CEPT ECC
Electronic Communications Committee

ECC Report 372

Use Cases, Audio Characteristics and Technology Options for Audio PMSE

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0 EXECUTIVE SUMMARY

This Report analyses the use cases, audio characteristics, and technology options for audio PMSE (Programme Making and Special Events) across Europe, providing detailed guidance for future spectrum management decisions. Audio PMSE covers applications such as wireless microphones, in-ear monitors (IEMs), and audio links supporting a wide range of scenarios from small-scale lectures and presentations to large-scale concerts and televised events.

This Report categorises use cases into three groups:

- Category A: Simple productions with low channel counts (e.g. schools, churches and small events);
- Category B: High-quality productions with moderate to high technical demands (e.g. TV studios, theatres and sports events);
- Category C: Large, high-value events requiring advanced coordination and high channel counts (e.g. festivals, major sports and nationally significant happenings).

Technical and operational requirements - including audio quality, latency, regulatory constraints, and spectrum use - vary greatly between categories. The 470-694 MHz UHF band remains the core spectrum for professional PMSE use due to its harmonisation, suitable propagation characteristics, and comprehensive industry support. The bands 1880-1900 MHz, 2.4 GHz and 863-865 MHz offer license exempt/general licensed options, mostly serving less-demanding applications or talkback communications.

The frequency band 1350-1400 MHz is starting to see some use for audio PMSE for Category B and Category C. Currently, 15 countries identify the frequency band, or parts thereof, as available for PMSE. Where it is available some conditions apply, e.g. indoor use only. Ideally, wider adoption across CEPT and more flexible conditions would increase the attractiveness of this band.

The industry's growing demand for spectrum reflects complex productions, increased audio channel needs, and higher audio quality standards. While innovative technologies like WMAS offer efficiency gains, access to sufficient amounts of ideally harmonised spectrum remains essential.

TABLE OF CONTENTS

0 Executive summary 2

1 Introduction 6

2 Audio PMSE - Use cases user groups (small, medium and large) 7
2.1 Categories of audio PMSE use 7
2.1.1 Category A: Simple productions 8
2.1.2 Category B: High-quality audio productions 8
2.1.3 Category C: Large events 9

3 Operational performance requirements across the range of PMSE applications, use cases and deployment options 13

4 Frequency requirements and use 14

5 Technology options that meet the different requirements 15
5.1 Overview 15
5.2 Technology 15
5.2.1 Narrowband 15
5.2.1.1 Analogue modulation 15
5.2.1.2 Digital modulation 16
5.2.2 Wireless Multichannel Audio Systems (WMAS) 16
5.2.3 Other wireless audio technologies 17
5.2.3.1 2.4 GHz microphones 17
5.2.3.2 1880-1900 MHz (DECT) 17
5.2.3.3 IMT-2020 (5G) based technology 17
5.3 Latency 18
5.4 Audio bandwidth and dynamic range 18
5.5 Physical characteristics 18
5.6 Body effect 19

6 Availability of tuning ranges across CEPT and THE REASONS THAT DIFFERENT TYPES OF EQUIPMENT ARE AVAILABLE FOR DIFFERENT TUNING RANGES 20
6.1 Overview of ERC Recommendation 25-10 20
6.1.1 Band 174-216 MHz – Tuning Range A2, B1 in ERC Recommendation 25-10 21
6.1.2 Band 470-694 MHz – Tuning Range A3, B2 in ERC Recommendation 25-10 21
6.1.3 Band 733-757.5 MHz – Tuning Range A4 IN ERC Recommendation 25-10 21
6.1.4 Band 821.5-832 MHz – Tuning Range A5 in ERC Recommendation 25-10 21
6.1.5 Band 863-865 MHz – Tuning Range A6 in ERC Recommendation 25-10 21
6.1.6 Band 1350-1400 MHz – Tuning Range A7 in ERC Recommendation 25-10 21
6.1.7 Band 1518-1525 MHz – Tuning Range A8 in ERC Recommendation 25-10 22
6.1.8 Band 1785-1805 MHz – Tuning Range A9 in ERC Recommendation 25-10 22
6.2 National allocations for audio PMSE outside ERC Recommendation 25-10 tuning ranges 22
6.3 Market adoption and use of bands in ERC Recommendation 25-10 23
6.3.1 Manufacturer data 23
6.3.2 Data from hire companies 24
6.3.3 Use of the bands by broadcasting 24
6.3.4 Use of the band by live venues/theatres 25
6.4 Summary 26

7 Regulatory considerations 27
7.1 Requirements 27
7.1.1 Widespread/harmonised availability 27
7.1.2 Regulatory certainty 27

7.1.3 Substantial block of contiguous spectrum 28
7.1.4 Regulatory conditions 28
7.1.5 Sharing conditions 28

8 Conclusions 29

ANNEX 1: Case study: Eurovision Song Contest 2023 (liverpool, the United Kingdom) 30
A1.1 About the event 30
A1.2 About the venue 30
A1.3 RF requirements 30
A1.4 Frequency planning 32

ANNEX 2: List of References 34

LIST OF ABBREVIATIONS

Abbreviation	Explanation
ALD	Assistive Listening Devices
CEPT	European Conference of Postal and Telecommunications Administrations
DECT	Digital Enhanced Cordless Telecommunications
DTT	Digital Terrestrial Television
DTTB	Digital Terrestrial Television Broadcasting
EBU	European Broadcasting Union
ECC	Electronic Communications Committee
ESC	Eurovision Song Contest
GSM	Global System for Mobile Communications
HH	Hand Held
IEM	In-ear monitor
IMT	International Mobile Telecommunications
MICS	Microphones
MCA	Mobile Communications on Board Aircraft
MCV	Mobile Communication Services on Board Vessels
MFCN	Mobile/Fixed Communications Networks
NR	New Radio
OFDM	Orthogonal Frequency-Division Multiplexing
Pearle	Performing Arts Employers' Associations League Europe
PMSE	Programme Making and Special Events
PPDR	Public Protection & Disaster Relief
RFID	Radio Frequency Identification
RLAN	Radio Local Area Network
RMR	Railway Mobile Radio
SRD	Short Range Devices
UAS	Unmanned Aircraft System
UHF	Ultra High Fequency
VHF	Very High Frequency
WMAS	Wireless Multichannel Audio Systems

1 INTRODUCTION

This Report provides detail on the Use Cases, Audio Characteristics and Technology Options for Audio PMSE and an analysis of the reasons that different tuning ranges have different availability in different countries and different types of equipment. It also identifies the different operational, deployment and performance constraints and trade-offs, for example audio quality and latency (bit depth, sampling rate, compression etc.) and explores which technology options can meet these requirements.

The Report characterises the wide range of PMSE use cases together with their associated audio characteristics and the types of solutions (e.g. narrowband, WMAS, analogue, digital) that may be used for spectrally efficient delivery of the content for onward use. The focus captures different aspects of the status, evolution and development of technology, equipment and operations over the medium term that are seen to be important for future spectrum demand and for possible future changes in regulation.

Recent years have seen changes in spectrum availability and technology options for audio PMSE applications (radio microphones, in ear monitors and communication links, also known as talkback). Audio PMSE applications are used across a broad range of activities from high-end event and broadcast live productions and state events with multiple PMSE links through to education and corporate use in presentations, meetings and lectures where only a single microphone might be used.

This range of use cases, along with the different applications (microphones, IEMs, talkback) have differing requirements with respect to their operational performance and deployment options. For example, a live music concert in a large arena, or a major festival, requires high audio quality and minimal latency, whereas a conference venue or company site can operate with reduced quality and higher latency. Some technology options, for example DECT, are now more widely used for talkback as the audio quality is sufficient for this application and has helped reduce demand in the UHF band, which better supports high-quality use.

Consequently, these differing requirements can be satisfied by different technologies (and different spectrum bands). For example, IMT-2020 (e.g. DECT-2020 and 5G NR) could satisfy the needs of corporate and campus type use cases, and possibly some news-gathering situations, but may not meet the demands of theatres, concerts and broadcast live productions.

Although this Report complements previous ECC Reports on PMSE, for example ECC Report 323 [2], it provides administrations with greater detail to help inform future spectrum management decisions that could affect audio PMSE by clarifying what applications, deployment options and use cases are within the scope of those discussions.

2 AUDIO PMSE - USE CASES USER GROUPS (SMALL, MEDIUM AND LARGE)

The term Audio PMSE is used to cover radio microphone, in ear monitor (IEMs) and audio link applications.

Categorising audio PMSE is difficult given the variety of deployment scenarios, both within a category or across different categories. For example, a live music performance may have four channels of audio or 120+. An event in a theatre may be a single microphone for one night, or 50+ channels in a fixed run over 15000 performances over a period of several decades. Events may be at fixed locations or tour across a country or across many countries.

Key metrics when considering options for a wireless audio channel are:

- Audio quality:
  - Audio frequency response - the range of audio frequencies that the microphone can pick up (e.g. 50 Hz - 20 kHz). This determines the clarity and fidelity of the audio;
  - Signal to noise ratio (SNR) - measured in decibels (dB), it determines the signal clarity relative to noise. It is noted that for digital systems, unlike analogue equipment, the audio quality is constant over a wide SNR range, and will fail suddenly (known as the cliff-edge effect which is common to many digital applications);
  - Dynamic range - is the difference between the softest and loudest sounds the system can handle;
- Latency - the delay in signal transmission, measured in milliseconds. This includes the time for audio signal capture and processing/coding, modulation, reception and decoding. The analogue to digital conversion and signal processing in digital systems introduces latency that does not exist with analogue equipment. Latency is critical for live performances where, for example, musicians hear themselves on a speaker/in-ear monitor: in this scenario, the maximum round trip latency is generally accepted to be less than 5 ms, based on experience;
- The operating frequency band;
- The tuning bandwidth/frequency range of equipment. A large tuning range provides greater flexibility of use;
- RF transmission power;
- Operating range - the maximum distance between transmitter and receiver without dropouts or interference (e.g. 20-100 m);
- Battery life and power consumption - how long the transmitter and/or the receiver will last on a single charge (e.g. 6-10 hours);
- Interference and spectrum efficiency - the ability to coexist with other wireless system and to make the best use of the available spectrum;
- Operational scenario - indoor or outdoor.

