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BT Series: Broadcasting service (television)

Technical parameters, operational characteristics and deployment scenarios of SAB/SAP as utilized in broadcasting

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at https://www.itu.int/publ/R-REP/en)

Series	Title
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BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
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F	Fixed service
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RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
TF	Time signals and frequency standards emissions

***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R BT.2344-3

Technical parameters, operational characteristics and deployment scenarios of SAB/SAP as utilized in broadcasting

(2015-2016-2018-2023)

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Introduction

The Radiocommunication Assembly 2019 (RA-19) updated Resolution ITU-R 59-2 – Studies on availability of frequency bands and/or regional harmonization and conditions for their use by terrestrial electronic news gathering systems[1], which:

quote

resolves

1 to carry out studies regarding possible solutions for global/regional harmonization of frequency bands and tuning ranges for ENG use, focused on bands already allocated, on a primary or secondary basis, to the fixed, mobile or broadcasting services, taking into account:

– that some frequency bands have more favourable properties suitable for ENG use;

– available technologies to maximize efficient and flexible use of spectrum;

– system characteristics and operational practices which facilitate the implementation of these solutions;

2 to develop ITU-R Recommendations and/or ITU-R Reports based on the aforementioned studies, as appropriate,

further resolves

1 to encourage administrations to develop relevant information concerning their national ENG use (e.g. a list of frequency bands available for ENG, spectrum management practices, technical and operational requirements, and spectrum authorization points of contact, as appropriate…) for use by foreign entities during worldwide newsworthy events;

2 to encourage administrations to consider, for harmonization purposes, frequency bands/tuning ranges used for ENG by other administrations,

invites

the membership to actively participate in the studies by providing contributions to ITU-R,

instructs the 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) as requested in *further resolves* 1;

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.

unquote

ITU-R established the following Questions to provide guidance to its studies:

– Question 89-1/6 – User requirements for electronic news gathering

– Question 93/6 – Frequency requirements for electronic news gathering

– Question 121/6 – Spectrum usage and user requirements for wireless microphones

Study Group 6 has been encouraged to undertake studies based on user and frequency bandwidth requirements of the broadcasting community’s contributions. Work under these Questions has been completed, and so the Questions have been suppressed.

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[1] Please see Chapter 1 for full definitions of terminology.

Overview

Broadcasters, in common with other creative industries, regularly use radio frequency links for gathering content from, for example, radio microphones or wireless cameras. These technologies are commonly known as Programme-Making and Special Events (PMSE), Electronic Newsgathering (ENG) or Services Ancillary to Broadcasting/Programme-Making (SAB/SAP). Fuller definitions of these terms and others are included in Chapter 1.

Since the publication of Report ITU-R BT.2069-0, wireless technology used for content gathering has made significant technical progress. This has led to the use of new technologies for SAB/SAP:

– the introduction of digital video links, for both point-to-point and mobile links;
– the introduction of digital radio microphones including Wireless Multichannel Audio System (WMAS);
– the possibility to use in programme contribution public networks, including GSM, UMTS; in programme contribution activities;
– the development of SAB/SAP equipment for UHDTV, etc.

This Report contains four Chapters and Annexes that address the major SAB/SAP use in broadcasting:

– Chapter 1: Definition of SAP/SAB, ENG/OB, SNG and further terminology
– Chapter 2: PMSE Applications for Broadcasting
– Chapter 3: Technical information on audio Applications
– Chapter 4: Technical information on video Applications
– Annex 1: Deployment Examples by Country or Event
– Annex 2: Information on Frequency Bands
– Annex 3: Supplemental Technical Informational for Audio PMSE
– Annex 4: References

Chapter 1

Definition of SAP/SAB, ENG/OB, SNG and further terminology

In order to provide an overview of the various terms used, the following definitions are provided.

SAB: Services ancillary to broadcasting (SAB) support the activities of broadcasting industry carried out in the production of their programme material. This was the original term used when only 'official' broadcasters had access to spectrum and made their own programmes in house.

SAP: Services ancillary to programme making (SAP) support the activities carried out in the making of 'programmes', such as film making, advertisements, corporate videos, concerts, theatre and similar activities not initially meant for broadcasting to general public.

This term came into use in the late 1980s as 'programmes' were increasingly made by independent organizations. The definitions of SAP and SAB are not necessarily mutually exclusive. Therefore, they are often used together as SAP/SAB to refer generally to the whole variety of services to transmit sound and video material over the radio links.

ENG: Electronic news gathering (ENG) is the collection of video and/or sound material by means of small, often hand-held wireless cameras and/or microphones with radio links to the news room and/or to the portable tape or other recorders. As the content is more important than quality in news gathering, quality of both sound and vision can be extremely low compared with normal programmes.

OB: Outside broadcasting (OB) is the temporary provision of programme making facilities at the location of on-going news, sport or other events, lasting from a few hours to several weeks. Mobile and/or portable radio links are required for wireless cameras or microphones at the OB location. Additionally, radio links may be required for temporary point to point connections between the OB vehicle, additional locations around it, and the studio.

The definitions of ENG and OB are not mutually exclusive and certain operations could equally well reside in either or both categories. Therefore, it has been a long practice to consider all types of such operations under the combined term 'ENG/OB'. It is also understood that ENG/OB refers to terrestrial radio communication services, as opposed to Satellite newsgathering (SNG)/OB term, which refers to similar applications but over the satellite radiocommunication channels [1].

The SAP/SAB applications include both ENG/OB and SNG/OB applications and also the communication links that may be used in the production of programmes, such as talk-back or personal monitoring of sound-track, telecommand, telecontrol and similar applications.

Quality requirements of SAP/SAB applications can vary depending on the task in hand. The bandwidth of the signal to be transmitted i.e. audio or video has a direct impact on the spectral bandwidth required.

The perceived quality of the signals is going to be dependent on their potential final use. The uses can vary from SNG links into a news programme through to a high-quality HD TV production.

The reliability of service again can vary according to the task in hand. Typically, within the events for large numbers of people and for broadcast applications there is frequently a need for a high degree of protection for the SAB/SAP signals. This required protection inherently puts constraints on the amount of spectrum required to guarantee this quality of service.

Over the years, the range of applications and use cases included in the definitions of SAP/SAB and ENG/OB has increased, for example use in meetings, conferences, cultural and education activities, trade fairs, local entertainment, sport, religious and other public or private events. In recent years, the term Programme Making and Special Events (PMSE) is used to refer to the wireless production tools (such as wireless microphones, video cameras and service links) and has largely replaced SAP/SAB, ENG/OB. For the purpose of this Report, the term PMSE has been used.

For the purpose of this Report, other terminology is also used and defined as follows:

Radio microphone	Handheld or body worn portable microphone
In-ear monitor (IEM)	Body-worn portable receiver with earpiece(s) for personal monitoring of single or dual channel sound track.
Intercom	Handheld or body worn portable device allowing on-site group communication
Portable audio link	Body worn transmitter used with one or more microphones, with a longer operating range than that of typical radio microphones.
Mobile audio link	Audio transmission system employing radio transmitter mounted in/on motorcycles, pedal cycles, cars, racing cars, boats, etc.

Temporary point-to-point audio link	Temporary link between two points (e.g. part of a link between an OB site and a studio), used for carrying broadcast quality (lossless or near lossless) audio or for carrying service (voice) signals. Link terminals are mounted on tripods, temporary platforms, vehicles or hydraulic hoists. Two-way links are often required.
Wireless camera	Handheld or otherwise mounted camera with integrated transmitter, power pack and antenna.
Portable video link	Handheld camera with separate body-worn transmitter, power pack and antenna.
Mobile airborne video link	Video transmission system mounted on helicopters or other aircraft.
Mobile vehicular video link	Video transmission system mounted in/on motorcycles, pedal cycles, cars, racing cars or boats.
Temporary point-to-point video links	Temporary link between two points (e.g. part of a link between an OB site and a studio), used for carrying broadcast quality video/audio signals. Link terminals are mounted on tripods, temporary platforms, vehicles or hydraulic hoists. Two-way links are often required. In some circumstances audio signals may be included/multiplexed with the video transmission as a single video/audio link.
Talk-back / IFB	For communicating the instructions of the director instantly to all those concerned in making the programme, including presenters, interviewers, cameramen, sound operators, lighting operators and engineers. A number of talk-back channels may be in simultaneous use to cover those different activities. Talk-back usually employs constant transmission. Also known as interruptible foldback (IFB).
Telecomm and/remote control	Radio links for the remote control of cameras and other programme making equipment and for signalling.

Chapter 2

PMSE applications for broadcasting

Broadcasting involves a broad range of applications where all forms of PMSE equipment are used.

2.1 Studio production

Studios use audio PMSE for talkback, radio microphones and IEM for presenters. The reason for using PMSE equipment with radio links is to give freedom of movement, flexibility and safety within the studio.

The nature of traditional studio use has changed. In some countries studios that were previously owned and operated by public broadcasters have now been taken over by private organizations. This has resulted in not only the public broadcaster using this studio but intensive use from other programme making companies. This has led to the development of Studio Villages or Media Cities with a concentration of facilities in a relatively small physical area. For example, 358 audio wireless systems per 1 km^2 are being used in Media Park, Hilversum.

The complex frequency environment of these sites requires detailed frequency planning to ensure that no interference is generated between the devices on site.

2.2 News gathering for TV/radio/internet

Major changes have taken place within this sector in recent years driven by multiple 24-hour news channels plus changes in mobile coverage and the public's requirement for "instant news", thus wireless cameras and radio microphones, including talkback systems and IEMs, will be present at any location where and when breaking news occurs.

TV news providers use radio links in order to provide rapid response coverage of developing news stories. Therefore, video links as well as talkback and radio microphones are used in the production of live and recorded news reports "from the scene".

Traditional terrestrial radio links, known under the term of ENG, consist of one or more microwave links that feed video and audio signals directly from the news location to a broadcaster's network or studio. ENG links are only one of a number of options used to transfer live or recorded material from location to the studio or network, others including:

– Bonded Sim cards are increasingly used for delivering content from camera to studio;
– SNG (satellite news gathering) refers to the use of satellite links;
– Fibre optic links can be used where a location has a fibre termination;
– Store-and-forward over public telecommunications lines can be used for non-live inserts;
– Similarly, non-live inserts can be recorded digitally and carried by motorbike or otherwise to the studio.

Each ENG operator (news provider) requires its own exclusive spectrum, for which it requires round-the-clock access over the designated area; there is no scope for event by event co-ordination as the time taken to respond to a news event is too short.

With the increase in mobile coverage and quality, it is common for a small team to be dispatched using handheld camera and radio microphones possible with DECT for talkback using bonded Sims for link to studio or a satellite phone for difficult locations.

ENG operators also operate a number of trucks, which can be quickly dispatched to a location where a news event is taking place. The truck contains all the facilities required to cover the story and transmits the signal back to the studio or network for (where necessary or appropriate) further production, editing and/or transmission.

It is estimated that altogether, ENG operators providing news coverage in major conurbations with a high density of news events (typically capital and other big cities, like London, Paris etc.) may require allocation on a city-wide basis of up to:

– 25-50 talkback narrowband channels or DECT;
– 15-30 channels for radio microphones;
– The video links are further described in Chapter 4 on video applications.

Indicative numbers for events are given in Table 1.

TABLE 1

Examples of links deployment for news gathering

Event type	Number of crews	Radio microphone	IEM
Local	1	2	1
Main	6	12	6
Large	15	30	20

Local and national sound broadcast stations use audio PMSE equipment for newsgathering, traffic reporting (including airborne use), sports reporting, and other applications. Talkback, radio microphones and audio links are the key services used. However, some stations may use content produced from a central source.

The internet has significantly increased the number of news distribution channels well beyond traditional TV and radio, augmenting the spectrum and equipment demands for ENG. New platforms such as YouTube extensively use PMSE.

2.3 Regular (sport) events and similar outside broadcasts

All forms of audio PMSE applications are used heavily for sports and other outside broadcasts. Such events have been divided into two sectors. This section covers routine outside broadcasts; the sort of events that occur week in, week out throughout the country. Although co-ordination is needed, difficulties rarely arise and no exceptional planning of frequencies is required. Spectrum allocated to other services does not have to be 'borrowed' from other uses to cover events in this section.

Exceptional events such as the Olympic Games occurring each two years[2] require detailed and specialized planning, sometimes on-the-ground co-ordination, and 'borrowing' of spectrum from other services. Other examples are the annual USA Super Bowl and the EBU Eurovision Song contest (see Annex 1).

This distinction should be emphasized: that there are many more regular events than major events. Therefore, it would not be desirable to have to expend the same planning effort that goes into the large events on the events in this section, unless there were clear rewards in terms of spectral efficiency.

The situation has been helped by the increase in availability of radio microphone manufacturer's software enabling scanning of a site and allocating radio microphones into clear spectrum, some units are capable of changing frequency on the fly.

However, it should be obvious that if there is more than one broadcaster covering an event or if several events occur in the same geographical area, then the above estimates should be multiplied by the number of broadcasters. Demand may also increase if it becomes necessary to duplicate some of the links, or use repeaters, etc. for topography or other reasons.

2.4 Sustained growth in the number of microphones and IEMs in use at the largest events

Live music events

In a modern musical concert, each performer typically uses a radio microphone as well as radio in-ear monitor (IEM) system. In the last decade, the PMSE events have grown more sophisticated year-after-year, requiring an increasing number of wireless links. This is coupled with considerable

[2] Considering both the summer and winter Olympic Games.

increase in the number of these live music events, due to the trend in the music industry for musicians to derive most of their income from live performances, rather than from recorded content.

Allocating wireless IEM and microphone to each performer avoids creating a hazard from tripping and affords free movement around stage or set. IEMs provide better overall live sound reproduction, avoid transporting large monitor speakers and amplifiers and associated cables providing a safer, cleaner stage and easier transport logistics, especially for touring productions. Performers now demand IEMs for live or TV performances, even for backing singers, instrumentalists and their technicians.

New television show formats

Audience appetite for new formats of television light entertainment has also driven up demand for microphones and IEMs. For example, contest or casting shows will often have each performer wearing a microphone and body-worn transmitter.

Theatre / Opera

In theatre productions, the audience expectation of quality and reliability sees many lead performers wear double microphones to ensure continuity in the performance in case of equipment failure or interference. In one leading production, eight leading performers each wore dual transmitters, while in other productions requiring quick costume changes, microphones are built into the costumes. All these resilience measures and working practices have developed to ensure continuity and quality, but they have all added to the demand for spectrum.

2.5 Contribution and distribution quality

At a high-level, the stages of production include preproduction (the planning stage), content acquisition/capture (contribution), post-production (editing and sound mixing), delivery (archiving) and then distribution. Within this workflow, content capture is where the intrinsic value lies, and the contribution link needs to deliver the highest quality product possible. Consequently, data compression of the raw audio and video content is kept to a minimum to avoid introducing losses and artefacts which cannot be recovered, and may be made worse, in post-production through to distribution.

It is important to highlight that the original content can serve a variety of markets other than broadcast distribution. For example, the production might have a live audience, be recorded for a DVD or streaming service, archived or prepared for international programme exchange. Each of these distribution options will have different quality expectations, but the initial content capture has to satisfy the highest quality requirements, and therefore contribution quality is typically far greater than that of distribution quality.

To achieve this, content capture uses the minimum compression ratios possible. For audio PMSE, ratios of the order of 2:1 for live performances, and 1:1 in studio environments are used to maintain audio quality with minimum latency. In video PMSE, a greater degree of compression is needed for content capture to reduce the raw video data to a rate that can be supported by the capacity of the radio link, for example, for 20.11 Mbit/s for HD video at 16-QAM 5/6 code rate, 1/32 guard interval, or 40 Mbit/s in a dual 8 MHz channel for UHD high dynamic range video.

As audience expectations grow, the requirement for increased quality of content capture also increases. For video, there has been the evolution from standard definition, through high definition to ultra-high definition with higher frame rates, especially for sports coverage to provide smoother motion. These trends require higher capacity links since higher resolution and higher frame rates both demand additional data to be coded.

Similarly, in audio there is a need for higher quality and increased ‘immersion’ for the audience and viewer and a need to capture the content at the highest quality possible to meet all the requirements for onward distribution and archiving. A digital microphone using 24 bit, 44.1 kHz sampling rate requires a data rate of 1.1 Mbit/s, and for a typical 200 kHz channel bandwidth a low compression ratio of 2:1 is used.

For distribution a compression scheme is applied in most cases. If compression is also applied on production a cascade of compression schemes is faced. If one compression scheme removes part of a sound or image and does not convert and transmit it, a following compression scheme may throw away another part of the remainder. This cascading may lead to a situation where the original content becomes unusable. It is therefore important to minimise data compression during content capture.

Chapter 3

Technical information on audio applications

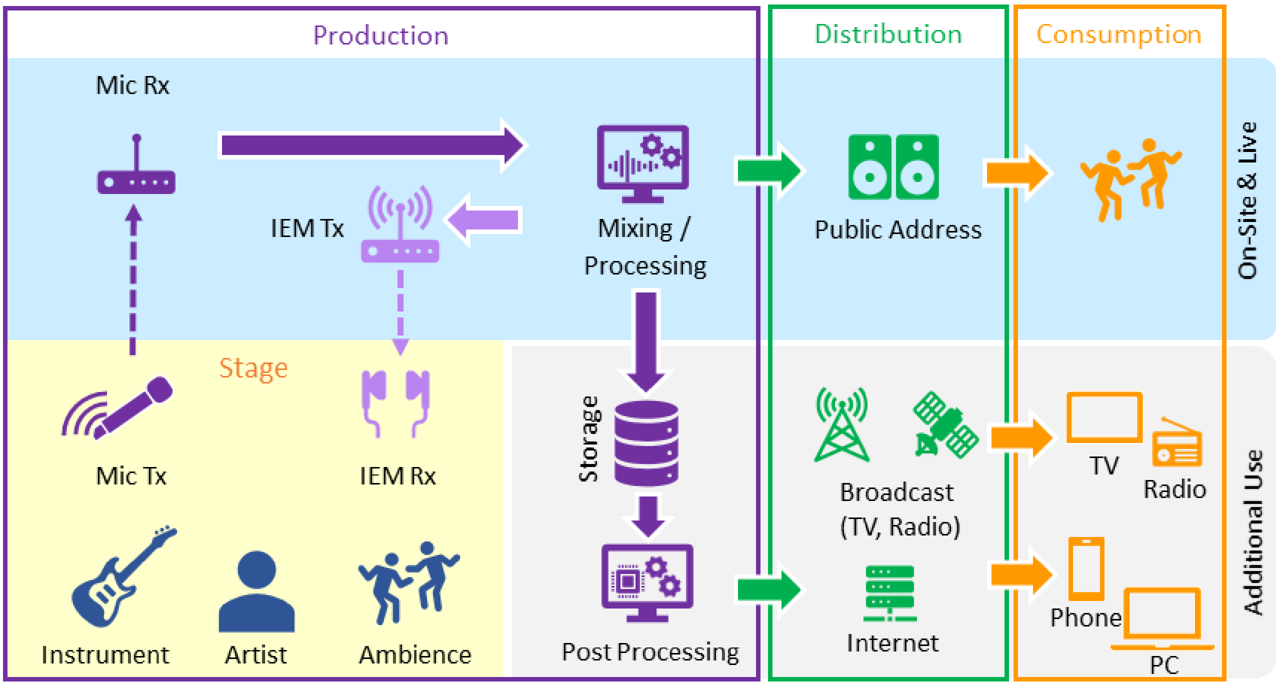
3.1 Overview

Audio PMSE applications use radio microphones, in-ear monitors, and intercom systems in a broad number of activities needing to capture and deliver sound. The operating requirements as well as the number of deployed devices depend on the requirements of the event and vary significantly. This chapter provides information and guidance on the technical and spectrum requirements for audio PMSE. Supplementary technical information is found in Annex 3.

Audio PMSE content capture sits at the start of the supply and value chains for a wide range of products, such as recordings of live performances or the archiving of culturally significant material. Consequently, content capture is expected to provide the highest quality possible, with producers and programme makers taking steps to ensure the quality and robustness of content capture and delivery. Figure 1 illustrates the signal chain from production to consumption.

FIGURE 1

Audio PMSE signal chain



PMSE uses both analogue and digital technology. Although more digital equipment is being introduced, high-end analogue equipment is likely to stay in the market as it brings benefits for users in terms of link latency: being close to 0ms because no signal conversions (analogue-to-digital, digital to analogue) are required. This is particularly important for IEMs.

Digital equipment provides benefits in terms of extended audio quality and flexibility in operational modes. Digital microphones can use techniques such as compression to increase the number of audio channels transmitted within a limited spectrum block, but at the cost of audio quality, reliability, range, latency, or a combination of all of these parameters. The demand for audio PMSE equipment has grown significantly with the increasing number of platforms requiring content. Further, higher resolution audio capture including 3D immersive recordings drive the development of new equipment and radio spectrum demand which show no signs of abating. The explosion of content production is driving the need for audio PMSE to have increasing access to spectrum enabling flexible operation with the required quality of service (QoS).

Professional audio PMSE equipment operates with a wide tuning range to access portions of spectrum that are not occupied by other radio services within the vicinity. The operation of PMSE applications e.g. wireless microphones, IEM and/or WMAS in the same service area require suitable frequency separation. Frequency planning and coordination in the service area are assisted by spectrum scanning procedures and software tools provided by manufacturers including support for mixed vendor deployment. This also supports the possible ad-hoc and nomadic deployments of audio PMSE in service areas (interviews, etc.) where audio PMSE is already in use.

In the recent decades, significant changes have occurred in the available spectrum in all the ITU-R Regions.

Region 1:

- The implementation of the GE06 broadcast agreement on DTTB;
- The WRC-07 decision, known as digital dividend 1, to allocate the frequency range 790-862 MHz to the Mobile Service on a co-primary basis and to identify it for IMT[3];
- The WRC-12 decision known as digital dividend 2 to allocate the frequency range 694-790 MHz to the Mobile Service on a co-primary basis and to identify it for IMT;
- Consequently, DTTB transmissions have been compacted in the frequency range 470-694 MHz resulting in less spectrum availability for PMSE.

