

November 27, 2019

Via Electronic Mail

Radio Spectrum Policy Group - Secretariat
DG CNET B4: Spectrum – Office: BU33 7/065
European Commission
B-1049 Brussels
Belgium

Ref: Comments on the Radio Spectrum Policy Group's Draft Work programme for 2020 and beyond

Ladies and Gentlemen,

Shure welcomes the opportunity to comment on the RPSG Work Programme 2020-2021.¹ For over 90 years, Shure has been a respected manufacturer of high-quality, innovative audio products.

Shure has actively participated in several EU consultations in the past, e.g. by filing comments on the 2017 Radio Spectrum Policy Group's Draft Opinion on a long-term strategy on future spectrum needs and use of wireless audio and video PMSE applications. This "**PMSE Opinion**" is now published.² The PMSE Opinion is a good basis for further work on the RSPG Work Programme.

Shure's position is as follows:

1. Shure commends the RSPG in its PMSE Opinion for its continued appreciation of PMSE's fundamental role in a broad range of events and activities – cultural, educational, business, entertainment, sports, religious and civic events;
2. Shure believes that the RSPG should not focus solely on 5G and its short-term needs and be wary of 5G spectrum demands;
3. The EC should stand by its given guarantee to protect PMSE in the remaining UHF-TV band at least until 2030;
4. PMSE is in a special situation and not a potential target for spectrum sharing;
5. Technology developments, especially for 5G, will not (see Attachment A) make up for a lack of available PMSE spectrum;

¹ https://rspg-spectrum.eu/wp-content/uploads/2019/10/RSPG19-029final-RSPG_work_programme_20_and_beyond.pdf.

² Date 21 November 2017, DG CNET/B4/RSPG Secretariat RSPG17-037 FINAL REV1, available at https://circabc.europa.eu/sd/a/d9e7f125-8919-4720-999a-1d67e28d6ac9/RSPG17-035final_progress_report_on_WRC-19-with_annex1.pdf

6. A common roadmap identifying principles and approaches of spectrum availability for PMSE across EU member states is needed to ensure that sufficient PMSE spectrum continues to be available across borders;
7. Two ITU Resolutions are highly relevant for PMSE: Res 59-2 and Res 235. Both require active support of the RSPG and EU spectrum regulators; and finally;
8. The RSPG should work with the PMSE industry to examine and defend the need for maintaining or identifying additional spectrum for PMSE.

Before we provide more details on the six work items, we have two general comments on the Work Plan. Shure is concerned about the long-term impact of 5G on PMSE and on PMSE's access to the UHF TV band (470 – 694 MHz):

A) Impact of 5G on PMSE

Shure believes that the RSPG should not focus solely on 5G and its needs, as current studies suggest that 5G will not support multi-channel radio microphone or In-Ear Monitors,³ but should also provide a longer-term European spectrum strategy for PMSE and other users with a 10-30 year horizon. This approach is in line with the goals of the PMSE Opinion that "[t]he RSPG recognizes that long-term regulatory certainty and visibility on spectrum access is desired by PMSE manufacturers and users in order to decide on investment and is a consideration in product development and improvement."⁴

B) Access to the UHF-TV band (470 – 694 MHz)

A decision to allocate the 470-694MHz band to IMT on a primary basis would leave PMSE without sufficient spectrum to support its multiple platforms and continue to support the myriad industries reliant on this equipment, as the state of the art in PMSE technologies is currently and has historically been based in this band. Research and development in this category takes years and currently the industry has no alternative common European spectrum on which to focus R&D efforts.

The given guarantee to protect the remaining UHF-TV spectrum that PMSE users rely on until 2030⁵ needs the support of all EU member states. As one of the pillars for anchoring PMSE firmly in the EU's spectrum policy in general, Shure re-emphasizes that UHF-TV (470-694 MHz) spectrum is essential to existing audio PMSE technology and operations *and will remain so for the foreseeable future*. The

³ PMSE XG project is annexed as Attachment A.

⁴ PMSE Opinion at 24.

⁵ Cf. PMSE Opinion at 25: "The frequency band 470-694 MHz will, in accordance with Article 4 of DECISION (EU) 2017/899, continue at least until 2030 to be an important frequency band for audio PMSE. The long-term strategy for the band 470-694 MHz is addressed in the RSPG opinion on a long-term strategy on the future use of the UHF band (470-790 MHz) in the European Union and is expected to be subject to review according to the Lamy Report37 by 2025. In this review the positioning of PMSE needs to be considered carefully."

PMSE Opinion acknowledges this requirement, in particular for peak demand.⁶ Accordingly, regardless of proposals to introduce new services into the UHF frequencies and discussions of evolving PMSE technologies to facilitate greater spectrum use, technical and policy solutions must ensure that some amount of clean UHF-TV spectrum and some smaller portion of VHF (174-216 MHz) spectrum, remains available to support ongoing PMSE operations. Clear and unambiguous protection of the 470-694 MHz band from supplementary down links (SDL) and similar services must be required through an EC decision to provide the industry and users spectrum certainty until the next review.

