

# **UHF 1 & 2 Future Demand Final Report**

**Ofcom**

**2607/BRFD/FR/V2**

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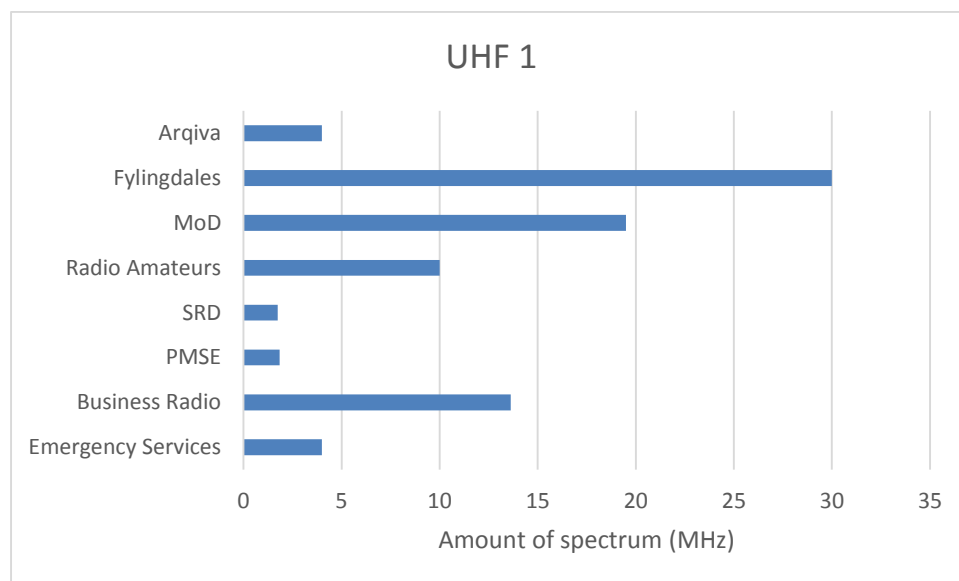
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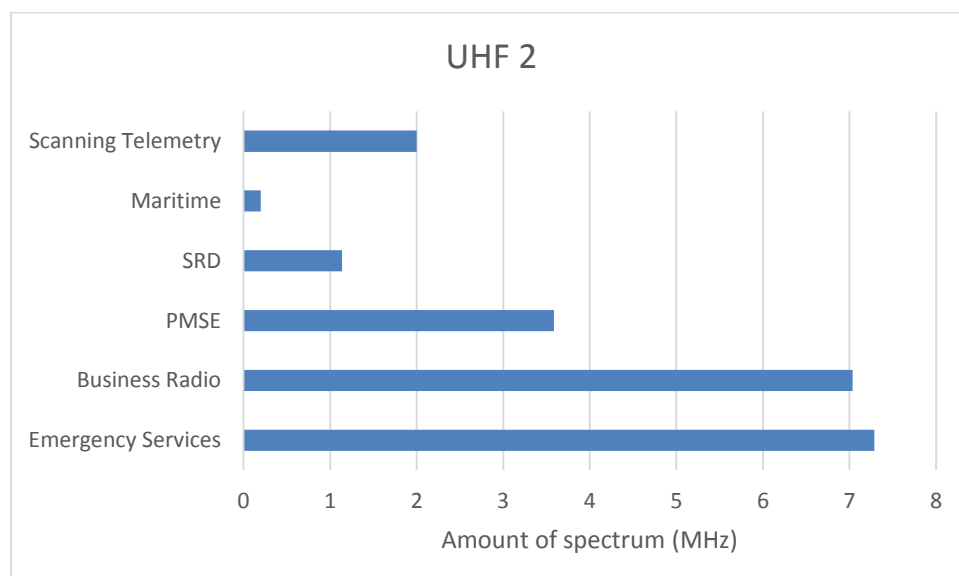
## 0. EXECUTIVE SUMMARY

The 420 to 470 MHz spectrum is attractive for both existing users and potential new users because of its favourable propagation characteristics which provide good coverage, potential to operate over non line of sight paths, as well as good building penetration. The use of spectrum is currently very fragmented because of the way it has historically been allocated taking into account limitations in the equipment deployed and existing users (initially MOD and Home Office). The spectrum is now used for a wide range of applications and users as shown in the figures below.

### UHF 1 (420 to 450 MHz) comparing use of frequencies (Source: Aegis)



### UHF 2 (450 to 470 MHz) comparing use of frequencies (Source: Aegis)



The total spectrum in both figures above is higher than the spectrum available in UHF1 and UHF2 (30 MHz and 20 MHz respectively) and this is due to the spectrum being shared between users. This is specifically noticeable in 420 to 450 MHz where a significant amount of the spectrum is shared between users (e.g. Business Radio and MOD and Fylingdales with the MOD and Fylingdales both imposing constraints on the use of the spectrum for Business Radio.

If we consider UHF 1 further there are three exclusive allocations between 410 and 420 MHz, 2 MHz to Emergency Services, 2 MHz to Arqiva and 6 MHz to MOD. However between 420 and 450 MHz there are no exclusive allocations and the following uses are present in the band:

1. MOD and the Fylingdales radar system
2. Business Radio
3. PMSE
4. Radio Amateurs

SRD use of the spectrum is authorised on a national and unco-ordinated basis through exemption regulation and the associated equipment constraints defined in the Interface Requirements.

In addition the fragmentation has led to a mix of simplex and duplex operation within the UHF 1 and 2 bands with different duplex spacings, which are not compatible with the internationally harmonised band plan defined in CEPT Recommendation T/R 25-08 which is used in neighbouring mainland European countries. Nevertheless, the bands carry a sizeable proportion of UK Business Radio traffic and most UK current users of these frequencies see them as being key to their business.

This report identifies potential demand and options for the ongoing access to and use of the 420 to 470 MHz bands through a number of scenarios which form the central focus of the Study. They are:

- Incumbent growth under the current band configuration
- Expansion (or reduction) of emergency services' use of the band
- Incumbent growth leading to band reversal
- Deployment of managed networks in the band
- Introduction of LTE 450 in the band

In addition the Study considered whether the appointment of a band manager would be helpful if the band was to be re-organised.



The outcome of the scenarios has highlighted the following challenges and considerations:

Challenges:

- Further spectrum might be required to support growth in demand from the Business Radio sector—it has been estimated that there may be a need for a further 1.4675 MHz of spectrum. Current congestion reported by Ofcom for technically assigned licences in London could extend to other major metropolitan areas (e.g. Birmingham, Manchester, Glasgow etc.). There is significant growth seen in demand for light licences (Simple UK and Simple Site) but this may in part be due to industry's perception that obtaining technically assigned licences in major metropolitan areas is difficult or even impossible<sup>1</sup>. There are also indications of an unmet demand for wideband systems.
- The Governmental requirements on the Utilities, leading to a huge increase in the number of monitoring points in their networks, will require substantial additional spectrum<sup>2</sup>.
- PMSE will continue to require a significant amount of spectrum and as a minimum will need to retain their current allocations.
- Emergency Services, whilst they have identified the need for further access to existing spectrum allocations to support new applications, may be in a position to release some of their current frequencies if they can further exploit consolidation of systems and sharing of existing allocations. This would include measures such as utilising the Department of Health spectrum in UHF1, looking at means to utilise the public safety bands at 380 MHz and 390 MHz post Airwave and potentially consolidating systems or looking to migrate them onto the future Emergency Services Network (ESN). However the viability and timescales of this would need to be considered as timings will need to be aligned with the ending of the current Airwave contract which is currently due to end in December 2020 according to the ESN milestones and timing information.

Considerations:

- There might be the potential to free up spectrum through a review of the licensing and assignment approach for Business Radio. Consideration should also be given regarding the option of migrating some users to other frequency bands or solutions. It is however unclear how effective this might be on its own. As an overall consideration, it is most likely that it will be

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<sup>1</sup> Light licences are used as a substitute for technically assigned licences.

<sup>2</sup> The Utilities do not consider that the cellular networks will be able to meet their latency or power back-up requirements.

extremely difficult to find sufficient 'useful' spectrum, especially any contiguous frequencies, to meet the new demand without a major re-engineering exercise of the 420 to 470 MHz band because of the fragmented use.

- Alternative technologies, such as CDMA 450 and LTE 450 might prove more efficient in meeting the Utilities increased network monitoring requirements whilst at the same time providing the potential to support their video and communications needs as well. This assumes the Utilities are combined on a single self-managed network. Band reversal would be necessary, in such an instance, as it is not expected that vendors would be willing to support a UK only solution or lead to a high cost / single vendor situation making it non-viable.
- The requirement to support the currently un-met demand for wideband PMR<sup>3</sup> would also require band reversal.
- It appears there might be some interest in providing managed networks using technologies such as dPMR, TETRA or CDMA 450. However it is not clear what the take up will be and much will depend on the attractiveness of the offerings and the level of service provided to the end users. Rolling out such networks nationally across the UK is likely to be both challenging and expensive compared to other countries where these networks have been launched. It is also not clear that there would be sufficient spectrum available if any of these became really successful. In addition to roll-out a network that meets potential user's needs it will be necessary to identify a reasonable amount of spectrum to allow for capacity requirements as well as geographic roll-out so that the risk of own interference does not lead to users leaving the network. If the networks of this type are not hugely successful it may tie up spectrum for many years without having any positive impact on the efficient use of the spectrum.
- Currently there are no indications of interest in using the 450 MHz band for LTE 450 for rural broadband solutions in Europe and where there are plans to deploy this it is based on a Fixed Wireless Access solution. Therefore it is expected that if LTE were to be deployed in the UK it would be within closed user groups (e.g. the Utilities) for M2M (telemetry) rather than by a MNO (Mobile Network Operator).

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<sup>3</sup> In ECC Decision ECC DEC(04)06 (see

<http://www.erodocdb.dk/docs/doc98/official/pdf/ECCDEC0406.pdf>) the term wideband is intended to cover digital systems providing data rates of several hundred kbit/s. Bandwidth requirements vary between 200 kHz for TETRA TAPs, 1.25 MHz for CDMA-PAMR and between 25 kHz and 200 kHz for TETRA Teds.

- There are indications of increased use of the UHF 1 and 2 bands in neighbouring countries and also reports of interference from this use. Band reversal has the potential to minimise the risks of interference from mainland Europe. This “new” interference is wideband and more challenging / impossible to escape from than the individual channel interference cases experienced in the past. Worsening the situation is the current UK band configuration as it is not the individual mobile that is suffering interference and unable to communicate but the base station receiver rendering the whole network of very little use. The interference risk would be much lower if the UK is aligned with Europe as any interference into base station receivers in the UK will be from mobile transmitters normally deployed at lower heights with the potential to be hidden in the clutter and transmitting with lower powers. The benefit is greater than often depicted<sup>4</sup> because of the traditional positioning of base station towers on natural high ground whereas mobiles will be used wherever communication is required averaging the geographical distribution more evenly.
- Band reversal is a significant exercise and the cost for UHF 2 was estimated to be between £260M and £310M in 2004<sup>5</sup>. For most users there is no perceived need to undertake such re-engineering as their spectrum requirements are met and there is no risk of interference. It is assumed that the only way band reversal may be achieved is through regulatory intervention from Ofcom who will need to make the decision on the basis of efficient and effective use of the spectrum and whether they can provide the market (industry and users) with the required usable spectrum to meet developing needs. The possibility of a Band Manager<sup>6</sup> facilitating band reversal was considered and rejected.

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<sup>4</sup> The normal approach to undertaking interference prediction is to use a standard approved propagation model at a certain time/location percentage. A 1% value is often used for such predictions. The model used for this Study is reasonably representative for base station to base station interference because the base stations are typically at a fixed location on natural high ground. However, to model interference to and from mobile equipment a time/location percentage of 50% would be more representative. A change from 1% BS/BS to 50% BS/MS and MS/BS will show a much larger impact of band reversal than the usual predictions where the 1% time/location will compress the result variations between BS and MS interference.

<sup>5</sup> Source: PA Consulting Study.

<sup>6</sup> Although a Band Manager might be able to provide financial incentives for users to move it is considered unlikely that any one would have a viable business case or sufficient flexibility to undertake such a significant exercise.

# 1 INTRODUCTION

The use of spectrum in the 420 to 470 MHz band in the UK is currently very fragmented because of the way it has historically been allocated taking into account limitations in the equipment deployed and existing users (initially MOD and Home Office). The spectrum is now used for a wide range of applications and users. This fragmentation has led to a mix of simplex and duplex operation with different duplex spacings, none of which are compatible with the internationally harmonised band plan defined in CEPT Recommendation T/R 25-08. As a result the UK has been unable to take advantage of wider band technologies such as CDMA450, which have been implemented in a number of other European countries. Nevertheless, the bands carry a sizeable proportion of UK Business Radio traffic and most UK current users of these frequencies see them as being key to their business.

A further constraint on the bands is that a significant part of the spectrum, 420 to 450 MHz, is allocated for use by the MOD on a primary basis and can only be used for other services on the basis of individual channels agreed between Ofcom and the MOD<sup>7</sup>. This has of course had a major impact on how the allocations in the spectrum have developed and as a result of the fragmentation, earlier attempts to bring the spectrum in line with use in mainland Europe<sup>8</sup> have proved impractical.

This report is intended to identify potential demand and options for the ongoing access to and use of the 420 to 470 MHz bands through a number of Scenarios which form the central focus of the Study. It should be noted that the views expressed here are not necessarily those of Ofcom or the interviewees but have been developed by the Study Team over the course of the Project.

Aegis Systems Ltd would like to thank everyone who contributed to this Report through the interview process.

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<sup>7</sup> See Annex C of the UK Frequency Allocation Table which details the frequency sharing arrangement between civil land mobile and military services in the 410 to 450 MHz band available at [http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-information/UKFAT\\_2013.pdf](http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-information/UKFAT_2013.pdf)

<sup>8</sup> In Europe the use of the band is aligned with CEPT Rec. T/R 25-08. In addition the use of the spectrum is generally less fragmented.