The metrics outlined above will be relevant in different degrees to different use cases. Equipment that performs highly across each of these metrics as they apply to audio quality, RF robustness and battery and spectrum efficiency are typically high-end products used in high-value, professional use cases (what may be considered as use cases for Category B and Category C as introduced in the next section). Due to the nature of use, these systems are typically deployed by specialist personnel.

Alternatively, in those use cases such as schools, conference venues and places of worship, users have a higher degree of tolerance to those metrics above, and therefore factors such as cost, scalability and user/operator competence may dictate choice of equipment (may be considered Category A use cases).

2.1 CATEGORIES OF AUDIO PMSE USE

As has been noted previously, capturing the varied use cases of audio PMSE is difficult, ranging from a single microphone used in news gathering or an office presentation, to events utilising hundreds of PMSE links for events and productions that are consumed by millions of people. To streamline these different cases, this report categorises audio PMSE into three broad categories.

2.1.1 Category A: Simple productions

Category A productions/events are characterised by low channel counts, often more cost sensitive users with lower levels of technical and frequency planning expertise. Use cases in this Category span a range of cases including small TV and news productions, social media content creation, smaller places of worship, schools, small conference venues etc. Typically, the consequences of equipment failure are relatively low in economic terms.

Table 1: Summary of examples of Category A use

Event sub-category	Comments
Webcasts and Camera-journalist (single person operates camera and audio)	Presenters and guests may use hand or body-worn/lavalier mics for clear speech, and interviews use hand-held for mobility.
Presentation and church sound systems	Presenters and guests wear lavalier microphone for clear speech, and interviews (questions from the audience) use hand-held for mobility. Equipment is often a fixed installation on a fixed frequency due to consistent use in the same location.
School/University Presentations (Lectures and Conferences)	Microphones are used to enhance communication in classrooms, conferences, media production, and student activities they require good coverage with opportunities for smart audio technology.

2.1.2 Category B: High-quality audio productions

Category B productions are typically associated with high-end TV and film productions, sporting events and, increasingly, conference and business productions where frequency assignments can easily be in the 50 to 100 channel range. Significant investment on equipment and personnel is made to ensure the event is delivered successfully.

Table 2: Summary of examples of Category B use

Event sub-category	Comments
Broadcasting - live news reporting, talk shows, and entertainment programs.	Clear, high-quality wireless audio is critical for performances during live broadcasts. Broadcast studios require stable, interference-free spectrum to function effectively. Latency in digital equipment may affect lip-sync accuracy. Spectrum congestion in cities affects signal quality.
Theatre, concerts, conference/exhibition venues and live music festivals	Wireless audio is essential for modern theatre production and enhance performances by providing clear, flexible, and professional audio. Conferences and exhibitions make significant use of wireless audio for multiple concurrent presentations and entertainment breaks by exhibitors. Singers and musicians (band members) use in-ear monitors. Stage managers and crew rely on wireless communications for coordination.
Sports events	Live coverage of sport events like matches, races, and athletic competitions provides a real-time live coverage. Wireless flexibility allows for on-field interviews and dynamic coverage. Technical risks are a major concern. The event can be supported by live music or other performances pre, post or during the event which are an additional requirement and must be coordinated alongside the main event itself. Growth in regional and community-level sports events driving demand for wireless PMSE. Expansion of sports broadcasting and streaming services, increasing market potential.

2.1.3 Category C: Large events

Category C events are characterised by high economic and cultural value events and productions, with high channel counts and significant investment in the production. Often, Category C events have logistical and planning challenges that require specialist knowledge and expertise to overcome.

Examples of Category C events include:

- Large music events;
- Studio/media complexes and large TV productions (talent shows operate daily with more than 150 devices). Short-term productions (like talent shows) are concurrent with day-to-day productions at studio complexes;
- Large sporting events;
- Congress centres;
- Large campus installations, such as universities;
- Events of national importance (coronations, elections, other political events e.g. G20 summit etc.).

Table 3: Summary of examples of uses in Category C

Event sub-category	Comments
Large Music Events (Concerts and Festivals)	Music festivals often attract huge crowds, so multiple main stages help distribute attendees and avoid overcrowding, and typically feature a wide variety of artists, from different genres and levels of popularity, requiring more big performance spaces. Performances can run simultaneously or in quick succession, keeping the audience engaged throughout the event. Outdoor festivals do not have shielding between stages and all wireless needs to be included. Some festivals have accompanying requirements from TV broadcast programmes providing news and artist interviews. Number of simultaneous PMSE links often exceeds 150.
Broadcast Centres (TV and Radio Studios)	Broadcast centres and media parks have a more controlled environment than live music and sports events. High-quality, real-time audio is critical for live TV, ensuring clear speech and production consistency. Broadcast centres and media parks benefit from dedicated infrastructure, stable frequency planning, and advanced technology. They are more project-based compared to stand alone live events, and controlled environments reduce interference risks. Growing market Expansion of 24/7 news, sport, digital streaming services, and hybrid remote production. Real-time live broadcasts are becoming increasingly important not only for linear broadcast but also for web-based programs. High-density use with day-to-day requirements alongside short-term productions.
Large Sports Events (Stadiums and Arenas)	Radio microphones, in-ear monitors and wireless intercoms are used for live commentary, sideline reporting, referees, and stadium entertainment. Fast movement, large distances, and stadium crowd noise require strong signal stability. Large sports events benefit from well-established frequency planning and dedicated spectrum allocations. Growth in spectrum use includes greater immersive experience for the spectator and viewer, e.g. microphones for officials, 'atmosphere' audio etc. Wireless congestion can occur when multiple broadcasters operate in the same area, especially at the finish of a sporting event and in the mixed interview zones. In some cases, there is need for redundancy to prevent signal loss leading to an increase in spectrum requirement.

Table 4 provides a summary of factors and considerations for each Category listed above.

Table 4: Summary of factors and considerations for each Category listed above

Factor	Category A	Category B	Category C
Example use cases			
Market	Stable growth with demand for high-quality content rising. More affordable analogue and digital proprietary equipment with improved audio quality and standardised technologies (e.g. DECT and 2.4 GHz equipment) in use.	Supports Economic Growth and Creative Industries. This supports thousands of jobs, from sound engineers to event organizers with contribution to film, TV, theatre, live performances, and public speaking engagements. Demand for high-quality content continues to rise creating a growing market for PMSE.	As for Category B. Demand for larger, more sophisticated events continues to rise to meet audience expectations. The resulting increase in spectrum density use might lead to challenges for PMSE and make large-scale events harder to manage.
Number of PMSE links	Up to 50	50 to 100	100 to 200+
Spectrum use	Less than 16 MHz in the 470-694 MHz band or may use alternative technologies in other bands, e.g. DECT or 2.4 GHz technology	32 MHz or more in the UHF band and/or using alternative spectrum for some applications e.g. talkback in DECT	Spectrum demand can exceed 150 MHz.
Why wireless	Ease of installation, often within existing buildings such as places of worship, lecture halls etc, where running cables is impracticable. General need for freedom of movement and deployment.	Wireless technology enhances mobility and allows performers, presenters, and production crews to operate without physical constraints. In general, there is a need for freedom of movement without cables. Wireless devices are crucial for high-quality audio productions (like broadcasting, theatre, concerts, live events and sports).	In general, it is the same as Category B with more devices used. In some instances, there may be multiple requirements for the production, e.g. at a music event there will be the requirements of the mainstage, incidental TV coverage such as talk shows and news items and red carpet or band interviews etc.
ERC Recommendation 25-10 tuning ranges used	A3, A5, A6, A9	A3, possibly A7 in future	A3, possibly A7 in future

Factor	Category A	Category B	Category C
Other spectrum bands used	1880-1900 MHz (DECT) 2.4 GHz	1880-1900 MHz (DECT) for communications/talkback	1880-1900 MHz (DECT) for communications/talkback
Authorisation regime	In most countries under general/licence exempt authorisations.	Equipment operates under both licensed and general/licence exempt authorisations depending on the country policy.	Equipment operates under both licensed and general/licence exempt authorisations depending on the country policy.
User Knowledge / Competence	Limited user knowledge with remote help from a "specialist" if needed. For business/organisation/campus related use such as lectures and conferences, installation and management may be under a general technical department such as ICT with limited RF knowledge. Technologies such as DECT and 2.4 GHz allow for ease of installation, use and scalability.	Due to the production-critical requirements of Category B events, there is increased demand for training and skilled personnel to operate and maintain systems.	There is specialist knowledge of the equipment. Increased demand for trained, skilled and experienced personnel to coordinate, operate and maintain the system.
Technology options	Proprietary equipment and standardised technologies (e.g. DECT and 2.4 GHz equipment) in use.	Principally proprietary equipment from main audio PMSE manufacturers and suppliers (e.g. hire companies) that operate in 470-694 MHz. Some use of DECT-based equipment for some applications, i.e. communications/talkback	Proprietary equipment from main audio PMSE manufacturers and suppliers (e.g. hire companies) that operates in 470-694 MHz. Some use of DECT-based equipment for some applications, i.e. communications/talkback

