - Place a noise signal of 8 MHz bandwidth occupying the TV channel which is used by ePMSE links. The Power Spectral Density of the interferer is equal to the maximum RF output power of ePMSE links.

Step 2 - Verify, that the DUT adjusts frequency utilization and there are no transmissions outside Test-LSDB allowed frequency range.

12 Example: Demonstration cases of the BMWi C-PMSE platform

12.1 Scope

The following clauses provide detailed descriptions of demonstration cases employed by the BMWi C-PMSE project to showcase some features of its demonstrator.

12.2 Description of demonstration cases

The demonstrations cases include:

a) Automatic setup mode of BMWi C-PMSE; and

b) Operational modes for automatic and user interactive operation of BMWi C-PMSE.

The demonstration cases of BMWi C-PMSE highlight frequency agile or RF output power agile actions of BMWi C-PMSE under different coexistence conditions, and/or especially highlight features.

12.3 Automatic Setup Mode

The goal of this demonstration case is to show the automatic process of BMWi C-PMSE setup.

BMWi C-PMSE is the first PMSE system offering a totally automated setup procedure.

The automatic setup process is composed of the following steps:

- Registration of wireless audio links in the DBC:
    - This process is currently manual and represents a limitation of the demonstrator.
- Negotiation of available frequencies with LSPM (clause 8.3):
    - The result of this negotiation process is a set of frequency ranges (Note: this set could be empty) available for C-PMSE operation at the event location.
- Scanning of the assigned frequency ranges making use of SCS.
- CEN rates the spectrum data coming from the SCS in terms of two assessment criteria: Quality and Risk.
- CEN starts initial frequency planning taking into account:
    - Number of managed wireless audio links.
    - Current spectrum conditions in terms of quality and risk metrics.

NOTE: Can be visualized in the DMO.

- CEN transfers the wireless audio link parameters (i.e. frequencies) to the HW (wireless microphones) for execution.
- CEN registers the wireless audio link frequencies by LSPM. Registration will be done at event location for a certain time.

12.4 Operational mode (automatic / interactive)

12.4.1 General

In general two different parameters of the wireless audio links are reconfigurable during operation which leads to two demonstration sets:

- demonstration of frequency agile behaviour;
- demonstration of RF output power agile behaviour.

Both are shown in two different operational modes:

- automatic mode: system's reaction is done without user interaction;
- interactive mode: every system's reaction should be confirmed by the user and / or can be initiated by him, additionally the user has the choice to accept recommendations/solutions from the CEN or to modify/renew it.

SCS monitors the useable radio spectrum (granted by LSPM) continuously while CEN computes convenient solutions (radio frequency or transmit power allocations) to fit on that spectrum. The spectrum rating process continuously translates scanning data into two assessment Criteria - Quality, Risk (clause 7.3.3) - which are then used to evaluate the suitability of the present solution and to trigger action if environmental changes occur.

12.4.2 Frequency agile behaviour

The idea of radio frequency agile behaviour is to mitigate interference by switching from an interfered frequency to a less interfered frequency during operation.

An interferer is switched on inside the operational frequency range of C-PMSE. This causes a decrease of Quality or an increase of Risk of one or several wireless audio links of C-PMSE.

Automatic mode

In automatic mode CEN takes the best possible solution - that with the highest fitness value [1] - and executes it immediately, i.e. all interfered wireless audio links are shifted in frequency.

Interactive mode

In interactive mode CEN proposes the user a list of alternative solutions to improve the interference situation. CEN waits for user input. The user has now the opportunity to accept one of the proposed solutions or even to combine and modify them. After getting user input CEN transfers the selected solution to the wireless audio links for execution and restarts computation of solutions.

12.4.3 Transmit power agile behaviour

Transmit power agile behaviour is used to mitigate interference by updating transmit power. Two demonstration cases are covered:

- Interference generated by a white space device.
- Interference caused by self-generated intermodulation products.

Automatic mode

The transmit power control algorithm is deterministic, based on the Quality assessment metric. The transmit power of each C-PMSE audio mobile terminal will be adjusted during operation as to keep the optimal signal-to-interference ratio. Minimizing the output power of each audio mobile terminal is desired in order to keep the interference levels as low as possible.

