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Plum Consulting on the Potential use of the 400 MHz band in Ireland

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Potential use of the 400 MHz band in Ireland

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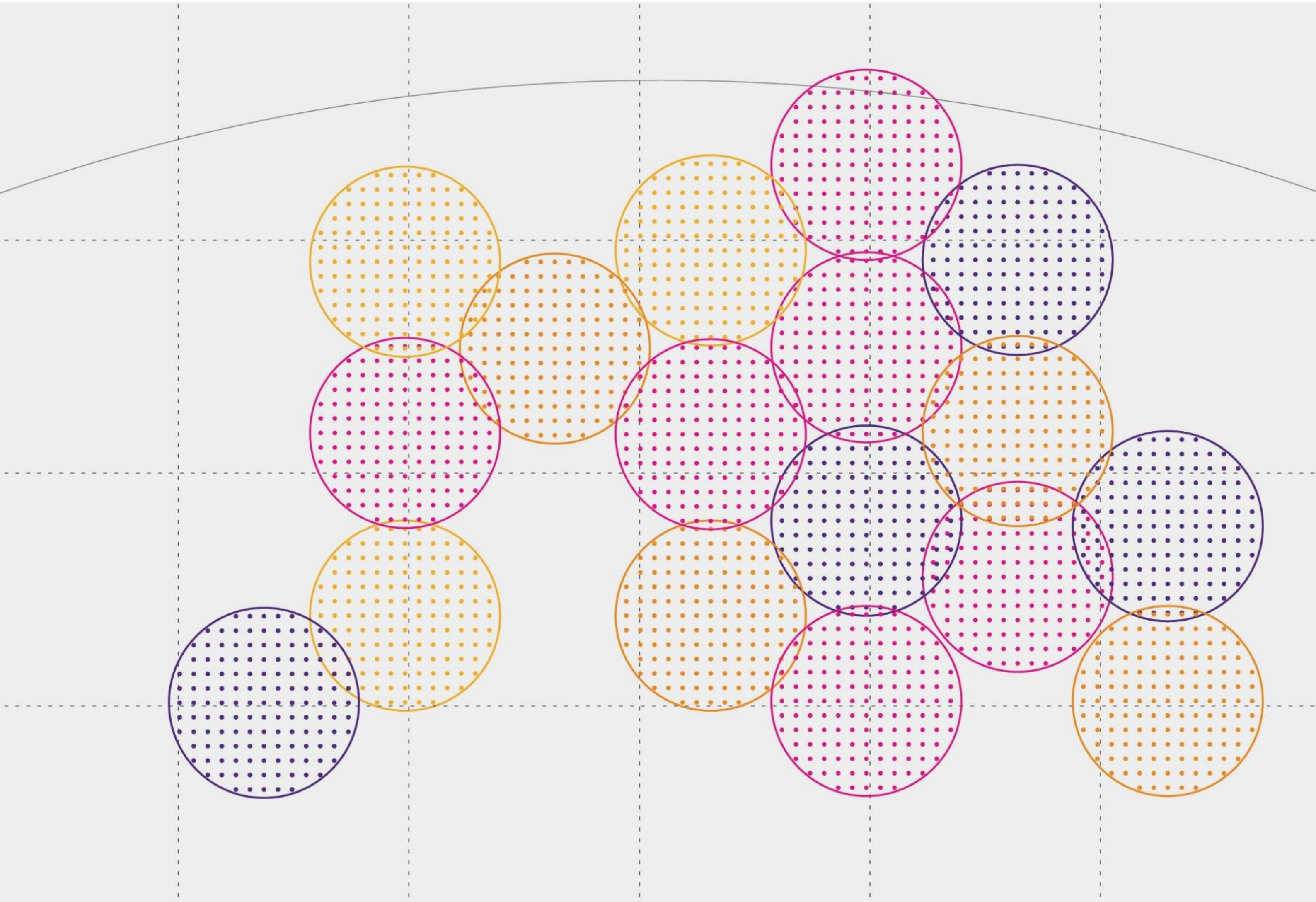

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About Plum

Plum is an independent consulting firm, focused on the telecommunications, media, technology, and adjacent sectors. We apply extensive industry knowledge, consulting experience, and rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial, and technology domains..

About this study

This study for ComReg addresses potential use of the 410-415.5 / 420-425.5 MHz band, also referred to as the 410-430 MHz band, and associated technical considerations for any future award..

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Glossary

The following abbreviations apply:

3GPP	Third Generation Partnership Project
BB	Broad Band
BEM	Block edge mask
BR	Business radio – interchangeable terminology used for PMR and PAMR
CDMA	Code Division Multiple Access
ECC	Electronic Communications Committee
e.i.r.p.	Equivalent isotropically radiated power
e.r.p.	Effective radiated power
FDD	Frequency Division Duplex
LTE	Long Term Evolution
MNO	Mobile Network Operator
NB	Narrow Band
PAMR	Public Access Mobile Radio
PMR	Professional Mobile Radio, Private Mobile Radio
PPDR	Public Protection and Disaster Relief
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio

1 Introduction

ComReg is considering the future use of spectrum in the frequency bands 410 - 430 MHz[1]. Understanding potential usage is important in optimising the way that the spectrum is packaged and awarded.

This report considers possible uses for the spectrum, the amount of spectrum these uses might need and the implications for spectrum packaging. It builds on previous consultations undertaken by ComReg and associated responses[2]. It is structured as follows:

- Section 2 considers the possible uses for the spectrum.
- Section 3 considers the spectrum requirements for the key uses identified.
- Section 4 examines whether there are any international co-ordination issues that would impact on band usage.
- Section 5 draws overall conclusions on future usage.
- Section 6 considers the implications for spectrum packaging and licence obligations.

[1] In particular 410-415.5 / 420-425.5 MHz band.
[2] In particular ComReg document 17/67 and the responses in ComReg document 17/105s.

2 Potential uses of the spectrum

2.1 Introduction

In considering possible uses for the 410 - 415.5 / 420 - 425.5 MHz frequencies (termed 410 - 430MHz in this report) a good starting point is to understand the characteristics of the band, as these influence its potential use. Broadly, the lower the frequency the better the propagation but the lower the amount of bandwidth available (due to limitations on the realistic size of channels).

The 400 MHz band is low in frequency compared to, for example, mobile or TV transmission and it has good propagation characteristics and a relatively long range. However, this range is only realised if efficient antennas can be deployed on terminal devices – at 400 MHz the optimal passive half-wave dipole antenna is around 35cm although sub-optimal quarter-wave antennas can also be used. This is larger than most mobile handsets so if the band were used for mobile the reduced antenna size would likely nullify the propagation gains over frequencies such as 800 MHz. This partly explains why, despite some attempts in the past to use the 450 MHz band for mobile, it has not proven popular. However, for other applications, such as PPDR to vehicles with external antennae, the increased range is realised, explaining in part why the 400 MHz band is where many countries have deployed TETRA for emergency communications.

Commensurate with the lower frequency, the bandwidth available is relatively small – around 2 x 5 MHz which is less in size than a single TV channel and increasingly 2 x 10 MHz or 2 x 20 MHz channels used for 4G and 5G communications.

A second important issue is harmonisation or use in other countries. The market size in Ireland is generally too small to make the provision of bespoke equipment cost-effective, suggesting similar uses as other countries. The 410 - 430 MHz band has little clear international harmonisation as can be noted by checking the current status of 3GPP / ETSI Standards, EC, CEPT Decisions and Reports but has variously been used for private business radio, public safety and Internet of Things (IoT) applications, often related to smart electricity metering[3].

These considerations generally align with the findings of the responses to ComReg's consultation document 17/67 on proposed release of the 410 - 415.5/420 - 425.5 MHz sub-band[4] which suggested that the main potential uses were:

- Smart Metering;
- Smart Grids;
- Public Protection and Disaster Relief (PPDR); and
- Other potential uses (Digital Mobile Radio (DMR) / TETRA Enhanced Data Services (TEDS)).

These are specific examples of the following more general communications networks, respectively:

[3] For example, EN301 449 is the harmonised EN for CDMA spread spectrum operating in the 450 MHz mobile band (CDMA 450) and 410, 450 and 470 MHz PAMR bands (CDMA-PAMR). There is also work ongoing in ETSI developing a Technical Report for the utilities sector that is looking into future spectrum requirements. ETSI TR 103401 v1.1.1 (2016-11) also addresses utilities and includes a helpful table of services versus priority and data rates. There are also a number of ECC Reports, such as ECC Report 218 and ECC Report 240 that relate to potential services / frequency bands. Work is continuing in FM PT 54 on the development of the draft ECC Report on 'Current Use, Future Opportunities and Guidance to Administrations for the 400MHz PMR/PAMR frequencies'.

[4] See ComReg document 17/105s at https://www.comreg.ie/publication/non-confidential-submissions-comreg-document-1767-proposed-release-410-415-5420-425-5-mhz-sub-band/

- Smart metering, IoT networks and smart grids;
- Networks with particular reliability and availability requirements; and
- Specialised and public voice and data networks.

Each of these is considered in outline below along with details of current deployments across Europe and future plans.

2.2 Smart metering, IoT networks and smart grids

IoT networks are general purpose networks optimised to communicate to machines. Smart metering is a specific application for IoT networks, although in some cases dedicated smart metering networks have been established. Smart grid is also a form of machine communications but with very different needs than general IoT solutions, in particular for low-latency and high reliability. For this reason, smart grids are often considered differently from smart metering, although there may be some situations where they could share the same network. General purpose networks are typically cheaper for the end user as the network deployment cost is spread across a broader base of end users, however some users may prefer to self-deploy or at least have some degree of network ownership. This is especially true of smart grids.