Factor	Category A	Category B	Category C
Technical risk tolerance	Tolerable audio quality requirements may not be met due to potential latency issues and interference in shared spectrum.	Low tolerance to errors or system failures. Multiple wireless devices (guitars, mics, in-ear monitors) create interference risks therefore event coordination is needed. Any failure directly impacts the audience experience. Up-time of equipment is 100%, and battery life and audio dropout can impact live performances. Proper precautions and technologies help mitigate risks and ensure that wireless audio PMSE is used effectively and reliably.	Low tolerance to errors or system failures. High equipment density (hundreds of devices) can create interference risks, equipment failures and signal congestion. Any failure directly impacts the audience experience. Up time is 100%
Technical support	Self-supporting, often with limited wireless/RF knowledge.	On-site support from people with wireless/RF coordination knowledge and technical expertise to properly set up, monitor, and maintain the equipment through the production.	Full on-site support. Highly skilled operators with proven and significant RF planning and wireless knowledge. RF planning and coordination is crucial to the effective and efficient delivery of the event.
Coordination requirements	Minimal at single-user venues. Campus type use may need local coordination by the user/technical support or via the equipment itself, e.g. DECT.	Coordination of all spectrum use is critical to prevent interference, audio degradation or failure.	Coordination of all spectrum use is critical to prevent interference, audio degradation or failure.
Venue / location considerations	Local, discrete (perhaps campus type) use. Low channels counts are often easily accommodated in any location.	Careful consideration of venue/location is needed for frequency planning, especially in places where there is multiple Category B use cases e.g. media parks and studio complexes.	Physical and logistical limitations of a venue can affect the ability to host a large event and may constrain the production. Lack of spectrum availability can compromise the production value and may, in extreme circumstances lead to PMSE not-spots i.e. an event will not visit a location as the production will not be able to be delivered to the audience as intended.

3 OPERATIONAL PERFORMANCE REQUIREMENTS ACROSS THE RANGE OF PMSE APPLICATIONS, USE CASES AND DEPLOYMENT OPTIONS

The choice of equipment, frequency band and technology for audio PMSE use is dependent on a number of considerations that apply, to a greater or lesser degree, to each use category.

Table 5: Summary of considerations when making audio PMSE choices

Consideration	Description
Technical	This relates to the tolerance for some form of technical disruption/interference which may vary between users in different categories.
Financial	Similar to technical risk but relates to potential financial loss (or penalties) in the event of a failure in the production.
Regulatory	Considerations regarding the regulatory situation may include: ▪ The timeframe of the availability of spectrum bands; ▪ Licensing – the timeframe of spectrum authorisations and related conditions.
Quality of service	This relates to the quality of the final audio. It is concerned with sample rates, bit depth, dynamic range, low latency and no/minimal compression.
Investment	Organisations have to balance investment decisions in equipment with their financial means.
Operation / control / technical competence	The installation and use of audio PMSE require different degrees of technical competence across the range of use cases. At one end, webcasting, wireless presentation, operators may just have the capability to switch on and switch off the equipment.
Spectrum use	As mentioned in section 2.1, spectrum requirements for events and productions depend on the size and scale of the event.
Flexibility of equipment	Flexibility of equipment relates to the requirement to satisfy different use cases and operational deployment.

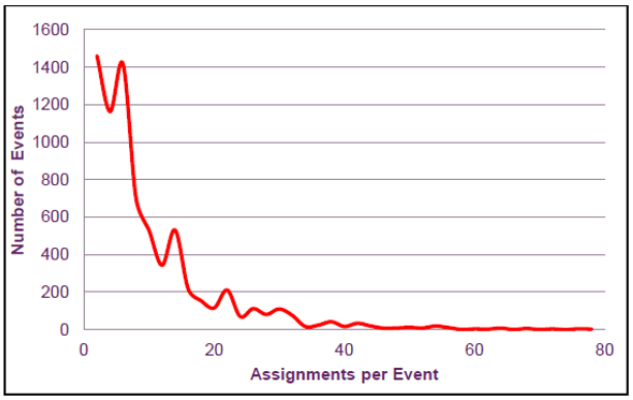
The considerations that govern equipment are interdependent and affect choice of equipment, technology and spectrum band. For some users, this will mean compromising on some requirements when determining their options. For example, a school may require a system that is easy to install and use, cheap and with long term regulatory certainty. This may mean that they choose equipment that operates in shared spectrum i.e. 863 - 864 MHz, 2.4 GHz or in 1880-1900 MHz, and therefore be more tolerant of technical risks and audio quality.

4 FREQUENCY REQUIREMENTS AND USE

Various studies and measurement campaigns have sought to determine the spectrum requirements for audio PMSE. However, the distribution of demand ranges from a single radio microphone to complex, multi-channel events with more than 150 frequency assignments.

The distribution of the number of frequency assignments across events is illustrated for two examples in Figure 1. There are many instances where only a small number of audio PMSE devices are used, and fewer instances where an event requires many assignments. It is important to highlight that these high-demand events provide the greatest economic, cultural and social value, and often reflect those events with the greatest national importance.

Source: Ofcom 2014



Source: UK SPF 2022

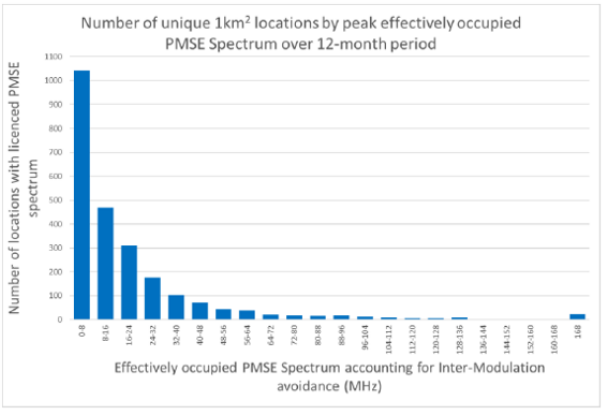


Figure 1: Examples of distribution of PMSE use across events

This distribution of audio PMSE use will be similar in every country, i.e. there will be many events with few assignments through to a smaller number of events with a very large number of assignments. The types of events that use large numbers of assignments broadly align with Category C events.

One study [7] has looked to determine the spectrum demand for different scales of events, mostly in Switzerland, which can be considered Category A (small), Category B (medium) and Category C (large).

It is highlighted that there is ongoing growing demand for spectrum for audio PMSE, and 50% of EU member states have observed a growth in demand. In addition, some member states have highlighted that meeting demand for PMSE post 700 MHz clearance is already difficult [8].

5 TECHNOLOGY OPTIONS THAT MEET THE DIFFERENT REQUIREMENTS

5.1 OVERVIEW

The technology options of wireless audio PMSE are diverse. Equipment may be analogue or digital, narrowband or broadband, use standardised technologies (e.g. RLAN, Bluetooth® or DECT) or be proprietary technology from audio PMSE manufacturers. Companies that specialise in the manufacture of audio PMSE equipment, typically have a range of products suitable for different user Categories and will look to standardised technologies where possible, for example implementing DECT (for conference/business/educational use cases) or RLAN (for social webcast/social media use). For those use cases where audio quality, flexibility and robustness are critical, users rely on high-end products based on proprietary audio PMSE manufacturer solutions.

The cost of equipment varies across product ranges of manufacturers, and some may target particular use cases, for example online content creators, etc, using standardised technologies. For many users in Category A, investment costs are a key consideration, and standardised technologies like RLAN and DECT allow for easy installation and use.

For users in Category B and Category C, standardised technologies operating in shared spectrum do not meet the audio quality or security of use requirements demanded by these users. Consequently, equipment is typically high-end operating in the TV broadcasting UHF band (typically 470-694 MHz).

5.2 TECHNOLOGY

In general, it is reasonable to say that, to date, audio PMSE technology is considered narrowband, operating with an RF bandwidth of 200 kHz, either using analogue or digital modulation schemes. However, more recently Wireless Multichannel Audio Systems (WMAS) have been introduced to the market which use a broadband RF channel to carry multiple PMSE links.

Digital microphones became more commonplace in the market after 2010 when issues around linearity (of components) and battery life were resolved. However, for IEMs, the critical requirement for low latency means that many IEMs use narrowband analogue technology.

Narrowband systems do not have an issue with range, but fast fading caused by multipath propagation on most applications (20 to 40 dB of fade is not uncommon) requires margin in link budget calculations. In addition, receive diversity is used to mitigate fading and reduce the probability of dropouts caused by fading.

RF channels such as entire TV channels of bandwidth offer broadband properties in most scenarios. Dropouts can be avoided by applying broadband transmission schemes such as OFDM. This eliminates the root cause for dropouts caused by fading. Although the propagation range of broadband channels is reduced due to higher thermal noise, it is more than compensated for in real environments due to a much lower demand for fading margin.

5.2.1 Narrowband

5.2.1.1 Analogue modulation

Analogue equipment using frequency modulation has been the mainstay of the audio PMSE ecosystem for many decades. The key benefit of analogue equipment is latency, which is often considered to be close to 0 ms. As noted in section 6.3, low latency is often considered to be a main requirement for performers, particularly for foldback monitoring[1].

[1] Foldback, also known as stage monitoring or simply “monitors,” refers to the practice of providing musicians with a way to hear themselves and their fellow bandmates on stage. This is essential for ensuring that performers can stay in time with each other, hear their pitch accurately, and maintain a cohesive sound throughout the performance

Audio from analogue devices is high-quality, but it is important to note that audio quality varies with the signal-to-noise ratio of the received RF channel. Given the inherent risk of fading (of a narrowband channel), particularly on a stage or set, it is necessary for the wanted signal to have a high fade margin, and antenna diversity to ensure a high level of SNR to ensure a high level of audio quality.