Region 2:

Many administrations have or will be re-purposing the 700 MHz band. This occurred in the United States in 2009 as part of the transition from an analogue TV standard to digital, consolidating terrestrial TV broadcast below 698 MHz. The United States of America subsequently also re-purposed the 600 MHz band to mobile and completed its transition in 2020, further consolidating and congesting the remaining 470-608 MHz TV-band. The 700 and 600 MHz bands were heavily used by ENG/PMSE for content creation, specifically wireless microphones (the definition of wireless microphones includes a wide variety of production tools such as intercom systems, in-ear monitors, and interruptible fold-back systems). Thus the Federal Communications Commission (FCC) opened access to alternate frequency bands for wireless microphone operations in the United States (see Annex 2) to partially offset the loss of availability of spectrum in the 700 and 600 MHz bands.

Region 3:

Given the geographical separation of many countries in Region 3, many countries have their own rules and arrangements. For example, in Japan, the band 710-806 MHz which had been assigned to the ENG systems and radio microphones was reassigned to commercial mobile phone and other applications in 2011. In consequence, the 1.2 GHz band and 2.3 GHz band were assigned to the ENG system, and the 470-710 MHz, 1 240-1 260 MHz (except 1 252-1 253 MHz) were assigned to radio microphones.

3.2 Technical aspects

3.2.1 General requirements and operating principles for audio links including radio microphones and in-ear monitor systems

Above all, audio PMSE equipment requires availability of clean, harmonised spectrum. PMSE is often operated in used TV channel which poses a challenge for manufacturers because the bandwidth of TV channel varies among different countries.

A range of technical characteristics for PMSE are interdependent and cannot be treated or adjusted independently.

3.2.2 Quality of service requirements

For PMSE, Quality of Service, QoS, requires that no degradation in the audio signal be perceived during the transmission period. Use of PMSE will vary from a few hours for a news conference to many weeks for a large event such as the G7 conference and permanently for use at studios and theatres.

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[3] International Mobile Telecommunications.

As such, any perceived interference of any form will impact the whole transmission chain. Irrespective if the chain is recorded or broadcast live, interference is likely to mean that the performance will be abandoned and, in many cases, will be unrepeatable. Therefore, interferences must not affect the QoS during the transmission.

Radio microphone and IEM systems must meet the highest demand for audio quality on a consistent and repeatable basis. However, some requirements may also differ from application to application.

The following section focuses on the requirements of high quality PMSE:

The key requirements for a state-of-the-art wireless system are:

– Providing an audio quality similar to an equivalent wired system.
– Low latency. In order to achieve an acceptable latency in the complete audio chain, the latency in the radio microphone at the start of the chain has to be as low as possible (typically below 2 to 4 ms roundtrip, see Report ITU-R BS.2161) especially for IEM applications or where lip sync is observable. For certain applications using radio microphones, delay is permissible for example, where the speaker is not seen by the audience or "on the spot news".

  In the case of IEM whose audio output is received in the ear canal of the user, damage to the user's hearing can occur if interference is generated to the transmission.
– Avoid multiple use of a single radio microphone by different users. Individual adjustment of the microphone's audio sensitivity is an obstacle to handing a microphone over to other users at an event. If the voice of the other user is louder, the limiter will start operating and downgrade the quality. If the voice of the other user is weaker, then it will sound less loud – at the mixing desk more gain needs to be added which will lead to a reduced signal-to-noise performance – a downgrade in audio quality.
– Depending on the application, an operation time of 6 to 10 hours without recharging or changing the power supply is required whereas the small form factor of the transmitter limits the size of the power supply.

3.2.3 Factors that affect the performance of radio microphones and in-ear monitors

The following factors may affect the performance of radio microphones and IEM:

– Interference from other users:
  • Interference (spurious or OOB) from other services that fall into the receiving frequency range of radio microphones and IEM;
  • Adjacent channel interference from other systems or services operating in the channel adjacent to the operating channel itself;
  • Intermodulation products that are generated either by other radio microphones or by other services (e.g. in house PMR use) that fall into the wanted receiving channel.
– Other factors:
  • Size of the venue, deployment density;
  • Properties of the venue regarding screening and antenna positioning;
  • Propagation aspects including multipath and fading;
  • Stage scenery: can introduce 40 dB or more propagation loss.
  • Video walls can cause significant, broadband interference.
  • Lighting and their controllers can also introduce EMC based interference.

3.2.4 Factors that determine the number of channels that can be deployed in a given bandwidth

A sound designer or audio engineer must have a clear understanding of the number of wireless audio channels needed for an event and the necessary spectrum required to support their operation[4]. If insufficient spectrum is available at that location, it imposes a material restriction on the artistic vision required by the director.

The amount and quality of spectrum available at a specific location depends upon:

– Allocations by the national Administration;
– The existing radio spectrum use in the service area (e.g. venue, may have multiple studios or stages);
– The frequency planning (if any) within service area; and
– The restrictions in place via policies of the venue, and license terms and/or national frequency regulation;
– On the tuning range supported by available audio PMSE equipment.

In order to improve the number of audio channels available in a given amount of spectrum, manufacturers have made a number of flexible parameters (e.g. power), but such flexibility must be considered as a trade-off against the robustness required by the production.

Intermodulation

When planning a project, a range of issues need consideration. This includes coordinating around potential intermodulation (IM) products. IM is the result of two or more signals mixing together, producing harmonic distortion. It occurs within active components, such as transistors, exposed to strong RF input signals. When two or more signals exceed a certain threshold, they can drive the active component into a non-linear operating mode that generates IM products that act like virtual transmitters. Without appropriate coordination, IM can interfere with the carrier frequencies of PMSE equipment. This can happen in the RF section of receivers, antenna amplifiers, or the output amplifier of a transmitter. In multichannel operation, when several RF input signals exceed a certain level the intermodulation products grow very quickly. Calculation of frequency sets that coordinate around potential IM products can be done by number crunching software. Problems due to intermodulation generated by the interaction of radio microphones has greatly improved in recent years through highly linear electronic designs that incorporate filters and circulars that suppress potential interfering signals. Regardless, external disturbing sources such as TV transmitters, public safety communications, high power walkie talkies (>5W) used by venue staff as well as security systems, talkback systems, show control systems, and spurious noise from digital equipment, etc., can generate intermodulation that should be taken into consideration. Compatibility among components of a system is achieved if the following conditions are met: each link in a multichannel PMSE wireless configuration functions equally well with all other active links, and no one single link – or any combination of multiple links – cause interference.

3.2.5 Propagation characteristics of frequency bands

PMSE primarily uses spectrum within the UHF frequency band because it provides a favourable balance for equipment in terms of good range, compact size, battery life and penetration through or around obstacles. Lower frequency bands require larger antenna that are less efficient. Higher frequency bands suffer from increased body adsorption effects, shorter range, and are more easily blocked by obstacles.

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[4] This will include density of performers, distance to be covered, make up and size of scenery and any other radio use such as scenery control.

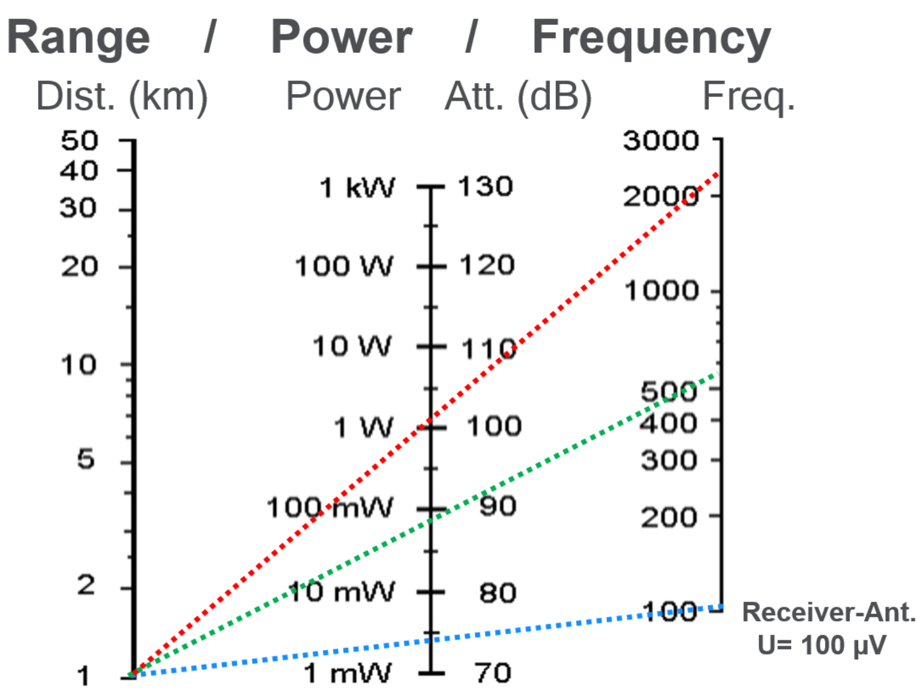
PMSE equipment has extremely high-performance requirements. It must be fully reliable (i.e. no drop-outs), in the case of audio have negligible latency, offer full audio frequency response, and be compact and lightweight. Video equipment in general relies on low latency and an ability to capture and pass onwards the highest quality content possible from the point of operation.

Equipment must also in many cases provide adequate operating range and battery life. Figure 2 shows the relationship between operating range, transmitter output power, and operating frequency. If the intended range is 1 km, and the operating frequency is 100 MHz, approximately 5 mW of transmitter output power is required (bottom – blue line). If the operating frequency is 2 400 MHz, approximately 1 W of power is required to transmit the signal the same 1 km (top – red line) whereas a transmitter operating at 600 MHz requires approximately 100 mW (middle – green line).

This demonstrates a primary reason why most battery powered wireless microphones require operating frequencies below 2 000 MHz, consistent with the conclusions of Report ITU-R BT.2338. Such operating frequencies yield acceptable range with moderate transmitter output power which in-turn affords designs with reasonable battery life of 6 to 10 hours.

FIGURE 2

Relationship between operating range, transmit power, and radio frequency



Some wireless microphones also operate in the upper VHF band of 169-216 MHz. Operating on frequencies much lower than this requires considerably longer antennas that generally suffer from lower efficiency. VHF is generally more susceptible to spurious emissions (i.e. RF noise) from poorly shielded electronics.

The UHF band below 1 GHz is the best band for audio PMSE due to the combination of antenna size, propagation, low body loss absorption and ambient noise floor, especially for body worn equipment. This spectrum contains the highest number of audio PMSE devices worldwide.

3.3 Audio PMSE specific radio technologies

3.3.1 Radio interface technologies

Most manufactures of audio PMSE equipment follow the technical requirements set forth in ETSI standard EN 300 422 [3] as the baseline for their product developments for the global market of audio PMSE equipment and keep the number of product variants to accommodate diverging national regulations to a minimum.

EN 300 422 contains a set of requirements and corresponding measurement tests that need to be fulfilled by audio PMSE equipment for the frequency ranges below 3 GHz for placing products on to the European Union market. Notably, EN 300 422 is also referenced by administrations outside of the European Union.

Three radio architecture interfaces are inherently described as:

a) Narrow-Band Analogue – following a traditional link-based approach;

b) Narrow-Band Digital – following a traditional link-based approach; and

c) Wireless Multi Audio-channel System (WMAS) – following a system-based approach to serve N portables.

Traditional narrow band systems require a separate frequency for each channel and separate racks for radio microphone receivers and IEMs.

Scaling the number of links to support multi audio channel applications in the link-based approach forms quite complex systems with microphone receivers and IEM transmitters being mounted to separate racks to avoid blocking. Each link requires its own centre frequency and RF channel.

Figure 3 shows the general setting for the link-based approach. The radio interface can employ analogue or digital modulation techniques for the audio plane, while the control plane is realized with an additional SRD link or IrDA interface.

FIGURE 3

Radio Interface for traditional Link-based Approach
a) Narrow-band analogue; b) Narrow-band digital

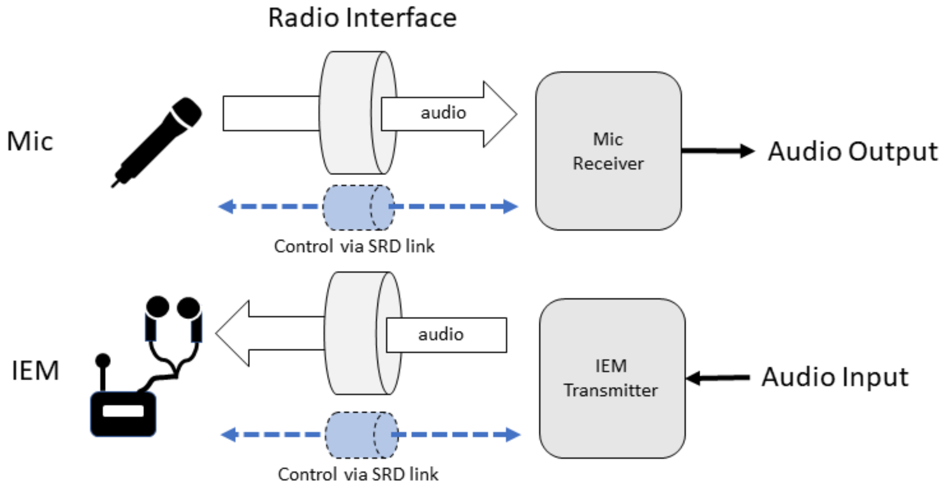
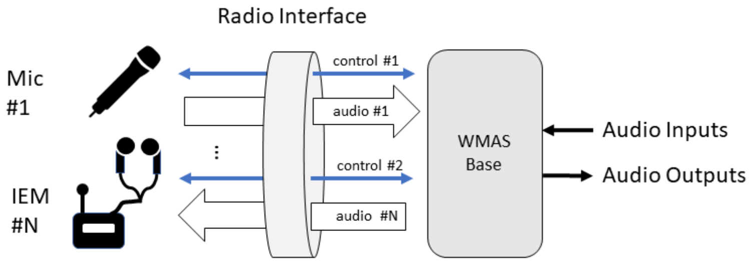


Figure 4 outlines the radio interface of a WMAS that offers multiple audio and control planes integrated in a single wideband radio interface. The direction of each dedicated audio plane is defined by the portable type connected. WMAS can support up to N devices.

FIGURE 4

Radio interface WMAS for #N portables



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

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

Frequency planning and coordination in the service area are assisted by spectrum scanning procedures and software tools provided by manufacturers including the support for mixed vendor deployments. This also supports the possible ad-hoc and nomadic deployments of audio PMSE in service areas (interviews, etc.) where audio PMSE is already in use.

a) Narrow-band analogue

This is defined as an audio PMSE radio interface employing analogue modulation techniques (with a link-based approach (dedicated transmitter-receiver pair for a single audio link transmission on a dedicated centre frequency). The audio content plane is unidirectional carrying a Mono or MPX-Stereo signal. Additional audio links are established via deployment of additional, unique RF channels.

TABLE 2

Parameters PMSE narrow-band analogue audio

Parameter	Description	Comments
Application	PMSE – link-based approach	
Frequency bands		See Annex 2
Channel bandwidth / Channel Spacing	Typical 200 kHz / Free tuning, placement on non-equidistant grid to account for transmitter intermodulation products	(1)
Modulation / occupied bandwidth	Analogue: frequency modulation	(1)
Direction	Audio plane: uni-directional Control plane: employing separate SRD radio interface	
Transmit power	Typical: 10 mW to 100 mW	(2)

TABLE 2 (*end*)

Parameter	Description	Comments
Transmit spectrum mask	EN 300 422 / EN 301 357 / EN 300 454	(3)
Channel access and occupation		
Frequency planning assumptions		(4)
Relevant Standard	EN 300 422 / EN 301 357 / EN 300 454	(5) (6)

(1) EN 300 422 enable certain other channel bandwidths within the range 50 kHz to 600 kHz (WMAS < 20 MHz)

(2) Configuration of portables via IrDA and/or a control plane is established via additional other radio interface in different frequency band.

(3) The maximum transmit power is defined in national radio regulations and interface descriptions. Higher maximum transmit power may be allowed by licensing terms / special permits.

(4) Constant duty cycle, up to 100% occupancy in time.

(5) Audio PMSE, being a low latency critical application, does not allow co-channel operation by other radio interface technologies.

(6) Frequency Planning assisted by spectrum scanning procedures and software includes support for mixed vendor deployments. Time parallel operation of radio microphones, IEM and/or WMAS in same coverage area require suitable frequency separation.

b) Narrow-band (NB) digital

This is an audio PMSE radio interface employing digital modulation techniques with a link-based approach (dedicated transmitter-receiver pair for a single audio link transmission on a dedicated centre frequency). Audio is Mono or Stereo. Additional audio links are established via deployment of additional, unique RF channels.

Digital transmission chains are used in many applications, including SAB/SAP video links. In a digital transmission chain, the acoustic signal is converted into an electric signal which is then transformed through an analogue to digital converter. Typically, the conversion into the digital domain and subsequent source encoding will be selected to obtain the desired trade-off between the transmitted signal quality and the amount of information to be transmitted. Once the signal has been digitized, it can be transmitted as any digital information through a transmission chain that potentially includes channel/forward error coding, mapping of the channel encoded information to a modulation scheme, digital to analogue conversion of the modulated signal, transmission of the radio-frequency signal, analogue to digital conversion of the received signal followed by demodulation and finally decoding of the channel/forward error correcting code.

Such a digital transmission chain may or may not involve a retransmission mechanism in case the packet is not error free at reception.

Typical transmission and reception chains are illustrated in Figs 5 and 6 below.

FIGURE 5

Typical frequency-synthesized digital transmitter

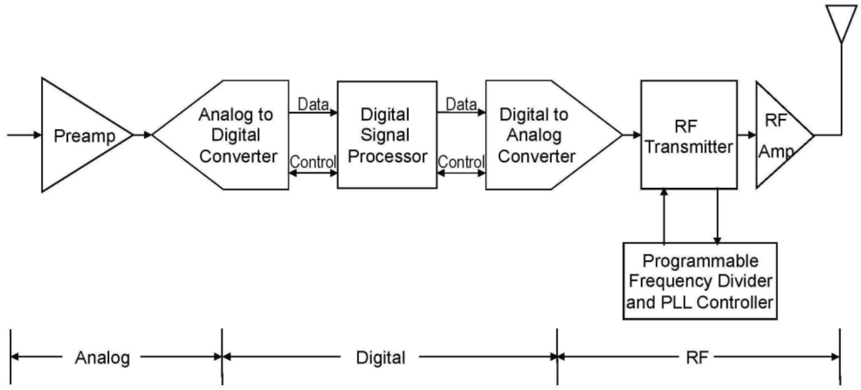


FIGURE 6

Typical frequency-synthesized digital receiver

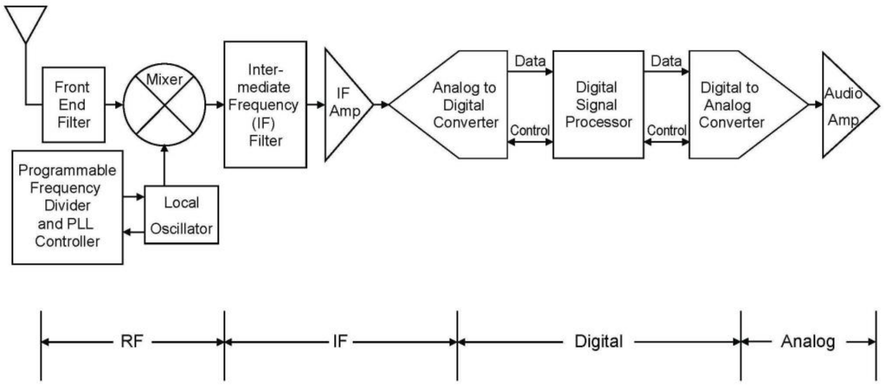


TABLE 3

Parameters PMSE narrow-band digital audio

Parameter	Description	Comments
Application	PMSE – link-based approach	
Frequency Bands		See Annex 2
Channel bandwidth / Channel Spacing	Typical 200 kHz / Free tuning, allowing equidistant grid, placement with typical 200 kHz to 600 kHz channel separation.	(1)
Modulation / Occupied Bandwidth	Digital Modulation	
Direction	Audio plane: uni-directional Control plane: employing separate SRD radio interface	(2)
Transmit Power	Typical: 10 mW to 100 mW	(3)
Transmit Spectrum Mask	EN 300 422 / EN 301 357 / EN 300 454	

TABLE 3 (*end*)

Parameter	Description	Comments
Channel Access and occupation		(4)
Frequency planning assumptions		(5) (6)
Relevant Standard	EN 300 422/ EN 301 357 / EN 300 454	

(1) EN 300 422 enable certain other channel bandwidths within the range 50 kHz to 600 kHz (WMAS < 20 MHz)

(2) Configuration of portables via IrDA and/or a control plane is established via additional other radio interface in different frequency band.

(3) The maximum transmit power is defined in national radio regulations and interface descriptions. Higher maximum transmit power may be allowed by licensing terms / special permits.

(4) Constant duty cycle, up to 100% occupancy in time.

(5) Audio PMSE, being a low latency critical application, does not allow co-channel operation by other radio interface technologies.

(6) Frequency Planning assisted by spectrum scanning procedures and software includes support for mixed vendor deployments. Time parallel operation of radio microphones, IEM and/or WMAS in same coverage area require suitable frequency separation.

c) Wireless Multi-Channel Audio System (WMAS)

WMAS is an audio PMSE radio interface establishing a system-based approach for multi audio channel applications serving e.g. microphone, IEM and talkback in a single or multiple RF channels dependent on capacity required. Additional scaling of capacity (e.g. more audio channels as supported by a single WMAS base) via deployment in additional RF channels is possible. WMAS allows flexible configuration of each audio channel regarding direction (IEM or Mic), mapping of audio channels to a device, latency, audio quality and link reliability. WMAS offers a permanent bi-directional control plane to each portable device. WMAS allows flexible configuration of each audio channel regarding direction (IEM or Mic), mapping of audio channels to a device, latency, audio quality and link reliability. WMAS has been designed to resolve the current latency limitations of digital microphones and IEMs while enabling superior audio quality in multi audio channel setups.