The UHF TV band within 470-694 MHz is the primary band for professional wireless audio PMSE operation globally. This band offers the most reliable operation due to a combination of good propagation, satisfactory antenna efficiency, and relatively low and predictable ambient noise and interference levels. Other bands that are used, where available, include the VHF television band in 174-216 MHz, 823-832 MHz, 1785 -1805 MHz and 863-865 MHz. These bands are subject to high levels of interference in certain locations. The aeronautical DME band ("Air Band") in 960-1164 MHz is currently being studied for shared use by PMSE. A few administrations have allowed licensed PMSE systems to operate in portions of the 1350-1400 MHz and 1518-1525 MHz bands, but the long-term availability of these frequencies is uncertain, and the administration in charge of the allocation should be encouraged to make them available to help alleviate the loss of the 700 MHz band.

On a **more detailed level**, Shure comments below on the specific six work items in the Work Programme 2010-2021:

- 1) Spectrum Sharing
- 2) Pioneer initiatives and bands
- 3) Additional spectrum needs and guidance on the fast rollout of future wireless broadband networks
- 4) Role of Radio Spectrum Policy to help combat Climate Change
- 5) "Good offices" to assist in bilateral negotiations between Member States
- 6) Peer review and Member States cooperation on authorisations and awards

I. Work Item 1: Spectrum Sharing

Shure supports the RSPG in its efforts to develop a roadmap for increased spectrum sharing and identify key pioneer initiatives and bands. However, PMSE is in a special situation as a potential target for spectrum sharing and thus not a likely candidate for sharing for a number of reasons:

⁶ At 14.

(a) Shure agrees with RSPG's observation in its Opinion that the ability to meet PMSE demand is "timing and/or location specific."⁷ This is illustrated in areas of intensive use such as large events (e.g., concerts, sporting events, etc.) and concentrated areas of multiple PMSE users (e.g., London's West End and other theatre districts), or large events such as the Olympic Summer Games in London and Paris which present special challenges. This demand is different from the demands other spectrum users have (e.g., IMT, broadcasting etc.).

(b) Sharing will become more difficult for PMSE as the overall demand for PMSE operations continues to rise for several reasons.

- First, the number of large production events in public is growing. Today, live performance music concerts, live theatre, sporting events, corporate events, and Houses of Worship productions are increasingly frequent and popular and growing in scale.
- Second, providing PMSE support to meet peak demand has become more and more complex and challenging as the size and sophistication of production events has increased (e.g., Cirque du Soleil, award shows, etc.).
- Third, demand for PSME support even in everyday uses has risen with the proliferation of access to content and programming from online sources, both pre-recorded and streaming.

The rising trend in all of these situations is expected to continue and, accordingly, the RSPG is correct in assuming that demand for wireless PMSE will continue to increase.⁸

(c) Wireless microphones are the pioneers in geographical spectrum sharing first in the VHF and then UHF TV bands.⁹ However, spectrum sharing is not a panacea. Due to new allocations in the UHF band the spectrum that wireless microphones can share with other applications is actually shrinking. All sharing must hence be carefully evaluated for its consequences on PMSE and content production. For instance, live broadcasts and performances using PMSE must not be interrupted and must not be limited by any other service claiming spectrum access.

In particular, UHF spectrum is essential to existing audio PMSE technology and operations *and will remain so for the foreseeable future*. Accordingly, regardless of proposals to introduce new services into the UHF frequencies and discussions of evolving PMSE technologies to facilitate greater spectrum use, the long term solution path(s) carved out for PMSE must ensure that a sufficient amount of clean UHF spectrum, and some smaller portion of the VHF band, remains available to support ongoing PMSE operations. Shure accordingly urges the RSPG to include a recommendation in its report that some portion of both the UHF-TV and VHF bands will need to be permanently designated to PMSE operations to accommodate current and long-term needs, along with other PMSE spectrum that

⁷ PMSE Opinion at footnotes 5 and 25.

⁸ Same source.

⁹ PMSE Opinion at 7.

can be made available. Support for this policy should be extended to the activities at the ITU and its Working Parties.

II. Work Item 2: Pioneer Initiatives and Bands

The PMSE industry is already very innovative, resourceful and embracing of new technologies. PMSE industry and academia continue research and development of advanced technologies to make better use of the available spectrum. While Shure continues to invest heavily in R&D, Shure cautions that anticipated technology developments, especially for 5G, cannot be counted on to make up for a lack of suitable spectrum for PMSE operation. Intensive reuse of spectrum already takes place at large events where users are assigned different time slots and/or locations. Furthermore, new spectrally efficient high-density digital PMSE modes require clean spectrum for successful operation.

Some of the current technical developments—for example, 5G -- present significant uncertainty as to their suitability for PMSE operation. The RSPG should simply commit to study their development without taking any premature action or offering any opinion regarding whether those technical strategies will ultimately bear fruit. One thing that is clear at this time is that none of the technology strategies identified by the RSPG -- standing alone -- present satisfactory and complete solutions in the foreseeable future for PMSE, particularly if PMSE spectrum needs go unaddressed or the situation worsens. Both access to sufficient, available, interference-free PMSE spectrum *and* continued advancements in PMSE technology will be required to ensure that peak demand events will be adequately supported in the future.

Shure agrees that use of digital microphones will become more widespread, although analogue technology will continue to meet certain specific needs.¹⁰ Much of the industry has transitioned to the use of digital transmission, which enables significant improvements in spectral efficiency. For example, in standard mode, Shure's *Axient* digital PMSE system enables up to 22 high quality audio channels to be transmitted in a single 8 MHz TV channel.