It is necessary to consider intermodulation products when coordinating and planning a multi-channel system; however, with advanced linear devices in high-end products, intermodulation is less of an issue.

5.2.1.2 Digital modulation

Equipment employing digital modulation schemes have several advantages over analogue equipment. Digital signals in audio PMSE have the benefit of maintaining a constant audio quality over a variable signal-to-noise ratio in the RF path. However, when the SNR drops below a threshold, the audio signal is lost - this is known as the 'cliff-edge effect' and is common in many digital transmission cases.

Some digital equipment has a very linear performance and built-in circulators meaning that spectrum planning and coordination at events does not need to consider intermodulation products caused by interactions between devices. In such cases, frequency channels can be equidistantly placed across the RF bandwidth, e.g. every 450 kHz increasing the efficiency of spectrum use.

In a digital system, the analogue audio needs to be converted to a digital input stream. Audio quality is determined by the sample rate and bit depth (the number of bits to represent the audio signal). If a 24-bit signal to encode the audio and a sample rate of 44.1 kHz is assumed, a bitrate of 1.1 Mbit/s is required. As bit depth and sample rate increase, the required bitrate scales accordingly and the captured audio quality improves. For example, 24-bit encoding at 96 kHz gives a bitrate of 2.3 Mbit/s.

There is a direct relationship between bitrate and RF bandwidth to carry the modulated signal - the higher the bitrate the greater the bandwidth needed for a given modulation scheme. For many digital systems, data compression is used to reduce the bitrate to fit within a 200 kHz RF channel. However, compression schemes typically remove data in the wanted signal (according to the coding algorithm), and carrying out compression takes time, increasing the signal latency. Both these artefacts (loss of quality and increased latency) are unwanted components in the audio signal. Consequently, as the requirement for audio quality increases, and includes 3D and immersive audio, bandwidth requirements will also increase.

5.2.2 Wireless Multichannel Audio Systems (WMAS)

Audio PMSE equipment manufacturers have continued to innovate and there is now broadband equipment in the market known as Wireless Multichannel Audio Systems (WMAS). WMAS provides multi-channel audio transmission capabilities by allocating one shared wideband RF channel for all audio channels. Audio channels can be for microphones, IEMs or a combination of both. WMAS can support different audio modes depending on the wireless application and the users' needs relating to audio quality and latency, robustness, range and number of simultaneously operated audio channels required.

As a wideband system, it is designed for scenarios where contiguous spectrum is available and multiple wireless audio channels are necessary. A single WMAS Base manages multiple WMAS Portables, such as hand-held microphones, body-worn microphones, in-ear monitors, or conference units, and provides all audio inputs and outputs for the supported wireless audio channels. This direct, real-time control of all devices connected to the base allows for improved workflow management.

The wideband approach of WMAS provides a link-budget advantage over narrowband systems. In a broadband RF channel, constructive and destructive interference happen simultaneously to the receive signal at different portions of the modulated spectrum - fading becomes frequency selective. This reduces the risk of dropouts dramatically. While new PMSE technologies like WMAS bring efficiency gains, both in terms of spectrum and workflow, they also unlock creative innovation and allow for more complex stage designs as productions grow in response to audience expectations.

5.2.3 Other wireless audio technologies

5.2.3.1 2.4 GHz microphones

Radio microphones that utilise 2.4 GHz, for example based on RLAN or Bluetooth® technology, provide a good inexpensive option for short-range, easily deployable use cases such as podcasting, karaoke, schools and churches and online content creation. Because audio equipment can easily synchronise with devices such as smart phones and tablets, these microphones may also be used in on-the-ground/pop-up news gathering for onward distribution.

The 2.4 GHz band is available throughout many countries across the globe for licence-exempt/general licenced use which makes it attractive for those users that have limited technical knowledge and low demands with respect to audio quality. Due to the extensive use of the 2.4 GHz band by many devices and applications, this band would not be considered for use by professional users, particularly those involved in live productions.

5.2.3.2 1880-1900 MHz (DECT)

DECT technology is widely used for cordless audio applications, including those used for PMSE. The 1880 - 1900 MHz band is available for DECT throughout many countries across the globe including the European Union, with other bands available for DECT in other countries.

Like 2.4 GHz technologies, DECT is easy to deploy and use which makes it an attractive option for cases where users may have limited technical knowledge and lower demands with respect to audio quality. Dynamic channel selection and auto-configuration simplify deployment and can support scalability where DECT microphones are commonly used, such as campus-based/on-site locations in universities, conference and business meeting facilities. However, it is highlighted that the band has a limit on the number of DECT devices it can accommodate and in many busy scenarios the channel requirement exceeds this capacity.

Locally there can be heavy use of DECT for cordless audio applications, for example internal phone networks and talkback, which can constrain use of the band for radio microphones. This is evident in studios where DECT is used indoors and outdoors for talkback and communication systems.

As the DECT band is a shared spectrum resource, it is unlikely to be used for high-quality live audio (i.e. users in Category B or Category C). However, in the professional production world DECT is extensively used for talkback and intercom systems as these have migrated from the TV UHF band as spectrum availability here has reduced.

5.2.3.3 IMT-2020 (5G) based technology

It is important to highlight that IMT-2020 (5G) is a technical specification [6] and not a technology. Any Radio Interface Technology (RIT) that meets the requirements set out in Recommendation ITU-R 2150 [3] is recognised as a 5G RIT. In the audio PMSE sector, testing and trials have been carried out on two 5G technologies, one based on 3GPP standardised technology and the other based on DECT-2020 NR standardised in ETSI.

Studies and trials over the last ten years of 5G based on 3GPP (including PMSE-xG, Live Interactive PMSE Services (LIPS) and 5G Records) have shown that radio resource and core network management are significant latency contributors, far exceeding what is tolerable for most audio PMSE use cases. Consequently, these trials indicated that there is no technical or economic feasibility for use of 3GPP based 5G for any audio PMSE use case.

Studies and trials of DECT-2020 NR for audio PMSE, e.g. the Franco-German research project MERCI (Media and Event production via Resilient Communication on IoT Infrastructure)[2], have shown the potential of this technology to meet some PMSE use cases. The technology has the first-generation chipsets on the market, and it has to be seen if the second-generation chipsets enable more use cases, increase audio channel

[2] MERCI – Franco-German Ecosystem for Private 5G Networks

numbers, reduce latency and increase reliability through the implementation of additional features and enabling access to more frequency bands.

5.3 LATENCY

Latency refers to the time taken between the generation of the audio signal to when it is perceived by the listener. For any type of live event, where the person generating the initial audio signal will also hear that signal, any latency over 10 ms is considered disruptive. The most critical case is live music where singers and musicians will have their (and band members') audio fed back to them, typically via a mixing desk and an in-ear monitor, where latency of less than 5 ms is the minimum requirement. When latency exceeds this period, performers find it difficult to stay on pitch and in time.

In analogue equipment, latency is often considered to be close to 0 ms, but for digital equipment, the encoding of the audio signal takes time and therefore introduces latency. For many performers, latency is more important than audio quality (particularly for IEMs where the performer's voice is fed back to them) and this is why some equipment has remained analogue for more than a decade after digital radio microphones became commonplace. Recent developments in technology, including the introduction of WMAS, now see the introduction of digital IEMs with latency figures below 2 ms.

5.4 AUDIO BANDWIDTH AND DYNAMIC RANGE

Audio bandwidth refers to the range of frequencies an audio system can capture and reproduce, typically from 20 Hz to 20 kHz, which encompasses the audible range for humans. It is crucial in audio content capture and production as a wider bandwidth allows reproduction of the nuances of different instruments and vocals, ensuring high-quality audio delivery, recording, archiving and onward distribution.

Dynamic range is the ability of the microphone to handle the acoustic input and is one of the core parameters for evaluating the performance of audio equipment. Dynamic range is the difference between the maximum sound pressure level (SPL) that a microphone can handle without distortion or clipping and its equivalent noise level and is measured in Decibels. Dynamic range impacts the audio quality and stability of the microphone in various scenarios such as recording studios, live performances, and public address. Different types of microphones, such as condenser microphones, dynamic microphones, and radio microphones, exhibit distinct characteristics in dynamic range performance due to differences in their structure, sensitivity, and circuit design.

All other parameters being equal, high audio bandwidth and large dynamic range increase the audio quality, and in both the analogue and digital domains increases the required radio channel bandwidth. In digital equipment, increased sampling rates (to handle the audio bandwidth) and bit depth (for dynamic range) lead to higher data rates and therefore increased spectrum requirements. In general terms, equipment with a high audio bandwidth and large dynamic range provide better audio quality and are towards the upper end of price and user categories, i.e. for users in Category B and Category C.

5.5 PHYSICAL CHARACTERISTICS

Wireless audio PMSE equipment is, by necessity, required to be small and light weight. For some applications, body-worn equipment can weigh as little as 100 grams (including the battery) and have a form-factor in the region of 60 x 50 x 20 mm. The size requirement limits the useful lower frequency of operation, as the increased antenna size is impracticable for most use cases.

Hand-held and body-worn PMSE equipment is battery powered and can be required to work for several hours, especially equipment which may be hidden under or within a costume and therefore cannot be easily accessed to replace the device or the batteries. To help maximise battery life, equipment is typically operated with low transmission power. Higher frequencies with greater propagation losses, including body loss, have less range than in the 470-694 MHz band. These losses could be overcome by using higher transmitting power but there is already a penalty in power consumption for all RF circuitry at a higher frequency, so there may be a limit set by the acceptable size and capacity for a battery.