## 2 OVERVIEW

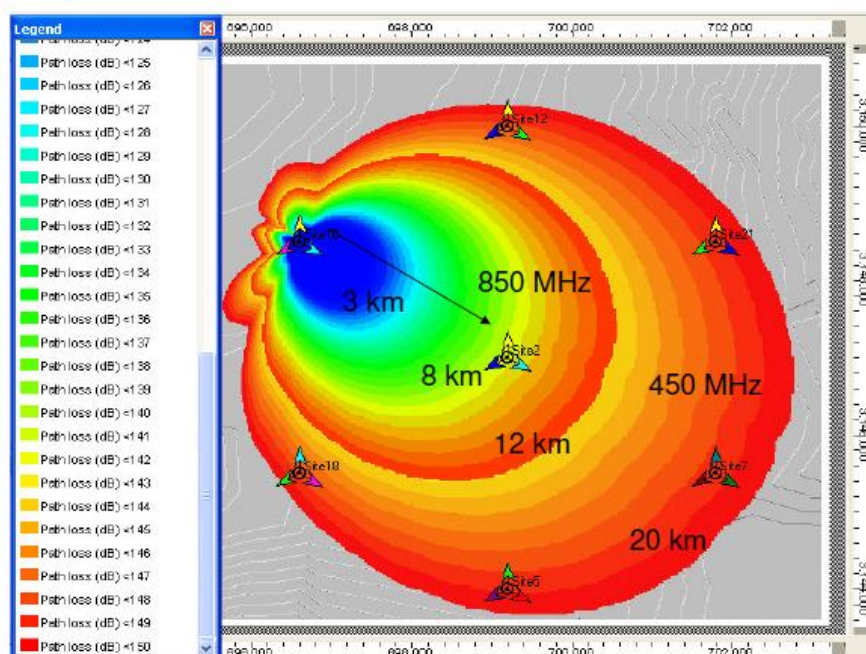
### 2.1 Why is This Spectrum Important?

The 420 to 470 MHz spectrum is attractive for both existing and potential new users because of its favourable propagation characteristics which provide good coverage, potential to operate over non line of sight paths, as well as good building penetration.

Comparisons have been made in terms of coverage between the 450 MHz band and other frequency bands and for example, according to Alcatel-Lucent a single 450 MHz base station can cover the same geographic area as 3 base stations at 850 MHz, 13 at 1900 MHz and 16 at 2.1 GHz. The figure below shows the typical distances that can be achieved from a transmitter site with 850 MHz and 450 MHz frequencies.

**Figure 1: Comparison of typical path loss and achievable coverage at 450 MHz and 850 MHz (Source: Qualcomm)**

#### Typical Path loss - Okumura-Hata Model



Clearly this makes the spectrum attractive for potential deployment scenarios where it is important to maximise coverage such as in rural areas or where wider coverage is required from a single site. Also in the case of rural cellular networks the increased coverage decreases the overall network costs as fewer sites and links are required.

Whilst the antennas that are required to use the band are larger compared with the 900 MHz band it is still possible to develop reasonably sized handheld terminals<sup>9</sup> acceptable to industrial users and at base transmitter sites pole mounted antennas such as Yagis can be deployed providing a significant cost saving compared with panel antennas.

In addition this spectrum has a low noise floor compared with other frequency bands<sup>10</sup>. This makes it attractive to use at sites where there is other equipment installed and potential for EMC interference. This feature also makes the band very popular for data transmissions, again helped by better long term fading characteristics than at the lower frequency bands.

Other advantages, especially in the case of SRD's, are the stability of the oscillators and the ability to provide devices that can be battery operated and fully encapsulated.

## 2.2 Available Spectrum

The amount of available spectrum is limited in terms of bandwidth even if all the existing users were migrated from the band. For example, if 410–430 MHz was paired with 450–470 MHz this would only provide 2 x 20 MHz of spectrum. However, this would of course not take into account Fylingdales<sup>11</sup> or the Maritime on-board international allocation which would lead to deployment constraints. It would however be incompatible with deployments of CDMA 450 in the Netherlands and Belgium. Another alternative approach could be to use the 447 to 467 MHz to create a two channel (i.e. 2 x 10 MHz) downlink and a smaller tranche (10 MHz) for uplink in 410–420 MHz<sup>12</sup>. This generally respects the Fylingdales allocation except for the 3 MHz (447–450 MHz), the licence exempt PMR 446 and the Maritime on-

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<sup>9</sup> In the case of hand portables used for Business Radio the UHF band is considered to be the only spectrum that is suitable. Handheld devices are viable with antennas less than 20 cm and will still be around 100% efficient whereas in the VHF bands the antennas would have to be around 40 cm in length and limiting them to 20 cm would significantly decrease their efficiency.

<sup>10</sup> For example see the document CBS/SG-RFC 2005/Doc. 5(1) which provides "Results of Ambient RF Environment and Noise Floor Measurement Taken in the U.S. in 2004 and 2005" submitted to Steering Group on Radio Frequency Coordination in March 2006.

<sup>11</sup> According to the Ofcom Business Radio Technical Frequency Assignment Criteria, see <http://licensing.ofcom.org.uk/binaries/spectrum/business-radio/technical-information/tfac/ofw164.pdf>, "all Business Radio frequency assignments in this band [420–450 MHz] must be coordinated with RAF Fylingdales. The coordination agreement requires that any new (or variation to an existing) Business Radio frequency assignment must not cause an increase in the total received interference power at the radar site beyond a pre-specified limit. Any new deployment and/or any change to the technical parameters of an existing deployment using this frequency band must be put through the UHF1 co-ordination process.

<sup>12</sup> This would provide an asymmetric FDD allocation that will potentially reflect likely traffic (i.e. greater traffic volumes in downlink than uplink).

board allocation just above 457 MHz and creates a guard band for Broadcasting operating above 470 MHz. However, it would require release of auctioned spectrum currently held by Arqiva, which is unlikely as part of this spectrum will be used to provide smart metering, and sharing agreements with the MOD to access the 414–420 MHz. This demonstrates the difficulties in re-arranging the use of the bands.

Another consideration for potential re-arrangement of the bands is Annex 1 of CEPT Recommendation T/R 25-08, see Figure 2 below, for Business Radio (Land Mobile) applications which provides the recommended spacing and location of base transmit, mobile transmit and simplex bands based on ERC Report 25<sup>13</sup>. This is the approach adopted in mainland Europe.

**Figure 2: Channel plans for UHF bands (Annex 1 T/R 25-08)**



Where Du refers to duplex operation, Si simplex operation, ML mobile station and FB base station.

## 2.3 Current Situation (Status Quo)

The UHF bands (UHF 1 and UHF 2) are highly sought after because of, as noted earlier, the propagation characteristics that make it possible to operate over longer, sometimes obstructed paths and for the good in-building penetration. As a result there are a wide range of uses and users in these two bands as demonstrated in Table 1 and Table 2 below:

**Table 1: UK UHF 1 showing current users / applications**  
(Source: Aegis based on Ofcom information)

Frequency range (MHz)	Amount of spectrum (MHz)	User / Licensee/ Application	Comments
410–412	2	Emergency Services (Department of Health)	See UK FAT 2013, Annex I
412–414	2	Arqiva	Auctioned spectrum
414–420	6	MOD	
420–450	30	MOD (Fylingdales military radar)	Places constraints on other users of the band.

<sup>13</sup> ERC Report 25—“The European Table of Frequency Allocations and Utilisations”

Frequency range (MHz)	Amount of spectrum (MHz)	User / Licensee/ Application	Comments
420–422	2	Emergency Services (Department of Health)	See UK FAT 2013, Annex I
422–424	2	Arqiva	Auctioned spectrum
424–425	1	MOD	
425–429	4	MOD	Shared with civil land mobile. See UK FAT 2013, Annex C
425.0125–429.475	4.4625	Business Radio	Shared with MOD who are primary users
425.3125–425.5625	0.25	PMSE	See UK FAT 2013, Annex H. Secondary use
427.7625–428.0125	0.25	PMSE	See UK FAT 2013, Annex H. Secondary use
430–440	10	Radio Amateurs	See UK FAT 2013, Annex F. Secondary use
431–432	1	MOD	Shared with civil land mobile. See UK FAT 2013, Annex C
431.00625–431.99375	0.9875	Business Radio	Shared with MOD who are primary users
433.05–434.79	1.74	SRD	Non Specific SRD—harmonised allocation. Model control UK. See UK FAT 2013, Annex B. Secondary use
440–443.5	3.5	MOD	Shared with civil land mobile. See UK FAT 2013, Annex C
440.0125–443.975	3.9625	Business Radio	Shared with MOD who are primary users
442.2625–442.5125	0.25	PMSE	See UK FAT 2013, Annex H. Secondary use
445.5–449.5	4	MOD	Shared with civil land mobile. See UK FAT 2013, Annex C
445.5125–449.725	4.2125	Business Radio	Shared with MOD who are primary users



Frequency range (MHz)	Amount of spectrum (MHz)	User / Licensee/ Application	Comments
446.425–447.5125	1.0875	PMSE	See UK FAT 2013, Annex H. Secondary use

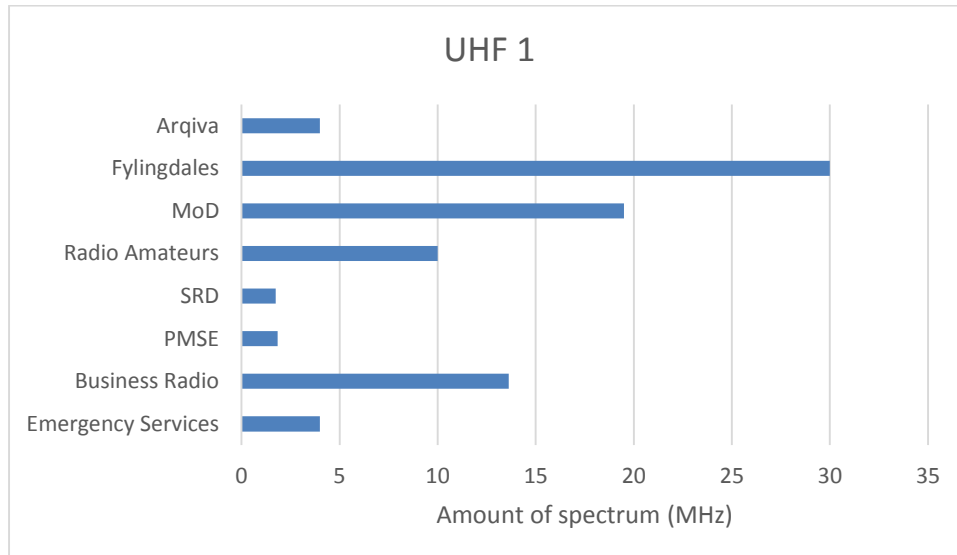
**Table 2: UK UHF 2 showing current users / applications**  
(Source: Aegis based on Ofcom information)

Frequency range (MHz)	Amount of spectrum (MHz)	User / Licensee/ Application	Comments
450–453	3	Emergency Services	See UK FAT 2013, Annex I
453.0125–455.875	2.8625	Business Radio	
454.9875–455.4625	0.475	PMSE	See UK FAT 2013, Annex H Secondary use
455.875–456	0.125	Emergency Services	See UK FAT 2013, Annex I
456–456.9875	0.9875	Business Radio	
457–457.25	0.25	Emergency Services	See UK FAT 2013, Annex I
457.25–457.475	0.225	PMSE	See UK FAT 2013, Annex H
457.475–457.5	0.025	Emergency Services	See UK FAT 2013, Annex I
457.5–457.6	0.1	Maritime	International allocation. Paired with 467.5–467.6 MHz
457.5–458.5	1	Scanning Telemetry (Utilities)	Paired with 463–464 MHz 80 paired 12.5 kHz channels
458.5–458.95	0.45	SRD	Telemetry & Telecommand and Model control. See UK FAT 2013, Annex B
458.95–459.5	0.55	SRD	Model control. See UK FAT 2013, Annex B
458.825	-	SRD	Fixed alarms. See UK FAT 2013, Annex B
458.8375	-	SRD	Safety alarms. See UK FAT

Frequency range (MHz)	Amount of spectrum (MHz)	User / Licensee/ Application	Comments
			2013, Annex B
458.9	-	SRD	Vehicle paging alarms. See UK FAT 2013, Annex B
458.9625–459.1	0.1375	SRD	Medical & biological. See UK FAT 2013, Annex B
459–459.49375	0.49375	Business Radio	
459.49375–459.50625	0.0125	Emergency Services	See UK FAT 2013, Annex I
459.50625–459.51875	0.0125	Emergency Services	See UK FAT 2013, Annex I
459.53125–459.54375	0.0125	Emergency Services	See UK FAT 2013, Annex I
459.54375–460.5	0.95625	Business Radio	
460.5–460.75	0.25	Emergency Services	See UK FAT 2013, Annex I
460.75–462.4875	1.7375	Business Radio	
461.23125–461.25625	0.025	PMSE	See UK FAT 2013, Annex H
462.5–462.75	0.25	Emergency Services	See UK FAT 2013, Annex I
462.75–463	0.25	PMSE	See UK FAT 2013, Annex H
463–464	1	Scanning Telemetry (Utilities)	Paired with 457.5–458.5 MHz
464–466.0625	2.0625	Emergency Services	See UK FAT 2013, Annex I
466.0875–467.25	1.1625	Emergency Services	See UK FAT 2013, Annex I
467.2625–469.875	2.1625	PMSE	See UK FAT 2013, Annex H. Secondary basis.
467.5–467.6	0.1	Maritime	International allocation. Paired with 457.5–457.6 MHz
469.875–470	0.125	Emergency Services	See UK FAT 2013, Annex I

