CEPT ECC

Electronic Communications Committee

ECC Report 292

Current Use, Future Opportunities and Guidance to Administrations for the 400 MHz PMR/PAMR frequencies

approved 8 February 2019

0 EXECUTIVE SUMMARY

0.1 INTRODUCTION

This ECC Report addresses the issue of the current and future use for the 400 MHz PMR/PAMR frequencies. It updates the ECC Report 25 (adopted in 2003 [2]) that in consequence is now obsolete.

WGFM conducted a questionnaire to CEPT administrations and industry on 400 MHz PMR/PAMR frequencies in 2014 [42], and it highlights that the use of the frequency bands between 400 and 470 MHz varies significantly throughout the CEPT countries. This variety and diversity has further increased since the completion of the survey. The results of the survey are summarised in Annexes 1 to 3.

The PMR/PAMR sector is highly competitive with more than 20 vendors and primarily provides standardised yet tailor-made solutions to various, mostly vertical market demands, and often for small and medium size business customers.

The adoption of information and communication technology in almost all sectors of the economy (e.g. Smart Grid, Smart metering and Industry 4.0) increases the demand for business and mission-critical Machine-to-Machine communication. Companies and organisations increasingly require communication that provides both the very high reliability and resilience possible in PMR/PAMR networks. Modern cost effective technologies allow for low latency, quality of service, much higher data rates, M2M optimisation and potentially very large numbers of connected devices, all possibly supplied by one vendor. For example, communications to 10,000 to 100,000 electricity sub-stations.

In light of these technical and commercial requirements, deployments of new mobile networks to enable robust connectivity to a very high number of M2M/IoT devices can be observed. While the 450-470 MHz band is a common band for PMR/PAMR, the band 450-470 MHz is also identified by ITU Radio Regulations (RR) footnote 5.286AA for use by administrations wishing to implement International Mobile Telecommunications (IMT). Further details may be found in Resolution 224 (Rev.WRC-15) [34]. This identification does not preclude the use of this frequency band by any application of the services to which it is allocated and does not establish priority in the Radio Regulations. Certain countries have licensed up to 2x5 MHz of MFCN/PAMR spectrum in 450-470 MHz initially deployed using Code Division Multiple Access (CDMA). Networks are already deployed in the Netherlands, Austria, Germany, Latvia, Russia, Sweden, Norway, Denmark, Finland, Hungary and the Czech Republic providing connectivity for millions of devices using CDMA450 or LTE450 technology. These networks have been assigned nationwide licences and it is assumed that existing CDMA networks are likely to migrate towards LTE including eMTC and NB-IoT.

Future LTE networks in the 400 MHz band may operate on a national basis, on a regional or on local basis. The significance of this is that spectrum used for narrowband PMR/PAMR is currently assigned based on nationwide, regional or local use. Whereas the spectrum assigned to be used based on cellular technologies will typically be assigned nationwide only and cannot be used PMR networks anymore. Such discrimination between 12.5 kHz based PMR and Mobile/Fixed Communications Networks (MFCN) is going to be significant if more cellular technologies are introduced for the current users of PMR/PAMR.

The evolution of technologies to support more data, varying frequency bandwidths, business and mission critical Machine-to-Machine (M2M) communications is important for users across industries. Such users should be enabled to continue to use their current PMR licences based on the current regulatory framework and evolve without being disrupted by a sudden frequency management policy that favours a single player's access to broader spectrum on nation-wide basis. The evolution of market demands, the availability of cellular mobile technologies in 400 MHz bands as well as evolving requirements for mission-critical M2M applications should be carefully reflected in spectrum management activities and in national frequency policies.

0.2 GUIDANCE

Depending on the PMR/PAMR usage situation in the country, CEPT administrations may decide which parts of the available spectrum for land mobile systems is made or kept available for networks based on specific narrowband, wideband or broadband technologies.

When identifying sufficient spectrum for wideband and broadband systems in the 400 MHz range, it is often difficult to identify continuous spectrum to reach LTE size channels of 1.4 MHz, 3 MHz or 5 MHz. National regulatory strategies are required for migration of narrowband usage to a certain frequency bands in order to achieve a contiguous range of spectrum for assignments of spectrum for land mobile systems based on LTE technology.

This Report describes options which administrations can employ such as:

- consideration of how VHF use could be fostered;
- foster increased shared use of PMR channels;
- to amend their PMR/PAMR regulatory framework. Regulation in some countries still have to follow the digitisation of the PMR/PAMR market (in other words: increase the frequency opportunities for digital use);
- achieving more contiguous band segments for wideband and broadband systems;
- more flexible approaches for licensing;
- adoption of a concept defining area licences (see section 5.4).

CEPT administrations should endeavour to comply with the provisions in Recommendation T/R 25-08 [3].

Many PMR/PAMR land mobile systems support critical communications, either business-critical, mission-critical or safety-related. There may be synergies in the way these are provided. The idea of having national common platforms is attractive when facing scarcity of spectrum in the 400 MHz range, especially for wideband and broadband networks.

0.3 RECENT SPECTRUM COMPATIBILITY STUDY RESULTS IN ECC REPORT 283

410-430 MHz

Following the investigations in ECC Report 283 [43], it is proposed that 3GPP should consider standardisation activities for the range 410-430 MHz.

The coexistence of LTE in the frequency band 410-430 MHz and radars operated on a secondary basis in the frequency band 420-430 MHz cannot be ensured only by technical conditions. It is to be noted that some countries have already concluded multilateral frequency co-ordination agreement for LTE usage without having taken into account the secondary radiolocation service.

Analyses show that co-existence between LTE systems (including BB-PPDR) and radio astronomy is feasible in the whole considered tuning range of 410-417 MHz / 420-427 MHz, provided that certain measures are ensured. Sufficient mitigation techniques may be adopted such as specific requirements on LTE network’s layout, if needed. However, the appropriate protection methods for RAS stations could be managed at national level and with international coordination. Given the limited number of radio astronomy, it is expected a need of coordination for the deployment of LTE stations at distances lower that 250 km from a RAS station located in a neighbouring country.

450-470 MHz

For the protection of DTT, it can be concluded that the limits defined for the base stations of LTE based BB-PPDR in ECC Decision (16)02 [44] should apply to the base stations of LTE based PMR/PAMR as well. At a national level, the out-of-band limit might be relaxed. For example, with a sparse network deployment, using high remote sites such as those used for DTT, the probability of interference to DTT reception is significantly reduced. Such a deployment has been successfully implemented in Scandinavian countries. Also, the requirement on the ACLR of the LTE PMR/PAMR BS can be relaxed when the victim DTT receiver is located close to the DTT transmitter so that the received DTT signal is strong enough to mitigate the interferer. Further mitigation measures, as described in Annex 8 of ECC Report 283, may allow solving possible remaining interference on a case by case basis.

LPWAN

For the co-channel cases in the 410-430 MHz frequency range, there is no possibility for compatibility between LPWAN system and airborne radar or LPWAN system and ground radar.

It is necessary to improve the LPWAN base station transmitter ACLR by 30 dB compared to original specifications for the 800/900 MHz range.

A guard band of 200 kHz is necessary between the TETRA base station (BS) and the LPWAN end device (ED). In the case of co-channel situation between TETRA and LPWAN systems, the minimum separation distance between base stations is more than 100 km.

Intermodulation

One interference effect to be taken into account is the potential impact of Intermodulation Distortion in PMR receivers caused by neighbouring broadband signals. This is dependent on frequency offset of the LTE carrier from the victim PMR receiver, the received power and the intermodulation performance of the victim PMR receiver at that frequency offset. No conclusion on the intermodulation effect from broadband interferers into narrow band victims could be reached in ECC Report 283 [43] and additional investigations are going to be conducted within ECC.

0.4 TRIGGERING POSSIBLE FUTURE STANDARDISATION ACTIVITIES

The following items for possible future standardisation activities have been identified:

- it is proposed that 3GPP should consider standardisation activities for the range 410-430 MHz;
- work item for ETSI standards and/or specifications for a means to facilitate PMR spectrum sharing;
- improved receiver specifications may be helpful to reach a more effective spectrum utilisation, e.g. by avoiding guard bands between different land mobile system operating in adjacent spectrum, in the 400 MHz frequency ranges. ECC Report 283 [43] provides useful guidance in this respect.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3G	Third generation mobile services
3GPP	3G (mobile) Partnership Project
4G	Fourth generation mobile services
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AF	Activity Factor
BB-PMR/PAMR	Broadband PMR/PAMR
BS	Base Station
BC	Bandwidth Correction
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
CR	Congestion Ratio
CTCSS	Continuous Tone-Coded Squelch System (sub audio tone squelch)
D2D/ProSe	Device-To-Device/ Proximity Services
DGNA	Dynamic Group Number Assignment
DMO	Direct Mode Operation
DMR	Digital Mobile Radio
DPMR	Digital Private Mobile Radio
DTT	Digital Terrestrial Television
ECA	European Common Allocations
ECC	Electronic Communications Committee
ECO	European Communication Office
ECS	Electronic Communications Services
ED	End Device
EHV	Extra High Voltage (above 230 kV)
eMTC	Enhanced Machine-type Communications
ERC	European Radiocommunications Committee
ERO	former European Radiocommunications Office (now ECO)
ERM	Electro-magnetic Radio Matters – ETSI

Abbreviation	Explanation
e.i.r.p.	Effective Isotropically Radiated Power
e.r.p.	Effective radiated power
ETCS	European Train Control System
ETSI	European Telecommunications Committee
EUTC	European Utilities Telecoms Council
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FRMCS	Future Railway Mobile Communication systems
FS	Fixed Service
GSM-R	Global Systems for Mobile Communications - Railways
HCM	Harmonised Calculation Method
HV	High Voltage (35 kV to 230 kV)
ICT	Information and Communication Technologies
IMT	International Mobile Telecommunications
IoT	Internet of Things
ITU-R	International Telecommunications Union - Radiocommunications
LPWAN	Low Power Wide Area Network
LSA	Licensed Shared Access
LTE	Long Term Evolution
LV	Low Voltage (up to 1kV)
M2M	Machine-to-Machine
MCL	Maximum Coupling Loss
MCPTT	Mission Critical Push to Talk
MFCN	Mobile/Fixed Communications Networks
MNO	Mobile Network Operator
MS	Mobile Station
MTC	Machine Type Communications
MV	Medium voltage (1kV to 35 kV)
NB-IoT	Narrowband IoT
NXDN	Next Generation Digital Narrowband
OOBE	Out-of-Band Emissions
PAMR	Public Access Mobile Radio

Abbreviation	Explanation
PMR	Professional (Private) Mobile Radio
PPDR	Public Protection and Disaster Relief
RAS	Radio astronomy service
RFID	Radio Frequency Identification Device
RM2M	Resilient Machine To Machine
RR	Radio Regulations
RSPG	Radio Spectrum Policy Group
RT	Railway Telecommunications
SCADA	Supervision, Control and Data Acquisition
SR	Special Report – ETSI
SRD	Short Range Devices
TC	Technical Committee
TDMA	Time Division Multiple Access
TEDS	Terrestrial Trunked Radio Extended Data Service
TETRA	Terrestrial Trunked Radio
TETRAPOL	Proprietary digital private mobile radio network
TG	Task Group
TM4	Transmission Multiplexing (Fixed Links) – ETSI
TR	Technical Report
UE	User Equipment
UHF	Ultra High Frequency
UTRA	Universal Terrestrial Radio Access
VHF	Very High Frequency
VOX	Voice-activated switch
VPN	Virtual Private Network
WRC	World Radiocommunication Conference

1 INTRODUCTION

This ECC Report addresses the current and future use for the 400 MHz PMR/PAMR frequencies. The Report updates the ECC Report 25 adopted in 2003 [2] which in consequence become obsolete.

The PMR/PAMR market can be characterised by two different trends. Whereas 6.25/12.5/25 kHz services (critical voice applications) and technologies are still demanded and used extensively, there is a trend towards PMR/PAMR systems using 200 kHz, 1.25 MHz, 1.4 MHz, 3 MHz and 5 MHz channels. This development has gained substantial momentum over the last two years with expected deployment of millions of devices. It is linked to the introduction of information and communication technologies (ICT) to several market sectors which request data oriented PMR/PAMR services.

The ongoing ubiquitous adoption of ICT changes the PMR/PAMR markets tremendously. Standardised IMT technologies adapted to the PMR/PAMR use cases can address evolving demand especially for robust Machine-to-Machine (M2M) communication. This robust M2M communication requires high resilience, implementation of quality of service applications, dedicated design and high scalability and capacity.

Technologies for PMR/PAMR such as CDMA and LTE require the availability of blocks of contiguous spectrum and can support efficient single frequency reuse especially when deployed on national basis. Due to limited spectrum blocks and required separation distances between networks, the approach used for PMR/PAMR networks with channel bandwidths up to 25 kHz is mostly based on a larger number of local/regional spectrum licences, wideband channels are often assigned to individual companies for private use, and with overlapping coverage. Such existing assignments cannot be used for deploying technologies with channel bandwidth of greater than 1 MHz.

In line with several ECC Decisions, this ECC Report focuses on the following UHF bands as these are more appropriate for the evolution of land mobile systems to support digital duplex narrow band, wide band and broadband technologies:

- 410-430 MHz;
- 450-470 MHz.

This ECC Report gives an overview on the current use as well as future opportunities. Against the background of current trends and envisaged use cases it provides guidance to CEPT administrations on the implementation of national frequency management strategies within the respective frequency bands. The conclusions aim at ensuring an efficient use of frequencies and giving incentives for innovations. With regard to existing ECC deliverables dealing with the respective frequency bands, this ECC Report highlights those deliverables which might be required to be amended to cover all relevant developments (e.g. land mobile systems using LTE in 450 MHz).

2 PMR/PAMR TODAY

2.1 DEFINITIONS

2.1.1 Private (Professional) Mobile Radio

Private (Professional) Mobile Radio (PMR) is traditionally characterised by being private (individually authorised) access, professional sector specific group communication, tailor-made design, using predominantly portable devices allowing the licensed users to stay in full control over their tasks at hand in order to optimise their operations.

A more formal, technical definition can be obtained from the ERC Report 052 [4], ERC Report 073 [5] and the ERO Report on PMR and PAMR (July 1997).

According to those Reports, PMR is part of the land mobile service based on the use of simplex or duplex modes at the terminal level to provide closed user group communications.

PMR can be both self-provided and self-owned by business users' small, wide or even national area networks or a tightly controlled set of inter-related closed user groups networks.

PMR covers mobile radio systems used by an organisation to establish communications in support of its own activities. PMR products follow standards such as EN 301 166 [19], EN 300 086 [6], EN 300 113 [7], EN 300 392 [1] and equivalent technical specifications. Typical PMR systems can be described as follows:

- wide area encompassing systems with a range of more than 1 km to regional or national coverage. Voice is used in majority of networks but data services in large scale networks are increasing;
- on-site systems for voice, voice and data or data only. They are typically used to provide communications with personnel on the move within the organisation's premises.

2.1.2 Public Access Mobile Radio (PAMR)

Public Access Mobile Radio (PAMR) is a type of service offered by an operator to business user groups over a large-scale network. The networks are operated to provide professional or critical communications facilities comparable to those of PMR networks. PAMR operators provide on a commercial basis such services to business professional user groups. Such networks could benefit from scale efficiencies and developments of IMT technologies.

2.1.3 Application Terminology

Recommendation T/R 25-08 [3] includes the planning criteria and cross-border coordination of frequencies for land mobile systems in the range 29.7-470 MHz. It does not distinguish between narrowband, wideband and broadband systems, but it refers as appropriate to the respective channel bandwidth.

Furthermore, ECC Decision (01)03 Annex 2 [31] includes as layer 1 application term 'land mobile' and on layer 2 the umbrella terminology 'PMR/PAMR' as well as 'MFCN'. This terminology is also to be used in ERC Report 25 [1] (the European Common Allocation Table), and in ECC harmonisation deliverables.

The existing terminology 'land mobile systems' and 'PMR/PAMR' is sufficient and there is no need to add additional terminology or 'umbrella terms'. IoT, ICT and M2M are too descriptive.

Hence, it is proposed to reuse the existing terminology throughout this Report as appropriate without the need to use terminology such as 'narrowband', 'wideband' and 'broadband'.

2.2 SERVICES

2.2.1 Services using channel bandwidth up to 25 kHz

These PMR/PAMR services include Group Call Voice Services (commonly referred to as 'all informed net' and/or 'talk group call'). This service is in the portable radio environment sometimes also used with a voice-activated head-set (VOX) to allow the user both hands free while communicating (Examples: the modern football/soccer referee or airport ground service staff at the apron).

Other Services include Pre-Emptive Priority Call (Emergency Call), Call Retention, Priority Call, Dynamic Group Number Assignment (DGNA), Ambience Listening, Call Authorised by Dispatcher, Area Selection, Late Entry, Direct Mode, Short Data Service and Packet Data Services.

Where required and specially authorised, encrypted communication channels may also be applied. This is of particular significance for so called dual-use equipment, which may be operated in both the military and civil sectors.

A specialised supply sector is serving this market with solutions ranging from very small single site systems to huge nationwide PMR/PAMR networks which are often very much customised to the specific needs of the users of such networks.

Key services of such PMR/PAMR land mobile radio systems include:

- Point-to-Multipoint communications (as opposed to cell phones which are point to area communications);
- Push-to-talk, release to listen — a single button press opens communication on a radio frequency channel;
- Wide coverage areas;
- Closed user groups;
- Many systems operating with the remote or mobile stations being able to hear all the calls being made. This may not always be satisfactory, and a system of selective calling may be required;
- Call set-up times which are generally short compared with cellular systems.

Many of these PMR/PAMR systems allow direct terminal-to-terminal communication, e.g. when they are out of the coverage area of a base station network or if the network operator uses a solution without base stations within a given area. Current PMR/PAMR systems are also hosting mission-critical M2M services such as Supervision, Control, and Data Acquisition (SCADA) systems, intelligent utility networks (e.g. for electricity, gas and water), sensor polling, alarm routing etc. because such services typically only require low data rate radio linking, e.g. smart meters, intelligent utility networks.

2.2.2 Services using greater channel bandwidth than 25 kHz

The availability of standardised and wide spread IMT technologies such as CDMA and LTE in 400 MHz bands allows the application of well-developed data and voice services in secure, resilient and reliable PMR/PAMR networks. Some of these services can be further optimised within the PMR/PAMR environment i.e. without taking into account an impact of the mass market services in public networks.

With the introduction of LTE using 1.4 MHz or higher bandwidths, it is envisioned that higher bit rate services will also provide low latency, high service differentiation such as deep coverage and quality of service, and security using complex encryption algorithms, which could also be introduced in the PMR/PAMR segments. Examples of applications used are: smart grid and smart metering applications, video alarm streaming, code and image scanning for the transport sector and general harbour logistics including container management. Similar to LTE systems for BB PPDR, LTE-based PMR/PAMR can also provide voice services.

In addition, industry has already developed a number of systems, including for example TETRA TEDS using 25 kHz, 50 kHz, 100 kHz and 150 kHz bandwidth, systems using 200 kHz channel bandwidth based on GSM technology, M2M/IoT based on NB-IoT [39], and LPWAN [14] (125-250 kHz; Low Power Wide Area Networks) technologies.

3 RESULTS OF THE 400 MHZ PMR/PAMR SURVEY

In order to get an empirical overview on the current use of PMR/PAMR a survey conducted for CEPT administrations has been carried out in 2014 [42]. The essential statements of the survey together with additional observations of market parties draw the following picture (more details in Annexes 1 and 2):

- First of all, the use of the frequencies varies from country to country. On one hand, there are countries with 100% analogue usage. On the other hand, there are countries with a high percentage of digital PMR;
- In general, PMR/PAMR supports an enormous range of businesses but is commonly associated with all types of transportation, utilities, retail, manufacturing, security and public safety. Spectrum can be shared with other users in the same coverage area. Simple, affordable and instant voice communications are key features, especially for business critical applications. Users require flexible communications and simple access to spectrum;
- The PMR usage density in 400 MHz bands over population density varies a lot in Europe. It is very high (above 10 per cent) only in the UK (since it accounts for about 25 per cent of PMR usage in 400 MHz in Europe), Netherlands and Switzerland. The usage density can also vary inside a country drastically band-by-band;
- There are 13.000 PMR licences in 410-430 MHz and about 31 000 in 440-450 MHz and 58 000 licences in 450-470 MHz band with a channel bandwidth of up to 25 kHz. The total estimate over CEPT is about 120 000 PMR/PAMR licences with a channel bandwidth of up to 25 kHz, excluding most likely some governmental use or PPDR use that was not counted;
- 27 administrations issue network licences. 16 administrations issue individual transmitter licences (of which 6 countries provide only individual transmitter licences for PMR);
- Congestions, if at all, in the 400 MHz band occur mainly in urban areas;
- In some CEPT countries, there are a number of requests for frequencies for land mobile systems in 400 MHz band with channel bandwidth of greater than 25 kHz. Due to the current use, there is not sufficient spectrum available to accommodate this need. Therefore, national share platforms and migration strategies of the use and a long term spectrum strategy for 400 MHz bands may be considered on national level;
- Channel bandwidth of up to 25 kHz, including most commonly opportunities for 6.25 kHz and 12.5 kHz based systems, are implemented throughout Europe. However, some CEPT administrations still allow only analogue systems in some parts of the 400 MHz PMR/PAMR frequencies or reserve the spectrum based on 20-25 kHz channel spacing only;
- With respect to digital technologies, the most mentioned in the responses to the WGFM questionnaire are DMR) (17 times) and TETRA) (16 times) and dPMR) (7 times). Other mentioned technologies are TETRAPOL, CDMA and NXDN.14 countries report either a slight increase or bigger increase of the PMR/PAMR usage of systems with channel bandwidth of up to 25 kHz in the 400 MHz frequencies. 14 countries report stagnation/constant numbers of licences and overall usage. Some countries report a reduction;
- An increase of demand for digital PMR/PAMR has been reported by about half of the responding countries. Increasing/new demand for land mobile systems with channel spacing of greater than 25 kHz has been reported by 5 countries (Denmark, France, Germany, Poland and Luxembourg), however without quantifying this demand;
- The questionnaire showed a limited current number of land mobile systems with channel bandwidth of greater than 25 kHz in 450-470 MHz. However, such licences are mostly nationwide and can accommodate millions of connected devices, e.g. smart meters;
- There is obviously cross-border coordination issue between systems using channel bandwidths up to 25 kHz on one hand and other systems which are based on e.g. TETRA TEDS, CDMA or LTE. Some TETRA manufacturers limit TETRA TEDS products to bandwidths up to 50 kHz, not manufacturing 100 kHz and 150 kHz options due to impracticalities to get 100-150 KHz as one piece of spectrum, especially at areas close to a border;
- The PMR/PAMR licence durations vary from 1 day to 15 years. However, most administrations issue typically licences for several years: 1 year (6), 5 years (13), 10 years (10) or even 15 years (2);

- Only a limited number of CEPT administrations have implemented shared PMR/PAMR use (use of the same frequencies within geographical overlap, using a sharing factor of typically 2 or 3), mainly those with congestion situations.

To sum-up the responses: there are two different groups of services to be further looked at: PMR/PAMR with channel bandwidth up to 25 kHz on one hand and land PMR/PAMR as well as other land mobile systems with channel bandwidth of greater than 25 kHz on the other hand.

The heterogeneous use of the frequencies in CEPT countries is continued. A harmonisation of frequency use is therefore constrained. As a consequence, national administrations act individually with respect to market demand.

It can be summarised as follows from these responses:

- Low (or even insufficient) availability of spectrum in the 400 MHz bands for land mobile systems is mentioned by several responders;
- Industries and users report about congestion of the spectrum or harmful interference cases, mainly in the 400 MHz land mobile frequencies and in metropolitan areas. A number of suggestions are made such as improved radio planning, additional frequencies, improved harmonisation, foster VHF use, or reduce radiated power in the 400 MHz bands;
- Importance of harmonisation: out of 11 responses from industry, 8 consider it as very important to have worldwide single products. 3 consider this as not important, as it is necessary to make regional variants anyway.

Possible enhancements are seen in the following areas (inter-alia):

- Consider how VHF use could be fostered;
- Increased shared use of PMR frequencies should be fostered;
- Regulation in some countries still have to follow the digitisation of the PMR/PAMR market (in other words: increase the frequency opportunities for digital use);
- Achieve more contiguous band segments for wideband and broadband systems;
- Consider most flexible approaches for licensing.

4 MARKET REQUIREMENTS AND OPERATIONAL NEEDS OF PMR/PAMR

4.1 CRITICAL COMMUNICATIONS ASPECTS

PMR and PAMR systems will continue to be needed by users requiring high availability and resilient systems for operational and other critical communications. The classifications of criticality could be stated as follows:

- Business-critical: A communication type that is frequently needed and which supports operations or other value-added activities that together, have a significant beneficial impact on the overall enterprise;
- Mission-critical: One or more communication systems the failure of which will have a very serious impact on the overall operations or effectiveness of the venture;
- Safety-related: One or more communication systems having relevance to actual safety issues and which may even extend to the preservation of safety of life.

The use of systems employing the above classifications may be effectively mandated by corporate or similar obligations in law.

