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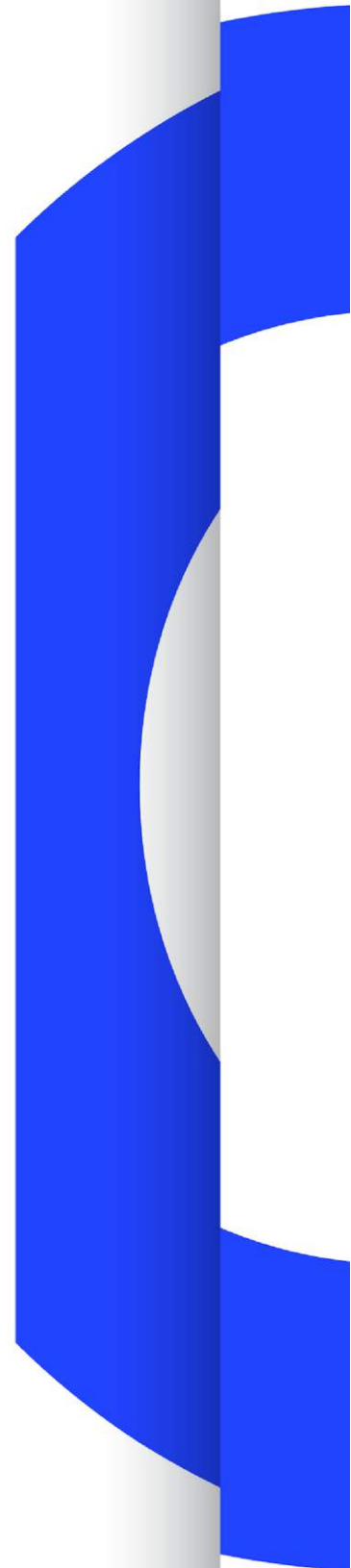
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BROADCASTERS' SPECTRUM NEEDS FOR AUDIO PMSE APPLICATIONS

Technical Report

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Executive summary

Public and commercial broadcasters use PMSE¹ applications to create content and provide comprehensive and balanced information, education, culture, and entertainment to all viewers and listeners across entire population.

Content production is at the start of the media value chain and underpins not only broadcasting but also online platforms. Therefore, the importance of PMSE extends far beyond broadcasting sector to include online media, wider creative and content production sectors, political, sports, and cultural live events, trade shows, conferences, educational, religious and community events. These activities generate a substantial public value and represent a significant part of the economy.

The most important frequency range for audio PMSE is the band 470-694 MHz. It is available for across Europe and beyond, its physical properties are suitable for PMSE applications, it provides substantial capacity, it has well established sharing conditions with regard to 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 available for audio PMSE applications are less important due to various, technical, operational, or regulatory constraints, including limited capacity or availability, less suitable physical properties or lack of industry support and equipment.

As the demand for PMSE use at large events is increasing and at the same time the amount of spectrum has been significantly reduced after the release of the 700 MHz and 800 MHz bands, frequency planning at events gets increasingly complex. PMSE users have taken various measures to cope with these conditions. However, despite these measures the frequency demand at some events is higher than availability, which may have detrimental impact on performers, producers, event organisers, and broadcasters. In some cases, it may not be possible to stage large events as originally intended.

For all the reasons above the PMSE sector has no alternatives but to continue to rely on access to the frequency band 470-694 MHz. Therefore, no regulatory change shall be introduced in this band.

¹ Programme Making and Special Events.

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Broadcasters' spectrum needs for audio PMSE applications

1. What is PMSE and why it needs spectrum

The trend in industry working practices at the largest events has been towards providing a microphone and radio in-ear monitor to each performer. Over the last decade the largest PMSE events have grown year-on-year. This is coupled with considerable growth in the number of live music events overall due to changes in the music industry. As a result, musicians now derive most of their income from live performances, rather than from recorded content.

The nature of high-profile live productions however demands the highest Quality of Service and reliable access to sufficient suitable spectrum without interruption or interference.

Performers and those producing news or live event coverage all rely on PMSE spectrum for radio microphones and in-ear-monitors, production communications and other links at the site. Historically, without spectrum co-ordination at large events, interference issues badly affected performances and the organisers welcomed the contribution of the regulator to better co-ordinate spectrum use, particularly for radio microphones and in-ear-monitors on the main stages.