If a white space device causes interference, increasing the transmit power will help to mitigate interference.

If interference is caused by self-generated intermodulation products, decreasing the transmit power of the audio mobile terminals generating the intermodulation will help to mitigate interference.

Interactive mode

Not applicable.

13 Heterogeneous C-PMSE

13.1 General description of heterogeneous C-PMSE system operation

Co-located C-PMSE are interconnected at various levels. It is important to consider what type(s) of interfaces and data formats will need to be supported. It is assumed that interconnected systems would use the same information acquisition C-PMSE IA (clause 9.1).

But if these C-PMSE are not interconnected, they might or might not use the same LSDB. It is desirable that all nearby systems access the same LSDB, because it would have more specific information than a national GLDB. Information from the LSDB should be used to inform the configuration of these C-PMSE.

In a large event, it is possible that multiple C-PMSE might be in operation simultaneously. The transmission range of the associated ePMSE and legacy PMSE links may be partially or completely overlapping. The most critical case occurs when these co-located PMSE share the same frequency resources, but they might also operate in completely different bands; e.g. UHF and 1,8 GHz. However, even if PMSE are using separate frequency resources, the possibility of interference should still be considered.

Heterogeneity is understood as a mixture of multiple C-PMSE and C-PMSE with legacy PMSE plus potentially vendor mix.

13.2 Scenarios with heterogeneous C-PMSE

13.2.1 General

The following clauses illustrate six possible configurations of heterogeneous PMSE.

13.2.2 Scenario 1

Both systems will operate in the same frequency range. They are not interconnected in any way. They are only connected to the same GLDB. So they do not have direct awareness of each other and they are not coordinated. If the two C-PMSE systems use the same frequency range, it may happen that they cause interference to each other or they may become instable.

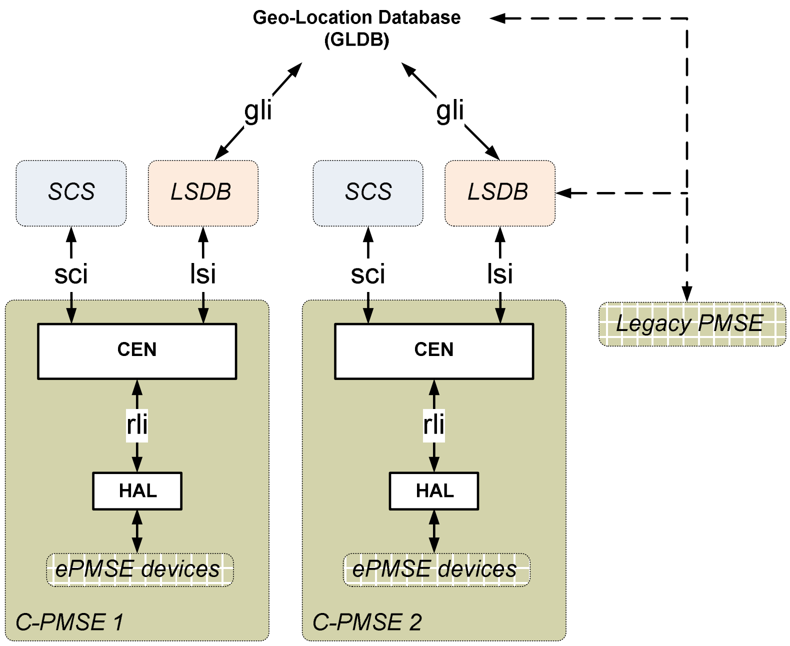

Figure 9: Two complete C-PMSE systems collocated

13.2.3 Scenario 2

In this case the two CEN are using the same SCS, but individual LSDB. Although the C-PMSE have the same information about the current spectrum availability, they do not talk to one another. They use different LSDB, which are only linked to the same GLDB. Nevertheless interference may occur, when the different CEN simultaneously command a frequency change to an identical frequency that is assumed to be free.

