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Technical characteristics for Audio PMSE equipment

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Contents

Intellectual Property Rights 6
Foreword 6
Modal verbs terminology 6
Executive summary 6
Introduction 7
1 Scope 8
2 References 8
2.1 Normative references 8
2.2 Informative references 8
3 Definition of terms, symbols and abbreviations 11
3.1 Terms 11
3.2 Symbols 12
3.3 Abbreviations 12
4 Comments on the SRdoc 14
4.1 User defined subdivisions of clause(s) from here onwards 14
5 Audio PMSE: equipment and technologies 14
5.1 General description 14
5.2 Technical details of Audio PMSE 14
5.2.1 Use of radio spectrum 14
5.2.1.1 Introduction 14
5.2.1.2 Spectrum efficiency - efficient use of spectrum 15
5.2.1.3 Spectrum planning 15
5.2.2 Audio PMSE parameters 16
5.3 Use cases and spectrum demand 17
5.3.1 Audio PMSE use cases and their typical spectrum requirements 17
5.3.2 Additional Spectrum use at events 19
5.3.3 Additional Spectrum used by Event audience 20
5.3.4 Increasing spectrum demand for Audio PMSE 20
5.4 Audio PMSE equipment 21
5.4.1 Wireless microphones 21
5.4.1.1 Description 21
5.4.1.2 Application examples 21
5.4.2 In-Ear Monitor system 22
5.4.2.1 Description 22
5.4.2.2 Application examples 23
5.4.3 High power audio links 24
5.4.3.1 Description 24
5.4.4 Wireless conference system 24
5.4.4.1 Description 24
5.4.4.2 Application examples 25
5.4.5 Talkback/intercom system 26
5.4.5.1 Description 26
5.4.5.2 Application examples 27
5.5 Technologies used for Audio PMSE applications 28
5.5.1 Audio PMSE-specific technologies 28
5.5.2 Other technologies in use for audio PMSE 29
5.5.2.1 Introduction 29
5.5.2.2 DECT 29
5.5.3.3 Proprietary technologies that are used in the 2,4 GHz - 5,2 GHz - 5,8 GHz bands 29
5.5.3.3.1 Radio Microphones 29
5.5.3.3.2 Wireless Conference system 29
5.5.3.3.3 Control Plane 29

5.5.3.3.4 System Interconnection 29
5.6 Future technologies for PMSE 29
5.6.1 Introduction 29
5.6.2 Wireless Multichannel Audio System (WMAS) 30
6 Market Information 30
6.1 Market Size and Impact 30
6.2 Examples of the economic impact of PMSE 31
6.2.1 West End of London 31
6.2.2 The Event Industry in Germany 31
6.2.3 Olympic Games: example of large event 32
6.3 Resources for PMSE market information 32
7 Technical Information 33
7.1 Detailed technical information 33
7.1.1 Tuning range concept 33
7.1.2 Technical parameters for Audio PMSE 33
7.1.2.0 General 33
7.1.2.1 Wireless microphones 33
7.1.2.2 In-Ear Monitor systems 34
7.1.2.3 High Power Audio links 34
7.1.2.4 Wireless conference systems 34
7.1.2.5 Talkback and intercom systems 34
7.1.2.6 Wireless Multichannel Audio System (WMAS) 34
7.1.3 Audio PMSE specific technical considerations 35
7.1.3.0 Introduction 35
7.1.3.1 Effects of antenna detuning and body loss 35
7.1.3.2 Building entry loss/Building attenuation 35
7.1.3.3 Audio PMSE protection criteria 36
7.2 Information and Studies at ITU and CEPT 36
7.2.1 ITU 36
7.2.2 CEPT Recommendations 36
7.2.3 Sharing and compatibility studies 36
7.3 Information on relevant standards 37
8 Radio Spectrum Request and Justification 37
8.1 Request 37
8.2 Justification 37
9 Regulation 38
9.1 Current Regulation 38
9.2 Proposed Regulation 38
Annex A: Technical background information 39
A.1 Propagation characteristics of frequency bands 39
Annex B: Examples for PMSE use 40
B.0 Introduction 40
B.1 Calculation of typical required spectrum in MHz 40
B.2 Live Event 40
B.2.1 Music Event 40
B.2.2 Theatre, Musicals 41
B.2.3 Sports Event 42
B.3 Presentation, Conferencing 42
B.4 Electronic News Gathering (ENG) 43
B.4.0 Introduction ENG 43
B.4.1 Local News 44
B.4.2 National/International News 44
B.4.3 Video blogger 44

B.5 Studio 44
B.5.1 Studio Production 44
B.5.2 Project Studio Production 44
B.5.3 Movie Production Sound Recording 44

Annex C: C-PMSE 46

Annex D: Details on evolving technologies for Audio PMSE 47

D.1 Audio PMSE - Drivers and requirements 47

D.2 Audio PMSE applications based on IMT technologies 47
D.2.1 Introduction 47
D.2.2 Future developments of the DECT family of standards for audio PMSE applications 48

D.3 WMAS 48

Annex E: Considerations on audio quality 49

E.1 Introduction 49

E.2 Objective parameters 49

E.3 Subjective parameters 49

E.4 Conclusions 50

Annex F: Bibliography 51

Annex G: Change History 52

History 53

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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 "**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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Executive summary

The present document provides the necessary technical background information on Audio PMSE equipment operating in various frequency ranges and its intended uses.

Further, the present document shows the updated position of audio PMSE at the time of publication. Increasing spectrum demand both from program manufacturer and identified issues related to the recent COVID 19 situation are already creating a shortage of spectrum. It is requested that further to 2030 the spectrum demand for Audio PMSE is clearly identified and manufacturers are given sufficient time to develop equipment for the market place.

On PMSE

The term Programme Making and Special Events (PMSE) covers Services Ancillary to Programme making (SAP)/Services Ancillary to Broadcasting (SAB), Electronic News Gathering (ENG)/Outside Broadcasting (OB) and audio-visual equipment used in meetings, conferences, cultural and educational activities, trade fairs, local entertainment, sport, religious and other public or private events.

PMSE is an enabler for the creation of audio and video content which is broadcast and consumed globally using a variety of platforms. PMSE content capture sits at the start of the supply and value chains for a wide range of products, such as recordings of live performances or the archiving of culturally significant material. Consequently, content capture is expected to provide the highest quality possible, with producers and programme makers taking steps to ensure the quality and robustness of content capture and delivery.

Audio PMSE operates on free tuning range basis - 470 MHz to 694 MHz is the primary band.

Audio PMSE equipment operates on a tuning range basis. Frequency bands identified for Audio- PMSE are given in ERC/REC 25-10 [i.9] and ERC/REC 70-03, annex 10 [i.10]. Implementation of the frequency ranges listed in the recommendations outside the 470 - 694 MHz and 823 - 832 MHz plus 1 785 - 1 805 MHz range are not harmonised for use throughout CEPT.

The band 470 - 694 MHz is the primary band for high quality Audio PMSE applications and the band is available globally.

The use of Audio PMSE will expand beyond 2030 and has growing demand for spectrum

The demand for high quality Audio PMSE applications will continue to rise and will not be countered by technology developments. According to the EC decision (EU) 2017/899 [i.62] (article 4) the availability of the frequency band 470 - 694 MHz is guaranteed till 2030.

However, the availability of a sufficient amount of interference free spectrum in that band is needed beyond 2030.

In order to sustain the many European industries and citizens reliant on PMSE equipment, the present document recommends work to identify how to support the proposals of the Lamy report [i.53] identified in the EC Decision [i.55] before any changes to allocations in 470 - 694 MHz. This work should recognize the necessity for a clean spectrum which has consistently been identified in CEPT, ECC and other reports on PMSE and should also take into account the interference implications of any IMT implementation and its effects on the use of duplex gap frequencies.

Spectrum identified in the suggested investigation should be made urgently available along with further harmonization of bands identified in current recommendations.

Introduction

The present document includes the necessary information to support the cooperation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

The use of PMSE equipment goes back at least 5 decades, in recent years there has been an explosion in use from its original primarily broadcast production to almost every aspect of life from media and event production, social media education, theatre, houses of worship, music, sports railway stations to video streaming platforms. PMSE in its broader context adds considerably to national GDP and cultural activities.

It is interesting to note that from an almost 100 % professional activity in its early years newer internet activities by individuals are now a major player and have brought a quality of audio and video to the internet which would not have been possible even a few years ago.

While PMSE includes video devices the present document concentrates on Audio PMSE equipment including, but not limited to:

- wireless microphones;
- in-ear monitor systems;
- talkback;
- wireless conference systems.

The technology used by PMSE has evolved over the years, however, the operating principles and the demand for a suitable, interference-free spectrum remains unchanged.

1 Scope

The present document describes the necessary technical background information on Audio PMSE equipment operating in various frequency ranges and its intended uses.

The present document includes in particular:

- Market information.
- Technical information, including expected sharing and compatibility issues.
- Regulatory issues.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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 referenced 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 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.2] ETSI EN 300 422-1 (V2.1.2): "Wireless Microphones; Audio PMSE up to 3 GHz; Part 1: Class A Receivers; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.3] ETSI EN 300 454 (all parts): "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Wideband audio links".

[i.4] ETSI EN 301 357 (V2.1.1): "Cordless audio devices in the range 25 MHz to 2 000 MHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.5] ITU-R Radio Regulations, edition of 2019.

[i.6] Void.

[i.7] ECC Report 204 (2014-02): "Spectrum use and future requirements for PMSE".

[i.8] ECC Report 323 (2021-02): "Spectrum use and future spectrum requirements for PMSE".

[i.9] ERC Recommendation 25-10 (2016-10): "Frequency Ranges for the Use of Terrestrial Audio and Video Programme Making and Special Events (PMSE) applications".

[i.10] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.11] ERC Decision ERC/DEC/(94)/03: "On the frequency band to be designated for the coordinated introduction of the Digital European Cordless Telecommunications system".

[i.12] Void.

[i.13] The Society of London Theatre: "The Wyndham report" (1998).

NOTE: Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/183554/2001Performing2001.pdf.

[i.14] C-PMSE demonstration/explanation video (see video from May 14, 2014).

[i.15] Recommendation ITU-R BS.644: "Audio quality parameters for the performance of a high-quality sound-programme transmission chain".

[i.16] Recommendation ITU-R BS.1284: "General methods for the subjective assessment of sound quality".

[i.17] Recommendation ITU-R BS.1548: "User requirements for audio coding systems for digital broadcasting".

[i.18] Void.

[i.19] ETSI TR 103 450 (V1.1.1): "System Reference document (SRdoc); Technical characteristics and parameters for Wireless Multichannel Audio Systems (WMAS)".

[i.20] ECC Report 286 (2018-09): "Body effect of hand-held and body-worn audio PMSE equipment".

[i.21] Guirao MDP, Wilzeck A, Schmidt A, Septinus K and Thein C (2017): "Locally and Temporary Shared Spectrum as Opportunity for Vertical Sectors in 5G", IEEE Network, nov, 2017. Vol. 31(6), pp. 24-31. Institute of Electrical and Electronics Engineers (IEEE).

[i.22] Pilz J, Holfeld B, Schmidt A and Septinus K: "Professional Live Audio Production: A Highly Synchronized Use Case for 5G URLLC Systems," in IEEE Network, vol. 32, no. 2, pp. 85-91, March-April 2018.

[i.23] Guirao MDP, Septinus K, Schmidt A, Wilzeck A: "Audio-visual networks and the road to 5G: On standardization, role models and spectrum access", e & i Elektrotechnik und Informationstechnik, Ausgabe 7/2018.

NOTE: Available at https://www.springerprofessional.de/audio-visual-networks-and-the-road-to-5g/16239928.

[i.24] German ministry of Economic Affairs (BMWi): "Monitoringbericht Kultur- und Kreativwirtschaft 2019 (document in German)".

[i.25] Research Institute for Exhibition and Live-Communication: "The Macroeconomic Significance of the Event Industry", 2020.

[i.26] GKF: "Strukturanalyse Medien- und Veranstaltungstechnik" (document in German), 2016.

[i.27] Oxford Economics and Event Industry Council: "Global Economic Significance of Business Events".

[i.28] PLASA: "Entertainment Technology Industry Research Report", 2018.

[i.29] Report ITU-SM.2257: "Spectrum management and monitoring during major events".

[i.30] Recommendation ITU-R SM.1896: "Frequency ranges for global or regional harmonization of short-range devices".

[i.31] Recommendation ITU-R SM.2153: "Technical and operating parameters and spectrum use for short-range radiocommunication devices".

[i.32] CEPT/ECC PMSE.

NOTE: Available at https://www.cept.org/ecc/topics/programme-making-and-special-events-applications-pmse.

[i.33] CEPT Report 32 (2009-10): "Technical considerations regarding harmonisation options for the digital dividend in the European Union 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.34] CEPT Report 50 (2013-03): "On technical conditions regarding spectrum harmonisation options for wireless radio microphones and cordless video-cameras (PMSE equipment). Technical conditions for the use of the bands 821-832 MHz and 1785-1805 MHz for wireless radio microphones in the EU".

[i.35] ECC Report 147 (2010-05): "Additional compatibility studies relating to PWMS in the band 1518 - 1559 MHz excluding the band 1543.45-1543.95 MHz and 1544-1545 MHz".

[i.36] ECC Report 185 (2013-01): "Complementary Report to ECC Report 159. Further definition of technical and operational requirements for the operation of white space devices in the band 470-790 MHz".

[i.37] ECC Report 191 (2013-09): "Adjacent band compatibility between MFCN and PMSE audio applications in the 1785-1805 MHz frequency range".

[i.38] ERC Decision ERC/DEC/(95)/01: "On the free circulation and use of certain radio equipment in CEPT member countries".