Shure views with caution the assertions with respect to the potential applicability of 5G technology for PMSE applications as the German PMSE XG project (below **Attachment A** and <http://www.pmse-xg.de/publications.html>) that was completed in March 2018¹¹ clearly shows.

At the present time, 5G technology and the use of the 5G technology platform is wholly unproven and undefined especially via the establishment of networks and therefore cannot be considered as a viable solution for PMSE at either the

¹⁰ Draft Opinion at 21.

¹¹ Fraunhofer Institute: <https://www.hhi.fraunhofer.de/en/press-media/news/2018/pmse-xg-project-successfully-completed.html> (in German)

technical or economic level. That said, Shure and other audio PMSE stakeholders are monitoring and actively exploring the potential development of PMSE technologies in 5G. While 5G is worthy of further study, there are very significant and fundamental technical, economic (especially for users), and practical questions that need to be answered before an assessment can be made about the realistic potential for successful PMSE operations in 5G.

Currently, professional PMSE users have access to dedicated, licensed or licence-exempt spectrum on which they can rely. The availability and cost of this spectrum is well-known, enabling PMSE users to carefully and reliably plan events. If PMSE systems operate in 5G spectrum that is shared with mobile services, PMSE users cannot be assured that spectrum will be available where and when it is needed. The 5G-based technology will likely be unsuited for large events that currently rely on PMSE technologies. Often, large PMSE productions take place in locations where there is also high demand for mobile services, such as sports venues and theme parks.

Other terms and conditions of PMSE use would need to be established including how spectrum access would work, whether PMSE systems would be able to operate on a "private node" basis or whether they would need to operate on a mobile provider's network, and how spectrum access would be priced. PMSE systems use hundreds of wireless microphones and sometimes operate for many hours at a time. The data cost for that scale of operation would potentially be prohibitive. Furthermore, in many cases, mobile networks are inaccessible or weak in areas where PMSE systems operate, such as inside large theatres and exhibition halls. Microcells would be needed in these areas, especially if 5G systems operate in multi-GHz frequency bands. The requirements would vary depending on whether PMSE systems were operated on a network or use private infrastructure and how frequency management was accomplished.

Other technical issues that need to be researched include latency, network reliability, data security and priority of access. For today's professional PMSE users, end-to-end latency of 2-3 milliseconds or less is expected for digital systems, dropped signals and unwanted noise are totally unacceptable, and priority over other uses for the duration of the program is mandatory.

III. Work Item 3: Additional Spectrum Needs

The main point here is that wireless broadband networks in the EU are currently not running efficiently. As Prof. Dr.-Ing. Georg Fischer of the University of Erlangen has shown, "MIMO¹² could provide much more capacity gains (x6...x8) than new spectrum (x2) [...] It is impossible to serve an exponential data growth by linear spectrum assignment. The game is lost already by today... MIMO has

¹² Multiple-input and multiple-output, or MIMO is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation.

more potential than more spectrum.”¹³ An efficient use of spectrum should receive the highest priority. Regulators should force IMT providers to use their spectrum efficiently, be prevented from spectrum hoarding and be fined where they do not comply with their committed rollout plans, in particular now that commercial launch of 5G has been started. The RSPG should not jump to conclusions and assume that additional allocations of spectrum will be necessary if current spectrum use is woefully inefficient.

Shure reiterates that a Common Roadmap identifying principles and approaches of spectrum availability for PMSE across EU member states is needed to ensure that sufficient PMSE spectrum continues to be available across the borders of the individual EU member states. Currently there is a great deal of variation within the EU member states’ spectrum access requirements for PMSE, and these disparate national allocations are problematic for PMSE users who operate internationally, both in terms of compliant operation and in equipment investment. National variations also create a significant cost penalty for manufacturers, who bear the expense of creating, certifying and licensing multiple product variants to meet country-specific regulations.

For the Common Roadmap the Member States and the RSPG should also be mindful of the threats to certain types of PMSE operation in the DECT band (1880 – 1900 MHz band in Europe). Devices operating in the band¹⁴ must adhere to the DECT protocol, which helps to ensure that the spectrum is shared efficiently and fairly among users. In addition, this band is available in many European countries, which facilitates cross border operation.

Recently, DECT spectrum has come under threat from IMT and Railway interests who propose to operate using their own transmission schemes. These systems would not adhere to the DECT politeness protocol and would be likely to cause severe interference to DECT equipment, rendering it unusable. In addition to the environmental and economic consequences of such an outcome, no suitable alternative spectrum has been identified for PMSE equipment using this band. Shure requests the RSPG and the Member States to look into this matter and consider other bands for IMT and Railway systems.

This common goal of an EU-wide PMSE roadmap can only be achieved by the proactive work of the RSPG and should include the relevant ETSI groups and industry representatives.

¹³ EUMW2019, WM-03, Workshop on PMSE, Paris, Sept. 30, 2019 - Presentation of Prof. Fischer available at https://www.apwpt.org/downloads/eumw2019_is-pmse-wasting-spectrum.pdf (slides 27 and 28).

¹⁴ Currently, DECT is used by PMSE equipment primarily for conferencing and discussion systems. These systems are installed either permanently or temporarily in many corporate offices, broadcasting studios, court rooms, conference centers, government offices, houses of worship, and the like.