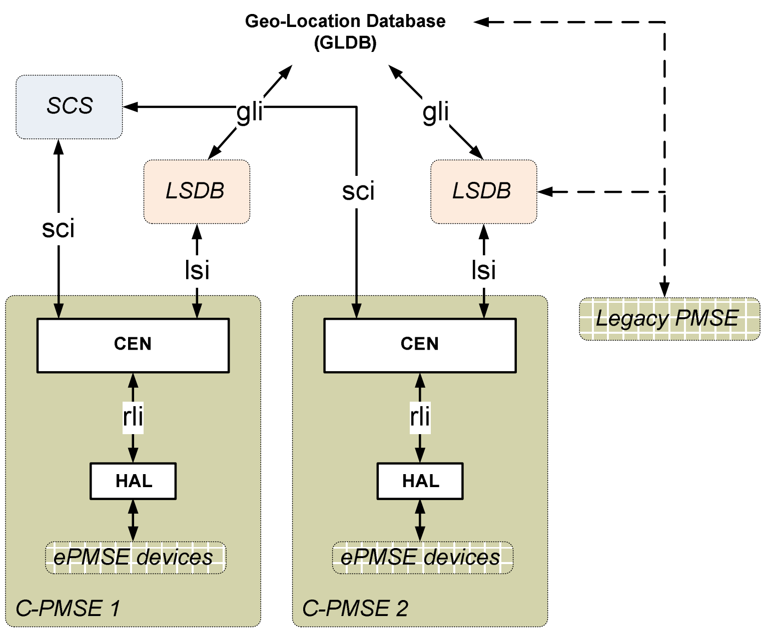

Figure 10: Two C-PMSE sharing SCS

13.2.4 Scenario 3

In this case a common LSDB is used by the two CEN. Depending on the update repetition between the multiple CEN and the LSDB, the probability of avoiding double frequency occupation by the two CEN is minimized. Dependent on the CEN decision it may nevertheless come to a clash of frequency allocations.

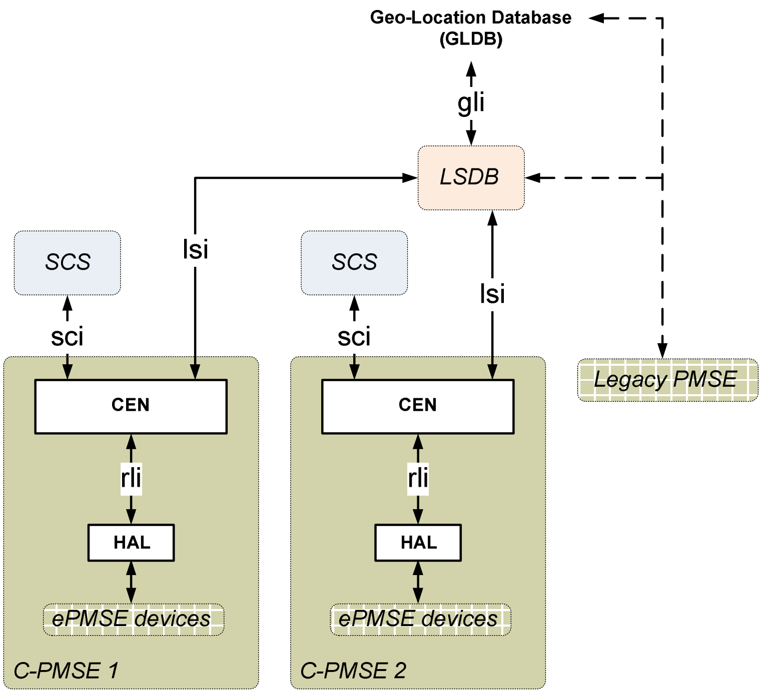

Figure 11: Two C-PMSE sharing LSDB

13.2.5 Scenario 4

Here the two CEN share the SCS and the LSDB. So the data integrity of SCS and LSDB is improved over the previous scenarios. The risk of interference between the links managed by the two CEN is reduced, because the CEN decisions are based on the identical information acquisition.