TABLE 4

Parameters PMSE WMAS audio

Parameter	Description	Comments
Application	PMSE – system-based approach	
Frequency bands		See Annex 2
Channel bandwidth / Channel spacing	Typical {6,7,8} MHz (international DTT channel grid) or 10 MHz / Free tuning but accommodating predominant channel raster of incumbent.	(1)
Modulation / Occupied bandwidth	Digital Modulation	
Direction	Multiple audio planes, bi-directional Multiple control planes, bi-directional	(2)
Transmit power / power spectral density (PSD)	Typical: 10 mW to 100 mW	(3) (4)

TABLE 4 (*end*)

Parameter	Description	Comments
Transmit spectrum mask	EN 300 422	
Channel access and occupation	Typical TDD TDMA Constant duty cycle, up to 100% occupancy in time.	(5)
Frequency planning assumptions	ETSI TR 103 450	(6) (7)
Relevant Standard	EN 300 422	

(1) EN 300 422 enables a channel bandwidth of up to 20 MHz for WMAS. However, based on practical considerations, WMAS is likely to be utilized in the channel grid employed by an incumbent service (e.g. broadcasting or other). EN 300 422 requires WMAS to support at least one mode supporting in minimum three audio channels / MHz.

(2) Bi-directional control plane is available, enabling permanent control and reconfiguration of all portables. This enables resource re-assignments at run-time to other portables.

(3) The maximum transmit power is defined in national radio regulations and interface descriptions. Higher maximum transmit power may be allowed by licensing terms / special permits. Larger occupied bandwidth results in lower PSD because maximum transmit power is per device. Example: PSD of an 8 MHz-wide WMAS is 16 dB lower than the one of a single 200 kHz link.

(4) In systems employing TDMA, the total transmit power in a given RF channel is not scaled with the number of WMAS devices deployed because each device only transmits in a short time slot and is limited to the maximum transmit power.

(5) ETSI TR 103 450 also envisions other duplex and multiple access schemes.

(6) Audio PMSE, being a low latency critical application, does not allow co-channel operation by other radio interface technologies.

(7) Frequency planning assisted by spectrum scanning procedures and software includes support for mixed vendor deployments. Time parallel operation of radio microphones, IEM and/or WMAS in the same coverage area require suitable frequency separation.

3.3.2 Standardisation

Most manufactures of audio PMSE equipment follow the technical requirements set forth in EN 300 422 as the baseline for their product developments for the global market and keep the number of product variants to accommodate national regulations to a minimum.

EN 300 422 contains a set of spectrum requirements and corresponding measurement tests that need to be fulfilled for the frequency ranges below 3 GHz for placing products on to the European Union market. EN 300 422 is also referenced by many administrations outside of the European Union either in full or by adopting spectrum masks, etc.

Manufactures have a large number of constraints when developing equipment for the global market. For example, even though wireless microphones are permitted to operate in the UHF TV band nearly every country, the size of the TV band and the TV channel raster varies among different Regions (i.e. 8 MHz in Region 1 vs 6 MHz in Region 2). Thus, standardisation has focused on the spectrum regulatory compliance.

To accommodate a rich set and range of application specific solutions, the technical implementation can differ among manufacturers, intended applications and employed frequency ranges. Hence, enabling manufactures to reach in their implementation technological key performances (e.g. audio quality, streaming latency, power consumption) and economic figures (e.g. price point, value-add), which as combination are currently not possible, or in business perspective not viable, in available standardized wireless technologies.

3.3.3 PMSE wireless solution employing other technology standards (e.g. DECT, 3GPP specifications)

Certain audio PMSE applications for consumer or business use have utilised realized using other standardized wireless technologies, provided that these technologies can fulfil high the required QoS and latency. This helps and relieve the spectrum pressure on the reduced UHF TV broadcast band, and provide ease of use as value-add to the end customer by technology inherent automatic frequency planning and interference management.

Existing

DECT technology (IMT-2000 FDMA/TDMA) for example is employed in ad-hoc settings of non-broadcast audio links to video cameras, solutions for presentation, ad-hoc conferencing solutions and for intercoms and talk backs has partly been

Some 3GPP technologies have been used for contribution by video links for some time. Bonded cellular solutions are used to mitigate the impact of but suffer from network capacity limitations. For some use cases (e.g. single-source video news gathering) these solutions are cost and time-competitive to the alternative options (e.g. satellite). However, they may not be adequate for complex multi-channel and high-value productions. Whether or not future systems will be able to overcome the current using spectrum with suitable propagation look to suffer from the same limitations will largely depend on the feature set and performance of future networks. A number of groups including 5G MAG are exploring the possibilities of 5G for programme production, to date the most successful work suggests private rather than public networks are a good fit for some activities but not all. Annex 1 contains a detailed section on the Peoples Republic of China activities.

Future

The standardisation process of DECT evolution and DECT-2020 (an IMT-2020 technology) at ETSI has partly been driven by audio PMSE stakeholders to improve the suitability and applicability of this technology to additional use cases.

The viability of 3GPP technologies for audio PMSE has been studied in recent public research projects co-funded by German ministries (PMSE-xG, LIPS). The PMSE-xG project pointed especially to several business implications, missing technical specifications or missing support of certain sensitive network functions including requirements to monitor and influence the network behaviour requiring changing before the technology is practical for PMSE use. It was concluded that a value-adding applicability of 3GPP technologies for PMSE is seen in frequency and geographically planned Non-Public Networks (NPN) employing local area licensed radio spectrum and establishing so-called Media Campus Networks. Further potential applications are seen in providing fibre-like connectivity to Audio-Visual (AV) production in remote sites, if it is within the coverage area of the public land mobile networks (PLMN).

In 2018, 3GPP started a feasibility study on Audio-Visual Service Production (AVPROD), which sought to study scenarios and use cases and propose potential requirements for AV production in 3GPP. The results of the study are captured in the Technical Report TR 22.827 Study on Audio-Visual Service Production. Requirements for 3GPP systems have been consolidated in the TS 22.263 Service requirements for Video, Imaging and Audio for Professional Applications (VIAPA) alongside similar requirements from other vertical applications, medical in particular.

TS 22.263 is part of 3GPP Release 17. However, it is expected that the related work will span several future releases. Therefore, improvements in the capability of the 3GPP systems will become available gradually or may not be realized due to complexity or economic reasons.

Viability of the AV production use cases in the 3GPP ecosystem will depend on technological and economic factors.

AV use cases that may fall under the new 3GPP technical specification are available outside 3GPP and in use in the field today using conventional PMSE and DECT technology, cellular bonding (for video) PMSE and audio-visual IP-workflows.

3.4 Future developments related to audio PMSE applications

3.4.1 Enhanced quality, higher resolution formats

Programme making continues to experience a trend for increasing sophistication in sound, depth, and quality. This fosters a need for additional audio channels. This is facilitated by increased use of both radio microphones and IEM in all forms of multimedia platforms, driving an increased requirement for spectrum. This is occurring at the same time as availability of clean, suitable spectrum has been shrinking.

Higher contribution quality on the production side is required for high resolution audio formats, set by production companies. Several high resolution formats are already well established in the market place and the music industry as standard. This has been driven largely by classical music – classic live is one branch in the audio industry that is growing and demands higher audio quality – and other genres are following.

The higher audio resolution that is given by these formats increases the resolution especially in the mid and higher frequencies. This gives more detailed facets of the instruments used and enhances the listener's experience.

Compression in any form, including dynamic compression, is not desirable during the contribution phase as compression always means losses for the subsequent reproduction.

For highest quality applications it is required to produce loss-less audio, without compression – with full dynamic range. This production material will be available for distribution via, TV SD/HD/UHD, CD, DVD, Blue Ray, etc. and future formats can use this recording as the high quality of the original production can be transferred to any future format.

This quality is a real challenge for wireless vocal, instrument and atmosphere/environment microphones, leading to higher number of radio microphones needing full audio frequency response and dynamic range, which increases the RF bandwidth requirements.

3.4.2 New RF channel bandwidth for PMSE equipment

For wired operations, studios currently employ 24 to 48 bit audio resolution. However, a 200 kHz RF channel bandwidth is still almost universal for most wireless audio PMSE devices, which poses a steep obstacle to support such high resolution. The introduction of Wireless Multi-channel Audio Systems (WMAS) with RF bandwidth up to 20 MHz will close the gap in audio quality between wired and wireless configurations and offers potential for greater spectral efficiency. Changes in spectrum regulation will foster this evolution. As technologies advance, higher quality audio to encompass surrounding sounds and other artistic inventions will be required. Greater use of cognitive abilities with narrowband systems and the forthcoming WMAS technology are the most likely response to the user requirements. Further into the future, depending on developments in technologies and access to non-public network spectrum, alternative platforms may be part of the answer.

3.4.3 Cognitive systems

Interference mitigation in PMSE by cognitive behaviour has been studied both in ETSI STF386 and in a German research project. Initial frequency assignments to PMSE links were calculated, frequency handovers due to simulated interference and power control to accommodate a varying link quality were publicly demonstrated. Furthermore, it was shown that link quality supervision can be done on analogue FM links in addition to digital systems.

The system consisted of a number of subsystems: The Local Spectrum Portfolio Manager, the Scanning system, together reflecting the infrastructure, which may be permanently installed at an event location. The C-PMSE is composed of the two subsystems plus the cognitive engine, which is the intelligence in the system, comprised of a database and the wireless audio links.

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

3.4.4 The use of new technology and/or software for preventing co-channel interference to primary users in the 1.4 GHz band

In Region 2, the United States of America has made 1 435-1 525 MHz available for licensed microphone operations on a secondary basis but will require equipment to follow procedures based on new technology and/or software control integrated into the equipment (e.g. an electronic key or related technology/software), together with a coordination process, before operation occurs for each production (where a production can be a single programme or a prescheduled series of programmes at a specified location). The technology/software will limit transmission of microphone signals to previously coordinated and authorized location(s), dates, and time periods. Microphone transmitters must automatically shut down if operation is attempted beyond these parameters. Wireless microphone license eligibility is limited to professional users and use of the range 1 435-1 525 MHz is intended for major events at a fixed location at large venues, such as those requiring 100-plus wireless microphones (includes monitors and intercom channels). Power limits are 250 mW per transmitter during major, pre-scheduled programmes.

The primary user in the band is aeronautical mobile telemetry (AMT), the operations of which in the United States of America involve safety of life. See also RR No. **5.343**. AMT operations are often scheduled in advance, as are broadcast operations, facilitating coordination. Together with the technological advances and regulatory restrictions mentioned above, the conditions for wireless microphones to share with AMT operations on a non-interference basis are maximized.

3.5 Deployment of audio PMSE applications depending on the category

PMSE is conducted both indoors and outdoors; terrestrial, airborne and marine, summarized in Table 5.

TABLE 5

Deployment by category

Sector	Deployment/Location of use	Deployment/Area of use
Theatres, rock, pop and touring shows	Everywhere	Indoor and outdoor
Studio production	Dedicated fixed site	Predominantly indoor
Demand for news gathering for TV/radio/internet	Everywhere, airborne, marine	Predominantly outdoor
Demand for sound broadcasters	Everywhere, airborne, marine	Indoor and outdoor
Demand for casual (sport) events and similar outside broadcasts	Everywhere, dedicated locations, airborne, marine	Predominantly outdoor
Demand for large outside broadcasting	Everywhere, airborne, marine	Indoor and outdoor
Demand of coverage of major events	Everywhere, airborne, marine	Indoor and outdoor
Demand for film and advert production	Everywhere, dedicated locations, airborne, marine	Indoor and outdoor

TABLE 5 (*end*)

Sector	Deployment/Location of use	Deployment/Area of use
Conference/political events	Everywhere, dedicated locations	Predominantly indoor but also outdoor

Chapter 4

Technical information on Video applications

4.1 Introduction

This section focuses on the video aspects of PMSE. However, any and all forms of PMSE equipment are liable to be present at any event or use of video links.

The introduction of digital television generated great advances in picture quality with a similar advance in TV and computer screen reproduction. As can be seen from information in this section, such advances come with a cost: greater spectrum use.

Broadcasters are moving rapidly from HD towards 4K with HDR and higher frame-rates. All this additional information needs to be transmitted and uses extra bandwidth. And although High Efficiency Video Coding (HEVC) helps with additional compression, it is still required to transport between 20 and 60 Mbps in low latency. For the lower bitrates, this can still be done in a 10 MHz channel using DVB-T2 and HEVC. For higher bitrates, however, 4K uses the so-called dual pedestal, meaning twice the bandwidth of a standard DVB-T2 HD camera. So, each wireless 4K camera ideally requires 20 MHz for operation.

Technological advances have combined with audience appetite for richer, more immersive viewing experiences in live sport. Point-of-view footage captured by on-board cameras (such as those on Tour de France bikes, or on Formula One cars) allows fans to experience the action from the “best seat in the house”. Dedicated “player cams” now track individual footballers in close-up around the pitch, in addition to the main live video feed of the match. Advances in drone technology means that the capture of aerial footage is no longer the preserve of broadcasters with access to aircraft and is therefore an increasingly common addition to programme-making.

Traditional television viewing is now complemented, or in some cases superseded, by internet or mobile-centric platforms which either purchase existing content or increasingly make their own. Much of this content is produced specifically for consumption on official social media channels, as a means of deepening fans’ engagement with their favourite sports and sportspeople.

In television light entertainment, new formats such as spin-off shows and reality shows, are also behind the increased use of wireless cameras, as broadcasters attempt to capture “fly on the wall” footage from every conceivable angle.

The cumulative effect of the demand for ever-more personalised and varied content is a growth in demand for video PMSE spectrum.

With the introduction of small battery HDTV cameras, their use has expanded to include aerial shots from drones and remote control boats, etc. adding to the spectrum required for a shoot.

Content for broadcasters also include “Film”: Film production boomed in Europe over the past ten years. More than 18 000 films were produced in Europe between 2007 and 2016, with overall production on the continent growing by 47%, from 1 444 feature films in 2007 to 2 124 in 2016. An upward trend for most of the period was recorded for both purely national productions and co-productions. Majority co-productions accounted for 20.4% of the overall production volume on the continent over the said period. The volume of documentaries boomed, almost doubling, to 698 films in 2016, while production of feature fiction also rose significantly, by 33%.

4.2 Wireless video cameras and video links

4.2.1 Rationale for cordless use

The question is often asked "why not use wired cameras and reduce the spectrum demand?" Analysys Mason, commissioned by Ofcom UK, investigated the use of cameras for the London Olympics and Paralympics and produced two reports [5] "for spectrum planning for the 2012 Olympic and Paralympic Games" and a part 2 which went into greater depth on a London wide hybrid system.

This report states that a reduction in level of usages of wireless camera less than that used in the Beijing Olympics is not a viable option for the London Olympics.

In addition to those reports, a range of other factors need to be taken into account, one major consideration is the Health and Safety aspects of any wired PMSE equipment at a site or venue, others are:

– Producers and directors have found greater artistic freedom in camera shots with increasingly smaller high definition units;
– Scenes can be shot anywhere indoor or out at short notice;
– With the miniaturization of camera units a number of cameras can be spread around a stage or studio providing the producer with multiple views to choose from:
  • Use in sport includes referees in football and bail cameras in cricket;
  • There is no other practical way to transfer images from sportsman's helmets and cars without the use of radio spectrum;
– Instant news stories in their varied forms do not allow for the time taken to "wire up" a site.

Thus, the answer to the question "why not use wired Cameras and reduce the spectrum demand?" are many and varied.

4.2.2 Changes in use of video links

With the spread of fibre optic cables and switching within the Telecommunications networks providing high quality definition and low latency it became practical to expand the number of network insertion points for regular sporting and cultural events and in many cases for regular news venues thus allowing the output from wireless cameras to be transferred to the studio without the use of high-power video links which previously were the only practical way to achieve the high "contribution" quality connection required between the site and a suitable Network Terminating Point.

4.2.3 Other platforms for wireless cameras

For a range of subjects such as instant news or internet use, viewers will accept lower or even poor quality pictures but not for other content such as sport or conventional TV and Film.

Mobile phones

With the increase in quality of mobile phone cameras and the mobile phone networks it is common and acceptable to see content from them incorporated into instant news stories especially accidents, or into internet content of social media sites. However, the use of mobile phone networks introduces latency which becomes evident in a two-way interaction between studio and interviewer which can be subject to delay in both video and audio.

Multiple Mobile phone channels (channel bonding)

A number of units are available on the market combining a number of mobile phone Sims to increase the bandwidth and thus the quality of a transmission. These still suffer from the network latency issues and are mainly used for “first to site” to gain a time advantage for conventional ENG crews.

In addition, the capacity of Mobile phone channel bonding is extremely variable, usually badly congested at major events and sites, and often only 100 kHz or 200 kHz capacity at best, or not available at all because of cell congestion.

Satellite phones

Extremely successful in providing content from war zones or other difficult to access areas, primarily used for news stories. High-cost option.

Wi-Fi

A number of low-quality wireless cameras are available using the 2.4 GHz and 5 GHz bands; however, these tend to be for non-professional domestic or security use. High quality very short-range links are possible i.e. to an adjacent plasma screen.

IP links using dedicated spectrum

Although ASI over IP is not the most efficient way (bits per Hertz) of transporting the data, there are a number of advantages using these point-to-point links in outside broadcasts:

– One system carries all the video and communication bidirectional;
– Low delay (must have a dedicated network);
– High bitrates (amount of data);
– Cost (practically off the shelf customer products);
– Easy to connect to other IP based systems.

These systems will only work when using a dedicated private network, such as a point to point fibre.

4.2.4 Next generation cordless cameras

Professional radio cameras tend to use DVB-T COFDM technology and achieve a spectrum efficiency of the order of 3 bits/sec/Hz. The BBC's Research and Development department prototyped a more advanced radio camera in 2015 using ‘Multiple Input Multiple Output’ (MIMO) technologies in conjunction with COFDM to provide increased throughput. By using LDPC error correction technology similar to that used in DVB-T2 and DVB-NGH, a spectrum efficiency of 4 bits/sec/Hz was demonstrated, and it was envisaged that systems providing up to 6 bits/sec/Hz could be developed. At the time of writing, no COFDM MIMO radio cameras are commercially available, however 5G technologies, which make use of MIMO techniques are currently being investigated for next generation wireless cameras

In November 2021, based on 5G Multicast and Broadcast Services (MBS), CBN completed the verification of new broadcasting services such as multi-angle viewing and panoramic VR video live broadcasting in the Beijing Winter Olympics test events. This is the world's first system capability verification of 5G MBS in commercial scenarios, which is of great significance to the subsequent acceleration of the industry chain maturity and full-scenario business innovation. Please see Annex 5.

Video PMSE is making greater use of higher frequencies such as the allocations around 7 GHz and above. This is relieving demand pressure on the core sub-3 GHz video PMSE bands. In exceptional cases, such as that of Formula 1 (which sees the largest simultaneous use of video PMSE at a single event), a migration to much higher frequencies has been accomplished. However, it is important to note that this solution is an exceptional case and not applicable to other use cases of video PMSE.

Use of higher frequencies (above 3 GHz) may be suitable for some short-range terrestrial PMSE use cases. But cycling, marathons, triathlons, and cross-country skiing rely on high-altitude microwave mid-points which need frequencies below 3 GHz for non-line-of-sight coverage. Similar considerations apply, for example, to the World Rally Championship racing where helicopters and fixed wing aircraft are an integral part of the content delivery system.

Where motorcycles are used, an important consideration is the safety of the cameraman seated at the rear of the bike and often facing backwards. At frequencies below 3 GHz, the EMF safety limits can be achieved; however, as frequencies become higher more power is required to maintain the same coverage and thus the EMF safety limit might be exceeded.

Service links

In addition to the video signal service links are required in many cases:

A PMSE service link is a communication channel that connects two or more devices for the purpose of data transmission. The link may be a dedicated physical or a virtual circuit that uses one or more physical links or shares a physical link with other telecommunication links such as wireless fixed links, communication satellites, terrestrial radio communications infrastructure and computer networks.

Audio PMSE uses service links primarily between the transmitter and receiver to allow battery information and in some cases changes in parameters such as power. The 2.4 GHz band is preferred for these links being common throughout the world.

Video PMSE requires many control service links, which may be carried either in-band of the video channel or in other spectrum. Examples are:

- data communication between a stand-alone camera and a base station;
- intercom station connected with another single internal intercom station;
- video communication between a stand-alone camera and a base station;
- a radio path between two points (Porto-Porto);
- two nodes of a network.

Broadcast links (as in one-to-many transmission) connect two or more nodes and support broadcast transmission, where one node can transmit so that all other nodes can receive the same transmission.

A broadcast link for PMSE use is for example:

- Wireless timecode for ENG;
- Wireless DMX for lightning;
- Ethernet;
- Director’s intercom (broadcast) with several listen systems for the crew.

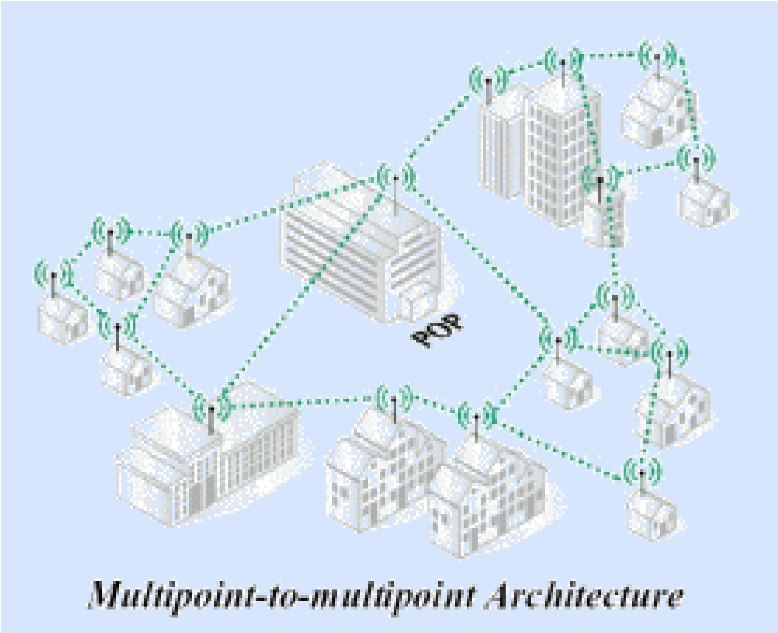
A multipoint link is a link that connects two or more nodes. Also known as general topology networks, these include ATM and Frame Relay links, as well as X.25 networks when used as links for a network layer protocol like IP.