[i.39] ECC Report 221(2014-09): "Adjacent band compatibility between MFCN and PMSE audio applications in the 700 MHz frequency band".

[i.40] ECC Report 245 (2016-01): "Compatibility studies between a PMSE and other systems/services in the band 1350-1400 MHz".

[i.41] ECC Report 253 (2016-09): "Compatibility studies for audio PMSE at 1492-1518 MHz and 1518-1525 MHz".

[i.42] ERC Decision ERC/DEC/(98)/02: "Exemption from individual Licensing of DECT equipment".

[i.43] ERC Report 58 (1998-01): "DSI Phase II (900 MHz issues) services ancillary to program making".

[i.44] ERC Report 63 (1998-05): "Introduction of radio microphone applications in the frequency range 1785 - 1800 MHz".

[i.45] ERC Report 88 (2000-02): "Compatibility and sharing analysis between DVB-T and radio microphones in bands IV and V".

[i.46] Void.

[i.47] COM(2018) 267 final / EU: "EU Commission, A New European Agenda for Culture", 22.5.2018.

[i.48] Void.

[i.49] ECC Report 121 (2012-09): "Compatibility studies between Professional Wireless Microphone Systems (PWMS) and other services/systems in the bands 1452-1492 MHz, 1492-1530 MHz, 1533-1559 MHz also considering the services/systems in the adjacent bands (below 1452 MHz and above 1559 MHz)".

[i.50] Recommendation ITU-R BT.2338: "Services ancillary to broadcasting/services ancillary to programme making spectrum use in Region 1 and the implication of a co-primary allocation for the mobile service in the frequency band 694-790 MHz". .

[i.51] Recommendation ITU-R BT.2344: "Information on technical parameters, operational characteristics and deployment scenarios of SAB/SAP as utilized in broadcasting".

[i.52] ETSI TR 102 801 (V1.1.1): "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)".

[i.53] Pascal Lamy; Report to the European Commission (2014): "Results of the work of the high level group on the future use of the UHF band (470-790 MHz)".

NOTE: http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=6724.

[i.54] Void.

[i.55] Commission Implementing Decision (01.09.2014) on harmonised technical conditions of radio spectrum use by wireless audio programme making and special events equipment in the Union (2014/641/EU).

[i.56] Research Project PMSE-xG Online: http://pmse-xg.research-project.de/ and White Paper: http://www.pmse-xg.research-project.de/Ressources/White%20Paper/PMSE-xG_White_Paper_v1p01.pdf.

[i.57] Research Project LIPS.

NOTE: Available at http://lips-project.de/.

[i.58] ECC Report 159 (2011-01): "Technical and operational requirements for the possible operation of cognitive radio systems in the "white spaces" of the frequency band 470-790 MHz)".

[i.59] CEPT Report 30 (2009-10): "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union".

[i.60] ETSI EN 300 175 (all parts): "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI)".

[i.61] ETSI TS 103 636 (V1.2.1) (all parts): "DECT-2020 New Radio (NR)".

[i.62] Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

analogue modulation: modulation technique whereby message signal, which is the analogue of some physical quantity, is impressed on a carrier signal for transmission through a channel (e.g. FM)

audio channel: representing a monaural (mono) audio signal

audio link: point-to-point or point-to-multipoint connection, which can carry one dedicated audio channel or multiple audio channels (e.g. left and right channel of stereo or multiple channels of microphone array)

audio PMSE: inclusive description consisting of wireless microphones, in-ear monitor systems, conference systems, talkback systems, tour guide systems, Cognitive PMSE (C-PMSE), Wireless Multi-channel Audio Systems (WMAS) and assistive listening devices

bodypack receiver: wireless receiver that can be attached to the human body, sometimes referred to as body worn receiver

bodypack transmitter: wireless microphone that can be attached to the human body, sometimes referred to as body worn transmitter

centre frequency: centre frequency of the operating channel

control plane: data channel for controlling or managing a device or system; can be uni-directional or bi-directional communication

declared channel bandwidth: width of a band of frequencies assigned to a single channel

digital modulation: any modulation scheme with discrete constellation points (e.g. FSK, PSK)

duty cycle: ratio, expressed as a percentage, of the maximum transmitter 'on' time and referenced to a given observation time

fixed: one part of a system that is permanently installed

handheld microphone: wireless microphone which is designed to be held and operated in the human hand

In-Ear Monitor (IEM) system: transmitter and one or more bodypack receivers with earpieces for personal monitoring of single- or dual-channel sound

intercom beltpack: bodyworn transmitter/receiver unit in an intercom system

mobile: both parts of the system can be in motion during operation

nomadic use: location of the equipment may change but is stationary while in use

occupied (channel) bandwidth: bandwidth containing 99 % of the total transmit power of the signal

operating channel: frequency range in which transmissions from the device occur during operation

operating frequency: actual transmitted frequency

portable: equipment such as receiver, transmitter or transceiver intended for portable (e.g. handheld) operation, powered by its own integral battery

RF channel: specific amount of spectrum for transmission between at least two devices

spectrum scanning procedure: functionality that allows PMSE equipment to perform a scan in order to identify available frequencies within the tuning range of the equipment

tuning range: maximum frequency range over which the receiver or the transmitter can be operated without hardware or firmware modifications

transmitter Inter Modulation Distortion (IMD): originates from non-linearities in electronic circuits when at least two signals on different frequencies are injected at the transmitter side resulting in at least third-order intermodulation products

wireless audio link: audio link established via a wireless point-to-point or point-to-multipoint connection

wireless microphone: microphone combined with a radio transmitter as a handheld or bodypack device; sometimes referred to as radio microphone

wireless receiver: item of electronic equipment designed to receive electromagnetic radio frequency emissions

3.2 Symbols

Void.

3.3 Abbreviations

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

3G, 4G, 5G	Stages of mobile technologies
ADS	Audio Distribution System
AM	Amplitude Modulation
CCI	Cultural and Creative Industry
CD	Compact Disc
CEPT	European Conference of Postal and Telecommunications administrations
dB	deciBel
dBm	deciBel relative to one milliwatt
DECT	Digital Enhanced Cordless Telecommunications
DMR	Digital Mobile Radio

DTT	Digital Terrestrial Television
DU	Delegate Unit (conferencing system)
DVB	Digital Video Broadcast
DVD	Digital Versatile Disk
e.i.r.p.	equivalent isotropically radiated power
e.r.p.	effective radiated power
EC	European Comission
ECC	Electronic Communications Committee
ENG/OB	Electronic News Gathering/Outside Broadcast
ERC	Electronic Radiocommuinication Committee
EU	European Union
FM	Frequency Modulation
GDP	Gross Domestic Product
GFK	German Gesellschaft für Konsumgüterforschung (society for market research on consumer goods)
IEM	In-Ear Monitor system
IMT	International Mobile Telecommuications systems (ITU-R)
ITU-R	International Telecommunication Union - Radiocommunication sector
LIPS	German public funded project: Live Interactive PMSE Services
NBA	National Basketball Association (US)
NF	Noise Figure
NR	DECT -2020 New Radio
OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open Systems Interconnection model
PA	Public Address system
PGA	Professional Golfer's Association
PLASA	Professional Lighning and Sound Association
PMR	Private Mobile Radio
PMSE	Programme Making and Special Events
PTT	Push To Talk
PWMS	Professional Wireless Microphone System
RF	Radio Frequency
RIT	Radio Interface Technology
RLAN	Radio Local Area Network
RR	ITU Radio Regulations
RRS	Reconfigurable Radio System
RX	Receiver
SAB	Services Ancillary to Broadcasting
SAP	Services Ancillary to Programme making
SNR	Signal to Noise Ratio
SRD	Short Range Device
STF	ETSI Special Task Force
TDD	Time Division Duplex
TDMA	Time Division Multipe Access
TV	Television
TX	Transmitter
UHF	Ultra High Frequency band

NOTE: In PMSE context 470 - 698 MHz.

UK	United Kingdom
URLLC	Ultra Reliable Low Latency Communication
VHF	Very High Frequency band

NOTE: In PMSE context 174 - 230 MHz.

WDU	Wireless Delegate Unit (conferencing system)
WMAS	Wireless Multichannel Audio System defined and described in ETSI TR 103 450 [i.19]
WRC	World Radiocommunications Conference

4 Comments on the SRdoc

4.1 User defined subdivisions of clause(s) from here onwards

No comments were received during the SRDoc enquiry.

5 Audio PMSE: equipment and technologies

5.1 General description

A range of Audio PMSE equipment is used to capture and replay audio in nearly all steps within a production (see Figure 1). At this production stage, the highest quality is required and this is referred to as "production" quality. Once it is processed via mixing desks or outside broadcast units some loss in quality is experienced and it is then referred to as "distribution quality". The present document focuses on production quality and resulting spectrum requirements in the "production" domain. Requirements of the "distribution" and "consumption" domain are not in the scope of the present document.

For the purpose of the present document, Audio PMSE equipment involves wireless audio links, transporting one or multiple audio channels.

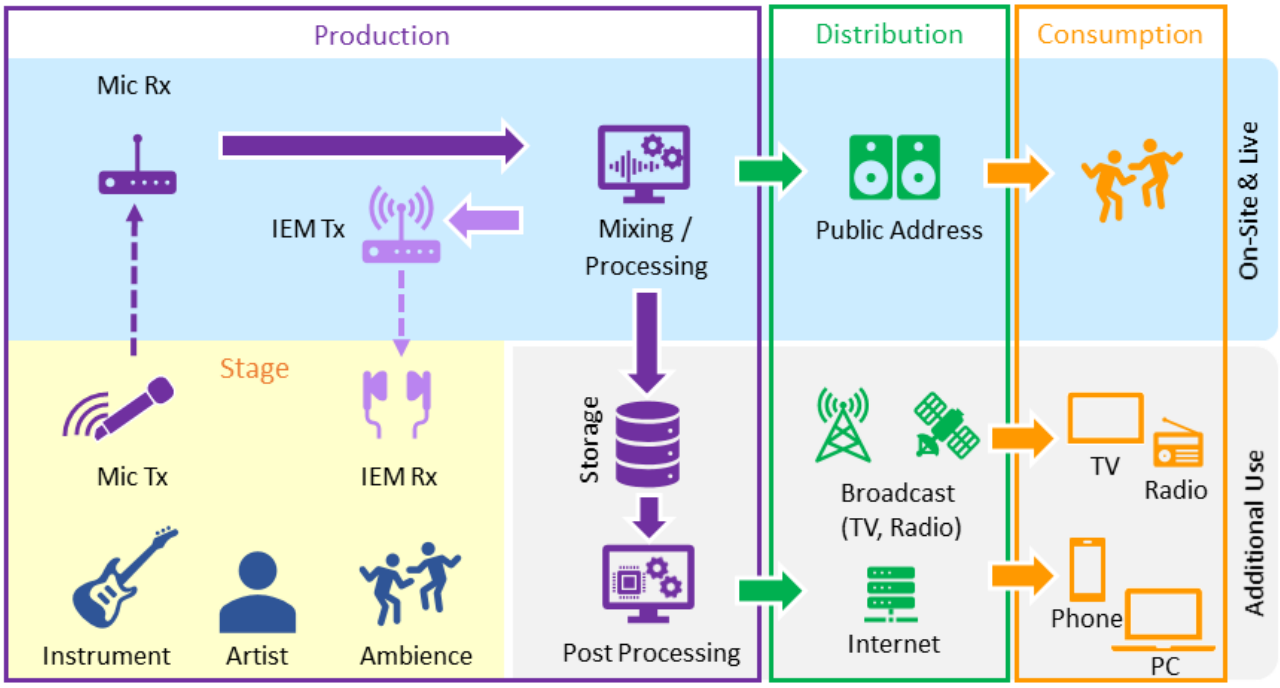

Figure 1: Overview of the different domains in PMSE use

5.2 Technical details of Audio PMSE

5.2.1 Use of radio spectrum

5.2.1.1 Introduction

The individual user of audio PMSE equipment configures a system according to the requirements of the production i.e. number of performers, musical instruments, sound effects and location with careful consideration of the link budget. Further information can be found in [i.51].

Available spectrum at a location has a major impact on the possible number of wireless microphone and IEMs. A lack of spectrum restricts the size and quality of the Audio PMSE system, which is commercially and artistically harmful.

Further considerations are:

- the tuning ranges of the available equipment;
- co-located events at the location (e.g. venue or adjacent buildings) i.e. there may be multiple performances simultaneously;
- other wireless equipment in use i.e. security, etc.; and
- the total number of audio channels, which has to fit into a given amount of spectrum. Many manufacturers now offer modes which double or triple the channel count but this currently comes at a price of reduced coverage, robustness or audio performance.

Usually, the use of audio PMSE frequencies in and around a location site is known. With these considerations and the observed use of radio spectrum the 'worst case' scenario of all equipment being in use can be assessed and calculated. This allows to establish a controlled interference scenario even in hotspot areas with dense Audio PMSE use.

5.2.1.2 Spectrum efficiency - efficient use of spectrum

In the present document, the term spectrum efficiency is used to describe how many audio channels can be accommodated within a given amount of spectrum while meeting the Quality of Service (QoS) requirements of the application and user. The spectrum efficiency of Audio PMSE equipment varies because audio PMSE devices are often designed for a specific application. The manufacturer has to focus on certain performance criteria (e.g. music/voice) to meet the requirements of the application.

5.2.1.3 Spectrum planning

Professional uses of audio PMSE needs detailed frequency planning in advance to guarantee interference-free operation:

- Large events of national interest are planned by the Administration in conjunction with the event organizer.
- Other large events require a dedicated frequency coordinator which may be the event organizer or an external expert.
- For smaller events, there is no dedicated coordinator, but the user himself plans the frequency use.