IV. Work Item 4: Role of Radio Spectrum Policy to Help Combat Climate Change

The RSPG could play a noticeable role as set out above in endorsing efficient spectrum management if the management is done right. For instance, changing spectrum allocations, moving PMSE and forcing PMSE users to buy new equipment (cameras, microphones, transmission equipment, etc.) to replace equipment that in most cases is functioning and not fully depreciated will *not* further the goal of combating Climate Change and will create waste. If content production is forced to leave the EU because of unavailable PMSE spectrum or unreliable spectrum access, such move will not only hurt the EU economy (job losses etc.), but it will not serve the EU's Climate Change goals (travel, costs etc.). By contrast, the suggested spectrum harmonization for PMSE in Europe across borders will further the EU climate protection goals as the same equipment can be used in multiple countries for content production.

V. Work Item 5: "Good Offices" to Assist in Bilateral Negotiations

Shure refers to its comments above on the Common Roadmap as the top priority.

VI. Work Item 6: Peer Review and Member States Cooperation on Authorizations and Awards

This process is ongoing and largely on track. Two ITU Resolutions are highly relevant for PMSE:

(a) **Res 59-2** in its slightly modified form as approved by the Radio Assembly 2019¹⁵ *"calls for the ITU Director of the Radiocommunication Bureau:*

- 1 to develop a publicly accessible webpage to consolidate links to administration lists of ENG information (such as related lists or charts of permitted frequency bands developed by the applicable Study Groups)[...];*
- 2 to invite the administrations of Member States to ensure that the information provided is kept up to date by submitting any modifications to the information referred to above on an ongoing basis."*

At a minimum, the RSPG should encourage the EU Member States and the EC to promote similar information as provided by the ECO PMSE webpages and associated Recommendations 70-03 and 25-10 be provided by other ITU Member states. We ask the RSPG to request the member states to actively support RES 59-2 as this industry is steadily growing and extensively peripatetic and generates new jobs, in particular in the new content-driven 5G world.

¹⁵ <https://www.itu.int/pub/R-RES-R.59-2-2019>

(b) **ITU Res 235¹⁶** calls on the regulators and industry “to carry out sharing and compatibility studies, as appropriate, in the frequency band 470-694 MHz in Region 1 between the broadcasting and mobile, except aeronautical mobile, services, taking into account relevant ITU-R studies, Recommendations and Reports.”

The Resulation is unchanged by WRC 19, but the CPM has instigated a Task Group to carry out work prior to WRC 23. We request RSPG to support this work in line with its policy of retaining use of the UHF TV band until at least 2030.

These are two ITU resolutions with high relevance to PMSE. We refer particularly to our comments on PMSE and spectrum sharing above (Work Item 1). By providing its input, the RSPG should recognize FM51 as the European guidance for PMSE needs.

Shure applauds the work of the RSPG and will continue to support its efforts to secure sufficient access to spectrum for PMSE as a vital industry that provides a critical service to the European economy, society and culture.

Regards,

Shure Europe GmbH

¹⁶ RESOLUTION 235 (WRC-15): Review of the spectrum use of the frequency band 470-960 MHz in Region 1
https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0029PDFE.pdf



White Paper

PMSE and 5G

Version 1.01

27.03.2017

CONTENT

1	Executive Summary.....	2
2	Introduction.....	2
3	Use Cases.....	3
4	Technical Requirements	5
5	New Business Models	7
6	PMSE and 5G: The Way Forward	8

THE PMSE-xG PROJECT

PMSE-xG is a pre-competitive research project studying 4G+/5G technologies and their applicability to wireless equipment deployed in Programme Making and Special Events (PMSE) applications. PMSE systems are mainly used by the Culture and Creative Industry, and cover all kind of production tools for audio or video processing.

PMSE-xG is a first step to bring stakeholders together and to assess the feasibility of current and future cellular mobile radio technologies (4G+ and 5G) for selected PMSE use cases. The assessment is based on implementation concepts and the validation of key performance indicators in proof-of-concept demonstrators. Research activities of PMSE-xG cover in particular ultra-reliable low latency streaming technologies for mobile and nomadic applications. Standardization activities contribute and highlight PMSE requirements to the running standardization of 5G.

PMSE-xG is co-funded by the German Federal Ministry of Transport and Digital Infrastructure. The PMSE-xG consortium consists of three leading PMSE manufactures (ARRI, Robert Bosch, and Sennheiser), an innovative mobile radio SME (Smart Mobile Labs), a leading chipset manufacture (Intel), two universities (Hannover, Erlangen-Nürnberg) and one research center of the Fraunhofer-Gesellschaft (HHI, Berlin). Several associated partners enrich the expertise of the PMSE-xG consortium by participating in an advisory board.



1 EXECUTIVE SUMMARY

The *Programme Making and Special Events* (PMSE) industry, the main driver behind professional equipment for the Culture and Creative Industry (CCI), is looking for solutions to the diminishing availability of dedicated spectrum for advanced wireless applications.

With the 5th generation mobile networks (5G) on the horizon, future cellular networks are considered as one viable option for wireless communication systems to fulfil the strict requirements of the PMSE scenarios including professional live audio and video production. The requirements from the PMSE industry extend further than the ones commonly considered for the 5G use case Ultra-Reliable Low Latency Communication (URLLC), i.e. latency below 1 ms and high reliability for a single packet transmission. In fact, even though the support of continuous streaming of packets is essential for any media application, the ability to have all devices tightly synchronized and the support of a reliable multicast are additional key requirements that PMSE applications necessitate for seamless operation. Finally, to enable the successful integration of PMSE applications into the 5G ecosystem, a viable business model for the PMSE industry, as a vertical sector within the scope of 5G, is essential.