Unlike broadcast links, there is no mechanism to efficiently send a single message to all other nodes without copying and retransmitting the message.

A multipoint link for PMSE use is, for example, a mesh network in which any radio station can be used as an intermediary to establish a connection to a point that cannot be reached directly.

FIGURE 7

Multipoint to multipoint network architecture



Point-to-multipoint link (or simply a multipoint) is a specific type of multipoint link which consists of a central connection endpoint (CE) that is connected to multiple peripheral connection endpoints. Any transmission of data that originates from the central CE is received by all of the peripheral CEs while any transmission of data that originates from any of the peripheral CEs is only received by the central CE.

Forward link is the link from a fixed location (e.g. a base station) to a mobile user. If the link includes a communications relay satellite, the forward link will consist of both an uplink (base station to satellite) and a downlink (satellite to mobile user).

Reverse link (sometimes called a return channel) is the link from a mobile user to a fixed base station. If the link includes a communications relay satellite, the reverse link will consist of both an uplink (mobile station to satellite) and a downlink (satellite to base station) which together constitute a half-hop. Examples of reverse links for PMSE use are:

- Data between motorcycle-helicopter-and ground station;
- wireless MIDI[5];
- Bluetooth;
- SNG.

Links are often referred to by terms that refer to the ownership or accessibility of the link:

- A private link is a link that is either owned by a specific entity or a link that is only accessible by a specific entity;
- A public link is a link that uses the public switched telephone network or other public utility or entity to provide the link and which may also be accessible by anyone.

In some cases, the same data is transmitted over several frequencies in order that the systems keep working and can work safely even when a data channel is interrupted.

More complex PMSE systems, for example a wireless camera robot, needs many service links:

---

5 Musical Instrument Digital Interface.

- Geolocation;
- Multipoint frequency for driving;
- Point to point frequency for safety;
- Reverse link frequency for moving head/data;
- Point to point frequency for video;
- Broadcast link frequency for shading.

4.3 Description of video PMSE applications

PMSE covers a wide range of equipment and applications. This section addresses wireless cameras and associated video links. These links will often also carry the associated radio microphone audio, service links and telemetry.

Video PMSE is the process of capturing the image and taking it from the camera to the production centre. Table 6 provides the definitions of video PMSE links.

TABLE 6

Definition of video PMSE links (subset of Annex 1 of ERC/REC 25-10)
https://docdb.cept.org/download/3424

Type of link	Definition
Cordless camera (CCL)	Handheld or otherwise mounted camera with integrated transmitter, power pack and antenna for carrying broadcast-quality video together with sound signals over short-ranges. This can be line of sight or non-line of sight depending on application and frequency band used (e.g. trackside at sports event).
Portable video link (PVL)	Handheld camera with separate body-worn transmitter, power pack and antenna. Usually higher power than cordless units.
Mobile air-to ground video link (MAGL)	Video transmission system employing radio transmitters and receivers mounted on helicopters, airships, drones or other aircraft (including repeaters and relays).
Mobile vehicular video link (including ground-to-air) (MGA)	Video transmission system employing radio transmitters mounted in/on motorcycles, racing motorbikes, pedal cycles, cars, racing cars or boats. One or both link terminals may be used while moving.
Temporary point-to-point video links (TPL)	Temporary link between two points (e.g. part of a link between an OB site and a studio), used for carrying broadcast quality video/audio signals. Link terminals are mounted e.g. on tripods, temporary platforms, purpose built vehicles or hydraulic hoists. Two-way links are often required.

Examples

Any and all of the PMSE elements described above plus audio PMSE and service links may be present in a production as illustrated in Fig. 8.

FIGURE 8

Actual example of ENG/OB demand for audio and service link channels in a European event

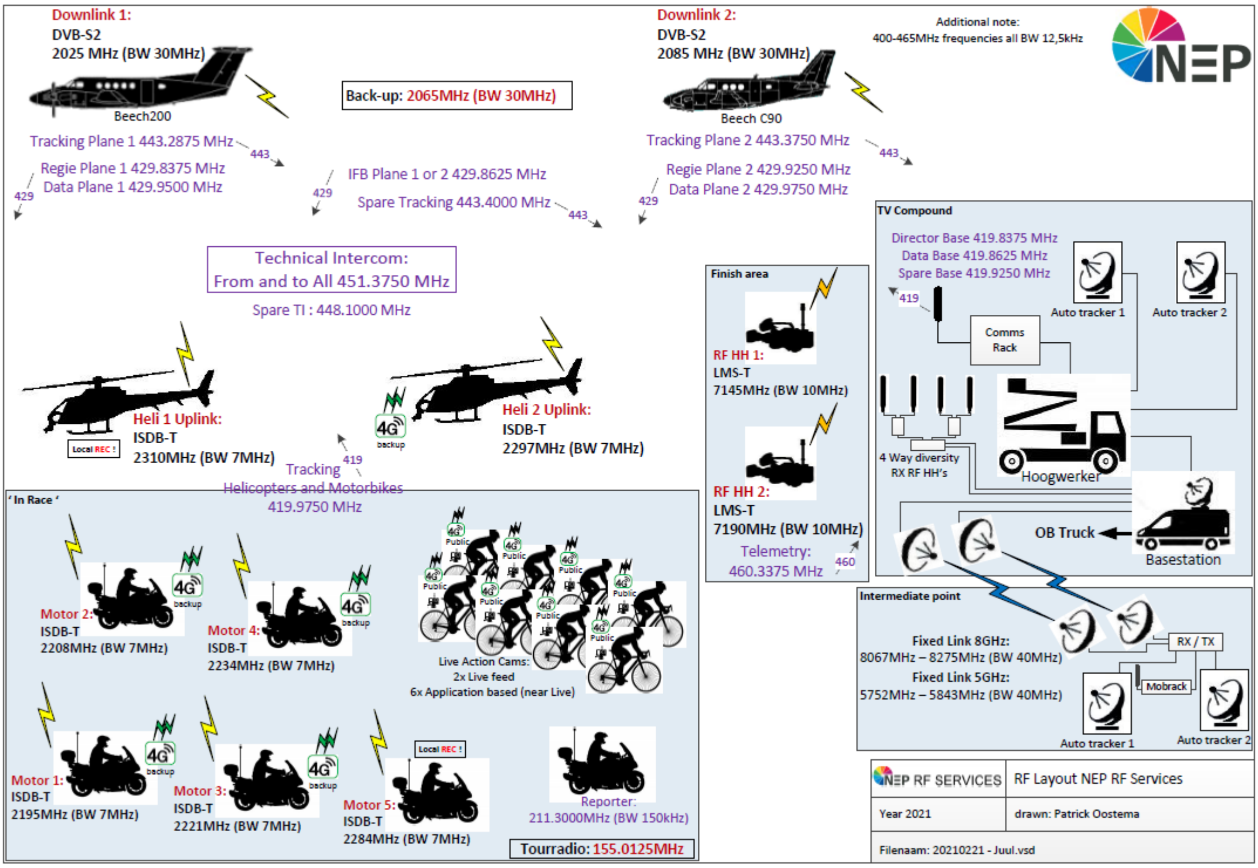


FIGURE 9

Wireless camera

As shown in Fig. 9, conventional wireless camera transmitter docks on the back of a traditional camera. Audio is incorporated with the pictures on the wireless camera link either from an on-board microphone or there may be a separate radio microphone receiver mounted on the camera. Remote control of the camera for colour balance, iris and tally light can also be by radio telemetry via a separate wireless channel received on the camera.

FIGURE 10

Cordless on-board camera

Often to bring pictures from close to the action, miniaturized cameras and transmitters are mounted on participants in cycling and motorsport (see Fig. 10), utilizing low profile antennas, such as patch antennas, to minimize the impact on performance. These can then be received on the ground via a network of switched receivers placed along the route, or received via an airborne platform.

To give a reliable link over a greater range, a Portable Camera Transmitter is used along with a directional antenna. In the example in Fig. 11 below, the unit is being moved to a new location, the transmitter, portable power supply, test equipment and the directional antenna are carried on a trolley. Once in place the camera is connected to it by cable. Typical applications would be motorsport or a golf course where the camera location is determined by the action. The equipment may also be mounted on a vehicle such as a golf buggy.

FIGURE 11

Portable camera transmitter

Mobile links can be mounted on a variety of vehicles including cars, buggies and motorcycles. In the example depicted in Fig. 12 below the cameraman sits on the rear of the motorcycle connected by cable to the video link, its components in the rear panniers and above the rear wheel. A low gain, typically a patch antenna, is mounted high, for safety and a clear view of the sky. RF power is limited by the EMF human exposure limits.

FIGURE 12

Mobile vehicular video link

FIGURE 13

Airborne video link

Above in Fig. 13, the gyroscopically stabilized camera can be seen on the front of the helicopter with receive and transmit antennas mounted on the landing skids. Other airborne vehicles such as airships and tethered blimps can also carry video links.

As well as relaying pictures directly from the on-board camera the airborne platform can additionally receive multiple links from the ground, then transpose and transmit them down to another point on the ground. In Fig. 14 below is an example of the on-board equipment required, perhaps for coverage of a marathon or cycle race.

FIGURE 14

Airborne video link equipment

FIGURE 15

Temporary point-to-point video links

Figure 15 shows auto tracking units installed in a hydraulic lift. These units will track by means of GPS information from the helicopter, or aircraft downlinks.

Point-to-point video links are used to relay pictures, sound and data from remote locations to a central production location. Programme makers need their own high quality, low delay links to be able to seamlessly combine the elements of a production. These may be relatively short distances for an individual camera at a horse racing meeting or many kilometres from a remote outside broadcast part way along a cycle race, to the finish line.

4.3.1 Applications versus spectrum limitations

4.3.1.1 Airborne use

Whilst the majority of airborne use is from helicopters, there are also a range of other airborne use from fixed wing aircrafts, airships to parachuting and the recent sub space height record. Expanding use of drones has given the directors ability to provide unusual shots for all productions.

Please note: Relay plane use high altitude (20 000 ft, approximately 6 100 m) often giving the need for cross-border harmonization for PMSE frequencies and a quick coordination scheme between Administrations.

All of these applications have one thing in common: a requirement for the transmitter and receiver antenna to “see” each other whilst the subject is moving.

Whilst auto tracking systems are a vital part of the link budget, the physical factors and the beam width determine the success of such a system.

Currently the 2-3 GHz band proved the best and, in some cases, the only spectrum available for airborne use.

4.3.1.2 Car and motorcycle use

This varies from rally cars to hill climbs and track racing: in each application the speed and terrain stretch the limits of the link budget with added complications of propagation in forests and pit arrears. Antenna size and coverage on both the transmitter and receiver have physical and technical limitations.

Once again, the best and in many cases the only practical combinations can be achieved in the 2-3 GHz band.

4.3.1.3 Cycle racing both road and track

Wireless cameras have a number of locations when covering these applications, the prime one being the helmet camera of the cyclist which is physically small and limited in its antenna size and its output power (by both power source and EMF limits).

In addition, vehicle, motor bike and airborne use will be used to cover an event.

Once again, the best and in many cases the only practical combinations due to the obstructed propagation path can be achieved in the 2-3 GHz band.

In many cases a low power head camera will be relayed to an aircraft or helicopter via a motorcycle, once again the EMF safety issue need careful consideration for the motorcycle personal.

4.3.2 Other applications

A range of activities such as yachting and powerboat racing will suffer from similar issues to those above plus the propagation losses from operating over water. In many cases a relay helicopter (Fig. 16) will be used to provide the link back to the Outside Broadcasting venue.

FIGURE 16

Relay helicopter

Golf in particular suffers from obstructed line of sight propagation even when using golf buggies as repeaters.

The video relay situations today is mainly based on high altitude airplane support instead of multiple helicopters.

– IP links between aircraft and base station (IP over DVB-S2).
– F1 migration to spectrum between 8 and 11 GHz. (It is assumed that this was due to a technology change in the cars, where on-board video is multiplexed onto channels in the 8-12 GHz band, rather than the 2 GHz band)
– UHD HDR over T2 or dual pedestal using DVB-T.
– 4G TDD private LTE in PMSE spectrum for multiple onboard cameras is now used during productions.

Annex 1

Deployment examples by country or event

Japan

HDTV/UHDTV digital terrestrial electronic news gathering (ENG) in Japan

Digital terrestrial ENG systems have been indispensable for broadcasters in Japan for transmitting video materials from the site of on-going news, sport or other events to studios at broadcasting stations. It is very much to a broadcaster’s advantage to have its own private transmitting landlines to initiate live broadcasts on established temporary point-to-point connections during a major natural disaster or accident.

This section describes the frequency bands, characteristics, use cases and developments of ENG systems in Japan.

Technical parameters

Tables 7 and 8 show technical parameters for the transmission of digital TV signals over portable microwave links.

TABLE 7

Example of user requirements and technical parameters for transmission of digital HD/SDTV signals over fixed/airborne (line-of-sight) portable microwave links

<table>
<tr><td colspan="2">Frequency</td><td colspan="2">1.2 GHz band (HDTV)
(The parameters are extracts of ARIB[6] STD-B57)</td></tr>
<tr><td colspan="2">Modulation</td><td>32-QAM(3/4)-OFDM</td><td rowspan="6">Transmission distance: 50 km</td></tr>
<tr><td colspan="2">Channel spacing</td><td>18 MHz</td></tr>
<tr><td colspan="2">Transmission power</td><td>25 W</td></tr>
<tr><td rowspan="2">Fixed</td><td>Tx antenna</td><td>Yagi</td></tr>
<tr><td>Rx antenna</td><td>Yagi</td></tr>
<tr><td colspan="2">Transmission capacity (TS rate)</td><td>45 Mbit/s</td></tr>
<tr><td colspan="2">Frequency</td><td colspan="2">2.3 GHz band (HDTV)
(The parameters are extracts of ARIB STD-B57)</td></tr>
<tr><td colspan="2">Modulation</td><td>32-QAM(3/4)-OFDM</td><td rowspan="6">Transmission distance: 50 km</td></tr>
<tr><td colspan="2">Channel spacing</td><td>18 MHz</td></tr>
<tr><td colspan="2">Transmission power</td><td>40 W</td></tr>
<tr><td rowspan="2">Fixed</td><td>Tx antenna</td><td>Yagi</td></tr>
<tr><td>Rx antenna</td><td>Yagi</td></tr>
<tr><td colspan="2">Transmission capacity (TS rate)</td><td>45 Mbit/s</td></tr>
<tr><td colspan="2">Frequency</td><td colspan="2">6-7 GHz, 10 GHz, and 13 GHz bands (HDTV)</td></tr>
<tr><td colspan="2">Modulation</td><td>64-QAM(3/4)</td><td rowspan="3">Nyquist bandwidth: 13.5 MHz
Roll off: 30%
Transmission bit rate: 81 Mbit/s
Information bit rate: 60 Mbit/s
Modulation: 64-QAM</td></tr>
<tr><td colspan="2">Channel spacing</td><td>18 MHz</td></tr>
<tr><td colspan="2">Transmission power</td><td>1.5 W</td></tr>
<tr><td rowspan="2">Fixed</td><td>Tx antenna</td><td>0.6 m dish</td><td rowspan="2">Transmission distance:
6-7 GHz: 50-100 km
(depending on necessary margin)
10 GHz: 7 km
(with necessary rain margin)
13 GHz: 5 km
(with necessary rain margin)</td></tr>
<tr><td>Rx antenna</td><td>0.6 m dish</td></tr>
<tr><td rowspan="2">Airborne</td><td>Tx antenna</td><td>0.2 m dish</td><td rowspan="2">Transmission distance:
6-7 GHz: 50-65 km
(depending on necessary margin)
10 GHz: 7 km
(with necessary rain margin)
13 GHz: 5 km
(with necessary rain margin)</td></tr>
<tr><td>Rx antenna</td><td>1.2 m dish</td></tr>
</table>

[6] ARIB: Association of Radio Industries and Businesses.

TABLE 7 (*end*)

<table>
<tr><td colspan="2">Frequency</td><td colspan="2">6-7 GHz, 10 GHz, and 13 GHz bands (HDTV/UHDTV)
(The Parameters are extracts of ARIB STD-B71)</td></tr>
<tr><td colspan="2">Modulation</td><td>1024-QAM-OFDM</td><td rowspan="6">Transmission distance:
6-7 GHz: 50 km
10 GHz: 7 km
13 GHz: 5 km</td></tr>
<tr><td colspan="2">Channel spacing</td><td>18 MHz</td></tr>
<tr><td colspan="2">Transmission power</td><td>2.5 W</td></tr>
<tr><td rowspan="2">Fixed</td><td>Tx antenna</td><td>0.6 m dish</td></tr>
<tr><td>Rx antenna</td><td>0.6 m dish</td></tr>
<tr><td colspan="2">Transmission capacity (TS rate)</td><td>104 Mbit/s</td></tr>
<tr><td colspan="2">Frequency</td><td colspan="2">42 GHz / 55 GHz (HDTV/UHDTV)
(The parameters are extracts of ARIB STD-B43)</td></tr>
<tr><td colspan="2">Modulation</td><td>16-QAM(3/4)-OFDM</td><td rowspan="6">Transmission distance:
42 GHz: 4 km
55 GHz: 3 km</td></tr>
<tr><td colspan="2">Channel spacing</td><td>125 MHz</td></tr>
<tr><td colspan="2">Transmission power</td><td>0.5 W</td></tr>
<tr><td rowspan="2">Fixed</td><td>Tx antenna</td><td>Dish (40 dBi)</td></tr>
<tr><td>Rx antenna</td><td>Dish (40 dBi)</td></tr>
<tr><td colspan="2">Transmission capacity (TS rate)</td><td>240 Mbit/s</td></tr>
</table>

NOTE 1 – User requirements and technical parameters in terms of basic video and audio quality for transmission of digital UHDTV/HDTV/SDTV signals in ENG applications are provided in Recommendation ITU-R BT.1872-1 – User requirements for broadcast auxiliary services including digital television outside broadcast, electronic/satellite news gathering and electronic field production.

NOTE 2 – Parameters of BAS video link systems operated in the mobile service are provided in Table 1 of Annex 1 to Recommendation ITU-R M.1824-2 – System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies.

NOTE 3 – Digital FS system parameters for BAS Video Systems are provided in Table 1 of Annex 2 to Recommendation ITU-R F.1777-3 – System characteristic of television outside broadcast, electronic news gathering and electronic field production in the fixed service for use in sharing studies".

Development of PMSE equipment for UHDTV in Japan

Ultra-high definition television (UHDTV) is certain to be one of the major applications of next-generation digital terrestrial broadcasting. Recommendation ITU-R BT.2020 – Parameter values for ultra-high definition television systems for production and international programme exchange, was published for this purpose in 2012.

Since 2012, studies on the transmission of UHDTV on DTT networks were started in several countries, and the results were summarized in Report ITU-R BT.2343. Additionally, ITU-R developed Recommendation ITU-R BO.2098 in 2016.

With ever more programmes being produced for UHDTV, PMSE for UHDTV has become an urgent requirement.

This section addresses the latest developments in PMSE for UHDTV.

42 GHz band transmission system for 8K UHDTV

A 42 GHz band transmission system for 8K signals was developed in Japan in 2016. This system transmits high quality 8K video and audio signals from the field (event venue, interview location etc.) to the broadcast station. This system uses Multiple-Input and Multiple-Output (MIMO) with dual polarization and can transmit up to 600 Mbit/s.

Technical specifications

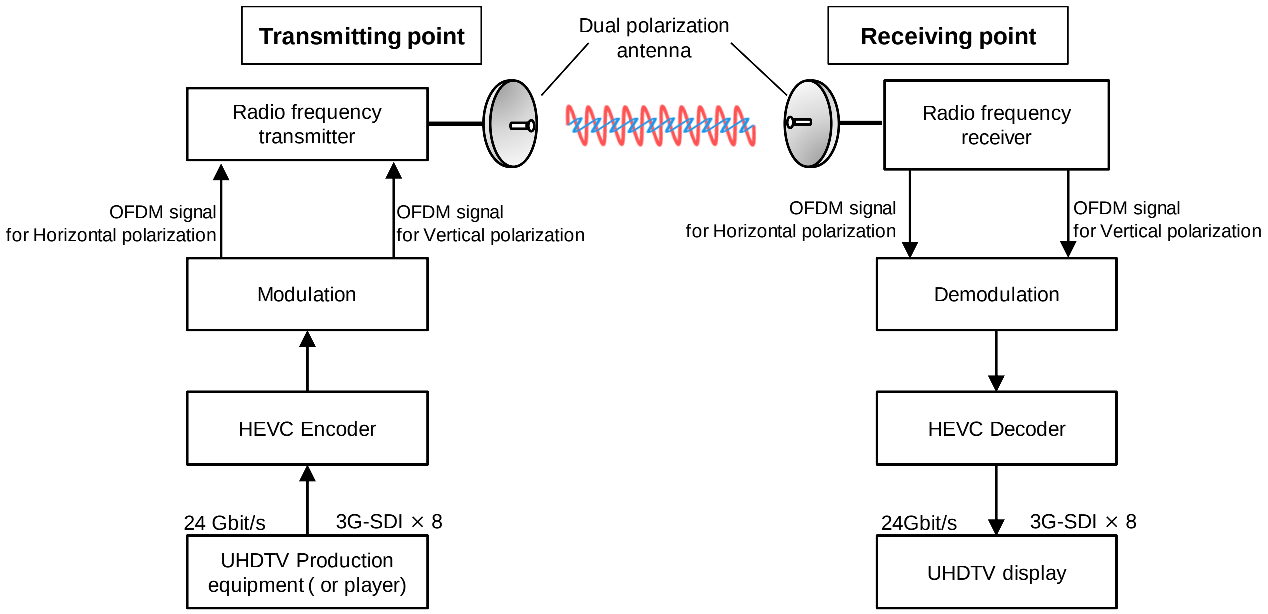
The block diagram of the 42 GHz transmission system is shown in Fig. 17.