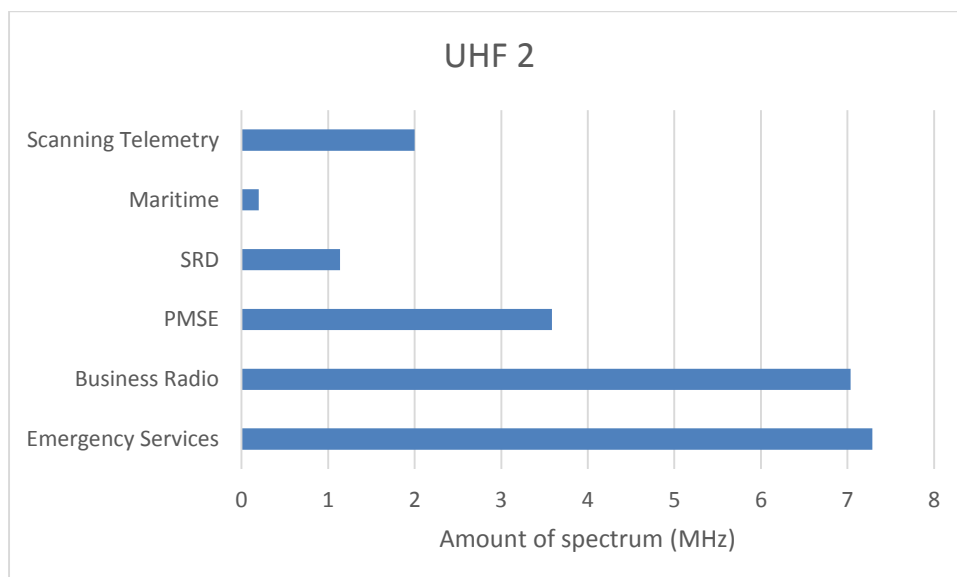
In Figure 3 and Figure 4 below the relative spectrum allocated by user / application is shown. It has to be remembered that with the exception of 410–420 MHz in UHF 1 the spectrum is shared (e.g. MOD and Fylingdales with Business Radio).

**Figure 3: UK UHF 1 comparing use of frequencies (Source: Aegis)**



The figure below provides an overview of the spectrum allocated to the various users in UHF2.

**Figure 4: UK UHF 2 comparing use of frequencies (Source: Aegis)**



As can be seen from the tables and figures above the existing users and uses of the UHF 1 and UHF 2 bands include:

- **MOD** in the 420 to 450 MHz (UHF 1) band where the frequencies are used at military bases as well as for manoeuvres and convoys anywhere within the country. The Fylingdales Early Warning Radar that uses 420 to 450 MHz also

imposes limits on the usage of the UHF 1 band and requires co-ordination as part of the assignment and deployment processes.

- **Business Radio** is used by a wide range of different users from taxi companies with limited geographic coverage to Utilities, rail and transport networks that may require national coverage and support hundreds of mobiles. Licences are either for frequencies that can be used over a defined geographic area or are for a single base station or equivalent system (technically assigned licences) with the frequencies re-used many times across the UK for different licensees across different geographies.

According to the FCS<sup>14</sup> demand for frequencies<sup>15</sup> from Business Radio services has remained buoyant in the UK despite the growth in cellular mobile radio. Equipment sales have been growing strongly with the advent of digital mobile radio<sup>16</sup>. Technology developments now enable two digital PMR voice or data channels to be carried in a single 12.5 kHz analogue voice channel, using either frequency division or time division techniques, enabling the available Business Radio spectrum to be used more efficiently.

Currently in the UHF bands channel spacings of 6.25 kHz, 12.5 kHz and 25 kHz are used, and other bandwidth and spacings may be assigned on request on a case-by-case basis<sup>17</sup>. The majority of systems currently operate on simplex or duplex 12.5 kHz channels. In the UHF 1 and UHF 2 bands a number of different duplex splits are used for dual frequency (duplex) channels; UHF1 mostly uses 14.5 and 20.5 MHz splits and UHF 2 mostly uses 5.5 and 6.5 MHz splits (the emergency service sub-bands use larger duplex separations, up to 14 MHz). It has been problematic for the UK to use the CEPT recommended 10 MHz duplex spacing because of the historic channel configuration. In addition to the above mentioned services there are also channels identified for paging systems.

In terms of the number of licences and amount of spectrum allocated, Business Radio is the most significant civil use of these bands. Table 3 below shows the information on number of customers, licences and assignments for the technically assigned and area defined licence classes at the end of 2013.

<sup>14</sup> Federation of Communication Services that represent the Mobile Communications Industry.

<sup>15</sup> Note a licence may include a number of frequencies so any increase in frequency demand may not necessarily be reflected in licence numbers. Additional frequencies may be requested by existing licensees and if it is feasible to meet their requirements will be included within an existing licence.

<sup>16</sup> Federation of Communications Services (FCS) reported in 2010 that up to 60% of new sales were digital and that the overall industry consensus was that the digital products might supersede analogue in 8–15 years but replacement of the complete radio base might take longer because of equipment lifetimes of 10 or more years. See “Future Strategy for Business Radio: Industry opinions on development of the sector—October 2010”.

<sup>17</sup> See Business Radio TFAC.

In UHF 1 (420–450 MHz) assignments are geographically limited by the need to share with MOD and the relevant geographic locations are detailed in the UK FAT Annex C. In addition frequencies have to be coordinated with RAF Fylingdales. It is these restrictions that account for the significantly lower number of Business Radio licences in this frequency range. For example there are 3,332 technically assigned licences in 13.625 MHz in 420–450 MHz and 12,854 in 7.0375 MHz in 450–470 MHz with a similar difference in the number of assignments.

Table 3 below provides an overview of the customers, licences and assignments in UHF1 and UHF2 for Business Radio Technically Assigned and Area Defined licences.

**Table 3: Information on Business Radio licences in UHF 1 band (420–450 MHz) and UHF 2 band (450–470 MHz) in 2014 (Source: Ofcom)**

Licence class <sup>18</sup>	UHF 1			UHF 2		
	Number of customers	Number of licences	Number of assignments	Number of customers	Number of licences	Number of assignments
<b>Technically assigned</b>	1,873	3,332	5,202	6,042	12,854	18,161
<b>Area defined</b>	14	14	51	35	65	112

In addition Ofcom also offers “Light licences” as shown in the table below.

**Table 4: Information on Business Radio Light licences in the UHF 1 and 2 bands in 2014 (Source: Ofcom)<sup>19</sup>**

UHF 1		UHF 2	
Number of customers	Number of licences	Number of customers	Number of licences
10,279	10,729	5,157	8,906

<sup>18</sup> See Business Radio TFAC

<sup>19</sup> There is no split available by different type of simple UK licence (i.e. simple UK, simple site and suppliers) available. Assignments are not relevant for these licence products as the licensees share frequencies from a defined group of available frequencies. For example in the case of Business Radio simple site licenses there are 17 channels available in the UHF 2 band between 459.05 and 459.475 MHz.

Looking at the number of licences in 2014, shown in Table 3 and Table 4, for the different Business Radio licence classes<sup>20</sup> it can be seen that the majority are for light licences (19,635) followed by technically assigned (16,186). Light licences include simple site and simple UK licences which allow licensees to choose from a set of 12.5 kHz and 25 kHz base and mobile transmit frequencies listed in the licence document. There is no guarantee of protection from interference but users have the option of retuning to an alternative frequency if there are any problems. In the case of simple site licences they are generally for a base station and mobiles operating over a very limited geographic area (e.g. 1 km radius). Technically assigned licences are generally requested where the requirement is to provide coverage over a “small to medium size geographic area<sup>21</sup> and require a degree of protection from other users”.

An indicative value for the frequency (channel) re-use has been calculated for the UHF 1 and UHF 2 bands of 5 and 33 respectively. This is based on the total amount of spectrum available to Business Radio in UHF 1 of 13.625 MHz (see Figure 3) and 7.0375 MHz in UHF 2 (see Figure 4) and assumes a typical channel bandwidth of 12.5 kHz and only considers the number of technically assigned assignments achieved as listed in Table 3<sup>22</sup>. In the case of the light licences it is expected that a much larger re-use of the available frequencies is achieved.

In the case of Business Radio it is important to note, when considering the scenarios in Section 3, that frequencies may be used by companies to provide managed networks for end users. These may be in the UHF band but others operate in the VHF band.

- **Maritime** where specific frequencies in the range 457.5–457.6 and 467.5–467.6 MHz are identified internationally for maritime on-board communications (ITU RR footnote 5.287), which may be used in coastal areas and navigable waterways.
- **Scanning telemetry** which is used mainly by the water, gas and electricity industries for data acquisition and control at remote sites has access to the

<sup>20</sup> For a description of the different classes of licences see <http://licensing.ofcom.org.uk/binaries/spectrum/business-radio/technical-information/tfac/ofw164.pdf>

<sup>21</sup> For example between 5 and 20 km radius.

<sup>22</sup> Whilst re-use is calculated on the basis that all the available spectrum is used for technically assigned frequencies (assignments) and assumes that each assignment has a bandwidth of 12.5 kHz it should however be noted that this spectrum is also available for area defined licences and also light licences (e.g. simple site and simple UK) so in practice greater usage of the available spectrum is achieved. In UHF 1 there is a total of 1090 12.5 kHz channels available and there are 5202 technical assignments so the re-use is 4.77 which has been rounded up to 5. In UHF 2 there is a total of 563 12.5 kHz channels and there are 18161 technical assignments so the re-use is 32.257 which has been rounded up to 33.

licensed spectrum 457.5–458.5 MHz (base transmit) paired with 463–464 MHz (mobile transmit). This spectrum provides a total of 80 paired 12.5 kHz channels which is divided between the 3 Utilities<sup>23</sup>. The telemetry systems are generally point to multipoint links that operate at low data rates (1200 to 2400 bit/sec) often over long and / or obstructed links, using technology similar to analogue Business Radio. A key requirement, especially for the electricity utilities, is low latency to avoid the risks of unintended tripping of the network leading to loss of power for significant geographic areas<sup>24</sup>. The systems deployed must conform to UK interface requirement 2037. Scanning telemetry plays an important role in the monitoring and control of critical national infrastructure and is considered essential to ensure a safe, reliable and resilient service to the businesses that use them.

- **Programme Making and Special Events (PMSE)** use the spectrum on a national basis for:
  - programme audio links which may be portable or temporary point to point links with channel bandwidth of 50 kHz,
  - talkback which is used to communicate instructions during the making of programmes and can be for wide area or on-site use at temporary locations or for indoor use at permanent locations (e.g. studios) depending on the frequency band. The channel bandwidth is generally 12.5 kHz and allowed radiated power varies by frequency band.
  - data links used for the remote control of cameras and other programme making equipment and for signalling. However it is noted that there is limited availability in urban areas for the 4 identified frequencies. It is however possible to “top-up” with other talkback frequencies. Bandwidths are typically 25 kHz but can operate within 12.5 kHz.

Table 5 below shows the number of licences, licence variations and assignments in 2013. The number of licence variations provide a very rough indication as to the number of changes that were requested by licensees over the course of 2013 and each one might include one or more changes of frequency and / or changes of location. In the case of the number of assignments it should be noted that some of these assignments could be for as short as a couple of hours or a few days.

It is understood that the majority of the assignments are for 12.5 kHz channel bandwidths and the case of the higher channel bandwidths, such as 50 kHz,

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<sup>23</sup> There are other users but the 3 Utilities are the major ones.

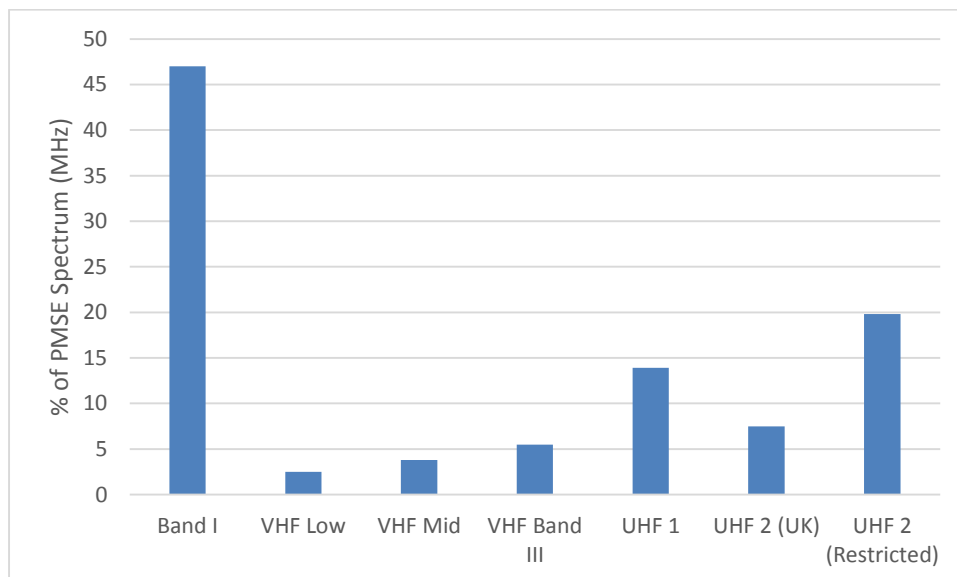
<sup>24</sup> For example Italy blackout in 2003 see <http://www.dailymail.co.uk/news/article-197749/Power-restored-Italy-blackout.html>

a significant number of the licences are for Regional or Area coverage rather than specific geographic locations.