Mission-critical PMR/PAMR networks normally require some customisation following key requirements from their users include:

- Very high coverage availability within the defined service area, including in some cases remote and unpopulated areas;
- Designed often to meet exact technical requirements, rather than for economic gain;
- Ability for best practice resilience / resilient M2M (RM2M) operation;
- Instant and guaranteed channel access;
- Up to 99.999% (e.g. power line protection and SCADA) link availability plus link diversity. When the primary route is interrupted, it is essential that the diversity route works immediately and correctly;
- System and transmitted data have high levels of network security and integrity, including: no connection to external and/or public communications systems such as public mobile networks and the public Internet;
- Network hardened to ensure reliable operation in severe environmental conditions, including electromagnetic disturbances such as lightning strikes;
- Up to 96 hours power backup;
- Ability for very low end-to-end latency, e.g. 10 ms for extremely high voltage protection circuits;
- Low jitter and synchronous requirements;
- Longevity of life and support, e.g. 10 to 20 years.

It is noted that mission-critical or business-critical applications carried on PMR/PAMR type schemes often carry higher availability and reliability demands than normal mobile PMR/PAMR communications.

4.2 MARKET SECTORS

PMR is characterised by being private (individually authorised) access, professional sector specific group communication, tailor-made design, using portable, mobile, and base stations (including e.g. data terminals and SCADA), allowing the licensed users to stay in full control over their tasks at hand and deliver mission critical or business critical applications such as instantaneous voice and group communications in order to optimise their operations and stay ahead of competition.

PAMR providers offer access to managed land mobile radio services to end users.

PMR/PAMR land mobile systems typically can support amongst others the industrial sector, the transportation sector (including airports and railways), the governmental sector (blue light forces, but also e.g. embassies), life-saving services (such as ambulance and emergency responders), the energy/utilities sector (smart metering/smart grids), hotels/tourism sector, financial sector, the industrial, the agricultural and forestry sector or the retail sector.

The digitisation of economies increases the need for Machine-to-Machine communications. This major trend affects various sectors albeit at different speeds. Forecasts [32] expect that the M2M/IoT connections in wireless networks will at least quadruple within the 2015-2022 timeframe, though solutions will not only use the 400 MHz bands. Certain M2M/IoT connections require high availability and security and will therefore use resilient and dedicated PMR/PAMR networks. Commercial mobile technologies will increasingly be used for business and mission critical purposes as these technologies offer better economies of scale, allow for additional features and services, and most importantly, can also be adapted to fulfil design and operational conditions of critical networks, with dedicated capacity or control over the network resources. It is therefore expected that, in addition to PMR/PAMR systems with channel bandwidths of up to 25 kHz, land mobile systems using channel bandwidth of greater than 25 kHz (e.g. 50 kHz, 100 kHz, 150 kHz and 200 kHz) as well as 3G/4G mobile technologies such as CDMA or LTE will be deployed to address this demand for resilient and secure PMR/PAMR services in a frequency efficient and cost-effective manner.

PMR/PAMR solutions were presented in the CEPT/ECC M2M Workshop in 2016, notably in the 400 MHz band, in particular, for mission-critical M2M applications. Different operation models, like dedicated PMR and shared PAMR networks as well as hybrids are possible, and may be chosen in accordance to market needs. The growing demand for critical M2M communication could also trigger the need to find synergies for national PMR/PAMR platforms.

4.2.1 Utilities

Many forecasts dealing with the volume of Machine-to-Machine-type communication expects a high demand for M2M applications from utilities in the coming years. Against this background, it is worthwhile to analyse the requirements of utilities in more detail:

The energy sector is subject to a substantial restructuring. The electricity supply infrastructure, which is characterised by large centralised power stations, has evolved into a system comprising both centralised and decentralised electricity supplies. New renewable power plants with highly volatile electricity production are built in regions with high winds or solar energy occurrence. The integration of the renewable power plants into the grid network require a redesign of the grid network taking into account this highly distributed production but also changes in the transport directions in various parts of the distribution networks. Therefore, the integration of the renewable power plants into the existing grids require critical wide area M2M communication networks for the monitoring and control of possibly millions of distributed assets. Besides the distributed and increasingly volatile electricity production the requirement for M2M connectivity may also be driven by regulatory smart grid and smart metering obligations.

- As a consequence extra high voltage (EHV) and high voltage (HV) smart grid require enhanced communication and resilience systems with very high reliable and very low latency communications (see Addendum to CEPT Report 059 [9] and ETSI TR 103 401 [10] which describes smart grid systems and other radio systems suitable for utility operations, and their long-term spectrum requirements);
- The medium voltage (MV) smart grid control and low voltage (LV) smart meter control may require connectivity to a large number of devices.

Examples of such networks are Utility Connect’s wideband PMR network in the Netherlands, ArgoNET wideband PAMR networks in Austria and 450connect wideband PAMR network in Germany.

4.2.2 Other sectors

In more general terms, some Machine-to-Machine communication as well as voice services are mission-critical. Mission-critical thereby means that one or more communications the failure of which will have a very serious impact on the overall operations or effectiveness in many economic sectors. The requirements of utilities might be considered as a proxy for other mission-critical services in various vertical markets.

5 LICENSING ISSUES

5.1 NETWORK MODELS

The focus in this section is on land mobile systems based on LTE technology in the 400 MHz range.

Already existing solutions provide PMR/PAMR like services for e.g. dedicated vertical markets, but also broadband access solutions for businesses and residential customers. Some business requirements develop in the direction that there is a need to support higher data rates, e.g. for video applications or dynamic map applications, or higher volumes e.g. as a result of a very high number and density of peers in a data network.

The same spectrum access model as for MNO for PMR/PAMR with channel spacing of greater than 25 kHz is expected to be used, i.e. exclusive individually authorised access to spectrum. No other contribution was received during the creation of this Report.

Another expectation is that LTE-based land mobile networks in the 400 MHz range will have a larger or national geographical coverage, similar to existing LTE-networks in the 400 MHz range such as those currently operating in the Scandinavian countries.

The first opportunities for LTE networks are currently expected for fixed installations in data networks where mobility and roaming under the network coverage is not necessarily required. This may change in the future if a vertical market would express demand and require mobility support functionality. A wide range of chipsets and modules for M2M-type user equipment is already commercially available. There are several vendors that introduced voice devices for the 450-470 MHz range.

The available spectrum resources limit the possibilities for the accommodation of PMR/PAMR networks based on LTE technology. PMR functionality can be supported by LTE-based technology (as of Release 13), hence competition on service level may still be given to some extent.

This has some consequences:

- Depending on the PMR/PAMR usage situation in their country, CEPT administrations may decide which parts of the available spectrum for land mobile systems is made or kept available for LTE-based and other technology-based networks;
- Sharing of the LTE-based network by several user groups, PAMR-like such as PPDR, transportation (e.g. railways), industrial use, utilities or even broadband access to remote residential users. Sharing could also be organised geographically and/or time. In such cases, the specific use cases, related service requirements and technical aspects (e.g. use of specific antennas in certain cases) have to be taken into account to develop an understanding on how exactly the available resources can be shared. A positive effect can be the common use of the network infrastructure under the expectation that the licence conditions are clearly defined for this sharing situation. Technical specifications could define priority mechanisms or multiple tiers of sharing of network platform resources.

5.2 SYNERGIES

BB-PPDR and for example railway radio applications (such as currently used in GSM-R) or PMR for utilities may use the same technical framework and equipment in the future (e.g. based on LTE). Some railway applications have similar requirements in terms of predictability and availability of the communications and can also be considered as mission-critical (e.g. the European Train Control System (ETCS) and other signalling application). There may be a possibility of having a common set of technical parameters for spectrum access.

Coordination and the associated broadband applications' demands will be dealt with on a national level, e.g. whether certain broadband applications with similar technical requirements use their own networks, share a common dedicated network or are delivered within public mobile networks; but still using a common technical framework. To find such synergies amongst broadband applications from specific market sectors is also in the interest of spectrum authorities who may find it difficult to provide dedicated spectrum to a variety of specific market sectors.

To find synergies, e.g. between BB-PPDR and Wideband PMR/PAMR , it would therefore be important to find a common technical framework. Synergies should recognise the right of national authorities on how to organise and use their radio spectrum for a certain application and should not limit individual national authorities from using that spectrum also for commercial wireless broadband. Interoperability and roaming between different networks, as well as commercial networks is also being considered of increasing importance. For hybrid networks, this may be essential. Synergies include that users can benefit from economies of scale, especially when using commercial products and from possible synergy with technology development in the commercial sector, including PMR/PAMR.

It is considered that dedicated frequency bands for PMR/PAMR will also offer in future the opportunities to roll out dedicated networks responding to national demand and security requirements and enable to provide specific PMR/PAMR services and needed reliability while benefitting from synergy with standards developed for the commercial mobile broadband. Interoperability between radio equipment of different user equipment manufacturers and infrastructure is required to make roaming possible.

5.3 CRITICAL M2M/IOT NATIONAL PLATFORMS

Many forecasts and studies show that Internet of Things (IoT) and Machine-to-Machine (M2M) communication will play an increasingly important role in Europe in the near future and will be a main contributor to economic development. The widely spread adoption of IoT/M2M applications is expected to provide major productivity gains while at the same time improving security and comfort of life. The total impact as calculated by McKinsey and company in their report of June 2015 is between $3.9 Trillion and $11.1 Trillion [35].

A significant portion of IoT/M2M applications will be used for critical applications in the private and government related sectors like Utilities, Smart Cities and national infrastructures and other sectors such as production, transport/logistics as well as in healthcare. Critical IoT/M2M applications require telecommunication networks with deep coverage, robust resilience and high service availability. A 450 MHz national platform can fulfil these requirements and thus enable many critical IoT/M2M services.

The propagation characteristics of the 450 MHz spectrum in terms of wide area coverage and deep in-building coverage allows the building of radio networks with high service availability in a cost efficient way. Due to the low number of radio sites, it is much more economical to install redundant power supply (battery back-up) and additional backhaul facilities compared to mobile networks in higher frequency bands with a much larger number of radio sites.

The highest demand for radio communications for distributed assets that require critical connectivity stems from the utility sector, mainly driven by the need to monitor and manage increasingly volatile electricity production and to fulfil regulatory obligations on smart grid and smart-meter rollouts. In several European countries where the 450 MHz frequency band was available, private networks are now being used to provide critical connectivity to electricity utilities.

New deployments of 450 MHz networks focussing on IoT/M2M are using either CDMA450 (such as Utility Connect in the Netherlands, ArgoNET in Austria and 450connect in Germany) or LTE450 (such as Ukko Mobile in Finland and MVM in Hungary). CDMA450 technology is widely used on a global scale, already customised for IoT/M2M and has a mature ecosystem with many suppliers and operators. With LTE450, the next generation of technology has become available which provides substantial benefits for IoT/M2M relating to coverage, performance, cost and power consumption.

Users are therefore required to focus on standardised and widely spread new generations of technologies that require more spectrum than PMR/PAMR systems with channel spacing of up to 25 kHz. However, from a spectrum availability perspective it is impossible for each user or user group to build a separate network. Given this, several operators, users and regulatory bodies may start looking at a new generation of shared national 450 MHz platforms and hence address the connectivity needs of multiple professional user groups.

Such an approach of a single national platform for critical IoT/M2M application using CDMA450 and LTE450 technology can support millions of IoT/M2M devices on a single network addressing connectivity needs of all critical users at very low cost per connection when widely used. The implementation of VPN techniques and Quality of Service classes allows users to be provided with improved security and required prioritisation while all benefit from the performance of a highly available and resilient network using standardised technology resulting in low cost per connection and very efficient use of spectrum.

Technology evolution in the 450 MHz frequency band mirrors that of the mass market. While currently available, CDMA450 technology is already a capable telecommunication platform for IoT/M2M applications, providing capacity for a high number of M2M devices. LTE450 technology provides further technical capabilities and cost benefits for IoT/M2M applications. The developments for LTE technology from 3GGP Rel. 12 onwards introduce important features for IoT/M2M applications such as:

- Link budget and coverage enhancements;
- Reduced device complexity and cost;
- Reduced power consumption for battery powered devices;
- Improved scalability (i.e. number of connected devices).

The combination of modern technologies and their features for IoT/M2M use cases and the favourable propagation properties of the 450 MHz band enable high resilient, high capacity and availably platforms for critical IoT/ M2M applications. The concept of building and operating shared nationwide 450 MHz networks instead of individual PMR networks for each user/user group could ensure that IoT/M2M connectivity needs of a large number of users from different sectors are satisfied in a frequency and cost efficient manner.

It should be noted that in the United Kingdom, where broadband access has not been available, 9.6 kbit/s in 12.5 kHz UHF systems are used to control electricity grids. This enables the spectrum to be licensed by multiple users (to meet the data requirements of the smart grid, the United Kingdom's electricity system will soon need to be updated to 64 kbit/s in 25 kHz channels as standard. Wider channel widths, e.g. for on-site use, may also be sought).

5.4 LICENCE AREA

For local PMR networks with channel spacing of up to 25 kHz, many regulators authorise the use of a PMR system operating a base station and mobile stations within a small area, typically within a radius of not more than 15 kilometres. A greater radius may be chosen e.g. 30 km link lengths to achieve coverage to remote / relatively unpopulated areas.

There are also some PMR onsite authorisations where spectrum is authorised within a short distance for one user. Typically, a base station for PMR would be deployed to provide coverage between 1 and 3 km. In the United Kingdom, a survey conducted by OFCOM in 2016 showed that the majority of licences only covers limited coverage under 5 km radius (59% of use is on-site). This knowledge can be used by the regulator to reuse the frequencies in a more efficient way.

Another concept is to define area licences. Within the defined area, licence holders can exclusively use frequencies within a grid square (e.g. around 50 km^2 within a country). Such grid squares can also be accumulated into larger geographical areas (e.g. for regional and nationwide use). Licensees are allowed to deploy transmitters anywhere in their area with the permit/clearance from the regulator, meeting clearly defined limits for emissions at the border of the defined licence area.

Many use cases like utility grid operations, railway, governmental services, transport, health and other critical services require large and deep coverage also in remote and sparsely populated areas. Wideband systems in 400 MHz bands can be used for building a national PMR/PAMR shared platform and provide deep indoor coverage and at the same time ensure an efficient use of spectrum.

In certain scenarios, areas allotted with PMR frequencies could be city wide or region/province wide or even on national basis to meet the requirements of certain categories of users such as public safety or transportation.

5.5 CROSS-BORDER ASPECTS IN THE 400 MHZ PMR

The Recommendation T/R 25-08 [3] contains provisions for the planning and cross-border coordination of frequencies for land mobile systems in the range 27.9-470 MHz for various analogue and digital land mobile applications, e.g. PMR (Professional (Private) Mobile Radio), PAMR (Public Access Mobile Radio), PPDR (Public Protection Disaster Relief), MFCN in 450-470 MHz, etc., and systems of various channel bandwidth up to 5 MHz. The focus is on the interference-free co-existence of systems with different channel spacing on both sides of a border. Conservative coordination threshold values are used as the default levels for all land mobile systems.

The threshold levels which trigger the coordination between neighbouring countries are based on the principle that indicative coordination thresholds are established at the border-line with regard to a reference bandwidth of 25 kHz.

The co-ordination thresholds should not be exceeded without co-ordination between neighbouring countries. This will be especially important where the proposed system may cause harmful interference to a system controlling a neighbour’s critical national infrastructure.

In the case where the co-ordination thresholds are exceeded, administrations should enter into co-ordination procedure. The coordination procedure might be based on bilateral or multilateral agreement. For this procedure or negotiation of agreement, “HCM Agreement” [36] or parts of it may be used as a basis.

CEPT administrations should endeavour to comply with the provisions in Recommendation T/R 25-08, when assigning frequencies to stations in the land mobile service, particularly in border areas, where coordination with neighbouring countries is necessary, as shown in Figure 1 below:

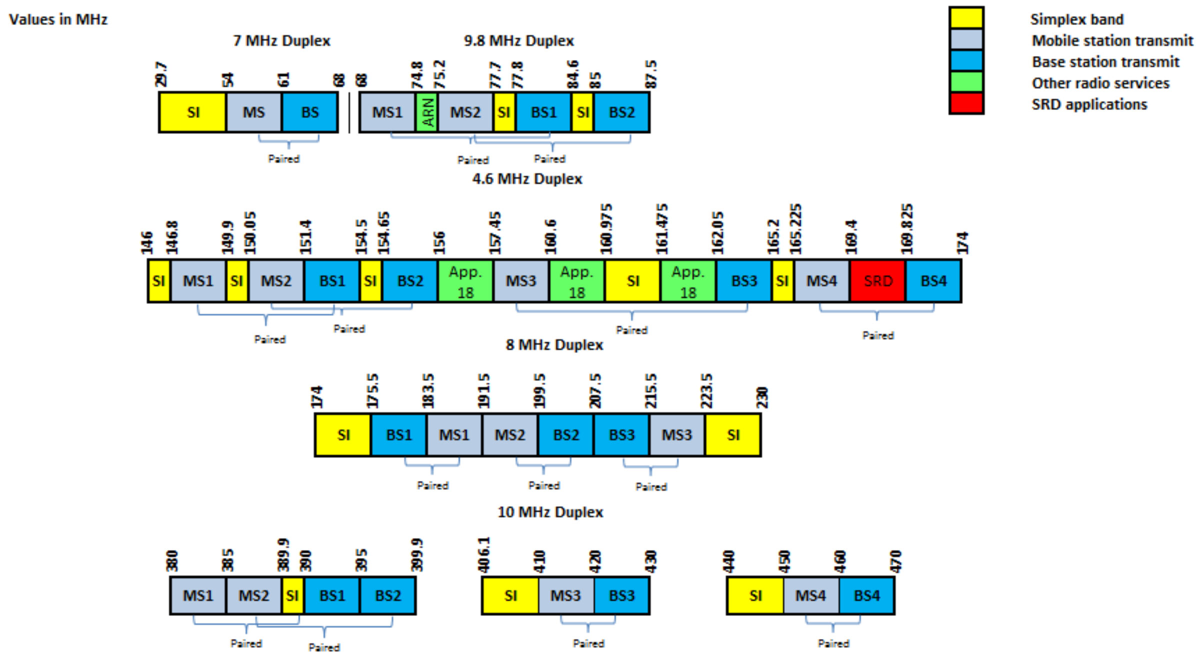


Figure 1: Recommendation T/R 25-08 [3] band plan for land mobile systems between 29.7 MHz and 470 MHz

In paired bands, Figure 1 above indicates the duplex separation for individual bands for the pairing of the respective MS (mobile station transmit band) and BS (base station transmit band), e.g. MS1 with BS1 within one frequency range.

It could be challenging for BB-PMR to obtain clearance to use a full block of 1.4, 3 or 5 MHz if narrow band systems are used on the over side of the border. Several CEPT administrations noted that coordination thresholds for broadband systems could be further increased in cases where two broadband systems operate in the same frequency band across the border. In particular, PCI code coordination for LTE systems is considered as an option to allow for the relaxation of threshold values (with the same centre frequencies or overlapping frequency use, preferential or non-preferential PCI codes). This situation was studied in ECC Report 276 [45] which provides the technical background for the coordination of land mobile systems with channel bandwidth greater than 1 MHz in situations where no or some overlap with systems with channel bandwidth up to 25 kHz occurs across the border

ECC Report 108 [13] already describes the situation of 2 systems CDMA vs CDMA.

Recommendation T/R 25-08 [3] has been revised taking into account the results of ECC Report 276.

Flexibility:

The channelling described in Recommendation T/R 25-08 section A1.2.1.1 supports all possibilities for the choice of bandwidth for land mobile systems up to a channel bandwidth of 25 kHz.

Section A1.2.1.2 recommends centre frequencies and channel spacings of 50 kHz, 100 kHz, 150 kHz, 200 kHz, 1,25 MHz, 1.4 MHz, 3 MHz and 5 MHz for land mobile systems with channel bandwidth of greater than 25 kHz. However, other centre frequencies and channel spacings are possible and not excluded, and the bandwidth correction formula in section A1.2.3 can also be used to facilitate technologies using different bandwidths.

In consequence, Recommendation T/R 25-08 supports the development of the new technology-neutral ECC Decision (19)02 [11] for land mobile systems in the frequency ranges 68-87.5 MHz, 146-174 MHz, 406.1-410 MHz, 410-430 MHz, 440-450 MHz, and 450-470 MHz. This ECC Decision supports land mobile systems with channel bandwidths up to 5 MHz, and which is replacing ECC Decision (04)06 [28] and ECC Decision (06)06 [29].

6 TECHNOLOGIES AND DEPLOYMENT

In Table 1, the different standards with channel bandwidths are listed:

Table 1: Technologies and standards

Technology	Channel (kHz)	Standard/Specification
Digital	6.25	EN 301 166 [19]
Analogue	12.5	MPT 1411 [20]
Digital	12.5	EN 300 113 [7]
Digital	12.5	EN 300 113
Digital	12.5	EN 300 113
Digital	12.5	EN 300 113
Digital	25	EN 300 113
Digital	25	EN 300 113
Digital	25	EN 300 113
Digital	25	EN 300 113
Digital	25	EN 302 561 [21]
Digital	25	EN 302 561
Digital	25	EN 302 561
Digital	50	EN 302 561
Digital	50	EN 302 561
Digital	50	EN 302 561
Digital	100	EN 302 561
Digital	100	EN 302 561
Digital	100	EN 302 561
Digital	150	EN 302 561
Digital	150	EN 302 561
Digital	150	EN 302 561
Digital	200	EN 301 502 [37] EN 302 511 [38] LTE NB IoT [39]
Digital	1250	EN 301 449 [22] EN 301 526 [22] EN 302 426 [22]
Digital	1400	3GPP bands 31 and 72. Current drafts of EN 301 908 for E-UTRA BS, UE and Repeater under development
Digital	3000	Current drafts of EN 301 908 for E-UTRA BS, UE and Repeater under development
Digital	5000	3GPP bands 31 and 72. Current drafts of EN 301 908 for E-UTRA BS, UE and Repeater under development

6.1 SYSTEMS WITH CHANNEL BANDWIDTHS UP TO 25 KHZ

These systems are almost exclusively used by PMR. Those systems are analogue like MPT 1327 [23] or digital (dPMR, DMR, TETRA and TETRAPOL).

Digital systems can provide voice services and low speed data applications. Due to operational and financial constraints, there is a trend to share large common rather than multiple independent networks.

6.2 SYSTEMS WITH CHANNEL BANDWIDTH OF GREATER THAN 25 KHZ

Wide band digital systems for PMR/PAMR are flexible in use. They can be used to provide low latency, high security applications, priorisation and quality of service or carry data rates of several hundred kilobits per second. IMT technologies providing these features have already been introduced in the 400 MHz bands in various countries such as Austria, Germany, Finland, Sweden, Norway, Denmark or Hungary. In Latvia and the Netherlands, the current CDMA operator is interested in migration towards LTE in the 450 MHz range. This development reflects the requirement for these features provisioned on secure and resilient networks.

It is to be noted that there are currently no work items in ETSI for CDMA based systems under EN 301 449, EN 301 526 and EN 302 426 [22] for editions under the Radio Equipment Directive. These harmonised standards were also removed from ECC Decision (08)05 [46] in 2016.

3GPP LTE frequency bands 31 and 72 in the 450-470 MHz band are currently not covered by the ETSI EN 301 908 harmonised standards family for IMT [47], but these Harmonised European Standards are expected to be updated. For the frequency band 410-430 MHz, there are currently no activities in 3GPP or ETSI for new specifications or standards for LTE-based systems. Following the investigations in ECC Report 283 [43], it is proposed that 3GPP should consider standardisation activities for the range 410-430 MHz.

In 3GPP Release13, a system for M2M applications with 200 kHz channel bandwidth called NB-IoT [39] has been introduced to the LTE specification. Other technologies based on 200 kHz channel bandwidth based on either star-topology or meshed networks may also exist which could potentially use the 400 MHz ranges.

6.3 OBJECTIVE FOR THE REGULATORY FRAMEWORK AND ROLE OF ASSOCIATED STANDARDS

The frequency regulatory framework in ECC Decision (19)02 [11] for land mobile systems in the frequency ranges 68-87.5 MHz, 146-174 MHz, 406.1-410 MHz, 410-430 MHz, 440-450 MHz, and 450-470 MHz is technology-neutral and flexible in support of all possible channelling and bandwidth options. This new ECC Decision includes the minimum necessary technical and operational parameters for land mobile systems operating in the frequencies set out by Annex 1 of the Recommendation T/R 25-08 [3].

There are no requirements set out in ECC Decision (19)02 for a minimum mandatory spectrum access protocol. This new ECC Decision is also neutral with regard to the network topologies of land mobile systems. Specific technical implementation solutions in support of spectrum sharing, common tuning ranges or for specific networks topologies may be covered by specifications or standards.

Applicable harmonised standards under the RE Directive include the technical requirements and their relevant methods of measurement for compliance purposes. For some options, the relevant harmonised standard does not exist yet.

7 RESULTS OF COMPATIBILITY STUDIES IN ECC REPORT 283

ECC Report 283 [43] is based on an anticipated roll-out for LTE systems (including narrowband M2M/IoT) from single site, multiple sites and large wide area networks.

7.1 THE BAND 410-430 MHZ

7.1.1 Options for spectrum arrangements in the frequency range 410-430 MHz

While the band has been studied in ECC Report 283, using parameters as for the 450-470 MHz frequency range, the band is currently not supported by standardisation activities for LTE technology in 3GPP or ETSI. Following the investigations in ECC Report 283, it is proposed that 3GPP should consider standardisation activities for the range 410-430 MHz.

Considerations on spectrum arrangements can therefore only be derived from the results of the available compatibility studies as well as specific national situations where some part of the band may be used for BB-PMR/PAMR.