On the transmitting side, 8K signals are encoded at the HEVC encoder and the error correction code and OFDM modulation are applied at the modulator for each polarization. Frequency conversion and power amplification are next performed at the radio frequency transmitter and, finally, the vertical and horizontal polarization waves are transmitted from the dual polarization antenna.

At the receiving end, both polarization waves are received by the dual polarization antenna and the frequency is converted from RF to IF by the radio frequency receiver. OFDM demodulation and error correction decoding follow at the demodulator and, finally, the signal is decoded by the HEVC decoder.

FIGURE 17

42GHz transmission system diagram for 8K

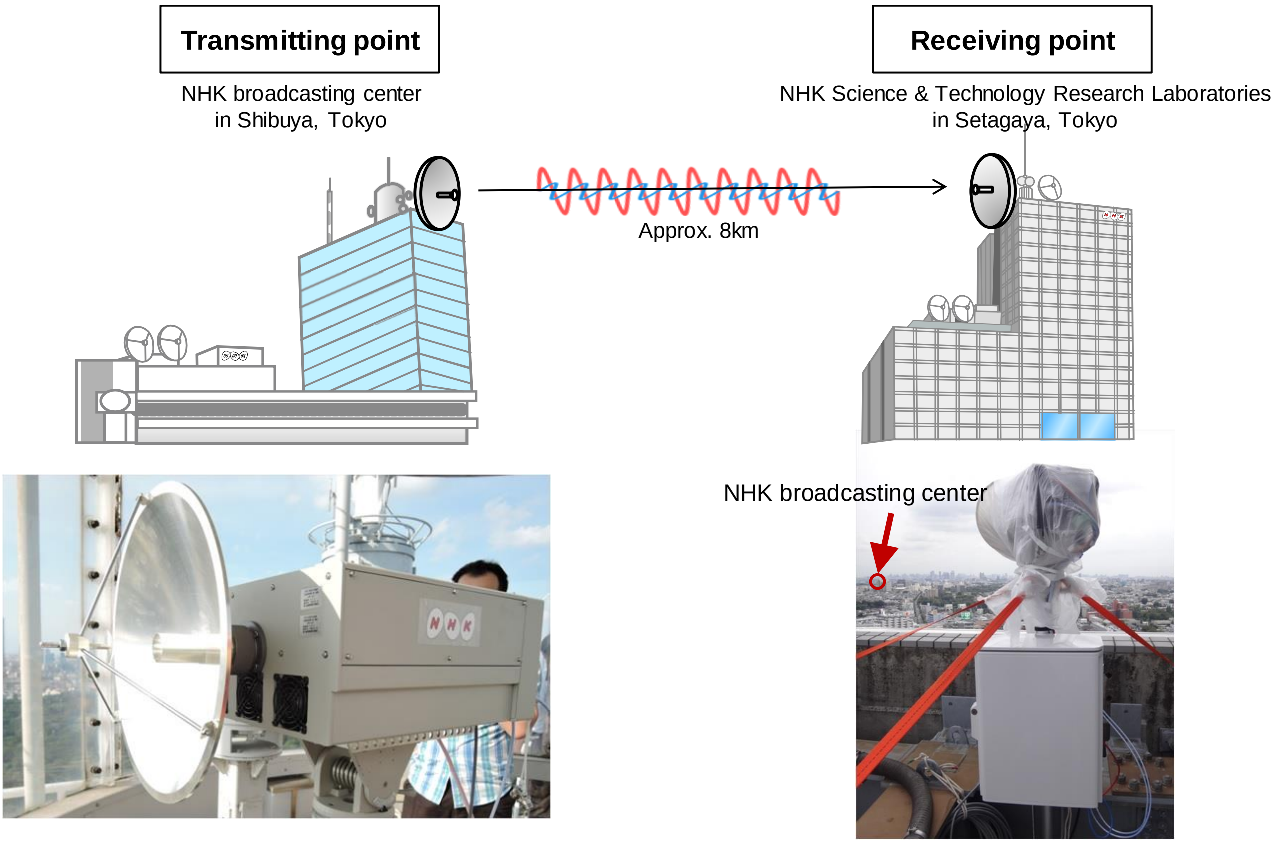


Field experiment

An overview of a field experiment involving transmission between the NHK Broadcasting Center and NHK Science and Technology Research Laboratories (STRL) is shown in Fig. 18. The NHK Broadcasting Center in Shibuya, Tokyo is the transmission point and NHK STRL in Setagaya, Tokyo the reception point. The distance is approximately 8 km.

FIGURE 18

Overview of field experiment



Transmission parameters used in this field experiment are shown in Table 8. The transmission bit rate was set at 600 Mbit/s.

TABLE 8

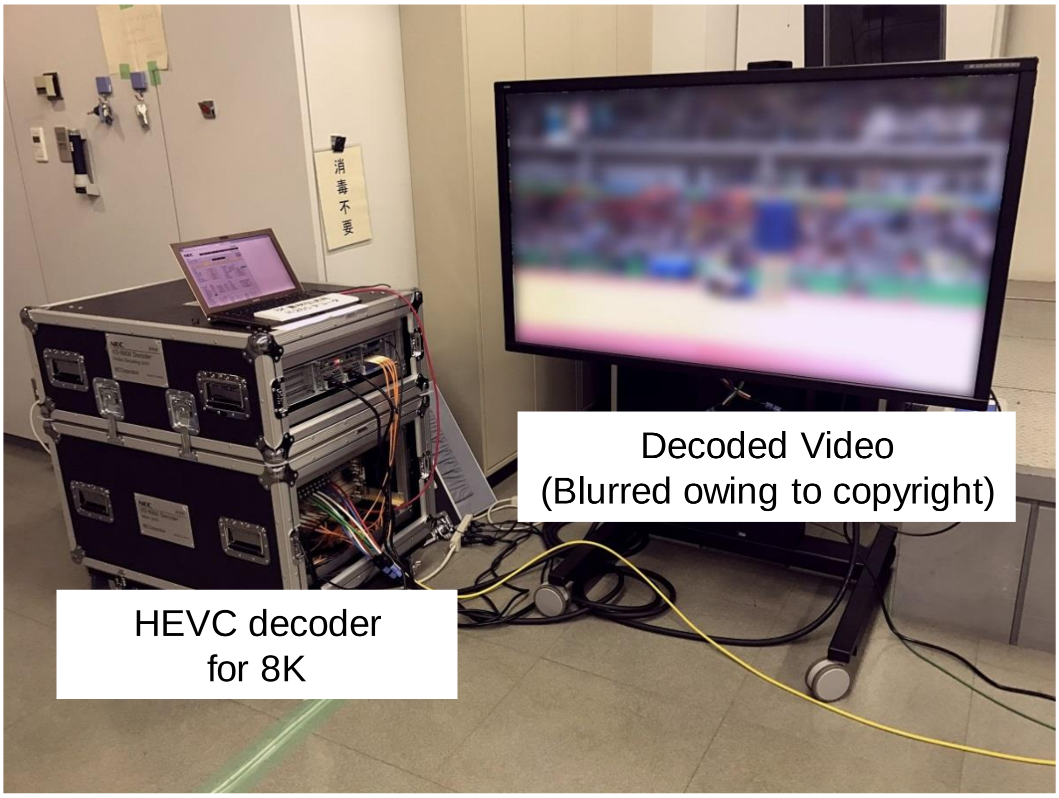
Transmission parameters in this field experiment on the 42 GHz band

Transmission system	2 × 2 dual polarization MIMO – OFDM
Radio frequency band	41.0 ~ 42.0 GHz
Channel spacing	125 MHz
Modulation	32 QAM
Outer code	Reed Solomon code (204, 188)
Inner code	Convolutional code (code rate: ¾)
Transmission power	250 mW / per polarization
Bit rate	600 Mbit/s

The HEVC decoder and 8K display used in this experiment are shown in Fig. 19.

FIGURE 19

Overview of field experiment



The results were error free when the outer code was confirmed by BER measurement, and long term stability was confirmed by 8 hours of continuous video transmission.

SNG system for 8K UHDTV transmissions

The SNG system supports the transmission of video and/or sound from the location of on-going news, sport games or other events to the broadcasting station or studio.

ENG and OB need to establish terrestrial radio communication link, but the SNG system can transmit the programme from any location as long as it has access to a communication satellite. This makes the SNG system effective for live sport events and the coverage of breaking news. Although the satellite link is easily affected by rainfall attenuation, it is still a powerful and essential transmitting tool.

An SNG system for 8K UHDTV has therefore been developed in Japan for the production and transmission via satellite of 8K signals to broadcasting stations.

FIGURE 20

An SNG system for 8K UHDTV

Technical characteristics

The SNG system has been developed to transmit 8K UHDTV video and multichannel audio. For 8K live productions, the SNG system needs to be connected to an 8K OB van equipped with 8K cameras, video switchers and other production tools.

FIGURE 21

System diagram for 8K UHDTV productions

The SNG system can deliver a single stream of 8K signals or two simultaneous streams of 4K signals via satellite. An outline of the transmitting equipment and a diagram of the video system are provided below.

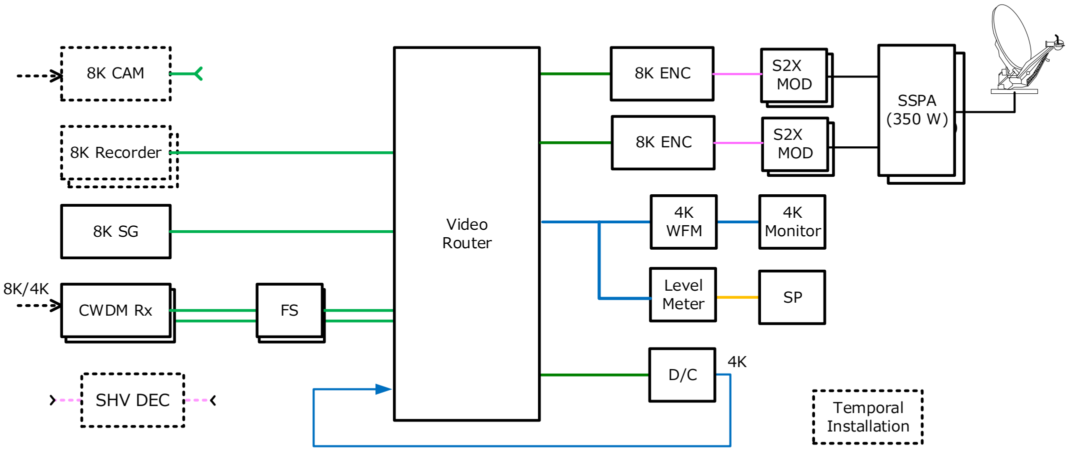
TABLE 9

Outline of the transmitting equipment

Antenna	1.5 m φ offset parabola
HPA	Two SSPAs (350 W)
Modulator	Two DVB-S2X modulators
Encoder	Two HEVC H.265 encoders

FIGURE 22

Diagram of the video system



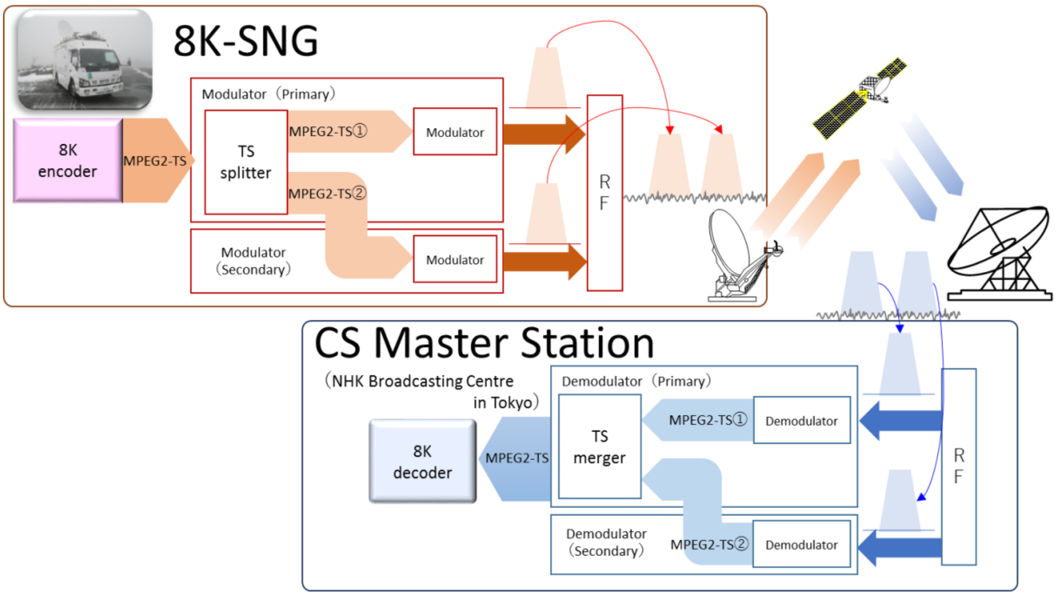
Channel bonding

The SNG system for 8K UHDTV utilizes the "channel bonding" of DVB-S2X. Channel bonding is a method to carry a single input stream over two transponders. In the case of the SNG system, a compressed signal stream is split and transmitted over two transponders. On the receiving side, the two encoded signal streams coming from the transponders are decompressed and merged into a single signal stream.

The two transponders ensure sufficient bandwidth to deliver the 8K signals. This enables the available slots of the transponders to be used more efficiently and flexibly. (The two transponders should have the same polarization.)

FIGURE 23

Channel bonding



Trial 8K signal delivery

In July 2017, a trial 8K signal delivery was conducted with the Grand Sumo Tournament in Nagoya.

By bonding 45 MHz over two transponders, a TS stream (approximately 150 Mbit/s) of 8K video and 22.2 multichannel audio was transmitted from the venue in Nagoya to the CS master station in Tokyo.

Live transmissions were provided for 12 hours in total over a period of three days. They were sufficient in terms of quality and reliability for live broadcasting. During the tournament, the reception point in Tokyo experienced some heavy rain. This caused attenuation of approximately 5 dB, but without any noticeable effect on the picture quality in the receiving video.

TABLE 10

Transmission parameters used in the trial

Channel spacing	45 MHz (bonding of 27 MHz and 18 MHz)
Modulation	32 APSK
Roll off rate	5%
TS bit rate	Approximately 150 Mbit/s
Video codec	HEVC/H.265
Audio codec	MPEG-4 AAC (22.2 multichannel audio tracks)

RF operations for the broadcast and production of the Super Bowl in USA

Background

The broadcast of the annual United States National Football League (NFL) championship game known as the Super Bowl™ is seen by over 100 million viewers and is broadcast in over 130 countries in more than 30 languages (see Fig. 24). This premier Programme Making and Special Events (PMSE) and Electronic News Gathering (ENG) event requires intense, extraordinary coordination of thousands of wireless links. The following is a blog post the U.S. Federal Communications Commission (FCC) issued after the 2016 Super Bowl.

FIGURE 24

ENG crews from dozens of countries cover the events during Super Bowl week

“A little known fact is that the Super Bowl represents one of the largest uses of wireless communications and spectrum every year. Whether in the vicinity of the stadium or streaming the game online, the wireless network traffic is immense. From television and radio broadcasters’ wireless video cameras and microphones, to wireless mics, cameras, and special effects for Lady

Gaga singing the National Anthem, and Beyoncé, Coldplay, and Bruno Mars performing at halftime, and of course, the teams, fans and stadium – all use a tremendous amount of spectrum."[7]

Subsequent to this 2016 blog post, the production surrounding the Super Bowl has become even more sophisticated. Also, the 600 MHz band where a large portion of wireless audio links traditionally operated has been re-purposed within the United States and is no longer available for PMSE use. Alternate frequency bands are now in use within the United States for such major events. Nevertheless, increased coordination and testing is required to ensure the production quality that audiences have come to expect.

Event frequency coordination system

During the prior two years (2018 and 2019), the NFL has overhauled its frequency-coordination effort, now called Event Frequency Coordination (EFC). It developed an online web portal database to coordinate its "normal" RF operations nationally throughout the season. The EFC collects data on equipment, stadium and related venues, local over-the-air TV channels, cellular carriers and other details. The EFC database lists technical details such as tuning ranges, bandwidth, and the power levels for each piece of RF equipment. It also denotes "static frequencies" for all the known frequencies normally in use at each stadium outside of special events, as well as the location of TV transmitters, any cellular carriers and Wi-Fi frequencies in use at the venue.

Super Bowl LIV

Super Bowl LIV[8] took place in Miami, Florida (USA). A wide variety of events were broadcast and/or staged throughout the city during the ten days leading up to the game at Hard Rock Stadium on Sunday, February 2nd, 2020. Continuous Super Bowl newscasts were broadcast from South Beach Miami (see Fig. 25).

FIGURE 25

One of several broadcast studio constructed in South Beach Miami that broadcast during Super Bowl week

Other specials events included NFL Honors at the Adrienne Arsht Center, the Super Bowl Week opening night ceremony at Marlins Stadium, Super Bowl Alley & Experience at the Miami Beach Convention Center, and a VIP party at American Airlines Arena. The NFL identified, assigned and coordinated nearly 1000 frequencies. This was almost 150 frequencies fewer (denied use) than the number requested by the 32 broadcasters and other wireless users at the events, including the NFL itself, underscoring the vastness of the RF demands at major NFL events and the limited amount of spectrum available. These spectrum demands were divided between pre- and postgame, in-game, and half-time. Note that a typical half-time frequency use must remain in operation from pre-game until the half-time event concludes. They were also spread out over a large geographic region, from the

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7 https://www.fcc.gov/news-events/blog/2016/02/11/no-pass-interference-super-bowl-50.

8 Super Bowls are named using roman numerals. Super Bowl LIV was the 54th such game.

media centre at the Miami Beach Convention Center to the Hard Rock Stadium, which are about 24 km (15 miles) apart. Links and their associated frequencies are also prioritized in case of conflicts. Following Public Safety, the highest priority applications include coach-to-coach and coach-to-player communications and officials' wireless microphones. The second priority is the venue for production and security within the venue. Next are the other team communications and the broadcast rights-holders. Frequency use was also coordinated with local, state, and federal security agencies to avoid potential conflicts in shared bands. Real-time spectrum analysis and monitoring was conducted throughout the week leading up to the game to ensure frequency compatibility (see Fig. 26).

FIGURE 26

Real-time spectrum monitoring on field level

Three days prior to the game a series of tests known as "RF Wars" is conducted (see Figs 27, 28 and 29). All wireless devices are turned on in a special sequence, at the stadium for several hours so that any potential interference can be detected, reported, and re-coordinated. During these tests for Super Bowl LIV, only minor issues were discovered and adjustments were made accordingly. No problems occurred during the actual game or the elaborate half-time show.

FIGURE 27

"RF Wars" tests for interference while all devices are operating

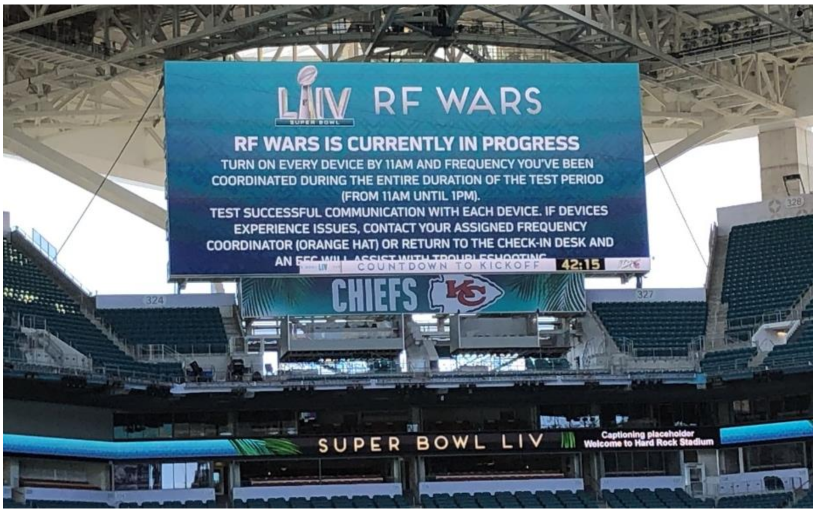


FIGURE 28

Handheld wireless microphones prepared for the half-time show

FIGURE 29

Testing of wireless intercom systems

Conclusion

Global events such as the Super Bowl continue to increase in sophistication and spectrum use intensity. In the United States and other countries, broadcasters continue to be under pressure to expand their wireless tools for production and communications in order to fulfil the audience expectations. The spectrum resources for these devices are clearly becoming more challenging as vacant channels within the traditional UHF-TV band have become scarcer due to repurposing to mobile broadband and the associated repacking of TV stations.

Audio wireless equipment

TABLE 11

Use of audio wireless equipment at Hard Rock Stadium

Venue	**Hard Rock Stadium (game site)**	
Frequency band	**Quantity**	**Device type**
450-451 MHz 455-456 MHz 476-482 MHz 506-512 MHz	120	2-Way Radio LMR Based High Powered Intercom
470-608 MHz 714-725 MHz (Note 1)	254	Wireless handheld and bodypacks
	101	Interruptible foldback and in-ear monitors systems
	12	Intercom base station
	40	Intercom duplex body packs
	2	Duplex intercom systems
902-928 MHz	1	Intercom base station
	30	Intercom duplex body packs
941.5-960 MHz	36	Wireless microphones and in-ear monitoring systems
1 920-1 930 MHz (DECT band)	1	Intercom base station
	50	Intercom duplex body packs
2.4 GHz	1	Intercom base station
	24	Intercom duplex body packs

NOTE 1 – Permitted by FCC Special Temporary Authorization (STA).