**Table 5: PMSE assignments in UHF 1 and UHF 2 bands in 2013**  
(Source: Ofcom)

UHF 1				UHF 2			
Number of licences	Number of variations	Number of assignments	Amount of spectrum (MHz)	Number of licences	Number of variations	Number of assignments	Amount of spectrum (MHz)
173	1193	2618	1.8375	614	7230	35161	3.1125

**Figure 5: Distribution of PMSE spectrum between 48 MHz and 470 MHz**  
(Source: JFMG response to Ofcom Spectrum Trading Consultation in 2004)



It was noted in the JFMG response to the Ofcom Spectrum Trading Consultation in 2004<sup>25</sup> that use of the UHF 1 band was mainly limited to short term temporary use (the MOD could terminate PMSE use<sup>26</sup> as they are the primary user of the band). UHF 2 was the most popular band but there was frequency congestion at major events and in these cases additional spectrum is sometimes sought from other 'donors'. Also this is the only band with channels for air-to-ground use which is critical for major events.

- **Short range devices / licence exempt.** The table below shows the current SRD applications and associated frequency ranges within the UHF1 and 2

<sup>25</sup> See [http://stakeholders.ofcom.org.uk/binaries/consultations/spec\\_trad/responses/jfmg.pdf](http://stakeholders.ofcom.org.uk/binaries/consultations/spec_trad/responses/jfmg.pdf)

<sup>26</sup> There is a short-notice pre-emptible arrangement that allows PMSE access to the band.



bands and it also identifies where the allocation is UK only. In total there is 1.74 MHz available in UHF 1, and 1 MHz in UHF 2 with much of the spectrum available on a secondary basis.

**Table 6: Short Range Devices and associated frequency bands  
(Source: UK FAT)**

Application	Frequencies (MHz)	Allowed transmitter power	UK only?
<b>Non-specific SRDS</b>	433.05–434.79	1 mW e.r.p.	No—harmonised
	434.05–434.79	10 mW e.r.p.	No—harmonised
<b>Telemetry and tele-command</b>	458.5–458.95	500 mW e.i.r.p.	YES
<b>Medical and biological</b>	458.9625–459.1	10 mW e.r.p.	YES
	458.9625–459.1	500 mW e.r.p.	YES
<b>Vehicle paging alarms</b>	458.9	100 mW e.r.p.	YES
<b>Mobile transportable &amp; Lone Worker Safety Alarms</b>	458.8375	100 mW e.r.p.	YES
<b>Fixed alarms</b>	458.825	100 mW e.r.p.	YES
<b>Model control</b>	433.05–434.79	1 mW e.r.p.	YES
	434.04–434.70	10 mW e.r.p.	YES
	458.5–459.5	100 mW e.r.p.	YES

There is extensive use of these SRD bands; for example from a previous study Aegis undertook for Ofcom looking at SRD use in the 863–870 MHz band we identified that the 458.5–458.95 MHz is used for telemetry and tele-command for a wide range of applications including industrial telemetry and control of traffic lights.

There is also the PMR 446 licence exempt band (446–446.1 MHz for analogue and 446.1–446.2 MHz for digital) which is used for business and personal use over small geographic areas for speech and / or data. PMR 446 is used in most countries in the EU.

- **Emergency and Public Safety Services (E&PSS).** At present, the bulk of voice communications and low rate data are carried over the Airwave Solutions TETRA network which operates across mainland Britain. The TETRA network

operates over the 2 x 5 MHz European harmonised emergency services band in 380–385 MHz paired with 390–395 MHz.

Similarly, across Northern Ireland, Isle of Man and the Channel Islands, there are individual TETRA networks in the same Emergency Services spectrum. In addition, the London Underground TETRA network, Connect, also utilises 15 channel pairs from this band and is operated across Greater London.

The Department of Health separately holds 2 x 2 MHz of spectrum in the band 410–412 MHz paired with 420–422 MHz. The vast majority of this spectrum is used to augment the Airwave network in the Greater London area. The Ambulance Service across mainland Britain utilises 7 paired channels in this band for DMO (Direct Mode Operation) purposes. In specific areas of Mainland Britain, parts of the Arqiva 2 x 2 MHz are also used to support the Airwave TETRA network.

Within the UHF 2 band (450–470 MHz), the Emergency Services hold approximately 7 MHz of non-contiguous spectrum, some of which can be paired with a 10 MHz duplex spacing. Whilst the vast majority of the voice communications migrated across to the TETRA networks in the 380/390 MHz band, the Emergency Services have collectively taken a policy decision to hold on to spectrum in this band and continue paying the licence fee until the next generation communications provisions (Emergency Services Network (ESN) via the Emergency Services Mobile Communications Programme (ESMCP)) are in place. Specific systems and applications still utilise the UHF2 band. These include:

- Prison TETRA system in England and Wales—16 paired channels
- Prison TETRA system in Scotland—2 paired channels
- Prisons in Northern Ireland—11 paired on site channels (non-TETRA)
- UK FRS Fireground (used by the Fire Brigade at incidents to provide handheld communications)—4 simplex and 2 duplex channels
- Retained Police systems utilising a varied number of 25 kHz channels across all of the UK
- Retained Scottish Government assignments (mostly 25 kHz channels).

The fragmented use of the UHF 2 bands by the Emergency Services in the UK can be seen in Table 2.

## 2.4 International Status of the UHF Bands

The 406–470 MHz frequency range has been used internationally for mobile communications for many years. With the exception of the UK and Ireland, usage of these frequencies generally conforms to the band plans laid down in CEPT Recommendation T/R 25-08, which defines harmonised sub-bands for simplex operation, base transmissions and mobile transmissions (see Figure 2).

Amateurs and Radiolocation are the primary services in the 430–440 MHz band and there is an internationally harmonised short range device band at 433.06–434.79 MHz. The frequency band 450–470 MHz was identified at the International Telecommunication Union (ITU) World Radio Conference 2007 (WRC-07) for the potential delivery of future IMT services.

There are no EC / EU Directives that apply to the 420–470 MHz bands but there are a number of current ECC Decisions and Recommendations (from 2008 and earlier) that propose the use of the bands for either wideband or narrowband solutions:

- ECC/DEC/(08)05 identifies the potential to use frequencies within the tuning range 380–470 MHz for narrowband and wideband digital PPDR. Wideband applies to TETRA TAPS, CDMA-PAMR, TETRA TEDS and other digital land mobile systems.
- ECC/DEC/(04)06 identifies frequency bands 410–430 / 450–470 MHz for wideband digital land mobile PMR/PAMR, and
- ECC/DEC/(06)06 identifies 406.1–430 / 440–470 MHz for narrowband digital land mobile PMR/PAMR.

CDMA 450 and LTE 450 are both IMT technologies and could potentially be deployed in this spectrum for Fixed Wireless Access, especially to provide services in remote rural geographic areas, or for the Utilities to run point to multipoint SCADA/Smart Grid. CDMA 450 requires 1.23 MHz channels and LTE 450 can be deployed in 1.4, 3 and 5 MHz channels. CDMA450 has the advantage of not being distance limited (no TDM) whereas most other digital technologies are range limited. CDMA450 coverage is a function of loading versus range due to cell breathing. LTE range, using PRACH<sup>27</sup> format 1, is limited to approximately 14 km whereas format 3 will allow up to a 100 km. The CDMA 450 equipment is available off the shelf whereas LTE450 is under standardisation at the moment (forms part of release 12). Huawei has stated that it expects to have LTE450 consumer premises equipment available during 2014. On this basis both technologies would be a viable option. The main focus of LTE450 currently is the provision of fixed broadband services in rural areas rather than conventional mobile cellular services, although the band could also have potential for M2M applications, particularly for the Utilities who already use this band for telemetry. M2M is also a prime motivator for CDMA450 deployment in some European countries, principally for smart meters, but in the UK this application is being served by other wireless technologies. However to deploy CDMA 450 or LTE 450 it would be necessary for the UK to adopt the harmonised

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<sup>27</sup> PRACH—Preamble Random Access Channel. The different formats define the frame structures that are used.

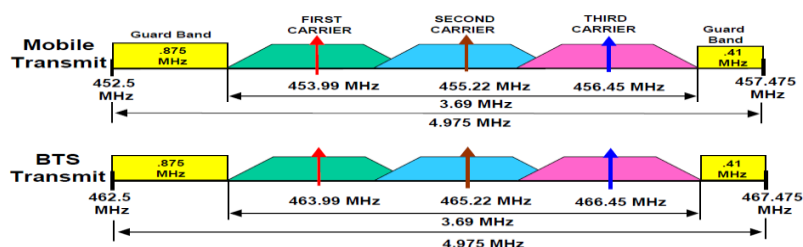
channel plans which would require adjacent services to be aligned with CEPT Report 25<sup>28</sup>.

However the introduction of CDMA 450 and LTE 450 would not alleviate the need to identify frequencies for voice and narrowband data services but it may not be necessary for all existing users to be catered for in the 420–470 MHz bands. Spectrum such as the 143–156 MHz band, which Ofcom is currently consulting on, or other VHF bands may be a suitable alternative for some.

Any of the 'potential' solutions of introducing the 'wide band' technologies would inherently produce guard band and duplex gaps which may prove useful for those types of narrow band services where industrial hand portable equipment is a must and for other 'fill-in' services (e.g. SRDs and PMSE on a secondary basis)<sup>29</sup>. Also the huge frequency range covered by Fylingdales may cater for many if not most of the services that cannot easily be migrated out of the spectrum.

Some of these options are considered further in the Scenarios which follow in Section 3.

<sup>28</sup> For example the CDMA 450 channel plan is aligned with the mobile transmit and base station transmit of T/R 25-08



<sup>29</sup> SRDs and PMSE do not generally require high transmitter powers for normal operation.

## 3 SCENARIOS

### 3.1 Introduction

To assist with the identification of potential demand and options for the ongoing access to and use of the 420 to 470 MHz bands, the following hypothetical future usage scenarios have been identified and are considered further in the following sections:

- Incumbent growth under the current band configuration
- Expansion (or reduction) of emergency services' use of the band
- Incumbent growth leading to band reversal
- Deployment of managed networks in the band
- Introduction of LTE 450 in the band

In addition it was considered whether the appointment of a band manager would be helpful if the band was to be re-organised (e.g. to support band re-alignment or address any surplus demand).

### 3.2 Incumbent Growth

#### 3.2.1 Description of the scenario

This scenario assumes that the current configuration and use of the spectrum remains but considers the implications of change in demand and specifically where there is growth in demand from the incumbents.

#### 3.2.2 Future demand

The following sections discuss potential future demand in the 420 to 470 MHz bands based on stakeholder interviews, responses to the Ofcom Spectrum Strategy Consultation and Ofcom licensing data which has been used to extrapolate demand. In the case of Business Radio, due to the Business Radio Reform in December 2008 which concatenated the Business Radio products from 21 to 5, licensing data is only available from 2010 onwards. The predictions are over the next 10 year period.

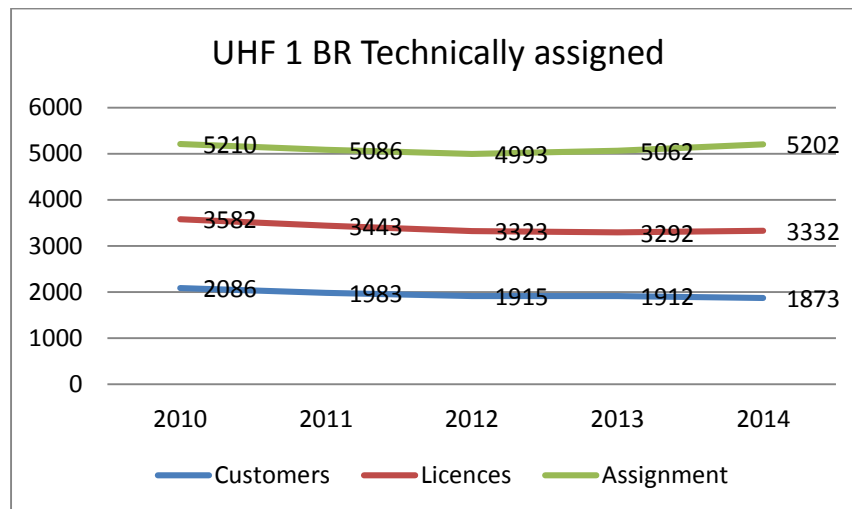
##### 3.2.2.1 Business Radio

We have analysed growth from the different BR products based on historical growth and interviews we held with stakeholders.

##### Technically assigned:

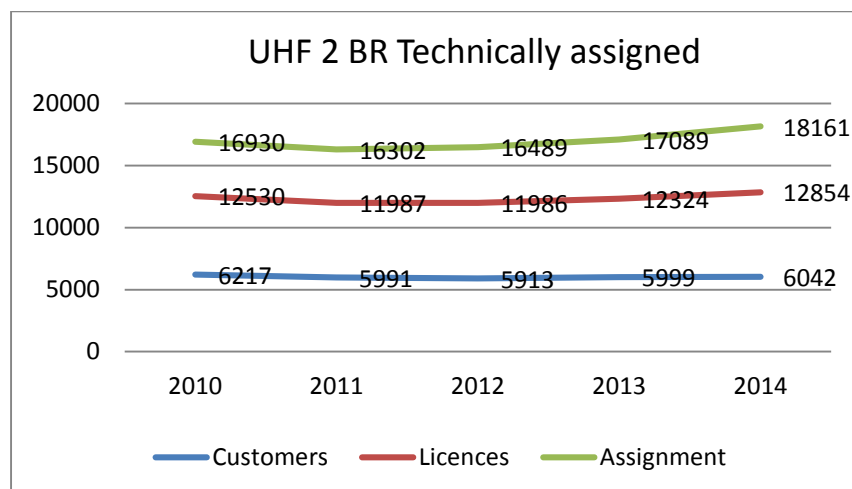
Licensing data held by Ofcom indicates there has been no increase in demand for assignments in UHF 1 between 2010 and 2014 as shown in Figure 6. There has been a decrease in number of customers (–10.2% between 2010 and 2014, –3% CAGR) and also licences (–7% between 2010 and 2014, –2% CAGR).

