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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

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Foreword

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

A future ETSI Technical Specification on the recommended spectrum access technique in the present document is planned as well as tests on a demonstrator built to the specifications in the TS. An ETSI Technical Report on the defined RF compliance tests carried out on the demonstrator for the selected spectrum access mechanism defined in the TS is planned to be prepared.

Please note that although the technology demonstrator will concentrate on one particular application, the technology will ultimately be transferable to other PMSE applications.

Introduction

Radio microphone devices use 100 % duty cycle to convey voice or music either for a live event such as concerts and theatres or for a recorded event such as the production of film and television programs. Interference during this process is not only commercially disastrous; it can be also harmful to the audience where a public address system is in use.

The regulations governing the operation of PMSE (Program Making and Special Events) systems are currently in flux in Europe. During the process of changeover compression of the television channels is taking place below 790 MHz. The spectrum between 790 MHz and 862 MHz has been considered a Digital Dividend and allocated for use by Electronic Communications Networks. This has resulted in a reduction of spectrum available for PSME.

Protection

PMSE devices use very low radiated power levels (the maximum PWMS RF power level is 50 mW) in comparison to most other radio communication systems. In order for them to function properly, they are protected from interference. Up to now this has not been a problem since PMSE equipment operated in locally unused TV channels that presented a very predictable RF environment. In the future, many different kinds of new devices, the characteristics of which are difficult to fully anticipate at this time, may be sharing this space. Some of these devices will be used for broadband data, and will occupy any spectrum which is available to them, i.e. from a few MHz to a multiple of 10 MHz. Other uses of the Digital Dividend, which may eventually go down to 600 MHz, are use by the emergency services and other mobile services.

The question of how to protect PMSE equipment from interference caused by new devices has been the subject of much discussion and debate. Traditionally, incompatible radio communications systems were assigned to operate in separate frequency bands, but this scheme is becoming impractical in today's world of intensive spectrum use. A more dynamic and robust solution is needed.

Spectrum efficiency

Including cognitive techniques into a PMSE system has a high potential for increasing spectrum efficiency. It has to be investigated which cognitive techniques are suitable and how they need to be modified to serve the needs of the PMSE system.

Flexibility of spectrum access

Including cognitive techniques into a PMSE system has a high potential for increasing the flexibility of spectrum access. It has to be investigated which cognitive techniques are suitable and how they need to be modified to serve the PMSE systems needs.

1 Scope

The present document analyses the various possible techniques for spectrum access systems for PMSE technologies and for the guarantee of a high sound production quality on selected frequencies utilising cognitive interference mitigation techniques and recommends a specific method.

2 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.

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

2.1 Normative references

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

Not applicable.

2.2 Informative references

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 TR 102 683 (V1.1.1): "Reconfigurable Radio Systems (RRS); Cognitive Pilot Channel (CPC)".

[i.2] Li, Y., Quang, T. T., Kawahara, Y., Asami, T., and Kusunoki, M. 2009. Building a spectrum map for future cognitive radio technology. In Proceedings of the 2009 ACM Workshop on Cognitive Radio Networks (Beijing, China, September 21 - 21, 2009). CoRoNet '09. ACM, New York, NY, 1-6.

[i.3] WiMAX Forum Spectrum and Regulatory Database.

NOTE: http://www.wimaxforum.org/resources/wimax-forum-spectrum-and-regulatory-database

[i.4] TEDDI database.

NOTE: http://webapp.etsi.org/Teddi/

[i.5] ETSI EN 300 422 (V1.3.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range".

[i.6] ETSI TR 102 546 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics for Professional Wireless Microphone Systems (PWMS); System Reference Document".

[i.7] ERC Recommendation 70-03 (2009): "Relating to the use of Short Range Devices (SRD) PWMS: Annex 10 + Annex 13".

[i.8] CEPT Report 30: "Technical identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union".

[i.9] CEPT Report 32: "Recommendation on the best approach to ensure the continuation of existing Program Making and Special Events (PMSE) services operating in the UHF (470-862 MHz), including the assessment of the advantage of an EU-level approach".

[i.10] ETSI EN 300 726 (V7.0.2): "Digital cellular telecommunications system (Phase 2+) (GSM); Enhanced Full Rate (EFR) speech transcoding (GSM 06.60 version 7.0.2 Release 1998)".

[i.11] Draft ECC Report 147: "Additional compatibility studies relating to PWMS in the band 1518-1559 MHz excluding the band 1544-1545 MHz".

[i.12] OET Report, FCC/OET 08-TR-1005: "Evaluation of the Performance of Prototype TV-Band White Space Devices Phase II".

[i.13] ETSI TR 102 802: "Reconfigurable Radio Systems (RRS); Cognitive Radio System Concept".

3 Definitions and abbreviations

Further definitions can be found on Terms and Definitions Interactive Database (TEDDI) [i.4].