TABLE 12

Use of audio wireless equipment at various venues in Miami

Venue	**South Beach (Studio Shows for FOX Sports, FOX News, ESPN, NFL Network), Adrienne Arsht Center, Marlins Stadium, Miami Beach Convention Center, and American Airlines Arena**	
76-88 MHz	7	Interruptible Foldback Systems
174-216 MHz	16	Wireless Handheld and Bodypacks
450-451 MHz 455-456 MHz 476-482 MHz 506-512 MHz	120	2-Way Radio LMR Based High Powered Intercom
470-608 MHz	144	Wireless Handheld and Bodypacks
	53	Interruptible Foldback and In-Ear Monitors Systems
	34	Remote ENG Wireless Microphone Links
902-928 MHz	1	Intercom Base Station
	24	Intercom Duplex Body Packs

TABLE 12 (*end*)

Venue	**South Beach (Studio Shows for FOX Sports, FOX News, ESPN, NFL Network), Adrienne Arsht Center, Marlins Stadium, Miami Beach Convention Center, and American Airlines Arena**	
941.5-960 MHz	18	Wireless Microphones and In-ear Monitoring Systems
1 500-1 525 MHz[9] (Note 1)	4	Wireless microphones
1 920-1 930 MHz (DECT band)	1	Intercom Base Station
	24	Intercom Duplex Body Packs
2.4 GHz	2	Intercom Base Station
	48	Intercom Duplex Body Packs

NOTE 1 – Permitted by FCC Special Temporary Authorization (STA) following coordination by the Aerospace and Flight Test Radio Coordinating Council, Inc. (AFTRCC), see: https://aftrcc.org/coordination/.

Video wireless equipment

TABLE 13

Use of video wireless equipment at Hard Rock Stadium

Venue	**Hard Rock Stadium (Game Site)**	
450-456 MHz	14	Camera Data Control
1 435-1 525 MHz[10] (Note 1)	7	Cameras
2 025-2 110 MHz	4	
2 360-2 395 MHz	3	
3 100-3 500 MHz	14	
5 835-6 000 MHz	2	
6 300-6 800 MHz	10	Player Tracking
6 875-7 125 MHz	10	Cameras

NOTE 1 – Permitted by FCC Special Temporary Authorization (STA) following coordination by the Aerospace and Flight Test Radio Coordinating Council, Inc. (AFTRCC), see: https://aftrcc.org/coordination/.

9 With respect to the band 1 435-1 525 MHz, wireless microphones are secondary in the U.S. to Aeronautical Mobile Telemetry (AMT) operations. AMT is an application of the Aeronautical Mobile Service (AMS). See footnote US84 in the FCC Online Table of Frequency Allocations, revised 19 April 2017, and included in the Code of Federal Regulations at 47 CFR part 74, subpart H, section 74.803, subparagraph (d).

10 With respect to the band 1 435-1 525 MHz, wireless microphones are secondary in the U.S. to Aeronautical Mobile Telemetry (AMT) operations. AMT is an application of the Aeronautical Mobile Service (AMS). See footnote US84 in the FCC Online Table of Frequency Allocations, revised 19 April 2017, and included in the Code of Federal Regulations at 47 CFR part 74, subpart H, section 74.803, subparagraph (d).

TABLE 14

Use of video wireless equipment at various venues in Miami

Venue	**South Beach (Studio Shows for FOX Sports, FOX News, ESPN, NFL Network), Adrienne Arsht Center, Marlins Stadium, Miami Beach Convention Center, and American Airlines Arena**	
450-456 MHz	14	Camera Data Control
1 435-1 525 MHz[11] (Note 1)	5	Cameras
2 025-2 110 MHz	4	
2 360-2 395 MHz	2	
3 100-3 500 MHz	6	
5 835-6 000 MHz	4	
6 425-6 225 MHz	2	

NOTE 1 – Permitted by FCC Special Temporary Authorization (STA) following coordination by the Aerospace and Flight Test Radio Coordinating Council, Inc. (AFTRCC), see: https://aftrcc.org/coordination/.

China (Peoples Republic of)

China Business Network (CBN) completed 5G MBS system capability verification in commercial scenario

In November 2021, based on 5G MBS, CBN completed the verification of new broadcasting services such as multi-angle viewing and panoramic VR video live broadcasting in the Beijing Winter Olympics test events. This is the world's first system capability verification of 5G MBS in commercial scenarios, which is of great significance to the subsequent acceleration of the industry chain maturity and full-scenario business innovation.

With 5G MBS, audiences in the stadium can freely choose to watch live content such as multi-angle and VR panoramas on 5G terminals including mobile phones and VR wearable devices, without video jams caused by high concurrency. 5G MBS realizes the high-concurrency transmission of high-bitrate multimedia content on consumer mobile phones, which cannot be achieved by traditional broadcasting technologies. The 5G MBS deployment integrating VR/XR and other new multimedia formats will create innovative services for broadcasting industry.

In the next stage, CBN will not only innovate and upgrade traditional broadcasting service, but also expand other new multimedia communication services in To C/To B, such as integrated high-tech media live broadcast, live broadcast of popular Internet content, Internet of Vehicles, Internet of Things through free switching between multicast and broadcast modes.

[11] With respect to the band 1 435-1 525 MHz, wireless microphones are secondary in the United States to Aeronautical Mobile Telemetry (AMT) operations. AMT is an application of the Aeronautical Mobile Service (AMS). See footnote US84 in the FCC Online Table of Frequency Allocations, revised 19 April 2017, and included in the Code of Federal Regulations at 47 CFR part 74, subpart H, section 74.803, subparagraph (d).

FIGURE 30

The ice hockey test field at Beijing Wukesong Stadium

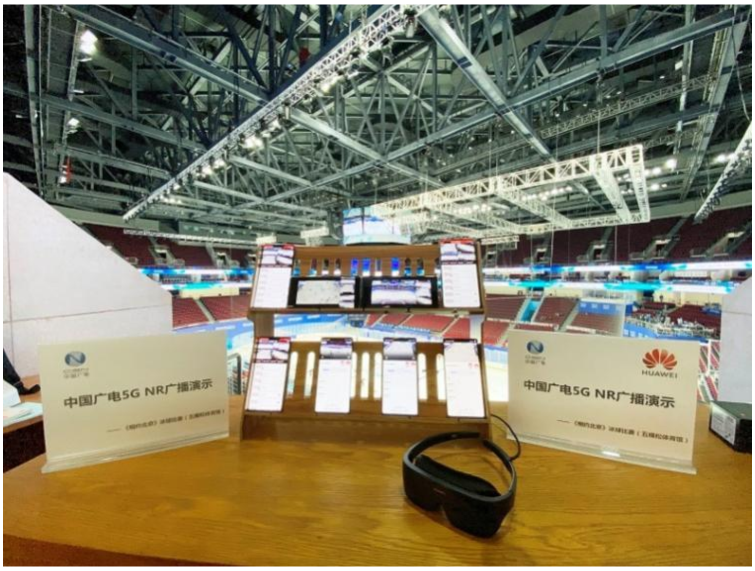


FIGURE 31

Live content such as multi-angle and VR panoramas on 5G terminals including mobile phones and VR wearable devices

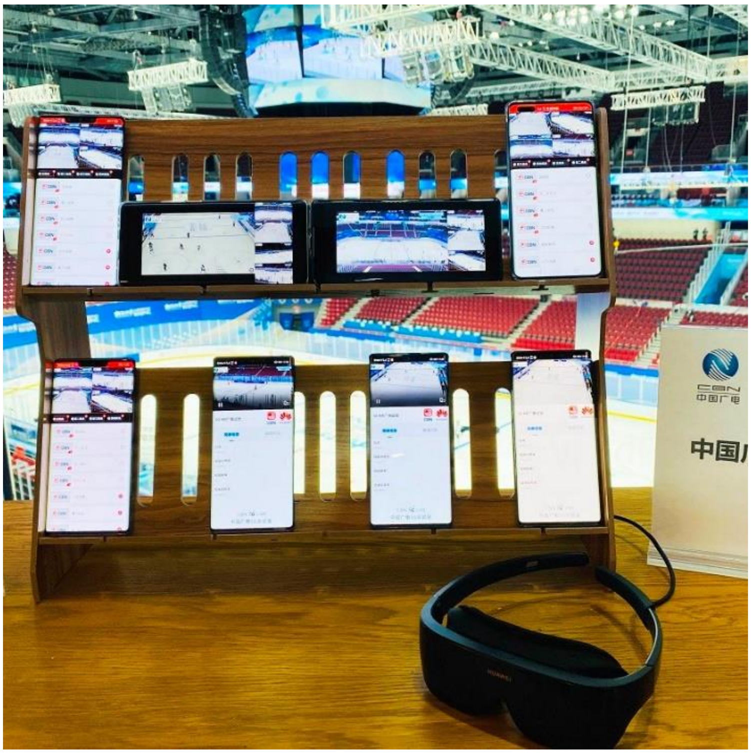
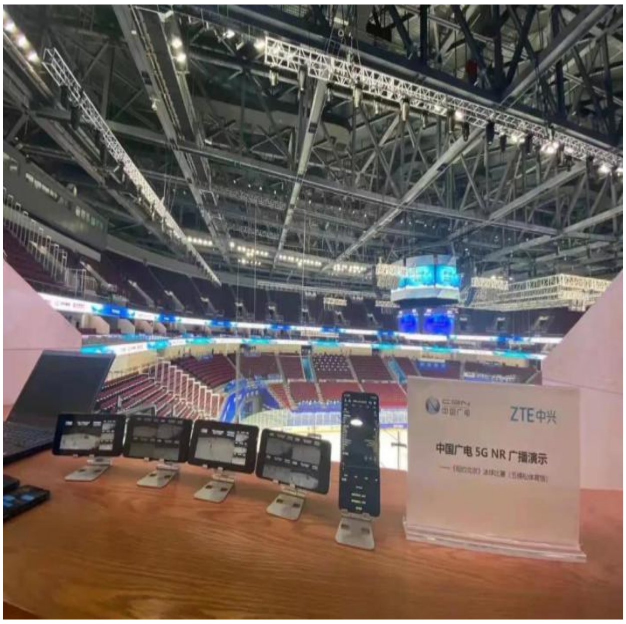


FIGURE 32

Panoramic video playback based on 5G mobile phones

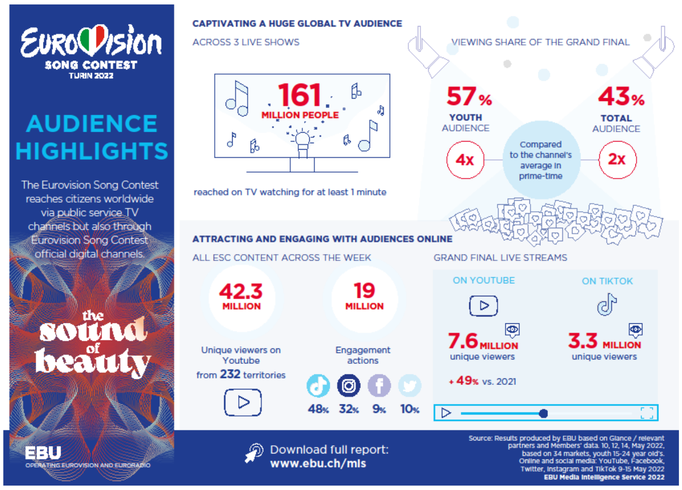


EBU Eurovision Song Contest

This event is held each year following national programmes to select their entry and normally held in the winning country.

Exceptionally popular around the world as can be seen from these statistics.

FIGURE 33



For the host county the spectrum planning is "interesting". During the event the following PMSE equipment was used:

- 60 duplex –simplex – intercom 440-470 MHz
- 8 channel for terrestrial trunked radio (TETRA)
- 8 data links for video cameras in 445-470 MHz
- 10 channel wireless cameras in 7 GHz, BW = 20 MHz
- 70 channel for reporter microphones ENG in 470-790 MHz
- 30 AVX ENG MICS, 1.9 GHz DECT

- 110 microphone channels in 470-790 MHz
- 4 microphones WIFI 2.4 GHz
- 37 wireless headphones (IEM) channels in 470-790 MHz.

Annex 2

Information on frequency bands

During the development of a report on PMSE in CEPT countries, a questionnaire was sent to administrations on the regulatory procedures used by administrations in granting access to spectrum for audio PMSE applications [2].

The questionnaire covered all frequency bands that are available for audio PMSE applications. Table 15 summarizes the results – based on the replies of 34 CEPT administrations – relevant for audio PMSE applications regarding availability and use.

TABLE 15

CEPT recommended frequency ranges for use by audio PMSE applications
https://docdb.cept.org/download/3424

CEPT – Audio

Frequency ranges	Application	Background information
29.7-47.0 MHz	Radio microphones In-ear monitors	Non-professional PMSE use. Legacy systems still in use. No broadcast quality equipment available. Shared use. ETSI EN 300 422
174-216 MHz		Shared use. EN 300 422
470-694 MHz		Currently a core band for professional PMSE use. Changes to the band will limit its utility for PMSE. The extent of the impact is dependent on national decisions (see ECC/DEC (15)01). Shared use. EN 300 422
694-790 MHz		Currently a core band for professional PMSE use. Changes to the band will limit its utility for PMSE. The extent of the impact is dependent on national decisions (see ECC/DEC (15)01). Shared use. EN 300 422
823-832 MHz		Risk of out of band emissions from adjacent mobile services means there is limited utility for broadcast quality audio Harmonised (within EU member states). EN 300 422
863-865 MHz		Risk of out of band emissions from adjacent mobile services and other short range devices means there is very limited utility for broadcast quality audio. Shared use (Note 1). EN 300 422 and EN 301 357
1 350-1 400 MHz		Newly recommended tuning range in 2016. Shared use EN 300 422
1 518-1 525 MHz		Newly recommended tuning range in 2016. Shared use EN 300 422

TABLE 15 (*end*)

Frequency ranges	**Application**	**Background information**
1 785-1 805 MHz		Harmonised (within EU member states). EN 300 422
174-216 MHz	Portable audio links Mobile audio links Temporary point-to-point audio links (Note 2) Talkback and Production communications (Note 3)	Shared use. EN 300 454
470-694 MHz		Shared use. EN 300 422 and EN 300 454
694-790 MHz		Changes to the band will limit its utility for PMSE. The extent of the impact is dependent on national decisions. Shared use. EN 300 422 and EN 300 454

NOTE 1 – The band 863-865 MHz is available for radio microphones, however due note should be taken that it is used also for non-professional and consumer radio applications (cordless audio, etc.).

NOTE 2 – Depending on application scenario, channel width and required transmitter power, the portable, mobile and temporary point-to-point audio links may be accommodated either in the frequency bands 174-216 MHz/470-694/694-790 MHz identified for professional radio microphones (typically for low power/wideband applications) or in other VHF/UHF bands, including Private Mobile Radio (PMR) bands (typically for high power/narrowband applications).

NOTE 3 – These applications are service links that operate in the audio PMSE bands.

From the information on the availability in each CEPT country of the recommended frequency ranges, it can be concluded that there are several tuning ranges currently available for SAB/SAP audio applications in the majority of the countries. The actual availability of certain frequencies at a given geographical location depends also on the use of other (primary) services.

Operating and/or usage restrictions in a given tuning range may result from other services working in the same or adjacent band as the audio PMSE applications. In addition, the propagation conditions discussed in § 3.2.5 play a large part on the usability of the band and on the type of audio PMSE applications which could be used in a given band.

Recommended frequency ranges for wireless camera and video links in CEPT countries

The recommended frequency ranges for the use of terrestrial video SAB/SAP applications in CEPT countries are provided in ERC Recommendation 25-10 [4] and summarised in Table 16 below.

TABLE 16

CEPT recommended frequency ranges for use by video PMSE applications ECC REC 25-10
https://docdb.cept.org/download/3424

Frequency ranges	Application	Background information
2 010-2 025 MHz	Cordless Cameras; Portable video links; Mobile video links	Harmonised (within EU member states). Shared use. EN 302 064. Note 1.
2 025-2 110 MHz		Shared use. EN 302 064. Note 1.
2 200-2 300 MHz		Shared use. EN 302 064. Note 1.
2 300-2 400 MHz		Shared use (see ECC Decision (14)02). EN 302 064. Note 1.
2 400-2 500 MHz		Shared use (see EC Decision 2014/641/EU). EN 302 064. Note 1.
2 700-2 900 MHz (Note 2)		Shared use. EN 302 064.
7.0-8.5 GHz	Cordless Cameras; Portable video links; Mobile video links; Temporary point-to-point video link	Shared use. EN 302 064.
10.0-10.68 GHz		Shared use. EN 302 064. Note 3.
21.2-24.5 GHz	Cordless Cameras; Temporary point-to- point video link	Shared use. EN 302 064.
47.2-50.2 GHz	Cordless Cameras	Shared use. EN 302 064.

NOTE 1 – Within the tuning range 2 010-2 500 MHz, the frequency band 2 110-2 200 MHz is not available for PMSE.

NOTE 2 – The tuning range 2 700-2 900 MHz is not available for mobile air to ground video links.

NOTE 3 – Within the tuning range 10-10.68 GHz, only occasional temporary point-to-point links should be allowed in the frequency band 10.6-10.68 GHz. Studies have concluded that even limited deployment of cordless cameras and portable video links in the band 10.6-10.68 GHz will result in interference to the EESS (passive) services using this band (see ECC Report 17).

It should also be noted that temporary point-to-point video links might be accommodated in the fixed service bands, following the same channel arrangements as the FS links.

From the analysis and results of the responses to the audio PMSE questionnaire, it can be concluded that there are eight tuning ranges currently available for PMSE audio applications in the majority of the countries from which responses were received. The actual availability of certain frequencies at a given geographical location depends also on the use of other (primary) services.

Current usage of certain frequency bands for wireless camera and video links in CEPT countries

During the development of the report to satisfy Resolution 232 (WRC-12) [2], the ECC developed a questionnaire to CEPT administrations on the regulatory procedures used by administrations in granting access to spectrum for PMSE. It covers many frequency ranges and PMSE use.

Band 2 025-2 110 MHz (ERC/REC 25-10) [10]: From the 32 countries providing a response on this band, 19 of them report about the availability of the band or parts of it for PMSE applications, namely temporary video links (portable, mobile with some allowance for airborne use) and wireless cameras as referred to in ERC/REC 25-10. This use is under an individual licensing regime. No change is expected for this band in relation to PMSE.

Band 2 200-2 500 MHz (ERC/REC 25-10): From the 32 countries providing a response on this band, 29 of them report about the availability of the band or parts of it for PMSE applications.

The main type (28 countries) is related to temporary video links (portable, mobile with some allowance for airborne use) and wireless cameras as referred to in ERC/REC 25-10. In most cases, this use is under an individual licensing regime, although low power wireless cameras can in a few countries operate under a general license. It is noted that, in addition or as an alternative, two countries mention specifically the use of the 2 400-2 483.5 MHz band for wideband data transmissions or non-specific SRD as per REC 70-03 for PMSE purpose. Five countries mentioned that current considerations on the potential introduction of Broadband Wireless systems either as a single block or via licensed Shared Access (LSA)[12] in the band 2 300-2 400 MHz will have an impact on the availability of the band for PMSE.

Band 2 500-2 690 MHz (ERC/REC 25-10): From the 32 countries providing a response on this band, five of them report about the availability of the band or parts of it for PMSE application, namely PMSE, video links. Amongst those, three countries expect that the use of PMSE will cease because of the introduction of terrestrial Electronic Communications Networks in the 2 500-2 690 MHz band. On this basis, the relevance of maintaining this band in the ERC/REC 25-10 may be considered.

Band 3 400-3 600 MHz (ERC/REC 25-10): From the 32 countries providing a response on this band, nine of them report about the availability of the band or parts of it for PMSE applications, which tends to confirm a decrease of the availability of this band for PMSE. PMSE applications in this band cover temporary video links (portable, mobile with some allowance for airborne use) and wireless cameras as referred to in ERC/REC 25-10 [10]. This use is under an individual licensing regime. The development of IMT in this band may have an impact on the spectrum available for PMSE in this band.

Band 4 400-5 000 MHz: From the 32 countries providing a response on this band, seven of them report about the availability of the band or parts of it for PMSE applications. PMSE applications in this band cover PMSE links for temporary use deployed in a coordinated way to protect other use (mainly military applications). This PMSE use is in most cases under an individual licensing regime.

Band 10.0-10.68 GHz (ERC/REC 25-10): From the 32 countries providing a response on this band, 26 of them report about the availability of the band or parts of it for PMSE applications. The amount of available spectrum and the frequency bands within the overall tuning range vary significantly depending upon the country. The main PMSE applications covered in this range are wireless cameras, portable video links and point-to-point video links for temporary use as referred to in ERC/REC 25-10. This use is in most cases under an individual licensing regime. No major change is generally expected for this band in relation to PMSE.

Band 21.20-24.50 GHz (ERC/REC 25-10): From the 32 countries providing a response on this band, 25 of them report about the availability of the band or parts of it for PMSE applications. The amount of available spectrum and the frequency bands within the overall tuning range vary significantly depending upon the country. The main PMSE applications covered in this range are wireless cameras,

[12] An LSA system comprises one or more incumbents, one or more LSA licensees, and the means to enable coordination between incumbents and LSA licensees, such that the latter may deploy their networks without harmful interference.

portable video links and point-to-point video links for temporary use as referred to in ERC/REC 25-10. This use is in most cases under an individual licensing regime. A few changes are expected, which may slightly increase the availability of spectrum for PMSE.

Band 47.20-50.20 GHz (ERC/REC 25-10): From the 32 countries providing a response on this band, 16 of them report about the availability of the band or parts of it for PMSE applications. The main PMSE applications covered in this range are wireless cameras and portable video links as referred to in ERC/REC 25-10. This use is in most cases under an individual licensing regime. No change is expected with regard to PMSE in this band.

Other bands: The availability of frequency bands within the 6/8 GHz range is mentioned by eight countries for fixed and/or mobile PMSE.

Japan

Frequencies and use cases

1.2 GHz / 2.3 GHz bands

The 1.2 GHz and 2.3 GHz bands (1 240-1 300 and 2 330-2 370 MHz) are mainly used for mobile transmitting of live streaming of events such as marathons and road bicycle racings.

The 770-806 MHz bands were originally assigned for such purposes, however, they were reassigned to commercial mobile phones and other applications in 2012. The 1.2 GHz and 2.3 GHz bands were consequently assigned to the incumbent ENG systems. This frequency migration was completed in 2017.