Generally, smart meters are considered to be the devices located at premises that record energy usage. They can also be used to measure water and gas usage. The connectivity requirements for these devices can be relaxed as the implications of a short delay on reading a meter are minimal. Smart grids for the electricity network are considered to be the elements of the electricity distribution network such as sub-stations and transformers. If there is a need to shut these down due to conditions such as overload, delays of milliseconds can be serious, hence network availability, reliability and resilience is essential. In the case of water supply there can be similar requirements to monitor key points in the water network such as the flow of water in major pipe lines or water levels in areas prone to flooding where it may be necessary to open or close various valves and dams to alleviate such risks.

Dedicated smart metering

The 410 – 430 MHz frequencies are already in use for smart metering in some countries – for example by Arqiva in the northern UK using Sensus technology[5]. Some IoT technologies are either adapted for these bands or could be repurposed such as LoRa and Weightless. However, smart metering is generally delivered in other bands, or using general-purpose networks. There are examples around the world of utilities gaining dedicated spectrum and sourcing bespoke IoT systems to deploy in bands such as 900 MHz in Taiwan, 168 MHz in China and many other options. The amount of spectrum needed for smart metering is dependent on factors such as the frequency of communications with the meters and the density of households. To date, solutions using around 2 x 200 kHz of spectrum for this type of application have been deployed.

IoT networks supporting smart metering

The optimal frequencies and technologies for IoT systems are still emerging. Mobile Network Operators (MNOs) have been able to capitalise on the need for smart metering with a range of legacy solutions based on GSM – this is what is currently used in the southern part of the UK. One emerging possibility is that MNOs will provide IoT connectivity in their LTE bands using NB-IoT technology. In Ireland, Vodafone activated an NB-IoT network

[5] See https://www.arqiva.com/overviews/smart-metering/flexnet/

in August 2017[6]. Non-MNO deployments of IoT solutions have concentrated on unlicensed bands such as 868 MHz, as a result this is where there is the greatest equipment availability. For example, VT[7] have deployed a Sigfox network[8] in Ireland and claim this can be used for smart metering.

Smart grids

Smart grid is a term used for advanced delivery systems for utility services (electricity, gas and water) from sources of generation and production to key elements in the grid networks and includes all the supervisory and control necessary for their effective management[9]. In some definitions this includes smart metering, but in this report, we exclude the consumer smart metering which we consider separately. Typically, such networks are deployed cautiously and deliberately after extensive trials and parallel operation given the critical national infrastructure which they will control.

In the case of smart grids (as compared to smart meters), the spectrum requirements are likely to be significantly greater as the applications may require higher data rates, for instance if in addition they require CCTV surveillance at sites. The EUTC (European Utilities Telecom Council) has identified[10] that there is a requirement for 2 x 3 MHz of spectrum to support the necessary monitoring and remote-control functions needed by smart grids. In some cases, very low latency is needed, particularly in the control of electricity sub-stations where latencies as low as 1ms have been quoted[11]. Existing mobile networks currently are unable to meet these requirements, with 4G networks having minimum latencies of around 30ms. Future 5G networks may have lower latencies including support for URLCC (Ultra Reliable Low Latency Communications) application but this will not be available until new radio access type is developed with market access expected in 2019.

Due to the nature of the smart grid networks (i.e. long distances and rural locations) there is a need for spectrum around 400 MHz (such as already used for scanning telemetry), and spectrum sharing with users of higher frequency bands, such as 800 MHz, would not be optimal.

There was a strong case made in the consultation responses for using these bands for electricity smart grids, deploying high-reliability bespoke networks that can monitor and control critical national infrastructure. There are a number of approaches that could be used to segment the spectrum to monitor and control critical national infrastructure including:

- A specific network just for smart electric grids.
- A more general network for all utilities.

While other utility providers did not respond to ComReg's consultation we would imagine that other utilities would find sharing such a network attractive. For example, the water industry needs real time monitoring to avoid / control flooding, to open sluice gates and other control mechanisms at the optimum time, and to monitor security at reservoirs and pumping stations. Gas utilities will have equivalent needs. Hence, there would seem to be a strong likelihood that if a network were deployed it could be used by multiple utilities. Whether it might be used by other entities beyond the utility space is discussed below.

[6] https://www.siliconrepublic.com/machines/vodafone-ireland-nb-iot
[7] VT is the exclusive operator of the Sigfox network in Ireland.
[8] https://vt-iot.com/
[9] This definition is based, in part, on the ITU definition as per Smart Grid Utility Management Systems, Report ITU-R SM.2351-2 06/17.
[10] http://eutc.org/wp-content/uploads/2016/04/EUTC-Spectrum-Position-Paper.pdf
[11] The JRC in the UK has indicated that for some of the critical applications, particularly with transformers, 0.25 the cycle time (i.e. 5ms) might be typical. IEC 61850 – design of electrical substation automation defines latency requirements by mapping protocols on IP networks. Requirement of total transmission time < 4ms for protective relaying (trips and blocking) and ≤ 10 ms for releases and status changes.

The technology deployed and hence bandwidth needed to meet the needs of smart grids may vary somewhat depending on these decisions, key contenders are:

- Digital private mobile radio systems of which TETRA is the leading contender.
- Private mobile, of which private LTE is the key contender.

The next section discusses general networks in more detail.

Implications

The discussion above has shown that the 400 MHz band clearly could be used for a general-purpose IoT network, a smart metering network, a smart grid network, or some combination of all of these. Whether this usage happens depends on factors such as decisions by the electricity and water supply companies, other national IoT network providers and the competitive offering from MNOs as they roll out NB-IoT. The amount of spectrum required will depend on which of these transpires, but, for example, MNOs currently consider a 2 x 200 kHz channel may be sufficient for NB-IoT, while in the UK Arqiva have an assignment of 2 x 2 MHz for its dedicated smart metering solution (but may not be using it all).

In the consultation responses, the general view was that these frequencies should not be used for smart metering or general purpose IoT networks since there were other frequencies available for this such as the 800 MHz mobile bands for NB-IoT and the 868 MHz unlicensed bands for technologies such as iDEN[12], Sigfox and LoRa. These other frequencies are more likely to be used in other countries and hence economies of scale and roaming capabilities will be better in these bands. We broadly agree with this (although note a possible exception later in the report). It is not attractive to build a general-purpose IoT network in frequency bands not aligned with other countries since the availability of chipsets, modules and base station equipment will be limited and there are already multiple general-purpose IoT networks in Ireland including NB-IoT and Sigfox as well as some LoRa deployments[13]. These issues are less relevant for a self-deployed smart metering network, but the costs of such a network are high and shared options generally preferred.

Conversely, the responses to ComReg's consultation show that there is strong support for a smart grid network, and as discussed above there is a rationale for building such a network to provide dedicated control of key resources. Such a network might use TETRA, private-LTE or a bespoke solution. As noted in the consultation responses, these technologies typically require something between around 2 x 1.5 MHz and 2 x 3 MHz to construct a viable network.

Note that it would be possible to deploy an LTE-based smart grid network in 2 x 3 MHz of the spectrum available in this band, and a NB-IoT wide-area IoT network in the remaining 2 x 2.5 MHz. There would not necessarily need to be guard bands between them since NB-IoT is designed to work in the guard bands of LTE networks. These two networks might be owned by the same entity or potentially by different organisations, however, for this to be attractive, there would need to be some likelihood of terminal equipment becoming available in these bands.

2.3 Networks with particular availability requirements

Historically, some organisations such as public safety, utilities and railways have chosen to build their own networks rather than procure service on general-purpose networks such as mobile, despite the often much higher cost of doing so. This has been so that they can be assured of the coverage, reliability, availability and

[12] iDEN was a proprietary standard developed by Motorola but is no longer being supported.
[13] https://www.semtech.com/company/press/Semtech-LoRa-Technology-to-Enable-Irelands-Nationwide-IoT-Network

security. As LTE networks have evolved and concepts such as network slicing as a technique to be deployed in 5G have emerged this has led to the potential to create virtual private networks across a common shared network, and for these to have higher levels of priority of access. However, this does not change overall network availability since if the network fails all the slices will also fail. In the UK, emergency services have opted to move to mobile using EE's LTE network and US public safety organisations are following a similar approach, although the process is far from smooth with the UK project currently experiencing concerns over its coverage and extended timescales for a transition from the current TETRA network. While it is far from clear, it seems plausible that public safety organisations in other countries will increasingly look towards either shared networks or use of commercial networks. However, the drivers for smart grids are somewhat different as there are typically no handheld terminals and so less need to benefit from the economies of scale of commercial mobile technology. Also, electricity networks clearly cannot be reliant on control networks that themselves need mains-supplied electricity to operate, whereas public safety organisations do not have the same direct linkage to critical need for communications at the point of electricity supply failure and restoration.

A further issue is that many users, including public safety and railways, have growing data demands for connectivity including in train WiFi & real-time video, and these may require bandwidths of 2 x 10 MHz or more. Hence, the bands considered here may be too narrow for effective public safety use. What transpires will depend on the decisions of a few key user groups, most notably public safety organisations.

The feedback from the consultation was clear that there was unlikely to be demand from emergency services (often termed public protection and disaster relief or PPDR). If emergency services simply wanted to expand their current system, there is spare spectrum in the existing 380 - 400 MHz band they can use for this. If they wish to deploy their own next-generation system they appear more likely to consider frequencies within the 700 MHz duplex gap where cross-EC harmonisation may occur, or perhaps to adopt a similar approach to the UK, moving onto an MNO's LTE or future 5G network.

There is unlikely to be demand from the railways who have their own frequencies at 900 MHz for the GSM-R system and are currently considering deploying their own LTE solution, likely in similar bands.