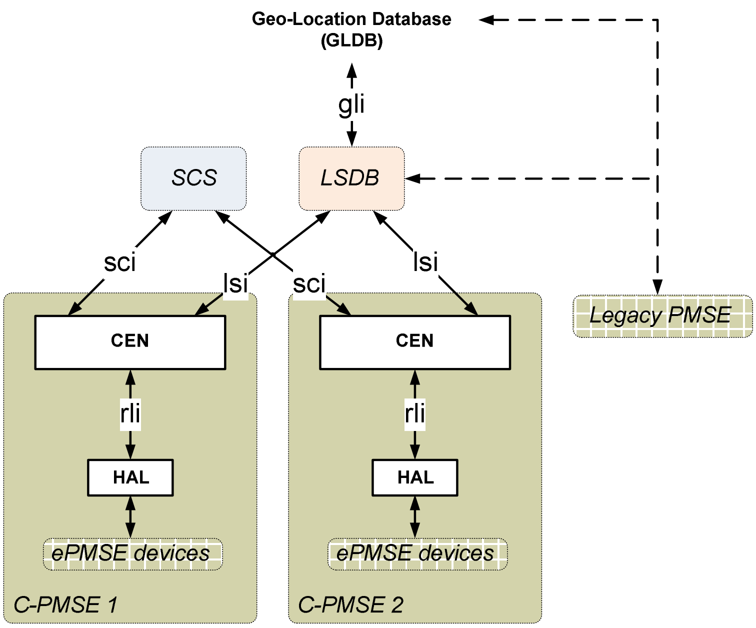

Figure 12: Two C-PMSE sharing C-PMSE information acquisition

13.2.6 Scenario 5

A more advanced concept is the use of different ePMSE with their corresponding HAL controlled by only one CEN. This allows different manufacturers to combine their ePMSE in one single event or location. The connection between the different devices is done via the HAL. In this case no interference should occur.

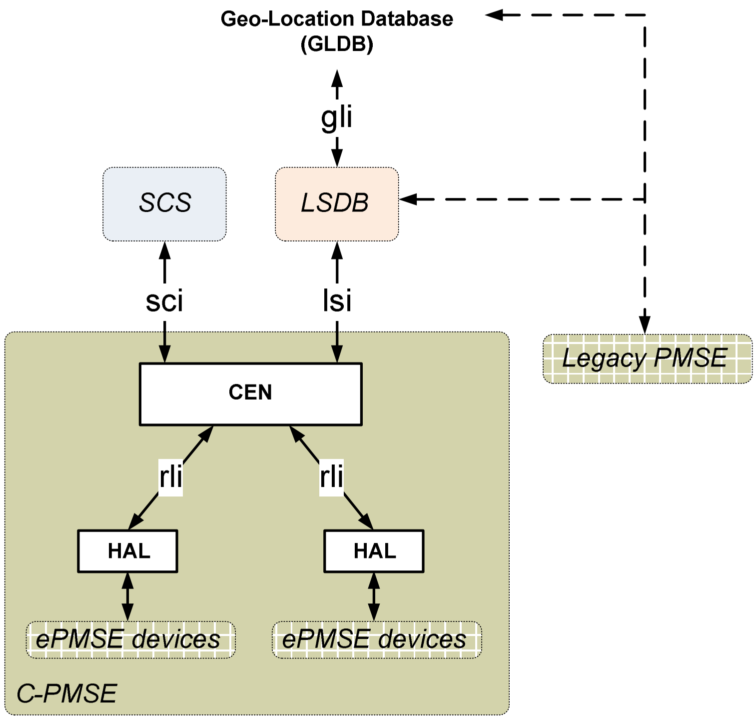

Figure 13: ePMSE with different HAL sharing the same CEN

13.2.7 Scenario 6

The highest efficiency of spectrum use (clause 5.2.3) with C-PMSE implementation is shown in the next figure. Here only one LSDB and only one SCS are used by one CEN and that CEN is managing all ePMSE. These ePMSE may be provided by different vendors supporting high efficiency of spectrum use with vendor mix.