ENG is normally utilized between two line-of-sight points, but non line-of-sight transmission is also required for mobile portable links. The 1.2 GHz and 2.3 GHz bands are relatively low for ENG frequencies, so they have broad coverage. Besides that, adopting COFDM, which is resistant to multipath fading, gives ENG systems on these bands non line-of-sight transmission capability.

Since these bands are not exclusively assigned to SAB/SAP in Japan, the frequencies need to be shared with other radiocommunication services. Users are required to submit applications some months in advance before they use the bands, which means broadcasters can operate on the 1.2 GHz and 2.3 GHz bands only if a schedule and the site of live streaming event have been specified.

Microwave bands (6-7 GHz, 10 GHz, and 13 GHz bands)

The 5 850-5 925 MHz, 6 425-6 570 MHz, 6 870-7 125 MHz, 10.25-10.45 GHz, 10.55-10.68 GHz and 12.95-13.25 GHz bands are most generally used for ENG in Japan, as they are suitable for transmitting video stably between two distant points.

HDTV has been used so far, and the technical standard of transmission system for UHDTV programme using these microwave bands was published in January 2018.

Millimetre-wave bands (42 GHz/55 GHz bands)

The 41.0-42.0 GHz and 54.27-55.27 GHz bands are susceptible to rain attenuation and the transmission distance is short (usually less than 10 km). On the other hand, transmitting capacity is good enough to carry high quality UHDTV video.

Spectrum and operation of radio microphones and planning for digital radio microphones in Japan

The tuning ranges of wireless microphones and licensing arrangements in Japan are described in Annex 2 to Recommendation ITU-R BT.1871-3.

Republic of South Africa

TABLE 17

Permitted frequency bands for PMSE in the Republic of South Africa

Frequency band	Notes
30.01-37.5 MHz	Wireless microphone (36.65-36.75 MHz)
40.02-40.98 MHz	Outside broadcasting (OB) links; Electronic New Gathering (ENG) Wireless microphones (40.65-40.7 MHz)
50-54 MHz	Wireless microphones (53-54 MHz)
174-223 MHz	The 173.7-175.1 MHz may be used for wireless microphones and assistive listening devise for services ancillary to Broadcasting (SAB) and services ancillary to programme (SAP) making
470-694 MHz	SAP/SAB Applications
862-890 MHz	Wireless audio systems and wireless microphones (863-865 MHz)
4 400-5 000 MHz	OB; ENG
5 850-6 700 MHz	The band 5 850-5 926 MHz may also be used for temporary deployment for ENG and OB links under the mobile and fixed services respectively on a strictly coordinated basis
10.5-10.68 MHz	SAP/SAB Applications (Video connections)
11.7-12.5 GHz	OB links; ENG; BSS feeder links
24.25-24.45 GHz	Temporary fixed links for ENG/OB
4 400-5 000 MHz	OB; ENG
5 850-6 700 MHz	The band 5 850-5 926 MHz may also be used for temporary deployment for ENG and OB links under the mobile and fixed services respectively on a strictly coordinated basis.
10.5-10.68 MHz	SAP/SAB applications (Video connections)
11.7-12.5 GHz	OB links; ENG; BSS feeder links
24.25-24.45 GHz	Temporary fixed links for ENG/OB

United Kingdom

All information is available via Ofcom’s PMSE webpages:

Programme-making and special events (PMSE) – Ofcom

The Ofcom PMSE Licensing Team can be contacted directly:

Contact the PMSE team – Ofcom

UK Interface Requirement IR2038 contains the requirements for the licensing and use of radio equipment for Programme Making and Special Events in the specified frequency bands:

UK Interface Requirement 2038 (ofcom.org.uk)

For information purposes, the following was the UK situation in July 2022:

TABLE 18

Permitted frequency bands for Audio PMSE in the United Kingdom

Frequency Band	Notes
Coordinated assignments (Coordinated assignments: the Licence schedule will specify the exact frequency, the location and the dates of use)	
175.150-175.350 MHz	Maximum 50 mW ERP Assignments can be: • short term e.g. for a few hours use at an outside broadcast or concert; • for several days or weeks at a theatre for a touring show; or • an annual assignment for regular use at a fixed site.
175.425-175.625 MHz	
176.300-177.100 MHz	
184.500-185.100 MHz	
191.600-193.100 MHz	
199.600-201.100 MHz	
207.600-210.100 MHz	
470-606 MHz	
614-702 MHz	
961-1 015 MHz	
1 045-1 075 MHz	
1 105-1 154 MHz	
Shared Licence (This licence authorises the use of the frequency, or any channel within the specified band, at any location at any time)	
175.250-209.800 MHz	Maximum 50 mW ERP 15 spot frequencies are specified on the VHF Shared Licence. 175.250 MHz, 175.525 MHz and 176.600 MHz are not available in Northern Ireland
606-614 MHz	Maximum 50 mW ERP These bands are included in the UHF Shared Licence. 1785-1805 MHz is not available in Northern Ireland
823-832 MHz	
1 785-1 805 MHz	
Licence Exempt	
173.8-175 MHz	max. 50 mW ERP
863-865 MHz	max. 10 mW ERP
2.4-2.485 GHz	10 mW e.i.r.p.

United States of America

The United States of America is a leader in content creation, thus demand for SAB/SAP applications is robust and growing. Wireless microphones (and similar devices) have traditionally operated in the UHF band. However, in 2009, the 700 MHz band was re-purposed and wireless microphone operations were consolidated below 698 MHz. The FCC 600 MHz incentive auction further reduced the spectrum in the lower UHF band that was available to wireless microphones. In 2015, in order to meet the current and future demands for SAB/SAP applications the FCC made available additional ranges appropriate for wireless microphone operations. The following is an updated Table that reflects these developments.

In the United States, many changes occurred as a result of the 600 MHz incentive auction:

– The 614-698 MHz band has been repurposed. Most of the band became unavailable to wireless microphones after the transition period that ended on 13 July 2020.
– Portions of the repurposed spectrum (i.e. the guard band and duplex gap) remained available to wireless microphones, but under different rules. Portions of the 600 MHz guard band and duplex gap are available for the exclusive use of wireless microphones (see below).
– Some TV stations that formerly broadcast on channels in the 600 MHz band moved to lower TV channels, thereby increasing congestion in the remaining TV spectrum. This further reduced the number of channels available to wireless microphones in the lower UHF and the VHF bands. However, the FCC's revision of co-channel operations (explained below) made previously prohibited channels available to wireless microphones.

New UHF band plan

The FCC's incentive auction had a multi-stage structure designed to repurpose up to 144 MHz of TV band spectrum, depending on various scenarios. Ultimately, only 84 MHz (614-698 MHz) was repurposed.

This left the majority of the UHF TV band (470-608 MHz corresponding to U.S. TV channels 14 to 36) allocation unchanged. Accordingly, any locally-vacant (i.e. white space) channel within this range remains available to wireless microphones.

White Space Devices

In 2010, the FCC established rules for White Space Devices ("WSDs") – formerly known as TV White Space ("TVWS") or TV Band Devices ("TVBD") – which are unlicensed equipment also operating on unused TV channels, like wireless microphones do. WSD deployment thus far has been slow but may accelerate. Licensed operation of wireless microphones takes precedence over unlicensed devices, including WSDs. White space devices use location sensing in conjunction with a channel assignment database. This database includes a list of channels reserved for wireless microphones used in registered events at protected areas, such as entertainment and sporting venues. WSDs must first access the database to obtain a list of permitted channels in the area before operating. A WSD lacking this capability can operate only under the direct control of another WSD that can access the database.

Co-channel operation with TV stations

The Commission revised its rules for the operation of wireless microphones on the same channel used by a TV station (referred to as "co-channel operation"). Previously, wireless microphones were only permitted to operate on a TV channel with a minimum separation distance of 100 kilometres (approximately 70 miles) between the wireless microphones and the TV broadcast antenna. Now, wireless microphones can operate 4 kilometres outside the actual service contour of a TV station, regardless of the location of the TV antenna. Licensed wireless microphone professionals are permitted to operate closer, or even within the service contour if they are indoors, and the TV signal measures less than -84 dBm. This field strength benchmark, rather than the traditional geographic separation from TV transmit antennas, opened a number of UHF TV channels to wireless microphone operations that would otherwise not be permitted.

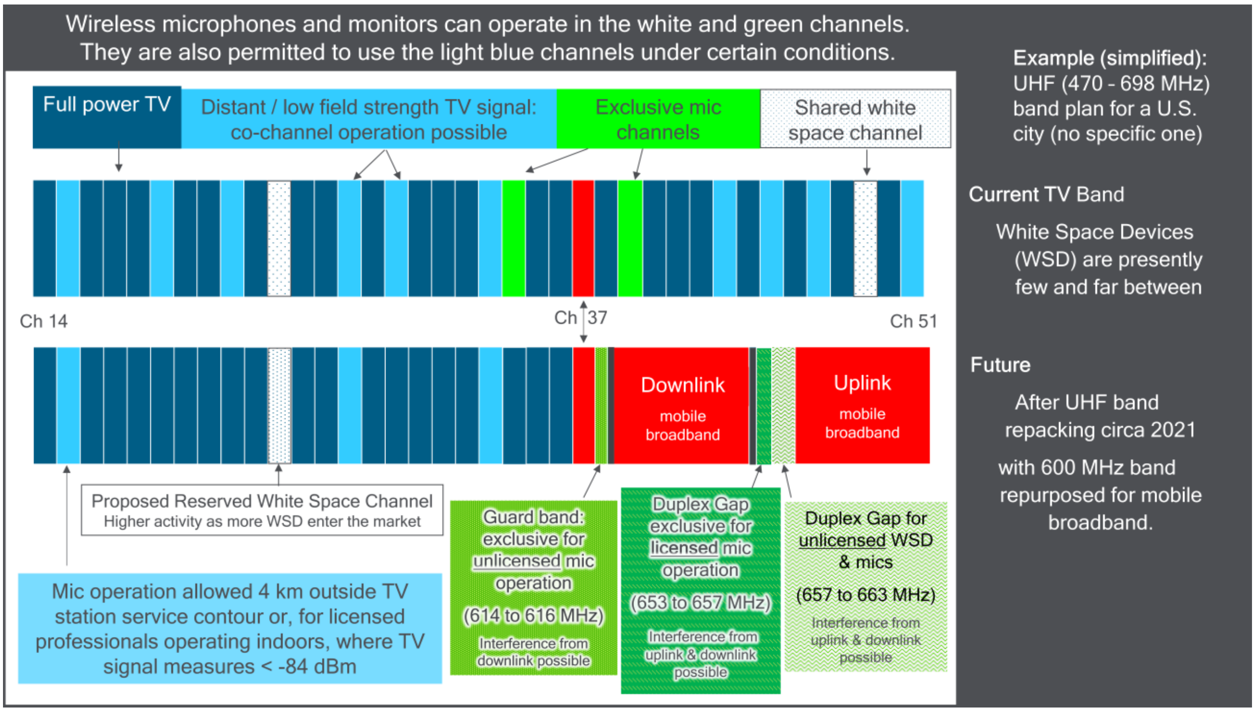
Operating in the Guard Band and in the Duplex Gap

An 11 MHz buffer band known as the duplex gap has been established between the forthcoming downlink and uplink 600 MHz mobile broadband blocks. No devices shall operate in the lowest 1 MHz adjacent to the downlink block. The next 4 MHz (653-657 MHz) are reserved for licensed wireless microphone operators, and will not be shared with white space devices. This will be particularly useful for electronic news gathering (ENG) crews covering spontaneous events. In contrast, the upper 6 MHz (657-663 MHz) of the duplex gap will be shared between unlicensed wireless microphones and white space devices.

A 3 MHz lower guard band will exist, separating mobile broadband from Channel 37. No devices shall operate in the upper 1 MHz (616-617 MHz) adjacent to the downlink block. Wireless microphones will have exclusive use of the remaining 2 MHz (614-616 MHz), and will operate under FCC Part 15 unlicensed rules.

FIGURE 34

470-698 MHz band in USA



Given that the guard band and duplex gap are buffers to control interference between adjacent services, there may be high out-of-band emissions (i.e. noise) from those services. Therefore, the possibility of interference to wireless microphones operating in these bands may be high.

Protection of existing services

Several services that require interference protection operate between 150-2 000 MHz and are not used for ENG / PMSE applications in the United States. These include aviation radio services and aeronautical mobile telemetry (AMT) in, for example, the 243 MHz, 328.6-333.5 MHz, 960-1 215 MHz, 1215-1400 MHz, and 1780-1850 MHz bands; the radio navigation-satellite service (i.e. GPS, GLONASS, Galileo, and other GNSS systems) that operate worldwide at 1 164-1 215 MHz, 1 215-1 300 MHz, and 1 559-1 610 MHz (along with any adjacent bands from which unwanted emissions could cause degradation) that are used by GPS, GLONASS, Galileo, and other GNSS systems; the mobile-satellite service bands at 149.9-150.05 MHz, 399.9-400.05 MHz, 406-406.1 MHz, 1 518-1 525 MHz, 1 525-1 559 MHz, 1 610-1 626.5 MHz, 1 626.5-1 660.5 MHz, 1 668-1 675 MHz, and 1 980-2 010 MHz; the radioastronomy and/or EESS (passive) bands at 608-614 MHz, 1 400-1 427 MHz, 1 610-1 613.8 MHz; and meteorological service bands from 400.15 to 406 MHz. Because of the nature of incumbent services and uses in these bands, global harmonization of these bands (and the 1 435-1 525 MHz band referenced below) for ENG/PMSE is not practical.

Access to alternate suitable frequency bands

In light of the above, and other factors, the FCC is accommodating ENG/PMSE operations partially through access to alternative frequency bands outside of the UHF TV band, as well as favourable modifications to certain operational rules, including:

– The current 944-952 MHz studio transmission link ("STL") band was effectively expanded to include portions within the 941-960 MHz band (specifically 941.500-944.000 MHz; 944.000-952.000 MHz; 952.850-956.250 MHz; 956.450-959.850 MHz) and is open to all licensed wireless microphone operators. Previously, the STL band was limited to licensed wireless microphone operators that were broadcasters. Primary services in this band are point-to-point fixed Microwave Services and Broadcast Auxiliary Services (BAS). Operation should be coordinated with the local Society of Broadcast Engineers ("SBE") frequency coordinator. To operate within 941.5–944 MHz, wireless microphone licensees will first need to coordinate with the local SBE coordinator and then apply for a license with the FCC, which will coordinate with incumbent Federal primary users of the band. This band can be useful for fixed venues, such as casinos, that need "house mics" on distinct frequencies from travel acts. Broadway theatres are another example of potential users.

– The rules governing the 169-172 MHz band (which lies just below high band VHF TV channels) were revised to make this range more practical for wireless microphones. Specifically, the Commission adopted channelization that will allow more wireless microphones to operate simultaneously in this band. Operation will be on discrete frequencies, and will be uniform nationwide – an advantage when traveling throughout the United States. A Part 90 license is required but eligibility is broader than for a Part 74 license. FCC states: "Entities eligible to operate wireless microphones under the Part 90 rules include a variety of users, including those eligible to hold LPAS licenses under Part 74 as well as many other entities, such as state and local government entities; commercial entities in general; educational, philanthropic or ecclesiastical institutions; clergy; and hospitals, clinics, and medical associations." The Commission further explains, "While all entities eligible for license under Part 74 are also eligible under Part 90, the inverse is not true: many entities eligible under Part 90 are not eligible under Part 74." The application process for a Part 90 license follows the same procedures as that for Part 74, described above.

– The 1 435-1 525 MHz band will be available to licensed wireless microphone operators. However, use of this band will require equipment with an electronic key and an approval process for each production. Operation in this band will be secondary to aeronautical mobile telemetry ("AMT") (i.e. flight testing). This GHz band is coordinated by the Aerospace and Flight Test Radio Coordinating Council ("AFTRCC"). Equipment must incorporate location, date, and time awareness. AFTRCC will provide a digital code (i.e. the electronic key) that will unlock the equipment, enabling the device to work at the approved time and location. In a number of other administrations, portions of this band (i.e. L-band) are allocated for IMT. The factors referenced here make the L-band particularly unsuitable for international harmonization.

TABLE 19

Frequency bands for SAB/SAP audio in the United States

Frequency band	Licensed/unlicensed	Rule Part
26.1-26.48 MHz (VHF)	Licensed	Part 74
161.625-161.775 MHz (VHF)	Licensed	Part 74
Portions of 169-172 MHz band (VHF)	Licensed	Part 90
88-108 MHz (FM)	License exempt	Part 15
450-451, 455-456 MHz (UHF)	Licensed	Part 74
54-72, 76-88, 174-216, 470-608, 614-616, 653-663 MHz (VHF and UHF)	Licensed and licensed exempt	Part 74 Part 15
941.500-952.000, 952.850-956.250, 956.45-959.85 MHz (UHF)	Licensed	Part 74
1 435-1 525 MHz *	Licensed	Part 87 and Part 74
6 875.000-6 900.000, 7 100.000-7 125.000 MHz	Licensed	Part 74
902-928 MHz, 2.4 GHz, 5 GHz (ISM bands)	License exempt	Part 15
1 920-1 930 MHz (unlicensed PCS)	License exempt	Part 15
Ultra-wideband (3.1-10.6 GHz)	License exempt	Part 15

* License and use is on a secondary basis and advance coordination is required with Aerospace and Flight Test Radio Coordinating Council, Inc. (AFTRCC), see: https://aftrcc.org/coordination/.

Annex 3

Supplementary technical information on audio PMSE

Emission masks

ETSI EN 300 422 defines transmit spectrum masks, which are tailored to foster multi-link, multi-vendor uses of the available frequency bands.

Three radio architectures are inherently described by EN 300 422:

a) Narrow-Band Analogue – following a traditional link-based approach;

b) Narrow-Band Digital – following a traditional link-based approach; and

c) Wireless Multi Audio-channel System (WMAS) – following a system-based approach to serve N portables. The following spectrum masks for analogue and digital narrowband systems, and for WMAS are provided in EN 300 422.

B is the *Channel Bandwidth* the link or system is designed for. Narrowband systems employ channel bandwidth B from 50 kHz to 600 kHz, with B = 200 kHz the typical value. WMAS can employ up to 20 MHz, with B = {6,7,8,10} MHz being typical values. All masks are relative to transmitter RF output power.

The mean power density, measured with resolution bandwidth (RBW) and RMS detector or in case of WMAS Peak detector, of the transmitter unwanted emissions shall not exceed the limits of the applicable mask.

FIGURE 35

Transmit spectral power mask for equipment employing analogue narrowband modulation, RBW = 1 kHz, RMS Detector

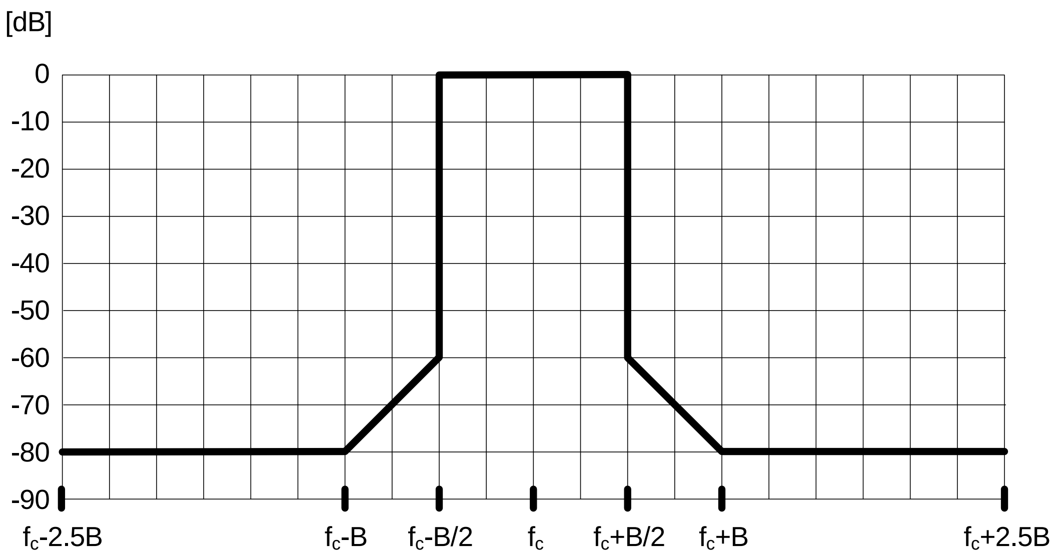


FIGURE 36

Transmit spectral power mask for equipment employing digital narrowband modulation, RBW = 1 kHz, RMS Detector

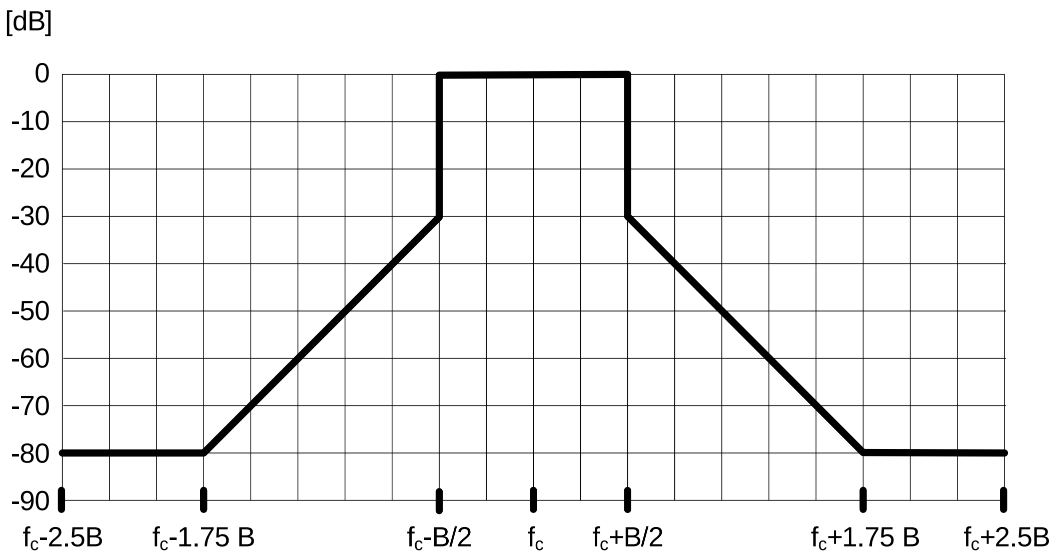


FIGURE 37

Transmit spectral power mask for WMAS, RBW = 100 kHz, Peak Detector

Frequency error

The frequency error shall not exceed 20 parts per million for frequencies below 1 GHz, 15 parts per million between 1 GHz and 2 GHz and 10 ppm above 2 GHz.