2 INTRODUCTION

The PMSE industry comprises all kind of production, event and conference technologies. It can be categorized into audio (e.g. microphones, in-ear monitor, and public address sound systems), video (e.g. cameras, displays and projectors) and stage control systems.

The usage of PMSE equipment plays a major role for the CCI sector. Today, for reliable operation of all the wireless equipment, such as cameras and microphones, professional PMSE requires controlled interference environments, e. g. through appropriate spectrum access and interference mitigation techniques. Up until now, the TV UHF band form the core spectrum for professional wireless audio productions even though PMSE devices share this spectrum with the actual primary user (Broadcasting Service). However, the trend within the CCI towards larger setups and the increase of quality requirements demand a much broader spectrum availability. Furthermore, dedicated spectral resources for PMSE applications become scarcer due to reassignment of important UHF frequency bands to the cellular industry¹.

Failures of wireless links during a live event or a live production are unacceptable for the CCI and their customers. Therefore, additional efforts towards an improved transmission robustness and a more effective interference management have to be considered. Not only reliability but also audio/video quality and latency are key parameters of wireless production equipment. In order to cope with all these requirements the spectrum demands increase further. However, due to the increasing reduced spectrum availability, business opportunities to expand the PMSE and CCI sectors are substantially limited. It is worth pointing out that there is a growing demand from the end users for new, and more differentiated services, like Augmented Reality (AR), Virtual Reality (VR) and other new

¹ BNetzA (online): Strategic Aspects of the Availability of Spectrum for Broadband Rollout in Germany (2017) <https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/Areas/Telecommunications/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/DemandIdentificationProceedings/StrategicAspects.pdf?blob=publicationFile>



immersive experiences. These services will require and consume even more additional resources of the available spectrum. Here, the forthcoming 5G standard and its correspondent technologies could offer solutions and open new possibilities by integrating PMSE use cases into the 5G eco-system, thus fulfilling the technical requirements of PMSE applications.

The dynamic transformation of the Media & Entertainment (M&E) vertical user experience is part of the ongoing discussions both in research communities, like the 5G-PPP association², and in standards bodies, like 3GPP³. Referring to these discussions, *“5G shall enable at least six main families of M&E use cases in the 2020s with an overall user experience that well exceeds that of 4G and other legacy networks: Ultra High Fidelity Media, On-site Live Event Experience, User/Machine Generated Content, Immersive and Integrated Media, Cooperative Media Production and Collaborative Gaming”*⁴. However, comparing the Key Performance Indicators (KPIs) of the mentioned six main families with the KPIs required for PMSE, it is clear, that use cases of typical PMSE applications, as described in the following section, are not yet covered by the technical requirements of M&E, as the focus of the works has been so far only on media distribution and reception.

The goal of this white paper is to increase the awareness of what is actually needed for the media production part of CCI with regard to the ongoing definition of 5G system. The rest of the document is organized as follows: section 3 illustrates PMSE use cases. Section 4 summarizes the technical parameters of professional PMSE applications within 5G. Section 5 discusses the substantial need for a business model and section 6 finally points out issues that are to be resolved before 5G becomes a viable option for the PMSE industry.

3 USE CASES

In today’s typical professional live production setups, there is a lot of wireless PMSE equipment in use, e. g., artists on stage use wireless microphones in combination with wireless in-ear monitoring systems, or wireless cameras deliver live content for big video panels placed around the stage. Every wireless audio/video link is composed of one transmitter and its destined receiver, which provides the input data for the further processing chain, or in case of an in-ear monitor system the audio stream for the artist on stage.

Transferring PMSE applications into the 5G eco-system, the complete on-site wireless equipment could be seen as one local high quality PMSE network (see Figure 1), processing audio and video data streams with a guaranteed quality of service regarding latency and reliability as well as control data for remote control of wireless devices.

The professional live audio performance use case is depicted by multiple wireless audio data flows, each of them being composed of the microphone’s signal, streamed to the base station, and the in-ear audio mix, which is sent back to the artist. Due to the latency requirements of professional musicians using monitor functionality on stage or during live

² The 5G Infrastructure Public Private Partnership: <https://5g-ppp.eu/>

³ The 3rd Generation Partnership Project: <http://www.3gpp.org/>

⁴ 5G-PPP: 5G empowering vertical industries (2016), online
https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf



production, the local high quality network must be capable of streaming audio signals with ultra-low latency. The whole network would have to receive numerous audio signals from the artists on stage and to stream different audio mixes back to the artists or to a Public Address (PA) system over wireless and wired connections. Therefore, audio mixing capability can be implemented in a mobile edge cloud attached to the base station of the local high quality network to reduce latency or other possibilities of connecting external mixing consoles should be given.