Outside of the utilities, we have not found evidence of any other demand for a high-reliability network of this sort with most users finding mobile systems sufficient for their needs. There is however a growth in IoT applications and need for wide area connectivity supporting the agricultural business in rural areas: Such solutions include; automated combine harvesting, remote monitoring of large dairy herds, fertiliser & soil monitoring, targeted pest control and automated drip water solutions for crops all with the aim of driving both cost savings and productivity efficiency.

We believe that there is little desire outside of the utilities for self-deployment of a feature-rich and high-availability network in these bands, with the agricultural sector (made up of small farms) unlikely to combine together to commission such a dedicated network. Equally, there appears little demand for a more general-purpose network. It may be the case that if the utilities deployed a network for their own use that some other users, especially agricultural in rural areas, would request to join (or use) such a network, subject to sharing being allowed under the licence and it being attractive to the network owner.

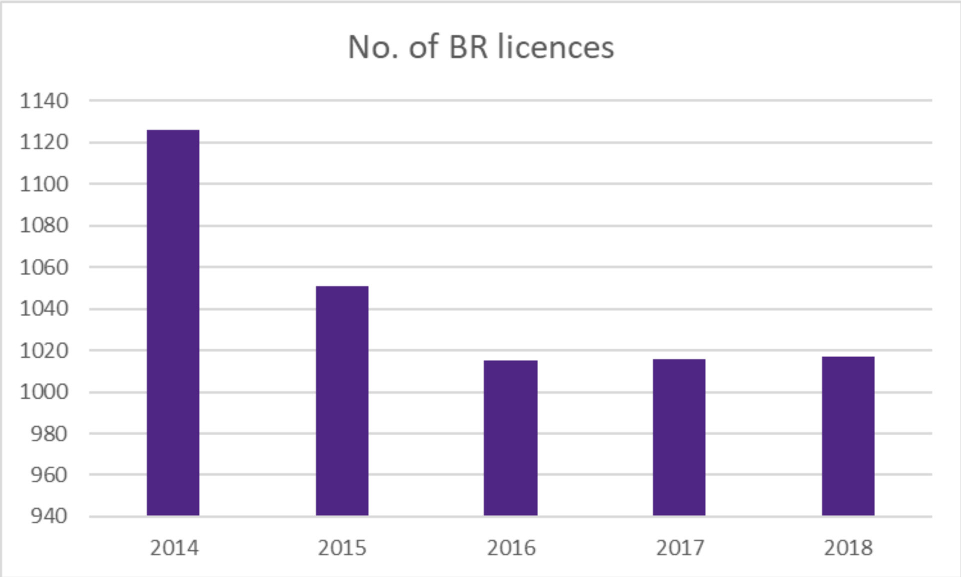
2.4 Specialised voice and data networks

The 400 MHz band has also been widely used for an application often known as private mobile radio (PMR) where organisations prefer to self-deploy a system rather than rely on mobile. For example, this has been popular at airports and on large scale construction sites where such self-deployed solutions can have specific features such as "push to talk" (PTT). The economics may also be preferable, especially where the coverage area is relatively small and call volumes relatively high.

The level of interest in these applications has generally faded as mobile has become more capable and less expensive (on a per call basis) and 3GPP / ETSI started to include support for PTT in its releases[14]. Historically, there have been shared networks that have aimed to offer specialised service equivalent to self-provision, but these have not proven commercially successful. There are other bands that are also used for these applications so assessing the level of demand for licenses in these bands will give a good indication as to whether the provision of additional bands at 400 MHz would be beneficial.

It can be seen from Figure 2.1 below that the number of business radio licences has remained steady over the last three years and there is no indication of likely increase in demand that cannot be met with currently available spectrum. Hence, we do not foresee a need for spectrum in the 410 – 430 MHz band for business radio use.

Figure 2.1: Number of business radio licences per annum (Source: ComReg)



2.5 Mobile networks and fixed wireless access

In a few cases, bands around 450 MHz have been used for mobile services. Historically, some Eastern European countries deployed CDMA450 – a variant of a US 2nd generation mobile standard. Since then, there has been little interest in these bands, with LTE mobile and 5G concentrating on higher frequency bands. At present we are only aware of equipment from Huawei, Ericsson and Nokia that can work in these bands as detailed in Huawei and Nokia's consultation responses and handset availability is very limited.

It seems very unlikely that MNOs will be interested in deploying a general-purpose mobile network in these bands in any countries. MNOs will have an opportunity to acquire additional spectrum in future 5G auctions / awards. The consultation responses were of the view that there would not be a use of these bands for consumer mobile.

It would be possible to deploy a network delivering high-reliability services to utilities, emergency services and others. From a spectrum viewpoint this is essentially the same as self-deployment, discussed above, but might

[14] ComReg indicated in their Radio Spectrum Management Strategy 2016 to 2018 (Doc. 16/50) that they believed the decline in number of business radio licences was partly due to increasing trend of substitution services.

have the benefit of being more spectrally efficient by enabling multiple services to use the same spectrum. This would essentially be a smart utility network, which happened to use mobile technology.

One variant of mobile use is fixed wireless access, where the mobile technology, or some variant, is used to provide connectivity to homes or premises. However, the bandwidth available is relatively small compared to most FWA solutions, including those until recently deployed in the 3.6 GHz band in Ireland, and except perhaps for the most rural of communities, would not appear attractive. There does not appear to be widely available FWA equipment in these bands, increasing the costs.

If these bands were to be used for mobile or fixed wireless access, a spectrum allocation of at least 2 x 5 MHz would typically be needed.

2.6 Current usage and plans in Europe

Information on current usage of the 410 – 430 MHz band and plans for broadband networks is relatively sparse. At a European level CEPT and ECO have conducted various surveys and are in the process of drafting guidance notes from which this section has been heavily based.

In general, the 410 – 430 MHz band is discussed alongside the 450 – 470 MHz band, sometimes without a clear distinction as both are seen as candidates for broadband and especially PPDR networks. The 450 – 470 MHz band is often preferred, primarily because it is already used for broadband in some countries who have licensed up to 2 x 5 MHz of spectrum in 450 – 470 MHz which has generally been used for Code Division Multiple Access (CDMA) – so called CDMA450 networks. Such networks are already deployed in the Netherlands, Austria, Germany, Russia, Sweden, Norway, Denmark, Finland and Hungary providing connectivity for millions of devices using CDMA450 or LTE450 technology. These networks have been assigned nationwide licences. The ECO assumes that existing CDMA networks are likely to migrate towards LTE including NB-IoT.

There have been some smart-grid type networks deployed, again predominantly in 450 MHz. Examples of such networks are Utility Connect's wideband PMR network in the Netherlands, the ArgoNET wideband PAMR networks in Austria and the 450 Connect wideband PAMR network in Germany.

CDMA450 technology is widely used on a global scale, already customised for IoT/M2M and has a mature ecosystem with many suppliers and operators but it is an old technology. While existing deployments may continue with CDMA 450 the expectation is that going forward new deployments of 450 MHz networks focussing on IoT/M2M will tend towards LTE450 and examples include Ukko Mobile in Finland and MVM in Hungary.

In 2014 CEPT asked each national administration about PPDR, which we do not consider to be relevant in Ireland but is a good indication of the ability to provide spectrum for broadband networks in general. The views of administrations on the possibility to make parts of the 400 MHz range available for PPDR networks were rather divided.

Approximately half of the respondents did not see any possibility of making frequencies in the 400 MHz range available for PPDR networks. These administrations either provide no argumentation or refer to the heavy usage of the band by other applications, predominantly by narrow band and digital PMR/PAMR systems, and the difficulty of refarming.

Roughly the other half of the respondents did see some possibilities of making limited parts of the 400 MHz sub-bands (some countries in both 410 – 430 MHz and 450 – 470 MHz bands) available in the future, or long-term future, for PPDR networks, though some administrations under various conditions, including the shared usage with commercial networks.

No country clearly indicated that 410 – 430 MHz would be available, although some countries were unspecific as to which of the two bands might be used.

2.7 Summary

Overall, there appears to be a clear potential for a network that, as a minimum supports smart grids. This might be deployed just by the electricity companies, by all utilities, or by a third party on their behalf. It is also clear that this spectrum is the only suitable spectrum available to provide for smart grid in Ireland[15]. It might offer services to other entities beyond smart grids - outside of the agricultural sector in rural areas, we have not identified who this might be, but it is likely to be industrial entities with similar requirements to the utilities rather than consumers. While, in principle, smart grid operation could be supported on mobile networks, there is strong rationale for a dedicated network because:

- Mobile networks may not be able to meet the availability and reliability requirements, in particular they may fail when the mains power fails, which is precisely the time when smart grid networks are most critically needed.
- Mobile networks may not have coverage in areas where smart grid elements such as remote sub-stations and wind farms are located, and the operators may have little incentive to provide this coverage.
- Despite new concepts such as network slicing, mobile networks may have insufficient capacity, or there may not be a clear business model to give the appropriate prioritisation to smart grid control messages.
- The benefits of using commercial networks are smaller for smart grids than public safety as there is little need for handsets which benefit substantially from commercial economies of scale.

We do not see demand for PPDR networks in these frequency bands, nor for general-purpose mobile networks.

We see no need for private business radio given the availability of other bands. Likewise, we see little appetite for IoT networks given the deployment of NB-IoT, the use of other bands elsewhere for unlicensed solutions and the lack of interest from consultation responses, although if an LTE-based smart-grid network were deployed in part of this band there might be some rationale for an NB-IoT network to be deployed in the remainder of the band.

Table 2.1 below shows the consultation responses and how well they align with our conclusions:

Table 2.1: Comparison of consultation responses and findings from this study

Respondee	Requests or points raised	Alignment with conclusions above
Eir	No specific uses should be prioritised, a flexible approach is needed	Reasonable alignment, while we suggest a bias towards a network suitable for smart grids [or similar applications] this could be general purpose.
Ericsson	Single national infrastructure for critical applications	Good agreement with our findings.
ESBN	Should be used for smart grid	Good agreement with our findings, although we believe a shared network may be beneficial.