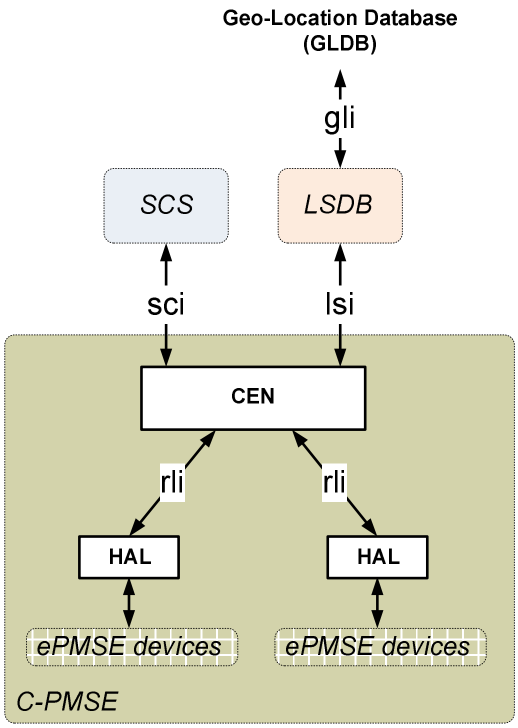

Figure 14: C-PMSE system without legacy PMSE

13.3 Interconnection with legacy PMSE systems

For the foreseeable future, it is likely that C-PMSE systems will sometimes be operated together with conventional (i.e. non-cognitive) PMSE systems. These legacy systems will in most cases only support a limited subset of C-PMSE features [No-CEN, but cognitive features]. It is important to consider what benefits can be obtained, if they are interconnected with such systems and how such interconnections can be accomplished; i.e. what type(s) of interfaces and data formats need to be supported. In the limiting case, information about co-located legacy systems might have to be exchanged manually with the LSDB.

There are several interfaces at legacy PMSE systems like an Ethernet connection with information about the used frequencies, transmitter power level and the keep-free-bandwidth. But this knowledge is in general only possible within one manufacturer. It could be advantageous, if a C-PMSE system allows manual input of any kind of available information from a legacy device.

13.4 Capability of location awareness (e.g. GNSS)

In order for a C-PMSE system to operate in fully-automatic mode, it will need to have location awareness capability. Otherwise, the operator should enter this information manually. Many consumer devices now have satellite-based geolocation capability built-in. However, PMSE systems are often installed indoors where satellite signals cannot be received reliably, if at all. Therefore, a different kind of geolocation technology is needed. Work is presently ongoing in this area. Cellular and other currently available geolocation technologies do not yield sufficient accuracy (e.g. within ±50 meters) for PMSE applications.

13.5 Coexistence of various types of PMSE systems e.g. video cameras, IEM (in ear monitor)

It is often the case that PMSE devices do share spectrum with other PMSE, such as in ear monitors (IEM), wireless intercoms, and video cameras. These systems have very different spectrum requirements, transmission duty cycles, signal-to-noise requirements, interference potential, etc. It is desirable that a C-PMSE system has the capability to manage coexistence between these systems when they are sharing the same or nearby frequency resources. To do this, the C-PMSE system should have knowledge of the parameters of these systems. It might be helpful, if wideband devices like video cameras use different frequency ranges to avoid interference with C-PMSE systems. To conclude, the set of controlled ePMSE devices by CEN may be very heterogeneous and therefore have a wide range of radio parameters.

13.6 Extension to power control, adaptive modulation and coding (AMC)

It is possible to include further capabilities within a C-PMSE like dynamic power control and adaptive modulation and coding.

14 Recommendation to reuse PAWS protocol for Communication to GLDB

14.1 GLDB access within BMWi C-PMSE project

The LSDB is reading information about available spectrum from GLDB based on a non-standardized proprietary protocol via website.

14.2 Automatic request for spectrum grant

In the foreseeable future it is desirable that the C-PMSE system itself can trigger automatic requests for spectrum grant (frequency range) through LSDB.

In order to achieve protection of ePMSE links, the C-PMSE system itself might want to place requests for reservation automatically towards GLDB in order to ensure high QoS.

14.3 Spectrum sharing with WSD

It is assumed that WSD have checked appropriate spectrum availability with the GLDB. This check might have been performed using PAWS protocol.