Based on the overall considerations, three options are recommended for broadband technologies for inclusion in ECC Decision (19)02 [11]:

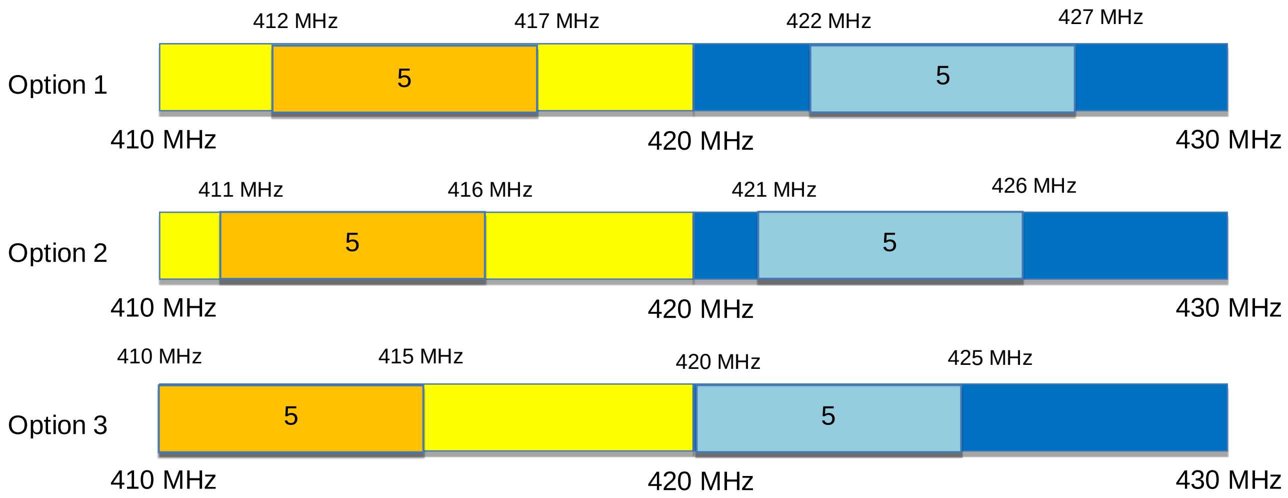


Figure 2: Non-exhaustive spectrum arrangement options for the band 410-430 MHz

7.1.2 LTE impact on systems within the 410-430 MHz as well as adjacent bands

7.1.2.1 LTE impact on PMR/PAMR systems with channel bandwidth up to 25 kHz (including paging and analogue PMR)

It should be noted that narrowband PMR/PAMR includes analogue, DMR and TETRA systems.

Simulations of interference from LTE transmitters into narrowband PMR receivers in adjacent frequency spectrum in ECC Report 283 [43] show that the probabilities of interference based on Out-of-Band Emissions (OOBE) and Blocking for low to medium Base station (BS) and Mobile station (MS) densities are generally on the average 1% or less, although unwanted emission improvement compared to the 3GPP Spectrum Emission Mask at the BS may be required to keep the interference from the LTE BS into the PMR MS to these low levels. However, the interference probability calculations are performed for downlink capacity/traffic limited systems; results may differ for uplink capacity/traffic limited systems, which may tolerate a noise rise in MS receivers up to level of the DL/UL imbalance. Please also note that other techniques needed to protect the LTE400 BS own reception band (such as duplex filtering) help to provide necessary attenuation of Out-of-Band emissions of the LTE BS into the TETRA MS reception band. Furthermore, interference probability averaged over the coverage area of narrowband BS decreases, if LTE cell size increases. The probability of interference is highest closest to the LTE BS. Out of Band Emission improvement may not be needed depending on the acceptable level of degradation over the coverage area.

The interference probabilities for the LTE BS impact on PMR MS are lower in comparison to the interference probabilities simulated in ECC Report 240 [24] for PPDR-LTE BS impact on PMR MS. Even lower interference probabilities are expected if the bursty nature of M2M traffic will be included in the calculations.

Another interference effect to be taken into account is the potential impact of Intermodulation Distortion (IMD) in PMR receivers caused by neighbouring broadband signals. This is dependent on frequency offset of the LTE carrier from the victim PMR receiver, the received power and the intermodulation performance of the victim PMR receiver at that frequency offset. The assessment of outage probability due to Intermodulation by simulations appeared to be far from straightforward. No conclusion on the intermodulation effect from broadband interferers into narrow band victims could be reached. It is expected to continue the work on an agreeable algorithm for SEAMCAT to provide usable results for the simulation of Intermodulation Distortion in Narrowband Receivers due to the deployment of spectrally adjacent Broadband Carriers.

7.1.2.2 LTE impact on narrowband fixed links

According to the worst-case estimation (assuming free space propagation between the stations and both antennas are pointing towards each other) in co-channel frequency range, the sharing will not be possible between LTE and the FS. In adjacent frequency ranges, compatibility is limited the remaining scenarios and would require protection distances of about 30 km.

A more realistic estimation implies the propagation model described in Recommendation ITU-R P.452-16 [51] between the LTE BS and the FS station. Between the LTE UE and the FS station the extended HATA propagation model is used. If more realistic investigation options are used, in co-channel frequency range, the sharing will be possible between LTE BS and the FS if protection distances of about 85 km are kept. In adjacent frequency ranges, compatibility can be expected, if protection distances of about 35 km are respected. Operations at smaller distances are possible but require coordination and/or lower OOBE level for the LTE station within the channel used by fixed service.

LTE UE satisfies sharing requirements for operation distances larger than 4 km to the FS station. If used in an adjacent frequency range, no interference for operational distances larger than 0.5 km is expected.

7.1.2.3 LTE impact on radiolocation systems

ECC Report 240 [24] demonstrated that LTE based BB-PPDR systems operating in the band 420-430 MHz could cause severe desensitisation of radars in the co-channel case. Calculations lead to large exclusion zones based on free space propagation loss and statistic propagation model (EPM73), therefore further studies were conducted based on additional assumptions.

The new studies focused on the impact of LTE BS (downlink) on radar systems and investigated several propagation models and scenarios for co-channel (420-430 MHz) and adjacent channel (430-440 MHz) operation of the two systems. The effect of the LTE UE (uplink) on the radar system was already addressed in the ECC Report 240 with 37 dBm e.i.r.p. of UE.

To avoid radar desensitisation operated in 430-440 MHz (-114.9 dBm/MHz) based on the studies in ECC Report 283, the proposed technical solution for operating LTE in 410-430 MHz frequency range is to respect both a guard band of 2.5 MHz from the upper edge of LTE BS channel to 430 MHz and 40 dB of OOBE reduction from the standard (e.g. with LTE BS duplexer filtering). Assuming the above mentioned guard band of minimum 2.5 MHz a possible LTE channel arrangement could be entirely placed in the tuning range of 410-417.5/420-427.5 MHz applying 100 kHz channel spacing.

The required separation distance is depending on the used propagation models (calculating with free space propagation and smooth Earth, or with the Earth curvature, diffraction, reflection or with tuned models using real terrain data).

For ground radars, the required separation distance is around 120 km in the co-channel scenario and less than 40 km in the adjacent channel scenario over smooth Earth (EPM73, Recommendation ITU-R P.526-13 [50]). Applying digital terrain based propagation models (General 450 and MYRIAD), the minimum required separation distance could be varied from 1.5 to 28 km in the adjacent channel scenario which can be further reduced by using proper mitigation techniques and a well-designed LTE network (calculating with LTE BS antenna downtilting, LTE BS power reduction, additional LTE BS duplexer filtering, etc.).

For airborne radars, the required separation distance remains more than 400 km required in the co-channel scenario if no particular mitigation technique is applied. The co-existence in adjacent channel scenario for airborne radars can be achieved with the appropriate filtering and frequency separation which however implies that airborne radars are limited to operate above 430 MHz even though radar tuning range is 420-450MHz. The coexistence of LTE in the frequency band 410-430MHz and radars operated on a secondary basis in the frequency band 420-430MHz cannot be ensured only by technical conditions. It is to be noted that some countries have already concluded multilateral frequency co-ordination agreement for LTE usage without having taken into account the secondary radiolocation service.

7.1.2.4 LTE impact on the radio astronomy service

Radio astronomy service allocation is in the band 406.1-410 MHz in direct neighbourhood of the 410-430 MHz band; therefore, the effect of broadband PMR/PAMR operation shall be considered in case of broadband mobile networks deployment. Compatibility studies are summarised in the ECC Report 283. Two studies by using different statistical calculation methods were used for evaluation of interference from LTE based BB systems operating in the band 410-430 MHz into radio astronomy stations in the band 406.1-410 MHz.

One study was done by using SEAMCAT and propagation model described in Recommendation ITU-R P.1546-5 [52] and Recommendation ITU-R P.452-16 [51] with different network layout when aggregated effect of BSs and UEs were taken into account. Analysis showed that for LTE network completely surrounding RAS station, exclusion zone varied from 117 km to 362 km depending on guard band and propagation model. Separation distances became smaller when LTE network's layout comprises a part of the ring placed on one side of RAS. The simulation results shrank down and varied from 18 km to 246 respectively. Such case could be met when coordination of different systems between two countries occurs.

The other study used MATLAB software. Analysis by using MATLAB with Recommendation ITU-R P.452-16 for the outdoor UE, considering a 1 MHz guard band, the separation distances for single emitter and aggregate cases become 78 km and 326 km, respectively. For indoor usage and additional wall attenuation of 11 dB the separation distances for single emitter and aggregate cases are reduced to 34 km and 190 km, respectively.

Protection of investigated services could be ensured by applying distances given by using Recommendation ITU-R P.1546; for more precise exclusion zone specification, real terrain data model might be applied. The sensitive areas are limited on radio astronomy observatories in Europe; the list of RAS stations locations in Europe is listed in Table 89 of ECC Report 283.

To conclude, the investigations show that co-existence between LTE systems (including BB-PPDR) and radio astronomy is feasible in the whole considered tuning range of 410-417/420-427 MHz, provided that certain measures are ensured. Sufficient mitigation techniques may be adopted such as specific requirements on LTE network's layout, if needed. Appropriate protection methods for RAS stations could be managed at national level and with international coordination. Given the limited number of radio astronomy, it is expected a need of coordination for the deployment of LTE stations at distances lower that 250 km from a RAS station located in a neighbouring country.

7.1.2.5 LTE impact on PMR links in audio-visual production

As a result from ECC Report 240 [24], co-existence, operating within these bands, is possible due to the additional filtering required to fulfil the 3GPP protection of own UL minimum requirement (UE) duplexers to limit the interference at an acceptable level. Indeed such duplexers are needed to ensure both to fulfil the 3GPP minimum requirements and to ensure the correct performance of the LTE400 system itself.

Two new scenarios (TDD PMSE and 100 m co-location) based on those considered in ECC Report 240, relating to the impact of LTE BS on PMSE BS (receiving in 453-455 MHz), have been studied:

- Considering the general spurious emissions limits given in 3GPP TS 36.104 [39], coexistence is unlikely to be reached due to large separation distances. Considering the level given in ECC Decision (16)02 [44] (e.i.r.p. limit of -43 dBm/100 kHz) are much smaller. Coexistence is expected if the BS spurious meet the minimum requirements of -96 dBm/100kHz emissions in emissions in the band 450-455 MHz (3GPP TS 36.104 [39] – see in Annex 2) except if the base stations are co-located within 100 m where the interference become significant.
- Considering scenarios differing from those considered in ECC Report 240, for example, TDD case or MS transmitting in 455-460 MHz, the achieved separation distances are larger and the risk of interference is quite high, in particular when the PMSE BS is located nearby the LTE BS and receiving in the first megahertzs adjacent to the LTE band. A mixture of TDD PMSE and LTE400 should be avoided.

Based on MCL calculations, the separation distance between LTE UE and PMSE MS is of the order of 10 m, leading to a risk of interference if they are operated in the same location.

7.1.3 LPWAN compatibility

7.1.3.1 LPWAN compatibility with TETRA

The results of the Monte Carlo simulations carried out show that TETRA and Low Power Wide Area Network (LPWAN) systems can cohabitate without any major difficulty in the band 410-430 MHz, if the following mitigation techniques are implemented:

- A guard band of 200 kHz between the TETRA base station (BS) and the LPWAN end device (ED). This guard band is needed to minimise the interference from TETRA BS transmitter to LPWAN ED receiver;
- A minimum separation distance of 90 m (64 dB minimum coupling loss) between TETRA BS and LPWAN BS. This minimum separation distance is needed to minimise the interference from TETRA BS transmitter to LPWAN BS receiver and can easily be achieved with on-site configuration when deploying LPWAN networks.

It should be observed that based on the assumptions of the analysis, the TETRA BS e.i.r.p. is 49 dBm/25 kHz, which is almost 15 dB more than the e.i.r.p. of the LPWAN BS. That could justify why the impact of the TETRA BS into the LPWAN systems is greater than the one in the reverse way. Given that many deployed PMR systems operate with an e.i.r.p. 40 dBm, it could be expected that real life operation of these two systems leads to even better compatibility than the results presented in this analysis.

In the case of co-channel situation between TETRA and LPWAN systems, the minimum separation distance between base stations is more than 100 km.

The co-channel operation in the same area is not possible between TETRA and LPWAN systems.

7.1.3.2 LPWAN compatibility with the radiolocation service

With the radiolocation frequency set to 430 MHz and the LPWAN system using the uplink frequency of 413.7375 MHz and downlink frequency of 423.7375 MHz with a 125 kHz channel bandwidth, the minimum separation distances needed to ensure the protection of the radiolocation service are presented in Table 2 below.

Table 2: Separation Distance between Radars and LPWAN system (km)

Separation Distance between Radars and LPWAN system (km)		Due to blocking (km)	Due to desensitisation in co-channel (km)	Due to desensitisation in adjacent channel (km)
Airborne Radar	LPWAN ED	0.04	1374	0.015
	LPWAN BS	0.015	522	0.0025
Ground Radar	LPWAN ED	0.14	9730	0.110
	LPWAN BS	0.66	46560	0.232

The results of the compatibility studies carried out show that the compatibility between LPWAN system and airborne radar is possible in the case of adjacent channel scenario with a minimum guard band of 0.5 MHz from edges. The minimum separation distances are then:

- 40 m between the LPWAN End Devices and Airborne;
- 15 m between the LPWAN Base Station and Airborne.

The compatibility between LPWAN system and Ground radar is possible in the case of adjacent channel scenario with a minimum guard band of 0.5 MHz from edges. The minimum separation distance is then:

- 140 m between the LPWAN End Devices and ground radar;
- 660 m between the LPWAN Base Station and ground radar.

For the co-channel cases, there are no possibility for compatibility between LPWAN system and airborne radar or LPWAN system and ground radar.

7.1.3.3 LPWAN compatibility with RAS

The compatibility between LPWAN system and the Radio astronomy service concludes that:

- For a frequency separation between the LPWAN base station and the RAS of 13.7375 MHz (edge to edge), the MCL calculation provides a required minimum path loss equal to 97.51 dB; using the Recommendation ITU-R propagation model P.452-16 [51], the calculated separation distance is 4.4 km;
- For a frequency separation between the LPWAN end device and the RAS of 3.7375 (edge to edge), the MCL calculation provides a required minimum path loss equal to 101.91 dB. Using the Recommendation ITU-R propagation model P.452-16, the calculated separation distance is 3.05 km.

7.1.3.4 LPWAN compatibility with LTE

This section summarises the compatibility between LTE and LPWAN systems in the 410-430MHz band as set out in ECC Report 283.

All the initial configurations of LTE systems are based on figures in the corresponding ETSI TS 136 101 [39] and TS 136 104 [39] and the stated LPWAN system parameters. LTE parameters were considered as invariant in the simulations, except when considering LTE ACLR in adjacent channel. ACLR was based on the measured LTE signal which is 20 dB better than that derived from the transmitter mask in the ETSI standard. It should be noted that the measured ACLR in the first adjacent channel is expected to be lower than the ACLR in adjacent channels further away from the BS centre frequency. According to the ETSI standard for LTE systems, there are minimum requirements for the protection of own reception which lead to an ACLR higher than 100 dB/3MHz, that will provide lower level of unwanted emissions in the LTE BS uplink band and its vicinity compared to the level of unwanted emissions resulting from the measured ACLR value used in the analysis. Due to the protection of LTE own reception according to the minimum requirements in the ETSI standards, it is hence expected that the compatibility between the two systems to be much better than the results presented in this analysis when the LPWAN operates in the LTE uplink band and probably in the case of operation close to this LTE uplink band.

Amongst the simulated interference scenarios, in three cases it was necessary to improve the ACLR and the Adjacent Channel Selectivity (ACS) of LPWAN system to ensure compatibility between LTE and LPWAN systems.

LPWAN BS impact on LTE BS:

With the initial LPWAN base station, transmitter ACLR and LTE base station receiver selectivity defined in ETSI standards, the LTE bit rate loss is higher than 5%. It is necessary to improve the LPWAN base station transmitter ACLR by 30 dB to reduce the bit rate loss below 5% in adjacent band scenario. Compatibility is not achieved in co-channel scenario.

LTE BS impact on LPWAN BS:

With the initial LTE base station transmitter ACLR of 45 dB (which is applicable in adjacent channel) and LPWAN base station receiver selectivity as derived from transmitters masks defined in ETSI standards, the probability of interference is higher than 10%. Based on the measurements, it can be assumed that the LTE base station ACLR is at least 20 dB better than the value defined in ETSI standards, therefore the compatibility is ensured with an improvement of the LPWAN receiver ACS by 30 dB (PI < 10 %). Due to the protection of LTE own reception according to the minimum requirements in the ETSI standards, it is expected that the compatibility between the two systems be much better than the results presented in this analysis when the LPWAN operates in the LTE protected band and probably in the case of operation close to it. Compatibility is not achieved in co-channel scenario.

LTE BS Impact on LPWAN ED:

It may be needed to improve LTE base station ACLR of 45 dB by several dBs to ensure the compatibility in the adjacent scenario.

Concerning the LPWAN End Device, compatibility is achieved in adjacent band scenarios. Compatibility is not achieved in co-channel scenario. The results in this analysis assume an activity factor of 100% of the LPWAN BS and of LTE BS. In practice, the activity factor of LPWAN BS and LTE BS may be lower. That may reduce the potential impact of on each system on the other, thus improving the compatibility between the two systems.

7.2 THE BAND 450-470 MHZ

7.2.1 Options for spectrum arrangements in the frequency band 450-470 MHz

The allocations of Band 31 and Band 72 are illustrated in the figure below.

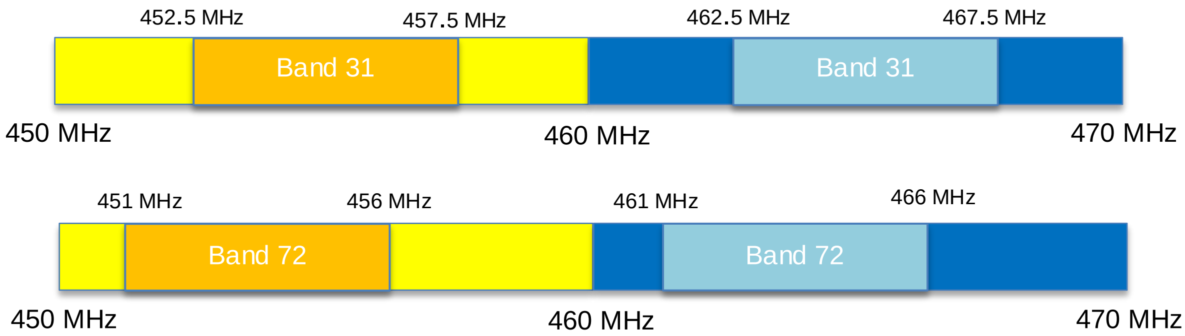


Figure 3: Spectrum arrangement options for LTE the 450-470 MHz band

3GPP has finalised work for the 450MHz E-UTRA FDD Band for LTE PPDR and PMR/PAMR in Europe.

Technical Report 3GPP TR 36.748 summarises the output of this work for 3GPP band 31 and 3GPP band 72, see Figure 3 above.

3GPP defined Power Class 1 (31 dBm) for UE in 3GPP bands 31 and 72. Other RF specification requirements are the same as for Power Class 1 UE applicable for 3GPP bands 14, 3, 20 or 28. The current ECC Decision (16)02 includes a maximum mean in-block power of up to 37 dBm.

UE power class 3 (23 dBm) currently considered as sufficient for ECC Decision (19)02 [11] (for information: Power Class 2 is 26 dBm). Administrations may use higher UE maximum mean in-block power for special deployment scenarios provided that the protection of other services, networks and applications is not compromised. Vice-versa, the maximum mean in-block power of UE may be limited on a cell-by-cell basis for the protection of other services.

The applicable channel bandwidths for bands 31 and 72 are 200 kHz, 1.4 MHz, 3 MHz and 5 MHz. eMTC and NB-IoT are supported by both bands and available from LTE Release 15 onwards.

Besides 450 MHz LTE bands standardised for Europe, the Chinese Government has proposed a new FDD band arrangement of uplink = 450-455 MHz and downlink = 460-465 MHz for Recommendation ITU-R M. 1036. As part of Release 15 a new LTE band 73 has been introduced to address this new IMT band arrangement, the output of the corresponding work item can be found in Technical Report 3GPP TR 36.759.

3GPP is of the general view that 2x5 MHz FDD band plans are feasible but 2x5.5 MHz FDD band plans are not suitable for full duplex operation of user equipment in the 450-470 MHz bands.

In addition, ETSI has adopted a work item for a new Harmonised European Standard for BB-PPDR following the publication of ECC Decision (16)02.

7.2.2 LTE Impact on systems within the 450-470 MHz as well as adjacent bands

7.2.2.1 LTE Impact on PMR/PAMR systems with channel bandwidth up to 25 kHz (including paging and analogue PMR)

The findings are the same as for the 410-430 MHz frequency range in section 7.1.2.1.

7.2.2.2 LTE impact on narrowband fixed links

The findings are the same as for the 410-430 MHz band in section 7.1.2.2.

7.2.2.3 LTE impact on PMR links in audio-visual production

The findings are the same as for the 410-430 MHz band in section 7.1.2.5.

7.2.2.4 LTE impact on DTT

The studies in ECC Report 283 have been carried out for LTE based PMR/PAMR systems in the 400 MHz band with various BS e.i.r.p. in the range of 48-62 dBm and with DTT receiver ACS of 61 dB. The analyses concluded that an ACLR of 67 dB/8 MHz would be required to minimise the interference from LTE BS to DTT reception at the cell edge, to cover any bandwidth and the activity factor as long as the LTE base station e.i.r.p. is below 60 dBm.

These requirements for LTE PMR/PAMR base stations are summarised in the table below.

Table 3: LTE400 Base Station e.i.r.p. and OOBE levels for protection of DTT above 470 MHz (based on worst case assumptions)

Frequency range	Condition on Base station in-block e.i.r.p. P (dBm/cell)	Maximum mean OOBE e.i.r.p (dBm/cell)	Measurement bandwidth
For DTT frequencies above 470 MHz where broadcasting is protected (NOTE 1)	P ≥ 60	-7	8 MHz
	P < 60	(P – 67)	8 MHz
For DTT frequencies above 470 MHz where broadcasting is subject to an intermediate level of protection or when mitigation techniques are used; at a national level depending on the type of mobile network deployment	P ≥ 56	-4	8 MHz
	P < 56	(P – 60)	8 MHz
NOTE 1: Based on these results, it can be concluded that the limits defined for the base stations of LTE based BB-PPDR in ECC Decision (16)02, should apply to the base stations of LTE based PMR/PAMR as well.			

At a national level, the out-of-band limit might be relaxed. For example, with a sparse network deployment, using high remote sites such as those used for DTT, the probability of interference to DTT reception is significantly reduced. Such a deployment has been successfully implemented in Scandinavian countries. Also, the requirement on the ACLR of the LTE PMR/PAMR BS can be relaxed when the victim DTT receiver is located close to the DTT transmitter so that the received DTT signal is strong enough to mitigate the interferer. Further mitigation measures, as described in Annex 8 of ECC Report 283 may allow solving possible remaining interference, on a case by case basis.

Additionally, it can be concluded that LTE eMTC and NB-IoT BS provide a better context of compatibility with DTT than conventional LTE BS.

Based on the results obtained for the user equipment (UE), it can be concluded that the limits defined for the UE of LTE based BB-PPDR in ECC Decision (16)02, should apply to the UE of LTE based PMR/PAMR. This requirement for the LTE PMR/PAMR UE is summarised in the table below:

Table 4: LTE UE OOBE level for protection of DTT above 470 MHz

Frequency range	User equipment maximum mean OOBE	Measurement bandwidth
For DTT frequencies above 470 MHz where broadcasting is protected	- 42 dBm	8 MHz

NB-IoT UE can coexist with DTT.

7.2.2.5 LTE impact on UHF maritime on-board communications

This section is not derived from ECC Report 283.

The ITU Radio Regulations stipulate in provision No. 5.287 (WRC-15) that the use of the frequency bands 457.5125-457.5875 MHz and 467.5125-467.5875 MHz by the maritime mobile service is limited to on-board communication stations. The characteristics of the equipment and the channelling arrangement shall be in accordance with Recommendation ITU-R M.1174-3 [30] and this includes possibilities for 6.25 kHz, 12.5 kHz and 25 kHz channelling options. The use of these frequency bands in territorial waters is subject to the national regulations of the administration concerned.

Since Recommendation ITU-R M.1174-3 includes the options of the characteristics of the maritime UHF maritime on-board communications and is part of the footnote 5.287 in the article 5 of the Radio Regulations since WRC-15, it was decided by ECC/WGFM that the Recommendation T/R 32-02 on the 'Frequencies to be used by on-board communication stations' was no longer needed.