5.6 BODY EFFECT

Both hand-held and body-worn audio PMSE equipment are affected by additional propagation losses caused by the proximity (to the antenna) of the human body. This effect is more pronounced for body-worn equipment as the antenna is very close to the body.

ECC Report 286 [5] provides details on the body effect of hand-held and body-worn PMSE equipment for both measured and modelled analysis. The Report demonstrates that the attenuation of the radiated signal increases with increase in frequency, i.e. higher frequencies experience greater body effect/loss than lower frequencies.

6 AVAILABILITY OF TUNING RANGES ACROSS CEPT AND THE REASONS THAT DIFFERENT TYPES OF EQUIPMENT ARE AVAILABLE FOR DIFFERENT TUNING RANGES

6.1 OVERVIEW OF ERC RECOMMENDATION 25-10

ERC Recommendation 25-10, annex 2 [1] lists the frequency ranges identified for audio PMSE within CEPT. ERC Recommendation 25-10, annex 4 andannex 5 provide national conditions for each of the tuning range mentioned in ERC Recommendation 25-10, annex 2. In addition to these identified tuning ranges, some CEPT countries make other bands available for audio PMSE which are not listed within ERC Recommendation 25-10.

ERC Recommendation 25-10 identifies 380 MHz for audio PMSE applications across eight tuning ranges. Table 6 and Figure 2 provide a summary of the bands listed in ERC Recommendation 25-10, annex 2. It should be noted that most of these tuning ranges identify spectrum shared with other applications.

Table 6: Summary of ERC Recommendation 25-10, annex 2

Tuning range	Bandwidth	Corresponding frequency bands in ERC Report 25 [6]
174-216 MHz (A2)	42 MHz	174-216 MHz
470-694 MHz (A3)	224 MHz	470-694 MHz
733-757.5 MHz (A4)	24.5 MHz	694-790 MHz
821.5-832 MHz (A5)	10.5 MHz	790-862 MHz
863-865 MHz (A6)	2 MHz	862-890 MHz
1350-1400 MHz (A7)	50 MHz	1350-1400 MHz
1518-1525 MHz (A8)	7 MHz	1518-1525 MHz
1785-1805 MHz (A9)	20 MHz	1710-1930 MHz

The identification of tuning ranges is not identical to the amount of spectrum actually made available for audio PMSE by national administrations. Local variations, including use by other incumbent applications and regulatory restrictions, may significantly reduce the amount of spectrum that can be accessed compared with the amount of spectrum identified by the tuning ranges. For example, Band A2 suggests 42 MHz is available for audio PMSE, but local restrictions mean that in some countries ~7 MHz is available, or may be limited to specific spot frequencies. When this is combined with the regulatory requirements to protect other applications that may have a higher status (and the effect of interference from those incumbents into PMSE) the amount of 'usable' spectrum is significantly constrained in those countries.

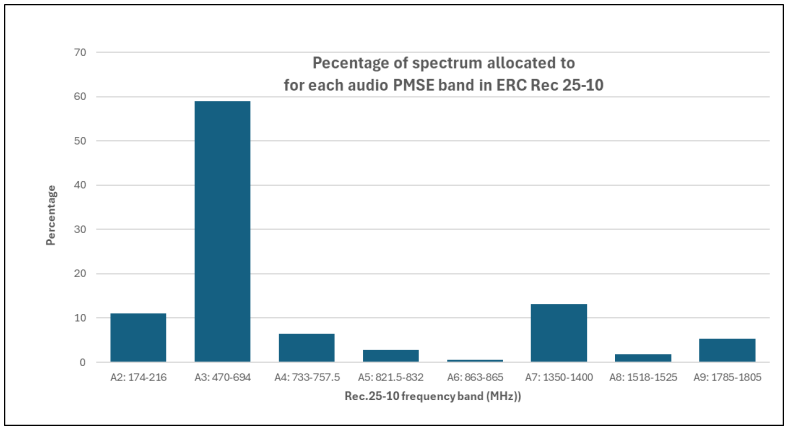


Figure 2: Ratio of spectrum available in each tuning range listed in ERC Recommendation 25-10

The application information provided in 6.1.1-6.1.8 is taken from the ERC Report 025, version of November 2025 [6].

6.1.1 Band 174-216 MHz – Tuning Range A2, B1 in ERC Recommendation 25-10

Tuning range A2 (and B1) is used only for niche applications in Category B and Category C (e.g. outside broadcast radio cars). Applications sharing the tuning range with Audio PMSE are Broadcasting (terrestrial) and Radio microphones and ALD.

6.1.2 Band 470-694 MHz – Tuning Range A3, B2 in ERC Recommendation 25-10

Tuning range A3 (and B2) is the core spectrum resource for audio PMSE and is heavily used by users in Category A, Category B and Category C. It identifies 224 MHz and accounts for ~60% of spectrum listed in ERC Recommendation 25-10. It is available in all CEPT countries with local restrictions to protect incumbent DTT broadcasting. Some countries exclude channel 38, 606-614 MHz, to protect Radio Astronomy. Even with these local restrictions there remains a significant amount of usable spectrum for audio PMSE. Applications sharing the tuning range with Audio PMSE are Broadcasting (terrestrial), Radio astronomy, Radio microphones and ALD and Wind profilers.

6.1.3 Band 733-757.5 MHz – Tuning Range A4 IN ERC Recommendation 25-10

ECC Decision (15)01 [9] includes PMSE as one of several alternatives for the duplex gap to be decided on a national basis.

Some countries have cleared PMSE from this frequency range as part of the reallocation of the 700 MHz band from Broadcasting and PMSE to MFCN. In addition, risk of adjacent channel interference from mobile may limit its utility in parts of the band for Category B and Category C. Applications sharing the tuning range with Audio PMSE are Broadcasting (terrestrial), MFCN and Radio microphones and ALD.

6.1.4 Band 821.5-832 MHz – Tuning Range A5 in ERC Recommendation 25-10

The band is harmonised within the EU by Commission Implementing Decision (EU) 2025/105 [4]. Some Category A use cases; risk of adjacent channel interference from mobile may limit its utility for as use cases for Category B and Category C. Applications sharing the tuning range with Audio PMSE are Broadcasting (terrestrial), MFCN, PPDR and Radio microphones and ALD.

6.1.5 Band 863-865 MHz – Tuning Range A6 in ERC Recommendation 25-10

Tuning range A6 identifies 2 MHz for PMSE. The band is widely available in CEPT due to the harmonisation for Short Range Devices alongside non-specific SRDs and wideband data. Suitable primarily for Category A use. The ERC Report 025 [6] covers the band 862-890 MHz and lists applications sharing that band to be Alarms, Audio PMSE, GSM, GSM-R, Land military systems, LPD-S, Maritime military systems, MCV, MFCN, Non-specific SRDs, Radio microphones and ALD, RFID, RMR, Social alarms, Telemetry/Telecommand (military), Tracking, tracing and data acquisition, and Wideband data transmission systems. The tuning range 863-865 MHz is designated in ERC Recommendation 70-03 [10] as for Non-specific SRDs, Radio microphones and ALD, and Wideband data transmission systems and these are the predominant applications permitted by CEPT administrations.

6.1.6 Band 1350-1400 MHz – Tuning Range A7 in ERC Recommendation 25-10

The tuning range identifies 50 MHz. Currently, 15 CEPT countries identify the band, or parts thereof, for PMSE sharing the band with different incumbent users, e.g. military/governmental, radar and fixed services. This currently results in non-uniform access conditions across administrations. Applications sharing the tuning range with Audio PMSE are Aeronautical military systems, Fixed, Land military systems, Maritime military systems, Radiolocation (military), Radio astronomy and Radio microphones and ALD.

6.1.7 Band 1518-1525 MHz – Tuning Range A8 in ERC Recommendation 25-10

The tuning range identifies 7 MHz. Currently 12 CEPT administrations as indicated in ERC Recommendation 25-10, annex 4, identify the band for PMSE within their national regulations. Applications sharing the tuning range with Audio PMSE are Fixed, IMT-2000 satellite component, Land military systems, Maritime military systems, MSS Earth stations, Radio microphones and ALD and Telemetry/Telecommand (military).

6.1.8 Band 1785-1805 MHz – Tuning Range A9 in ERC Recommendation 25-10

The band is harmonised within the EU by Commission Implementing Decision (EU) 2025/105 [4]. Category A use cases; risk of adjacent channel interference from mobile may limit its utility in parts of the band for as use cases for Category B and Category C. The ERC Report 025 [6] covers the band 1710-1930 MHz and lists applications sharing that band to be DECT, GSM, Land military systems, Land mobile, MCA, MCV, MFCN, Radio microphones and ALD, RMR and UAS.