Although Audio PMSE devices comply with the same spectrum mask defined in [i.2], the channel spacing may be different depending on the recommendations of the equipment manufacturer or depending on which Audio PMSE application is to be served (e.g. speech, live-music, etc.).

In order to handle receiver blocking issues:

- transmitters such as wireless microphones should be sufficiently separated in frequency and distance from receivers e.g. handheld/bodypack transmitter and in-ear receiver worn by one person;
- devices with much higher output power than e.g. 50 mW such as high power audio links should be sufficiently separated in frequency from low power devices.

Frequency planning should take into account possible intermodulation products that may cause interference. To simplify this, most manufacturers implement a predefined intermodulation-free frequency list, from which the user can choose. For small events with devices from one manufacturer only, those plans ensure the best results, but for larger events with a mixture of different devices software tools for frequency planning are necessary.

Information with regards to a specific portion of the TV-UHF band can be found in [i.50].

In addition, the surrounding radio equipment (identified in Table 3, clause 5.3.2) and devices which may be in use by the audience (see clause 5.3.3) have to be considered.

Some manufacturers provide software tools which assist multi-vendor frequency planning and can consider the effects of transmitter intermodulation. Some of s these tools are equipped with spectrum scanning procedures helping to observe the local RF environment.

Automatic procedures for interference mitigation techniques based on cognitive behaviour have been studied both in ETSI STF386 and an accompanying German research project funded by the German Federal Ministry of Economics and Technology named C-PMSE (Cognitive-PMSE) A project demonstration is available in [i.14]. PMSE devices that use cognitive functionalities are referred to as C-PMSE systems and are used in very large events, where the additional cost of spectrum scanners and frequency management equipment is justified by the commercial requirement for very high transmission reliability.

Frequency planning is also necessary to make spectrum sharing possible and to guarantee no interference with the broadcast service, which is the primary user in the 470 - 694 MHz TV-UHF band. Spectrum sharing in the VHF-TV (174 - 230 MHz) and UHF-TV (470 - 694 MHz) band has been in place since the 1960s on a geographical limited basis. Both ranges are used by Audio PMSE worldwide.

From the perspective of Audio PMSE users spectrum sharing is only possible if the spectrum used by the incumbent is:

- observable, e.g. by spectrum scanning procedures or other information;
- predictable, e.g. stable in its operational times and frequency for the PMSE event time and location.

5.2.2 Audio PMSE parameters

In general, Audio PMSE devices are designed for one dedicated application, such as a presentation or live music performance, in order to provide the best solution for the user's needs. Concerning the RF parameter, usually only the centre frequency of the wireless channel within the tuning range of the device and the output power are adjustable.

So key parameters of different technologies of Audio PMSE are given in Table 1.

Table 1: Parameters of technologies used for Audio PMSE

Please note WMAS and DECT Evolution are future technologies.

Technology (examples) with B = declared channel bandwidth	Audio Quality (relative grading)	Typical Number of Audio Channels per 1 MHz	Typical Latency	Reliability (relative grading)
Analog B = 200 kHz	Better to Best	1,0 - 1,5	~0 ms	Better to Best
Digital B = 200 kHz	Best	1,5 - 2,0	2 - 3 ms	Better to Best
Digital "Density Mode" B = 100 - 200 kHz	Better to Best	3 - 8	2 - 3,5 ms	Good to Better
Digital 2,4 GHz	Good to Better	0,1 - 0,2	4 ms	Good
WMAS, e.g. B = 6 / 8 / 10 MHz	Configurable per Audio Channel: Good Better Best Studio	2,0 - 8+ Standard mode: 3	Configurable per Audio Channel: 1 - 20 ms	Configurable per Audio Channel: Good Better Best
DECT	Good to Better	0,6 -3,0	10 ms - 20 ms	Better
DECT Evolution	Better	0,6 - 3,0	3 ms	Better

The following paragraphs provide descriptions of the information provided in Table 1.

Typical Number of Audio Channels per 1 MHz:

- The parameter Typical Audio Channels per 1 MHz specifies how many audio channels can be placed in a bandwidth of 1 MHz. This parameter usually scales with the other two parameters: Audio Quality and Reliability.

Audio Quality:

Audio Quality is provided as a subjective grading in the categories "Good", "Better", "Best" and "Studio". Further considerations on audio quality are provided in Annex E:

- Good: sufficient for speech application such as presentation or talkback, entry level for musicians.
- Better: entry level for ambitious musicians and for live music performances.
- Best: standard level for audio production of all kind of live performances.
- Studio: close to quality of wired transmission.

Reliability:

Reliability is the ability to constantly meet the required audio quality over a specified service area. It is indicated as a relative grading in the categories "Good", "Better", "Best":

- Good: reliability of operation is given up to a range of 50 m line-of-sight; venue size is small to medium.
- Better: reliability of operation is given up to a range of 75 m line-of-sight; venue size is medium; support for multi-channel applications.
- Best: reliability of operation is given up to a range of 100 m line-of-sight; venue size is large; designed for dense multi-channel applications.

Latency:

Latency describes the one-way time delay from audio source (i.e. singer) to audio receiver output.

The parameters identified in Table 1 are not independent and multiple parameters have to be taken into account to achieve the best results for the user requirements. To achieve the lowest latency analogue technology is the first choice, but digital technology can deliver the best audio quality. In addition, digital technology can offer the possibility to scale the equipment in terms of Audio Quality, Latency, Reliability and Audio Channel count.

5.3 Use cases and spectrum demand

5.3.1 Audio PMSE use cases and their typical spectrum requirements

Audio PMSE equipment is used in a wide range of scenarios and use cases. The applications can be clustered into the following main use cases [i.8]:

- Live event
- Presentation
- Conferencing
- Electronic News Gathering (ENG)
- Audio for Video

Live event

Summarizes all audio productions with a live character such as concerts, theatres, etc. latency requirements for musicians or singers equipped with an IEM are the most stringent one for Audio PMSE. Here, the roundtrip latency, which is the latency, from microphone to mixing console input and from mixing console output to IEM receiver output needs to be below 4 ms. The number of audio channels can range from 5 for small events to more than 200 for large events. An audio signal can also be distributed via a Public Address system (PA), internet (e.g. streaming) or traditional broadcast.

Presentation

Describes applications where people give a presentation: a lecture or similar, including portable microphones to pick-up questions from an auditorium and for podium discussions involving multiple persons. The audio signal can be distributed via a public Address System (PA), internet (e.g. streaming) or traditional broadcast. Even, if the latency requirement is not critical for presentation, it has to be considered, especially, if a PA is in use.

Conferencing

Includes small ad-hoc uses up to installations in large conference rooms and venues with hundreds of units and portable radio microphones. Normally, the size of a conferencing system is described by the count of attached delegate units or satellites. Conference systems typically use DECT and 2,4 GHz with radio microphones in the 470 - 694 MHz band.

ENG

Ranges from a team consisting of at least one presenter and one cameraman up to multiple teams from different broadcasters working at the same location. Usually, the receiver of the wireless microphone is mounted on the camera providing the resulting audio/video stream to. The OB van or remote production site.

Audio for video

Focuses on entertainment provided by both professional and non-professional parties. It includes video blogger as well as broadcast studio recording and movie production.

Table 2 summarizes the audio PMSE use cases and their characteristics including typical spectrum requirement, and frequency range, type of use, which distinguishes between fixed, mobile - ad-hoc, scheduled, and area of use (indoor, outdoor). In all use cases, the place of use can be everywhere and anytime.

NOTE: DECT is typically used for talkback and lower quality audio (presentation).

Table 2: Audio PMSE use cases and their typical spectrum requirements

Use categories	Typical Use		Deployment		
		Required spectrum (typical value)	Location of use	Type of use	Area of use
Live event	Live Event - Music, Theatre - Sport, Olympics	Small: 20 MHz Medium: 45 MHz Large: 90 MHz Mega: > 150 MHz > 95 % in the band 470 - 694 MHz; In addition to PMSE in UHF; Devices using Technologies in another spectrum e.g. Wi-Fi or DECT may be used in these events	Everywhere including dedicated sites or race track	Scheduled Nomadic or Fixed	Indoor and outdoor
Presentation/Conferencing	Presentation, Conferencing	Small: 8 MHz Medium: 20 MHz Large: 45 MHz Mega: more than100 MHz	Everywhere	Nomadic or Fixed	Predominantly indoor, but also outdoor
ENG	News Gathering: Local News, International News	1-2 teams: 5 MHz 10 teams: 20 MHz 50 teams: 50 MHz Mega event: more than 100 MHz	Everywhere	Ad-Hoc Nomadic or Mobile	Predominantly outdoor, but also indoor
Audio for Video	Studio - Studio Production	Small: 20 MHz Medium: 45 MHz Large: 90 MHz	Everywhere including dedicated sites/media villages	Nomadic or Fixed	Predominantly indoor
	Studio - Project Studio Production	10 MHz	Everywhere	Nomadic or Fixed	Predominantly indoor

To guarantee interference-free operation frequency planning is either done before the event or in the case of ENG is often carried out on site between the various teams. Events such as the Olympics have a dedicated team for frequency coordination from an Administration and start to work some 12-18 months before the event other events especially where multiple countries are involved will require starting work 6-12 months before the first date.

Regular events, such as theatre or studio, usually have a permeant annual allocation.

More information about audio PMSE, its spectrum use and requirements can be found in [i.7] and [i.8].

5.3.2 Additional Spectrum use at events

At every event where PMSE is in use, there are additional radio infrastructures and radio services that serve the safety and organization of the event. Due to the physical proximity, power and coexistence of such services have to be taken into account when setting up the audio PMSE band plan.

Table 3 shows typical numbers of radio links in use for different event sizes.

Table 3: Technologies in use and spectrum requirements for event organization

Service/use	Frequency	Power(W)	Likely numbers		
			Small event	Theatre	Large event
Security	450 - 470 MHz	5 - 25	1-6	5-10	20-150
Front of house	450 - 470 MHz	5 - 25		8	
First Aid	450 - 470 MHz	5 - 25	1	2	10-25
Ambulance	450 - 470 MHz	5 - 25			2-4
Police	380 - 400 & 410 - 470	5 - 25			>50
Fire	450 - 470 MHz	5 - 25			2-6
Parking	450 - 470 MHz	5 - 25			30
Event Organiser	450 - 470 MHz	5 - 25	7	12	30
Technology					
PMR/DMR	410 - 470 MHz	Up to 5			
DECT	1 880 - 1 900 MHz	0,2	1	1	20
Wi-Fi®	2,4 GHz & 5,6 GHz	0,5	1	3	10
Drones	2,4 GHz & 5,6 GHz	0,5	1		3
Video	2 GHz - 11 GHz	0,5 - 10		4	18
SRD for scenery control, etc.	169 - 921 MHz	0,1 - 0,5	4	5	50

5.3.3 Additional Spectrum used by Event audience

Nowadays it is normal that every visitor of an event carries at least one mobile phone with them which they leave switched on during the event in order to be permanently reachable or connected to the Internet. Sometimes additional wireless services (interactive) are also offered to the visitors on site, e.g. information about the visiting team at a soccer match. It should also be noted that some radio services are rarely switched off even when not in use.

As a minimum the following wireless technologies are in use by the audience:

- IMT (2G / 4G / 4G+ / 5G)
- Wi-Fi: (2,4 GHz, 5 GHz)
- Bluetooth: (2,4 GHz)

5.3.4 Increasing spectrum demand for Audio PMSE

ECC Report 323 (published in 02/2021) [i.8] *Spectrum use and future requirements for PMSE* provides information on the diverse and expanding use of PMSE it should be considered along with ECC report 204 [i.7] its companion publication.

The general trend is increasing audio PMSE demand at large events with a concurrent growth in the number of these events. This situation has also been impacted by Covid 19 measures where previously shared equipment is now replaced by individual devices (and spectrum). Spectrum scarcity may occur if short term events themselves generate extremely high demand, or if a temporary event occurs at a location where PMSE use is already high (for example, in proximity to a broadcast studio complex). The following Table 4 taken from [i.8] provides an indication of the increasing demand for spectrum used by audio devices. It shows the growing number of frequency assignments of London (see note).

NOTE: The UK has a PMSE licensing system which enables statistics not available from other administrations

High power audio link refers to radio microphones with sufficient power to allow wireless connection over longer distances, mainly for portable use [i.3].

ADS refers to Audio Distribution Service and is intended for the transmission of audio content for direct reception within a small defined area, typically a sports stadium or conference hall. It will permit a multicast connection to a closed user group such as referee's comments, or conference translations, or audio descriptions for the visually impaired.

Talkback refers to a wireless system used for multichannel or single channel communication for instructions to ensure a safe and error-free running audio/video production.

Table 4: Number of frequency assignments by band - London [i.8]

Frequency Range	Application	Year 2014	Year 2015	Year 2016	Year 2017	Year 2018
25 - 65 MHz	High power audio link, ADS	42	66	41	75	59
65 - 470 MHz	Talkback, radio microphone, IEM, high power audio links	12 479	13 824	13 581	16 062	15 130
470 - 790 MHz	Talkback, radio microphone, IEM	55 003	64 556	72 522	77 791	87 128

5.4 Audio PMSE equipment

5.4.1 Wireless microphones

5.4.1.1 Description

Wireless microphones are devices that use radio technology to transmit audio signals over a short distance (typically up to 100 m) to a corresponding receiver that is connected to other audio processing equipment via cable. The absence of cables for the audio transmission gives the user a high degree of freedom of movement and action and avoids cabling safety problems in the production space. Wireless microphones are available in three different types:

- Handheld microphone: compact device consisting of microphone capsule, transmitter electronics, antenna and battery.
- Bodypack transmitter: body-worn device consisting of transmitter electronics, antenna, battery and audio input connector to attach any kind of audio source e.g. a body-worn microphone.
- Plug-on transmitter: small device converts conventional wired microphone into wireless; it consists of transmitter electronics, antenna, battery and audio input connector

Common to all three types of wireless microphones are the continuous transmission of audio data, the long operation time (>8 hours), the high reliability of radio transmission and the high mechanical robustness to function faultlessly even in harsh conditions.