A table provides an overview of the "UHF frequencies", with the associated conditions of use, authorised for on-board communications in CEPT countries. This information has been collected by the European Communication Office (ECO) and is fully based on the information provided by the CEPT administrations who responded to the relevant ECO questionnaire.

This overview is intended to provide to CEPT administrations and their national maritime stakeholders the most recent information available to ECO on the permitted use of the UHF frequencies by on-board communication stations in individual CEPT countries which have responded to the questionnaire.

It should be noted that in some CEPT countries part of these frequencies are used by land mobile safety related applications (e.g. by railway companies). Such a situation creates the risk of harmful interference to these applications from unauthorised on-board communications from foreign ships within country's territorial waters. The study in ECC Report 283 illustrates difficulties with regard to the impact of LTE based systems on PMR systems with bandwidth of up to 25 kHz. The study was looking entirely on PMR as a victim, as the protection of LTE from narrow band carriers can be handled by many advanced mitigation techniques such as MIMO selectivity arrangements even though this is less effective at such low frequencies as 400 MHz. The studies show that only the upper LTE-resource blocks 14 and 15 generate essential interference (e.g. in cases where the LTE system operates on frequencies up to 457.5 MHz / 467.5 MHz).

7.2.3 LPWAN impact on systems within 450-470 MHz

7.2.3.1 LPWAN compatibility with TETRA

The findings are the same as for the 410-430 MHz band in section 7.1.3.1.

7.2.3.2 LPWAN compatibility with LTE

The findings are the same as for the 410-430 MHz band in section 7.1.3.4.

8 GUIDANCE TO ADMINISTRATIONS

8.1 HOW THE INCREASED SHARED USE OF PMR/PAMR FREQUENCIES COULD BE FOSTERED

The increased shared use of PMR frequencies and related methodologies such as ‘sharing number’ seem to represent a significant opportunity for serving more users in the existing spectrum for PMR.

It is comparable to the addition of a significant block of spectrum being made available to PMR services. The focus is hereby on digital PMR solutions with 6.25 kHz, 12.5 kHz or 25 kHz (e.g. dPMR, DMR and TETRA). The creation of such increased “spectrum headroom” is especially helpful in local situations where the scarcity of spectrum is identified. According to the 400 MHz survey in Annexes 1 and 2 to this Report, this most frequently is found in urban, metropolitan centres or in border areas. It is recognised that the currently uncoordinated operation is likely to remain a very high proportion of all PMR spectrum arrangements for a considerable period.

Whilst trunked systems will continue to cover a significant proportion of the deployed population, they are considered to be largely coordinated and offer far better efficiencies for large fleets and are typically deployed on exclusive channels. These systems are not the subject of this section.

8.1.1 Working Definition for sharing headroom

The sharing headroom is defined as the minimum amount of usable spectrum available to an additional number of users, irrespective of the technology those additional users are applying.

Spectrum channels that can be cleared following the introduction of a sharing number (typically 2 or 3) and could be re-purposed towards data-only use and exclusive use as well as providing further opportunity for general growth. It is also possible to start with a sharing number of 2 and increase thereafter to 3 on the basis of experience that the UK has implemented in 2018.

This means, if the sharing number introduced is 2, the channels made available is 50% of the total currently in use. Each sharer would be permitted only 50% of the available capacity leaving 50% to the other.

There is merit in work that would lead to an ETSI standard on channel access procedures on data-only shared channels.

8.1.2 Important aspects for sharing

Data transmissions appear not to cause interference to voice if the data transmission strategy mimics voice transmission in the time domain. However, data services that comprise long strings of rapid bursts of data generally sterilise the channel for other use. Accordingly, the definition of sharing should be done in a way to safeguard the capacity left available for other sharing users.

The sharing of the same channel is by uncoordinated users at the same location. The policy effectively assumes that the level of loading is sufficiently low to provide that the call success rate is high enough to meet the users’ operational needs. Typically, this translates to a first-time call success rate requirement in excess of 90%. It will often be advantageous to apply some form of “Carrier Detect-and-TX-Avoid” and/or CTCSS (sub audio tone squelch), which are all readily available functions in f. inst. PMR 446.

Experience shows little evidence that indicates that mixing voice and data is intrinsically a problem, provided that the structure of the data transmissions is similar to that expected in voice communications. I.e. the data transmissions are leaving considerable periods of time during which other communications can take place.

In cases where the data structures (in the time domain) did not leave significant periods of time for other communications, there probably is a serious risk of channel collisions. If data systems comprise a near continuous stream of short-duration bursts of data with short gaps between e.g. GPS, polling schemes are adjustable over a wide range of burst durations and gap durations. However, even at the longest settings of gap durations, the usability for other users is challenging. The gaps between the data bursts are generally insufficient to sustain a voice message and so clashing is highly likely (or even certain) to occur. The opportunity to avoid clashing through a prioritisation system could be considered. Whilst this obviously improves the position of the communications having priority, the user whose communications does not have priority is disadvantaged. The question then is who decides "who should have priority?" Such a prioritisation is difficult to implement. It is concluded that these services are generally unsuited for deployment on ordinary shared channels and should be off-loaded to data-only channels. Nothing prevents the development of shared data-only channels but of course, some form of channel access protocol may be beneficial.

8.1.3 General Guidelines

When introducing PMR spectrum sharing, the initial sharing number is recommended to be 2.

The assignment policy should seek migration of existing users onto a smaller number of shared channels than they occupy today (transitioned through a licence renewal process). This would allow for the clearance of some of the current non-shared channels. These could in turn be re-purposed to data-only channels and exclusive channels as well as offering the opportunity for normal growth.

The geographical overlap (e.g. 25%, 50% or 100%) of the coverage shared by other users and the statistic distribution of mobiles can be taken into account to improve the sharing possibilities;

A period of at least a year should be allowed to examine the impact in the field of the sharing before moving to any higher sharing number (e.g. 3). The United Kingdom has moved to a sharing number of 3 in 2018. Annex 9 to this Report includes additional information about the use of data in PMR shared channels as it was investigated in the United Kingdom.

It should be made clear that transmissions that effectively prevent the shared channel being used by other users are not in compliance with the licence. Data transmissions must follow the rules of sharing and leave usable gaps for other communications. The licence application and renewal should seek information on the data structure to ensure that the structure is compatible with sharing.

Data schemes which cannot provide the necessary opportunity for other users to operate are expedited on data-only channels. In considering data-only channels, there is a case to introduce a policy of shared data-only channels. Because the data is probably not as time-critical as voice, there is a good chance that a successful channel access protocol could be employed that would greatly increase efficiency on the data-only channel.

A work item for an ETSI standard or specifications for approaches facilitating PMR spectrum sharing could be initiated. Some form of randomisation of the re-tries could be appropriate for inclusion in the access strategy. Sharing could be described in a framework for medium utilisation where a higher traffic is allowed as long as PMR equipment accesses spectrum in a polite manner.

PMR spectrum sharing can be especially useful for low occupancy telemetry and other PMR systems having low overall spectrum occupancy. Administrations should look at traffic type (voice, data) and not on the technology. Trends suggest that a huge increase in data is likely and this may have a major impact of data on channels shared with voice. Exclusively voice channels could share more than at present and be safe from degradation due to introduction of data.

It would be more appropriate to consider defining spectrum products via congestion ratio (CR) instead of activity factor (AF).

8.1.4 Summary of section

The 400 MHz PMR bands are amongst the most occupied in CEPT, with over 100,000 active licences. It is obvious, that apart from the coordinated trunked systems, the uncoordinated smaller PMR systems offer a potential for the creation of sharing head rooms, such that spectrum utilisation can be increased. It is understood that apart from the technological aspects of sharing, also the way spectrum is regulated (licensed) can be shaped to create incentives to deploy sharing capable radio platforms. In return for the procurement of new sharing capable PMR equipment, users and their businesses should be offered reduced licence fees in compliance with national needs.

Additional information can be found in the documents FM54(15)24 [40] and FM54(15)23 [41].

Further possibility of building national PMR/PAMR platforms is presented in the section 5.3. Such shared platforms are already implemented or under implementation in the Netherlands, Austria, Hungary, Finland and Germany.

8.2 STRAGEGIES FOR REGULATION IN SOME COUNTRIES STILL HAVE TO FOLLOW THE DIGITISATION OF THE PMR/PAMR MARKET

The current usage of the 29.7-87.5 MHz, 146-174 MHz and 380-470 MHz frequency ranges by land mobile PMR/PAMR systems includes still a large percentage of analogue legacy systems. The situation varies from country to country. On one hand, there are countries still with 100% analogue usage. On the other hand, there are countries with a very high percentage of digital PMR/PAMR use. From recent data such as from the DMR association [see http://dmrassociation.org/dmr-in-the-market/), it seems clear that most of the new PMR/PAMR equipment which is placed on the market in the 400 MHz bands is digital.

Digitisation takes place in the 400 MHz PMR/PAMR frequencies. The digital technologies with the most mentioning in the responses of the CEPT administrations to the questionnaire in 2014 were DMR (17 times), TETRA (16 times) and dPMR (7 times). Other mentioned technologies were TETRAPOL, CDMA and NXDN.

Narrowband channel spacings are implemented throughout Europe. However, some CEPT administrations still allow only analogue systems in some parts of the 400 MHz PMR/PAMR frequencies or reserve the spectrum based on 20/25 kHz channel spacing only.

The use of digital technology which is more spectral efficient and can also use more sophisticated cognitive spectrum access technologies should go together with rewarding the use of these techniques. In addition, rewarding polite spectrum access technologies which can support sharing of PMR/PAMR spectrum, should be fostered. Cognitive techniques allow radios to access available radio resources in time, frequency and space that might not otherwise be exploited. Polite spectrum access techniques further minimise unnecessary use and encourage equitable sharing of the scarce radio resource. By efficiently utilising these resources, additional PMR/PAMR services and applications can be offered within the same spectrum. This type of behaviour should be encouraged by the applied regulatory regime,

The following can therefore be suggested to CEPT administrations:

- Incorporate the full set of narrowband channel spacing of 6.25 kHz, 12.5 KHz, and 25 kHz as much as possible in the 400 MHz frequency ranges;
- Foster/encourage the use of spectrally more efficient digital PMR/PAMR equipment;
- Another option is to consider to not award new PMR/PAMR licences for analogue PMR/PAMR use;
- Licence renewals of existing legacy analogue PMR/PAMR should only be conducted where appropriate e.g. to enable continued analogue operations where land mobile systems with greater user equipment populations can be demonstrated to be effectively in use;
- The narrowbanding approach determining a minimum spectral efficiency of one channel/6.25 kHz (fulfilled by e.g. dPMR, DMR and TETRA) can be used as a minimum technical requirement in areas where congestion issues arise (e.g. capital cities or close to border situations);
- Reward the sharing of PMR/PAMR frequencies.

The above suggested measures will contribute to more efficient spectrum use and hence will also help CEPT administrations to find more contiguous spectrum for PMR/PAMR usage requiring more than 25 kHz of bandwidth. So far, the possibilities for PMR/PAMR applications with channel bandwidth of greater than 25 kHz are very limited and according to the responses to the questionnaire in 2013, not more than about 200 land mobile systems with bandwidth of greater than 25 kHz were in use in European countries.

However, in countries with available spectrum resources for the introduction of wide band technologies such as CDMA or LTE, wideband PMR/PAMR networks are already built or under construction as national platforms for potentially millions of connected devices (chiefly M2M) providing for very efficient use of spectrum and very cost effective PMR/PAMR services.

8.3 CONSIDER MOST FLEXIBLE APPROACHES FOR LICENSING

There are several ways to consider more flexible approaches for PMR in the 400 MHz bands:

- Introduce the possibility of trading/leasing to PMR national and regional licence types;
- Technical framework should allow greatest possible frequency partitioning as well as technology neutrality (one common technical framework / set of restrictions);
- Removal of any non-spectrum related licence conditions;
- Introduction of trading of wider area type licences (sub-leasing and 'LSA-like');
- Introduction of national and regional licences where users operate in large geographical areas and based on exclusive access to spectrum. Licensees are allowed to deploy transmitters anywhere in their area;
- Simplified pricing approaches;
- Consider introduction of an online based licence application tool.

Some of the points above can also foster the introduction of more wideband PMR applications / introduction of new technology (e.g. LTE), where possible.

A more flexible PMR regulatory environment does not need to differentiate between PMR and PAMR. This will also foster the finding of synergies between PMR usages having similar requirements (e.g. PPDR related, Smart Grids, or railway applications in the 400 MHz range)

Examples from the United Kingdom through a licence product offering (light Licensing) and trading and leasing is provided in Annex 4 to this Report.

8.4 NARROWBANDING ASPECTS TO INCREASE THE EFFICIENT USE OF THE SPECTRUM

Table 5: Current spectrum efficiency

Technology	Bandwidth	Comment
Analogue	12.5 kHz 25 kHz	Used for voice only solutions and also for paging. 25 kHz analogue should not get new licences in PMR congestion areas
FDMA (DPMR / NXDN)	6.25 kHz 12.5 kHz	Allows users to utilise 6.25 kHz channels in 12.5 kHz
TDMA (DMR)	12.5 kHz	2 timeslots available in 12.5 kHz
TETRA	25 kHz	4 timeslots available in 25 kHz

It is noted that major countries outside of Europe make the use of digital technologies mandatory for new PMR equipment placed on the market (e.g. China, USA). Current spectrum efficiency for analogue PMR is one channel in 12.5 kHz, while new digital technologies provide a two-fold increase to 6.25 kHz equivalent. There has been so far no motivation on users to replace equipment.

Individual CEPT administrations may consider identification of a minimum required spectral efficiency to support the migration to digital, more spectrum efficient technology which will allow the creation of additional channel capacity within the same radio spectrum, and support more users.

When introducing narrowbanding requirements on national level, it is suggested to be introduced with some announcement in advance as part of a longer term migration plan, so that the market participants are prepared in advance that a new requirement is coming. Narrowbanding can in particular cases be useful, e.g. in areas where spectrum congestion is experienced.

8.5 THE FREQUENCY RANGE 406.1-406.2 MHZ

The footnote 5.265 in the radio regulations and following Resolution 205 (Rev. WRC-15) requests administrations not to make new frequency assignments within the frequency band 406.1-406.2 MHz under the mobile and fixed services. This means that these 100 kHz of spectrum will become unavailable for PMR/PAMR in the future. This is also reflected in a considering in ECC Decision (19)02 [11] for land mobile systems.

8.6 GUIDANCE ON LICENCE DURATIONS AND FEES

The questionnaire results (see ANNEX 1: to this Report) reveal that most CEPT administrations provide normally (standard) PMR licences for either 1 year (6 countries), 5 years (13 countries), 10 years (10 countries) or even 15 years (2 countries).

It is recommended to CEPT administrations to focus on a 5 to 10 year licence term for assignments with channel bandwidths up to 25 kHz, combined with a low flat fee, simple process and possibility of online application. The licence is an asset that can be traded with the business. Alternatively, an administration can also issue an annual licence renewal process under which operations continue as long as the annual licence fee is paid.

For networks requiring greater investments or in support of a high population of terminal devices, the operator's expectation will clearly be that the frequencies awarded will be available over a longer period, e.g. 15-20 years. This is to protect the investments made by the operator. However, a licence expiry date can also be considered as of when the spectrum can be re-purposed. Without the clear definition of an expiry date at the start, repurposing of the spectrum might be challenging.

The United Kingdom presented in document FM54(15)14 [55] possibilities for PMR licensing arrangements as used in the United Kingdom. This includes:

- Fees are apportioned to the national channel rate in proportion to the population within the service area (high, medium and low population);
- Fees for shared use of spectrum are less expensive than for exclusive use of spectrum;
- Fees in the 400 MHz ranges are more expensive than in the VHF frequency ranges.

8.7 GUIDANCE FOR IN-BUILDING SYSTEMS

The need to make assignments for tall buildings that extend well above the local building height in cities has become increasingly apparent. Transmitter installations in tall buildings have to be carefully planned. Transmitters will give extended radio coverage whilst receivers located in these elevated positions are also susceptible to receive signals from far away. For the purposes of spectrum planning in tall buildings, it is considered at heights of greater than 30 metres and above the surrounding clutter.

Modern building techniques can present challenges for indoor coverage and in most cases the design of the radio system infrastructure can address internal coverage and also minimise the impact outside the building itself.

The most successful implementation will be one that can be installed during the fit out of the building. Possible solutions to fit radio systems in tall buildings include:

- A radiating 'leaky' cable is one way of delivering low levels of radio frequency (RF) throughout a building. It provides 'a slight leak' of transmitted RF along its length and so the cable can be routed to provide coverage into the most inaccessible parts of a building and throughout each floor, including basements etc.;
- The use of more robust terminal receivers to limit the risk of picking up signals from other users. This can be facilitated by using less sensitive receivers, low or even negative terminal antenna gains, or use of techniques such as digital colour codes or CTCSS tones helping to reject any transmissions not intended for reception;

- Organising the indoor use in tall buildings in small cells with limited transmitted RF levels, e.g. by a distributed antenna system floor-by-floor.

Additional information and guidance is provided in document FM54(17)29 [54].

Repeaters and amplifiers of land mobile systems are a growing source of potential interference. Recent annual CEPT interference statistics (link) also demonstrate that such considerations are necessary to avoid interference between installations in tall buildings and other systems sharing the spectrum outside of these buildings.

If the proposed installation site is above 30 metres and the application proposes use of an antenna that is not a radiating cable or distributed antenna system, then the operator will be asked to provide the site engineering justification of the proposed choice of antenna such as an omnidirectional. As part of the licensing process, what is required is the highest point of a mobile terminal so that this can be modelled to give an accurate coverage prediction rather than using the default mobile height of 1.5 metres above ground.

Communication throughout the entire tall building and for a small area outside at ground level for events such as fire evacuation could be facilitated by use of antennas which are directed vertically up or down (down-fire/up-fire; characteristics include -15 to -20 dB gain towards the horizon).

A licence for an installation in a tall building above 30 metres may include reference to using a radiated cable or any other antenna integrated into the system, including associated installation requirements.

8.8 CONSIDER HOW THE VHF USE COULD BE FOSTERED

11 responses from industry (out of 14) indicate that digital PMR products are available or at planning stage for the 146-174 MHz band.

For the 68-87.5 MHz band, there were 9 respondents which indicated the availability of products for this frequency band. 5 respondents consider the 68-87.5 MHz band as not suitable for digital PMR/PAMR. The stated reasons are insufficient demand, the band cannot provide the required availability, equipment size to big or PMR communications suffer from over range characteristics. Another challenge might be a relatively high noise floor at VHF frequencies.

While the majority of the responders consider the existing regulations to suit their PMR/PAMR applications for VHF frequencies, some improvements might be possible:

- Allow higher emission levels for PMR in VHF below 100 MHz;
- Align better with CEPT regulatory approaches in details in the regulatory approaches amongst countries;
- Introduce a band factor for the VHF licence price–less popular bands in VHF will attract only a fraction of the price of the more popular bands full rate in UHF. Prices can even be lowered for areas with mid and low population density but can also be increased for high population density areas.

VHF band in 47-68 MHz

A more detailed investigation about 47-68 MHz was performed using the EFIS database and national available information to get an overview about which countries have already PMR/PAMR solutions in these frequencies.

There are about 30 countries with land mobile radio and defense applications (e.g. tactical radio relay) in parts of the band (NJFA 2014: land military systems in 47-68 MHz) [48]. Apart from this, PMR/PAMR use is very limited in many CEPT countries (16 countries in EFIS set out PMR/PAMR use in parts of the band). Terrestrial broadcasting use is also very limited, e.g. only in isolated areas in the Russian Federation; no use in Western Europe anymore). The footnote ECA3 in the European Common Allocation Table requests CEPT administrations to take all practical steps to clear the band 47-68 MHz of assignments to the broadcasting service.

Other usage may also exist in the band. As a result of the questionnaire and following discussions, it seems that the majority of the PMR/PAMR use in the VHF frequency bands is above 100 MHz. The demand for

PMR/PAMR solutions at frequencies below 100 MHz can easily be satisfied within the 68-87.5 MHz spectrum.

However, it is also to be taken into account that individual countries can only use a fraction of the band based on preferred frequency use. International coordination agreements between neighbouring countries may move the threshold limits far into the neighbouring country for 'preferred frequencies', typically by around 80-100 km at spectrum around 50 MHz.

Administrations are asked to consider whether they have sufficient capacity within this frequency range to accommodate new (or additional) alternative services in this band. The existing framework for land mobile systems in Recommendation T/R 25-08 [3] is seen as a good starting point for such new or alternative services.

9 IMPLEMENTATION ISSUES

9.1 NEED TO CONSIDER ALTERNATIVE SPECTRUM FOR PMR/PAMR IN THE FUTURE

Spectrum availability in the 400 MHz bands for LTE based systems to meet all BB-PMR/PAMR needs is questionable in some CEPT countries due to its current use and additional alternative PMR/PAMR use, the future implementation of BB-PPDR in the 450-470 MHz band and the difficult coexistence with radio astronomy and radiolocation services in the 410-430 MHz band. Moreover, it is expected that the 400 MHz bands will not be suitable to meet specific BB-PMR/PAMR needs with increased throughput in confined space environment such as metro lines, buildings (for example video traffic related to automated urban metros). Higher frequency bands could be more appropriate to meet such BB-PMR requirements therefore it seems essential to consider the possibility to access MFCN bands, in addition to the 400 MHz band.

This Report considers PMR/PAMR in 400 MHz bands in which broad and deep coverage for mobile applications and connectivity for large number of distributed assets is possible. For such usage scenarios higher frequency bands are less suitable.

LTE technology can support use of PMR functionalities and therefore any MFCN bands could be suitable for BB-PMR/BB-PAMR as possible options on national basis. Within the ECC, ECC PT1 conducted a review of MFCN deliverables to ensure that they contain no provisions that might inhibit BB-PMR/BB-PAMR usage.

At an industrial level, it appears that equipment suppliers within the mobile and PMR sectors have formed partnerships for the development of PMR solutions based on LTE, including infrastructure communications and mobile devices. LTE seems to be a technology that can evolve to meet all or part of PMR needs with channel bandwidths up to 5 MHz. In particular LTE Release 12 introduced D2D/ProSe communications, necessary to address MCPTT requirements, which will be further enhanced within Release 13.

For example, several PMR users have taken the initiative of conducting preliminary trials for the use of BB-PMR in LTE bands (in particular the 2570 MHz-2620 MHz band) and report that the first results are encouraging as the demonstrated performance is very similar to theoretical models.

Information about an example of a framework for the deployment of BB-PMR in an alternative band (2570-2620 MHz) has been provided by France in ANNEX 8:.

The designation of Electronic Communications Services (ECS) frequency bands is non-exclusive and therefore does not preclude the use of PMR applications. Additionally, according to Directive 2002/21/EC [27] of the European Parliament and of the Council, “Electronic communications service means a service normally provided for remuneration which consists wholly or mainly in the conveyance of signals on electronic communications networks, including telecommunications services and transmission services in networks used for broadcasting”. Depending on the business model that will be chosen for BB-PMR networks, they may fall under the scope of the definition of ECS (see also section 4.1).

Therefore additional harmonised MFCN bands may be used on a national level to provide an alternative or complementary spectrum resource for BB-PMR.

9.2 BAND RE-ALIGNMENT

As shown in the responses to the PMR survey, the 400 MHz band is currently heavily used by other applications in some CEPT countries.

Identifying sufficient spectrum in the 400 MHz range in some countries could be difficult as a set of narrow band channels of continuous spectrum to reach LTE size channels of 1.4 MHz, 3 MHz or 5 MHz needs to be identified. National regulatory strategies are required for migration of narrowband usage to certain frequency bands in order to achieve a contiguous range of spectrum for assignments of spectrum for land mobile systems based on LTE technology.

Some administrations may want to align their 400 MHz band configuration with the ERC Report 25 (ECA Table) and Recommendation T/R 25-08 in order to benefit from common equipment. This represents an implementation issue but may also be an opportunity in the long term.

9.3 REFARMING

Clearing the identified block of spectrum will require re-planning of the band

Co-channel users could be moved to:

- A new PMR/PAMR network;
- Alternative narrowband (NB) channel;
- An existing or new WB-PAMR network;
- MFCN network.

Adjacent channel users will need to be moved to:

- A new PMR/PAMR network;
- Alternative NB band channel;
- An existing or new WB-PAMR network;
- MFCN network;
- Protected by adjusting the authorisation;
- Increasing power;
- Tilt of antennas etc.

9.4 IMPLEMENTATION ISSUES WITH REGARD TO THE VARIOUS MODELS

The PMR/PAMR survey conducted in 2014 highlights that the use of the 400 MHz frequency bands varies significantly throughout the CEPT countries. This variety has further increased since the completion of the survey. The adoption of information technology in almost all sectors of the economy increases the demand for Machine-to-Machine communication. There are several challenging needs for some of the Machine-to-Machine applications such as massive deployment (up to several ten thousands of devices per km^2), very high reliability, resilience, low costs and low latency communications. In light of these technical and commercial requirements, new models of frequency use can be observed.

Coming from a situation where many local narrowband networks shape the frequency landscape, the upcoming M2M requirements cannot be delivered over traditional narrow band technology. In response, industry has already developed 3G and 4G systems enabling the required communication's parameters. However, the deployment of wide band systems based on 3G and 4G standards is bounded to some economic and regulatory key points which have to be fulfilled.

Although there are thousands of licences granted with respect to narrow band services, the single licence holder will not be in position to bear the costs of the deployment of wide band technologies. A migration from (analogue) narrow band to wide band technologies requires economies of scales. The same applies to frequency efficiency. Wide band technologies cannot be deployed by the thousands of licence holders due to spectrum scarcity and costs. In response of this economic reasoning, there are market developments that aim at establishing frequency platforms for various undertakings in various sectors. Those platforms ensure an efficient use of frequencies by granting open access. Thus, synergies between different sectors can easily be exploited.

