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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)

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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

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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.

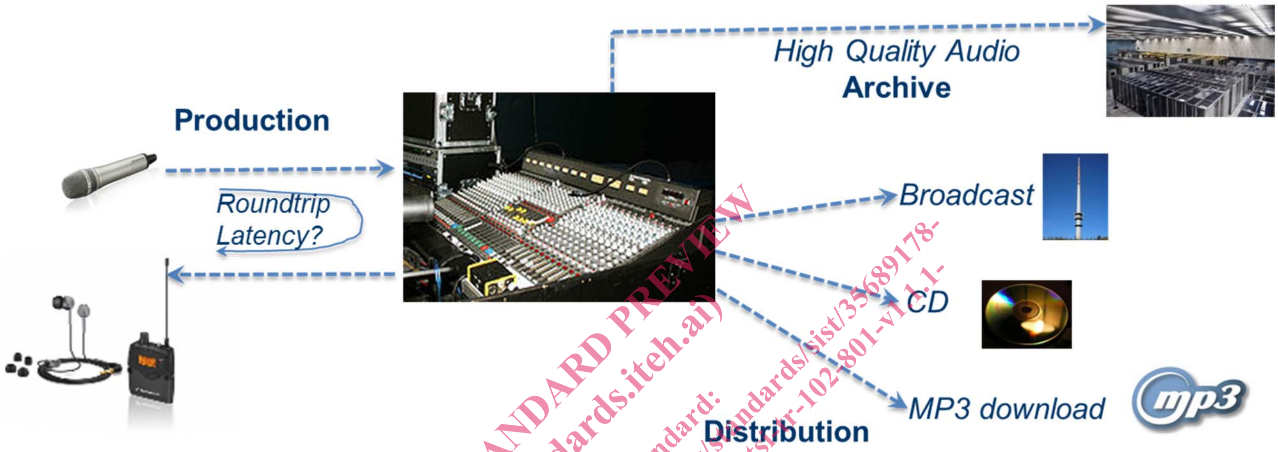

Figure 1: Roundtrip Problem scenario

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.