Technical parameters for wireless microphones are provided in clause 7.1.2.1 and ETSI EN 300 422-1 [i.2].

5.4.1.2 Application examples

Figure 2 shows some typical applications of wireless microphones. On the left side of Figure 2, a singer is depicted using a handheld microphone onstage. In the middle a plug-on transmitter converts conventional wired microphone into wireless is shown and a bodypack transmitter connected to an electrical guitar serving as the audio source is shown on the right hand side. Here, the bodypack transmitter is attached to the guitar strap. Another possible use for a bodypack transmitter is shown in Figure 3. It shows a presenter wearing a Lavalier microphone which is connected to a bodypack transmitter.

Figure 2: Singer using a handheld microphone (left), plug-on transmitter (middle), bodypack transmitter (right)

Figure 3: Presenter with Lavalier microphone connected to bodypack transmitter (out of view)

5.4.2 In-Ear Monitor system

5.4.2.1 Description

An In-Ear Monitor system (IEM) provides the user with the possibility to receive wirelessly an acoustic, individual feedback signal throughout the production space. The feedback signal can include instructions from stage direction, acoustic aids such as an audible metronome (click track) or a personal mix of vocals and stage instrumentation.

Typically, the wireless audio link supports two independent audio channels, which can be used for one stereo mix or two mono mixes. A singer on stage, for example, receives a mix of his own voice and the instrumentation of the rest of the band including a click track signal. Due to the particularity that the singer hears himself twice via the bone conducted sound propagation and via the IEM, the time difference between both signals will cause comb filter effects. Depending on the intensity of the effects and his skill level the singer gets irritated and will not be able to perform anymore. Similar observations can be made with all kind of musicians, for whom physical coupling with the sound source is perceived in combination with the corresponding IEM signal.

In practice, the round trip time, defined from analog input (the microphone) via mixing console to analog output of the IEM receiver, needs to remain below a certain limit (4 ms). In the case of a presenter using IEM in order to receive pure instructions, one audio channel will be sufficient, and the latency limits are by far no longer so critical.

An In-Ear Monitor system typically consists of a transmitter that is connected via cable to the audio source (e.g. a mixing console) and a corresponding bodypack receiver worn by the user. The bodypack receiver is connected via cable to small ear canal headphones (ear pieces), which are often provided with customized ear moulds to increase the level of noise reduction from ambient surroundings.

Compared with traditional monitor/foldback loudspeakers onstage IEM improves the overall sound quality of the monitor mix and decreases the overall sound level onstage, which can help protect the users from hearing loss.

In some application, IEMs are used in a multicast approach, which means, that one wireless channel is established between one transmitter and several bodypack receivers receiving the same audio channels.

The number of IEM systems used per event is increasing rapidly due to gains in flexibility and quality for the user onstage compared to a foldback loudspeaker system with less possibility of hearing loss.

Technical parameters for In-Ear Monitor systems are provided in clause 7.1.2.2.

5.4.2.2 Application examples

In-Ear Monitor systems are used for a wide variety of applications from delivering the cue feed to a presenter/TV anchor to delivering a feedback signal to musicians during their performance onstage. Figure 4 shows the typical arrangement for an IEM system consisting of a bodypack receiver and custom moulded, noise cancelling ear piece.

The typical usage of IEM is shown in Figure 5: on the left a singer wearing custom moulded ear pieces to hear her personal monitor mix, on the right a guitar player wearing his bodypack receiver on his belt. On the guitar strap, a second bodypack can be seen which is a bodypack transmitter for the guitar audio sound.

Figure 4: Typical IEM system: bodypack receiver and custom moulded, noise cancelling ear piece

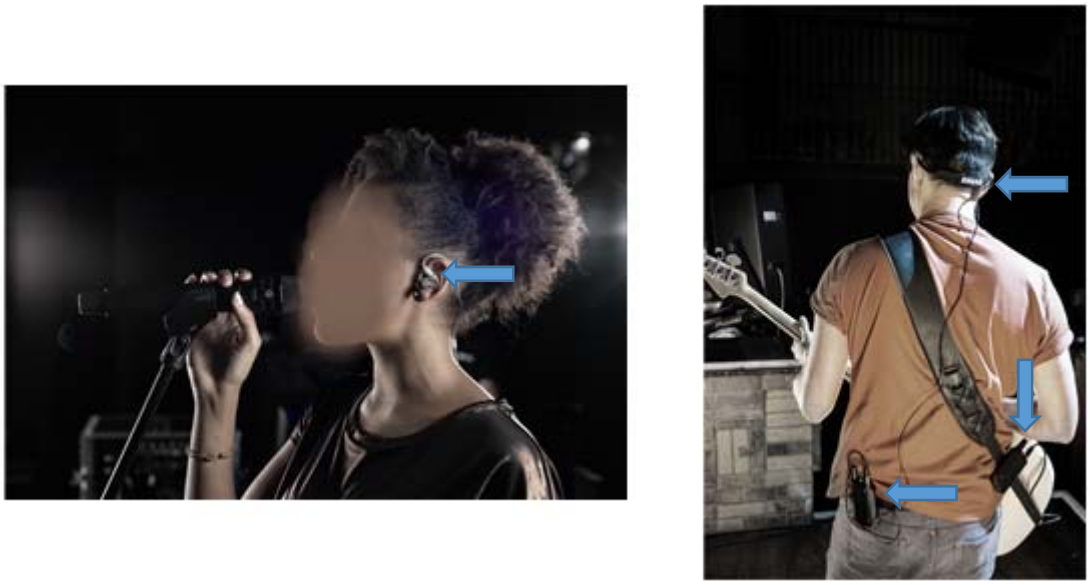

Figure 5: Singer with IEM ear piece (left), guitarist with IEM bodypack receiver connected to a headphone (right)

5.4.3 High power audio links

5.4.3.1 Description

High power audio links are wireless microphones of sufficient power to allow wireless connections over greater distances with radiated powers typically around 1 W.

This application is mostly used for Electronic News Gathering (ENG) and for outdoor use often at sporting events such as golf tournaments where commentators or effects microphones are required to roam over wide areas operating over path lengths of several hundreds of metres. Multiple receive sites may be rigged with high gain antennas on well sited and elevated platforms to provide reliable coverage or via an accompanying vehicle or golf cart with an additional link to the main OB unit.

They can be implemented as a specifically designed self-contained device or a low power wireless microphone in combination with a separate power amplifier.

Technical parameters for high power audio links are provided in clause 7.1.3.3.

5.4.4 Wireless conference system

5.4.4.1 Description

A conference system is defined as a fixed installed or movable central unit, multiple microphone station /delegate unit (DU) per each or per two delegates and a number of roving microphones. The delegate unit contains at a minimum a microphone and a push button to activate the microphone. It also often contains a small built-in loudspeaker for decentralized sound reinforcement to achieve a better sound intelligibility.

A Conference system also may contain additional features including electronic voting buttons and meeting management functions to organize "Request to Speak" queues, voting or recordings, show the name of the current speaker, show the speakers picture, support the access of handicapped people to conferences, organize the timing of speeches, allow remote control of cameras focussing on speaking delegates.

For this additional processing time, certain limits apply as it will not be accepted by participants of a conference due to high delay the speaker will hear an echo of his own voice (more than 20 ms). In general the shorter the latency the better experience for the user.

DECT, Wi-Fi and RLAN (2,4 GHz, 5,1 GHz and 5,8 GHz) are typical used for conference systems.

Technical parameters for wireless conference systems are provided in clause 7.1.2.4.

5.4.4.2 Application examples

Conference systems are used in many situations which include political and cultural, events, corporate applications and multinational meetings. Previous systems where delegates physically cued to go to the stage to make a comment, have been replaced by allowing each delegate to be clearly heard at their seat. Audio intelligibility is provided by a conference system for each delegate even in acoustically difficult sites.
For recorded or broadcasted events it is essential to make the spoken word available not only inside the conference room but to a wider audience. Figure 6 shows the typical setup for a wireless conferencing system.

Low latency is required for interactive systems as the delays in communication are uncomfortable to the user and do not reflect the usual conditions of everyday conversation and discussion.

Multi-channel conference systems are also essential for international events providing the ability for simultaneous interpretation.

In conference systems where the translation is used, the interpreters need to understand the spoken floor language loud and clear without any distracting background noise. Listening to a floor language and talking simultaneously into another language requires high concentration of interpreters. Because of the required concentration by the interpreters they work normally in 20-minute slots after which a colleague will take over. Low-quality sound transmission, distortions or even disruptions will create a disaster in translation under these circumstances. Figure 7 shows an example of a setup of a wireless conference system in a large room with additional functions like simultaneous interpretation and additional speakers for the room.

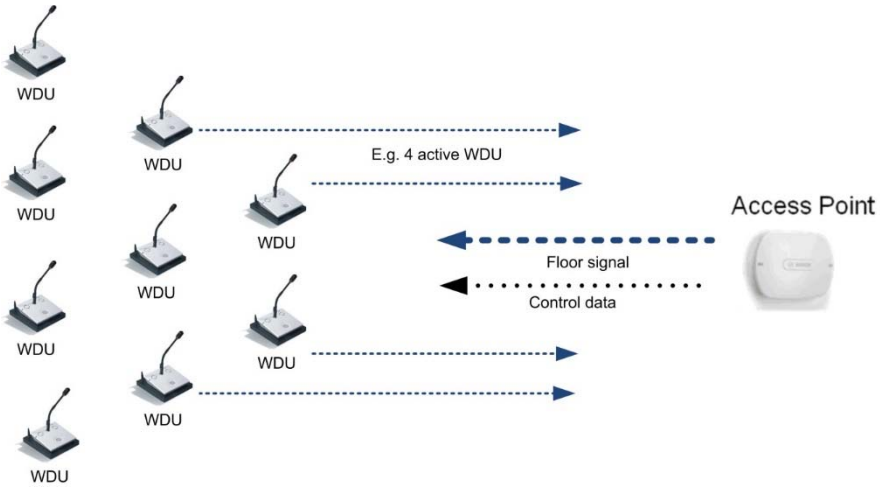

Figure 6: Wireless conferencing system with Wireless Delegate Units (WDU)

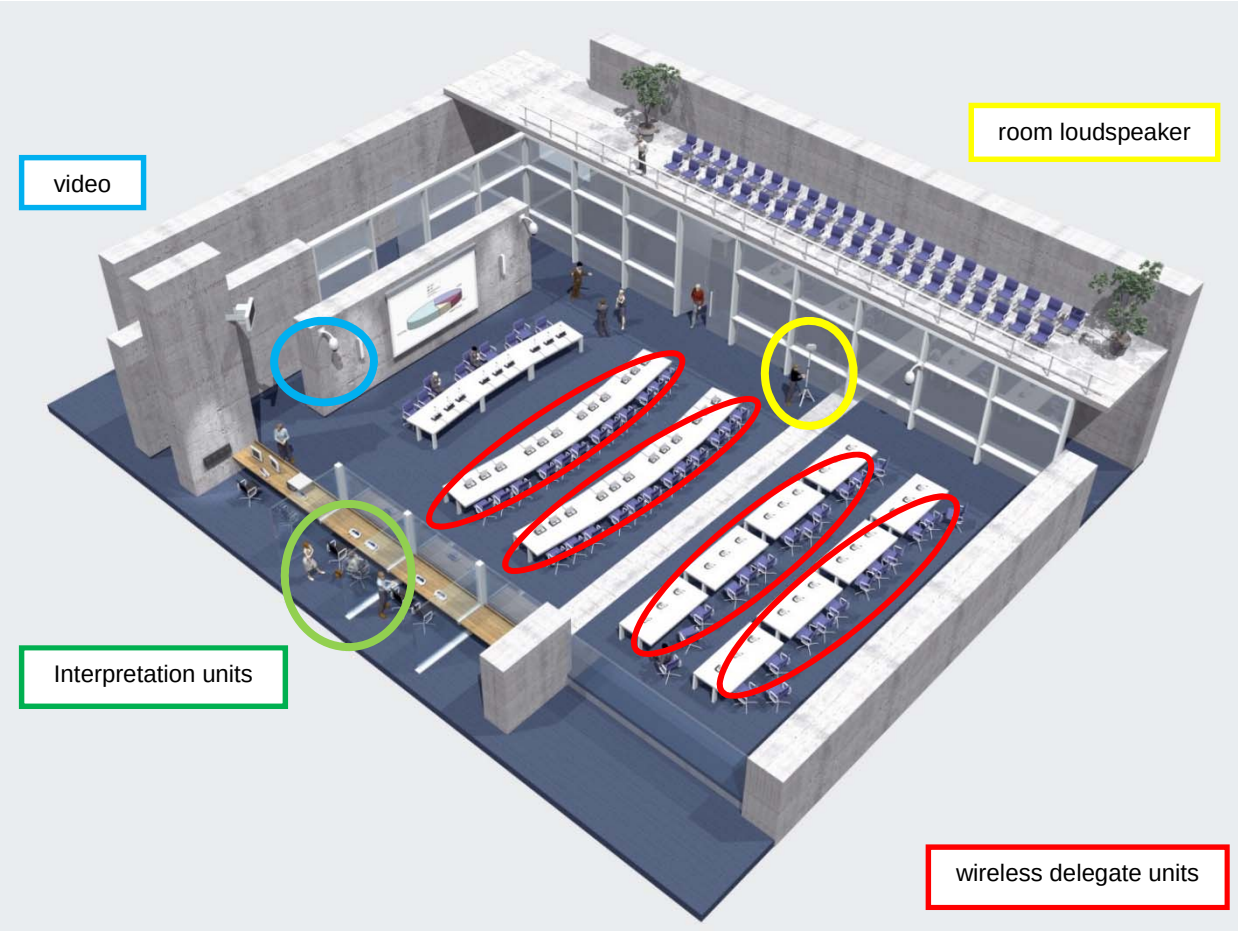

Figure 7: Example for a wireless conferencing system in a large meeting room

5.4.5 Talkback/intercom system

5.4.5.1 Description

The term talkback refers to a multichannel communications systems used by production staff and can also include presenters and other individuals in front of the camera or on stage. It is also known as Interruptible Foldback and is the means by which instructions and cues are wirelessly communicated between everyone involved in a production or event.