In order to facilitate this market development, licence duration as well as licence fees should reflect the public value of the enabled services. To provide confidence that the spectrum is available for a long time is essential to attract investments. Furthermore regulatory authorities should assess whether dedicated spectrum for mission-critical applications (in different sectors) might support the adoption of ICT in the economy.

Against the background of the parallelism of traditional narrow band networks and the upcoming use of wide band technologies for PMR/PAMR applications, regulatory authorities should formulate in accordance with market developments an integrated approach towards the future use of the frequencies between 400 and 470 MHz. Thereby, administrations should reflect that the introduction of digital systems in various sectors of the economy, the extension of digital PAMR networks and the migration to wide band systems may over time lead to a migration of some of the traditional PMR users operating their own networks onto such shared networks, possibly reducing the spectrum demand for PMR systems;

Administrations should facilitate the deployment of new services based on (new) wide band systems which can support mission-critical communication as users currently expect.

10 CONCLUSIONS

ECC Decision (19)02 [11] was developed for land mobile systems in the frequency ranges 68-87.5 MHz, 146-174 MHz, 406.1-410 MHz, 410-430 MHz, 440-450 MHz, and 450-470 MHz and replaces ECC Decision (04)06 and ECC Decision (06)06.

ECC Report 283 provides study results which can be taken into account when designating spectrum for wideband and broadband land mobile systems in the 410-430 MHz and 450-470 MHz frequency ranges.

For the band 47-68 MHz, CEPT administrations are asked to consider whether they have sufficient capacity to accommodate new (or additional) alternative services in this band. The existing framework for land mobile systems in Recommendation T/R 25-08 [3] is seen as a good starting point for such new or alternative services.

Depending on the PMR/PAMR usage situation in their country, CEPT administrations may decide which parts of the available spectrum for land mobile systems is made or kept available for networks based on specific narrowband, wideband or broadband technologies.

When identifying sufficient spectrum for wideband and broadband systems in the 400 MHz range, it is often difficult to identify continuous spectrum to reach LTE size channels of 1.4 MHz, 3 MHz or 5 MHz. National regulatory strategies are required for migration of narrowband usage to certain frequency bands in order to achieve a contiguous range of spectrum for assignments of spectrum for land mobile systems based on LTE technology.

This ECC Report describes options which administrations can employ such as:

- consideration of how VHF use could be fostered;
- foster increased shared use of PMR channels;
- to amend their PMR/PAMR regulatory framework. Regulation in some countries still have to follow the digitisation of the PMR/PAMR market (in other words: increase the frequency opportunities for digital use);
- achieving more contiguous band segments for wideband and broadband systems;
- more flexible approaches for licensing;
- adoption of a concept defining area licences (see section 5.4).

CEPT administrations should endeavour to comply with the provisions in Recommendation T/R 25-08.

Many PMR/PAMR land mobile systems support critical communications, either business-critical, mission-critical or safety-related. There may be synergies in the way these are provided. The idea of having national common platforms is attractive when facing scarcity of spectrum in the 400 MHz range, especially for wideband and broadband networks.

The following items for possible future standardisation activities have been identified:

- it is proposed that 3GPP should consider standardisation activities for the range 410-430 MHz;
- work item for ETSI standards and/or specifications for a means to facilitate PMR spectrum sharing;
- improved receiver specifications may be helpful to reach a more effective spectrum utilisation, e.g. by avoiding guard bands between different land mobile system operating in adjacent spectrum, in the 400 MHz frequency ranges. ECC Report 283 provides useful guidance in this respect.

ANNEX 1: 400 MHZ PMR/PAMR SURVEY

A1.1 OVERVIEW

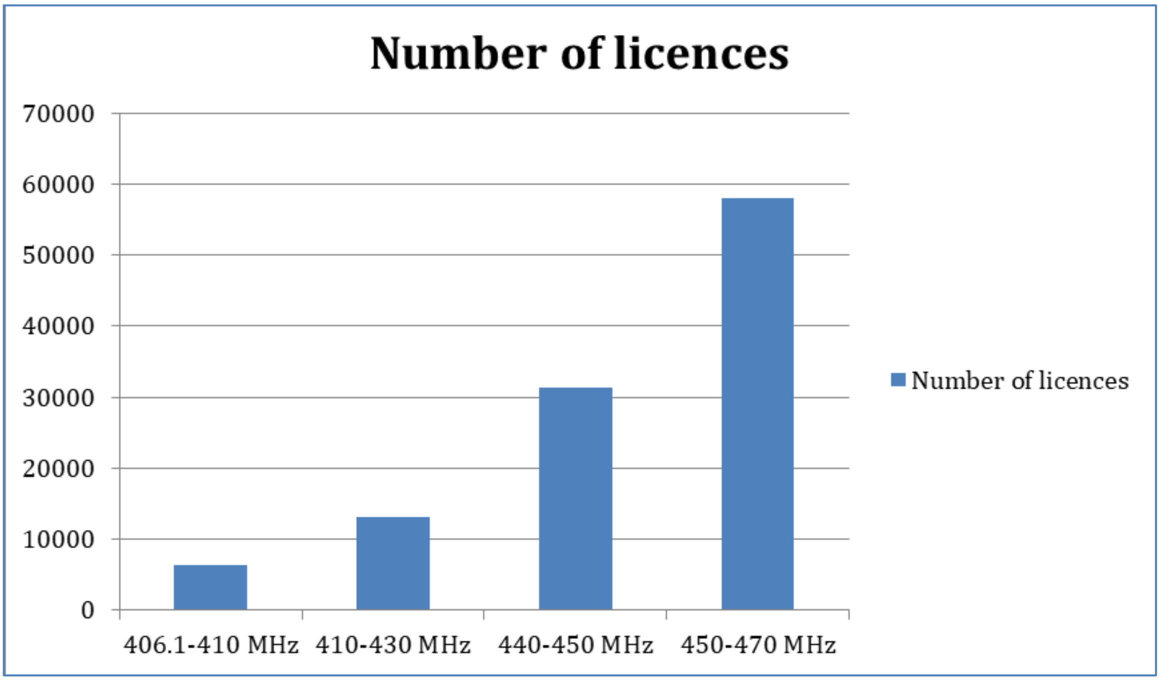


Figure 6: Number of PMR/PAMR licences per frequency band (basis: 33 CEPT countries in 2014)

The total number of licences within the 32 CEPT countries is 108.648. A conservative total number over the whole CEPT is 120.000 licences. In terms of bandwidth, the overall estimate for CEPT is about 550.000 units of use measured in 12.5 kHz equivalent units.

There is some more use in 420-430 MHz compared with 410-420 MHz while there is a quite equal distribution of use in 450-470 MHz. The frequency re-use amongst licences in 450-470 MHz is much higher than for the 410-430 MHz band. A main reason for this is that there is a higher percentage of nationwide networks in 410.430 MHz.

Licences for other use than PMR/PAMR and PMR/PAMR licences with air interfaces greater than 25 kHz are quite limited. The total number of recorded licences was 110 for the 32 CEPT countries, many of them however nationwide.

Only a limited number of CEPT administrations have implemented shared PMR/PAMR use (use of the same frequencies within geographical overlap, using a sharing factor of typically 2 or 3), mainly those with congestion situations.

A1.2 QUESTIONS TO ADMINISTRATIONS

Question 1: How many individual licences for PMR/PAMR services in the 400 MHz range do exist in your country? This may also include applications such as paging, asset tracking etc. Provide the overall number of the individual authorisations per frequency range

32 administrations provided an overview about the number of NB PMR/PAMR licences. 19 countries have also provided WB licences (in some cases a very limited number of WB licences).

Question 2: Indicate whether PMR/PAMR licences are network licences or as per individual transmitters

27 administrations issue network licences. 16 administrations issue individual transmitter licences (of which 6 countries provide only individual transmitter licences for PMR)

Question 3: Indicate the possible channel spacing for each frequency range / sub-frequency range. Remarks can also be added, if considered necessary. Please indicate whether certain frequency ranges are for digital and/or analogue PMR/PAMR usage (digital only, analogue only, both digital/analogue)

Question 3 confirms that the NB channel spacings of 12.5 kHz and 25 kHz are throughout Europe implemented. Not all administrations define also 6.25 kHz spacing (e.g. dPMR), some have still PMR frequencies with 20 kHz channel spacing (5). The WB PMR/PAMR frequency opportunities are limited (see also question 1)

Question 4: For the existing population of PMR/PAMR radios/licences which technology is in use, i.e. either analogue or digital? If digital, please indicate the technology to the extent possible (e.g. TETRA, TETRA TEDS, TETRAPOL, DMR, dPMR, other). If possible, please indicate the approximate percentage of analogue and digital usage.

Many administrations could not precisely answer this question. It seems clear that digitization takes place slowly but steadily in the 400 MHz PMR/PAMR frequencies. **The digital technologies with the most mentioning are DMR (17 times) and TETRA (16 times) and dPMR (7 times).** Other mentioned technologies are TETRAPOL, CDMA, NXDN.

Question 5: For new PMR/PAMR radios/licences added in the last 12 months which technology is in use, i.e. either analogue or digital? If digital, please indicate the technology to the extent possible (e.g. TETRA, TETRA TEDS, TETRAPOL, DMR, dPMR, other). If possible, please indicate the approximate percentage of analogue and digital usage.

The situation varies from country to country. On one hand, there are countries with 100% analogue usage. On the other hand, there are countries with a high percentage of digital PMR. Possible reasons may need to be investigated (e.g. lack of opportunity or incentives for digital PMR in some countries?).

Question 6: Please indicate the change/tendency of change of the overall number of narrowband and wideband PMR/PAMR individual licences (increase/reduction/stagnation, estimate in %) over the last 5 years. Responses should be made for each frequency band.

14 countries report either a slight increase or bigger increase of the NB PMR/PAMR usage in the 400 MHz frequencies. 14 countries report stagnation/constant numbers of licences and overall usage. Some countries report a reduction. It may be a point for investigation in FM54 to find out possible reasons for increase or reductions.

Question 7: Please indicate the demand trend, e.g. increase of digital PMR/PAMR, e.g. as a percentage of all new licences in the last year or increasing percentage over the last years. In addition, please indicate whether you see increasing demand for wideband/broadband PMR/PAMR applications.

An increase of demand for digital PMR/PAMR has been reported by about half of the responding countries. Increasing/New demand for wideband/broadband PMR/PAMR has been reported by 5 countries (Denmark, France, Germany, Poland and Luxembourg), however without quantifying this demand.

Question 8: Is there complementary licence information available or to be taken into account? E.g. a link to PMR/PAMR licensing information on your webpages or a master document describing PMR/PAMR spectrum opportunities in your country.

The complementary licence information can be used (together with national contact information) to set up a PMR/PAMR information website on the ECC website (similar to other applications such as PMSE, satellite services etc.)

Question 9: Please describe the main technical attributes of "normal" PMR licences (such as typical coverage radius/area); local, regional/ nationwide use). (If necessary, divided by frequency range)

Most administrations provide local, regional and nationwide PMR/PAMR authorisations (there are not so many administrations who do not issue national wide coverage, if so demanded). Local coverage definitions (possible radius) vary country-to-country.

Question 10: Please indicate the main market sectors (as a rough %, e.g. how many PMR/PAMR licences are in the transportation field, industrial field or other market sectors)

The industrial sector, transportation sector (including airports and railways) and governmental sector (blue light forces, but also e.g. embassies) are the most important market sectors in general in Europe. Other mentioned sectors are the energy/utilities sector (smart metering/smart grids), hotels/tourism sector, financial sector, and agriculture and forestry sector, retail sector.

Question 11: What is the typical PMR/PAMR licence duration?

With some simplification, where the licence duration can be between 1 to 5 years, licence durations vary from 1 day to 15 years. Most administrations provide normally (standard) licences for either 1 year (6), 5 years (13), 10 years (10) or even 15 years (2).

Question 12: Do you have any plans for providing spectrum in 400 MHz range for wideband (or even broadband) PMR/PAMR (e.g. dedicated sub-bands for narrowband PMR/PAMR and wideband/broadband PMR/PAMR)?

The situation differs greatly from country-to-country. For both the 410-430 MHz band and the 450-470 MHz band, opportunities for wideband/broadband PMR/PAMR exist in more than 10 countries respectively. Some countries indicate current investigations to find new opportunities for wideband/broadband PMR/PAMR or PPDR. Some other countries find it difficult to accommodate wideband/broadband PMR/PAMR in the 400 MHz frequency band. Some countries see no WB/BB demand.

Question 13: Link to designated contacts in CEPT administrations with respect to PMR/PAMR. In order to set up a website with the list of contacts points in CEPT administrations concerning PMR/PAMR related activities, it might be helpful to provide links to national websites and a central contact point for enquiries.

The complementary licence information can be used (together with national contact information) to set up a PMR/PAMR information website on the ECC website (similar to other applications such as PMSE, satellite services etc.)

Question 14: Considering analogue PMR/PAMR, do you assign nationwide exclusive channels (i.e. not allowed for shared use). If yes, please indicate the percentage of exclusive and shared channels. For shared PMR channels what kind of radio planning (e.g. CTCSS, maximum allowed number of equipment in the same channel) is used?

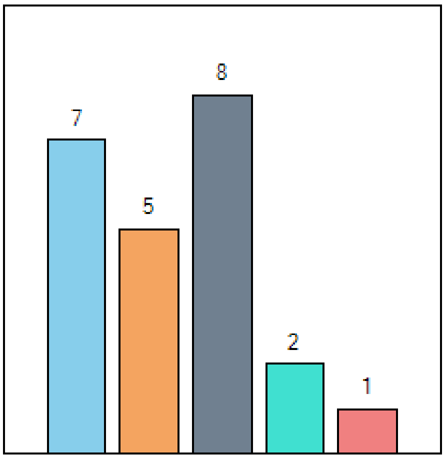
CTCSS used by some administrations (10) for sharing, DCS and CCIR or even measurement of spectrum occupancy also mentioned for sharing. The percentage of exclusive channels and the possibility of assignment of exclusive (nationwide) channels differ greatly from country-to-country. The existing radio planning approaches seem to apply to some extent also on simple geographical separation. A question can therefore be, to consider how the efficient use of the PMR/PAMR spectrum could be increased by allowing more sharing. (see also question 15 about digital-analogue co-existence)

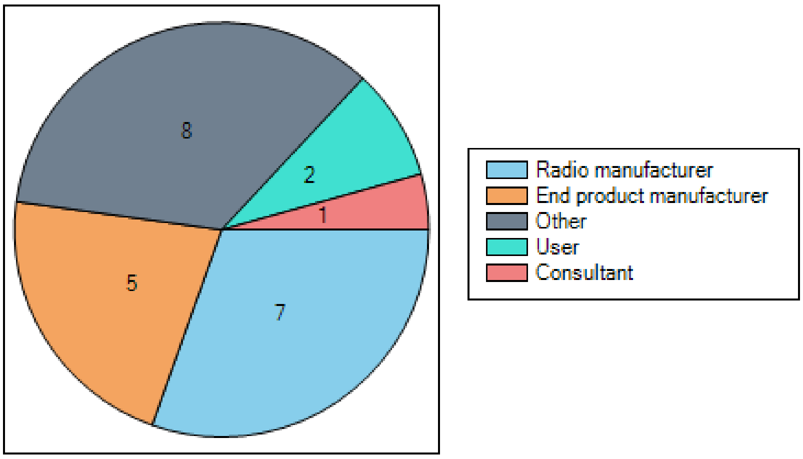
Question 15: Today PMR/PAMR equipment can be digital but also significant numbers of them are still using analogue transmission which can be less efficient in terms of spectrum usage. Some equipment in the market can use both analogue and digital technologies. Please consider two PMR/PAMR scenarios: analogue vs digital shared environment and digital vs digital shared environment.

Some administrations permit digital and analogue PMR in the same channel, others do not. This has also to be seen from the perspective of technology neutral authorisations (applied by some administrations) and the fact that some technologies allow for co-existence of analogue and digital equipment, also in support of digitization of the PMR population at a specific frequency. The answer may indicate that increased sharing may be possible?

QUESTIONS TO INDUSTRY AND STAKEHOLDERS

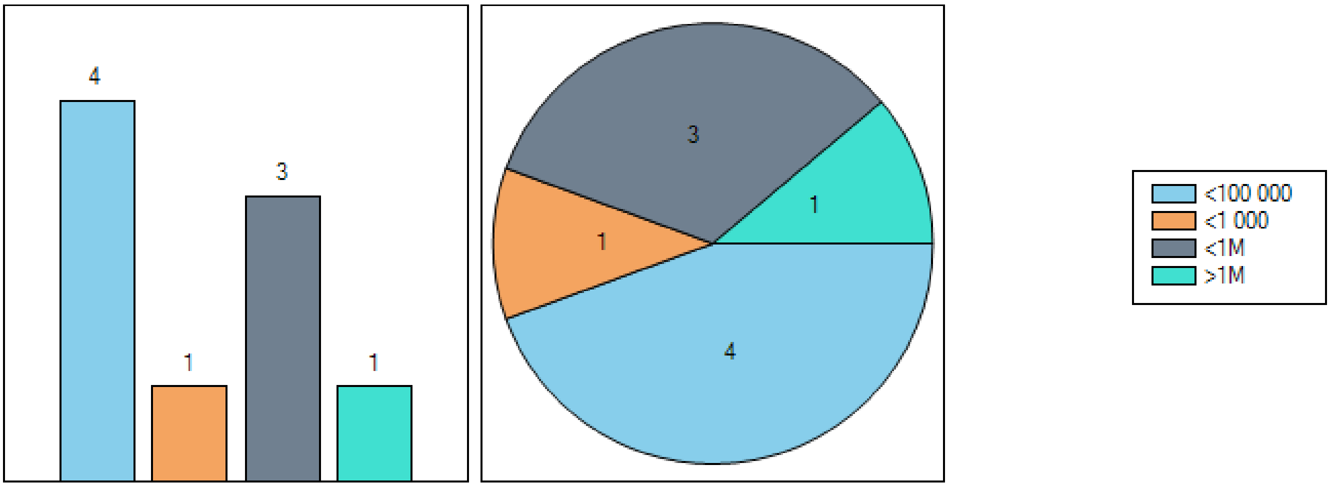
14 entities from industry and users provided a response.





Multiple selections were possible; ‘other’ includes industry and user associations, PMR/PAMR dealers etc.

Number of devices sold per entity (9 responses, including from industry and user associations). It is difficult to conclude on the overall European market size for PMR/PAMR in Europe from these figures but it gives some indication about the PMR/PAMR market sector is comparison to other surveys (e.g. UHF SRDs in ECC Report 182 or public mobile surveys). The radio manufacturers are actually all organised in ETSI ERM TG DMR.



Question 1: After reading the introduction, do you understand the aim of the questionnaire?

All 14 responders from industries and users answered with YES.

Question 2: Have you already designed or integrated digital PMR/PAMR devices into modules or end products?

146-174 MHz: 11 YES and 3 N=; 68-87.5 MHz: 9 YES and 3 NO. I.e. there are also digital PMR/PAMR products for the 2m-band and the 4m-band. The responses in Question 3: If yes (Q23), for what kind of PMR/PAMR application or portion of the 68-87.5, 146-174 MHz, 406.1-470 MHz band? provide more detailed information.

Question 3: If the answer for Q2 is 'no' for 68-87.5 MHz or 146-174 MHz, are you planning to use these bands in the future for digital PMR/PAMR?

5 responders consider the 68-87.5 MHz band as not suitable for digital PMR/PAMR. Stated reasons are insufficient demand, cannot provide the required availability, equipment size to big, suffers from over range characteristics. 2 providers which have so far no digital products in the 146-174 MHz indicated to have plans for the future for digital equipment operating in the band.

Question 4: Do the existing PMR/PAMR regulations in the three aforementioned bands suit your application(s)? Why?

The majority considers the existing regulations to suit their PMR/PAMR applications. However, challenges are reported for the VHF frequency ranges (high noise floor, not enough power permitted in some regulations, lack of harmonisation (or even misalignment of CEPT regulatory approaches) in details in the regulatory approaches amongst countries. Less (or even insufficient) availability of spectrum in UHF for WB and BB PMR/PAMR applications is mentioned by several responders.

Question 5: Do you have knowledge of situations where the normal operation of your PMR/PAMR application/device is affected by congestion of the spectrum or harmful interference? (If necessary please multiply table below)

Industries and users report about congestion of the spectrum or harmful interference cases, mainly in the UHF PMR/PAMR frequencies and in metropolitan areas. A number of suggestions are made such as improved radio planning, additional frequencies, improved harmonisation, foster VHF use, or reduce radiated power in UHF.

Question 6: If you are producing products for the world market, how important is harmonisation between the different regions to you?

11 answers received. 8 consider it as very important to have a worldwide single product. 3 consider this as not important, it is necessary to make regional variants anyway.

Question 7: Do you feel it is possible to enhance the existing PMR/PAMR band regulations? (For example reducing further band segmentation, increase flexibility etc…). If yes, please specify your suggestion.

Possible enhancements are seen in the following areas (inter-alia):

- Consider how VHF use could be fostered;
- Increased shared use of PMR/PAMR frequencies should be fostered;
- Regulation in some countries still have to follow the digitization of the PMR/PAMR market (in other words: increase the frequency opportunities for digital use);
- Achieve more contiguous band segments for wide area systems;
- Consider most flexible approaches for licensing

Question 8: Are there emerging market needs or requirements for your business applications that would fall in any portion of the three aforementioned PMR/PAMR bands? If yes, may they be fitted in the present regulations?

Several responses suggest in general terms that more spectrum may be needed for wideband and broadband applications in the future. LTE as a possible technology for PMR/PAMR in the future in UHF has also been mentioned. Remote CCTV has been mentioned as a possible PMR application. At the same time, commenters emphasise the lack of enough spectrum for wideband PMR/PAMR applications. The lack of detail in the description of WB/BB PPDR requirements or application mentioning may suggest that this emerging market need is not so obvious. Two commenters refer to existing market analysis for up to 2020 and beyond would demonstrate that the requirement for broadband PMR/PAMR (LTE PMR) is not a priority for the industrial/commercial users.

Question 9: Do you agree with the principle of "application and technology neutrality"?

A total of 24 answers was received (including all the Motorola MSI dealers), 13 answering with NO and 11 with YES. Those not in favour consider different technical requirements for the different PMR/PAMR technologies and application sectors in contradiction to the full application of the principle of technology and application neutrality. Benefits of the principle are seen in the greater flexibility in offering innovative solutions. Further investigation and consideration may be helpful. ETSI remarked that they agree with technology neutrality as long as the technologies are compatible and co-exist. For example studies show LTE interferes with other PMR technologies so is not viewed as compatible.

Question 10: Any other suggestion?

A number of suggestions have been made by industry, associations and users. These suggestions should be discussed by PT FM54.

The opinions concerning LTE in the 400 MHz vary. On one hand, it's a technology option for the future for WB/BB PMR/PAMR applications; on the other hand there are concerns about the lack of spectrum in UHF in metropolitan areas and border areas as well as concerns about interference triggered by the unwanted emissions from WB/BB systems into narrowband PMR/PAMR. One suggestion is to look closer to the successful regulatory approach applied in the United Kingdom (considerable PMR/PAMR market growth in the UK in recent years vs stagnation or even reduction in many others).

It can be summarised as follows from these responses:

- Less (or even insufficient) availability of spectrum in UHF for WB PMR/PAMR applications is mentioned by several responders;

- Industries and users report about congestion of the spectrum or harmful interference cases, mainly in the UHF PMR/PAMR frequencies and in metropolitan areas. A number of suggestions are made such as improved radio planning, additional frequencies, improved harmonisation, foster VHF use or reduce radiated power in UHF;
- Importance of harmonisation: out of 11 responses from industry, 8 consider it as very important to have worldwide single product. 3 consider this as not important, as it is necessary to make regional variants anyway.

Possible enhancements are seen in the following areas (inter-alia):

- Consider how VHF use could be fostered;
- Increased shared use of PMR/PAMR frequencies should be fostered;
- Regulation in some countries still have to follow the digitisation of the PMR/PAMR market (in other words: increase the frequency opportunities for digital use);
- Achieve more contiguous band segments for wide area systems;
- Consider most flexible approaches for licensing.

ANNEX 2: DETAILED INFORMATION FROM 400 MHZ PMR/PAMR QUESTIONNAIRE

32 responses have been received from administrations in 2014:

Albania	**Lithuania**
Andorra	**Luxembourg**
Austria	The former Yugoslavian Republic of Macedonia (FYROM)
Azerbaijan	
Belarus	**Malta**
Belgium	Monaco
Bosnia and Herzegovina	**Montenegro**
Bulgaria	Moldova
Croatia	**Norway**
Cyprus	**Poland**
Czech Republic	**Portugal**
Denmark	Romania
Estonia	**Russian Federation**
Finland	San Marino
France	**Serbia**
Georgia	**Slovak Republic**
Germany	**Slovenia**
Greece	**Spain**
Hungary	**Sweden**
Iceland	**Switzerland**
Ireland	**The Netherlands**
Italy	**The United Kingdom**
Latvia	Turkey
Liechtenstein	Ukraine
	Vatican City

In addition, the following 14 entities from industry and users have provided a response: Maxxwave (UK), JRC Ltd (UK), RADMOR S.A. (PL), Selex ES S.p.A. (I), Telecommunications Association of the UK Water Industry, Airbus Defence and Space (Cassidian) (F, FI), ANITEC (I), Thales – RCP (UK), TETRA and Critical Communication Association, Sepura plc (UK), Federation of Communication Services (UK), Motorola Solutions Inc (US, D, UK, DA), Motorola - MSI Dealers from various countries, ETSI ERM TG DMR.