[15] As discussed in detail in Section 4.2, the 450-470MHz is currently used in Ireland for a range of applications including PBR and short range devices and is therefore not available for smart grid usage.

Respondee	Requests or points raised	Alignment with conclusions above
EUTC	Should be used for smart grid	Good agreement with our findings, although we believe a shared network may be beneficial.
Huawei	Single national multi-use network using LTE	Good agreement with our findings for a general purpose network, Huawei has a preference for one specific technology which we consider to be one contender.
M2M	Agree with all suggested uses and highlight national IoT network	Moderate agreement, we anticipate a national IoT network is more likely to be deployed by MNOs in their 800 MHz LTE spectrum but note an NB-IoT network could be deployed alongside a smart grid network.
JRC	Should be used for smart grid	Good agreement with our findings, although we believe a shared network may be beneficial.
Nokia	Single national multi-use network using LTE	Good agreement with our findings for a general-purpose network, they have a preference for one specific technology which we consider to be one contender.
Sensus and Sigma	Smart metering and smart grid	Good agreement, although we believe the bias should be towards smart metering
Vodafone	No view on usage	N/A
WHP	Should be used for smart grid	Very good alignment with our findings.

As can be seen, the alignment is good, with differences only being around whether the network(s) should be single or multi-use and which technology is optimal.

Taking forward the findings for the next section on spectrum requirements, the key points to note are:

- There is likely to be either just one network deployed, or at least just one network that requires a large fraction of the bandwidth available.
- The technology to be used is uncertain, a minimum bandwidth might be 2 x 1 MHz, a likely bandwidth 2 x 3 MHz, hence a flexible approach to technology and bandwidth would be helpful.
- The technology deployed is likely, but not certain, to be a global standard such as LTE.

3 Spectrum requirements

3.1 Introduction

As well as identifying the potential uses of the band it is also important to consider the associated bandwidth requirements to understand how much of the band may be required and more importantly identify if there is sufficient spectrum available to support one or more of the use cases identified in Section 2. This will then be used to inform our final conclusions and spectrum packaging inputs into any award process.

3.2 Potential use versus spectrum requirements

In the following sections we have considered the spectrum requirements for each potential use based on:

- Likely technology,
- Bandwidth required to meet anticipated demand, and
- Any specific constraints that might impact on the spectrum requirements.

In addition, we have concluded on whether there are alternative bands that could meet the needs of each use.

3.2.1 Technologies

In Section 2.7 the most likely technologies that were identified were:

- PMR (Private Mobile Radio)
- TETRA (or other PAMR (Public Access Mobile Radio) technologies)
- CDMA
- LTE, or a
- Proprietary technology.

PMR and PAMR (Public Access Mobile Radio):

The latest technologies being deployed for PMR are digital, specifically dPMR (Digital Private Mobile Radio) and DMR (Digital Mobile Radio), and we would not expect many new PMR systems to use older or less spectrally efficient analogue equipment. The dPMR technology provides 6.25 kHz Frequency Division Multiple Access (FDMA) radios using a 4FSK modulation scheme. There are a number of different modes available ranging from:

- dPMR 446[16] which operates in licence exempt spectrum at 446.1 – 446.2 MHz.
- dPMR Mode 1 which supports peer to peer operation and is similar to dPMR 446 but supports higher transmitter powers and is intended for use in limited geographic areas such as hotels, shopping centres

[16] ETSI Technical Specification TS 102 490.

etc. where there is no requirement for repeaters. In Mode 2 multiple repeaters can be supported which increases the coverage area. This is typically used by Business, Industrial and Governmental users.

- dPMR Mode 3 which offers multichannel, multisite radio networks.

Equipment is available in the VHF (137 – 174 MHz) and UHF bands (406 – 470 MHz) from a number of vendors including JVC Kenwood, ICOM and Kirisun

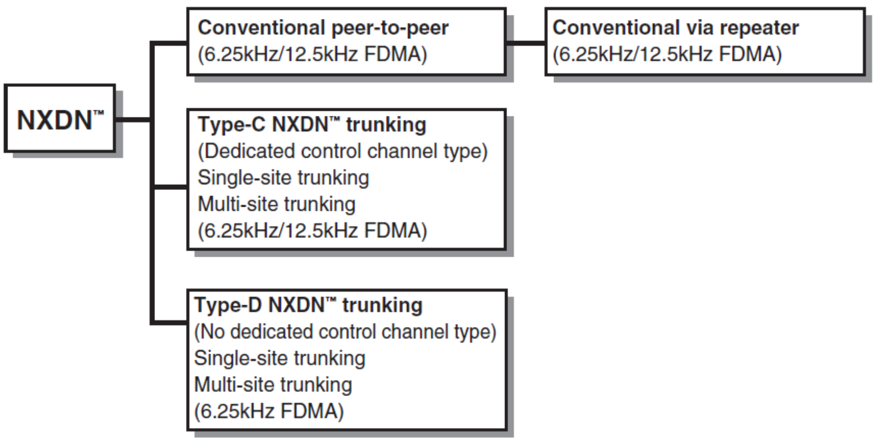
The DMR standard was developed to provide a potential migration from analogue to digital technology. DMR allows a single 12.5 kHz channel to support two simultaneous and independent calls. Whilst the technology[17] uses an equivalent of bandwidth of 6.25 kHz it is necessary to allocate a 12.5 kHz channel.

Similarly, to dPMR the DMR protocol covers unlicensed (Tier I), licensed conventional (Tier II) and licensed trunked (Tier III) modes of operation, although in practice commercial application is today focused on the Tier II and III licensed categories. Today, products designed to its specifications are sold in all regions of the world. For example, a significant vendor of DMR is Motorola with MOTOBRO. Equipment is available that operates in the frequency range 400 – 480 MHz.

There are also standards that have been developed for specific markets such as NXDN which is a narrowband digital protocol that was developed to satisfy the FCC narrow banding[18] mandate in the VHF and UHF bands.

There is a suite of standards as shown below:

Figure 3.1: NXDN standards (Source: NXDN Forum)



It is stated on the NXDN forum[19] that products have been deployed on a worldwide basis and are available for the frequency ranges 136 – 174 MHz and 400 – 520 MHz.

It can be seen that to allow the deployment of any of the above potential technologies the smallest channel size is 12.5 kHz.

[17] Uses TDMA providing two 6.25 kHz time slots
[18] 12.5 kHz was considered to be narrowband but ultimately the aim was to move to 6.25 kHz.
[19] See http://www.nxdn-forum.com/what-is-nxdn/nxdn-a-brief-overview /

TETRA is probably the most deployed trunked system in Europe mainly for Public Safety Systems. There are two releases of TETRA (Release 1[20] and Release 2). Release 1 uses Time Division Multiple Access (TDMA) to provide four user channels on one single 25 kHz traffic channel. TETRA requires duplex frequencies.

In the case of TETRA Release 2[21] [22] wider channel bandwidths of 50, 100 and 150 kHz may also be used, in addition to 25 kHz, allowing for higher data rates[23]. Both point-to-point and point-to-multipoint transfer can be used. In addition to voice and dispatch services, digital data transmission is also included in the standard but at a low data rate of 7.2 to 28.8 kbit/s for Release 1 and 15.6 to 269 kbit/s for Release 2.

TETRA is a trunking system and for each cell there are a number of channels available which can be dedicated to a user on a call by call basis improving spectrum efficiency. In a 200 kHz bandwidth TETRA can support 32 channels. The number of channels that are required for a network depend on the required grade of service (GoS)[24].

TETRA is therefore ideal for larger networks or where there is a public operator that offers services to a large number of users or where a number of users "pool" their spectrum and share a network. It supports multiple base stations over a wide area or national basis.

CDMA

CDMA450 refers to the CDMA systems that can be deployed in the 450 MHz band. It includes CDMA2000 1X, CDMA EV-DO and CDMA 1XEV-DO/EV-DV[25]. CDMA 2000 1X uses a single radio frequency carrier of 2 x 1.25 MHz and can support data speeds of between 80 – 100 kbps in commercial applications. CDMA 1XEV-DO supports data rates up to 2.4 Mbps in the down link. CDMA 2000 3X uses 3 carriers and therefore requires 2 x 3.75 MHz. CDMA450 systems were deployed in a number of countries[26], many around a decade ago but since then it has been superseded for mobile communications by 3G, 4G and soon 5G.

CDMA does therefore not seem to have any future for additional deployment in the band as it has largely been superseded by LTE in other bands (see below) and additionally an initial analysis would be that deployment in the band, current BEM profile and the need for gaps (either side of assignment) to reduce interference with other users would reduce the overall spectrum efficiency in the band

LTE

LTE is available in the 450 MHz band (Band 31) which provides for 20 MHz (2 x 10 MHz) channels between 450 and 470 MHz[27]. There is equipment available and there are markets in Europe including Finland, Hungary, Norway and Sweden[28]. Work is ongoing within ECC Working Group FM on the 410 – 430 MHz band with a new work item approved for the implementation of BB-PPDR and work on developing the technical requirements for the draft new ECC Decision for land mobile systems[29]. It is Plum's understanding that there is interest in developing equipment for the 410 – 430 MHz band[30] and based on little or no equipment being available for 1.4 MHz bandwidth in any of the LTE bands then the expectation is the minimum bandwidth will be 3 MHz.