14.4 Suggestions for a standardized interface gli between LSDB and GLDB

14.4.1 General

To standardize an international format for exchange of information between national authorities and local or temporary databases the IETF PAWS group proposed a draft specification [i.9] called "Protocol to Access White-Space Databases". It seems appropriate to adopt this specification for the gli communication between LSDB and GLDB, rather than to invent a new protocol. For gli communication in the context of C-PMSE systems only a small subset of the PAWS command set is required. In the following clauses a small subset of protocol commands as described in Draft [i.9] and their messages are discussed.

Furthermore it could be studied to commutate data on international level between regulatory authorities based on the full range of the PAWS protocol.

14.4.2 PAWS command "Database Discovery"

Due to different requirements for the approval and operation of databases by the regulators, it is necessary that the Master Device should support a database discovery. The Database Listing request procedure uses two commands:

Command - 'LISTING_REQ'

This command is used for the database-listing request message.

Command - 'LISTING_RESP'

This command is used for the database-listing response message.

In the context of C-PMSE system this is used for identifying the GLDB hooked to the LSDB.

14.4.3 PAWS command "Device Initialization"

The IETF PAWS group proposes two commands which should be used by a master device for an initialization procedure to establish an information exchange with a database whenever the Master Device powers up or initiates communication with the Database. The followed commands are used to establish a communication (table 8).

Table 8

Initialization Commands	Parameters
'INIT_REQ'	deviceDesc:DeviceDescriptor (M) location:GeoLocation (M)
'INIT_RESP'	rulesetInfos:list (M) databaseChange:DbUpdateSpec (O)

Command - 'INIT_REQ'

A 'INIT_REQ' command is used to initialize a request message by a master device with the Database.

Command - 'INIT_RESP'

A 'INIT_RESP' command is used to communicate the initialization response message with database parameters to the requesting device.

In the context of C-PMSE system the CEN as the master of all PMSE links is initialized with the GLDB.

14.4.4 PAWS command "Device Registration"

NOTE: May be used by the Master Device and may be implemented by the Database as a separate component or as part of the Available Spectrum Query (clause 4.4 of [i.9]) component.

If a device has to be registered it has to send its registration information to the database to establish certain operational parameters. The following commands are used to perform the registration (table 9).

Table 9

Registration Commands	Parameters
'REGISTRATION_REQ'	deviceDesc:DeviceDescriptor (M) location:GeoLocation (M) deviceOwner:DeviceOwner (M) antenna:AntennaCharacteristics (O)
'REGISTRATION_RESP'	rulesetInfos:list (M) databaseChange:DbUpdateSpec (O)

Command - 'REGISTRATION_REQ'

The 'REGISTRATION_REQ' message contains the required registration parameters as the ruleset IDs to indicate the regulatory domains for which the Device wishes to register.

Command - 'REGISTRATION_RESP'

The 'REGISTRATION_RESP' command is the response message to acknowledge the registration. The RulesetInfo is included for each regulatory domain in which the registration is accepted. An error should be returned if none of the regulatory domains it supports is accepted.

In the context of C-PMSE system all PMSE links are registered.

14.4.5 PAWS command "Available Spectrum Query"

The commands for the inquiry of available spectrum should be supported by the Master Device as well by the Database. The request contains the geo-location of the Master Device and any parameters required by the regulatory rules. The response of the database contains the description which frequencies are available plus the allowed transmit power and the schedule of the time when they can be used.

The main commands are as follows (table 10).

Table 10

Registration Commands	Parameters
'AVAIL_SPECTRUM_REQ'	deviceDesc:DeviceDescriptor (O) location:GeoLocation (O) owner:DeviceOwner (O) antenna:AntennaCharacteristics (O) capabilities:DeviceCapabilities (O) masterDeviceDesc:DeviceDescriptor (O) masterDeviceLocation:GeoLocation (O) requestType:string (O)
'AVAIL_SPECTRUM_RESP'	timestamp:string (M) deviceDesc:DeviceDescriptor (M) spectrumSpecs:list (M)

Command - 'AVAIL_SPECTRUM_REQ'

The 'AVAIL_SPECTRUM_REQ' message is used to query available spectrum and it should include the geo-location of the device.

Command - 'AVAIL_SPECTRUM_RESP'

This response message includes elements containing a list of one or more spectrum schedules with permissible power levels over time. Each element is used for one corresponding regulatory domain supported at the location requested by the 'AVAIL_SPECTRUM_REQ' command.