**Figure 6: Comparison of number of licences and assignments for technically assigned licence class in UHF 1 band between 2010 and 2014 (Source: Ofcom)**



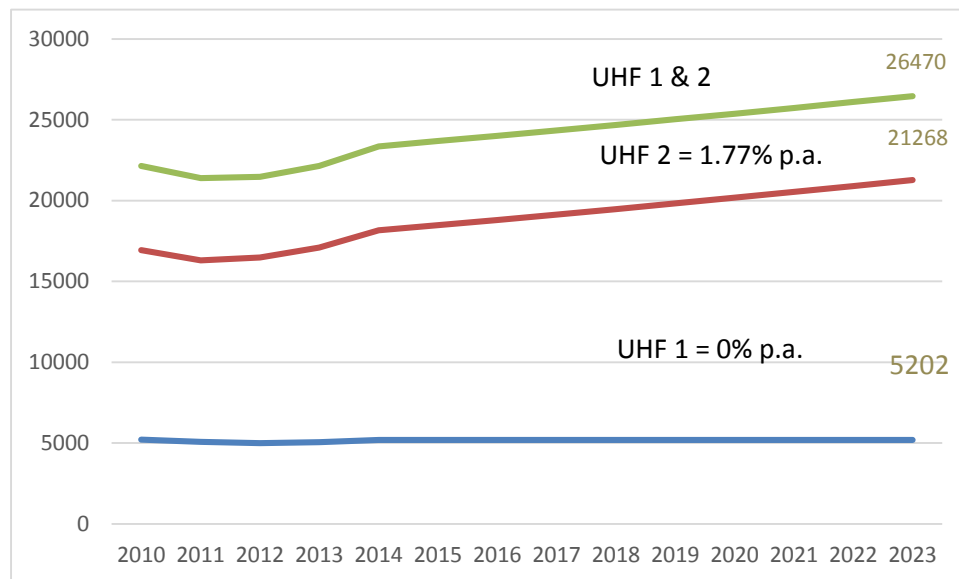
In Figure 7 (UHF 2) there is a slight increase in number of licences between 2010 and 2014 (less than 2.8%) and around a 7.3% increase over the same period in the number of assignments although the number of customers has decreased slightly.

**Figure 7: Comparison of number of licences and assignments for technically assigned licence class in UHF 2 band between 2010 and 2014 (Source: Ofcom)**



If the current demand for assignments between 2010 and 2014 was extrapolated forward to 2024, assuming there were no constraints on licensing new frequencies, then potential future demand is shown in Figure 8 for UHF 1 and UHF 2. The percentage increase per annum values of 0% and 1.77% respectively are based on the increases seen in assignments between 2010 and 2014.

**Figure 8: Potential future demand for number of technically assigned assignments in UHF 1 and UHF 2 bands (Source: Aegis)**



It is estimated that an additional 0.88 MHz of spectrum may be required, in addition to the current 13.625 MHz at UHF 1 and 7.0375 MHz at UHF 2, between now and 2023 for technically assigned licences providing voice and narrowband data services based on the following:

- There is already congestion in London and also significant potential for congestion in other Metropolitan areas<sup>30</sup> so there is no under used spectrum in some geographic areas.
- A re-use of 33 for a 12.5 kHz channel that was calculated earlier for UHF 2 (see Business Radio in Section 2.3), and assuming that the extra growth is all catered for in spectrum that is not constrained.
- Assumes that the current assignment / efficiency is not improved by changes to the assignment process.
- All new demand is met by a 50:50 mix of 6.25 kHz and 12.5 kHz channels and the re-use value is the same for both.
- Everyone who has required a technically assigned licence / assignment has applied and been provided with one. There is a concern raised by interviewees that requests have not been submitted where there is no expectation of obtaining an assignment and in the BRIG meeting notes<sup>31</sup> it was indicated that light licences are being used if there is a shortage of spectrum in conurbations for Technically Assigned applications.

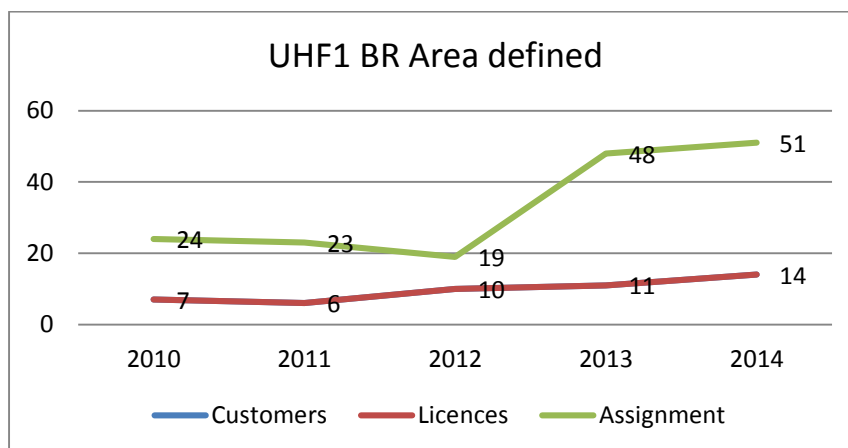
<sup>30</sup> Anecdotal information from stakeholders interviewed indicated there was already congestion in specific areas of Manchester and Birmingham.

<sup>31</sup> BRIG minutes of 24<sup>th</sup> April 2013.

### Area defined

In the case of Area defined licences the historical data for the UHF 1 and UHF 2 bands are shown in Figure 9 and Figure 10 respectively. It can be seen that in both bands there is an increasing demand. However in the case of the UHF 1 band if the current trend (i.e. 2012 to 2013) was to continue then the requirements over the next 10 years would be significant. Figure 11 shows the likely future demand in terms of assignments assuming the trend between 2010 and 2014 continues for UHF 2 (33.3% growth between 2010 and 2014, CAGR of 7%) and that the trend between 2013 and 2014 applies for UHF 1<sup>32</sup>. Again it is assumed that there are no constraints on availability of frequencies.

**Figure 9: Comparison of number of licences and assignments for Area defined licence class in UHF 1 band between 2010 and 2014 (Source: Ofcom)**

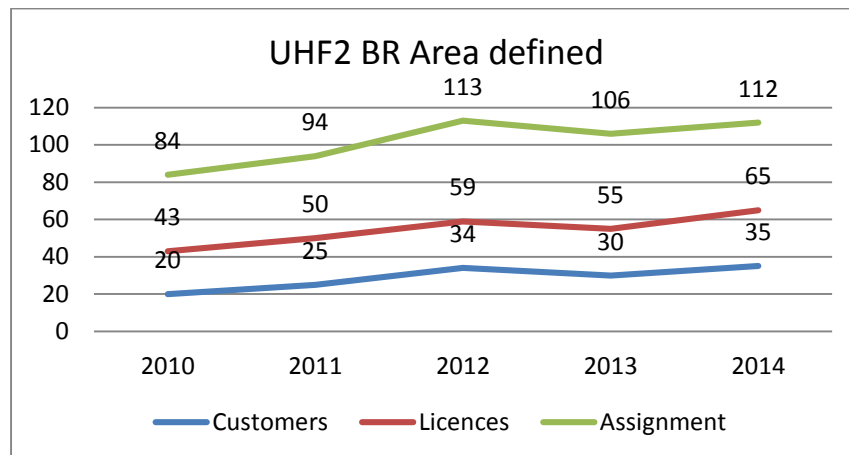


Note: Number of customers and number of licences is the same for the UHF 1 band.

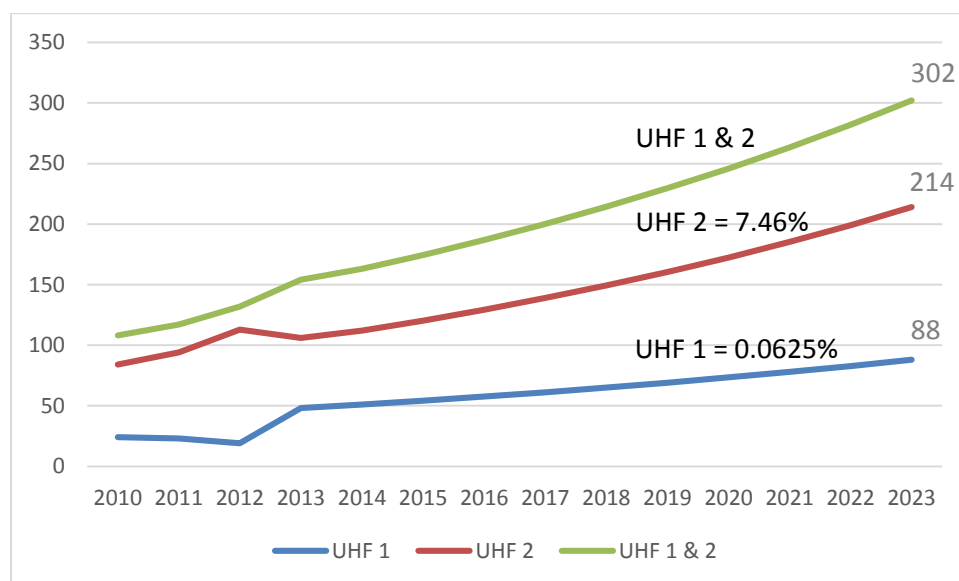
<sup>32</sup> It is extremely difficult to predict likely future demand when there are small numbers of licences and assignments. A number of new customers and associated licences could have a significant impact on future demand as could a number of existing licences being returned. Also the fact that the geographic area for an assignment can vary between national to the smallest area of a 50 x 50 km national grid square has an impact.



**Figure 10: Comparison of number of licences and assignments for Area defined licence class in UHF 2 band between 2010 and 2014 (Source: Ofcom)**



**Figure 11: Potential future demand for Area defined assignments in UHF 1 and 2 bands (Source: Aegis)**



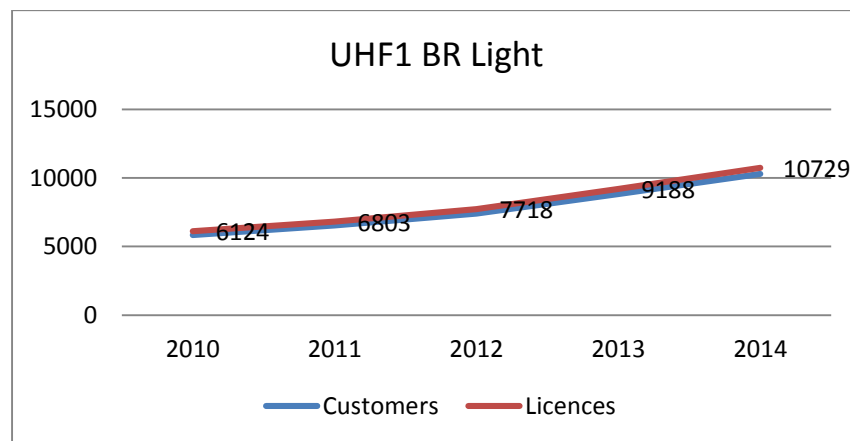
It can be seen that there is continued growth for area defined licences but on the basis that there are small numbers of area defined licences and they are supported within the same spectrum as technically assigned it is assumed that no further spectrum, than the already identified 0.88 MHz, will be required to meet this demand.

#### Light licences

Finally in the case of the light licences (Simple UK and Simple Site) there is significant annual growth as shown in Figure 12 and Figure 13 below. In the case of the UHF 1 band the number of customers and licences has increased by nearly

78% between 2010 and 2014, with an annual growth of 15% and in the UHF 2 band there has been an increase of 14% between 2010 and 2014<sup>33</sup>. It is understood from Ofcom that they may be seeing campus demand being met by on-site products. In total there is around 0.5875 MHz of spectrum available to support the Simple UK and Simple Site licences and with a total of 19,635 licences that equates to a reuse of around 410<sup>34</sup>. This is significantly greater reuse than for the licensed Business Radio products but it has to be noted that the transmitter powers and also antenna heights are significantly smaller<sup>35</sup> than for the assigned options where the potential for interference is significantly smaller. Also in the case of the light licences it is expected that more than 2 users may well share a frequency in a geographic area.

**Figure 12: Number of licences for light licence categories in UHF 1 band between 2010 and 2014 (Source: Ofcom)**

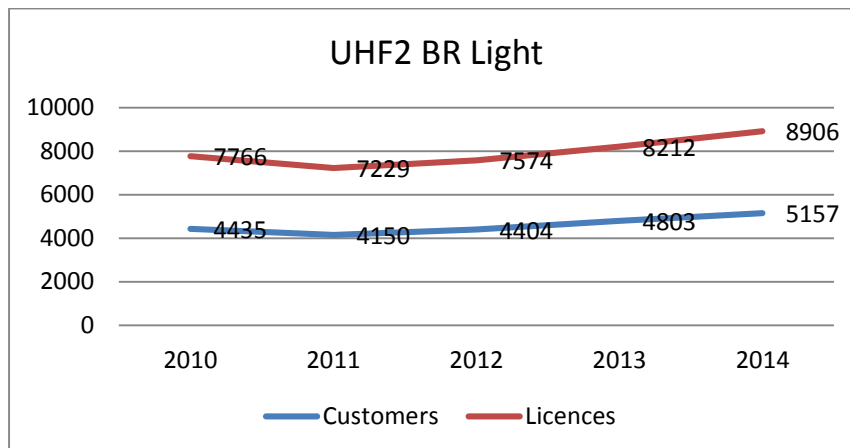


<sup>33</sup> It is noted that in the BRIG minutes of 24<sup>th</sup> April 2013 "the number of "Live" licences has increased by 20% in this past financial year [2012 / 2013]. The current number of "Light Licence" products stands at approximately 9000. This figure is based on the assumption that people are upgrading from [the licence exempt] 446 MHz and [using this licence option] if there is a shortage of spectrum in conurbations for Technically Assigned applications."