6.2 NATIONAL ALLOCATIONS FOR AUDIO PMSE OUTSIDE ERC RECOMMENDATION 25-10 TUNING RANGES

In information obtained from EFIS, using the first level search term "PMSE" for frequencies from 160 to 2000 MHz, some CEPT countries make spectrum available for audio PMSE in bands outside the harmonised tuning ranges listed in ERC Recommendation 25-10. These are summarised in the following table:

Table 7: Summary of bands available for audio PMSE outside the harmonised tuning ranges in ERC Recommendation 25-10 [1] obtained from EFIS

Frequency band (MHz)	Country information
Below 174	▪ The band 162.0375-174 MHz is recorded by 6 countries (Albania, Bulgaria, Croatia, Denmark, Moldova and Portugal); ▪ Some narrow frequency bands are recorded by Czech Republic, Cyprus, Estonia, Germany, Hungary, Malta, North Macedonia and the United Kingdom, but there are no common bands.
216-470	▪ 216-223 MHz: 13 countries (Albania, Cyprus, Denmark, France, Greece, Italy, Liechtenstein, Moldova, Netherlands, Portugal, Slovakia, Spain and Switzerland) ▪ 216-230 MHz: 5 countries (Bulgaria, Czech Republic, Germany and Iceland) ▪ 216-240 MHz: 1 country (Sweden) ▪ Some narrow frequency bands are recorded by Austria, Iceland, Malta, Portugal and the United Kingdom, but there are no common bands
694-733	▪ 694-698 MHz: 1 country (France) ▪ 694-703 MHz: 1 country (Austria) ▪ 694-790 MHz: 18 countries (…)
757.5-821.5	▪ 694-790 MHz: 18 countries (…)
832-863	▪ 862-870 MHz: 18 countries (Bosnia and Herzegovina, Bulgaria, Cyprus, Denmark, Greece, Luxembourg, Moldova, Portugal, Romania, Slovakia, Türkiye, Montenegro, Croatia, Serbia, North Macedonia, Albania and Andorra)
865-1350	▪ 862-870 MHz: 18 countries (Bosnia and Herzegovina, Bulgaria, Cyprus, Denmark, Greece, Luxembourg, Moldova, Portugal, Romania, Slovakia, Türkiye, Montenegro, Croatia, Serbia, North Macedonia, Albania and Andorra) ▪ 960-1154 MHz: 1 country (the United Kingdom)

Frequency band (MHz)	Country information
	▪ 1215-1240 MHz: 1 country (Greece) ▪ 1260-1300 MHz: 1 country (Greece)
1452-1518	▪ 1452-1518 MHz: 1 country (Germany) ▪ 1492-1518 MHz: 5 countries (Belgium, Bulgaria, Cyprus, Moldova and Slovenia) ▪ 1517-1518 MHz: 2 countries (Austria and the United Kingdom)
1525-1785	▪ 1525-1530 MHz: 1 country (Slovenia) ▪ 1559-1610 MHz: 1 country (Greece) ▪ 1710-1930 MHz: 1 country (Portugal)
1805-1930	▪ 1710-1930 MHz: 1 country (Portugal)

6.3 MARKET ADOPTION AND USE OF BANDS IN ERC RECOMMENDATION 25-10

6.3.1 Manufacturer data

Several audio PMSE manufacturers have provided market data on equipment sales for 2024/25 in the tuning ranges listed in ERC Recommendation 25-10 [1] and other frequency bands. These data have been combined and anonymised in the interest of commercial confidentiality and provided in the following table. This summarises the proportion of items of equipment sold in each band.

Table 8: Proportion of sales in each tuning range

Tuning range	Combined manufacturer data on proportion of sales in each tuning range
174-216 MHz (A2)	0.25%
470-694 MHz (A3)	89%
733-757.5 MHz (A4)	0%
821.5-832 MHz (A5)	0.75%
863-865 MHz (A6)	0.5%
A5 and A6 (Note 1)	7.75%
1350-1400 MHz (A7)	0.25%
1518-1525 MHz (A8)	0%
1785-1805 MHz (A9)	0.5%
Other	1%
Note 1: Some manufacturers provide equipment that tune to both bands A5 and A6, so it is not possible to present the data for bands A5 and A6 individually	

Some manufacturers have recently released WMAS products that operate in the 1350-1400 MHz band, and at this early stage there are no meaningful market data available, but it is noted that Band A7 is beginning to see market engagement.

In addition to the bands listed in ERC Recommendation 25-10, some countries have made other spectrum bands available for audio PMSE that can support users in Category B and Category C. Manufacturer support

for these bands will often hinge on an assessment by each manufacturer of a market's potential to deliver a return when set against the costs of bringing equipment to market that can operate in those bands.

As mentioned above, the large Category A user market values ease of use, installation, regulatory conditions and with a lower price point that operates in the 800 MHz duplex gap (Band A5) and the SRD band (Band A6). In response to this market, manufacturers also provide significant volumes in bands A5 and A6 as shown in the table above, which also reflects the clear benefit of harmonisation.

It is highlighted that, particularly for Category A users, manufacturers also support and provide a range of products that operate in the 1.9 and 2.4 GHz bands, for microphones, and users in Category B and Category C for intercom and production communication systems.

6.3.2 Data from hire companies

Several large-scale audio equipment hire companies have provided information on their product inventories for audio-PMSE within the tuning ranges listed in ERC Recommendation 25-10 [1] and other bands where this is relevant. These data are summarised in Table 9.

Table 9: Proportion of inventory in each tuning range

Tuning range	Combined hire company data on proportion of inventory in each band
174-216 MHz (A2)	0.25%
470-694 MHz (A3)	83%
733-757.5 MHz (A4)	0%
821.5-832 MHz (A5)	0.25%
863-865 MHz (A6)	0.25%
1350-1400 MHz (A7)	0%
1518-1525 MHz (A8)	0%
1785-1805 MHz (A9)	0%
Other (Note 1)	17.25%
Note 1: This includes inventory in the 961-1154 MHz range and in 1880-1900 MHz (DECT-based equipment)	

6.3.3 Use of the bands by broadcasting

The European Broadcasting Union published its Technical Report on Broadcasters' Needs for Audio PMSE Applications (TR 075) in 2023. For the Technical Report, the EBU canvassed its members on their use of frequency bands for audio PMSE. A summary of this survey is provided below in the following table.

Table 10: Equipment availability and use of audio PMSE spectrum bands by EBU Members (Source: EBU TR 075 (table 1), May 2023)

Tuning range	Equipment availability	Reported use by EBU Members	Remarks
174-216 MHz (A2)	Yes	Very lightly used	Some limited use but limited spectrum availability internationally, outdated sharing criteria and planning issues
470-694 MHz (A3)	Yes	Heavily	Dominant band for professional audio PMSE

Tuning range		Equipment availability	Reported use by EBU Members	Remarks
			used	with good international spectrum and equipment availability. Capacity of the band may not be sufficient for all very large events. This is liable to be further aggravated as the demand for spectrum for wireless audio production continues to grow
733-757.5 MHz (A4)		Yes	Lightly used	Little and declining use for professional audio PMSE due to expanding IMT services in the range
821.5-832 MHz (A5)		Yes	Very lightly used	Little use for professional audio PMSE due to interference from adjacent IMT
863-865 MHz (A6)		Yes	Very lightly used	Little use for professional audio PMSE due to the band sharing with uncoordinated short-range devices
1350-1400 MHz (A7)		No	Not used	Little equipment and poor international spectrum availability, only indoor use
1518-1525 MHz (A8)		Yes	Not used	Little equipment and poor international spectrum availability, only indoor use
1785-1805 MHz (A9)		Yes	Not used	Small spectrum range with limited equipment availability and the risk of interference from services in adjacent bands
Other:	960-1154 MHz	Yes	the United Kingdom only	Available for audio PMSE only in the United Kingdom for a similar use as the 470–694 MHz band
	1880-1900 MHz (DECT)	Yes	Heavily used	Currently only suitable for production communications, not low latency professional audio PMSE
	2400-2483.5 MHz (RLAN)	Yes	Heavily used	Less demanding applications, low quality, no short latencies

The Technical Report highlights that for broadcasters the most important frequency range for audio PMSE is the band 470-694 MHz. It is available across Europe and beyond, its physical properties are suitable for PMSE applications, it provides substantial capacity, it has well established sharing conditions with DTT, and it is well supported by equipment manufacturers. As a result, this band is extensively used by EBU Members and other PMSE users with tens of thousands of professional equipment units in use in most countries.

Other frequency bands are less important for EBU Members due to various, technical, operational, or regulatory constraints, including limited capacity or availability, less suitable physical properties or lack of industry support and equipment. The lower frequencies, such as VHF suffer from high levels of electromagnetic noise coming from computers, screens, light walls, and other devices. Therefore, EBU Members consider these bands to be a complement to, but not a substitute for, the band 470-694 MHz.

6.3.4 Use of the band by live venues/theatres

Pearle* - Live Performance Europe is the "Performing Arts Employers Associations League Europe", the European Federation of Music and Live Performance Organisations. Pearle* represents through its members, theatres, concert venues, theatre production companies, orchestras, operas, ballet and dance companies, festivals, promoters and other professional organisations in the performing arts in Europe.

Pearle* polled its members on their use of the tuning ranges set out in ERC Recommendation 25-10. The results of this survey are presented in the following table.

Table 11: Assessment of use of frequency bands for audio PMSE in live venues by Pearle* (September 2025)

Tuning range		Mics and IEMs	Intercom
174-216 MHz (A2)		Not used	Not used
470-694 MHz (A3)		Very heavily used	Very lightly used
733-757.5 MHz (A4)		Very lightly used	Not used
821.5-832 MHz (A5)		Very lightly used	Very lightly used
863-865 MHz (A6)		Very lightly used	Not used
1350-1400 MHz (A7)		Not used	Not used
1518-1525 MHz (A8)		Not used	Not used
1785-1805 MHz (A9)		Not used	Very lightly used
Other:	410-470 MHz	Not used	Used
	1880-1900 MHz (DECT)	Not used	Used
	2400-2483.5 MHz (RLAN)	Not used	Used

6.4 SUMMARY

The 470-694 MHz band is the core spectrum resource for the audio PMSE industry. The band supports all categories of PMSE use, is widely available for PMSE across the World, and therefore provides significant market opportunities for manufacturers and the supply chain, including hire companies, sellers and distributors. Manufacturers provide a wide range of products at various price-points to cater for all use cases and is the band where the development of new products is typically focussed.