In the context of C-PMSE system the LSDB queries available spectrum.

14.4.6 PAWS command "Device Validation"

If the regulatory domain requires Slave Device validation, appropriate commands should be implemented by the database as well by the Master Device to ensure that the Slave Device is permitted to operate (table 11).

Table 11

Registration Commands	Parameters
'DEV_VALID_REQ'	deviceDescs:list (M) masterDeviceDesc:DeviceDescriptor (O)
'DEV_VALID_RESP'	deviceValidities:list (M) databaseChange:DbUpdateSpac (O)

Command - 'DEV_VALID_REQ'

The 'DEV_VALID_REQ' command is used to request the permission for operation of a Slave Device. The inquiry is made by the Master Device to the Spectrum Database.

Command - 'DEV_VALID_RESP'

The response message is handled with the 'DEV_VALID_RESP' command containing a list of Slave Devices and whether this devices are valid.

In the context of C-PMSE system each PMSE link is validated with GLDB.

14.5 Status of PAWS protocol

As document [i.9] is in draft state, there might be changes that could lead to alterations of appropriate commands. The capabilities and the applicability in the context of C-PMSE system of the PAWS protocol needs further assessment.

15 Consequences for ETSI EN 300 422-1

15.1 Scope

The scope of this clause is to recommend changes and additions to ETSI EN 300 422-1 [i.1].

15.2 Wireless signalling

The CEN decides on necessary changes to PMSE links. The implementation of those changes with the radio links requires that the two ePMSE devices of a radio link are parameterized identically i.e. both have to be tuned to the same carrier frequency or the same codec with digital transmission. The CEN has to signal to the ePMSE devices, which parameters to use. The question now is how such a signalling can be implemented and incorporated in standards.

Content and control plane can be mapped onto different radio technologies. E.g. an analogue audio link could be accompanied by a digital signalling link at another radio resource. The transmission schemes of content and control plane do not depend on each other.

A reliable functionality of signalling is important for any cognitive resource management. If the content plane is interfered and a frequency change is necessary, the control plane should still work to ensure that the situation can be overcome.

The other question is which radio resource could be used for wireless signalling? An inband bidirectional signalling imposes strong requirements on e.g. a wireless microphone. While transmitting with 100 % duty cycle, the microphone would have to be enabled to simultaneously receive signalling, which would be a strong blocking case. Furthermore simultaneous transmission of content and signalling could cause transmitter intermodulation products.

Another frequency band and even another type of physical layer could be used.

Signalling should be viewed as a subset of Telecommand/remote control as defined in ECC Report 002 [i.8] and therefore ETSI EN 300 422-1 [i.1] should be modified to include Telecommand/remote control as a permissible use.

15.3 Architecture

With the introduction of C-PMSE systems new elements are introduced (clause 9.1). These elements have to be defined in ETSI EN 300 422-1 [i.1]. Inside C-PMSE Information Acquisition C-PMSE-IA there are the scanning system SCS and the frequency booking. Inside C-PMSE there are cognitive Engine CEN and evolved PMSE ePMSE.

15.4 Interfaces

The newly introduced elements of a C-PMSE system interlink via new interfaces (clause 9.2), which have to be standardized in ETSI EN 300 422-1 [i.1]. When they are provided they have to be compliant in order to facilitate vendor mix. The sci, which carries scanning jobs and results, connects the C-PMSE with the SCS and the lsi connects C-PMSE with frequency booking. Inside C-PMSE rli allows for connection of arbitrary ePMSE devices through the hardware abstraction layer HAL.

15.5 Necessary additions to ETSI EN 300 422-1 (TDOC220)

15.5.1 Introduction

Recommendation ITU-R BT.2069-5 [i.5] and ECC Report 002 [i.8] describe the "Telecommand/remote control" as "Radio links for the remote control of cameras and other programme-making equipment and for signalling". Therefore wireless signalling with PMSE is already reflected in ITU and ECC reports.

The current ETSI EN 300 422-1 [i.1] does not explicitly state wireless signalling. However it can be seen as some sort of telecommand/remote control.