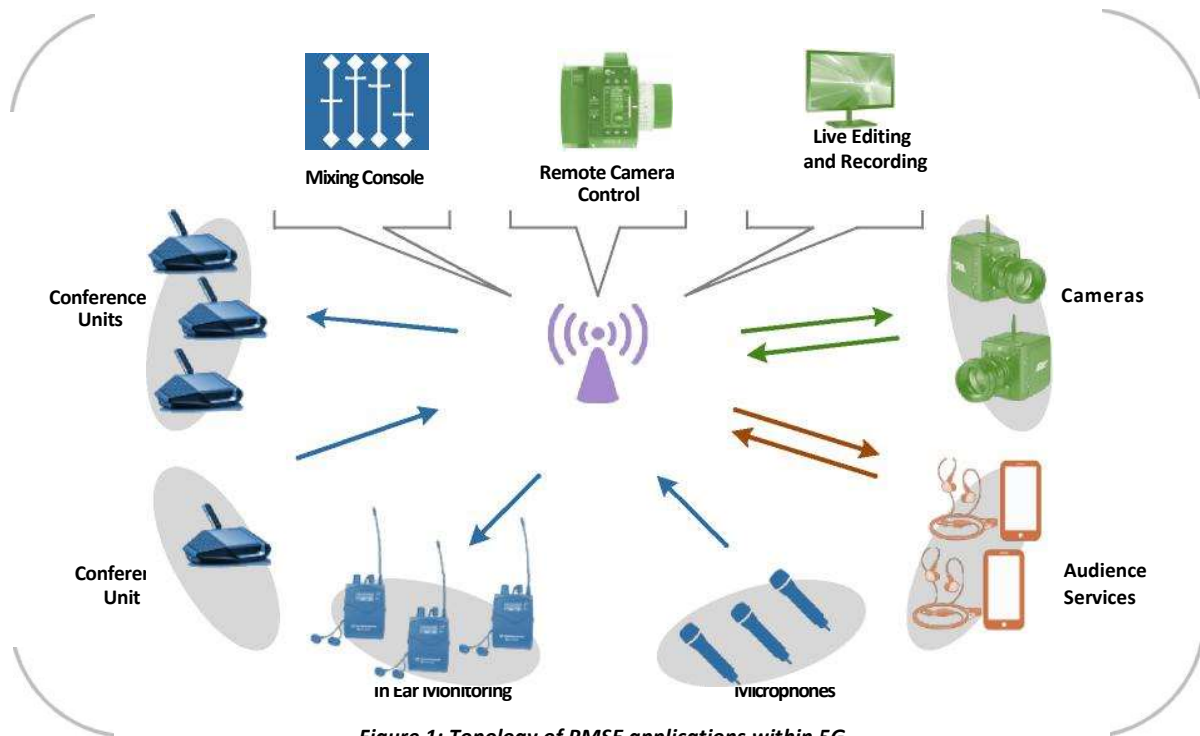


Figure 1: Topology of PMSE applications within 5G

A second use case is conferencing, which would require a similar setup. In a conference system the voice of several speakers is captured by a conference unit, transmitted to the base station of the Local High Quality Network, where the mixing of the different audio streams is done, and distributed to all other conference units connected to the network, which replay the received audio stream. Low latency is an issue because the speakers always hear themselves speaking.

In addition to the audio streams the cell processes video data, which represents the third use case. High quality video data is streamed wirelessly from several cameras to the base station and the attached mobile edge cloud, where it can be recorded or be edited. Moreover, the system should allow remote operation of the camera (e.g. focus control) by sending and receiving control data to and from the camera.

Such local high quality wireless networks for audio and video would be relevant for concerts, TV shows, sports events, theatres and musicals, press conferences and electronic news gathering. Furthermore, the scenario of a live event, where a local high quality wireless network is used to collect audio, video and other content for further distribution, offers the possibility to distribute new kind of content to the audience, e. g., individualized audio mixes, or different camera angles, which provides new ways of user experience. The respective content can be received with future standard consumer hardware (e.g.



smartphones). These services also might help people with impaired vision or hearing to follow live events.

4 TECHNICAL REQUIREMENTS

Achieving required audio/video latency together with the high reliability throughout the whole operation time is the challenge for professional PMSE applications in wireless networks. Thereby, *reliability* describes the required robustness of the service, looking at the percentage of audio/video packets that arrive in-time and without errors at the application level.

System delay refers to the latency introduced per link by the wireless communication system. In contrast to common user plane latency definitions⁵, the overall system delay shall not exceed a certain upper bound independently of the system load during pre-determined time durations for reliable operation. Looking at the minimum requirements⁶ defined for IMT 2020, they indicate that a maximum latency of 1 ms shall be specified. However, the stated condition under which the communication system has to fulfil these requirements namely using a single small packet in a system with no other users, is not applicable to the PMSE use case. In fact, PMSE implies that the multi-user case is explicitly considered and moreover, the specified value has to be met by every packet of a potential audio/video stream with the specified data rates.

In particular, professional live audio shows and productions require reducing the end-to-end latencies to a few milliseconds. As A/D and D/A conversion and general processing steps like audio mixing must be subtracted from the latency budget, the delay of the wireless communication system per hop has to be deterministic and shall be 1 ms or even less. Consequently, additional latencies introduced by the interface between the wireless modem and the audio/video applications must be embraced in the overall specification and calculation.