[20] Initially referred to as TETRA Voice plus Data (V+D).
[21] Also referred to as Tetra Enhanced Developments or TEDS.
[22] There has been limited deployment of TETRA TEDS.
[23] Higher data rates are achieved by using adaptive modulation schemes (4 QAM, 16 QAM and 64 QAM) and larger channel bandwidths.
[24] Defined by the ability of a user to access the trunked system during the busiest hour. It is specified as the probability of a call being blocked or the probability of a call being delayed beyond a certain amount of time.
[25] All the standards are published by the TIA as TIA-EIA-IS-CDMA2000.
[26] See http://www.cdg.org/worldwide/index.asp#result
[27] Specifically, 452.5-457.5 MHz paired with 462.5-467.5 MHz
[28] See Virtual Access where they mention LTE 450 markets: http://virtualaccess.com/lte-450mhz-routers/?gclid=CjwKCAjw4PHZBRA-EiwAAas4ZumzKhNOCiYYVRnBI-gP59NX4INdBj1MrM5X4hODJWTEwlJV5iimjRoCzBAQAvD_BwE
[29] See Doc. ECC(18)104 Rev 1 from the recent ECC Meeting (July 2018).
[30] For example, LG already provides a handset for this band.

As noted LTE 450 is FDD and this is likely to be the same for the 430 MHz band. The decision on whether FDD or TDD may be determined by other markets – for example if the UK[31] decides to make this band available for LTE it is understood that TDD will be preferred because of current MoD ("Ministry of Defence") usage. However, current indications are that FDD may be somewhat preferred by equipment manufacturers.

In the case of Ireland FDD would appear to be the better solution. This would align with likely equipment availability and with the use of this and neighbouring bands both in Ireland and other countries. It is also noted that the draft ECC Decision on land mobile systems in the 410 – 430 MHz frequency range assumes paired spectrum[32]. TDD can bring some advantages where the traffic is asymmetric and where the system is capacity constrained when resource can be biased towards the higher capacity link direction (typically the downlink). In the cases identified in earlier sections, specifically smart utilities, it is unclear whether there will be significant asymmetry – if there is it might be biased more towards the uplink – and capacity constraints may not be severe.

The EUTC has expressed the most interest in a network supporting smart grid applications in this band although they are agnostic to the network technology deployed as long as it can meet the necessary technical requirements of data speeds, capacity, latency etc. LTE has considerable spectrum efficiency advantages over other technologies and fits within the limited bandwidth available in this band

NB-IoT

LTE has developed a series of techniques which are largely frequency agnostic for supporting developments in IoT and competing with other Low Power Wireless Access (LPWA) solutions for IoT connectivity.

- LTE-M (also known as LTE Cat-1 and above) delivering scalable performance and seamless mobility for high performance IoT use cases
- NB-IoT (also known as Cat-NB1) which is optimised for low cost/power, low-throughput, delay-tolerant IoT use cases

The target is to serve a wide area market with LTE-IoT with low power, high energy efficiency radios, supporting massive scale of devices (1million per km) and aggressive link budget for rural applications down to 164db at 160bps.

Table 3.1: Key parameters for IoT

	LTE Cat 1 (R8)	NB-IoT Cat NB 1 (R13)
Peak data rate	<10Mbps	<100Kbps
Bandwidth	<20MHz	200KHz
Duplex Mode	TDD/FDD Full Duplex	FDD Half Duplex

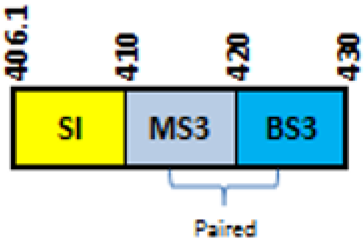
[31] There has been significant interest from the JRC in the UK to gain access to this band for smart grid networks.
[32] Draft ECC Decision (19)02 https://cept.org/files/9522/Draft%20Decision%20(19)AA%20for%20PC.docx

Bandwidth requirements

PMR and PAMR

The total amount of spectrum required for PMR will be a multiple of 12.5 kHz depending on the likely demand and deployment scenario of the licensee. An important consideration is that PMR does not require contiguous spectrum and even little pockets of spectrum are of use. However, the need to take account of interference from and to adjacent services may impact on the spectrum efficiency of identifying a limited number of channels. Typical rule of thumb planning indicates around 40 km separation before a frequency can be re-used, assuming a 25 watt transmitter power, and greatest demand is generally in urban areas. A 100 kHz allocation could support up to 16 off 6.25 kHz channels). Figure 3.2 shows the typical channel plans that may be used in the 406.1 MHz to 430 MHz band for which standardised equipment is readily available. The lower half of the band is identified for simplex operation and the upper part of the band for duplex operation with a duplex spacing of 10 MHz.

Figure 3.2: 400 MHz channel plans (Source: 25-08)



TETRA, as with dPMR and DMR, requires very large reuse distances for it to work as intended. A frequency reuse of 36 is the theoretical ideal where the network becomes noise limited rather than self-interference limited however in practical deployments this value will approach 49. Therefore, a minimum capacity network providing wide area coverage would require around 2 x 1.25 MHz. Network deployments have typically used 2 x 3 MHz to 2 x 5 MHz of spectrum.

CDMA

Bandwidth requirements for a CDMA network are either 2 x 1.25 MHz or 2 x 3.75 MHz depending on capacity requirements.

NB-IoT

In Section 2.3 it is noted that MNOs currently consider that 2 x 200 kHz channels may be sufficient for NB-IoT whereas in the UK the Arqiva network for smart metering may be using up to 2 x 2 MHz. Based on the limited amount of data that will be sent it is our view that it is more likely to be less than 2 x 1 MHz that is required.

Mobile Network operators can choose deployment options to suit different network environments. NB-IoT is designed to fit into 180 kHz of spectrum, so it fits neatly within one or more standard LTE Physical Resource Blocks (PRBs). Where it's undesirable to divert any capacity away from LTE, NB-IoT can be deployed within the "guard band" at the edge of an LTE allocation. NB-IoT can also be deployed standalone on a single GSM carrier spectrum, for example in locations where a carrier's full 4G rollout plans aren't yet defined, or standalone alongside an LTE spectrum band.

LTE

As noted above the expectation is that LTE equipment for the 410 – 430MHz will be FDD and use a minimum bandwidth of 3 MHz (i.e. a total of 2 x 3 MHz) and a 5 MHz variant is also anticipated. The equipment should be able to cover the entire band in a single variant so there should be no requirement to specify access to a specific portion of the band.

Summary of potential bandwidth requirements

Based on the above it is concluded that the following minimum bandwidths may be required:

Table 3.2: Technologies and associated bandwidths

Technology	Minimum bandwidth	Comments
PMR	2 x 100 kHz	Allows number of 6.25 / 12.5 kHz channels to be supported
TETRA	2 x 1.25 MHz	Networks typically use 2 x 3 or 2 x 5 MHz
CDMA	2 x 1.25 MHz	Also 2 x 3.75 MHz depending on capacity requirements
NB-IoT	2 x 200 kHz	
LTE	2 x 3 MHz	Also 2 x 5 MHz

3.2.2 Availability of alternative bands

PMR and PAMR

In the case of PMR as noted in Section 3.2.1 equipment is available for a significant number of alternative bands and in Ireland[33] these include:

- 440 – 450 MHz for land mobile,
- 455 – 456 MHz for digital land mobile civil,
- 456 – 469 and 460 – 470 MHz for land mobile for commercial services and Government services, and
- 459 – 460 MHz for land mobile.

When considering TETRA technology there are a number of frequency bands available which include 380 – 385 / 390 – 395 MHz which are used for emergency services in Europe, the 410 – 430 MHz bands, 450 – 470 MHz and the 800 MHz band (806 – 824 / 851 – 869 MHz) used in Asia Pacific and South America. In China there is a variant for the 350 – 370 MHz range. There are two bands identified in Ireland for TETRA:

- 380 – 385 paired with 390 – 395 MHz for a network for the emergency services, and
- 385 – 389.9 paired with 395 – 399.9 MHz for a civil network.

[33] See the Radio Frequency Plan for Ireland, Revised 3 May 2017, ComReg Doc. 17/34

CDMA 450

The CDMA 450 MHz band includes sub-bands in the frequency ranges of 410 – 430 MHz, 450 – 470 MHz and 470 – 490 MHz.

LTE

LTE is available in all the specified 3GPP bands including 450 MHz (Bands 31, 72 and 73).

3.3 Conclusions

In determining the likely and best use of the 410 – 430 MHz band it is important to consider a number of factors including:

- the likely technology that will meet the needs and the associated minimum spectrum building block requirements,
- the availability of alternative frequency bands or alternative solutions to meet the requirements,
- the demand and any specific considerations that might need to be taken into account.

The likely technologies that have been considered for the different use cases are based on those that are either most recent (digital PMR, NB-IOT and LTE) or, whilst they may be an older technology, networks are still being rolled-out (TETRA). CDMA 450 has not been specifically considered due to the age of the technology and the use of LTE as the natural replacement. The minimum spectrum building block size, based on our analysis, equipment specifications and typical deployments, ranges between 2 x 100 kHz for dPMR / DMR and 2 x 3 MHz or 2 x 5 MHz for LTE and TETRA networks. It is however noted that, depending on the availability of access to other frequency bands, the actual spectrum requirements for some uses may be greater.

It is noted that the EUTC has indicated a need for 2 x 3 MHz[34] to support smart grids and this fits within the available spectrum. It could also allow expansion to 2 x 5 MHz if this was considered necessary. Also, the 400 MHz band is optimal in terms of providing the necessary geographic coverage to locations in remote rural locations (e.g. where wind farms may be located).

As noted the majority of use cases already have access to spectrum and networks are rolled out and, in some cases such as PPDR, further harmonised frequency bands are being identified. There are also alternative solutions to self-provided networks emerging such as provision of PPDR and smart metering over MNO networks.