A talkback/intercom system can be configured in a number of ways and use a variety of different wireless technologies and frequency bands. The dominant technology is narrowband FM (PMR or DMR) in VHF or UHF bands, using base stations and handheld 'walkie-talkies'. Constant carrier systems would use the 410 - 470 MHz range on a licensed basis, additionally, there are systems that still operate in the 470 - 862 MHz range.

As the reallocation of the 470 - 862 MHz band has progressed the "clean" spectrum remaining in the band has been reserved for radio microphones and IEM by larger organizations and talkback was transferred to DECT, or other technologies such as PMR and DMR.

Digital technologies including DECT is increasingly employed in talkback systems despite greater latencies, more for the technical staff than presenters. The typical DECT based system is configured half-duplex with the base station operating in a continuous transmit mode.

Typical intercom systems operate in a semi-duplex operating mode: The director addresses everyone involved in the production via a constant carrier on a common channel. Hearing this on their handheld 'walkie-talkies' the production crew have the ability to respond in PTT (Push-to-Talk) mode. Multiple duplex channels may be employed for different aspects of the production and some simplex channels may also be used for production staff to communicate between each other directly.

Technical parameters for talkback/ intercom systems are provided in clause 7.1.2.5.

5.4.5.2 Application examples

Talkback systems are used in a variety of scenarios such as:

- TV studio production
- Film
- Major events
- Theatres

Figure 8: Intercom beltpack

Figure 9: Setup and programming of intercom beltpack during production

5.5 Technologies used for Audio PMSE applications

5.5.1 Audio PMSE-specific technologies

Three radio interfaces are described in ETSI EN 300 422-1 [i.2]:

a) analogue;

b) digital;

c) Wireless Multichannel Audio System (WMAS) - following a system-based approach to serve multiple portable units.

All audio PMSE equipment typically operates on a tuning range basis to accommodate specific local radio spectrum deployment conditions and to account for existing radio spectrum occupancy within their service area.

The time parallel operation of PMSE applications e.g. wireless microphones, IEM and/or WMAS in the same service area requires suitable frequency separation.

Frequency planning and coordination in the service area are assisted by spectrum scanning procedures and software tools including the support for mixed vendor deployments. This approach also supports the possible ad-hoc and nomadic deployments of Audio PMSE in service areas where Audio PMSE is already in use.

Figure 10 shows the general setting for a wireless audio link. The radio interface can employ analogue or digital modulation techniques for the audio plane, while the control plane uses an additional radio (SRD) or infrared link.

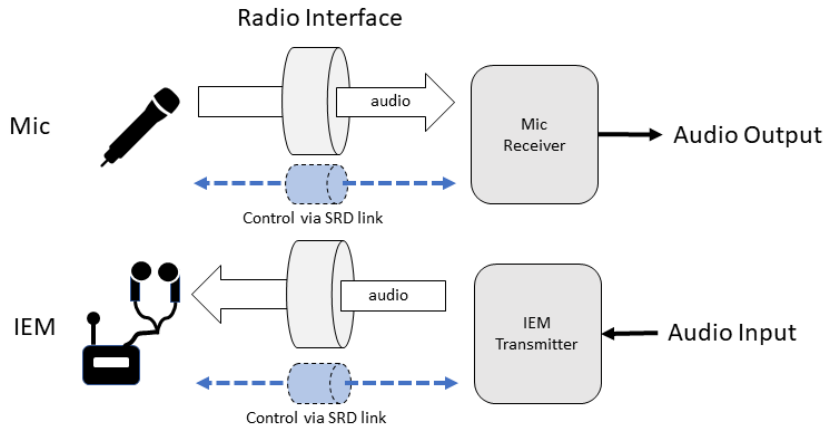

Figure 10: Radio Interface for channel-based Approach

Figure 11 shows the radio interface of a WMAS (a future technology) that offers multiple audio and control planes integrated into a single wideband radio interface. The direction of each dedicated audio plane is defined by the type of portable that is connected. WMAS can support up to a number of N devices.

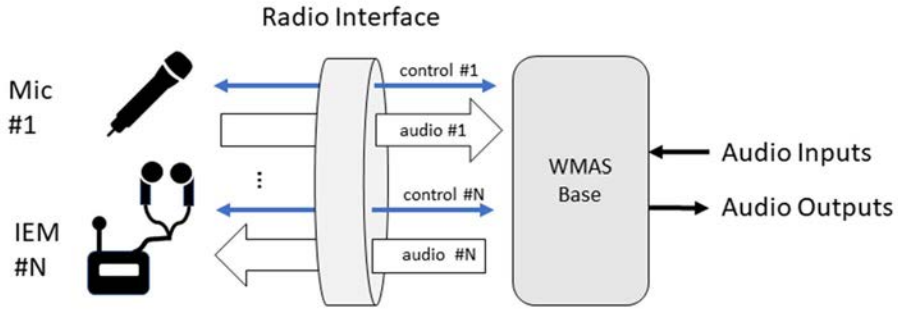

Figure 11: Radio Interface WMAS for #N portable units

5.5.2 Other technologies in use for audio PMSE

5.5.2.1 Introduction

Certain audio PMSE applications can use standardized wireless technologies that, allow for acceptable QoS, acceptable link latency and provide ease of use to the end customer.

The following clauses describe technologies adopted by the market to realize certain Audio PMSE use-cases.

5.5.2.2 DECT

With the reduction of spectrum available in the 470 - 862 MHz band, many Audio PMSE users have changed from talkback systems using FM or digital modulation to systems using DECT in order to preserve the 470 - 694 MHz for wireless microphones and IEM. It is a solution only for applications where latency is not a top priority.

The Digital Enhanced Cordless Telecommunications (DECT) system is operating in Europe in the band 1 880 - 1 900 MHz [i.11]. CEPT developed decisions guaranteeing the free circulation of DECT equipment [i.38] and decided on the license exempt use for DECT equipment [i.42]. It has spread around the globe and has become the most successful digital cordless telephone system in the world. This global availability is attractive to Audio PMSE users. In the production and contribution of media content, legacy DECT is primarily used for conferencing, audio for video, intercoms, and wireless microphones for presentations and lectures, but not for musicians.

Initiatives within ETSI are striving to improve DECT, also with regard to Audio PMSE applications. Current and futures developments of the DECT family of standards for audio PMSE applications are provided in clause D.2.2.

5.5.3.3 Proprietary technologies that are used in the 2,4 GHz - 5,2 GHz - 5,8 GHz bands

5.5.3.3.1 Radio Microphones

There are a number of radio microphones available they are not suitable for professional production quality and the band only provides a few channels.

5.5.3.3.2 Wireless Conference system

Wireless Conferencing Systems that are using the 2,4 GHz, 5,2 GHz and 5,6 GHz bands have been available for many years and generally work well depending on the internet access required by the site.

5.5.3.3.3 Control Plane

Many larger audio PMSE systems and devices use Bluetooth, Wi-Fi for a range of functions including battery monitoring.

5.5.3.3.4 System Interconnection

Larger audio PMSE systems are interconnected via Wi-Fi for remote control and areas such frequency scanning devices.

5.6 Future technologies for PMSE

5.6.1 Introduction

Audio PMSE manufacturers continuously evaluate new technologies and if possible develop products based on new technologies. The following clauses describe technologies under evaluation, however at the time of the development of the present document (2021/05) no products using these technologies are commercially available on the market. Annex D provides further details on future technologies for Audio PMSE.

5.6.2 Wireless Multichannel Audio System (WMAS)

WMAS is a new technology platform under construction by a number of manufacturers, it seeks to provide a flexible, bidirectional, scalable spectrum efficient platform encompassing the various types of current PMSE devices and allow for future requirements. Figure 12 shows an example of the WMAS topology. WMAS is targeting especially on multi-channel audio applications, e.g. wireless microphones and IEMs in live audio production such as concerts, musicals, theatres or TV shows. WMAS allows a flexible configuration of each audio channel regarding direction (IEM or Mic), mapping of audio channels to a device, latency, audio quality and link reliability.

Technical information on WMAS is provided in ETSI TR 103 450 [i.19], The WMAS platform is defined as frequency agnostic and designed to operate in all frequency ranges currently identified for audio PMSE use.

Technical parameters for WMAS are provided in clause 7.1.2.6.

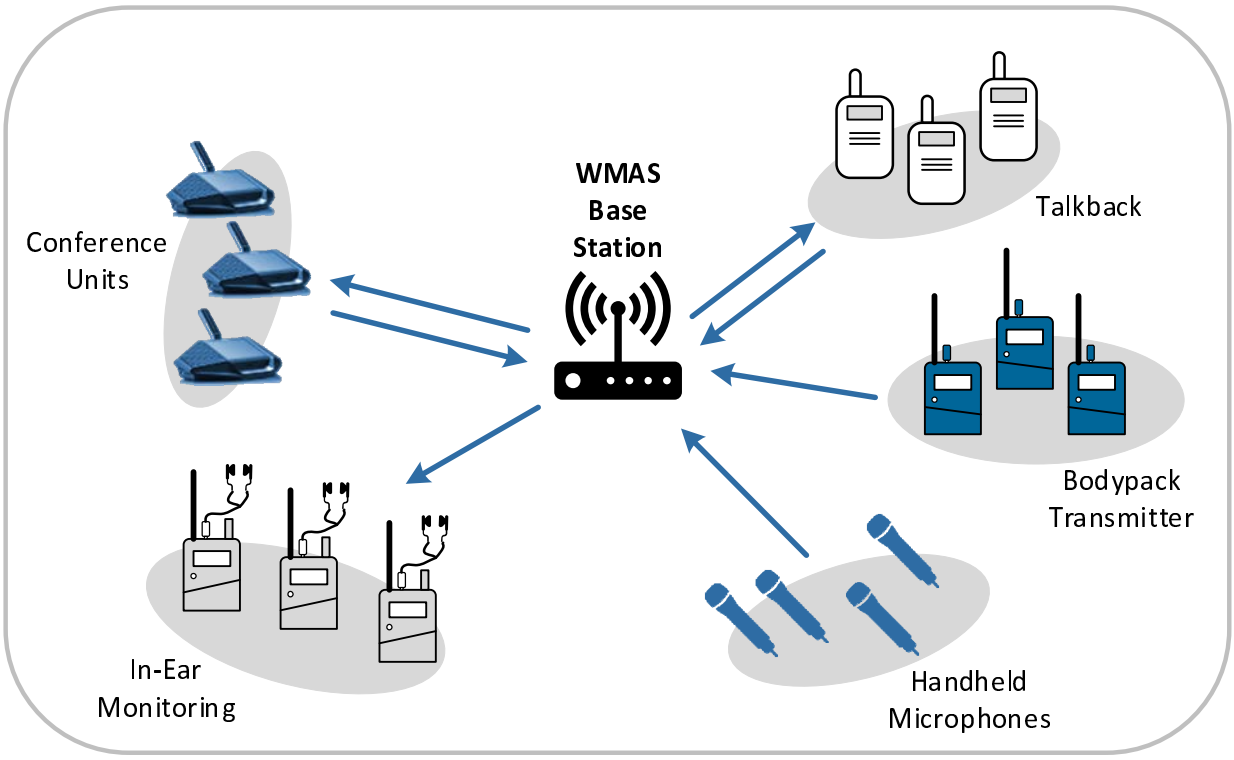

Figure 12: Example of WMAS topology

6 Market Information

6.1 Market Size and Impact

Audio PMSE can be considered as the "pen" of media production and as such it is almost impossible to clearly separate and identifies its financial worth but most cultural, film and broadcast activities could not take place without it, therefore it is reasonable to consider the overall "worth" of the cultural sector.

The contribution of the creative and culture industry to the EU economy is based on the information provided in [i.47]:

- 4,2 % GDP (Gross Domestic Product) by CCI and specifically in Performing Arts, Music, Film, TV, Radio: ~1,4 % GDP (in comparison - automotive sector: 4 % GDP).
- 8,4 million jobs by CCI and especially in Performing Arts, Music, Film, TV, Radio: ~3,7 million jobs (in comparison - automotive sector: 12 million jobs).
- € 8,7 billion trade surplus in cultural goods.

- 1 million directly employed (the industry is the second-largest employer with 1 939 000 direct and indirect jobs - comparison: 1 800 000 jobs in the Automotive industry).

Within the UK in 2018 it contributed more than £100 billion to GDP and generated £35 billion of exports.

6.2 Examples of the economic impact of PMSE

6.2.1 West End of London

The Wyndham Report [i.13] which was published in 1998 showed that an average of £4,4 was spent in the wider West End economy by theatregoers for every £1 they spent at the Box Office on tickets. To date, there has been no statistical information to suppose the overall ratio has changed.

Direct employment in West End theatres, including cast, musicians, technicians, administrators, front of house and catering staff and theatre specific trades amounted to circa 27 000 with a further 14 000 employed indirectly.

Figures from different years are available that show the development of the economic potential in London West End venues. A selection of these figures is shown in Table 5 below.