<sup>34</sup> The reuse of 410 is based on a total of 587.5 kHz being available to support light licences. Assuming channel bandwidths of 12.5 kHz this equates to a total of 47 channels available across the UK. There are a total of 19,365 licences in 2014 and on the basis each of the licences allows the use of a single 12.5 kHz channel then the reuse is 19,365 / 47( i.e. 412).

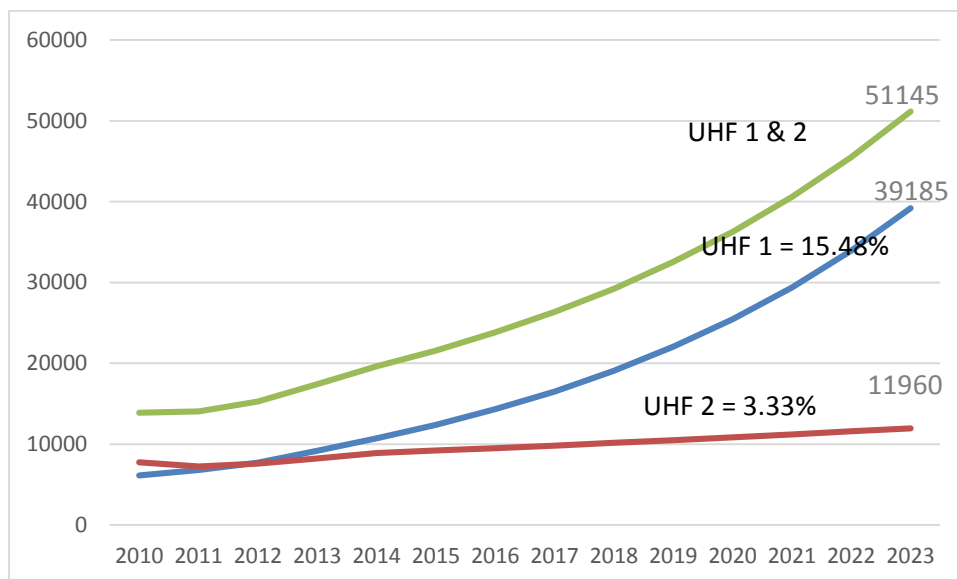
<sup>35</sup> Simple UK allows a maximum ERP of 5 W for mobile stations (there are no base stations) and Simple Site allows a maximum ERP for a base station of 2 W and maximum antenna height of 15 m.

**Figure 13: Number of licences for light licence categories in UHF 2 band between 2010 and 2014 (Source: Ofcom)**



The future demand for light licences, based on the current annual increase in demand, is shown in Figure 14 below.

**Figure 14: Potential future demand for light licence class in UHF 1 and 2 bands (Source: Aegis)**



In terms of spectrum requirements it is anticipated that to ensure that such licences remain attractive there will need to be an increase in the number of channels to minimise the potential for interference. On the basis that for Simple Site and Simple UK licences there is currently around 0.5875 MHz identified, excluding that spectrum used for the suppliers licences, we would suggest it is likely that around double this spectrum will be required i.e. an additional 0.5875 MHz.

#### All licences

The predictions for future demand show overall growth for all Business Radio licences, based on licensing information trends from 2010 to 2014, with a particularly strong growth for Light licences. There are currently no indications that

such demand will decrease based on the stakeholder interviews. We have estimated that if the above predicted growth occurs then there may be a need for a further 1.4675 MHz of spectrum for Business Radio. Of course this could vary significantly depending on the geographic location and also channel bandwidth requirements of future demand.

It is also important to recognise that the licensing data cannot provide information on unmet demand where applications are not submitted to Ofcom either because an application cannot be supported in the current licensing regime (e.g. wideband Business Radio applications) or the expectation is it will not be possible to obtain a frequency because of congestion in a specific geographic area (e.g. if a licensee wants to deploy a network to serve businesses within the M25 using a congested site such as Millbank Tower in London). It is expected that dealers will have a view on where it is difficult or even impossible to obtain frequencies and steer their customers to alternative solutions<sup>36</sup>.

The FCS response to the Ofcom Spectrum Strategy consultation observed that there is currently no allocation of spectrum for wideband Business Radio applications, claimed that there is a rising demand for professional wideband networks and argued that the current use of public mobile networks may not be meeting operational requirements. This was supported by anecdotal examples provided during our stakeholder interviews of users reverting to Business Radio because the coverage and delays in connection meant that the cellular networks were not meeting their operational needs.

Broadband services, such as video, are considered to be less of an issue as occasional interruptions will generally not cause a problem (except of course for PPDR and some security related applications), so public mobile networks are meeting much of this demand. For more critical applications such as public safety the use of multi-SIM terminals that can access any available 3G network help to overcome the coverage limitations of these networks to some extent.

The FCS has indicated that the sales for digital Business Radio units continues to expand at 20% per annum and other inputs indicate this might not just be for upgrades of existing analogue systems but also new users. Predominant users are on-site rather than wide area and they often require in building coverage (e.g. banks, process industries, ports and hospitals). These users might well be using the Simple UK or Simple Site licences instead of technically assigned. Whether this is by choice or the perception of lack of availability of technically assigned licences is unclear. Indications from industry are that there is already perceived congestion in London and this is expected to extend to other major metropolitan areas (e.g. Birmingham, Manchester, Glasgow etc.).

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<sup>36</sup> There were strong indications from the interviews that this was happening and that the majority of demand was in the metropolitan geographic areas.

Ofcom have indicated that most technically assigned assignments require some adjustments in London. Ofcom have to try and contain coverage to just the areas needed and so leaky feeder, down tilt antennas etc. are often the only way assignments can be accommodated. In practice if a customer asks for a high power assignment and has not proposed the use of tailored antenna patterns then Ofcom will discuss the possible options and these might also include lower transmitter power to ensure the QoS (Quality of Service) level can be achieved for both the new application and existing assignments.

### 3.2.2.2 *Maritime*

There is a WRC-15 agenda item 1.15 that is addressing on-board communications stations in the maritime mobile services (MMS) in the UHF band. This may or may not have an impact on future harmonised use of further spectrum in the 420–470 MHz bands as the international allocation will have precedent but it is noted that any new allocations are likely to take longer than 10 years to implement because of the global implications. There is demand from the maritime sector but for now, and for the foreseeable future, this is being met by employing digital technologies.

### 3.2.2.3 *Utilities and other M2M*

The Utilities have been using scanning telemetry for a significant time to deliver the required control and monitoring of their distribution networks. In the future this demand could expand significantly to support the rollout of smart grid networks, but may also be able to make use of more efficient wideband technologies such as CDMA or LTE<sup>37</sup>. However, under this scenario in the absence of band re-planning any growth would need to be accommodated within existing allocations, either in the UHF bands or elsewhere and using the existing technology. There are differences between the electricity, gas and water network infrastructures that are used to deliver their services and any communications solutions have to match with the locations and physical environments as well as meeting specific operational requirements in terms of the networks and personnel.

### Energy Industries

The Joint Radio Company (JRC), which manages spectrum on behalf of the fuel and power industries, has indicated that there is a need for 2 x 3 MHz of additional spectrum for SCADA and automation to support these Industries, focused especially on the period 2015–2020. This is required not just for further monitoring of the networks to support the objectives of reducing energy consumption by 20%, generating 20% of energy needs from renewable sources and reducing CO2 by 20% by the year 2020 but also to safeguard supplies and speed-up restoration when supplies are interrupted. What this means in practice is that it will be

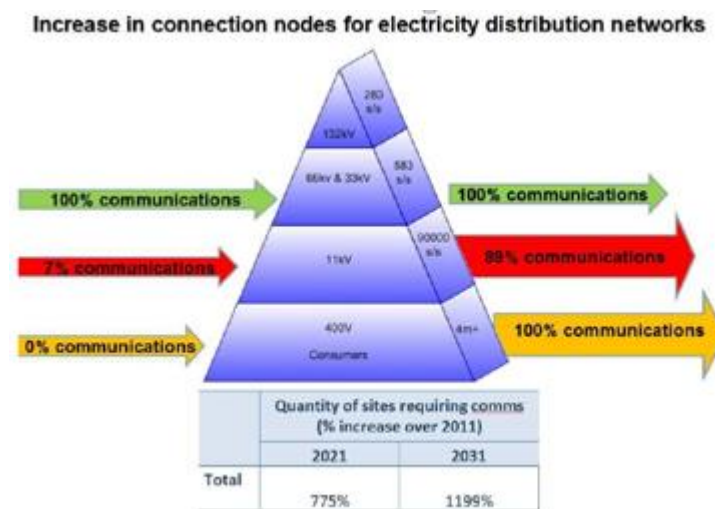
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<sup>37</sup> It is understood that the Utilities within Europe are looking at both CDMA 450 and LTE 450 as potential solutions for their communications needs.

necessary to control and manage many thousands of items of electrical plant within the grid network.

A study undertaken for the JRC indicated that for a “typical distribution company with 4 million customers serving an area of 29,000 km<sup>2</sup> through a network of 80,000 km of underground cables and 48,000 km of overhead lines” the increase in connected end points, compared with 2011, “would grow by 775% by 2021 and 1199% by 2031”.

**Figure 15: Increased number of sites to be connected for the electricity distribution networks (Source: JRC)**



The JRC argues that this demand cannot be met by public mobile networks because of the specific requirements in terms of:

- “Data rates much less than consumer data rates (typically 9.6 kbits/s rising to 2Mbits/s, although some applications operate at rates as low as 50 bits/s;
- Enhanced resilience to enable networks to operate in the absence of mains electrical power for an extended period;
- Geographic coverage to include less populated areas if they contain significant utility infrastructure;
- Exacting availability, latency, jitter and synchronous requirements;
- Upload-centric as opposed to download centric for public data networks;
- High levels of security to prevent malicious disruption of utility operations; and
- Longevity of product support in recognition of longer investment cycles.”

### Water Industries

The Water Industries use a mix of licensed and unlicensed solutions to meet their telemetry requirements. Telemetry is used to ensure compliance with statutory requirements as well as reducing maintenance and operational costs and is required

across all areas of the operations (water recovery (e.g. reservoirs), treatment and distribution of water, control and monitoring of the water quality as well as monitoring sewers and operation of flood defence). There are also specific European Directives (e.g. bathing water<sup>38</sup>) that have to be met which may require a significant increase in sensors and they may potentially need to be quadrupled (there are currently an installed base of over 10,000 sites using the licensed UHF2 band). "In addition, the continuing trend towards greater granularity of distribution and process data will require an increase in the number of points to be monitored and controlled. This will result in increasing volumes of telemetry data."<sup>39</sup>

The Water Industries are moving to "always on" technologies including self-provided licensed UHF Scanning Telemetry Systems. As well as the UHF frequencies the Water Industries are using devices in the un-licensed UHF 458.50 to 458.95 MHz band for less critical applications as well as in the licensed VHF Band1 to provide links to locations where UHF is not feasible and to provide resilience. Due to the business criticality and safety issues<sup>40</sup> associated with much of the telemetry requirements licensed spectrum is essential to ensure protection from interference. Scope to migrate more systems to VHF Band 1 is likely to be limited due to the very large antennas that are required which make it less suitable for critical applications.

Whilst the Water Industries have not provided specific indications of additional spectrum requirements as they are fully utilising their existing self-managed UHF spectrum (24 national 12.5 kHz channels) it would be reasonable to assume that they will require further spectrum. Given the critical nature of many water industry applications (e.g. reservoirs, flood defences) and the remoteness of many installations the bulk of this spectrum is likely to be needed in licensed bands where a higher level of coverage and Quality of Service can be assured.

### **Other M2M Applications**

M2M communications in the UHF bands is currently limited to Utility telemetry and smart metering applications and low power telemetry services in the 458 MHz licence exempt band. There are no indications currently that this spectrum is being identified for other M2M applications. In principle the existing Business Radio band could be used to serve some M2M applications, however in general these are currently served by the public cellular networks or licence exempt short range technologies, the latter generally operating in internationally harmonised licence exempt bands.

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<sup>38</sup> See <https://www.gov.uk/government/policies/improving-water-quality> for further information

<sup>39</sup> See TAUWI response to Ofcom Spectrum Review consultation.

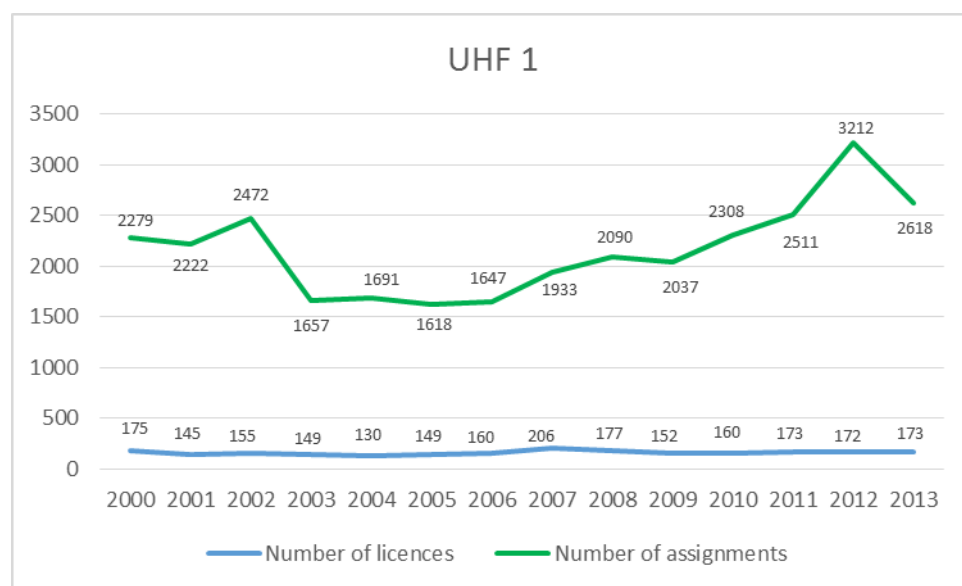
<sup>40</sup> It would not be ideal if for example a manhole cover was blown up because of increasing gas levels that lead to an explosion because the telemetry data was not received because of interference from other devices uses the same licence exempt spectrum.