Given the ubiquitous use of the 470-694 MHz band, other components such as filters, combiners, power amplifiers, antennas, RF over fibre links are also specifically designed to support this frequency range. Consequently, particularly when considering Category B and Category C events with high channel counts, fixed installations and temporary deployments are typically in this band. Off-loading any spectrum demand to other bands creates significant engineering challenges, additional ancillary equipment and cabling, brings additional risks of technical issues and increases costs. An example of a high-profile Category C event that made extensive use of 470-694 MHz spectrum is given in Annex 1.

The Category A market is significant, with many different users, organisations and uses. Many businesses, hotels, conference rooms, schools and colleges, bars, places of worship etc, are all users of audio PMSE. Many of these operators do not have the resources, financial and/or technical skills, to manage complex setups, and their operational requirements in terms of audio performance are adequately covered by lower specification equipment operating in the SRD band (863-865 MHz) or the duplex gaps, or with equipment that operates in the 1.9 or 2.4 GHz bands.

Although this market is heavily fragmented, in terms of the types and number of users, it is sizeable enough and with harmonised spectrum, to be viable for audio PMSE manufacturers.

7 REGULATORY CONSIDERATIONS

Audio PMSE use continues to grow, both in terms of the scale and sophistication of events and productions and audio quality developments relating to dynamic range, frequency response and latency. This drives the increase in audio channel requirements and the subsequent increase in spectrum use, to the degree that some large-scale/high demand use cases are already spectrally constrained, i.e. the number of audio channels envisioned for the production cannot be supported by available spectrum that is supported by the available equipment in the location. Given the wide adoption of the 470-694 MHz band, both from a regulatory and market adoption perspective, these events typically use this band.

Off-loading, or utilising, other bands to support an event is possible but mixed setups bring engineering challenges that increase complexity, bring additional risks (in terms of audio dropouts) and increase costs through duplication of ancillary equipment and installation configurations. In addition, tuning ranges (other than A3) are not so well supported by the market and therefore equipment availability is limited.

Some tuning ranges, for example A5 and A6 (and 1.9 and 2.4 GHz), support a particular type of use i.e. Category A. The Category A market is large, primarily due to the sheer volume of users rather than the scale of demand for a single user and are typically more price-sensitive and quality tolerant than users in Category B and Category C. Consequently, these bands see significant market support but generally do not have the capacity to satisfy the demands of use in Category B or Category C.

Excluding A3 and A7, the tuning ranges identified provide limited capacity and are isolated from each other so that they do not provide an economically viable combined tuning range, i.e. it is not feasible to produce high-quality audio PMSE equipment (and ancillary equipment such as antennas, combiners, filters etc) that span A4 to A9, nor is it practicable for an event to utilise these bands as a single spectrum resource - the difference in propagation characteristics (such as range, fading and body loss) between bands are such as to make engineering an event using different bands unviable.

7.1 REQUIREMENTS

In order to address the viability and utility of a spectrum band for audio PMSE there are certain requirements to promote or encourage market interest. All requirements need to be met.

7.1.1 Widespread/harmonised availability

Ideally, any spectrum band for any radio application should be available on a global basis or at a regional basis to promote economies of scale in equipment production and market adoption and audio PMSE is not different in this regard. At a minimum, several countries with strong PMSE markets need to make a band available to encourage industry support.

Where PMSE shares with other services and applications, these incumbent uses should be the same as far as possible across countries to ideally allow the same sharing conditions to be adopted. Where existing use cases are different between countries this might constrain the potential for PMSE use in those countries where the existing use is incompatible with audio PMSE.

7.1.2 Regulatory certainty

Availability and access to a particular band needs to be assured for an extended period of time (ideally 10 years or more) to allow the audio PMSE industry to make meaningful returns of investment. Manufacturers need to design, develop and test new products and modify factories and tooling to build new products. Distributors, hire companies and users then invest in these new products and expect these to last for many years of use.

7.1.3 Substantial block of contiguous spectrum

It can be seen that a fragmented supply of relatively small islands of spectrum do not support key as use cases for Category B and Category C. Equipment owners and hirers would need to hold multiple items to access small, discrete parcels of spectrum which is economically challenging.

Additionally, it is necessary that within any block of contiguous spectrum a significant amount of the band should be locally usable, i.e. if only a small amount of spectrum is usable within a large band identified then this reduces the viability of the band.

7.1.4 Regulatory conditions

The regulatory conditions should be as flexible as possible to support the maximum number of audio PMSE use cases. For example, regulations that limit use to indoor only prohibits use of equipment at outdoor festivals and other large outdoor events and productions. Such a restriction reduces the attractiveness of a band, particularly for outdoor as use cases for Category B and Category C, and therefore reduces market interest.

7.1.5 Sharing conditions

Historically, audio PMSE shares spectrum alongside an incumbent user where this is possible. For many decades this has primarily been in the UHF TV broadcasting band sharing with analogue, and now digital, TV broadcasts. Given that there are no 'empty' frequency bands the assumption is that for a meaningful block of contiguous spectrum to be identified this would likely involve audio PMSE sharing with another application or service.

8 CONCLUSIONS

This Report provides detail on the Use Cases, Audio Characteristics and Technology Options for Audio PMSE and an analysis of the reasons that different tuning ranges have different availability in different countries and different types of equipment.

The 470–694 MHz band is currently the core band for professional audio PMSE in Europe: it enables a broad range of use cases, is internationally supported, allows for high-quality, high-density operations, and underpins the professional PMSE market found in in use in Category B and Category C.

The bands (e.g. 863–865 MHz, 1880-1900 MHz and 2.4 GHz) are an important and valuable resource for simple, cost-sensitive, or licence-exempt/general license use. However, these bands cannot support the technical and operational requirements of demanding, large, or professional events and thus serve mainly users in Category A. In general, there is no spectrum access issue for these users as the channel count is low, although it is noted that in the 1880-1900 MHz band congestions can, and does, occur in some scenarios.

When considering the potential for increased use of other tuning ranges listed in ERC Recommendation 25-10, specifically A2, A4 and A8, these ranges may not satisfy all the requirements set out in section 7.1.1 and therefore the market responds accordingly. In relation to band A9 it is not considered by users in Category B and Category C. Users in Category A have established supply chains in bands A3, A5 and A6.

Tuning range A7 is starting to see some use for audio PMSE for Category B and Category C. Currently, 15 countries identify the tuning range, or parts thereof, as available for PMSE. Where it is available some conditions apply, e.g. indoor use only. Ideally, wider adoption across CEPT and more flexible conditions would increase the attractiveness of this band.

The industry's growing demand for spectrum reflects complex productions, increased audio channel needs, and higher audio quality standards. While innovative technologies like WMAS offer efficiency gains, access to sufficient amounts of, ideally harmonised, spectrum remains essential.

Sustainable PMSE growth depends on:

- Stable, harmonised, and long-term spectrum access;
- Substantial contiguous blocks of usable spectrum;
- Flexible and predictable regulatory frameworks;
- Ongoing industry and regulator cooperation to manage interference and operational challenges.

Fragmented, non-harmonised spectrum allocations and restrictive regulatory conditions elevate costs, complexity, and technical risk, undermining large-scale and cross-border events.

Strategic spectrum planning should focus on safeguarding the sufficient spectrum access for PMSE, while meeting the above requirements, encouraging market and equipment harmonisation, and supporting regulatory conditions that enable growth and innovation in this sector.

ANNEX 1: CASE STUDY: EUROVISION SONG CONTEST 2023 (LIVERPOOL, THE UNITED KINGDOM)

A1.1 ABOUT THE EVENT

The Eurovision Song Contest (ESC)[3] is an annual TV event which is broadcast worldwide and usually hosted by a different country each year. In 2023, the ESC was hosted by the BBC in the United Kingdom.

To most viewers, the Eurovision Song Contest appears to be just one TV show on one evening a year. However, the modern-day production consists of nine shows, several of which are broadcast live across the globe. There are semi-finals and multiple full-length rehearsals each of which takes place in front of a full live audience. The whole RF requirement of the event must be fully available for approximately two weeks. The build-up to the event on-site, during which everything is assembled and tested, takes approximately four weeks prior to the fortnight of live shows. The wireless systems cannot be fully tested without access to all the relevant spectrum so the RF requirements stretch back over several weeks prior to the event, far earlier than many might expect.

A1.2 ABOUT THE VENUE

The 2023 ESC venue was the M&S Bank Arena in Liverpool. The floor of the Liverpool arena is significantly below ground level and the parts of the building which are above ground level are constructed in such a way that they provide a high level of RF shielding. This is helpful from a frequency planning perspective as it provides substantial shielding from any UHF radio signals – whether TV broadcast, mobile phone service, or other PMSE users. The availability of UHF radio frequencies for PMSE use inside the venue is therefore considerably better than it would be for other venues without this level of shielding. Since the shielding of the Arena is so effective against DTT the whole TV UHF band was available for PMSE.

The Arena is attached to, and integral with, a substantial multipurpose exhibition and conference venue, the ACC Liverpool. The ACC has a large quantity of UHF radio microphones for its day-to-day commercial activities, and these needed to remain operational for “business as usual” during the entire ESC event. For the most part, the ACC does not benefit from the “below ground” shielding that is afforded to the Arena, therefore the ACC's practical UHF frequency choices are more constrained by terrestrial television than is the case inside the Arena.