Additionally, professional live audio productions and upcoming immersive 3D recording setups require capturing samples at the exact same times. In this context, we refer to the term *synchronicity* as the maximum allowed time offset at application level between user equipment of one wireless network (see Figure 2). Each professional audio/video terminal has to independently refer to an accurate reference signal that reaches all terminal devices simultaneously, i.e. within a phase jitter much smaller than the audio/video sampling period. Without general limitations for upcoming setups, higher sampling rates for audio, e.g. 192 kHz, are also considered. Consequently, phase jitters must be controlled in the order of sub-microseconds. Both, the professional audio and video system rely on ultra-precise time synchronization at application level and would benefit from IEEE 1588 PTP and Time Sensitive Networking (TSN) features already developed or under development by IEEE 802.1⁷.

⁵ For instance in 3GPP: TR 38.913

⁶ ITU-R WP5D: "Minimum requirements related to technical performance for IMT-2020 radio interface(s)", Attachment 5.8 (2016)

⁷ <http://www.ieee802.org/1/pages/tsn.html>

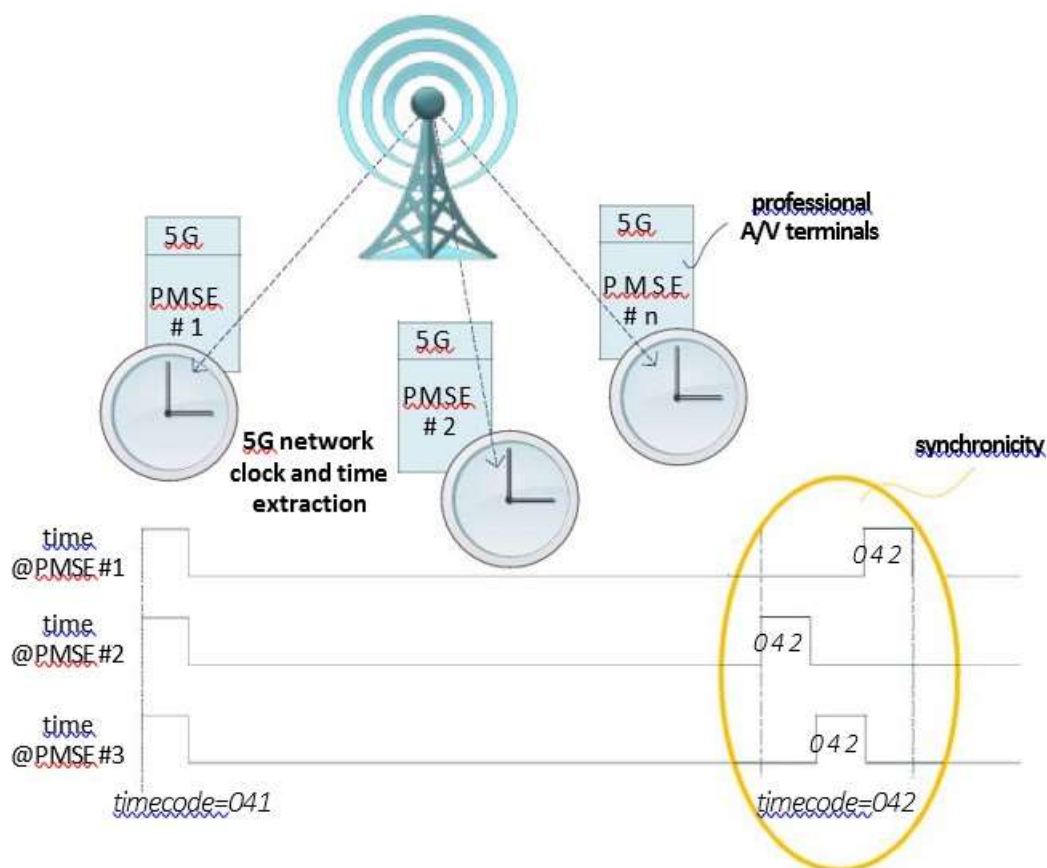


Figure 2: Time reference and synchronicity at application level

The previous described use cases make different demands on latency and reliability, and bring in the requirement of synchronicity at application level. For the three audio use cases the range of values of each requirement is summed up in one maximum value, the video requirements are defined by one use case. All discussed technical requirements driven by PMSE applications are summarized in Table 1 in comparison to the maximum value defined for IMT 2020. In contrast to IMT profiles, where a subset of the maximum requirements has to be met, PMSE use cases need all listed maximum requirements to be kept simultaneously.

Table 1 Maximum requirements driven by audio and video use cases in comparison to discussions within the 5G-PPP

	System delay [ms]	Link data rate [Mbit/s]	Reliability [%]	Number of data links	Synchronicity	Area of operation [m x m]	Mobility [km/h]
audio	1	4.61	99.99	150	1is	100 x 100	50
video production	10	2000	99.999	20	1is	100 x 100	100
IMT 2020⁺	1	20000	99.999	10 ⁶	n.a.	1000 x 1000	500

+ The requirements for IMT 2020 in current discussion are specified for the transmission of a single packet in a single-user scenario. The requirements for the PMSE equipment, however, assume a continuous stream of packets in a multi-user setup. Even though the numbers look the same, e.g. delay equal to 1 ms, the scenarios in which the PMSE equipment has to fulfil these requirements are more demanding. The number of data links for this scenario comes from a massive machine type communication use case, where participants are not active for large amount of time due to power limitations (e.g. sensors).