This area of potential future demand is considered further in the scenario of incumbent growth leading to band reversal as the band would need to be reversed to support the likely technologies.

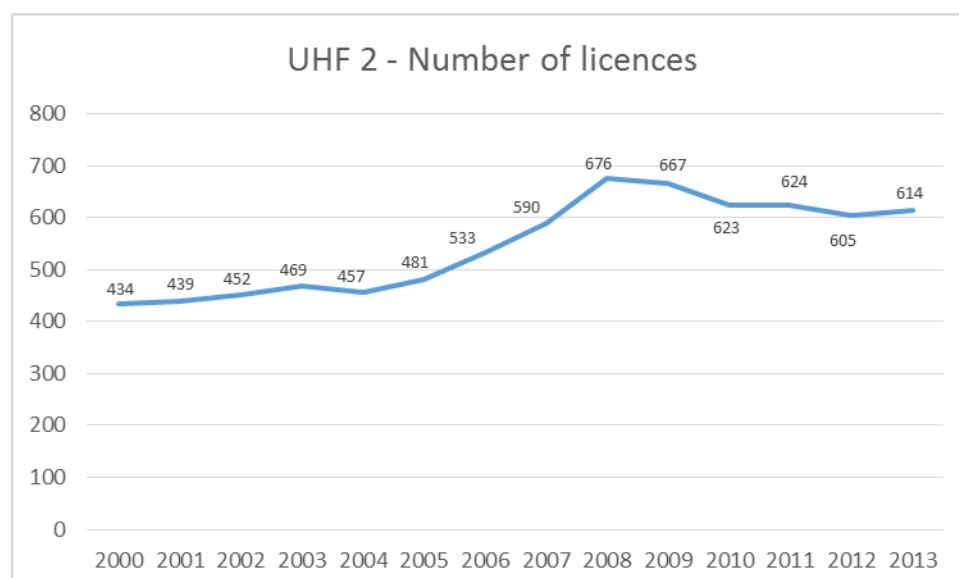
### 3.2.2.4 PMSE

The figures below indicate the volume of PMSE licences and associated number of assignments over the period 2000 to 2013. It should be noted that whilst there are high numbers of assignments this does not necessarily indicate that there is greater spectrum use as they may be used in different geographic locations and for a wide range of timescales (e.g. for as short a time as a couple of hours or a few days).

**Figure 16: Total number of PMSE licences and assignments in UHF 1 band over the period 2000 to 2013 (Source: Ofcom)**

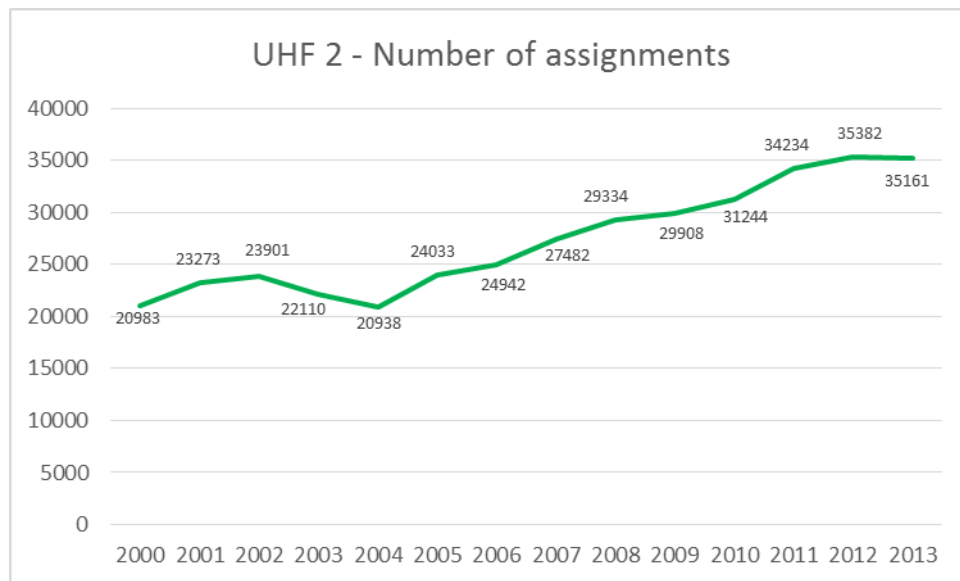


**Figure 17: Total number of PMSE licences in UHF 2 band over the period 2000 to 2013 (Source: Ofcom)**





**Figure 18: Total number of PMSE assignments in UHF 2 band over the period 2000 to 2013 (Source: Ofcom)**



It can be seen from Figure 16 and Figure 17 that the number of PMSE licences has varied between 130 and 206 in the UHF 1 band and 434 and 676 in the UHF 2 band over the last 13 years. In the case of the assignment numbers shown in Figure 16 and Figure 18 they are representative of the total number of assignments that have been supported by the two frequency bands and demonstrate the difference between the available spectrum between UHF 1 (1.8375 MHz) and UHF 2 (3.5875 MHz) bands. It is expected that the peak in assignment numbers in 2012, in UHF1 could be attributed to events such as the Royal Jubilee and an increased number of events as a result of the UK hosting the Olympic and Paralympic Games.

There is no obvious trend in number of licences for PMSE although the number of assignments in UHF 1 and 2 has indicated growth<sup>41</sup>. It is assumed that for the next 10 years the number of licences and associated assignments would most likely remain similar and within the ranges shown in the Figures unless there were changes (i.e. reduction) in terms of spectrum available to PMSE in other frequency bands, such as the “white spaces” available for the deployment of audio applications above 470 MHz. In the case that it was necessary to migrate, for example, wideband talkback to lower frequency bands it has been estimated that there may be a need for around 6 MHz of spectrum<sup>42</sup> which would not be feasible with the current total amount of spectrum available to PMSE in the UHF 1 and 2 bands. It is

<sup>41</sup> This ignores the 2012 blip in numbers.

<sup>42</sup> This was based on a system with 6 base stations & 24 mobiles (one transmitter each) over two frequency ranges over two listen channels (each broadcasted twice, one for each of the bands used) using current technologies.

also noted that there have been congestion issues for major events in the UHF 2 band as far back as 2004<sup>43</sup>.

#### 3.2.2.5 *Short Range Devices*

There were no specific comments received during the interviews to indicate that there may be further demand for frequencies for SRDs. However it is noted that the telemetry and command frequencies are the only ones available in the UK for this application. Concerns were raised about:

- the impact of LTE in the 800 MHz band on SRDs operating in adjacent spectrum and the implications if they need to be moved to alternative spectrum, and
- portable traffic lights operating in the 458 MHz band were interfering with scanning telemetry<sup>44</sup>.

#### 3.2.2.6 *Emergency Services*

The future demand is expected to arise due to the need to introduce new applications or systems in UHF 2, including:

- New breathing apparatus telemetry assignment on a UK wide basis between 469.875–470.000 MHz (50 kHz allocation providing a 25 kHz channel with 12.5 kHz guard bands on either side<sup>45</sup>)
- Home Office System with around 100 kHz bandwidth
- Requirement for AGA<sup>46</sup> communications of around 2 x 0.5 MHz, and
- Potential requirement for slow scan video of around 650 kHz but the expectation is this will be supported by the new Emergency Services Network.

Further information is included under the Emergency Services scenario in Section 3.3.

### 3.2.3 **International developments**

There are no specific international developments that relate to this Scenario.

### 3.2.4 **General considerations**

In this section we identify topics and issues that need to be taken into account when identifying potential solutions.

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<sup>43</sup> See JFMG response to Ofcom consultation on spectrum trading.

<sup>44</sup> It was considered that the 100% duty cycle of the traffic lights was the problem.

<sup>45</sup> Tests are due to be completed shortly to confirm this spectrum requirement.

<sup>46</sup> Air to ground.

#### 3.2.4.1 *Business / service requirements.*

The reason users opt for Business Radio is to meet specific coverage and capacity requirements where the system owner has a high degree of control over the system and can also manage costs in a predictable way. The current Business Radio solutions meet the requirements for voice, low speed data, reliability, health and safety and specific requirements such as group calling and PTT (press to talk) communication. Similarly the scanning telemetry systems meet the specific operational requirements of the Utilities such as of resilience, latency etc. mentioned in Section 3.2.2.3.

#### 3.2.4.2 *Investment costs.*

For many Business Radio users the aim is to minimise the cost of communications as they are primarily an enabler of the core business and not an investment as in the case, for example of MNOs (Mobile Network Operators). Any upgrade to equipment or annual fee is a cost to their business and they will only upgrade existing equipment or move to alternative solutions if there is a push (e.g. equipment can no longer be maintained because of its age or increased cost of spectrum) or a concrete benefit to their core business (such as supporting the rollout of smart grids in the case of the Utilities).

A number of Business Radio users, according to Stakeholders, have recently replaced their analogue equipment with digital and having incurred this cost are unlikely to be amenable to investing further. Migration onto, for example a managed network, is only likely to provide marginal benefits for these users, if any.

We understand from our discussions with the Water Industry that their Scanning Telemetry networks have been built up over the last 25 years and that organisations tend to work on a 5% to 10% per year replacement plan for the equipment. This is likely to influence their view on migration to other solutions.

#### 3.2.4.3 *Lack of suitable alternative options.*

Alternative spectrum may not be a viable option because of the specific requirements of some of the users (e.g. need to deploy compact hand-held equipment that would not be practical in VHF Business Radio bands or the need for non-line of sight scanning telemetry, ruling out the use of microwave fixed link bands). It is likely that most potential Business Radio users whose operational needs can be met by cellular have already migrated to these networks and that those that remain have specific needs<sup>47</sup> that cannot currently be met by cellular. For example, Motorola's response to Ofcom's Spectrum Strategy Consultation noted that the current popularity and growth in the 450–470 MHz Business Radio band is

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<sup>47</sup> Such users will have no incentives to move to cellular until these networks can support the required PMR facilities / functionality (e.g. Group Call).

its suitability for hand held radios used for on-site work and that this market is resilient to replacement by services provided by traditional MNOs because of:

- The very specific site coverage needs of the user base,
- The reliability that is needed at times of crisis which is when public networks are not reliably available due to high demand, and
- The cost certainty (employees cannot access the internet or make private calls).

However there may well be alternative options for those users that are using vehicular installed mobiles.

PMSE makes considerable use of spectrum but in recent years changes have led to frequencies used by PMSE being reallocated to other services which are not able to operate co-channel and co-located with PMSE<sup>48</sup>. Alternative frequency bands to UHF are just above 174 MHz which provide good propagation, minimum wall absorption, low reflection or diffraction but require large antennas that make them less ideal for body worn devices. Another option might be to use wired solutions but these do not provide the freedom of movement required for many PMSE applications and in some cases could be a health and safety risk (risk of people falling over the large amount of cables required for wired systems).

#### 3.2.4.4 *Fragmented use of the 420–470 MHz spectrum.*

The fragmented use of the spectrum makes it very difficult to move to harmonised band plans and align with mainland Europe (although this is the case with the 420–424 MHz band). Also our stakeholder feedback indicates that the UK- specific nature of the current band plan has not been an issue for availability of Business Radio equipment for the UK (which is one of the larger Business Radio markets in Europe and attractive to equipment vendors). Vendor's solutions are based on modules and the frequencies can be set in software as the equipment can cover a wide range of frequencies. There are no indications that the UK users are paying a premium for their equipment.

#### 3.2.4.5 *Move to digital in Business Radio.*

The ongoing migration to digital technology should over time increase the capacity of the existing Business Radio spectrum, since it allows two voice / data channels to be accommodated in a single 12.5 kHz channel. Although it has been suggested that digital systems require a greater protection ratio and re-use distance than analogue and the concentration of Business Radio licences in the three main conurbations could make the problem worse.

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<sup>48</sup> See ECC Report 204.

#### 3.2.4.6 *MOD and Fylingdales.*

The MOD is the primary user of frequencies in the UHF 1 band and places a significant constraint on the use of the spectrum<sup>49</sup>. In addition it is necessary to manage total power levels into Fylingdales (420–450 MHz) radar and this places a further constraint on the use of the spectrum compared with other European countries. This is clearly demonstrated by the re-use of channels for Business Radio (i.e. it is estimated that a re-use of around 5 for UHF 1 and 33 in UHF 2 is achieved for a single channel across the UK). It is also not possible to use the band for any systems that require national coverage.

#### 3.2.4.7 *Co-ordination with neighbouring countries.*

The HCM (Harmonised Calculation Method) levels are used to trigger coordination with neighbouring mainland Europe and the expectation is that a foreign administration will request coordination from Ofcom if they are likely to exceed the HCM level.

#### 3.2.4.8 *Interference*

There are already instances of interference that are believed to be due to the changing use of the UHF bands in mainland Europe. Clearly any networks that are safety or business critical cannot be operated on frequencies where there is likely to be a loss of communications for any period of time.

### 3.2.5 **Challenges**

The current situation appears untenable in the longer term, in the context of the increased demand identified for the existing spectrum users. In this scenario the biggest challenge is what can be done in the band to maximise the use of the available spectrum and cater for the diverse range of users and uses whilst managing the potential for interference. Whether they can all be supported within the 420–470 MHz band is highly questionable.