The detailed ECO summary of the questionnaire is embedded here:

ECO Summary of the WGFM Questionnaire

ANNEX 3: COMPARISON OF PMR USAGE DENSITIES

The comparison of PMR usage densities amongst some CEPT countries from the questionnaire in 2014 (see Annexes 1 and 2 to this Report) reveals that there are big differences amongst CEPT countries. The example focusses on the 450-470 MHz band and takes into account the population and size of the respective country.

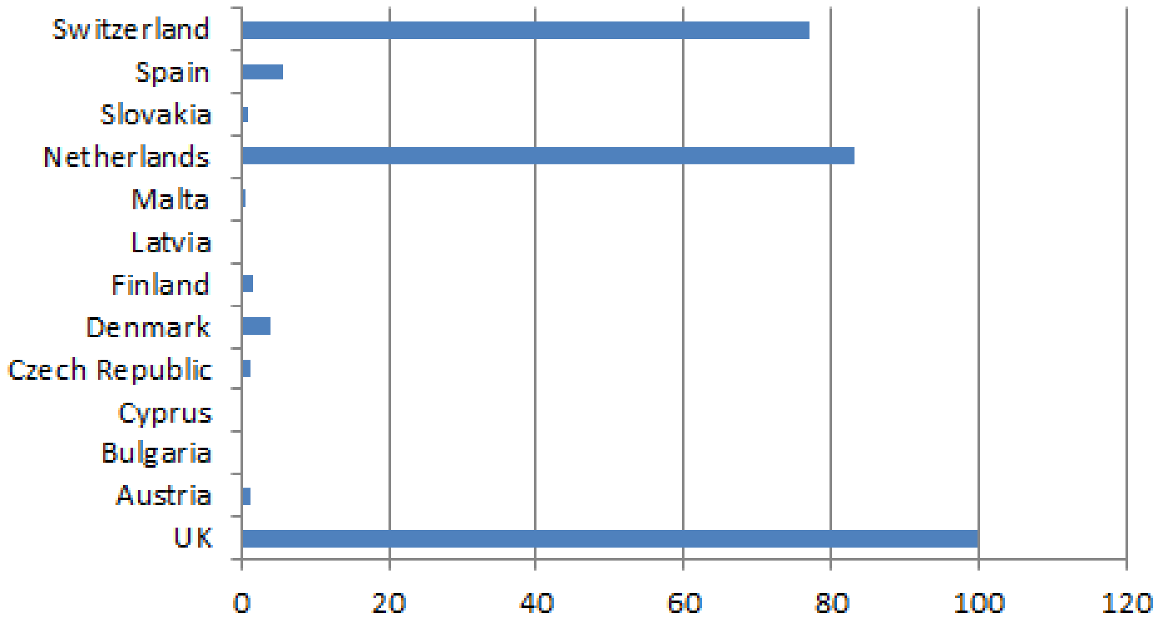


Figure 7: Example comparison of PMR usage densities

National PMR/PAMR usage densities vary a lot. The usage density can also very inside one country dramatically on a band-by-band basis.

In general, one can see from this example that there are already congestion situations in some countries due to the well-developed PMR/PAMR market, mainly in the capital city or major metropolitan areas, as well as sometimes in border areas. On the other hand, in a significant number of CEPT countries, the usage densities are rather limited and may leave much more opportunity also for new technologies such as LTE-based solutions.

More details can be seen in the embedded file below.

FM54(15)11_Summar
y Sheet PMR_PAMR 4

ANNEX 4: IDENTIFICATION OF SPECTRUM FOR SMART ENERGY GRIDS OF ELECTRICITY NETWORKS

Figure 8 shows the UK mainland's Extra High Voltage (EHV) 400 kV and 275 kV electricity transmission systems. These connections are typically both directly and via one or more diverse routes. This diversity is intended to ensure that there will always be an alternative route if the direct route were to be interrupted, e.g. by storm damage. The diagram shows that the 400 kV lines are stepped down to 275 kV around the areas of densest population.

The transmission system feeds into the regional High Voltage (HV) 132 / 66 / 33 / 11 kV distribution networks. The 11 kV sub-stations are ultimately converted down to 400 / 230 V Low Voltage (LV).

Figure 8: UK mainland's 400 kV and 275 kV electricity transmission system

Figure 9 shows the population densities within the UK in 2011. (Note: one hectare is 100m x 100m. So, 100 hectares in 1 km x 1 km)

There is likely to be good wire-line / fibre communications to sub-stations in densely populated areas. Whereas communications to sub-stations in less densely populated areas may be a challenge.

There is also a need for wide-area resilient voice communications. This system is likely to need to cover everywhere there are power lines, e.g. the remotest rural areas. A third-party non-resilient system that only covers, say, major roads would not be suitable.

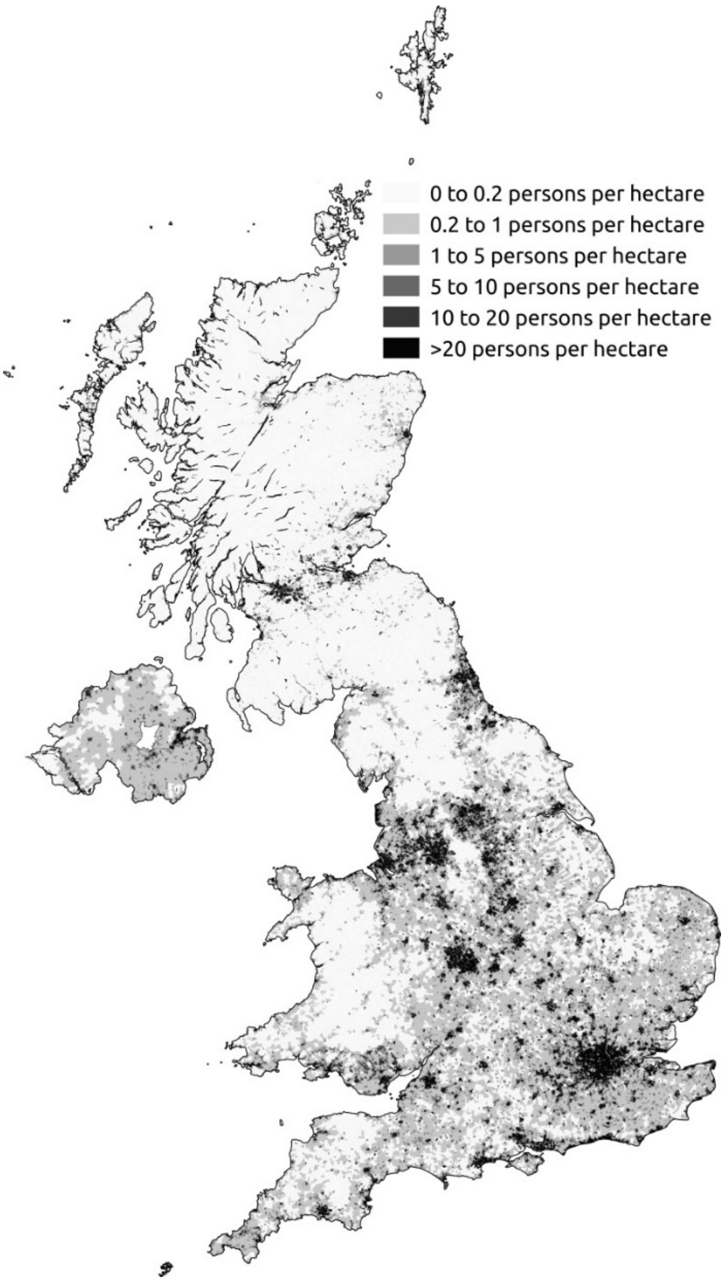


Figure 9: Population densities within the United Kingdom in 2011

Figure 10 below, highlights the estimated percentage of sub-stations that had communication connections in 2011 in the UK. It also shows the estimated percentage of 11 kV high voltage sub-stations that will need to be connected by 2031 as part of the Smart Grid. (These percentages are expected to be representative of the requirements in most other Member States.)

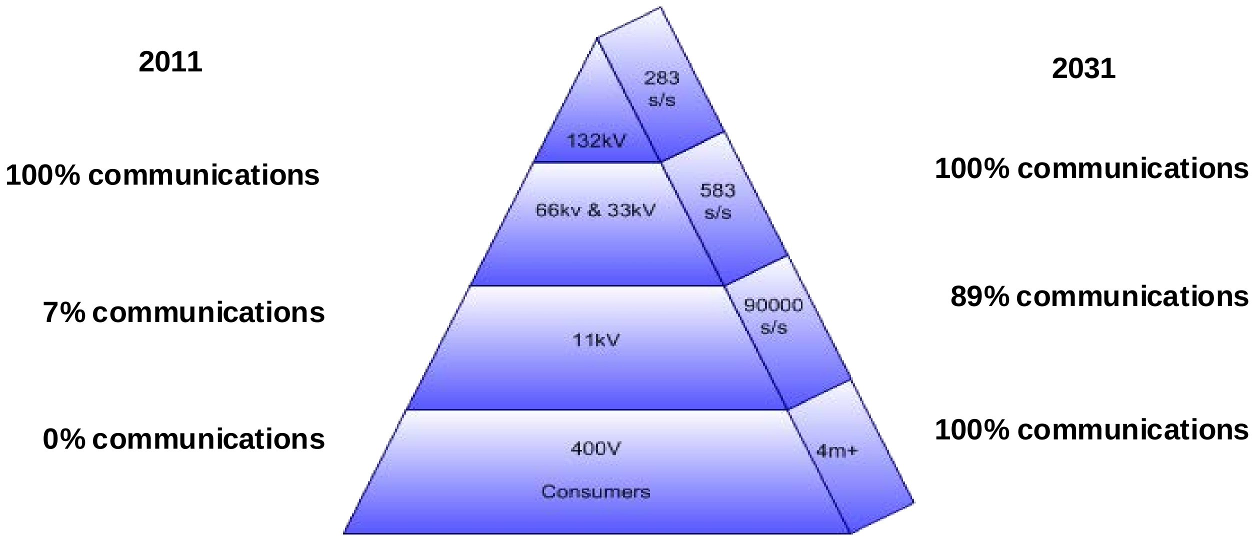


Figure 10: Predicted percentage increase in the number of high voltage sub-station connections

Table 6: "Predicted percentage increase of sites requiring communications"

	Quantity of sites requiring communications (% increase over 2011)	
	2021	**2031**
Total	775%	1199%

Typically, the distribution of the 11 kV sub-stations will be proportional to the adjacent population / industrial densities. As a guide, within the UK, each 11kV sub-station supplies a few hundred residential properties. A sub-urban town with a population of 50,000 will therefore have approximately two hundred 11 kV sub-stations. In rural areas the sub-stations are smaller, often mounted on poles, and serve just a few homes.

The predicted 12 times increase in sub-stations needing control and monitoring, plus further increases in the number of control and monitoring points for the Smart Grid, is likely to have an impact on spectrum requirements. For example, within the UK, each 12.5 kHz narrow band scanning telemetry system controls ~20 sub-stations. The predicted 12x increase in sub-stations needing monitoring could therefore increase the number of channels by 12 times. Additionally, the predicted increase in data rates from 9.6 kbit/s to 64 kbit/s may require the existing 12.5 kHz narrow band channels to be increased to 25 kHz narrow band channels. If so, this may further double the spectrum needs to 24 times the existing requirements. Further, the increased modulation levels of the 25 kHz systems will require an increase in the channel re-use distances. This would then multiply the spectrum requirement by approximately a further four times.

At first sight, the future spectrum requirement appears to be equivalent to approximately 50 times the present number of 12.5 kHz narrow band channels. Of course, a percentage of the future sub-stations requiring connection will be within the coverage areas of existing control systems so, with efficient planning, it should be possible to add a significant number of them to the existing sub-station control systems. Additionally, an allocation of 10 MHz in the 1350 MHz band for TDMA systems would reduce the amount of 400 MHz UHF spectrum required.

The details of the future spectrum requirements will be expanded within a forthcoming ETSI Systems Reference document.

ANNEX 5: APPLICABLE CURRENT ECC DELIVERABLES FOR PMR/PAMR IN THE 400 MHZ RANGE

Table 7: Applicable deliverables

Frequency band	European Common Allocation	Footnotes	ECC Deliverables	Application	Harmonised European Standards (Note 1)	Notes
406.1 MHz - 410 MHz	LAND MOBILE, RADIO ASTRONOMY	5.149, 5.265, ECA36	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301166, EN 302 561	Single frequency applications.
410 MHz - 420 MHz	MOBILE EXCEPT AERONAUTICAL MOBILE	ECA36	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	ML paired with 420-430 MHz.
420 MHz - 430 MHz	MOBILE EXCEPT AERONAUTICAL MOBILE, Radiolocation	ECA7, ECA36	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	FB paired with 410-420 MHz.
440 MHz - 450 MHz	MOBILE EXCEPT AERONAUTICAL MOBILE, Radiolocation	ECA7, ECA36	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	Single frequency operation. Wide area paging on a tuning range basis in 440-470 MHz such as NP2M
450 MHz - 455 MHz	MOBILE	ECA7, ECA34	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341,	ML paired with 460-465 MHz. Wide area paging on a tuning range

Frequency band	European Common Allocation	Footnotes	ECC Deliverables	Application	Harmonised European Standards (Note 1)	Notes
					EN 300 390, EN 300 471, EN 301 166, EN 302 561	basis in 440-470 MHz such as NP2M
455 MHz - 456 MHz	MOBILE	ECA7, ECA34	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	ML paired with 465-466 MHz. Wide area paging on a tuning range basis in 440-470 MHz such as NP2M
456 MHz - 459 MHz	MOBILE	5.287, ECA7, ECA34	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	ML paired with 466-469 MHz. Wide area paging on a tuning range basis in 440-470 MHz such as NP2M
459 MHz - 460 MHz	MOBILE	ECA7	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	ML paired with 469-470 MHz. Wide area paging on a tuning range basis in 440-470 MHz such as NP2M
460 MHz - 470 MHz	MOBILE	5.287, 5.289, ECA7, ECA34	ECC Decision (19)02, Recommendation T/R 25-08	PMR/PAMR	EN 300 086, EN 300 113, EN 300 219, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 301 166, EN 302 561	FB paired with 450-460 MHz. Wide area paging on a tuning range basis in 440-470 MHz such as NP2M
Note 1: It is expected that ETSI will develop (a) new Harmonised European Standard(s) for PMR/PAMR systems based on ECC Decision (19)02						

Looking back to ECC Report 25 (2003) [2], PMR usage in the bands 870-876 MHz / 915-921 MHz has not materialised and as such could not help to free some spectrum in the 400 MHz ranges above for new PMR/PAMR systems or land mobile systems in general. The existing usage situation in these 400 MHz bands is described by the survey results, see Annexes 1 to 3.

ECC Decision (19)02 [11]

This new ECC Decision addresses the use of the bands 68-87.5 MHz, 146-174 MHz, 406.1-430 MHz, and 440-470 MHz by land mobile systems and has replaced ECC Decision (06)06 [29] and ECC Decision (04)06 [28].

The band planning and guidance for cross-border coordination for these frequency bands is set out in Recommendation T/R 25-08 [3]. In line with Recommendation T/R 25-08, this ECC Decision covers both duplex operation and single frequency operation.

Land mobile systems in these frequency bands are mainly, but not exclusively, used for PMR/PAMR (Private (Professional) Mobile Radio / Public Access Mobile Radio) applications. For the frequency ranges 410-430 MHz / 450-470 MHz, this Decision also includes harmonised technical conditions to be applied for land mobile systems to be used for MFCN (Mobile/Fixed Communications Networks) and M2M/IoT (Machine-to-Machine/Internet of Things).

ANNEX 6: RSPG REPORT ON STRATEGIC SECTORAL SPECTRUM NEEDS (NOVEMBER 2013)

RSPG has not identified any indications that the bandwidth requirements of the narrowband PMR sector will increase within the medium or long term future. A possible future evolution towards PMR broadband services would raise the need of availability of spectrum resources. However, before any technical concept has been presented for wideband PMR the RSPG finds it difficult at this stage to estimate any possible new spectrum needs or the future market demand for these applications or services. The RSPG considers that the development in this area should be closely monitored.

The current ETSI-CEPT cooperation is used for a number of sectors (Intelligent transport systems, smart energy grids and smart meters, PPDR, PMSE, Internet of Things including RFIDs and M2M and PMR). In practice, this cooperation also includes the possibility for EU to decide on mandates to CEPT and ETSI.

PMR seen as one possible solution/option for smart energy grids and smart meters: Private wireless solutions (PMR/PAMR) using national allocations in VHF or UHF bands (promising option given the availability of mass market commercial technologies and products which can be used in such private networks, challenge: limited bandwidth allocated to PMR).

At this stage, those networks/systems/on site usage could be digital but also numbers of them are still using analogue transmissions which are less efficient in terms of spectrum usage. The amortisation of such equipment may largely differ depending on the category of usage. Some equipment is staying in operation more than 15 years and there are little benefits for the users to migrate to more efficient technology.

The current spectrum efficiency for analogue PMR is one channel in 25 kHz or 12.5 kHz, while new digital technologies provide a two-fold to four-fold increase to 6.25 kHz equivalent spectrum efficiency such as the technologies standardised in ETSI, e.g. TETRA25, Digital mobile radio (DMR), dPMR. However, there is no incentive for users to replace their less efficient equipment. Experience so far with DMR suggests that users use the extra capacity to improve operations (e.g. introduction of data, mainly short messages), so the increased spectrum efficiency does not materialise.

The evolution of technologies is expected to follow the general evolution in the radio communication sector. In general, there is a trend towards mobile usage of services that require access to data high or very high speed, driven by increased use of services for image and video applications which consume more bandwidth such as video surveillance, real-time video, fast exchange of large files (including the exchange of medical information for remote intervention) and access to databases.

LTE seems to be a technology that can evolve to meet all PMR/PAMR needs with channel bandwidths of e.g. 1.4 MHz, 3 MHz, 5 MHz or 10 MHz. It would rather be based on national PMR/PAMR shared platforms for business and mission-critical applications than on local or regional licences In May 2013, one Member State published the results of a public national consultation on broadband PMR, receiving 24 contributions from industry and PMR user groups. The consultation underlined the importance to have sufficient spectrum resources, in particular to satisfy future needs for broadband PMR.

A possible future evolution towards PMR broadband services would raise the need of availability of spectrum resources. However, before any technical concept has been presented for wideband PMR the RSPG finds it difficult at this stage to estimate any possible new spectrum needs or the future market demand for these applications. However, the development in this area should be closely monitored;

There are no indications that the bandwidth requirements of the narrowband PMR sector will increase within the medium or long term future;

Some Member States have noticed a trend where PMR users are migrating to public mobile broadband systems. New functionalities such as push-to-talk and group calls introduced in future LTE specifications (with PPDR as a main driving force) will probably further accelerate this migration when this functionality is available in public LTE networks;

In order to improve spectrum efficiency, and to promote migration from analogue to digital PMR, administrations may consider identification of a minimum required spectral efficiency to support the migration to digital, more spectrum efficient technology which will allow the creation of additional channel capacity within the same radio spectrum, and support more users. This also provides an opportunity to upgrade radio systems and improve interoperability. Furthermore, based on available digital narrowband PMR/PAMR technology and the national needs, the administration may impose a minimum required spectral efficiency such as 6.25 kHz or 12.5 kHz.

ANNEX 7: NATIONAL EXAMPLE FOR THE AUTHORISATION OF PMR/PAMR

A7.1 UNITED KINGDOM

A7.1.1 To a National Administration

Light licensing

1. The Simple UK, Suppliers and Simple Site licence products offer Business Radio customers' a low cost and expedient way of communicating using Private Mobile Radio (PMR). They have proved popular and in September 2018 nearly twenty-five thousand licences are on issue for the three products - see the table below.
2. Licence holders share a defined list of frequencies offered by Ofcom with other stakeholders who hold the same type of licence. There is no guarantee of the quality of service and is a best efforts type approach.
3. The Simple UK and Simple Site products reduce the pressure on requests for bespoke 'Technically Assigned' assignments. If the radio user does not require any particular quality of service, then a light licence may suffice. If a channel is occupied/busy then the radio users trying to communicate can select from the list of frequencies available on the licence.

Table 8: amount of licences and customers involved

Product description	Count customers	Count licences
403010 - Business Radio (Simple UK)	13776	14285
403020 - Business Radio (Simple Site)	5167	9438
403030 - Business Radio (Suppliers Light)	1249	1265
Total	19247	24988

Business Radio (Simple UK) - This type of licence is for mobile to mobile communication anywhere in the UK. Use of base stations is not permitted. The maximum permitted e.r.p. power for mobile stations is 5 Watts.

Business Radio (Simple Site) - This type of licence is for the use of base station systems that use a pre-packaged set of frequencies for applications such as paging. The maximum permitted e.r.p. for base stations is 2 Watts with a maximum antenna height of 15m. The maximum permitted e.r.p. for mobile stations is 2 Watts, except for the 25 kHz bandwidth channels where the maximum permitted e.r.p. is 0.02 Watts.

Business Radio (Suppliers Light) - This type of licence is for use by radio suppliers and dealers only. The maximum permitted e.r.p. for base stations is 10 Watts. The maximum permitted e.r.p. for mobile stations is 25 Watts. The maximum permitted base station antenna height above ground level is 20m.

A7.1.2 To PMR Users

Cost saving/sharing to licensee – trade/lease

1 Spectrum leasing **is only available** for the Area Defined licence in the UK. It allows the licence holder to lease out access to their spectrum within the region they have licensed from the regulator, for example, a defined geographical area, a region such as Wales or UK wide.

2 Ofcom is not involved with the lease; it is commercial agreement between the licence holder and lease holder. Conversely if spectrum is traded, you have to apply and notify Ofcom, so there is an advantage to the licence holder with leasing as it does not involve Ofcom.

3 Depending on the specific licence conditions (duration, location, frequency), it could be said that the licence rights could be seen as an asset and in certain circumstances generate a financial return.

4 From a licensee perspective, spectrum trading allows access to a frequency through sharing with another licensee. This solution may be attractive if it proves difficult to source spectrum from the regulator especially in congested spectrum areas. The combination of frequency and coverage area may suit a customer's requirements and it allows the original licensee to benefit from a commercial deal.

5 As the licence holder you are expected to manage the assignments on your network and anticipated interference and intermodulation issues.

6 There is no restriction on the leasing or trading fee that the licence holder can charge to others. The proposed fee does not have to match Ofcom's published fees but in reality this is usually the case with a service or admin fee on top.

ANNEX 8: AN EXAMPLE OF FRAMEWORK FOR THE DEPLOYMENT OF BB-PMR IN AN ALTERNATIVE BAND (2570-2620 MHZ): THE FRENCH CASE

A8.1 NATIONAL NEED FOR DEDICATED BB-PMR SPECTRUM

In 2016, Agurre, a consortium of so-called Vital Infrastructure Operators (Opérateurs d'Infrastructures Vitales or OIV in French) expressed the need for dedicated spectrum in order to cover the requirements of BB-PMR networks in strategic sectors such as transports and energy distribution.

The band 2570-2620 MHz was considered as a viable national candidate as it was not being used by MFCN networks (despite existing licences). Several temporary licences were subsequently granted in order to perform trials that lasted from 2016 to 2018. These trials covered, in particular, scenarios involving urban rail communications, aircraft maintenance and crisis management on a nuclear power plant.

It was concluded that LTE technology offers high performance suitable to answer the communication needs for urban rail and airport services (including mission-critical requirements), showing very good results in terms of throughput, packet loss, interruption time, and latency parameters. LTE is also seen as an efficient solution to answer mobile requirements and to support several QoS parameters in multiple applications, as well as to manage priority mechanisms for higher-priority services. The energy network tests have also concluded positively on the suitability of the 2570-2620 MHz band.

To fulfil their operational and safety responsibilities as an urban railway, airport or energy operator, each stakeholder concluded that:

- the deployment of a dedicated radio network (independent from operated public networks) appears to be the unique viable model;
- an access to frequencies in the 2570 MHz- 2620 MHz band is a required condition for a future operational deployment of such dedicated LTE networks.

A8.2 DEVELOPMENT OF A FRAMEWORK FOR BB-PMR IN THE 2570-2620 MHZ BAND

Recognising the potential for the use of the 2570-2620 MHz band for dedicated BB-PMR networks operated by strategic stakeholders, France conducted two successive public consultations to assess the exact spectrum needs and to establish suitable technical and licencing conditions.

The first public consultation on "New frequencies for superfast access in the regions, for businesses, 5G and innovation" ran from the 6 January 2017 until the 6 March 2017 and reached the following conclusions:

- The need for BB-PMR usage in the 2.6 GHz band has been recognised as urgent and it was foreseen to allocate a portion of the 2570- 2620 MHz band to BB-PMR in 2018. In particular, a 40 MHz sub-band (2575-2615 MHz) has been targeted to cover the PMR needs.

The second public consultation on "Frequency licencing modalities in the 2.6 GHz TDD band for broadband mobiles networks covering professional needs in metropolitan France" subsequently took place between the 6 March 2018 and the 22 April 2018.

While the results were not publicly available at the time of publication of this ECC Report, the working assumptions for the licences were as follows:

- It is planned to grant blocs of 10, 15 or 20 MHz within the 2575- 2615 MHz band;
- Licences shall be granted for a maximum of 10 years;
- Licences shall be granted within limited geographical areas, each applicant shall specify the requested area and justify the spectrum needs within that area;
- Frequencies shall be licenced exclusively for a TDD use;
- The applicable technical conditions shall follow EC Decision 2008/477/EC [49];
- The maximum field level at the border of a geographical area shall be 30dBµV/m/5MHz at 3 m.