3.1 Definitions

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

Adaptive Modulation and Coding (AMC): protocol that sets modulation and coding parameters depending on channel state

Ask Before Talk (ABT): spectrum access protocol requiring a cognitive radio device to consult a local database, frequency coordinator or other authority before starting transmission

Cognitive PMSE system (C-PMSE): PMSE system, which includes a Cognitive Engine (CEN)

NOTE: See ITU definition CRS below. However adding the highlighted wording:

A radio system (optionally including multiple entities and network elements), which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically, autonomously and whenever possible **proactively** adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. minimize a loss in performance or increase spectrum efficiency;
- and to learn from the results of its actions in order to further improve its performance

Cognitive Radio System (CRS): radio system (optionally including multiple entities and network elements), which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically, autonomously and whenever possible adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. minimize a loss in performance or increase spectrum efficiency; and to learn from the results of its actions in order to further improve its performance

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

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

control plane: control data plane (contains control and management information)

Detect And Avoid (DAA): technology used to protect radio communication services by avoiding co-channel operation

NOTE: DAA operates as follows: before transmitting, a system senses the channel within its operative bandwidth in order to detect the possible presence of other systems. If another system is detected, the first system avoids the transmission until the detected system disappears.

Direct Mode: Mobile-to-Mobile communication

downlink: communication from master to slave

NOTE: The terms "Forward / Reverse Link" are not used in the present document due to potential irritations. Instead downlink and uplink are used.

Dynamic Frequency Allocation (DFA): protocol that allows for changing transmit frequency during operation

Dynamic Power Control (DPC): capability that enables the transmitter output power of a device to be adjusted during operation in accordance with its link budget requirements or other conditions

fixed: physically fixed, non- moving device

NOTE: includes temporary event installations as well.

infrastructure: nomadic entities

latency: time difference between input and output

NOTE: A professional audio system consists of many different devices such as loudspeakers, amplifiers, mixing desks, etc . The PMSE latency value discussed in the present document is defined as *analogue electric audio input to analogue electric audio output from one transmitting device to its receiving device.*

link adaptation: result of applying all of the control mechanisms used in Radio Resource Management to optimize the performance of the radio link

Listen Before Talk (LBT): spectrum access protocol requiring a cognitive radio to perform spectrum sensing before transmitting

location awareness: capability that allows a device to determine its location to a defined level of precision

master: unit which controls the radio resource changing actions

mobile: physically moving device

Professional Wireless Microphone System (PWMS): wireless microphones, IEM, audio links, etc.

Programme Making and Special Events (PMSE): production equipment, especially wireless equipment used by broadcasters, musical and theatrical shows, and others

radio environment map: integrated multi-domain database that characterizes the radio environment in which a cognitive radio system finds itself

NOTE: It may contain geographical information, available radio communication services, spectral regulations and policies, and locations and activities of collocated radios.

Service Level Agreement (SLA): defined level of service agreed between the contractor and the service provider

signalling plane: plane which contains only signalling information, 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 signalling and content plane are used.

slave: unit which performs the commanded actions by the Master

uplink: direction from Slave to Master

NOTE: The terms "Forward / Reverse Link" are not used in the present document due to potential irritations.

white space: label indicating a part of the spectrum, which is available for a radio communication application (service, system) at a given time in a given geographical area on a non-interfering / non-protected basis with regard to other services with a higher priority on a national basis

White Space Device (WSD) = TV Band Device (TVBD): cognitive devices proposed to work in the VHF / UHF-TV-Band

3.2 Abbreviations

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

ABT	Ask Before Talk
AMC	Adaptive Modulation and Coding
AMCT	Adaptive Allocation Table
AMR	Adaptive Modulation Rate
AP	Access Point
BER	Bit Error Rate
CEN	Cognitive Engine
CPC	Cognitive Pilot Channel
cpi	inter cognitive PMSE interface
C-PMSE	Cognitive - Programme Making Special Event entity or system
CRS	Cognitive Radio System
CSI	Channel State Information
DAA	Detect And Avoid
DAT	Device Allocation Table
DEM	Device Manager
DFA	Dynamic Frequency Allocation
DIC	Diversity Interference Cancellation
DIP	Dual In-line Package
DPC	Dynamic Power Control
DTV	Digital TeleVision
DVB-T	Digital Video Broadcasting - Terrestrial
ECN	Electronic Communications Network
EFR	Enhance Full Rate
EIRP	Equivalent Isotropic Radiated Power
ENG	Electronic News Gathering
FAT	Frequency Allocation Table
FCC	Federal Communications Commission (U.S.)
fci	frequency coordinator interface
FCO	Frequency Coordinator
FDD	Frequency Duplex Division
FFT	Fast Fourier Transformation
FM	Frequency Modulation
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
HMI	Human Machine Interface
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
ID	Identifier
IEM	In Ear Monitoring
IMD	Intermodulation Distortion
ISM	Industrial Scientific and Medical frequency band
LAN	Local Area Network
LBT	Listen before Talk
LTE	Long Term Evolution
MMI	Machine-to-Machine Interface
MRC	Maximum Ratio diversity Combining
MSS	Mobile Satellite Service
PAT	Power Allocation Table
PMO	Performance MOnitor