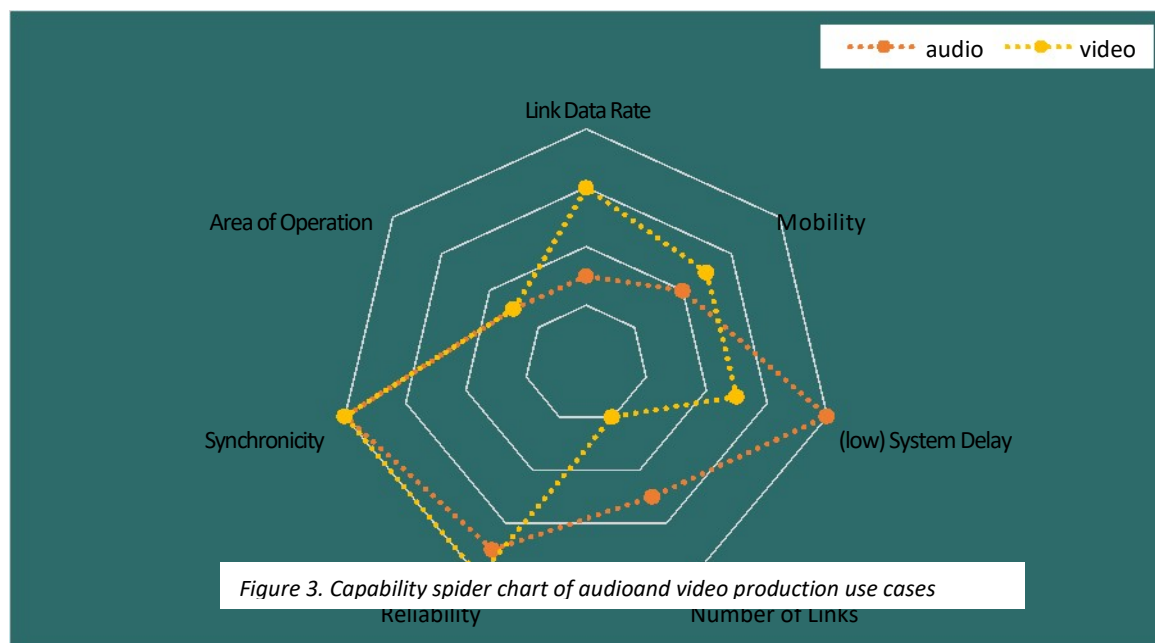


The audio case stresses strict timing requirements including low latency for medium rate audio streams covering the range from 150 kbit/s up to a maximum value of 4.61 Mbit/s per link while meeting high reliability at the same time. The reliability figure is valid for a packet length of 1 ms (corresponding to a packet size between 150 bit and 4610 bit) while holding the following two error distribution criteria:

- first, the maximum continuous error duration is equal to 30 ms
- second, a consecutive minimum continuous error-free duration need to be 100 ms.

The video case similarly emphasizes high data rates of up to 2 Gbit/s per camera link (Ultra High Definition, 120 frames per second, video production codec) and high reliability (not more than one corrupted video frame per hour). Considerable mobility arises from high-speed cable cameras. Both use cases consider indoor as well as outdoor scenarios and coverage of a football pitch area.

Figure 3 visualizes the stated technical requirements. The boundaries of the spider chart refer to the maximum values currently discussed in the 5G-PPP. Note that the requirement



synchronicity is a new KPI and replaces 5G-PPP's KPI positioning accuracy in this overview.

5 NEW BUSINESS MODELS

There will have to be viable and sustainable new business models in cooperation with network operators or license holders that allows the global deployment of the PMSE equipment in a simple and cost-efficient way. At the moment it can be thought of two deployment scenarios that have a direct influence on the involvement of a network operator and, hence, lead to different business models. One option is a dedicated Local High Quality PMSE wireless Network with spectrum access through standardized licensed-shared access (LSA) schemes. It would imply that the network infrastructure - the base station and the core



network - has to be installed and operated by the PMSE user. The license for the spectrum has to be leased from the license holder, which could be any incumbent including IMT. A second option is the deployment of a PMSE service within a public network. It would demand a contractually guaranteed service level by the network operator that allows the undisturbed operation of the PMSE service. Hence, the PMSE user utilizes the public network and only manages the PMSE equipment and the corresponding software applications.

6 PMSE AND 5G: THE WAY FORWARD

To become a suitable alternative technology for wireless PMSE applications the 5G ecosystem would have to meet three basic prerequisites:

First, the 5G standard needs to meet the technical requirements derived from the above discussed PMSE use cases, which are currently not covered by the 5G / IMT 2020 use cases. Second, not only would the forthcoming 5G standard have to fulfill the described requirements, but the necessary adaptations of the 5G standard would have to be implemented in commercially available 5G chipsets. In contrast to mobile phone producers the PMSE industry ships only a small number of units per year, which makes support of the PMSE industry less attractive for the IC manufacturers. However, the commercial availability of 5G chipsets is crucial for the PMSE industry to offer 5G-enabled PMSE equipment.

Third, an integration of PMSE application into 5G networks would only be feasible, if new business models are developed in close cooperation between network operators and the PMSE industry.

In conclusion, the prospective deployment of PMSE services within a 5G ecosystem in the future is not only a technical challenge but also depends on the early collaboration of the cellular industry with the PMSE industry and all other vertical sectors.