2. Cultural, social and economic impact of PMSE

Public and private broadcasting create the public space for broad and reliable information for the population and social cohesion, especially in times of crisis. In times of fragmented information landscapes, increasing disinformation and hate speech, quality media make an indispensable contribution to political discourse by producing, verifying and distributing reliable information. They are a central factor in the democratic decision-making process.

Public value plays an important role in broadcasting across all genres, in informative as well as entertaining formats, in "classic" news and political information, in special information and entertainment offerings and broadcast coverage of high-profile special events. In this way, high quality content is available to all segments of the population. The basic mission of public broadcasting is to provide comprehensive and balanced information, education, culture and entertainment to all viewers and listeners. There is huge public value in broadcast coverage of different events, from small community-based events through to the large national and international occasions.

In addition to the social and cultural role of public broadcasting, there is also an economic aspect: in 2020, European public services broadcasters invested approximately 18 billion Euros in content production in Europe, 86% of which was allocated to original content. [5] This is augmented by the investments made by commercial broadcasters and other media producers.

It should also be noted that production of media content underpins not only broadcasting but also online platforms. Therefore, the importance of PMSE extends far beyond broadcasting sector to include online media, trade shows, live cultural, sport, political, and community events.

3. Equipment and spectrum for audio PMSE

Table 1: Equipment availability and use of audio PMSE spectrum bands by EBU Members

Allocated for PMSE Audio	Equipment Availability	Reported use by EBU Members	Remarks
29.7 - 47.0 MHz	NO	Not used	High levels of man-made noise and no equipment availability for professional audio PMSE. Limited international spectrum availability
174 - 216 MHz	YES	Very lightly used	Some limited use but limited spectrum availability internationally, outdated sharing criteria and planning issues
470 - 694 MHz	YES	Heavily used	Dominant band for professional audio PMSE 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.
694 - 790 MHz	YES	Lightly used	Little and declining use for professional audio PMSE due to expanding IMT services in the range
823 - 832 MHz	YES	Very lightly used	Little use for professional audio PMSE due to interference from adjacent IMT
863 - 865 MHz	YES	Very lightly used	Little use for professional audio PMSE due to the band sharing with uncoordinated short-range devices
960 - 1164 MHz	YES	Only UK	Available for audio PMSE only in UK for a similar use as the 470-694 MHz band
1350 - 1400 MHz	NO	Not used	Little equipment and poor international spectrum availability, only indoor use
1518 - 1525 MHz	YES	Not used	Little equipment and poor international spectrum availability
1785 - 1805 MHz	YES	Not used	Small spectrum range with limited equipment availability and the risk of interference from services in adjacent bands
1880 - 1900 MHz (DECT Standard)	YES	Heavily used	Currently only suitable for production communications, not low latency professional audio PMSE
2400 - 2483.5 MHz (WIFI)	YES	Heavily used	Less demanding applications, low quality, no short latencies

Some of the spectrum bands in Table 1 are listed in the CEPT ERC Recommendation 25-10 [1] as the tuning ranges for audio PMSE. That Recommendation defines the term “tuning range” as *‘a range of frequencies over which radio equipment is envisaged to be capable of operating; within this tuning range the use in any one country of radio equipment will be limited to the range of frequencies identified nationally (if any) within that country for PMSE and will be operated in accordance with the related national regulatory conditions and requirements. Within each tuning range, CEPT countries may assign specific sub-bands or particular frequencies for PMSE links subject to availability, actual demand and sharing arrangements with primary services using those bands.*

Ideally, PMSE equipment should be capable of being operated within the whole tuning range and even beyond in order to provide flexibility for operation in different countries.'

These frequency ranges are predominantly shared between PMSE and other services. Not all frequency ranges are available in all countries. For each tuning range, the ERC Recommendation 25-10 provides detailed information about the availability and national conditions for PMSE use in individual European countries.

When a potential new frequency band is considered for PMSE use specific properties of the band must be taken into account. Different frequency bands have different characteristics, such as distances that can be covered by radio links, the capacity that could be achieved the band, the body absorption properties, line-of-sight requirements, support for mobility. Not all frequency bands are suitable for all PMSE applications.