In the case of smart grids, whilst their needs have historically been met through scanning telemetry networks to provide the necessary command and control of a centralised grid network, these networks are changing to distributed networks requiring a new level of control that cannot be met with legacy technology as these existing telemetry systems are unable to support the bandwidth requirements for Smart Grids. For example, in the case of the electricity network there is a shift from the focus on fossil fuels (power stations) to renewable energy which by its nature tends to be intermittent in comparison to the controllable nature of the former. This requires many more "points" in the network to be monitored and controlled as energy will be flowing in two directions rather than the one-way flow from the power station to the end user.

[34] ETSI TR 103 401 V1.1.1 (2016-11) also mentions the need for 2 x 3 MHz in 400 MHz UHF band available to be self-managed for Critical Infrastructure Utility Operations Networks

In terms of demand for the 400 MHz band for the different identified uses there is no indication from the licensing of PMR that there is a need for further spectrum and even if there was congestion there is always the potential to encourage more efficient use by migrating to narrower channels. There are a number of smart metering solutions already deployed, including NB-IoT in licensed bands and Sigfox in unlicensed bands and no indications that there is a need for further options. In the case of PPDR we understand there is already spare spectrum available in the 380 – 4OO MHz TETRA band allocated for Emergency Services Digital Radio and within Europe there are a range of bands identified that might be feasible in Ireland such as the centre gap of the 700 MHz band. Smart grids are the only case where there is a definite requirement for a solution that can support a wide range of services as shown in Figure 3.3 below:

Figure 3.3: Typical services required by smart grid (Source: JRC)

The requirements for smart grids[35] are:

- support low to medium data rates typically 9.6 kbit/s to around 64 kbit/s (as required by the services), but if there is sufficient bandwidth available then video (remote surveillance) of key installations may be an attractive option,
- provide enhanced resilience – for example this requires battery power back-up which far exceeds that provided over MNO networks,
- instant and guaranteed channel access,
- ensures longevity of products and support- grid networks are expected to be deployed for a significant time (e.g. 10 to 20 years)
- extensive geographic coverage (including less populated areas) to provide 100% coverage of the utility network;
- stringent latency requirements;

[35] These are mainly based on the requirements specified by the EUTC as well as information available to the authors of this report and ETSI Technical Report TR 103 401 V1.1.1 (2016-11).

- low jitter and synchronous requirements; and
- high levels of security.

In Table 3.3 below we summarise the different potential use cases assessed against the criterion that relate to spectrum requirements considered in more detail above.

Table 3.3: Summary of different potential use cases

Potential use cases	PMR type uses	PPDR	Smart metering	Smart grids
Spectrum considerations:				
Applicable technologies	dPMR / DMR	TETRA LTE	NB-IOT[36]	LTE
Minimum spectrum building block (See Section 0)	2 x 100 kHz	2 x 3 MHz or 2 x 5 MHz	2 x 200 kHz	2 x 3 MHz
Availability of alternative frequencies (See Section 3.2.2)	Yes. 440 – 450 MHz 455 – 456 MHz 456 – 470 MHz	Yes. Alternative bands identified for broadband PPDR in ECC[37] that potentially could be made available in Ireland.	Yes. Range of potential frequencies as well as technologies / solutions. Include MNO frequency bands and unlicensed frequencies (e.g. 868 MHz).	No. Applications to connect to sub-stations and alternative energy sources requires sub 1 GHz spectrum to achieve required distances. Whilst 450 – 470 MHz may be available to utilities in some countries[38] that is not the case in Ireland.
Availability of alternative solutions	Yes. PMR / PAMR already supported in licensed bands.	Yes. Current TETRA network 380 – 385 / 390 – 395 MHz.	Yes. Can be provided over MNO networks (e.g. NB-IoT in LTE spectrum bands) and licence exempt bands such as 868 MHz.	Yes. Currently use scanning telemetry for control and monitoring but cannot support requirements for changes to supply networks.
Identified demand	No. The number of business radio licences has remained stable over the last 3 years see Figure 2.1.	Potentially there may be a need in the future for a broadband PPDR network to enhance or replace the current TETRA network.	No. Solutions are readily available.	Yes. The European Utilities (EUTC) have been seeking access to suitable spectrum to allow self-provided monitoring and control networks.

[36] As well as MNO solutions there are also bespoke solutions for smart metering available which have concentrated on unlicensed bands.
[37] See ECC Decision (16)02 which in decides 2 and 3 mentions frequencies in the 700 MHz and 450 – 470 MHz bands. https://www.ecodocdb.dk/download/1cadc836-23e4/ECCDEC1602.pdf
[38] For example, according to a JRC presentation to techUK, 2 x 3 MHz is available in the Netherlands in the 450 – 470 MHz band, 2 x 4.4 MHz in Denmark, Finland and Portugal, 2 x 5 MHz in Sweden and 2 x 7.2 MHz in Hungary for use by the Utilities.

Potential use cases	PMR type uses	PPDR	Smart metering	Smart grids
Future availability of technology	Yes. Latest digital PMR solutions expected to be available for considerable time period as has been the case for analogue PMR.	Potentially There are still a substantial number of operational networks that will need continued support. The availability of LTE may impact.	Yes. Many solutions are already deployed and should be available for a significant period of time.	Yes for LTE. No for CDMA 450. Requires latest technologies to ensure support over lifetime of utilities equipment.

As noted above it can be seen that for smart grids there are currently no wireless solutions in Ireland to meet the new requirements for control and monitoring of utility network infrastructure. The 410 – 430 MHz band can support the necessary propagation distances (extensive coverage required including rural areas) and also has sufficient capacity indicating this might be a best use of part or all of the band.

4 International co-ordination issues

4.1 Fit of proposed uses with MoU

There is an existing Memorandum of Understanding (MoU) between the Republic of Ireland (ROI) and the United Kingdom regarding the frequency band 410 – 414 / 420 – 424 MHz. It specifies that a station may be "established without co-ordination provided that the predicted power spectral density (PSD) produced by the station, at a height of 10m above ground at all locations beyond a line 15 km inside the border or coast line of the neighbouring country does not exceed -140 dBW in a bandwidth of 25 kHz. It is understood that this level is based on the 900 MHz GSM Decision[39] and calculations were made to reference to a 25 kHz channel. In paragraph 1.4 there is mention of the possibility of EV-DO CDMA technology being deployed.

In the UK a 10 MHz duplex channel spacing is used. 420 – 422 MHz band (transmit) paired with 410 – 412 MHz is used for emergency services and 422 – 424 MHz band (transmit) paired with 412 – 414 MHz is awarded[40]. This approach is consistent with the channel arrangements currently for the band 410 – 414 MHz paired with 420 – 424 MHz in the ROI.

Any uses that require FDD and can utilise a 10 MHz duplex arrangement should not require a change to the MoU to allow equitable access to the frequencies between the ROI and UK. For those technologies / potential uses that require bandwidths of greater than 25 kHz then they may experience a greater risk of interference from the narrowband networks in the UK. An adjustment might be considered for systems using a channel spacing of greater than 25 kHz similar to that proposed in CEPT Recommendation 25/08[41] and the Harmonised Calculation Method (HCM) Agreement.

In the case of TDD deployment in ROI then there could be an increased risk of interference into base station receivers in the UK when base stations transmit in the lower frequencies (i.e. 410 – 414 MHz). Such interference would be a constant, compared with the interference from a base station transmitter into a mobile receiver, as there is no amelioration. In the case of interference into mobiles as they move location the interfering signal may be screened and also mobiles are typically used at much lower heights and so are screened by buildings etc. As discussed in Section 1, our findings are that FDD is more likely.

Plum recommends that the MoU between the ROI and UK should be revisited to take account of possible wider band systems in the ROI and any possible changes in current or planned use of the band in the UK.

4.2 Other potential uses

Ofcom, the UK regulator, undertook a strategic review of the UHF Band 1 and Band 2[42] with a consultation in December 2016. Part of the consultation addressed whether it was appropriate to reverse the existing band configuration for UHF Band 2[43] and align it with the configuration used in continental Europe. Any changes to the configuration in the UK would have implications for Ireland which follows the same band plan.

[39] The MoU can be found at: https://www.comreg.ie/publication/mou-between-ireland-and-uk-in-the-frequency-range-790-mhz-to-2690-mhz/
[40] Based on information provided in Ofcom consultation on the strategic review of UHF spectrum at 420-470 MHz in December 2014.
[41] This recommendation that covers land mobile systems in the 29.7 to 470 MHz range was amended 27 May 2016 and covers various analogue and digital land mobile applications.
[42] UHF band 1 and 2 occupy in total 420 – 470 MHz
[43] The same band configuration is used in the Republic of Ireland.

Networks deployed in the UHF2 band in continental Europe (e.g. France and the Netherlands) have the potential to interfere with networks in the UK and due to the reverse band configuration, this will be base station into base station with limited opportunity to mitigate the problem.

Ofcom, and previously the Radiocommunications Agency, have considered band reversal but it has been difficult to identify a simple solution with so many and varied users of the spectrum. Also, to date there has been limited experience of interference due to the limited number of networks / users of the band in Europe and particularly France and the Netherlands.

Ofcom in its Statement[44] published on 25 May 2017 "concluded that it is not necessary or proportionate to change the band configuration as there is insufficient evidence to suggest that the benefit would outweigh the costs" and mentioned in the consultation that "aligning UHF 2 would be a major intervention and would cause significant cost and disruption to all users of the band, most of whom would receive limited, if any, benefits from alignment..

However, with increased interest in deploying LTE 450 in the band as well as rollout of CDMA 450 that situation may change at some time in the future. The 450 – 470 MHz band in Ireland is used for:

- PMR systems[45],
- Third Party Business radio (TPBR) licences that were introduced in 2005 with subsequent licensing rounds in 2010 and 2015[46],
- Scanning telemetry systems, and
- SRDs.