PMSE	Programme Making Special Events
PWMS	Professional Wireless Microphone System
QoS	Quality of Service
RAT	Radio Access Technologies
REM	Radio Environmental Map
RF	Radio Frequency
RFID	Radio Frequency Identifier
RMS	Root Mean Square
ROI	Return on Investment
RRM	Radio Resource Manager
RRS	Reconfigurable Radio System
RSS	Received Signal Strength
RSSI	Received Signal Strength Indication
sci	scanning receiver interface
SCR	Scanning Receiver
SINR	Signal to Interference and Noise Ratio
SLA	Service level Agreement
SLE	Service Level Entry
SLM	Service Level Monitor
SNR	Signal to Noise Ratio
SRD	Short Range Device
T-DAB	Terrestrial Digital Audio Broadcast
TEDDI	Terms and Definitions Interactive Database
TTI	Transmission Time Interval
TTV	Time To Violation
TVBD	Television Band Device
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunication System
UWB	Ultra-Wideband
W-CDMA	Wideband - Code Division Multiple Access
WiMax	Worldwide Interoperability for Microwave access
WLAN	Wireless Local Area Network
WSD	White Space Device

4 Differences between mobile services and Professional Audio Transmission

4.1 General remarks

This clause compares the differences in the operation of mobile services and PMSE systems and the features implemented to meet those.

Mobile services technology is very advanced and has evolved dramatically over the last decade. Sophisticated advancements have been widely implemented and have become state of the art. Therefore it has been suggested that the PMSE market adopt features from the mobile world that have been widely accepted and proven as being very beneficial.

This clause comments on the specifics of PMSE systems and those of mobile services. It also comments on why features of mobile systems cannot be simply taken over one-to-one, and instead have to be adapted to the specifics of PMSE.

4.2 Comparisons in the operation of PSME against other mobile systems

PMSE systems are required to meet very high quality levels for audio transmission. This means e.g. audio bandwidths of more than 20 kHz and SNRs of more than 80 dB. Consider e.g. a typical CD recording based on 16 bit resolution, equal to 96 dB dynamic range. By contrast, for a simple voice telephone service 3 kHz audio bandwidth and SNRs in the range of 20 dB are sufficient. However, the most critical criterion is that short interruptions are not acceptable on PMSE, but can be tolerated on mobile systems. In moderate quality PMSE equipment, interruptions still have to be kept below approximately 1 ms.

In general, PMSE systems so far are designed under the objective of maximizing audio quality and ensuring that the quality levels are met 100 % of the time. In contrast to this, mobile systems are mainly designed under the objective of maximizing capacity/spectral efficiency and coverage.

Increasing the coverage of a base station means the investments for installing a network are lowered, as a smaller number of base stations are needed to cover a certain area.

Increasing the spectral efficiency of a system means that more traffic, either voice or data can be transferred in a given swath of spectrum. As a consequence, the service provider can earn more money and increase the return on investment (ROI) in spectrum licenses.

4.3 Latency

PSME systems require a maximum latency of 3 ms to 5 ms in order to maintain lip synchronisation. Unfortunately, existing and planned mobile communication systems cannot support this latency requirement.

Various techniques which can be considered cognitive are used within various short range devices; these include Listen Before Talk (LBT) and detect and avoid (DAA). Unfortunately these techniques allow a time gap before logging a new frequency. PWMS require continuous transmission in order to convey the full range of speech or music. Therefore these techniques are not suitable for PWMS usage.

4.4 Signalling between mobile and infrastructure equipment

PMSE devices are mainly unidirectional, whereas mobile phones are bidirectional. A wireless microphone on or behind stage cannot be advised remotely by a central network element to change RF parameters such as e.g. its frequency or its power during operation. Typically these parameters are fixed or can be configured by DIP-switches or menu settings by using an infrared interface. Planning for those parameters is done in advance of an event production.

The same applies for the other direction e.g. an in-ear monitor on or behind the stage. The receiver worn by an artist or actor typically cannot signal its actual receive quality to the in-ear-monitoring transmitter.

Back-channels are only partly implemented, mainly for battery supervision and power down of e.g. wireless microphones.

Another aspect is that PMSE devices typically cannot be identified. A wireless microphone does not transmit its ID, nor a training sequence or training symbols. Digitization would surely help here, but this comes at the cost of latency.

4.5 Link reliability

The main difference between PMSE and mobile service links is the link quality. For a high quality audio production, the high link quality objective has to be met 100 % of the time. In a mobile system, link quality varies over time and counteraction is taken on a sensed link quality degradation, so it is a reactive scheme. For PMSE a reactive scheme is not sufficient, which means that if an upcoming link degradation is predicted or even known, a counteraction has to be conducted in advance.

So far the need for ensuring a certain quality level 100 % of the time has led to the necessity to typically set PMSE operational parameters in a way that the highest audio quality can still be met even under the worst case. It is clear that this is a waste of radio resources; however the only way around this is that to know upcoming degradations well in advance. Proactive schemes are needed in contrast to reactive schemes as implemented in mobile services.