Spurious emissions limits at transmitter antenna port

TABLE 20

Spurious emission limits at transmitter antenna port (from ETSI EN 300 422-1)

State	**Frequency**		
	47 MHz to 74 MHz 87.5 MHz to 137 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other Frequencies below 1 000 MHz	Frequencies above 1 000 MHz
Operation	4 nW	250 nW	1 µW
Standby	2 nW	2 nW	20 nW

Measured values for equipment in each frequency band must be below the values given in Table 20 above.

Minimum required audio quality

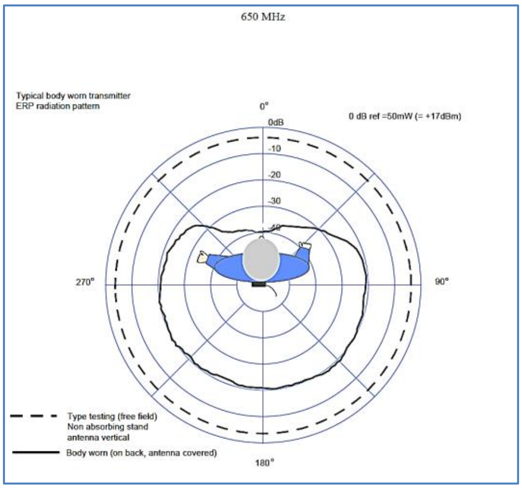
The minimum performance criterion for an audio PMSE receiver is a 30 dB SINAD at its audio output, which needs to be maintained for a measurement time ≥ 10 s without any dropouts or time outs in the measurement routine.

Propagation issues

This section presents some information to the typical transmission path from the transmitter to receiver units.

FIGURE 38

Measurements of an antenna radiation patterns



Calculation of transmission path loss

Path loss for a radio microphone transmission is often interpreted as a simple line of sight scenario however this is not the case.

Components of microphone transmission path can be described as:

– Microphone output power (ERP) 17 dBm

– L_{FSPL} – Free space path loss −32.44-20*log$_{10}$(d/1000 m)-20*log10(f / 1 MHz)

– L_A – Expected loss of microphone antenna loss & detuning effect up to −15 dB

– L_B – Expected loss while carrying antenna on human body (average) up to −25 dB[13]

– L_F – Fading Margin (Wireless Channel) up to −30 dB

– $G_{Rx,D}$ – Gain by using antenna diversity techniques up to 7 dB

– $G_{Rx,A}$ – Gain through receiver antenna typical 7 dB

Typical PMSE devices employing narrowband modulation techniques deploy antenna diversity systems with two antennas. These antennas have the same characteristics and are physically separated (spatial diversity).

The total loss in a worst case employing a typical installation by using diversity receiver antennas can described as:

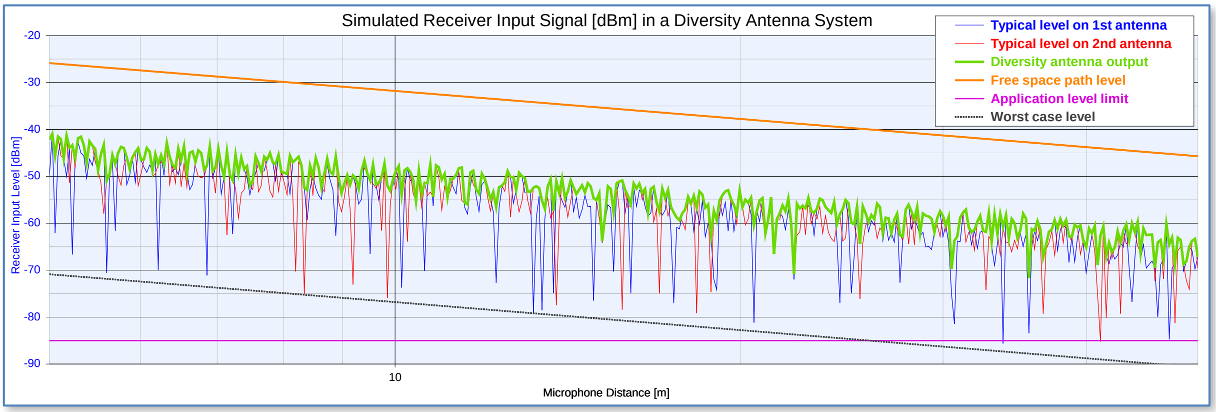
$$\text{Total Loss in Worst Case (dB)} = L_{FSPL} + L_A + L_B + L_F + G_{Rx,\,D} + G_{Rx,A}$$

Diversity receivers using two antennas and a signal switching system vary in their effectiveness depending on the spacing and type of antennas in use.

Figure 39 shows the complex situation of the transmission path if all parameters are considered.

[13] ECC Report 286 "Body effect of handheld and body worn audio PMSE equipment".

FIGURE 39



Notes to Fig. 39:

– The red and blue lines represent the reception level of both antennas.

– The green line is the best-case signal resulting from the diversity algorithm. The diversity scheme is unable to eliminate all path notches but can reduce their effect.

WMAS employs RF channel bandwidths larger than the coherency bandwidth of the wireless channel, so that deep fading notches are less of an issue. WMAS is able to benefit from multi-path propagation by time and frequency diversity techniques. In WMAS, the use of multi-antenna diversity techniques at receiver-side can provide gains of 4 dB or more (3 dB due to doubling the number of antennas and at least 1 dB by spatial diversity are assumed).

Link budget

Beside the path loss the reception of the receiver is affected by additional interference (e.g. adjacent band interference, man-made noise) or additional losses (e.g. antenna placed within actor costume or stage installations). For any production there may be a range of link budgets dependent on the relative locations of the radio microphone user and the receive antenna. Fading, where the actor moves behind scenery is a constant problem and can be 30 dB or even more.

The following is a typical link budget calculation using a diversity antenna system for a digital narrowband and a WMAS system at centre frequency of 600 MHz.

TABLE 21

Typical link budget

Input parameter

	Digital NB	**WMAS**	
d – Distance	20	20	m
f – Frequency	600	600	MHz
P_{out} – Transmitter output power (ERP)	17	17	dBm
L_A – Antenna loss & detuning effect	−15.0	−15.0	dB
L_B – Loss effected while carrying antenna on human body	−25.0	−25.0	dB
L_F – Fading Margin (Wireless Channel)	−30.0	−10.0	dB
$G_{Rx,D}$ – Gain by using antenna diversity techniques	7.0	4.0	dB

TABLE 21 (*end*)

Input parameter

	Digital NB	**WMAS**	
$G_{Rx,A}$ – Gain through receiver antenna	7.0	7.0	dB
B_{Rx} – Receiver channel bandwidth	180	7 500	kHz
N_{NF} – Receiver noise figure	8.0	8.0	dB
SNR_{min} – Receiver minimum SNR	20.0	20.0	dB

Constant parameter

TNF – Thermal noise floor	1 Hz bandwidth at 20 °C	−174.0	−174.0	dBm

Calculation

L_{FSPL} – Free space path loss using 0 dB dipole antennas	−32.44-20*log10 (*d* / 1 000 m)-20*log10 (*f* / 1 MHz)	−54.0	−54.0	dB
L_{Total} – Total path loss	$L_{FSPL} + L_A + L_B + L_F + G_{Rx,D} + G_{Rx,A}$	−110,0	−94.0	dB
N_{TNF} – Thermal noise floor at receiver channel bandwidth	at 20 °C	−121.4	−105.4	dBm
N_{Rx} – Total receiver noise power	$N_{TNF} + N_{NF}$	−113.4	−97,4	dBm
P_{min} – Minimal needed receiver input signal	$N_{Rx} + SNR_{min}$	−93.4	−77.4	dBm
P_{in} – Receiver input signal	$P_{out} + L_{Total}$	−93.0	−76.0	dBm
Link budget	$P_{in} – P_{min}$	**0.4**	**1.4**	**dB**

NOTE:

– A link budget greater than 0 shows the physical link feasibility in absence of interference.

– Any additional interference leads to a reduction in the practical link distance.

Receiver distribution system

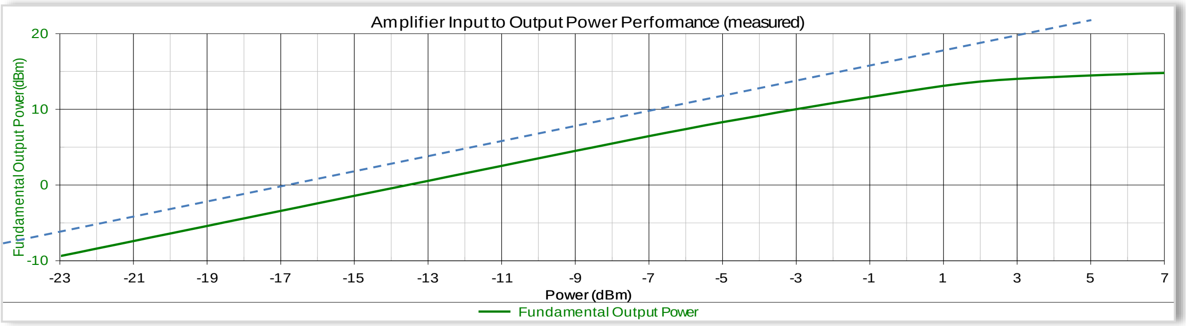
In a simple environment, each receiver has its own antenna. A large production would therefore require 50 or more antennas. Besides the impracticality to mount 50 antennas, the performance would be degraded as antennas would influence each other in their receiving field strength. Therefore, the professional event uses antenna distribution systems. The signal of the receiving antenna is split into many receiver paths. An antenna signal amplifier can compensate for a signal loss created by cable loss and splitter loss. Nonlinearity of such antenna signal amplifier in combination with high-bandwidth (e.g. 24 to 100 MHz) can degrade the desired receiver performance. The receivers can be affected by interference from the intermodulation generated within amplifiers. Therefore, many scenarios use additional components, such as filters, to minimize intermodulation and provide protection from other radio signals.

Non linearity of an antenna distribution amplifier

A typical antenna amplifier was measured for its linear transfer function (Fig. 40).

FIGURE 40

Typical antenna amplifier



Note to Fig. 40: The dotted blue line shows the linear admittance function.

Transmitter distribution system

IEMs typically use a fixed transmitter mounted in "19" size racks. It is impractical to use individual antenna in a large system Therefore transmitter outputs are combined to a common antenna path. RF power losses (e.g. cable loss, combiner loss) might be compensated by use of an amplifier. Nonlinearity in combination with high-bandwidth degrades the desired transceiver performance if the transmitted signal is inserted into the next IEM transmitter, which will generate IM products. An antenna combiner can help to reduce such IM products to a minimum.

Additional filters are used to provide protection to other radio application outside the microphone band.

Intermodulation

An important issue to maximize spectral efficiency is to avoid interference from intermodulation (IM) products. Intermodulation is the result of two or more signals mixing together, producing harmonic distortion. This occurs within active components, such as transistors, exposed to strong RF input signals. When two or more signals exceed a certain threshold, they drive the active component into a non-linear operating mode and intermodulation (IM) products are generated. In an environment where multiple devices are operating in close proximity, several RF input signals may exceed a certain level resulting in the generation of numerous intermodulation products that limits the amount of clean spectrum for desired signals.

Wireless microphones are used in every echelon of society and thus are available in a wide variety of quality levels. High-end systems that are appropriate for PMSE applications have extraordinarily demanding technical requirements and are routinely used in large numbers for sophisticated productions. To mitigate interference that could be caused by intermodulation, they incorporate highly linear designs with top grade electronic components that draw extra current providing headroom, preventing IM harmonics from being created. Furthermore, intermodulation between wireless microphone transmitters can be avoided through the use of circulators that prevent signals from entering the antenna in reverse fashion. Of course, this increases the cost of professional wireless microphone systems by several magnitudes but allows dense packing of multiple audio channels within a limited block of spectrum, such as a TV channel. However, it should be noted that any other wireless (non-microphone) devices operating co-channel or in adjacent channels that do not incorporate similar IM migration techniques may pollute the spectrum, causing interference to all devices.

Multi-venue sites

At sites where multiple venues are clustered together such as TV studio complexes, conference centres, and theatre complexes, we also have to consider the effect that events in one area of the complex may have on another. Radio microphones are portable transmitters which may travel around a venue (or beyond) outside the coverage of their receivers such as when an actor returns to the dressing room between scenes, or a conference speaker leaves the room between presentations. The dressing room or the route to it may be adjacent to another studio or, the conference centre may be adjacent to another conference room. Taking the frequency planning for each venue on site solely in isolation exposes the receivers in each venue to the danger of intermodulation created by the proximity of a transmitter (or transmitters) from another area coming within range of the receivers. Careful planning can and does eliminate these risks allowing unhindered mobility of event participants and their radio microphones. Similar risks exist where IEMs are used in multiple adjacent venues, but since in this case the transmitters are usually fixed in their location the situation is more controlled.

In all of the above, however, the common factor is that the distribution and use of PMSE radio frequencies in and around a site is known and the ‘worst case’ scenario of everything being in use at once can be assessed, calculated and allowed for.

Digital PMSE

Whereas the effects of intermodulation or any form of interference may become apparent and a nuisance to analogue PMSE services at even relatively low levels the onset may be gradual and the noticeable degradation in performance as levels of interference increases gives some warning of impending problems. Low levels of interference under certain circumstances (where the protection criteria are not respected) such as in location news gathering may be deemed acceptable even when noticed if the alternative is no sound (or news) at all.

By comparison, low levels of radio interference may not be evident in the audio output of current digital radio microphone until the C/I degrades up to or very near the point at which the audio output is suddenly lost or corrupted beyond recognition. Far from being completely immune to intermodulation issues, the choice is between managing the quantifiable audible intrusion of increasing interference or total loss of audio connection with little or no warning. Both will suffer interference as a result of intermodulation in some way. How analogue and digital systems behave in terms of interference is difficult to compare. It is expected that digital PMSE will be less subject to intermodulation issues resulting in better frequency efficiency in some cases.

Annex 4

References

[1] ECC Report 002: SAP/SAB (Incl. ENG/OB) spectrum use and future requirements.

[2] Resolution 232 (WRC-12) – Use of the frequency band 694-790 MHz by the mobile, except aeronautical mobile, service in Region 1 and related studies. (Withdrawn by WRC-15)

[3] ETSI EN 300 422 – Harmonized European Standard for Wireless Microphones; Audio PMSE up to 3 GHz, 2017, https://www.etsi.org/deliver/etsi_en/300400_300499/30042201/02.01.02_60/en_30042201v020102p.pdf

[4] ERC Recommendation 25-10: Frequency Ranges for the Use of Terrestrial Audio and Video Programme Making and Special Events (PMSE) applications (2021).

[5] Report for OFCOM from Analysys Mason: spectrum Planning for the London 2012 Olympic and Paralympic Games
http://stakeholders.ofcom.org.uk/binaries/consultations/london2012/annexes/wire_wireless.pdf
http://stakeholders.ofcom.org.uk/binaries/consultations/london2012/annexes/wire_wireless2.pdf (Part 2).

ITU

Resolution 233 (WRC-12) – Studies on frequency-related matters on International Mobile Telecommunications and other terrestrial mobile broadband applications. (Withdrawn by WRC-15)

Report ITU-R BS.2161 – Low delay audio coding for broadcasting applications.

Report ITU-R BT.2069 – Tuning ranges and operational characteristics of terrestrial electronic news gathering (ENG), television outside broadcast (TVOB) and electronic field production (EFP) systems.

Other references

EC

European competitiveness report 2010, http://bookshop.europa.eu/en/european-competitiveness-report-2010-pbNBAK10001/

Creative Industries Economic Estimates, December 2011, Department for culture, media and sport, United Kingdom: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/77959/Creative-Industries-Economic-Estimates-Report-2011-update.pdf

Decision 243/2012/EU of 14 March 2012 "on establishing a multiannual radio spectrum policy programme".

Decision 2010/267/EU "on harmonized technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union".

Decision 128/1999/EC "on the coordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community".

European Commission Decision 2006/771/EC on harmonization of the radio spectrum for use by short-range devices.

EC Mandate to CEPT on technical conditions regarding spectrum harmonization options for wireless radio microphones and cordless video-cameras (PMSE equipment), https://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=7473

CEPT

CEPT Report 32: Recommendation on the best approach to ensure the continuation of existing Programme Making and Special Events (PMSE) services operating in the UHF (470-862 MHz).

CEPT Report 50: "Report A from CEPT to the European Commission in response to the Mandate "On technical conditions regarding spectrum harmonisation options for wireless radio microphones and cordless video-cameras (PMSE equipment)", Technical conditions for the use of the bands 821-832 MHz and 1 785-1 805 MHz for wireless radio microphones in the EU, 2013, download at: https://docdb.cept.org/document/50

CEPT Report 51: Report B from CEPT to the European Commission in response to the Mandate "On technical conditions regarding spectrum harmonisation options for wireless radio microphones and cordless video-cameras", Technical conditions for ensuring the sustainable operation of cordless video-cameras, 2013, download at: https://docdb.cept.org/document/51

CEPT Report 61: Harmonised compatibility and sharing conditions for video PMSE in the 2.7-2.9 GHz frequency band, taking into account radar use, 2016, download at: https://docdb.cept.org/document/978

ECC Report 44: Guidance for radio usage at special events, 2014, https://docdb.cept.org/document/992

ECC Report 121: Compatibility studies between Professional Wireless Microphone Systems (PWMS) and other services/systems in the bands 1 452-1 492 MHz, 1 492-1 530 MHz, 1 533-1 559 MHz also considering the services/systems in the adjacent bands (below 1 452 MHz and above 1 559 MHz), 2008, https://docdb.cept.org/document/229

ECC Report 159: Technical and operational requirements for the possible operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz, 2011, https://docdb.cept.org/document/267

ECC Report 185: Complementary Report to ECC Report 159. Further definition of technical and operational requirements for the operation of white space devices in the band 470-790 MHz, 2013, https://docdb.cept.org/document/292

ECC Report 186: Technical and operational requirements for the operation of white space devices under geo-location approach, 2013, https://docdb.cept.org/document/293

ECC Report 191: Adjacent band compatibility between MFCN and PMSE audio applications in the 1 785-1 805 MHz frequency range, 2013, https://docdb.cept.org/document/298

ECC Report 219: Characteristics of PMSE digital video links to be used in compatibility and sharing studies, 2014, https://docdb.cept.org/document/326

ECC Report 220: Compatibility/sharing studies related to PMSE, DECT and SRD with DA2GC in the 2 GHz unpaired bands and MFCN in the adjacent 2 GHz paired band, 2014, https://docdb.cept.org/document/327

ECC Report 221: Adjacent band compatibility between MFCN and PMSE audio applications in the 700 MHz frequency band, 2014, https://docdb.cept.org/document/328

ECC Report 243: Wireless video links in the frequency bands 2 700-2 900 MHz and 2 900-3 400 MHz, 2016, https://docdb.cept.org/document/349

ECC Report 245: Compatibility studies between a PMSE and other systems / services in the band 1 350-1 400 MHz, 2016, https://docdb.cept.org/document/351

ECC Report 253: Compatibility studies for audio PMSE at 1 492-1 518 MHz and 1 518-1 525 MHz, 2016, https://docdb.cept.org/document/957

ECC Report 285: Best practices for Video Programme Making and Special Event (PMSE) in the 2 700-2 900 MHz band, 2018, https://docdb.cept.org/document/6038

ECC Report 286: "Body effect of hand-held and body-worn audio PMSE equipment, 2018, https://docdb.cept.org/document/6160

ERC Recommendation 70-03 – Relating to the use of Short Range Devices (SRD)ERC Report 25: The European table of frequency allocations and applications in the frequency range 9 kHz to 3 000 GHz.

ERC Report 42: Handbook on radio equipment and systems radio microphones and simple wide band audio links.

ERC Report 204: Spectrum use and future requirements for PMSE (2014).

ERC Report 323: Spectrum Use and future spectrum requirements for PMSE (2021).

Ofcom and the London 2012 Olympic and Paralympic Games, http://stakeholders.ofcom.org.uk/consultations/london2012/report-olympic-paralympic-2012/ CEPT Report 50: Technical conditions for the use of the bands 821-832 MHz and 1 785-1 805 MHz for wireless radio microphones in the EU.

United Kingdom

The Wyndham report: the economic impact of London's West End theatre, 1998.

UKEMTS 2011 Report on the development of the British event industry.

Audio Engineering Society Standard 42.

APWPT input to CEPT

FM50(11)037 – Appendix 2 from APWPT: Economic potential of PMSE applications.

Japan

ARIB STD-B12 – Microwave band fixed digital transmission system for television program contribution.

ARIB STD-B13 – 800MHz-band OFDM transmission system for television program contribution.

ARIB-STD-B43 –Millimeter-wave band portable digital transmission system for ultra high definition television program contribution.

ARIB STD-B57 – 1.2 GHz/2.3 GHz-band portable OFDM digital transmission system for television program contribution.

ARIB STD-B71 – Microwave band portable OFDM digital transmission system for ultra high definition television program contribution.

ARIB STD-T112 – Specified radio microphone for land mobile radio station (TV white space band, exclusive band, 1.2 GHz band).

ARIB STD-15 – Radio microphone for specified low power radio station.

ARIB STD-22 – Specified radio microphone for land mobile radio station.

Others

EBU Technical Report 001, Results of the EBU questionnaire on spectrum requirements for SAB/SAP & ENG/OB applications, http://tech.ebu.ch/docs/techreports/tr001.pdf