In case of body-worn PMSE equipment, the electromagnetic properties of the human body interact with the equipment design, leading to antenna directivity. In some use cases that involve movement of the person wearing the microphone (e.g., an artist on stage or in the studio) the resulting directivity may lead to strong signal fading and dropouts of radio link. This effect is not significant at lower frequencies such as the UHF band, but it becomes more pronounced at higher frequencies where the physical size of the body significantly exceeds the wavelength of the radio signal.

Furthermore, some PMSE use cases require form factors of the PMSE equipment that can be concealed from view (e.g., within the artist's costume), which significantly constrain the design options including power consumption, battery size or possible diversity solutions.

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 regard to 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 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, these bands are a complement but not a substitute for the band 470-694 MHz.

4. Spectrum use and needs for PMSE

Wireless production tools are the basis of any broadcast production: in film productions or entertainment productions, in sporting events such as the World Cup or the European Football Championship, in any reportage formats, in breaking news, but also in narrative formats, documentaries, entertainment and music productions.

Viewers and listeners value, and have also become accustomed to, the high production values that modern wireless production tools provide, and which are currently available to content producers. The demand for wireless production tools has been increasing for years. [8]

4.1 Events and their stakeholders

PMSE spectrum users range from individuals to large broadcasters and the quantity of spectrum required for each production will vary. A news broadcaster may only require a handful of radio microphone frequencies to relay a crucial news event, but it remains critical to avoid interruption or interference to that modest amount of spectrum.

Alternatively, a high profile, high budget live entertainment production may use a significant quantity of spectrum but an interruption to any single frequency could also seriously impact the coverage and enjoyment of the event by the audience and the risk of reputational damage to broadcaster.

Significant financial investment may have been made by broadcasters to secure the rights to distribute high profile content with the requirement of a guaranteed quality of output. The broadcaster is therefore the major stakeholder in ensuring a sufficient quantity of spectrum without interruption on behalf of the audience who will be paying directly or indirectly towards the broadcaster's costs.

A common model of sourcing live content is to use independent production companies, their expertise and facilities, rather than for broadcasters to retain their own extensive in-house resources beyond those for news gathering. The risk then falls upon these suppliers to guarantee the quality of output. They may need to employ more expensive and elaborate spectrum solutions to ensure the required production quality to the broadcasters.

The number of platforms and services offering content to viewers and subscribers has been increasing in recent times and there appears no reduction in the rate of expansion.

Traditional broadcasters as well as streaming services have been investing substantially in content production and the competition between suppliers has led to bigger productions and new production centres, all relying upon access to PMSE spectrum of suitable quality and has been and will continue to be, a competition increase.

Regardless of how modern content is consumed now or in the future, the vast majority of that content is originated in the first instance utilising wireless UHF PMSE equipment. This is highly dependent on access to adequate clean UHF spectrum from the very beginning of the production process for live and recorded broadcasts/events.

If the capture of such material is compromised by lack of spectrum or interference, then playback and any future consumption of the material will always include the compromised quality no matter what platform is used to consume it.

In an assessment of spectrum demand for PMSE the UK Ofcom report [8] estimated the maximum spectrum demand for audio PMSE in 2024. Recent experience has shown these figures to remain broadly correct.

Table 2: Maximum Spectrum Demand for Audio PMSE for Representative Production Scenarios [8]

Scenario	Peak Number of Devices Used	Total Spectrum Required (MHz)	Equivalent Number of 8 MHz DTT Channels Required
Filmmaking: (A major film and/or TV Production Centre)	200	82	11
Large Theatre Production	94	39	5
Outdoor Music Event	260	106	14
TV News Gathering	45	18	3
TV Sporting Event	140	57	8

Relying on a number of assumptions for spectral occupancy for current technology it estimated the requirement for an equivalent number of 8 MHz channels, particularly for the range 470-694 MHz.

The requirement for 8 MHz channels is based on a conservative estimate of the number of radio microphones and IEMs, their implementation and their technologies.

Whilst theatre and outdoor music events may not at first appear relevant to broadcasters there are instances where there is TV coverage of these high-profile live events and access to sufficient suitable quality spectrum becomes vital.