A1.3 RF REQUIREMENTS

On the face of it, the RF requirements of the ESC appear modest. Each national entry is limited to six or fewer performers, referred to as a “delegation”. Consequently, at any one time during any of the shows, there are a maximum of six “live” radio microphones being used by the delegation. However, this is a massive over-simplification because:

- Each performer can choose between hand-held or body-worn microphones. This means 12 microphones need to be available for each delegation – six hand-held and six body-worn microphones;
- The turnaround time between the performances is approximately forty seconds. This means that there are three operational sets of hand-held and body-worn microphones required:
  - Set 1 – Delegation which has just finished (1st, 4th, 7th, etc. to perform);
  - Set 2 – Delegation on-stage (2nd, 5th, 8th, etc. to perform);
  - Set 3 – Delegation preparing to go on-stage (3rd, 6th, 9th, etc. to perform).
- The body-worn and hand-held microphones each need separate, mutually compatible, frequencies. This means there are 36 separate frequencies required just for the performers with 12 frequencies needed in each set (six frequencies for hand-held and six for body-worn microphones), not including operational spares;

[3] Eurovision is the name of a network operated by the European Broadcasting Union (EBU). https://eurovision.tv/history/origins-of-eurovision

- The type of hand-held microphone chosen for the ESC 2023 provides redundancy in the RF channel by employing two separate frequencies. This doubles the number of frequencies required for hand-held microphones from 18 to 36 (6 microphones × 3 sets × 2 frequencies), bringing the total to 54 frequencies for delegates' microphones;
- All performers use personal in-ear monitors (IEMs) which are rotated between the delegations along with microphones. Therefore, each set includes six IEM frequencies giving a total of 18 frequencies;
- Due to time constraints, there must be operational spares for the radio microphones and IEMs. These spares are allocated frequencies so that they can be exchanged with minimal disruption if they are suddenly required;
- The show's presenters, of which there were four in 2023, each had:
  - A hand-held radio microphone (these are the same microphones as used by the delegates so employ two frequencies);
  - A head-worn radio microphone;
  - An IEM system.
- The frequency allocation for the presenters' equipment is 16 frequencies, not including the fully working presenter spares. For operational reasons, it is not possible for the presenter spares and performer spares to be shared;
- "Interval Acts". In addition to the contest delegates' live performances, there are a number of other live music performances from high-profile acts that take place during the live broadcast. The radio spectrum requirements of whichever artist is performing at each show must be fulfilled without disrupting the RF requirements of the contest. The scale of the guest artists' radio requirements varies widely and may equal or exceed the needs of the contest itself;
- The "sound check room". This is a facility integral to the running of the contest. All contest delegations pass through this room multiple times during the two weeks of rehearsals and performances. A further set of twelve radio microphones and six IEM frequencies are required;
- The BBC's live evening TV show occupied a temporary studio in the ACC adjacent to the Arena during the final few days leading up to the Grand Final. During the Grand Final, there was some live crossover with a presenter from the "ONE Show" visiting the Arena live on air complete with radio microphone and IEM. Therefore, the RF requirements of their nightly live TV broadcast also had to be included and coordinated with the frequency plan for the ESC in the main Arena;
- In addition to all of the above, there are a handful of other radio microphone and IEM channels in use, including for example:
  - Roving audience "fish pole" microphones;
  - Floor manager;
  - Guest hand-held microphones.
- As well as the actual performance stage it is necessary to ensure that all of the competing delegations' radio microphones and IEMs operate smoothly in various "backstage" areas as well. Whilst this does not materially affect the spectrum requirements of the event it does further complicate the required infrastructure required for radio microphone reception and IEM transmission to achieve the required coverage.

Combining the requirements summarised above, the total number of frequencies needed for the duration of the ESC was 191 channels. This is broken down as follows:

- For the ESC and supporting activities:
  - 128 radio microphone channels;
  - 37 IEM channels.
- For the "One Show" temporary studio:
  - 10 radio microphone channels;
  - 4 IEM channels.
- For the neighbouring ACC Liverpool:
  - 12 radio microphone channels (the ACC Liverpool | Waterfront Conference and Event Venue agreed to release 64 channels of its assigned 76 channels for use by the ESC).

A1.4 FREQUENCY PLANNING

The DTTB information provided by the Ofcom UHF PMSE planning portal only shows two TV channels, 46 and 49, as having full quality (i.e. quality 4) indoors. The portal shows all other DTTB channels as impacted by DTT interference. Fortunately, as mentioned above, the actual real-world situation inside the Liverpool Arena is far better than the planning portal suggests. If this was not the case the ESC could not have taken place in its 2023 format due to the restriction on spectrum availability.

Due to the shared use of Channel 38 (606-614 MHz), it is not possible to coordinate or control its use. Consequently, as is common practice at major events, Channel 38 was left unused by the production and made available to visiting “field production” teams. This was communicated to any visiting productions. As a precautionary measure, TV channels 37 and 39 were also left empty to mitigate the risk of intermodulation interference from any use of Channel 38. Again, this is common practice.

The ESC also did not make any use of the other the United Kingdom Shared Licence audio PMSE bands, namely VHF, 823-832 MHz (the 800 MHz duplex gap), 1785-1805 MHz (1800 MHz duplex gap), nor did it use the 960-1154 MHz band. Visitors were informed that requests for coordination of frequencies in the ranges 470-606 MHz and 614-703 MHz would be declined and were advised to operate in any of these unused bands.

Some ESC activities were supported in bands outside the 470-694 MHz range to reduce the demand on the UHF band. For example, a single transmitter in the 60 MHz band provided a lower-grade IEM service for the large number of participants involved in a flag parade. Also, event communications made extensive use of DECT technology.

Frequencies for IEMs and mics used in the “Sound Check Room” were carefully interleaved with frequencies used on the main show. This was only possible because:

- The construction and the location of the sound check room relative to the Arena floor allowed sufficient signal attenuation;
- The movement of wireless equipment used in the sound check room could be tightly controlled to ensure that, e.g. the microphone transmitters did not leave the room at any point;
- IEM transmitters by their nature do not normally move around when in use;
- The use of directional antennas further reduces the risk of signal leakage.

This approach reduced the number of TV channels required overall. Had this not been possible then at least two, possibly three further TV channels would have been needed to accommodate the needs of the event.

The following table provides a summary of the spectrum plan in the 470-694 MHz band employed at the ESC.

Table 12: PMSE allocation at ESC 2023

ESC radio use by TV channel				Frequency (MHz)	
TV Channel	DTT	Use	Notes	Lower	Upper
21		ACC		470	478
22	DTT	ACC		478	486
23	DTT	ACC		486	494
24		ACC		494	502
25	DTT	N/A (DTT)	Detectable DTT levels	502	510
26	DTT	Arena HH Mics	FOH reference mics	510	518
27		Arena HH Mics	Wisycom – One Show ENG	518	526
28	DTT	N/A (DTT)	Detectable DTT levels	526	534

ESC radio use by TV channel				Frequency (MHz)	
29		Arena HH Mics	Wisycom – One Show ENG	534	542
30	DTT	Arena HH Mics		542	550
31		Arena HH Mics		550	558
32		Arena HH Mics	Soundcheck room HS (x1)	558	566
33	DTT	Arena IEMs		566	574
34		Arena IEMs	Soundcheck room IEM (x4)	574	582
35		Arena IEMs	Soundcheck room IEM (x2)	582	590
36	DTT	Arena IEMs	Soundcheck room IEM (x4)	590	598
37		Guard band	Visitor – “eOne” - Mics	598	606
38		UHF Shared licence	Visitor – “eOne” - Mics	606	614
39	DTT	Guard band		614	622
40		One Show ACC IEMs		622	630
41		Arena IEMs	Soundcheck room HH	630	638
42	DTT	Arena IEMs	Soundcheck room HH	638	646
43	DTT	Arena IEMs	ACCL UHF R - unused	646	654
44		Arena IEMs	ACCL UHF R - unused	654	662
45	DTT	Arena IEMs	Soundcheck room HH	662	670
46		Not used	Guard band between mics and IEMs	670	678
47		Arena Body Pack Tx	Soundcheck room HH	678	686
48	DTT	Arena Body Pack Tx		686	694
49		Arena Body Pack Tx		694	702
50		Guard band to IMT		702	710

ANNEX 2: LIST OF REFERENCES

[1] ERC Recommendation 25-10: “Frequency Ranges for the Use of Terrestrial Audio and Video Programme Making and Special Events (PMSE) applications”, approved 1995 and latest amended June 2023, national implementation latest amended October 2023

[2] ECC Report 323: “Spectrum use and future spectrum requirements for PMSE”, approved February 2021

[3] Recommendation ITU-R M.2150: Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)

[4] Decision (EU) 2025/105: “Commission Implementing Decision (EU) 2025/105 of 22 January 2025 amending Decision 2006/771/EC updating harmonised technical conditions in the area of radio spectrum use for short-range devices and repealing Implementing Decision 2014/641/EU on harmonised technical conditions of radio spectrum use by wireless audio programme making and special events equipment in the Union”

[5] ECC Report 286: “Body effect of hand-held and body-worn audio PMSE equipment”, approved September 2018

[6] ERC Report 025: The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz, approved 1994, latest editorial update November 2025

[7] Schweizer Radio und Fernsehen: "Report on spectrum requirements for Audio PMSE", available: here

[8] European Commission: "Study on the use of the sub-700 MHz UHF band for TV broadcasting and events", available: here

[9] ECC Decision (15)01: “Harmonised technical conditions for mobile/fixed communications networks (MFCN) in the band 694-790 MHz including a paired frequency arrangement (Frequency Division Duplex 2x30 MHz) and an optional unpaired frequency arrangement (Supplemental Downlink)”, approved March 2015

[10] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)", approved October 1997, corrected 4 December 2025