At the time of writing, there was no indication that the above licencing conditions would be significantly challenged by the outcome of the public consultation.

ANNEX 9: USE OF DATA ON PMR SHARED CHANNELS IN THE UNITED KINGDOM

This Annex includes information about an investigation of the use of data on PMR Shared Channels. This investigation was conducted in the United Kingdom (UK) after practical experience had been gained with the provision of PMR shared channels.

The sharing of the same PMR channel by uncoordinated users at the same location is a long-established and highly successful UK spectrum management practice. The policy assumes that the level of loading is sufficiently low to permit the call success rate to be high enough to meet the users' operational needs. Typically, this translates to a first-time call success rate requirement in excess of 90%.

So successful has this spectrum management strategy been that even quite sensitive communications have been successfully supported on shared channels. For example, some schemes that include operations of the emergency services (with the consequential potential for Mission-Critical or even Safety-Related communications occasionally being involved) do exist[1].

The UK has not developed a regulatory mechanism to directly control the amount of capacity used by a user. Instead, the regulator places a hard limit on the number of licences that can be granted in the same location and on the same shared channel. Today, this sharing factor is three (3). It was increased to a sharing factor of 3 after having gained experience with PMR shared channels.

In recent years, the introduction of systems with better value propositions to many users has meant that the PMR has enjoyed a sustained period of growth that has been very beneficial. The better services have, in the main, been accomplished through the introduction of increased amounts of data schemes that implement the desired service.

The introduction of data on shared channels is already in progress. It is believed to be starting to undermine the sharing philosophy in that the types of data that are carried on these channels may be fundamentally incompatible with other services. In short, types of data that cannot co-exist with other services on the same channel at the same location without serious risk of "harmful interference" are already being deployed on PMR shared channels.

The expectation is that as PMR continues to grow and improve, more of these types of schemes will be desired by users. The industry concern therefore is that were increasing numbers of these schemes to be deployed on shared channels, the overall impact will be to reduce the amount of value that can be derived from this radio spectrum.

Therefore, the intention is to ascertain what can and should be done at this early stage to maintain the optimal level of benefits to the UK.

A9.1 OBJECTIVES

1. Provide a listing of the types of voice and data traffic in terms of the characteristics that affect spectrum management that may be in use or soon will be in use on shared channels. This to include examples.
2. Provide an analysis of the impacts on other users that could result. This would include a form of Hazard and Risk assessment (if possible).
3. A series of examples of actual cases seen in the field with notes on the causes.
4. To consider a number of ancillary parameters that affect the issue (this could include the impact of future increase in users and proximity impacts etc.)

[1] A security patrolman may rely for his personal safety on his radio to quickly obtain assistance when needed.

5 To develop a set of Recommendations for Spectrum Management Measures that could be taken to mitigate these impacts.

A9.2 THE SCOPE OF THE REPORT

A9.2.1 User Tolerance Levels Vary

The call to establish a Sub-Group looking at data on shared channels arose due to problems reported from the field by many people. However, the situation is complex.

This Report focusses on the likelihood of wanted and unwanted signals clashing. The impact on the users of this clashing is not quantifiable by any known mechanism. However, the following notes may be helpful:

1. On even the best protected service, unwanted signals may cause a noise burst. It is predictable that if this noise burst is only very occasional, the impact on the user will be small and probably capable of being ignored. But if the burst is loud and intrusive and frequent, it is understandable that users will consider that unacceptable.
2. Similarly, if the unwanted signal causes the failure of a call attempt occasionally, that is probably acceptable to most users except those who have very high resilience requirements (and who might well be better-off on an exclusive channel). However, if the unwanted signal causes a very noticeable number of call attempts to fail, that is clearly not acceptable.
3. This Report stresses that which signal is 'wanted' and which is 'unwanted' depends on who you are. Thus, to the new data user (say) who has just commenced operations on the channel, the pre-existing services on the channel are the unwanted signals. And may be causing interference that is "Harmful" to his use. Said Harmful Interference must be addressed on an equal basis as per the current policies.
4. Further to (3), if a data service is established on a shared channel and the shared voice service prevents it operating due to clashing, that is a feature of operating on shared channels and must be accepted[2]. The data system will probably store up the content for transmission at a time the voice system is not transmitting. However, if the data system is not able to accommodate such clashing or the user cannot tolerate the delays, it may be preferred to move to an exclusive channel.

A9.2.2 Market Structure

It is recognised that **uncoordinated operation** is likely to remain a very high proportion of all Business Radio spectrum arrangements (not just on BR shared spectrum) for a considerable period. Whilst trunked systems will continue to be a significant proportion of the deployed population, they are considered to be largely coordinated and have much better efficiencies for large fleets and are typically on exclusive channels in the context of Ofcom's licensing database[3]. They therefore fall outside the scope of this Report.

Many users prefer uncoordinated operation as an operational solution; some even consider it to be essential for reasons of control and resilience.

The authors note the recent rise in the popularity of other solutions such as PTT Over Cellular (POC). However, as yet, these solutions are supported by radio spectrum outside the BR shared bands. Therefore, they are not included in the scope of this Report.

[2] Of course, it is extremely likely that the voice service is compliant to the principles of the sharing policy. However, beacon/control channels might not be compliant.

[3] At least insofar as the control channel and primary traffic channel are concerned.

A9.2.3 Content Types

A9.2.3.1 A Note on Traditional Voice

Today, Business Radio shared channels are predominantly used for voice communication. This almost always follows long-established norms of series of bursts of communications, each lasting between 1 and 50 seconds (typically) which together, form an interchange. Between such interchanges, there will possibly be substantial periods of silence.

Obviously, because the sharers do not coordinate their communications, there is a statistical possibility of the voice interchanges clashing and so causing one party to experience a call failure. However, at the low loads typically experienced on these shared channels, experience has shown that this level of interference falls within acceptable bounds.

The reader will recall that it is often the voice communication that is the most critical in operations. Thus, it is good practice to assign greater importance to the voice call than to some of the other services.

Digitally encoded voice can and does follow the same structure of relatively short period of air traffic separated by substantial periods of silence as seen with analogue voice. However, this is not necessarily so. The digital transmissions can be nearly continuous (perhaps carrying other content in some instances) with the voice content only occasionally being carried.

A9.2.3.2 A Listing of Content Types and Typical Characteristics

The following table provides examples of types of data already seen on BR channels with their typical associated uses categorised by whether the access to the channel is in accordance with some ‘politeness’ arrangement or not:

Table 9: Data Structures and Typical uses

Type of Data	Polite	Non-Polite
Voice communication carried by data protocols with data intermixed	Normal	Emergency calling
Status Messaging initiated by user command	Old-fashioned Status information Arrived / Left Site Log On / Off Duty Doors Opened / Closed Voice Call Request	Operations status Security guard status (Man-Down) Emergency Call Request
Short automatically generated telegrams sent at random times	Transducers Condition monitoring on event - Static Trailer Hitched / Unhitched + Location	Traffic Lights. A common problem Water system controls Fuel tank valves Safety controls Emergency condition alerts Security guard status + Location
Long automatically generated telegram sequences at random times	Fax Maintenance/fault diagnosis data	‘Triggered’ surveillance data Fault reporting Stolen Vehicle/ Site Equipment + Location
Polling – Grouped		
Polling – Intervals greater than 60 seconds	Checking remote equipment is still operating.	Vehicle GPS (Taxis, Public Transport, Haulage, Local delivery, Local government e.g. Gritters / Refuse Trucks)

Type of Data	Polite	Non-Polite
Polling – Intervals less than 60 seconds	Location systems	
Rapid Polling – Intervals of 1 sec or less		The biggest concern? Differential GPS Beacon signalling on trunked or pseudo- Trunked schemes Radio Registration
Large volume slow (<5kB/s) data	Firmware upgrades Document upgrades FAX	
Large volume faster data (>5kB/s<24kB/s)	Consolidations of slow data Pictures Documents Metrics data for large processes	SCADA User "Apps" converted from other technologies

It will be noticed that wideband and broadband data systems are not included in the table above. This is because both wideband and broadband data schemes are likely to be impracticable on BR Shared channels due to their near-certainty to cause harmful interference (Ref 6).

A9.2.4 Power Levels and Range effects

In creating this Report, the Sub-Group considered the impact of differing power levels and range effects. This also included the well understood "Hidden Terminal (node)" effect.

There are three possible scenarios.

1. That the unwanted signal is at lower power and will therefore only cause problems when the wanted signal is not present. This is clearly not a form of interference but could cause call-failure problems (see False synchronisation). It is further important that other sharers may receive the wanted transmission which will be an unwanted signal from their perspective and manifest itself as harmful interference.

2. That the unwanted signal and the wanted signal is at roughly equal powers at the receiver. This will result in intermittent success and failures and the harmful interference will be difficult to identify. It is entirely possible that harmful interference is experienced by all parties in this case.

3. That the unwanted signal is at a higher power level than the wanted signal at the receiver. This will cause -easily identified harmful interference behaviour.

It is accepted that all these effects will change an outcome on a case-by-case basis. However, the Sub-Group notes that overall, the impact of such considerations does not change the fundamental problem that either there is harmful interference to a communication or there is not. In general, to interfere in this context, the unwanted signal must be present at the time of the wanted communication and also at a power level sufficient to disturb the wanted communication.

Indeed, it is a fundamental feature of channel sharing that some communications will be lost when signals clash in time and power level. However, it is less common that both signals are lost in cases of simultaneous transmission. Due to capture effects, it is more common that one signal prevails over the other at a given location. But, because of the different signal conditions at each point in a communication, it may be that overall; the loss of communications is more severe than may at first be thought.

It is worth noting that normally, range and location effects are very important assignment considerations for the avoidance of interference. However, in the case of Shared Channels, the whole policy starts from the assumption that coverage will overlap and that the frequency will be the same. Therefore, this report places the greatest emphasis on the avoidance of clashing in the time domain.

A9.2.5 Losses Due to False Synchronism

In the case of general data communications, there is a (possibly) slightly greater opportunity for unwanted communications to confuse digital receivers than with more resilient data schemes or analogue. However, it is not yet clear that this effect causes a significantly higher level of call failure.

The call failures resulting from false synchronism onto an unwanted signal arise as follows (Figure 11):

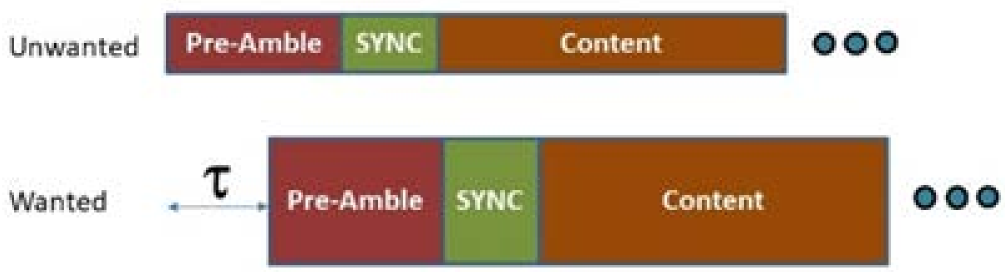


Figure 11: Harmful interference through false synchronisation

In this case, the receiver is exposed to an unwanted, but compatible signal that arrives a time (τ) before the wanted signal. Both signals are of sufficient power level for the receiver to operate. In Figure 11 the wanted signal is shown with larger boxes to indicate a more powerful signal. There are at least two possible outcomes:

1. That the wanted signal is of sufficient power that the unwanted signal is lost and the communication can be re-tried fairly simply.
2. That the difference in power levels is not sufficient that the receiver loses synchronism with the unwanted signal and continues to synchronise to that for the duration of the unwanted signal's pre-amble and synch. After that it may be too late to synch to the wanted signal.

Note that a receiver's ability to maintain reception of a wanted signal in the presence of a more powerful unwanted signal such as gives rise to outcome (2) above, is highly desirable as there will be many cases where the wanted signal is at a lower power level than the unwanted signal due to range effects etc.

Normally, the data scheme is to be set up such that the sync word (or some such other mechanism) has different identification codes and so the receiver is able to reject the incoming unwanted signal[4]. If the identification is not set differently, the receiver can be expected to receive, decode and permit the operator's apparatus to act on or even allow the operator to hear, the content of the unwanted data stream. Obviously, this is highly undesirable and could even be dangerous.

The effect seen by the user will therefore either be that they fail to receive the wanted communication which will manifest itself by an inflated call failure rate and/or that they hear someone else's communications. As the radio spectrum gets busier, this will become increasingly common. The reader is referred to the Channel Sharing study (Ref 1) for a mathematical analysis of this.

Note also that re-try strategies are very effective in some situations. This Report very much includes them in the scope but, as the appropriateness of their use is dependent on the nature of the service being supported, no specific additional points can be made beyond saying that they are common and well accepted where they are used. Specifically, it is noted that if a re-try strategy can be adopted, a first-time probability of

[4] Currently, Ofcom authorise and record the CTCSS tones to be used to protect analogue communication for this exact same reason. However, as yet, the codes used to protect the data systems in this way are either authorised or recorded. Thus, licensees have no guidance as to what ID codes to set in the data scheme to avoid this problem.

success of 0.8 can be turned into a success rate of 0.992 with two re-tries. But, it is extremely important to recall that Business Radio is used for operational communications. Having a system that requires the operator to re-try once or twice every 5th call is unlikely to be well accepted by the users and probably not effective overall (except in certain situations). Furthermore, re-tries occupy additional channel resources which may, itself, present a problem.

A9.2.6 What will the End User Experience?

In this section, the types of content are examined again in terms of what the end user might experience (and some further notes provided).

In considering all these impacts, it is noted that the radio spectrum channels are shared by users whose use is and likely will remain, uncoordinated for some time to come. Thus, interference WILL happen. The essential point is more towards how much interference there will be and whether a sufficiently resilient service[5] to meet the user operational requirements can be hosted.

Throughout this Report, the specific technologies of the wanted signal and the interfering signal are not considered. Thus, if wanted and unwanted signals clash there could be a range of possible outcomes from a small noise click heard by the operator up to the complete loss of communications by one or more sharers. Experience shows that even a small "click" can be extremely disruptive of communications if it happens often enough and thus falls within the scope of Harmful Interference.

[5] The Resilience requirements vary considerably across the market sector. However, it could be considered that a service with an availability of above 99% may meet the demands of several users whereas availability below 75% would not be likely to meet the need. The specification of the full range of factors that affect the overall Resilience of a system has been problematic for many years.

Table 10: Data Structures and the Effect on Wanted Communications

Type of Data	Typical Experience	Notes
Voice communication carried by data protocols with data intermixed	Occasional failure of a call to go through at the first attempt. Bursts of noise or even speech from an unwanted source during a call.	This is normal for shared channels. Making sure the IDs of the callers are controlled so they are not the same will reduce this in digital systems
Status Messaging initiated by user command	Random bursts of noise or occasional failed calls.	Normal situation for shared channels. The presence of a user may serve to reduce the impact because the user may monitor the channel prior to transmit in some arrangements. These transmissions may be very hard to detect and identify the interference.
Short automatically generated telegrams sent at random times	Bursts of noise and occasional failed calls	Transmissions may not take into account the use by others of the channel. So, interference potential could be higher. These transmissions may be very hard to detect and identify the interference.
Long automatically generated telegram sequences at random times	Increased noise and failed calls through longer channel occupancy of unwanted signal.	May be much easier to detect
Polling – Grouped	Bursts of Noise and failed calls	Very similar to Voice situation
Polling – Intervals greater than 60 seconds	Occasional noise and failed calls best case with potential for serious harmful interference	May present an increased issue due to regularity of pulses. If the wanted signal is also regular, clashes may occur every time.
Polling – Intervals less than 60 Seconds	Near constant harmful interference.	Easier to detect
Rapid Polling – Intervals of 1 sec or less	Probable that level of harmful interference is sufficiently high to deny use of the channel by the sharer	Easy to detect
Large volume slow (<5kB/s) data	Probable that level of harmful interference is sufficiently high to deny use of the channel by the sharer	Easy to detect
Large volume faster data (>5kB/s<24kB/s)	Probable that level of harmful interference is sufficiently high to deny use of the channel by the sharer	Easy to detect

Clearly, in many cases, the development of specialist detection equipment may greatly assist enforcement operations.

A9.2.7 Repetitive Data Structures

It will be immediately obvious that repetitive data structures challenge the fundamental assumptions upon which the policy of sharing channels is built. This is so because even though the transmissions may well not exceed the 50% duty-cycle assumption[6], the pulse repetition frequency (PRF) may be such as to preclude the possibility of the use of the channel by other sharers.

Example: A repetitive data stream may comprise of pulses of duration 100ms with gaps between the pulses of 400ms. Thus, the policy assumption of a sharer taking 50% or less of the capacity of the channel (as capacity is currently defined) has been met. But, obviously, no normally-structured voice service can operate to any quality in 400ms[7]. Therefore, in reality, the data stream has sterilised 100% of the channel capacity because it denies other sharers any clash-free access to the channel. By setting the PRF to two pulses, a second (assuming the sharer is unable to tolerate a lot of noise bursts and some lost calls), the data scheme has turned a shared channel into what is effectively an exclusive channel without the need for an exclusive channel licence.

The relevant questions for UK spectrum managers relate to the likelihood of harmful interference under the current policy and at what stage may the current policy be expected to become unsustainable. It is to these questions the report now turns.

A9.2.8 The Probability of Avoiding Harmful Interference as the Unwanted Signal PRF is Varied

It is informative to assess the probability of a successful call in the presence of an unwanted repetitive signal using an illustration.

The possibilities of the form of the unwanted signal are varied. For this illustration, three scenarios are presented as illustrations.

Table 11: Pulse Characteristics used in Illustration

	Scenario 1	Scenario 2	Scenario 3
Rise Time (ms)	5	5	5
Fall Time (ms)	5	5	5
Hang Time (ms)	0	250	1000
Payload Duration (ms)	50	100	200
Total Duration (ms)	**60**	**360**	**1210**

The scenarios are chosen to be representative of significantly different applications. Scenario 1 is typical of pulses found in rapid polling schemes. The pulses of Scenario 2 are typical of some location schemes and Scenario 3 has pulses that could relate to status/condition polling. The rather longer hangtime may be preferred if there is a possibility that a second pulse may be necessary immediately after the first (not part of this calculation).

Clearly, the variability in the field conditions experienced at any time makes a detailed theoretical analysis inappropriate. The principle points can be illustrated with a simple analysis.

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[6] This Report notes that the current sharing policy is not supported by a body of obligations within the licence. This has proved sufficient for many years because blocking other sharers by simply leaving the transmission on continuously simply runs the battery down and so the amount of channel access preference that can be accomplished by such behaviours is limited and may result is inconvenience for the perpetrator. The assumption that underpins the current policy is that such tactics don't work well and so are pointless. This is not the case with repetitive data as the power consumption may be much less and perhaps even mains electricity-supplied so the length of time the channel may be denied to other sharers could be days or even indefinitely.

[7] A digitally-coded voice system with the capability to transmit voice using bursts shorter than 400ms might, with care be so-constructed to dynamically adapt its transmissions to avoid the unwanted signal. No such scheme is known to be in wide use at this time.

In a repetitive data scheme, the usability of the time left available for the sharer's use is dictated by the Pulse Repetition Frequency and to a lesser extent, the duration of the pulse.

In this illustration, the pulse repetition frequency is allowed to vary from 0.0005 pulses per minute up to 1,000 pulses per minute.

A9.2.9 Illustration Methodology

The following results have been obtained by a simple process of calculating the silent time in each repetition cycle for the three different pulses and across the applicable range of PRFs. Then the probability of successfully inserting a wanted signal without a clash in that silent time is calculated.

A9.2.9.1 Scenario 1

Figure 12 shows the available time that sharers are presented as the PRF is increased as considered by the current policy. As noted above, this is just a total time and takes no account of the fact that at more rapid PRFs, that free time may not be useable and so should not be considered available for use.

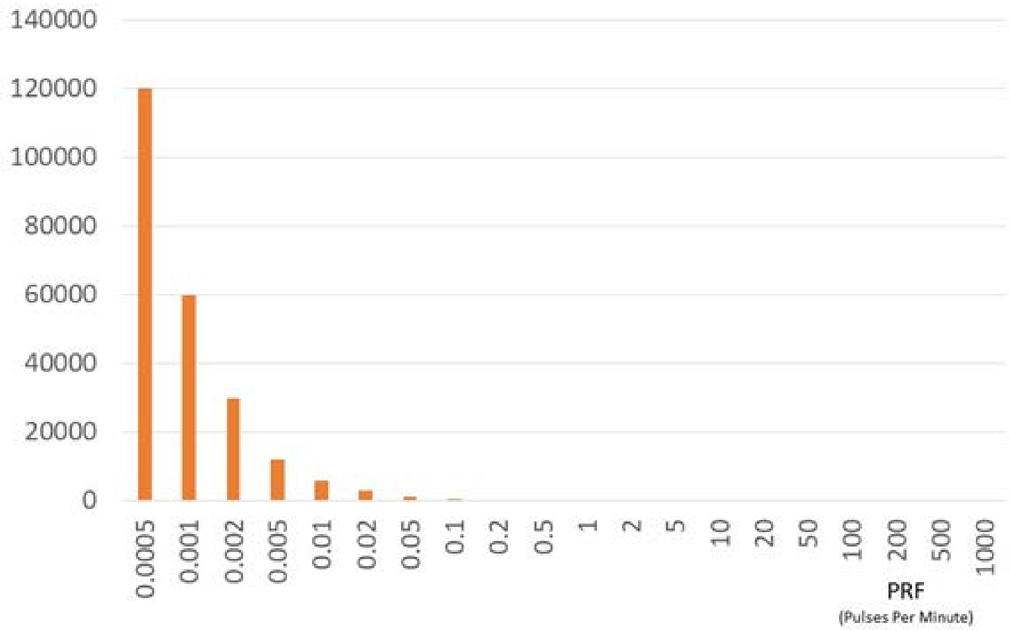

Figure 12: Time available to sharers - Scenario 1

This confirms that the available time is mostly at low PRFs of the unwanted signal. This unsurprising result has implications throughout the illustration and is the basis of the current concern.

Figure 13 shows the same information as Figure 12 but in a percentage of the total time format to demonstrate the extremely rapid roll-off as the PRF is increased.

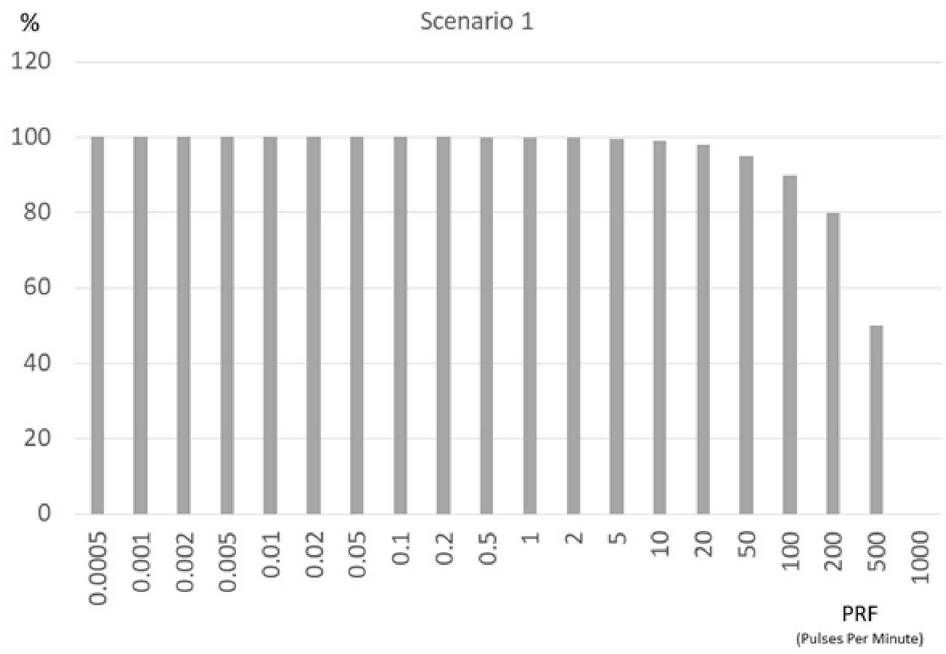

Figure 13: Time available (%) to the sharer - Scenario 1

The importance of this above figure is that, together with the later graphs, it clearly illustrates the point that even though the sharer is presented with the majority of the time, they can't use it at higher PRFs without clashing with other sharers. To that end, the reader is asked to take particular note of the data point at a PRF of 1 pulse per minute (so, by polling standards, very slow). At this PRF, the sharer is offered almost all the time for their use. When examining the following results, the reader will easily appreciate how these data schemes can harmfully interfere with wanted communications, far more than might be expected if only the total available time is considered.

The reader is further encouraged to note that the available time "rolls-off" very rapidly. There is hardly any diminution of the percentage of time made available (but not necessarily useably) until the rapid decline from 100 and upwards

Figure 14 confirms that a single wanted data pulse of the same characteristics as the unwanted data can enjoy high success rates until the roll-off starts in earnest at 200PPM. This is the first indication that call success problems start much earlier than the available time "rolls-off". In this case, at 200PPM the success is already less than 80% and about to drop to zero.

Of course, data pulses are often in sequences. Thus, the wanted communication may take the form of a string of pulses with silence between, just like the unwanted signal. Figure 15 computes the success of a string of five such pulses in avoiding clashing.