As wireless signalling is already part of telecommand/remote control, telecommand/remote control should be added to ETSI EN 300 422-1 [i.1].

15.5.2 Implementation

This clause deals with the necessary additions to ETSI EN 300 422-1 [i.1] V1.4.2 (2011-08) recommended by ETSI STF 386 to reflect the introduction of cognitive properties for PMSE.

STF 386 proposes to add a Part III on cognitive radio resource management. Part III should cover the following aspects:

- Definition of new terms (e.g. definition of ePMSE).
- Discuss the role of content and control plane.
- Definition of new elements of a C-PMSE system.
- Interface definitions.
- New protocols.
- Requirements.
- Testing setups.
- Testing for compliance.

- References (e.g. the present document).

15.5.3 Proposal for additions to existing standard

Proposed addition to clause 2.1, Normative Reference:

- Include the present document.

Proposed additions to clause 3.3:

- Include new definitions, symbols, and abbreviations.

15.5.4 Proposal for addition of a new Part III

Proposal for a clause:

- Definition of C-PMSE system (e.g. copy figure from clause 9.1). General overview of the functionality of a C-PMSE system. Explain the functionality of the elements and how they interact via the interfaces.

Proposal for a clause:

- Definition of the elements of the C-PMSE system (SCS, Frequency Booking, C-PMSE, ePMSE).

Proposal for a clause:

- Definition of the interfaces (sci, lsi, rli).

Proposal for a clause:

- Conformance Testing of a C-PMSE system (e.g. apply stimulus to the system as a whole).
- Maybe defined as a sole "OTA" (over the air) test stimulus.
- Interface tests (if interfaces are provided).
- Protocol testing.

16 Conclusions

16.1 Summary

The present document on "Operation methods and principles for spectrum access systems for PMSE technologies and for the guarantee of a high sound production quality on selected frequencies utilizing cognitive interference mitigation techniques" analyses the various possible techniques and recommends methods for interference mitigation.

PMSE has very unique and stringent requirements in terms of quality, availability, and latency. A C-PMSE system does not necessarily provide, on its own, an increase in efficiency of spectrum use. It mainly assures the reliability and quality of service required for PMSE links. Digital transmission of content is not a prerequisite for a C-PMSE system. Integration of legacy equipment is possible and likely necessary for the foreseeable future.

Link quality and spectrum supervision together with dynamic radio resource management are key elements of a C-PMSE system. The cognitive engine reflects the core functionality of the C-PMSE system.

Radio resource management includes dynamic frequency change, transmit power control and eventually also adaptive modulation and coding.

C-PMSE system does require a control plane. The content plane and control plane can be treated independently. The signalling is not required to be an integral part of content transmission.

At start-up C-PMSE need to obtain knowledge about legally appropriate spectrum. C-PMSE should not start wireless content transmission without that knowledge. Moreover a periodic update is required. Real-time connection to a GLDB is not a requirement, but could provide further benefits in terms of interference protection and potentially could increase overall efficiency of spectrum use.

If location of system components is known to sufficient accuracy in the order of 1…10 m, then a tighter frequency reuse becomes feasible, which also increases efficiency of frequency use. Propagation characteristics play an important role with frequency reuse. Indoor location might require an additional location system.

The new methods have been demonstrated in the course of the BMWi project C-PMSE in Germany.

16.2 Suggestions for standardization

Several additions and changes to ETSI EN 300 422-1 [i.1] are suggested, which are discussed in clause 15.

16.3 Implications to spectrum regulators

C-PMSE system, due to its cognitive capabilities, will increase efficiency of spectrum use, i.e. enabling higher spectrum sharing opportunities. Therefore regulators could consider opening additional spectrum for C-PSME systems compared to legacy PMSE.

The technical parameters of C-PMSE systems for sharing studies on potential additional frequencies need an update of ETSI EN 300 422-1 [i.1]. Specific C-PMSE parameters are e.g. description of mitigation techniques.

It is suggested that the access protocol to GLDB should be harmonized. Preferably the PAWS protocol should be applied. A more frequent update on GLDB and LSDB will increase efficiency of spectrum use.

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