Table 5: West End of London: economic figures for selected years

Year	Information available
1997	UK theatre receipts: 589 million Euro. For London the increase in tourist expenditure was calculated at 618 million Euro.
2010	Total Attendances: 14 152 230. Total Box Office Revenue: £ 512 331 808 00. Total number of performances given: 18 615.
2018	Total Revenue from ticket sales: £ 765 800 051 00 Total Attendances: 15 529 054. VAT paid: £127 633 342 00 Total number of performances given: 18 708.

6.2.2 The Event Industry in Germany

The Event Industry in Germany can be characterized by the information below. Further details can be found in the resources listed in clause 6.3:

- 129 billion Euros in total annual turnover
- 1 800 event centre's with 423 million participants/year
- 2,8 million events take place in event centre's every year
- 75 % of all meetings and congresses take place in traditional event centre's
- Trade fair visitors spend an average of EUR 4,7 billion per year
- Exhibition exhibitors spend an average of EUR 9,9 billion per year
- 375 EURO average daily expenditure of participants in the case of work motivated events
- 171 EURO average daily expenditure by participants for other events
- 1,4 days average length of stay/event
- 54 % of all business trips from Europe to Germany are based on events that take place

6.2.3 Olympic Games: example of large event

Based on the 2004, 2008 and 2012 Olympic Games, the number of viewers has been analyzed. In [i.7] the analysis is provided in Figure 13.

The London 2012 Games was the most-watched Games ever, with over 51 million viewers in the UK watching at least 15 continuous minutes of Olympic coverage. This represented 20 % more people aged 4+ than the Beijing Games and 14 % more than the Athens Games. At 31 million people, the Paralympics attracted 141 % more viewers than the Beijing Games and 193 % more than the Athens Games.

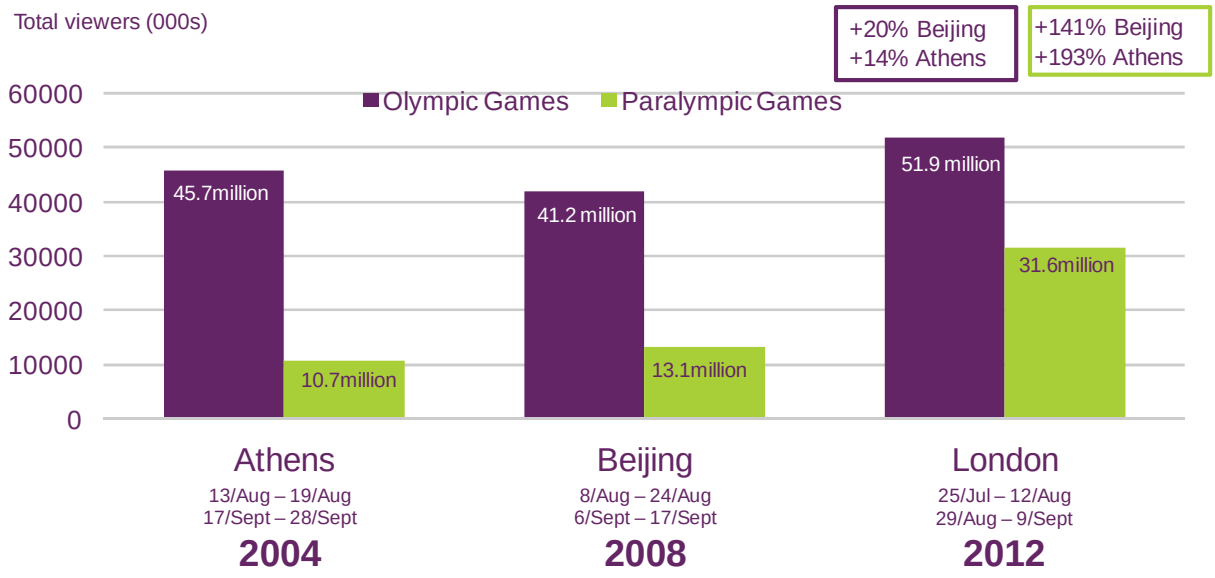

Figure 13: Audience at the Olympic Games

Both the opening and closing ceremonies for the Olympic Games 2012 attracted peak audiences of about 27 million viewers.

6.3 Resources for PMSE market information

Many organizations produce studies that provide information on certain aspects of PMSE market size. Below some examples are provided:

- German ministry of Economic Affairs (BMWi): "Monitoringbericht Kultur- und Kreativwirtschaft 2019 (document in German)" [i.24].
- Research Institute for Exhibition and Live-Communication: "The Macroeconomic Significance of the Event Industry", 2020 [i.25].
- GFK: "Strukturanalyse Medien- und Veranstaltungstechnik" (document in German), 2016 [i.26].
- Oxford Economics and Event Industry Council: "Global Economic Significance of Business Events" [i.27].
- PLASA: "Entertainment Technology Industry Research Report", 2018 [i.28].
- Further market information can be found in [i.1].

7 Technical Information

7.1 Detailed technical information

7.1.1 Tuning range concept

The availability of spectrum for audio PMSE applications is determined by national administrations and geographical availability, according to different national audio PMSE requirements, licensing mechanisms and divergent national frequency plans. This results in a very fragmented range of geographically usable spectrum contrasting on the one hand with the preference of internationally operating PMSE stakeholders for equipment that may be operated across multiple countries, and on the other hand with the economic efficiency in innovation and investment in the development of new equipment by manufacturers.

To reduce these problems, the tuning range concept has been identified by CEPT. A tuning range is the frequency range in which equipment is able to operate. Within this tuning range, the use in any one administration of radio equipment will be limited to the range of frequencies identified for PMSE nationally/geographically within that country and will be operated in accordance with the related national regulatory conditions and requirements.

There are some practical limits to the concept of tuning range:

- too large a frequency range increases the cost of the equipment due to higher complexity in design, increases power consumption and challenges for the performance of the antenna system;
- where the whole tuning range of the equipment comprises frequency ranges available for PMSE interspersed with other frequency ranges not available, operations need to be limited to appropriate frequencies.

7.1.2 Technical parameters for Audio PMSE

7.1.2.0 General

All figures in tables 6 to 10 provided in the following clauses are typical values and maybe varied by administrations via license or regulation requirements.

7.1.2.1 Wireless microphones

Table 6: Technical parameters wireless microphone systems (analogue and digital modulation)

Parameter	Typical Value	Remark/ comment
Maximum TX power	50 mW e.r.p. below 1 GHz 50 mW e.i.r.p. above 1 GHz	Devices with higher transmit power could be used and individually licensed for specific uses e.g. outside broadcast
Channel bandwidth	200 kHz	
duty cycle	100 %	
RX sensitivity	-90 dBm	Related to 200 kHz bandwidth
RX noise figure	6 dB	
Minimum required RX SNR	15 dB for analogue modulation 20 dB for digital modulation	Depending on the audio quality
channel spacing	350 - 400 kHz	Depending on equipment

7.1.2.2 In-Ear Monitor systems

Table 7: Technical parameters IEM systems

Parameter	Typical Value	Remark/ comment
Maximum TX power	50 mW e.r.p. below 1 GHz 50 mW e.i.r.p. above 1 GHz	Devices with higher transmit power could be used and individually licensed for specific uses e.g. outside broadcast
Channel bandwidth	200 kHz	
duty cycle	100 %	
RX sensitivity	-90 dBm	Related to 200 kHz bandwidth
RX noise figure	6 dB	
Minimum required RX SNR	15 dB	Depending on audio quality
channel spacing	600 kHz	

7.1.2.3 High Power Audio links

Table 8: Technical parameters high power audio links

Parameter	Typical Value	Remark/ comment
Maximum TX power	25 W	
Channel bandwidth	200 kHz	
Duty cycle	100 %	
RX sensitivity	≤-90 dBm	
Typical RX noise figure	6 dB	
Typical Minimum required RX SNR	10 - 15 dB for analogue modulation	
Channel spacing	600 kHz	

7.1.2.4 Wireless conference systems

Wireless conference systems typically use DECT, Wi-Fi or RLAN technology in the 2,4 GHz and 5,8 GHz and 5,2 GHz bands. The technical parameters of these technologies are provided in the relevant ETSI standards.

7.1.2.5 Talkback and intercom systems

The technical parameters provided in Table 9 refer to FM and PMR/DMR based systems.

Technical parameters for DECT based systems follow the relevant DECT standards.

Table 9: Technical parameters talkback and intercom systems

Parameter	Typical Value	Remark/ comment
TX power	5 - 25 W	25 W for base station
Channel bandwidth	12,5 kHz	
duty cycle	Push To Talk operation (PTT)	
RX sensitivity	0,5 uV	
Typical RX noise figure	2 dB	
Typical Minimum required RX SNR	10 - 15 dB for analogue modulation	
Channel spacing	12,5 kHz	in the range 420 - 470 MHz

7.1.2.6 Wireless Multichannel Audio System (WMAS)

WMAS allows a flexible configuration of each audio channel regarding direction (IEM or Mic), mapping of audio channels to a device, latency, audio quality and link reliability. All figures in Table 10 are typical values.

Table 10: Technical parameters WMAS

Parameter	Typical Value	Remark/ comment
TX power	50 mW e.r.p. below 1 GHz 50 mW e.i.r.p. above 1 GHz	
Channel bandwidth	8 000 kHz	Typical {6, 8, 10} MHz; up to 20 MHz
Time occupancy of channel	Up to 100 %	Typical TDD TDMA operation
RX sensitivity	-77 dBm	For 8 MHz bandwidth
RX noise figure	15 dB	
Minimum required RX SNR	20 dB	Depending on audio quality and number of audio channels

7.1.3 Audio PMSE specific technical considerations

7.1.3.0 Introduction

This clause provides further information on parameters that are unique/ specific to Audio PMSE and are relevant for a QoS and interference free use.

7.1.3.1 Effects of antenna detuning and body loss

Handheld microphones and bodypack transmitters are designed for handheld and body-worn use. Both types of operation have effects on the radiated output power of the device caused by:

- antenna detuning;
- body loss or absorption.

It is difficult in practice to distinguish between these effects, but both reduce the radiated output power and have to be considered when calculating the link budget. In general, the antenna detuning effect predominates with a handheld microphone without a stand, whereas the body loss effect predominates with a bodypack transmitter since it is worn in close proximity to the human body.

ECC report 286 [i.20] provides an analysis of the body effect in PMSE applications. The way the user holds his microphone, the way the bodypack transmitter is attached to the user, the general shape of the user's body, costume and the frequency range all have a strong influence on the level of both effects. Therefore, it is not possible to specify a typical value for the loss of the output power caused by both effects. Table 11 gives typical ranges for body loss.

Table 11: Typical values for body loss

Handheld microphone	Between 5 dB and 25 dB
Bodypack transmitters	Between 15 dB and 35 dB

7.1.3.2 Building entry loss/Building attenuation

There are several ECC and CEPT reports available, have used different values for the building entry loss. It is proposed to use 15 dB in future compatibility studies.

Table 12 provides a non-exhaustive list of values for building entry loss that is used in different ECC and CEPT reports.

Table 12: Examples of values for building entry loss

ECC Report 204 [i.7]	A value of "more than" 15 dB is used.
ECC report 159 [i.58]	Several references show that the building penetration loss varies significantly with different wall materials. Therefore calculations, which include building penetration loss should be performed for a minimum and maximum wall attenuation, ranging from 5,5 dB to 20 dB. These values cover 99 % of all possibilities.
CEPT report 30 [i.59]	Mean wall loss 8 dB @790 MHz, standard deviation 5,5 dB.

7.1.3.3 Audio PMSE protection criteria

Considering equipment under ETSI EN 300 422-1 [i.2], the receiver sensitivity at room temperature of 20 °C is:

$$P_{min} = -174\ dBm + 10 \times \log(B) + NF + SNR_{needed}$$

where B is the bandwidth, NF the noise figure and SNR_{needed} the required SNR at receiver-side.

ETSI EN 300 422-1 [i.2] allows B to have values in the range of 50 kHz to 600 kHz for narrow-band technologies.

For high-quality audio transmission, a typical value of SNR_{needed} is 20 dB.

NF can be assumed to be 6 dB for narrow-band technologies.

This results in a receiver sensitivity of -90 dBm (600 kHz), -95 dBm (200 kHz) and -101 dBm (50 kHz).

Considering that typical narrow-band equipment employs B=200 kHz the typical receiver sensitivity level is about -95 dBm resulting, considering 20 dB received SNR an acceptable co-channel interference level of -115 dBm/200 kHz.

WMAS is equally protected by assuming such a co-channel interference level of -115 dBm/200 kHz.

7.2 Information and Studies at ITU and CEPT

7.2.1 ITU

In the countries listed in RR 5.296 [i.5], the frequency band 470 - 694 MHz is also allocated on a secondary basis to the land mobile service, intended for applications ancillary to broadcasting and programme-making.

Other frequency ranges used by PMSE are considered SRD as laid out in Recommendation ITU-R SM.1896 [i.30]. An overview of the existing national SRD regulation in some countries is available in the report Recommendation ITU-R SM.2153 [i.31]. In ITU-R there are reports available that describe the technical parameters, operational requirements and deployment scenarios [i.50], [i.51].

7.2.2 CEPT Recommendations

ERC Recommendation 25-10 [i.9] and ERC Recommendation 70-03, annex 10 [i.10] provide a list of tuning ranges that CEPT administrations may consider for audio and video PMSE applications. On the CEPT website, there is a dedicated section with information on PMSE available [i.32].