For two scenarios with the highest demand more detail is given below.

4.2 A major Film/TV production centre

It is common practice to concentrate major content production in a single location with multiple studios or stages, taking advantage of shared facilities and local access to skilled technicians and creatives. The outsourcing of resources by broadcasters and film companies has contributed to these independent production centres.

Different and sometimes competing content producers will operate side-by-side in flexible production spaces which they occupy for the duration of a shoot. These shoots may concern individual productions or be for long term projects. Such production spaces are in high demand, not least due to the rise in demand for content production from streaming services that are now also establishing their own dedicated centres.

The requirement for sufficient PMSE spectrum becomes a challenge when maybe as many as ten production spaces are operating simultaneously. Requirements ramp up and down as productions come and go, requiring close management of the available spectrum from day-to-day. A requirement for 200 individual frequencies is easily achieved for audio PMSE, with a mix of radio microphones and in-ear monitors that need to operate without interaction. The frequency band of 470-694 MHz is the dominant range in use, with barely sufficient suitable spectrum, particularly after discounting that utilised by local DTT services. There is currently no suitable alternative spectrum of the same utility that provides reliable, high-quality audio with low latency - and no new technologies are as yet available.

4.3 Large event case study – Glastonbury

The Glastonbury Festival is one of the biggest cultural and artistic events in the UK, held annually and attended by over 200000 people with extensive TV, Radio and Online coverage of the event consumed by many millions around the world. Held over three days there are hundreds of individual acts with simultaneous performances across ten main stages and more than 50 other stages and performance areas on the site.

The festival itself is close to a high power DTT transmission site severely reducing the amount of suitable UHF spectrum for PMSE also carefully managed during the 800 MHz and 700 MHz clearances (DD1 and DD2) while demand for PMSE has kept growing.

The major spectrum issue relates to radio microphones and in-ear-monitors in the range 470-694 MHz. While one act is performing the next is preparing backstage for a swift turnaround and is testing its radio equipment. That requires perhaps double the number of compatible assignments at a given moment. Multiplied by the number of stages that may result in 20 compatible sets of channels simultaneously in use across the main stages.

Fortuitously the distance between stages does allow reuse of spectrum than would be possible for assignments in closer proximity, but coordination between stages still needs to be in place. There may be spectrum constraints with the acts' preferred equipment not always able to tune across the full range of available spectrum, meaning that the best plan may not be viable.

High power DTT services exclude certain ranges, further restricting options. The spectral efficiency of radio microphone equipment in terms of assignments per MHz has improved in recent years, particularly for digitally modulated equipment.

The overall spectral efficiency, however, remains limited by the use of analogue modulated in-ear-monitors, together with the requirement to still employ intermodulation free assignment plans. Assignments for the TV coverage of the event, although fewer in number, still need to be compatible throughout the three days of Glastonbury with all the performances and their assignments across multiple stages according to editorial requirements.

Accounting for all these constraints, only through a careful combination of temporal and spatial planning can demand be met. Assignments are time-restricted for the performance times and their preparation. Measurements and experience inform how close similar sets of assignments can be made to those concurrent on nearby stages.

Table 3: Individual Wireless Microphone, In-Ear and Talkback Assignments in 470-694 MHz at Glastonbury 2022 (Source: Ofcom UK)

Date	Total number of Assignments in the 470 - 694 MHz band
24 th June	561
25 th June	642
26 th June	572

These figures show the total assignments across the main stages and for coverage of the event. There will be many more used across the other stages, sharing the spectrum and in uncoordinated ranges too. For a given moment a smaller number will be in use simultaneously but accounting for all the constraints set out, without continued access to the full range 470-694 MHz it will become impossible to stage an event such as the Glastonbury Festival in its current form and with the high production values that have come to be expected.