Any future proposals by the UK to realign the UHF2 band would likely require Ireland to follow suit. The 410 – 415.5 / 420 – 425.5 MHz band could be used to facilitate such a change as it is suitable for PMR and PAMR with equipment already available (see 3.2.1).

4.2.1 Should spectrum be retained for future UHF2 band reversal?

The feasibility of using the band to facilitate reversing the UHF2 band is based on:

- Whether the UK decide at some unknown date in the future to realign the UHF 2 band and so requiring the same in Ireland, and
- Whether it is efficient spectrum management to hold part or all of the 410 – 415.5 / 420 – 425.5 MHz band to support realignment.

On the basis that there is identified demand for access to this band it seems inappropriate to hold in reserve the spectrum to facilitate an event that may, or may not, occur at some stage in the future.

[44] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/102185/Statement-on-strategic-review-of-UHF-Band-1-and-Band-2.pdf
[45] ComReg document 00/007aR1 (Guidelines for Business Radio Licences)
[46] Licences valid for 5 years and so licences valid until 2020/2021.

5 Conclusions on potential uses

Based on the above deliberations we have concluded that:

- There are a number of potential uses as identified in this report and reflected in the responses to ComReg's earlier consultation but there is no other suitable spectrum available in the medium term to meet the critical communications needs of smart grids compared with the situation for the other identified uses.

- Smart grids will require a minimum of 2 x 3 MHz contiguous spectrum due to likely equipment variant availability not supporting smaller bandwidths. Whilst there is currently no requirement for 2 x 5 MHz over time, applications such as video surveillance of key installations may be introduced requiring access to the full spectrum available.

- Alternative uses of spectrum in excess of 2 x 3 MHz may be suitable for NB-IoT which also uses LTE technology and so will not require any guard bands.

- While ComReg's preliminary view in their previous consultation was to award spectrum with 500 kHz bandwidth based on the potential uses mentioned in this report, and in particular PMR, it may be appropriate to consider smaller lots such as 100 kHz (see Table 3.2). Whatever the minimum block size it will be important to allow those who need greater bandwidth to aggregate channels and enable those who need contiguous channels to acquire them at low risk.

- If it is necessary, as part of the award procedure, to specify spectrum that is available to support contiguous channels then, considering ComReg's statutory obligations, we would propose that avoiding interference with existing services, at the upper end of the band, rather than what might materialise at the lower end (Radio Astronomy), should be a higher priority. Therefore, the lower part of the band should be identified for contiguous channels such as would be required by Smart Grids.

6 Implications for spectrum packaging and licence obligations

6.1 Spectrum packaging

Key questions for spectrum packaging are:

- FDD or TDD.
- Channel bandwidth.
- Out-of-band emission limits.

In considering these questions there is always a balance between technology neutrality and allowing as wide a range of uses as possible and reducing the risk of interference to other users in the same band and to adjacent bands.

FDD or TDD

As discussed in Section 3.2.1, there is a preference for FDD. While retaining the flexibility to use TDD would be ideal, TDD significantly increases the risk of interference to other users. Hence, our recommendation is to assume FDD, but to consider any future requests for TDD operations that might transpire on their merits and in the light of other nearby users.

Channel bandwidth

As discussed above, required bandwidths might vary from 100 kHz to 3 or even 5 MHz. The consultation document suggested that the spectrum be awarded with 500 kHz bandwidth allowing those who needed greater bandwidth to aggregate channels, but it is considered that, depending on the potential uses, that a 100 kHz bandwidth may be more appropriate for the award. This appears a viable strategy subject to an award approach that enables those who need contiguous channels to acquire them at low risk.

Emission limits

Current adjacent use is that the bands on the lower edge of each block are vacant whereas the bands on the upper edge are used for analogue PBR (Private Business Radio). There is a 250 kHz guard band proposed between the block to be awarded and the PBR usage. Unusually, the duplex direction varies across the PBR band, with some users having their uplink in the lower frequencies and some in the upper frequencies. PBR usage is light, with 13 licensees, some having multiple channels at multiple sites and mostly restricted to a few cities, especially Dublin.

The interference that might occur depends on the technology used in the 410 – 430 MHz block. As discussed above, the most likely technology appears to be LTE. ECC Report 240 and draft Report 283 suggest that there will be little interference between LTE and PBR if the uplink/downlink arrangements are in the same direction (e.g. uplink next to uplink) and the normal out-of-band emissions masks are used for LTE.

With the mix of duplex directions in Ireland, the risk of interference is increased somewhat. Set against this, is the very light PBR usage. On balance, it would seem better for Ireland to have least restrictive emission limits for the 410 – 430 MHz band, enabling the most advantageous use of the band, rather than a highly restrictive mask. Interference will likely not occur to PBR systems, but if it does then it should be relatively easy to provide new channels to the PBR users, further from the 410 – 430 MHz band, that will overcome these issues.

Hence, it seems likely that the OOB emissions limits set out in the various standards for broadband systems such as LTE and CDMA450 will be adequate to provide protection to PBR and no additional measures will be needed.

The relevant LTE emission masks are as follows:

Table 6.1: Relevant LTE mask[47]

Table 6.6.3.1-2: Wide Area BS operating band unwanted emission limits for 3 MHz channel bandwidth (E-UTRA bands <1GHz) for Category A

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement (Note 1, 2)	Measurement bandwidth (Note 8)
0 MHz ≤ Δf < 3 MHz	0.05 MHz ≤ f_offset < 3.05 MHz	$-5dBm - \frac{10}{3} \cdot \left(\frac{f\_offset}{MHz} - 0.05 \right) dB$	100 kHz
3 MHz ≤ Δf < 6 MHz	3.05 MHz ≤ f_offset < 6.05 MHz	-15 dBm	100 kHz
6 MHz ≤ Δf ≤ Δf_{max}	6.05 MHz ≤ f_offset < f_offset_{max}	-13 dBm	100 kHz
NOTE 1: For a BS supporting non-contiguous spectrum operation within any operating band, the minimum requirement within sub-block gaps is calculated as a cumulative sum of contributions from adjacent sub blocks on each side of the sub block gap. Exception is Δf ≥ 10MHz from both adjacent sub blocks on each side of the sub-block gap, where the minimum requirement within sub-block gaps shall be -13dBm/100kHz. NOTE 2: For BS supporting multi-band operation with Inter RF Bandwidth gap < 20MHz the minimum requirement within the Inter RF Bandwidth gaps is calculated as a cumulative sum of contributions from adjacent sub-blocks or RF Bandwidth on each side of the Inter RF Bandwidth gap.			

The relevant CDMA mask is as follows:

[47] Taken from LTE Evolved Universal Terrestrial Radio Access (E-UTRA) Base Station (BS) radio transmission and reception 3GPP TS 36.104 version 14.7.0 Release 14

Table 6.2: Relevant CDMA mask[48]

Table 3: Transmitter conducted unwanted emission limits for Band Class 11

For |Δf| Within the Range	Applicability	Emission Limit	
750 kHz to 885 kHz	Single carrier	-45-15(|Δf|-750)/135 dBc in 30 kHz	
885 kHz to 1 125 kHz	Single carrier	-60-5(|Δf|-885)/240 dBc in 30 kHz	
1,125 MHz to 1,98 MHz	Single carrier	-65 dBc / 30 kHz	
1,98 MHz to 4,00 MHz	Single carrier	-75 dBc / 30 kHz	
4,00 MHz to 6,00 MHz	Single and multiple carrier	-36 dBm / 100 kHz	
6,00 MHz to 10,00 MHz	Single and multiple carrier	-45 dBm / 100 kHz	
> 10,00 MHz	Single and multiple carrier	-36 dBm / 1 kHz -36 dBm / 10 kHz -36 dBm / 100 kHz -30 dBm / 1 MHz	9 kHz < f < 150 kHz 150 kHz < f < 30 MHz 30 MHz < f < 1 GHz 1 GHz < f < 12,5 GHz

NOTE 1: All frequencies in the measurement bandwidth should satisfy the restrictions on |Δf| where Δf = centre frequency - closer measurement edge frequency (f).
NOTE 2: For multiple-carrier testing, Δf is defined for positive Δf as the centre frequency of the highest carrier - closer measurement edge frequency (f) and for negative Δf as the centre frequency of the lowest carrier - closer measurement edge frequency (f).
NOTE 3: Limits >10MHz are aligned with CEPT/ERC/REC 74-01E [15].