7.2.3 Sharing and compatibility studies

Since 1990 a wide range of compatibility reports and information has been produced, details are available from the CEPT website https://www.cept.org/ecc/deliverables/:

- CEPT Report 32 [i.33]
- CEPT Report 50 [i.34]
- ECC Report 121 [i.49]
- ECC Report 147 [i.35]
- ECC Report 185 [i.36]
- ECC Report 191 [i.37]
- ECC Report 221 [i.39]
- ECC Report 245 [i.40]
- ECC Report 253 [i.41]
- ERC Report 58 [i.43]

- ERC Report 63 [i.44]
- ERC Report 88 [i.45]

7.3 Information on relevant standards

Table 13: Information on relevant standards related to audio PMSE

ETSI standard	Application	Frequency ranges	Responsible ETSI TC ERM Task Group
ETSI EN 300 422-1 [i.2]	Wireless Microphones; Audio PMSE up to 3 GHz	up to 3 GHz	ETSI ERM TG 17
ETSI EN 300 454 [i.3]	Wideband audio links	25 MHz - 3 GHz	ETSI ERM TG 17
ETSI EN 301 357 [i.4]	Cordless audio devices in the range from 25 MHz to 2 000 MHz	25 - 2 000 MHz	ETSI ERM TG 17

As described in clause 5 of the present document, devices that use other technologies or a combination of technologies such as e.g. DECT, Wi-Fi, RLAN, Bluetooth: appropriate standards will be found on the ETSI website https://www.etsi.org/.

8 Radio Spectrum Request and Justification

8.1 Request

In order to sustain the many European industries and citizens reliant on a PMSE infrastructure: instigate work to identify how to maintain the proposals of the Lamy report [i.53] identified in the EC Decision [i.55] prior to any 470 - 694 MHz spectrum being allocated to IMT.

This work should recognize the necessity for clean spectrum which has consistently been identified in CEPT, ECC and other reports on PMSE and take into account the interference implications of any IMT implementation and its effects in the use of duplex gaps. Harmonised spectrum or adjacent spectrum bands are the best option for users and manufacturers as identified below.

8.2 Justification

Spectrum requirements for PMSE varies with: time location & production and whilst the larger events and studios have been carefully analysed in a number of reports, however, the day to day use of PMSE generated by the multitude of video streaming and video conferencing platforms has not. It has been impossible to accurately estimate use due to the unlicensed nature of most wireless microphone and In-Ear Monitor systems. The Covid 19 lockdowns have generated an explosion of PMSE use for both communications between families and friends and start-up companies innovating in this environment.

The only work covering PMSE spectrum requirements over all was carried out by the European Commission's *Public consultation on the future use of the UHF TV broadcasting band* -and the subsequent Lamy Report [i.53] and EC decision [i.55].

The figures identified in the present document are considered to be the minimum required, but the use of duplex gaps with their inherent background interference is to be avoided for public and broadcast events but useful for day to day non broadcast use.

Within the study process for the preparation of WRC-2023 Agenda Item 1.5 a survey was conducted. The results of the study show that most regulators are looking to sustain the use of the 470 - 694 MHz spectrum until 2030 with PMSE as a secondary service. This is also in line with the Lamy report [i.53]. However, depending on the decision of WRC 23 the use of the 470 - 694 MHz band may change. The introduction of the mobile service in the frequency band 470 - 694 MHz in any Administration would effectively sterilize that spectrum for an extremely large geographical area including cross border. Therefore identification of additional European harmonised spectrum should be started, as currently spectrum outside the 470 - 694 MHz band identified in ERC/REC 70-03 [i.10] is extremely limited in its geographical availability and a single PMSE device is unable to cover all bands meaning users of peripatetic events would need to carry more than one set of equipment and manufacturers cannot achieve economic production.

9 Regulation

9.1 Current Regulation

All PMSE equipment operates on a tuning range basis. Frequency bands identified for Audio and Video PMSE are given in ERC/REC 25-10 [i.9] and ERC/REC 70-03, annex 10 [i.10]. Implementation of the frequency ranges listed in the recommendations outside the 470 - 694 MHz and 823 - 832 MHz plus 1 785 - 1 805 MHz range are not harmonized throughout CEPT.

The band 470 - 694 MHz is the primary band for high quality Audio PMSE applications. The band is available globally.

9.2 Proposed Regulation

Spectrum identified in the suggested investigation should be made urgently available along with further harmonization of bands identified in current recommendations.

It should be borne in mind that manufacturers will require upwards of three years to develop new equipment and further 2-5 years for significant market deployment

It should be noted that identification of spectrum within the 470 - 694 MHz band would be preferable as this would greatly reduce cost to the multitude of industries currently using a PMSE infrastructure.

Due to the high amount of unplanned (ad-hoc) usages, the availability of flexible usable, interference free spectrum able to support Audio PMSE is increasingly required.

The demand for high quality, Audio PMSE applications will continue to rise and will not be countered by technology developments. According to the EC decision (EU) 2017/899 [i.62] (article 4) the availability of the frequency band 470 - 694 MHz is guaranteed till 2030.

However, the availability of a sufficient amount of spectrum in that band should continue beyond 2030.

Annex A:
Technical background information

A.1 Propagation characteristics of frequency bands

Table A.1: List of frequency bands with their characteristics [i.7]

Frequency band	Propagation characteristics
29,7 to 47,0 MHz	Good propagation, minimum wall absorption, no reflection or diffraction. Shielding from metal structures is low. Only very low or lowest body absorption in this frequency range. This band may not be practicable for all types of Audio PMSE applications due to the high ambient noise levels. Due to the fact that it requires the implementation of very large antennas it is not suitable for body-worn equipment. Not suitable for large multi-channel systems.
VHF band above 174 MHz	Good propagation, minimum wall absorption, low reflection or diffraction. Shielding from metal structures is low. Body absorption in this frequency range is low. Low frequencies require large antennas. The noise floor and clock frequencies in electronic equipment may create interference to audio PMSE applications.
UHF band below 1 GHz	Good propagation, some wall absorption, depending on the surrounding structures reflection or diffraction can occur. Shielding from metal structures occurs. Significant body absorption. Wall absorption and shielding effects of metal structures can be beneficial in reusing available frequencies in larger system setups. Small antennas possible. System performance can be optimized by the use of directional antennas.
UHF 1 to 1,7 GHz	Acceptable propagation, wall absorption, depending on the surrounding structures reflection or diffraction occurs. Shielding from metal structures occurs. Significant increased body absorption. Wall absorption and shielding effects of metal structures can be beneficial in reusing available frequencies in larger system setups. Small antennas possible. System performance can be optimized by the use of directional antennas.
UHF 1,7 to 2,5 GHz	Acceptable propagation, wall absorption, depending on the surrounding structures reflection or diffraction occurs. Shielding from metal structures occurs. Critical body absorption. Wall absorption and shielding effects of metal structures can be beneficial in reusing available frequencies in larger system setups. Small antennas possible. System performance can be optimized by the use of directional antennas.

Annex B:
Examples for PMSE use

B.0 Introduction

This annex provides a non-exhaustive overview on typical deployment scenarios of audio PMSE use.

Some examples for the PMSE spectrum needs and monitoring activities at large events is provided in [i.29].

The field of audio PMSE can be separated into the following major use case areas:

- Live Event - Music, Theatre - Sport, Olympics
- Presentation, Conferencing
- News Gathering: Local News, International News
- Studio - Studio Production
- Studio - Project Studio Production

B.1 Calculation of typical required spectrum in MHz

Audio PMSE manufacturers are offering frequency compatibility calculation tools/frequency management tools. Those tools calculate available frequencies for e.g. wireless microphones and IEM considering:

- Available interference free spectrum
- Avoiding DTT allocations
- Considering other audio PMSE devices already in use
- Technical specifications
- Tuning range of the equipment
- Intermodulation Products
- Filter options of antenna systems, receivers and transmitters

The required spectrum demand listed in the following clauses provides a typical number in MHz.

B.2 Live Event

B.2.1 Music Event

Doing business in the music industry has significantly changed over the years. In the past, media (albums, DVD) was the predominant income source of the artists beside touring. As of today, music events and touring are the predominant source of income for artists. Notably, audio streaming platforms have only delivered low payouts per play and so far, all existing audio streaming platforms are not earning money with their service
(see https://www.digitalmusicnews.com/2018/12/25/streaming-music-services-pay-2019/).

Figure B.1: Example for live music event

Typical Events, Venue or Locations: Eurovision Song Contest, Live concerts… event locations up to large halls, sport stadiums, indoor and outdoor.

Typical audio channel count:

- Small event, e.g. local distribution: Wireless Microphones 16 or more; In-Ear Monitor system 4-8 (typical required spectrum ~ 20 MHz).
- Medium event, e.g. regional distribution: Wireless Microphones 24 or more; In-Ear Monitor system 8-16 (typical required spectrum ~ 45 MHz).
- Large event, e.g. national festivals: Wireless Microphones 64 or more; In-Ear Monitor system 16-24 (typical required spectrum ~ 90 MHz).
- Mega event with international distribution: Wireless Microphones 192 or more); In-Ear Monitor system 44 or more (typical required spectrum > 150 MHz).

The above channel counts are for the productions themselves. Large national or international events will also call for broadcast crews requiring roaming wireless microphone use for interviews, camera video-links, live-broadcasting of the event.

Other PMSE use:

- Light, scenery and effect control.
- Multiple fixed, mobile, portable, line or flying video cameras to capture stage, backstage, audience.
- Large Intercom/talkback setup for event direction and security.

B.2.2 Theatre, Musicals

Typical Event, Venue or Location: Dedicated buildings with fixed installations but also touring at indoor and outdoor event locations.

Typical audio channel count:

- Small event, e.g. school: 16 or more (typical required spectrum ~ 8 MHz).
- Medium event, e.g. regional theatre: 24 or more (typical required spectrum ~ 20 MHz).

- Large event, e.g. national tours, New York Broadway, London WestEnd: 62 or more, sometimes over 100 (typical required spectrum > 60 MHz).

B.2.3 Sports Event

Sporting events require individual audio content by multiple reporters from various countries.

Moreover, it is becoming increasingly common for officials at sporting events to also use wireless microphones and In-Ear Monitor solutions to talk to remote services. E.g. Video-assisted referees (Premier League & Bundesliga), Television Match Officials (Rugby Union). For redundancy purposes, each official typically uses two wireless transmitters and one In-Ear Monitor system.

Match officials: 8+ wireless microphones, 4+ In-Ear monitors.

Broadcasters and leagues are also working to make sports television more interactive, and this new approach includes attaching microphones to the players themselves. The U.S. National Basketball Association (NBA), for instance, currently uses wireless microphones on each player to capture on-court audio.

The PGA European Tour is investigating adding wireless microphones to professional golfers to capture on-course dialogue for broadcast. See https://www.bbc.co.uk/sport/golf/52841949.

Cases, where the PMSE service area is moving along with the athletes (e.g. Tour de France: bicycle race; U.S. Super Bowl; Olympics).

Olympics and other sport events of national or global interest.

Mega Events might require every single available piece of spectrum. In some cases, it is necessary to lease spectrum from other allocations, applying PMSE technology typically used in other countries or regions, which would not be allowed to be deployed at the event location under normal circumstances.

Typical audio channel count: 190 and more (sometimes over 1 000).

B.3 Presentation, Conferencing

This scenario covers person(s) giving a presentation, speech, lecture, and sermon, moderation employing handheld or body-worn wireless microphones. Free movement of equipped person(s) during use.

Additional handheld wireless microphones might be in use to pick-up questions from the auditorium and for podium discussions involving multiple people.

Additional IEM-like devices might be in use for hearing assist, especially in schools and universities.

Audio is immediately distributed via the Public Address (PA) system, but also available for recording or live streaming to the Internet.

People might be equipped with earphones (IEM) to receive instructions from event direction or security.

Latency requirement: Latency of play back via PA needs to be low enough, so that the presenter(s) and audience are not distracted by lack of lip-sync.

Typical Venue or Locations:

- Dimension: board room, Larger Rooms, Hall, Lecture Theatre.
- Deployments include schools, universities, conference centres, hotels, trade fairs, shopping centres, restaurants, churches, multi-purpose halls, press conference, political event areas and public places including streets and parks.

Typical wireless audio channel count:

- Small event, e.g. local outreach: 4 or more (typical spectrum requirement ~ 8 MHz).
- Medium event, e.g. regional outreach: 12 or more (typical spectrum requirement ~ 20 MHz).

- Large event, e.g. national: 24 or more (typical spectrum requirement ~ 45 MHz).
- Mega event with international outreach: 48 and more, plus multiple interpretation channels (typical spectrum requirement more than 60 MHz).

Other PMSE use:

- Light control
- Multiple video cameras
- Intercom for event direction and security
- Wireless voting
- Interpretation, multi-language wireless distribution

B.4 Electronic News Gathering (ENG)

B.4.0 Introduction ENG

In ENG Wireless audio link between video camera and wireless microphone handheld or body worn are used. The used Video camera might provide remote link. Audio and video (remote or OB van) are typically linked to the production facilities.

Figure B.2: Example of PMSE use in ENG situation

Typical wireless audio channel count for ENG use:

- 1-2 ENG teams: 1-4 or more (typical spectrum requirement 2 - 5 MHz).
- 10 ENG teams: 12 or more (typical spectrum requirement ~ 20 MHz).
- 50 teams: 25 or more (typical spectrum requirement ~ 50 MHz).

- Mega news event: 48 and more, plus multiple interpretation channels (typical spectrum requirement more than 90 MHz).

B.4.1 Local News

Each market area generally has several independent news crews that provide information to local residents.

B.4.2 National/International News

ENG team follow the news event so that cross border use is routine.

A huddle of multiple ENG teams in one news event location, if event is of major importance. Wireless audio channel count can reach well over 100 (national) and more than 300 if international.

B.4.3 Video blogger

Video bloggers provide streaming or new media portals, e.g. YouTube. Video bloggers have discovered that wireless audio provides significant improvements in audio quality and flexibility in deployment, while producing content in daily routine.