5. Measures already taken to overcome congestion

Due to the increasing demand for PMSE equipment at events and at the same time a significantly reduced amount of spectrum after the release of the 700 MHz and 800 MHz bands, PMSE users have already taken various measures to cope with these conditions. Usually, the following measures are implemented:

- PMSE users buy high-quality equipment with a wide tuning range that gives the flexibility in selection of the operating frequency. A typical tuning range for equipment is between 30 MHz and 100 MHz. Furthermore, intermodulation-free devices can profit from an equidistant frequency planning, which increases the density of possible channels per MHz.
- Some high-quality digital equipment offers a mode that increases channel density per MHz. In this mode, the device runs at a lower RF power level with reduced audio bandwidth and with greater latency. These compromises are of little benefit in broadcast applications and overall bring a higher risk to quality of service.
- In countries where PMSE audio devices are licence exempt, event organisers usually contract a frequency coordinator which manages the frequency demand and plans the frequencies for users so that the available spectrum is used in the most efficient way.
- The operating frequencies are coordinated in a time-based manner. Different users can

re-use the same frequency in different time periods. But there are organisational limits and clear logistical rules have to be implemented to not risk a double use.

- In frequency planning spatial distance is also taken into account. When different users operate at defined locations and sufficiently distant from each other, the minimal spacing between their frequencies can be reduced.
- Use of advanced frequency coordination software facilitates and automates the most efficient spectrum planning.
- The event organisers encourage frequency users on a voluntary basis to use wired microphones wherever possible.

6. Remaining limitations

Further to the measures described above, we recognise that frequency planning at events gets increasingly complex. This leads to additional costs for event organisers and PMSE users.

Even applying all the concepts mentioned above, the frequency demand at some events is higher than the availability. In those situations, the frequency demand among users needs to be prioritised. Some users may need to obtain equipment in other frequency ranges, which may not always be acceptable to the artists. In some cases, not all users can be accommodated.

Therefore, an insufficient amount of PMSE spectrum may lead to discrimination between performers, production teams or even whole productions, reputational damage, higher production costs, complexity and economic loss for event organisers, artists, content producers and broadcasters. In some cases, it may not be possible to stage large events as originally intended.

7. Conclusions

Especially in these times of fake news and hate speech, broadcasting continues to be of great importance for democracies in Europe. To fulfil this task, broadcasters carry out a large number of high-quality productions every day.

Wireless microphones are the basis of every broadcast production: in film and drama productions, sporting events, reportage formats, breaking news, but also in narrative formats, documentaries, entertainment and music productions. The demand for wireless production tools has been increasing for years.

Since the release of the 800 MHz and 700 MHz bands, which severely reduced the available spectrum for wireless audio productions, a shortage of frequencies has become more common in daily production as well as for large events. Measures such as more complex and costly frequency coordination, lower radiated powers and narrow band techniques that limit the audio quality and, in extreme cases, substitution of wired equipment, can restrict artistic freedom and increase production costs.

While there are several frequency bands available for the use of wireless audio production, the only frequency range harmonised across Europe and sufficiently large is 470-694 MHz. This frequency range is also physically best suited for audio PMSE as it provides good propagation characteristics, low power consumption and a compact device design with suitable antenna length and complementary sharing arrangements with DTT. Other frequency bands are less used due to various reasons, including limited capacity or availability, less suitable physical properties or lack of industry support and equipment. Therefore, these bands are a complement but not a substitute for the band 470-694 MHz.

Compared to other frequency ranges, the band 470-694 MHz offers a wide choice of devices on the market which also can be used on an international basis - an essential requirement for the cultural industry. Currently, this band is by far the most heavily used and vital frequency range for audio PMSE.

For all the above reasons, the PMSE sector has no alternatives but to continue to rely on access to the frequency band 470-694 MHz. Therefore, no regulatory change shall be introduced in this band.

8. References

[1]	ERC Recommendation 25-10 : <i>Frequency Ranges for the Use of Terrestrial Audio and Video Programme Making and Special Events (PMSE) applications</i> . This recommendation includes the information on implementation in different frequency bands and in different countries.
[2]	ERC Recommendation 70-03 : on the use of Short-Range Devices (SRD) in CEPT. Annex 10 covers frequency bands and regulatory as well as informative parameters recommended for radio microphone applications (also referred to as wireless microphones or cordless microphones). This recommendation also includes the information on implementation in different frequency bands and in different countries.
[3]	ECC Report 204 : <i>Spectrum use and future requirements for PMSE</i>
[4]	ECC Report 323 : <i>Spectrum use and future spectrum requirements for PMSE</i>
[5]	Public Service Media's Contribution to the European Creative Sector , EBU MIS Report, August 2022.
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