Figure 15 clearly shows that at 200PPM, the wanted communication is in serious difficulty and the overall scheme is probably becoming unusable for many operations if the unwanted signals PRF are 50PPM or more. At 50PPM, the sharers are being presented with in excess of 90% of the time. This early result may surprise many readers.

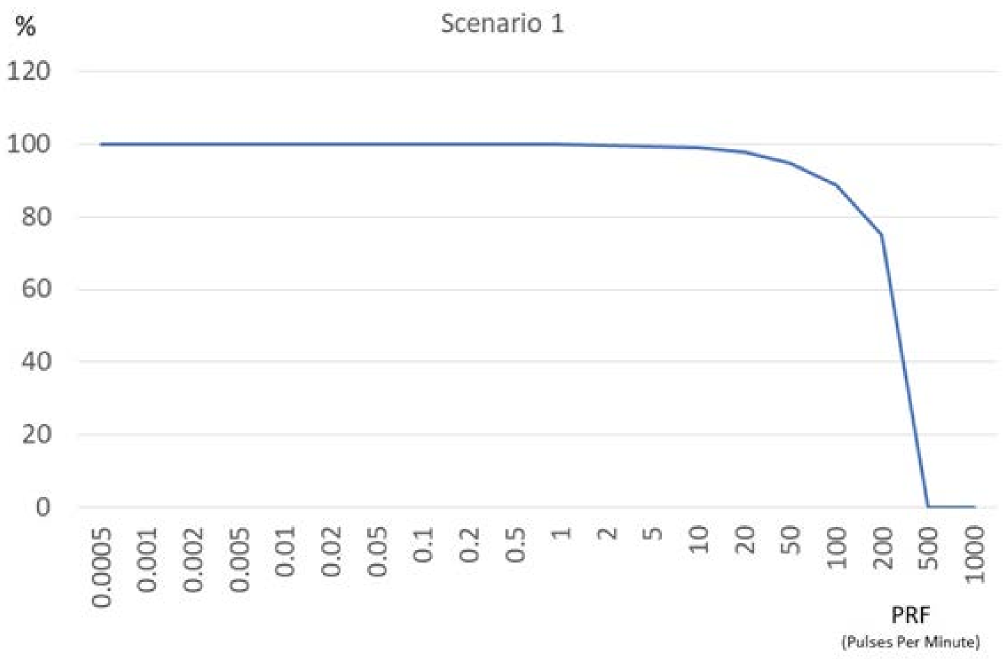

Figure 14: Probability (%) of a single wanted data word being successfully received - Scenario 1

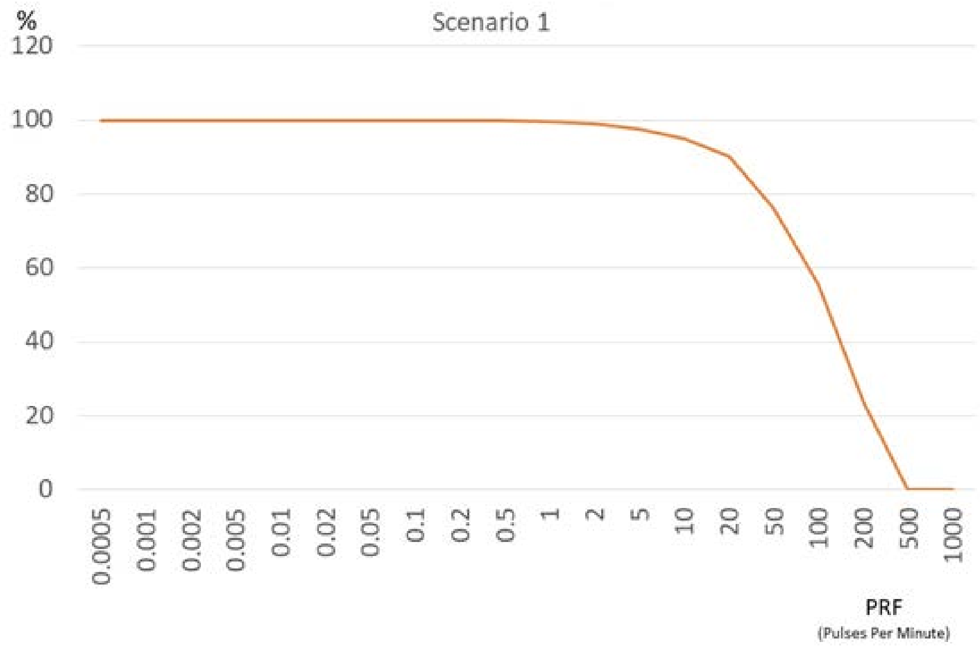

Figure 15: Probability (%) of 5 consecutive data words being received successfully - Scenario 1

The situation becomes more difficult if the wanted signals are voice or voice-like in their structure.

In this case, the Illustration considers voice (or voice-like) message transmissions ranging from 1 second in duration up to 50 seconds in duration. It will be immediately obvious that clashing with the unwanted signal is much increased, leading to a much worse incidence of Harmful Interference.

Figure 16 shows the probability of a voice message avoiding any clashing with the unwanted repetitive data stream. In this case, results for six voice message durations are presented:

Dark Blue	1 second
Orange	2 seconds

Grey	5 seconds
Yellow	10 seconds
Light Blue	20 seconds (typical of operational voice schemes)
Green	50 seconds (slightly above the typical message duration for operational voice schemes)

Note: In the figure the voice message durations are quoted in milliseconds, not seconds.

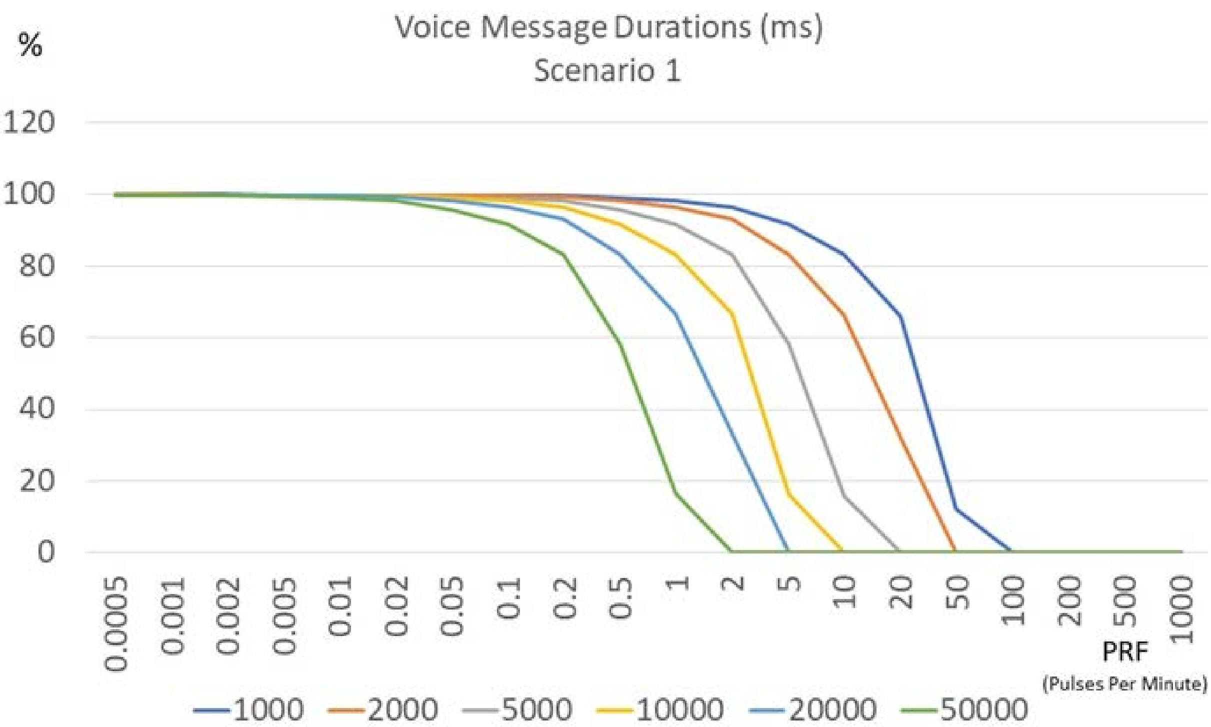

Figure 16: Probability (%) of reception of a voice message for different voice message durations (ms)

Figure 16 confirms that if the PRF of the unwanted signal is 20PPM or more, the probability of avoiding a clash is unacceptably low even for the shortest duration voice message. For the 50-second duration voice message, the channel is probably unsatisfactory for real-world operational use if the unwanted signal PRF is greater than a pulse every five minutes.

As noted before, if only the total time available to the sharer is considered, at this PRF and with this short interfering data structure, it would appear that virtually all of the time is made available by the user of the unwanted signal to the sharer for their wanted signal. It is the PRF that matters, not the total available time.

As in the case of data communications, several voice messages may be necessary to perform the operational function. Thus Figure 17 presents the probability of five consecutive similar voice communications successfully avoiding a clash with the interfering data repetitive data stream. Not surprisingly, the situation is significantly worse than with the results for a single voice message transmission.

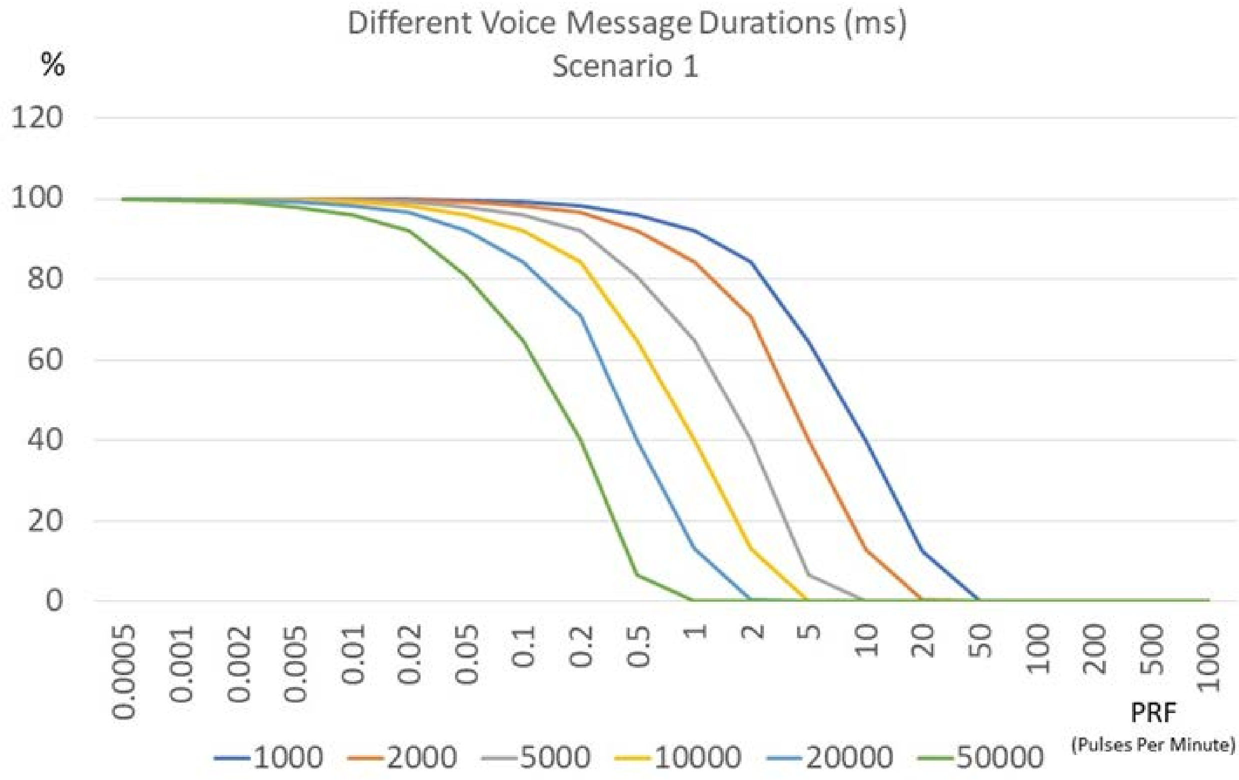

Figure 17: Probability (%) of 5 consecutive voice messages being received for different voice message durations (ms)

As noted above, the "roll-off" displayed in these results as the PRF of the unwanted signal increases is, of itself, a very important factor. It is clear that a user may have a scheme that is providing Mission-Critical resilience or even resilience consistent with Safety-related operations today but, as the demand for data increases and the content becomes more-rich, the sharer who has always on the channel may move from low-speed to a higher speed PRF. At that point and without any warning or any need to inform Ofcom, suddenly the user with the mission-critical service suddenly finds their radiocommunications scheme to be unusable due to the change in the unwanted signal. Furthermore, the long-established user of the system that provides that unwanted signal may be completely unaware of the impact their change has.

It may be instructive to show these results for a single voice message in tabular form, highlighting the very narrow transition between typical success probabilities that a mission-critical system could have to something that no mission-critical system could cope with (much less if there are safety implications). This table is provided as Table 12.

In the table below, two-nines operation is assumed to be "good enough" for mission-critical operation and is highlighted in Green whereas success rates below 70% is thought to be unlikely to be sufficient and is highlighted in red. The transition between is in white. The transitions for the six different voice durations are provided for consistency.

Obviously, a similar table for the case of five consecutive voice messages can be provided.

This Report will return to the implications of this in the Conclusions section.

Table 12: Rapid transition from high resilience to unusable - Scenario 1

(s)	Repetition Rates (Pulses Per Minute)										
	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
1	99.9833	99.9667	99.9167	99.8333	99.6666	99.1662	98.3317	96.66	91.6248	83.16498	65.98639
2	99.9667	99.9333	99.8333	99.6666	99.3332	98.3325	96.6633	93.32	83.2496	66.32997	31.97279
5	99.9167	99.8333	99.5833	99.1666	98.333	95.8312	91.6583	83.2999	58.124	15.82492	0
10	99.8333	99.6667	99.1666	98.3332	96.666	91.6625	83.3166	66.5999	16.2479	0	0
20	99.6667	99.3333	98.3332	96.6663	93.332	83.325	66.6333	33.1997	0	0	0
50	99.1667	98.3333	95.8331	91.6658	83.33	58.3125	16.5832	0	0	0	0

A9.2.9.2 Scenario 2

Scenario two has a different unwanted signal pulse. The unwanted signal has a 250ms hang time and 100ms content causing the overall unwanted transmission duration to be longer. All the results are repeated for this new unwanted signal. The illustration reinforces that it is the PRF of the unwanted signal that is the main disruptive factor although the longer duration pulse does result in the undesirable impacts happening at slightly lower PRFs for the unwanted data stream.

Notice particularly that the range of the unwanted signal PRFs has been truncated at 20PPM. This is because the longer pulse duration prevents faster PRFs.

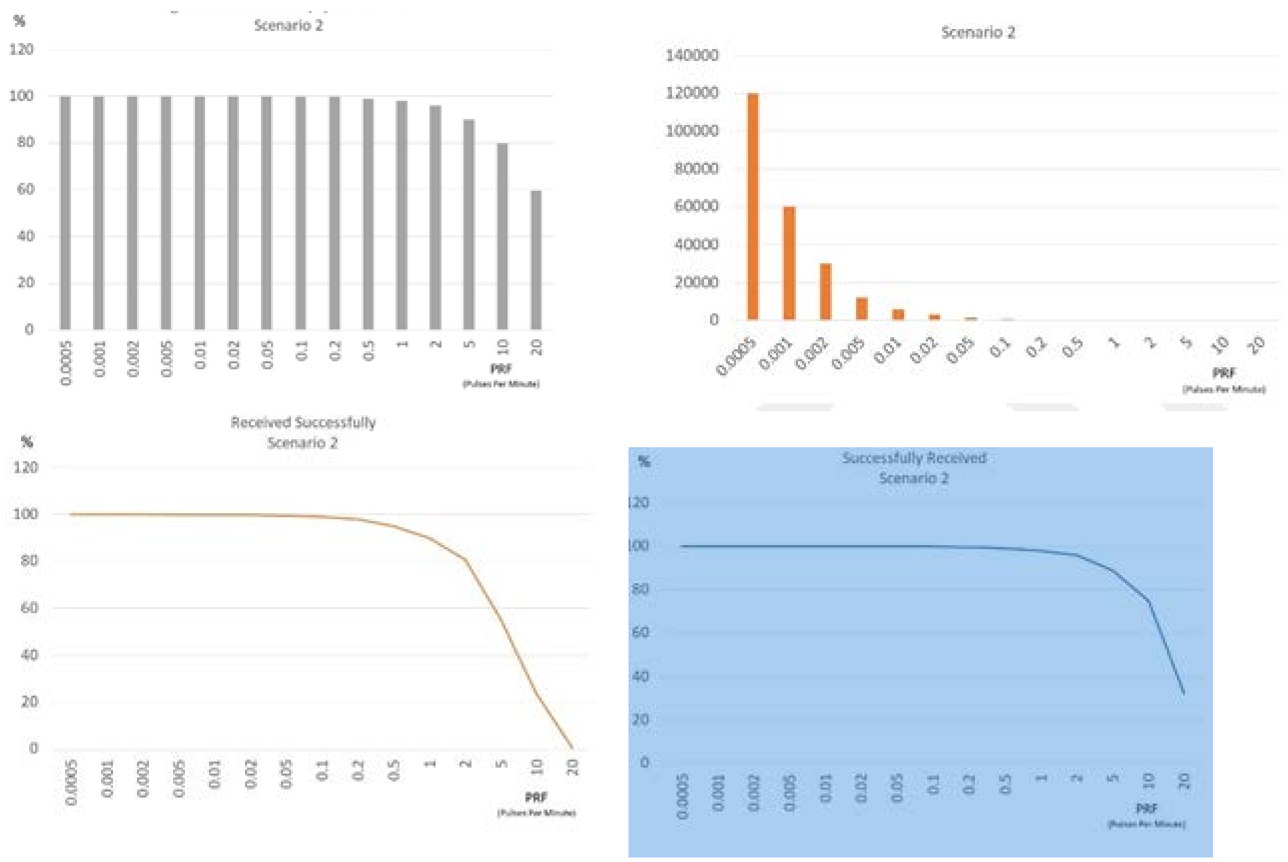

Figure 18: Scenario 2 results

Clearly, the profiles of the results are very similar but the PRF at which the undesirable clashing takes place is lower.

In general, the expectation is for more and richer data service and so Scenario 2, even though it looks very similar to scenario 1, actually represents a predictable very significant reduction in the future usability of shared channels as currently conceived and so it is desirable that action is taken, sooner rather than later, to ensure the continued effective use of the radio spectrum.

A9.2.9.3 Scenario 3

The data pulse considered in Scenario 3 is intended to represent rather different repetitive data use. In this case, the amount of user-content per pulse is greater and the hang-time is significantly greater to allow the scheme to hold control over access to the shared channel for a longer time.

However, the effect on the sharers is for similar outcomes but the PRF at which the wanted signals are likely to clash with the unwanted signal is lower still.

Figure 19 presents the corresponding results for Scenario 3.

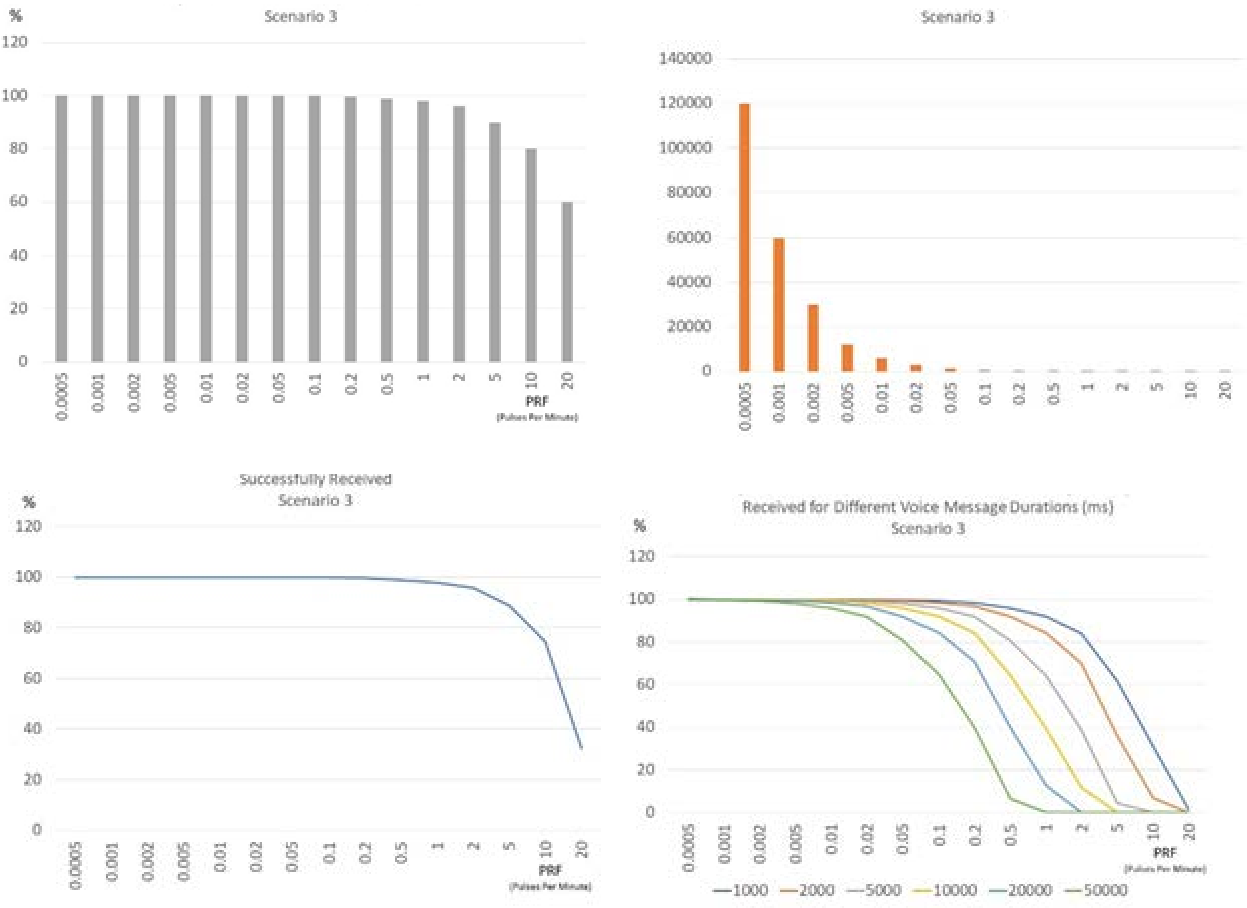

Figure 19: Scenario 3 results

The results show that even though the amount of time that is supposedly available to the sharer is about the same between the scenarios, the actual probability of avoiding a clash with voice communications varies significantly.

Table 13: Key Differences Between Scenarios

	Scenario 1	Scenario 2	Scenario 3	1-3 Comparison
Total Pulse Width (ms)	60	360	1210	X20
PRF for 80% Probability of Avoiding a Clash in 5 Messages of 20s Duration	0.2	0.15	0.1	X2
Available time (s) per cycle at PRF of 1PPM	59.9	59.6	58.7	2%

Table 13 shows that the PRF at which the probability of the wanted signal avoiding a clash with the repetitive unwanted signal reduces to 80%, only changes by a factor of two. But the duration of the pulse varies by a factor of 20 between the scenarios. Crucially, the guidance to spectrum managers on the likely impact using today's total available time policy, is very limited with the available time only varying by approximately 2%. This could also present the enforcement teams with some difficulty.

A9.2.10 Non-Repetitive Data Structures

From the perspective of avoiding Harmful Interference, the difference between non-repetitive interference from data and repetitive interference is that there may very well be intervals where the sharer may obtain service[8]. This reduces concerns over the non-repetitive data case to something very similar to the current experience when using shared channels where there are sufficient USABLE gaps to permit sharers to sustain their communications as well.

Thus, assuming an absolute limit on the duration of the transmission[9], certain types of data can be accommodated on shared channels.

A9.2.11 Key Result

The analysis shows that the shared channel assignment strategy will continue to provide a viable, low interference service for non-repetitive data streams and very low PRF data streams. But, repetitive data streams of typical PRFs (and higher) effectively make the sharing assignment strategy highly vulnerable to clashing which many users may consider to be non-viable.

Table 14 summarises this. The unimpeded voice figures are calculated from figures presented before. The repetitive data signal figures used to develop the results are for a 20 second voice call in the presence of a repetition every 15 seconds.

[8] In contrast, in the repetitive case, if a clash occurs, there is a very good chance that the clashes will continue indefinitely.

[9] Under today's policy, it is understood that a transmission could be 3 months in duration and still be in accordance with the policy if the period of silence until the end of the year was greater than the transmission time.

Table 14: Comparison of Viability of Sharing with Voice/Voice-like and Voice with Typical Repetitive Data

	Voice/Voice Like Data shared with Voice (Values taken from Ref 1)	Typical Repetitive Data Shared with Voice
Sharing Number of 2	99%	19.8%
Sharing Number of 3	97.5%	19.5%
Higher PRF		0%

Clearly, performance over 95% will be acceptable to many customers whereas performance at less than 20% success rate is almost certainly unacceptable.

But even more importantly, if the PRF goes higher, the success rate goes to zero and stays at zero for as long as the repetitive data is transmitted. This could, as noted above, be indefinitely. This last result is independent of the sharing number or any other form of congestion factor. In other words, a single repetitive data transmitter could permanently remove viable operation for all other sharers on that channel, even in rural areas.

ANNEX 10: LIST OF REFERENCES

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