Beside sharing specific community news. Video bloggers deliver content like product testimonials, advertising and entertainment: 2-5 audio PMSE channels.

B.5 Studio

B.5.1 Studio Production

Production facilities in media villages or at broadcaster sites including mobile studios.

Studio production might be nomadic to event venues.

B.5.2 Project Studio Production

There has been a business shift from studio-based audio production to project studio audio productions by musicians and sound engineers, so that more geographic locations and more stakeholders are involved. Such studios are demand very high audio standards as well.

B.5.3 Movie Production Sound Recording

Significantly more entities in addition to traditional broadcasters and movie studios are now producing content, e.g. video streaming platform providers, independent film makers and project studios.

Action scenes require high mobility and reliability in audio transmission as the number of film shoots are limited due to cost and safety reasons.

Sound recordists typically carry more than 4 channels of wireless microphones for capturing dialogue on a set. They also have additional wireless transmitters for camera-links and fold-back to the directors and producers on set. A large movie set may have more than 30 channels of wireless.

Typical wireless audio channel count:

- Project studio: 10 (typical spectrum requirement ~ 20 MHz).
- Small studio production: 12 and more (typical spectrum requirement ~ 20 MHz).
- Medium studio production: 25 or more (typical spectrum requirement ~ 45 MHz).

- Large studio production: 48 and more (typical spectrum requirement ~ 90 MHz).

Annex C: C-PMSE

The main goal of a C-PMSE system is to enhance the reliability, stability and quality of the audio channels.

The technical report ETSI TR 102 801 [i.52] "Methods, parameters and test procedures for cognitive interference mitigation techniques for use by PMSE devices" developed by ETSI STF 386 describes cognitive PMSE systems (C-PMSE system) in detail, including block diagrams and interface descriptions of the different modules.

On 29th of May 2013 as a result of the C-PMSE research project (funded by German Ministry of Economics and Technology), a practical demo on cognitive behaviour was given at the Messe Berlin (Berlin Trade Fair centre).

For the purpose of demonstration five halls of the Messe Berlin (Berlin Trade Fair centre) are equipped with, a total of 30 scanning receivers forming a large scanning grid. The scanning gird is permanently installed and is still in use thus gaining more experience with operating it. It can be accessed remotely by the project partners. Initial frequency assignments to Audio PMSE links are calculated, frequency handovers due to raising interference and power control to accommodate a varying link quality were shown to the public. Furthermore, it was shown that link quality supervision can be done on analogue FM links in addition to digital systems. A presentation of the practical test setup is available in a project demonstration video [i.14]. Further findings and research results of the C-PMSE research project were incorporated in phase C of ETSI STF386 activity.

The C-PMSE system concept can be combined with any audio PMSE radio interface: analog narrow-band, digital narrow-band or WMAS.

Currently available PMSE systems offer various cognitive capabilities as a standalone hardware product. Additional cognitive features can be achieved if the PMSE system is used in conjunction with specially designed software to create a frequency management network.

The C-PMSE system concept as such can be combined with any audio PMSE radio interface:

- analog narrow-band;
- digital narrow-band; or
- WMAS.

Annex D:
Details on evolving technologies for Audio PMSE

D.1 Audio PMSE - Drivers and requirements

Audio performance demands, ease of use and production workflow requirements including the topics of spectrum availability and licensing will be the most likely innovation drivers for PMSE.

Audio PMSE-specific technologies will also lead to innovations by enabling new features to support audio production workflows, by the integration of connectivity and 3rd party services, and by improving digital audio performance in terms of quality (going towards studio audio quality in wireless) and latency (coming closer to the latency of analog transmission, which is almost 0 ms).

Topics like wireless 3D audio capture, 3D immersive audio playback and object-oriented audio production provide additional future scenarios for the innovative fields of professional audio.

Higher resolution audio capture including 3D immersive recordings and flexibility in use will promote the development of new equipment, but it will also lead to growing demands for spectrum resources. Especially capturing of 3D audio from a microphone array needs to account for more audio channels (3 to 36+ microphone capsules per array) and to be on higher audio resolution (e.g. 24 bit) and sampling rate (e.g. 96 kHz).

Automation of spectrum licensing and access procedures will likely become an important topic of the future as users of audio PMSE request a hassle-free deployment and coordination at any location of the world and at any time. A possible future solution is database-driven or certificate-based spectrum sharing approaches, e.g. eLSA (under development by ETSI TC RRS).

As studied by the LIPS project [i.57] - in the future, open interfaces and open access for seamless interworking of various radio access technologies in ad-hoc, nomadic or fixed local area deployments with Wide Area Networks (Public Land Mobile Networks, fiber, satellite) seem to be of major importance to generate value-adds for future production workflows. Future audio production workflows will incorporate remote production, remote rehearsals, and professional networked music performances but will also require incorporating new audience services like remote participation and on-site assistive listening.

D.2 Audio PMSE applications based on IMT technologies

D.2.1 Introduction

To date investigations for the use of IMT platforms have shown that it is unsuitable for audio PMSE use, for a range of technical reasons including latency and the commercial case for niche use will be hard to make for suitable chip development plus exclusive spectrum availability from licence holders is unlikely to be economically viable.

However the industry continues to keep this under investigation and takes part in various projects which explore such possibilities.

The viability of 3GPP technologies for PMSE has been studied in recent public research projects (PMSE-xG [i.56], LIPS [i.57]) co-funded by German ministries.

In 2017, the PMSE-xG project evaluated and developed requirements for several audio PMSE use cases under consideration of the 5G vision. These use cases and requirements have been also contributed to and represented in the standardization process of 3GPP. Furthermore, the PMSE-xG project has analyzed the technology outlook and the implications to the business models of the PMSE sector at this early stage in time. Results and Details can be found in the following selected publications: [i.21], [i.22], [i.23].

D.2.2 Future developments of the DECT family of standards for audio PMSE applications

Due to the reduction of the 470 - 862 MHz band spectrum, DECT has become throughout CEPT the preferred option for talkback systems and conference systems.

Attractions for DECT use include harmonised European spectrum and a wide range of equipment options but in some large outdoor events using hundreds of handsets are experiencing congestion.

ETSI TC DECT has been working on two additional standards since 2017:

- *DECT evolution* is an update of the DECT standards ETSI EN 300 175 [i.60] to improve support of applications regarding latency, data-rate, and reliability based on current physical layer. The required changes to the DECT standard have been already incorporated to the relevant DECT standard parts.
- *DECT-2020 NR* is a Radio Interface Technology (RIT) specified in ETSI TS 103 636 [i.61]. It provides a slim but powerful technology foundation (OSI Layers 1 to 3) for wireless applications deployed in various use cases and markets. DECT-2020 NR is employing OFDM and is designed towards URLLC and mMTC use cases as envisioned by IMT-2020. It further enables coexistence with legacy DECT and DECT evolution in current frequency bands allocated to DECT.

Like DECT, DECT evolution and DECT-2020 NR as technology foundations are targeted towards local area wireless applications, which can be deployed anywhere by anyone at any time.

D.3 WMAS

WMAS is the newest audio PMSE radio interface and system concept. The system-based approach for multi-channel audio applications will ease the deployment and operation of audio PMSE in large events due to the integration of the microphones, IEMs and talkbacks. WMAS allows fully synchronized operation and flexible configuration of each audio channel regarding direction (IEM or Mic), mapping of audio channels to a device, latency, audio quality and link reliability.

Annex E:
Considerations on audio quality

E.1 Introduction

When considering during sharing and compatibility studies the impact of unwanted emissions and interference into an audio PMSE system, the audio quality needs to be considered and assessed. Unlike other communication systems, the system performance of an Audio PMSE system is characterized by measurable, objective and subjective parameters. Emissions from other spectrum users may influence some or all parameters that describe the audio quality and therefore the performance of an audio PMSE system.

E.2 Objective parameters

The audio quality parameters listed below (taken from [i.15]) are the most relevant for analogue equipment. For the characterization of the audio quality of an audio PMSE system all or some of the listed parameters can be used. Some of the parameters are also appropriate for the characterization of digital equipment, however additional parameters are required for digital equipment:

- Nominal audio bandwidth
- Amplitude and frequency response
- Group delay variation
- Non-linear distortion
- Error on reconstituted frequency
- Error in amplitude and amplitude response
- Level stability
- Noise (and single tone interference)
- Disturbing modulation by power supply

For digital equipment, in addition, the following quality parameters are considered:

- Jitter
- Sample rate
- Bit depth
- Sample accuracy/ synchronization

E.3 Subjective parameters

Subjective threshold values are thresholds of perception, found by subjective statistical research under ideal test conditions. In broadcasting grading scales are used for subjective tests in order to permit more consistent statistical processing methods independent form the language used to express the opinions. Recommendation ITU-R BS.1284 [i.16] provides a list of main-attributes and sub-attributes and examples of common descriptive terms for the absolute assessment of sound quality in detail.

Audio PMSE Manufacturers and users use their own non-harmonized test methods to assess the subjective audio quality of an audio PMSE system. These methods may have similarities with the elements described in the available Recommendations ITU-R.

Subjective audio quality parameters and their assessment are not considered in the present document.

Table E.1 provides an example for subjective audio quality grading and the associated descriptions and definitions as provided in [i.16].

Table E.1: Audio quality categories

Category	Audio Quality	Application
(1)	Very high quality, with sufficient quality margin to allow cascade (concatenation) and post-processing.	Contribution, distribution, production and post-production
(2)	Subjectively transparent quality, sufficient for the highest quality broadcasting.	High-quality ("CD quality") emission
(3)	Equivalent to or better than good FM service quality, or equivalent to or better than good AM service quality.	Intermediate quality emission

E.4 Conclusions

- For the characterization of the audio quality of an audio PMSE system all or some of the listed objective parameters can be used. Depending on the audio PMSE application the degradation of an individual parameter is perceived differently.
- The methods used for subjective testing by the different audio PMSE stakeholders may have similar elements as the available
  Recommendations ITU-R, however they are not comparable and details are not publicly available.
- When using qualitative terms for describing the audio quality, the baseline for the used terms would need to be clearly defined. E.g. "CD quality" in Recommendation ITU-R BS.1548 [i.17], Annex 3. Qualifiers like "good", "better", "best" provide a relative grading for the audio quality of a system.
- Therefore it is proposed that the above listed measurable, objective audio parameters will be used in this document to assess the impact of unwanted emissions from other spectrum users on the system performance in sharing and compatibility studies.

Annex F: Bibliography

- ECC Report 44 (2014-02): "Guidance for radio usage at special events".

Annex G:
Change History

Date	Version	Information about changes
2020-02	1.2.0_0.0.8	Material from existing document transferred into new skeleton
2020-03	0.0.9	Further development of the document
2020-03	0.0.10	Output of drafting session 20200310
2020-03	0.0.11	Output of drafting session 20200311
2020-04	0.0.12	Output of drafting session 20200429
2020-05	0.0.13	Output of drafting session 20200515 + further development of clauses 5.2 and 5.4
2020-06	0.0.14	Output of drafting session 20200527 + further development of clauses B5, B8, 5.4, 5.5, 5.3.3, 7.1.2, 7.1.3 + general review of text + added new annexes
2020-06	0.0.15	Output of drafting session 20200616 + general review of the document + further development of clauses 5.2.3, 5.3.2, 7.1.3
2020-07	0.0.16	Output of drafting session 20200721 + added 5.2.1.5, further development of clauses 5.2 and subsections, 7.1 and subclauses, 5.4 reviewed
2020-09	0.0.17	Output of drafting session 20200903 + adding new clause 5.4, rearranging text, added material that was provided in contributions
2020-10	0.0.18	Output of drafting session 20201007 + added material provided in document 17 + general review of the document, removal of old material Figures and tables renumbered in right order, list of references and references inserted
2020-10	0.0.19	Output of drafting session 20201027 + further development of the document
2020-12	0.0.20	Output of drafting session 20201127 and 20201209 + further development of the document + adding material to clauses 7.2 and 7.3
2021-01	0.0.21	Output of drafting session 2021015: revisions in clauses 7.1.2.1 and 7.1.3 added new clause in Annex A (protection criteria) + further development of the document
2021-01	0.0.22	Full document: editorial updates, restructuring and addition of informative references Outcome of drafting session 20210128 + contributions to drafting session incorporated into the document
2021-02	0.0.23	Full document: editorial updates, restructuring and addition of informative references Outcome of drafting session 20210212 + contribution to drafting session incorporated into the document. Clause 5.2.1 reordered
2021-03	0.0.24	Outcome of drafting session 20210305: clause 5.6.1 and clause A.5 revised and amended. Text in clauses 8 and 9 added Clause numbers and figure numbers revised Informative references added
2021-03	0.0.25	Clause 7.1 revised, un-used elements deleted, renumbering of the clause, references revised accordingly, numbering of figures and tables revised, formatting of text and tables revised, checked for consistency in the use of terms Outcome of drafting session 20210326: Restructuring Annex D, new clause in clause 7.1 editorial updates (as provided in Doc 13)included in clause 5.1/5.2/5.2.1.2/5.2.1.1/5.2.1.3/5.2.1.5/5.2.1.6/5.2.2/5.3.6 revision and restructuring of the whole document based on the received contributions
2021-04	0.0.26	revision and restructuring of the whole document based on the received contributions outcome of drafting session 20210423: definitions revised and new definitions added based on input doc 16
2021-05	0.0.27	Definitions clause aligned with latest draft version of ETSI EN 300 422-1 [i.2]. Restored alphabetical order Outcome of drafting session 20210513: reviewed the full document → fixed editorial issues/ removed hanging clauses →solved all comments/converted to clean document elevated to stable draft

History

Document history		
V1.1.1	February 2007	Publication
V2.1.1	October 2021	Publication