The relevant TETRA mask is as follows:

Table 6.3: Relevant TETRA mask[49]

Table 6.6: Wideband noise limits for frequencies below 700 MHz

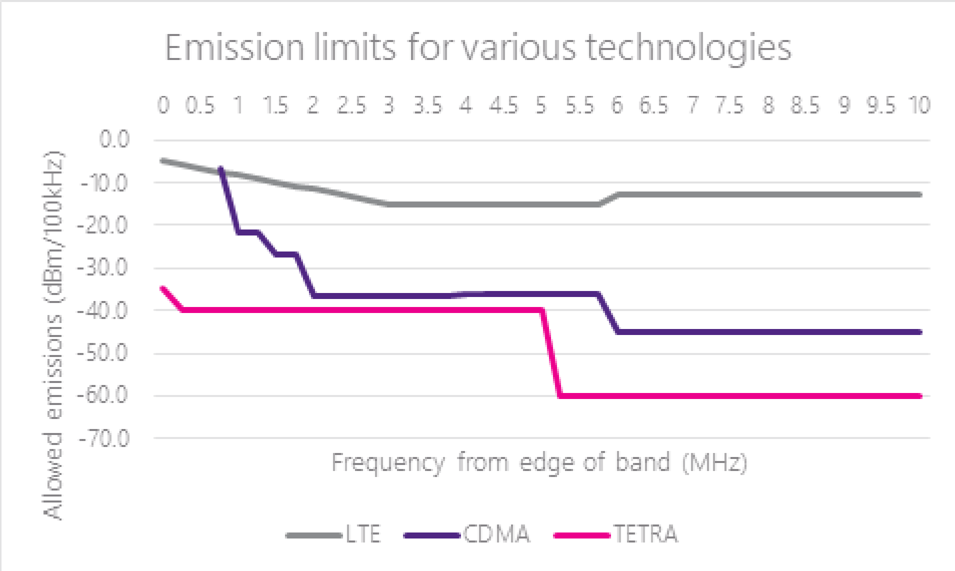
Frequency offset	Maximum wideband noise level		
	MS nominal power level ≤ 1 W (class 4)	**MS nominal power level = 1,8 W or 3 W (class 3L or 3)**	**MS nominal power level ≥ 5,6 W (class 2L) BS all classes**
100 kHz to 250 kHz	-75 dBc	-78 dBc	-80 dBc
250 kHz to 500 kHz	-80 dBc	-83 dBc	-85 dBc
500 kHz to f_{rb}	-80 dBc	-85 dBc	-90 dBc
> f_{rb}	-100 dBc	-100 dBc	-100 dBc

NOTE: f_{rb} denotes the frequency offset corresponding to the near edge of the receive band or 5 MHz (10 MHz for frequencies above 520 MHz) whichever is greater.

The figure below shows these drawn graphically:

[48] Taken from ETSI EN 301 449 V1.1.1 (2006-07)
[49] Taken from ETSI EN 300 392-2 V3.8.1 (2016-08)

Figure 6.1: Comparison of emission limits



From this is can be seen that LTE has by far the highest allowed out-of-band limits. Hence, these could be used for the emission masks with no limitations on other technologies.

Draft ECC Decision (19)02[50] has been developed in CEPT FM54 addressing the necessary technical conditions for sharing compatibility for land mobile systems in a number of frequency ranges including 410 – 430 MHz and for a range of different bandwidths from 6.25 kHz up to 5 MHz. It should be noted that Decides 2 currently says that "CEPT administrations have the right to decide which of the land mobile systems contained in the Annexes 1 to 4 this Decision can be introduced in their national frequency utilisation plan". The following proposed limits are based on Annex 2 which provides masks for 1.25, 1.4, 3 and 5 MHz channel bandwidths (wide band) in 410 – 430 MHz[51] as we expect LTE to be the most likely use of the band. It is noted that 1.25 MHz CDMA channelling arrangements could be implemented in the 410 – 420 MHz /420 – 430 MHz. The technical requirements defined in the draft ECC Decision are derived from ECC Report 283[52].

A) Base station transmitter mask

Table 6.4: BS frequency range of out-of-block emissions (1.4 MHz, 3 MHz and 5 MHz channel bandwidth)

Frequency range	Maximum mean out-of-block e.i.r.p. (dBm/cell)	Measurement bandwidth
UL band 410 – 420 MHz	-43	100 kHz
0 MHz ≤Δf < 0.2 MHz offset from BS transmit band edge	-11 dBm (see note)	100 kHz
0.2 MHz ≤Δf < 1 MHz offset from BS transmit band edge	-26 dBm (see note)	100 kHz
1 MHz ≤Δf < 10 MHz offset from BS transmit band edge	-43 dBm (see note)	100 kHz
Note: additional 40 dB out-of-block emission reduction may be needed on national level for the protection of radiolocation services.		

[50] https://cept.org/files/9522/Draft%20Decision%20(19)AA%20for%20PC.docx
[51] Specifically refers to LTE FDD channelling arrangements in the paired 410-415 MHz / 420-425 MHz, 411-416 MHz / 421-426 MHz and 412- 417 MHz / 422-427 MHz bands.
[52] Compatibility and sharing studies related to the introduction of broadband and narrowband systems in the bands 410-430 MHz and 450-470 MHz.

Table 6.5: BS frequency range of out-of-block emissions (1.25 MHz channel width)

Frequency offset from centre frequency (MHz)	Channel width 1.25 MHz	Measurement bandwidth
±0.885-1.98	-17 dBm	30 kHz
±1.98-4	-22 dBm	30 kHz

B) User Equipment

Table 6.6: UE transmitter characteristics

Parameter	Value
Channel bandwidth	1.25, 1.4, 3 or 5 MHz
Maximum mean in-block power	23 dBm
Note: administrations may use higher UE maximum mean in-block power for special deployment scenarios, e.g. fixed terminal stations in rural areas provided that protection of other services, networks and applications is not compromised. Vice-versa, the maximum mean in-block power of UEs for the protection of other services may be limited on a cell-by-cell basis.	

Table 6.7: UE maximum unwanted emission levels (1.4 MHz, 3 MHz and 5 MHz channel width)

Frequency offset from channel edge (MHz)	Channel width			Measurement bandwidth
	1.4 MHz	3 MHz	5 MHz	
±0-1	-10 dBm	-13 dBm	-15 dBm	30 kHz
±1-2.5	-10 dBm	-10 dBm	-10 dBm	1 MHz
±2.5-2.8	-25 dBm	-10 dBm	-10 dBm	1 MHz
±2.8-5		-10 dBm	-10 dBm	1 MHz
±5-6		-25 dBm	-13 dBm	1 MHz
±6-10			-25 dBm	1 MHz

Table 6.8: UE maximum unwanted emission levels (1.25 MHz channel bandwidth)

Frequency offset from channel edge (MHz)	Channel width 1.25 MHz	Measurement bandwidth
±0.885-1.98	-24 dBm	30 kHz
±1.98-4	-44 dBm	30 kHz

The limits for wideband systems in the draft ECC Decision are more conservative (stringent) than the usual BEMs you would see in the traditional cellular bands as noted in Figure 6.1.

The technical requirements for land mobile systems with channel bandwidths of between 6.25 kHz and 200 kHz are defined in Annex 1 of the draft ECC Decision and specify:

Wanted channel effective radiated power: 40 dBm for user equipment and 53 dBm for base station equipment

Adjacent and alternate adjacent channel power: Power in upper and lower channels shall not exceed a value of 60 dBc below the transmitter power level without the need to be below the -36 dBm e.r.p.

Unwanted emissions in the spurious domain: During operation shall not exceed -36 dBm for frequencies up to 1 GHz and -30 dBm for frequencies above 1 GHz. During standby shall not exceed -57 dBm for frequencies up to 1 GHz and -47 dBm for frequencies above 1 GHz.

Whether it is feasible to deploy a mix of narrow and wideband systems in the 410 – 430 MHz band is less clear. In Section 2.2 it was mentioned the possibility of deploying NB-IoT in the LTE guard band and Annex 4 of the draft ECC Decision addresses the technical conditions for such a deployment – in particular Tables 14 to 16 in section A4.3. However, the situation for deployment of other narrowband systems will very much depend on the sensitivity required of the narrow band system in the geographic vicinity of the wide band system. Interference from a wideband system into a narrowband system will appear as if it is white noise[53]. Even with the more stringent limits the 5 MHz wide channel does not roll-off like a PMR network and there is still -26dBm / 100 kHz at a frequency offset of 200 kHz to 1 MHz and -43 dBm/ 100 kHz between 1 and 10 MHz. So even with a 200 kHz guard band there is the potential for the near far effect which could be alleviated by co-siting or close siting of the PMR and wideband transmitters – this could be considered as an acceptable condition to support a mix of narrowband and wideband systems or indicate that additional spectrum for PMR will need to be managed by ComReg and information provided by wideband users on their BS locations.

Another consideration is potential use of the 406.1 – 410 MHz band for radio astronomy. The draft ECC Decision notes that ' … the band 406.1 – 410 MHz is allocated on a primary basis to both the land mobile service and the radio astronomy service whereas footnote 5.149 of the Radio Regulations urges administrations to take all practicable steps to protect the radio astronomy service from harmful interference.' In Annex 2 of the Draft ECC Decision it says, "an additional 40 dB out-of-block emission may be needed on a national level for the protection of radiolocation services".

It might be reasonably expected that were Radio Astronomy to be introduced after licensing the band above 410 MHz that the astronomers and the licence holders could look to coordinate deployments around critical areas. Hence, while it is not possible at this stage to guarantee that any radio astronomy deployment would be possible for any use of the band above 410 MHz, in practice it seems likely that future use could be accommodated.

Based on the likely technologies to be deployed in this band, as discussed in Sections 2 and 3, we recommend that the appropriate limits from Draft ECC Decision (19)02 as they are based on the recently conducted sharing studies between different technologies as described in ECC Report 283 and should provide sufficient protection as well as being suitable to be used as the basis of coordination between licensees. As noted earlier Annex 2 will apply to CDMA and LTE where the bandwidths are between 1.25 MHz and 5 MHz and Annex 1 to land mobile technologies where bandwidths are between 6.25 kHz and 200 kHz.

6.2 Licence obligations

The potential uses and technology options for the band will have implications for the licence obligations and in particular for the licence duration as discussed below.

[53] It should be noted that in general studies have looked 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.

6.2.1 Licence duration

The potential uses are mainly for services and networks that have an expectation of a long lifetime (15 years or longer) and networks will not be replaced as long as they continue to meet the operational and economical requirements. In particular the investment in networks is significant and the timescales for replacement are several years with the added need for comprehensive testing. In the case of smart grids, it is necessary to refit sensors and controllers which is a significant overhead as well as the cost of the communications network. It also requires comprehensive testing. Scanning telemetry was introduced over 20 years ago in the UK for the utilities. The technologies deployed, and associated equipment, therefore must be available and supported by vendors for equivalent timescales. Therefore, we foresee that licences will need to be equivalent to the expected lifetime of the networks of no less than 15 years.