In Section 3.2.2 the potential future demand of the incumbent users is discussed. It can be seen that over the next 10 years there is a potential need for a further 1.4675 MHz of spectrum for Business Radio and 2 x 3 MHz for scanning telemetry.

In addition there is unmet demand for professional wideband networks and additional spectrum may be needed to support PMSE if there is a loss of spectrum for audio applications above 470 MHz but it is considered unlikely that such demand can be met within 420–470 MHz. Whilst the Emergency Services have also identified the potential need for further applications in their existing spectrum in the band, there is not necessarily a further requirement for additional spectrum.

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<sup>49</sup> See UK FAT 2013, Annex C which defines, for example, limited geographic areas where civil land mobile may use frequencies and outside such areas use has to be agreed with MOD on a case-by-case basis.

### 3.2.6 Potential solutions

In this section we consider the potential solutions based on the general considerations and the challenges identified in the previous sections. It should be noted that some of the solutions are covered in other Scenarios and are therefore not included in any detail here.

#### 1. Changes in the Business Radio market structure.

A view expressed was that the offerings available over the mobile networks in conjunction with the spectrum congestion in the UHF bands may trigger changes in the structure of the Business Radio market. There might be a possible sea change where the emphasis is “build to enable” rather than “sell from the book” so solutions provided, for example by dealers, are more tailored to the end users’ needs. In such a new market model there would be the potential for new applications developers and providers and new value chains. This could lead to increased airtime and implications on the structure of spectrum. Currently use of the 420 to 470 MHz spectrum is only for narrowband systems but wideband at 128 kbps requires concatenated channels which are not readily available. Dealers that are more forward thinking could overcome the spectrum issue via trading and leasing wherever possible to obtain the necessary spectrum. The requirements for wideband systems and associated spectrum could be a massive driver for consolidation in the market—those with access to spectrum will have a value add and spectrum could become a major business factor. In this scenario the Business Radio market itself may naturally evolve to support future demand. However there are still questions on how wideband systems may be provided without reversing the band.

In the situation where the Business Radio market does not naturally evolve or show signs of evolving or cannot evolve then it will be necessary to consider alternative solutions such as those considered below:

#### 2. Licensing. There may be the potential for Ofcom to improve the efficiency of the current Business Radio spectrum use and so cater for some of the future demand. There were a range of suggestions proposed from Stakeholders that Ofcom could implement as part of their licensing and assignment process which indicate there may be a benefit in Ofcom revisiting their current approaches and policies. These suggestions included:

- Ensure that transmitter powers are the minimum necessary to provide the requested coverage area.
- Ensure transmitter powers take into account whether using hand portables on a network or mobile terminals as there may be the potential to reduce transmitter powers.

- Discourage or even prohibit the use of high sites to provide wide area coverage, especially for single users, as the geographic area over which the service is provided is small compared with the sterilised area<sup>50</sup>.
  - Require existing licensees to substantiate requests for additional frequencies at a site rather than simply assigning additional frequencies on request<sup>51</sup>.
  - Ensure that where licensees propose to use dPMR they justify the traffic they will be supporting will require both 6.25 kHz channels<sup>52</sup>.
  - Encourage and allow greater sharing of frequencies. Use of the available spectrum can be improved as it is possible for more than one Business Radio system to share a radio channel using protocols such as Continuous Tone-Coded Squelch System (CTCSS) to differentiate between the systems. The potential of more than two users sharing a channel was also raised especially where there are a limited number of terminals and limited usage.
  - Undertake monitoring and identify those unused frequencies<sup>53</sup>. Consider implementing a use it or lose it approach to ensure that frequencies are released back into the “central pot” for re-assignment. This approach would need to be “squared” with the spectrum being tradable.
  - Encourage use of trunked systems for enhancing spectrum efficiency 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. Trunked systems take advantage of the probability that not all users require access to a channel at the same time and therefore fewer radio channels are required to support a given number of users.
3. Migrate users to cellular networks. A more interventionist approach may be to encourage those users that do not require Business Radio for safety related communications to migrate to cellular networks.

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<sup>50</sup> 12 dB margin between DSA and sterilised area.

<sup>51</sup> It is noted that this would require a change in Ofcom policy as if there is frequencies available they will be assigned and licensed.

<sup>52</sup> ERP for both channels has to be half that of the 12.5 kHz channel but if only a single 6.25 kHz channel is used there is no improvement in spectral efficiency as it can potentially use the full ERP.

<sup>53</sup> It is noted that there could be issues in how this might be implemented as some frequencies are only used very lightly such as for “emergency back-up” type use for critical communications.

4. Migrate users to alternative frequencies (VHF band). Existing users might even be moved to lower frequency bands such as VHF mid, high or low band. Some applications, in particular the vehicular and dispatch type services that do not require small handheld terminals might be served just as well in these lower bands with transmission powers limited to match the required coverage area<sup>54</sup>. Using modern digital equipment many of the past problems with these bands have disappeared. The modern equipment is much more resilient to fading. The man-made noise (EMC) from other road vehicles (ignition noise) is no longer a serious problem and interference arising from enhanced propagation during periods of high pressure is less likely to occur due to the greater robustness of the digital transmissions. However the key issue is users' perception and it would need to be made clear that they can still use smaller antennas<sup>55</sup>—they are less efficient but can still achieve the required coverage and there are studies that indicate building penetration is greater than at 450 MHz. Concern is that it is a niche market and for mainstream products there is a need a volume market. But it should be possible!

5. Review sharing potential. There could be benefits in investigating whether the sharing of the MOD bands could be more effectively managed, for example by Ofcom as part of the assignment process, whilst still protecting MOD interests but also providing better access for commercial users. This might, for example, include reviewing the restriction areas and how co-ordination may be achieved within these areas.

In the case of the Fylingdales military radar in 420–450 MHz it might be appropriate to consider whether the current allocations are best suited to sharing with Fylingdales and also between each other<sup>56</sup>. For example use of the spectrum might be maximised by ensuring only low power uses are located in the frequencies that overlap with 420–450 MHz. However if a band re-arrangement is considered beneficial it does raise the question whether it would be more appropriate to undertake band reversal at the same time.

6. Utilities share scanning telemetry frequencies or a network. If the Utilities share / coordinate frequencies and / or a network there may be the potential for economies of scale as monitoring points could be at different geographic locations.

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<sup>54</sup> It was noted that in the '80s VHF users were migrated to UHF. It was necessary to offer higher transmitter powers (25 W in UHF compared with 2 W in VHF) to encourage the move.

<sup>55</sup> E.g. use  $\frac{1}{4}$  wavelength antennas.

<sup>56</sup> It is not proposed that the current sharing agreements should be revisited / revised but what services are operating co-channel with Fylingdales.



7. Emergency services release spectrum. There is the possibility of the emergency services reducing the amount of spectrum they require within UHF 2 and if this could be used by commercial users on a long term basis this might provide additional solutions. This might be achieved by either moving applications into other UHF bands the emergency services will have access to post 2020 or by incorporating existing systems into the forthcoming Emergency Services Network (ESN).

In addition to the potential solutions listed above there are a number of others covered in the scenarios “business as usual with band reversal” and “deployment of managed networks” which are addressed in later sections.

### 3.2.7 Risks

In this section we consider the main risks associated with this scenario<sup>57</sup>. Some of these risks will impact on the viability of some of the potential solutions listed above.

1. Future demand from existing and new applications cannot be met. There is already, we understand from industry, excess demand for Business Radio in London and this is expected to extend to other metropolitan areas so there will be users that require access to frequencies for business and safety reasons that might not be able to do so. The Utilities (water and electricity) want to extend significantly their network monitoring capabilities to ensure they meet Government ratified European Directives and also to minimise the impact of weather, such as experienced in the UK over the winter of 2013 / 2014, on end users. The fragmented use of the spectrum between different users and with different duplex spacings prevents the introduction of more efficient technologies such as CDMA / LTE<sup>58</sup> so it is not possible to meet the demand for wideband PMR services or to cater for the anticipated growth in M2M demand from the Utilities. To allow for the introduction of a national network to support the utilities based on CDMA or LTE technologies or to cater for wideband PMR it would be necessary to reverse the band.
2. Interference. Increasing interference from mainland Europe could impact the use of the bands for critical and resilient applications. In recent years there has been limited use of the bands in neighbouring countries following on from the removal of the 450 MHz analogue cellular networks but there is now increasing use of the spectrum for new systems such as CDMA450 which increases the risk of interference in the future. This ‘new’ interference is wideband and more challenging/impossible to escape from than the individual channel interference cases experienced in the past. Worsening

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<sup>57</sup> Some of these risks also apply to other scenarios.

<sup>58</sup> In respect of efficiency see for example ECC Report 042 that compares the efficiency of CDMA-PAMR, TETRA and PMR for voice and data.

the situation is that it is not the individual mobile that is suffering interference and unable to communicate but the base station receiver, potentially rendering the whole network of very little use.

This is already becoming a problem in some areas—for example we understand that Scanning Telemetry coverage is being lost on occasions in East Anglia during propagation lifts. The FCS has also indicated that its membership has seen that interference from the continent is already becoming apparent and is expected to grow significantly, presenting a potentially serious impediment to services operating in the affected areas. The impact of interference can last for several days or even weeks which is consistent with lifts (ducting over sea paths) in high-pressure weather. During these periods the interfering field strength can be elevated by some 40 dB or more<sup>59</sup>. The effect can extend quite a long way inland in flattish areas (East Anglia, East Kent, Thames estuary, Lincolnshire, etc.). Ofcom has observed that the roll out of CDMA 450 in Nordic countries has caused interference during periods of anomalous propagation conditions and that users (utilities) have lost communications for days at a time in East Anglia and the Midlands.

Even when there is no ducting there is still the chance of interference into Southern and Eastern England from sites deployed in nearby Europe as shown by the analysis in the “incumbent growth with band reversal” scenario.

3. Loss of critical infrastructure. This risk is directly related to lack of frequencies to support future needs of critical infrastructure and also the impact of interference. If communications used in support of critical infrastructure such as Utilities and Railways, fail, there is the potential for regional power outages, sewage spillage, flooding and delayed or cancelled trains. These would all have an impact on the UK economy.
4. Cellular does not meet users’ requirements. Stakeholders have raised concerns that cellular is not always a viable alternative to Business Radio. For example cellular networks are typically planned to provide coverage to users located at a pre-defined height (e.g. 1.6 m above ground level) so applications that require communications to underground devices may find that cellular is not a suitable option. Also coverage and the installation of base stations is determined by commercial drivers—a base station will only be installed if there are sufficient users in the area so that it costs in.

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<sup>59</sup> Measurements undertaken by Aegis in support of the Ofcom study on “Time Varying Interference, Implications for Digital Switchover” show the implications of ducting on the received signal strengths from transmitters located in France and the Netherlands. It is pointed out in the report that there is a large year-to-year variability.

Recently the coverage<sup>60</sup> provided by MNOs has been viewed to have deteriorated with the advent of EE and network sharing which means some base stations that might have been providing marginal coverage to some users, have been removed. There is anecdotal information that some ex Business Radio users that migrated to cellular may want to reinvest in supplying their own communications. The amount of traffic generated by many Business Radio users is small compared with other cellular users so they will have little / no influence on network deployment. Perhaps most importantly, cellular networks simply do not provide the functionality that many Business Radio users require, such as group calling and instant push-to-talk communication.

### 3.2.8 Conclusions

There are a number of potential approaches that might help in meeting some of the future demand such as changes to licensing as described earlier (see Section 3.2.6). Also release of some of the Emergency Services spectrum as described in the next scenario (see Section 3.3) might provide additional spectrum for commercial users. However it is more likely that it will be necessary to prioritise access to the spectrum such that the UHF bands should first be used to support critical business applications and then users with lower business/use priorities may have to select another band or another communications service<sup>61</sup>.

Nevertheless it is very difficult to see the current usage of the 420 to 470 MHz band continue in the long term with the increasing demand for frequencies for existing uses and users. For example there is ideally a need to accommodate higher bandwidth technologies like CDMA or LTE in the band to meet demand for wideband PMR services or to cater for the anticipated growth in M2M demand from the Utilities. The fragmented use of the spectrum makes it extremely difficult to identify contiguous frequencies without a re-arrangement of the existing users.

The potential for interference from mainland Europe appears to be increasing with the deployment of new networks using technologies such as CDMA and in the future LTE and there have been instances of interference problems in recent years.

There appears to be a strong argument for re-organising the current allocations in 420 to 470 MHz—the solution, trigger point and decision, has to come from Ofcom taking into account what they see is best for the market and the efficient use of the

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<sup>60</sup> However where cellular coverage is the problem, this could be solved by self installation of a “home pico cell” or Wi-Fi connected to an ISDN line and Business Radio users need to be made aware of this solution as it may resolve some of the perceived issues with cellular. This is no different to the PMR situation where it may be necessary to install a specific base station with leaky feeders / antenna to provide coverage.

<sup>61</sup> This matches with Ofcom's policy of ensuring spectrum is used for the highest value purpose where in this instance the highest value is defined by business criticality.

spectrum. Implementation of a national network for wideband PAMR or M2M for the Utilities will, almost certainly, require band reversal across all of the UK and major re-engineering of the remaining spectrum, due to the consequential interference into the incumbent users.

The potential for interference from mainland Europe is in our view an important but secondary issue as it does not impact on all users and only in a limited geographical area. There is always the possibility to implement limited band reversal on a piece meal basis when specific interference issues are identified and the interference impact of such changes may however help to start a “snowball” effect. The current use of the spectrum is so fragmented that it is highly unlikely that a band reversal solution could be driven by market forces, although they may help on the edges or when the process has started.

### 3.3 Emergency Services Scenario

#### 3.3.1 Introduction and description of the scenario

The Emergency Services jointly hold access to over 7 MHz of non-contiguous spectrum in UHF 2. They also have access to 2 x 2 MHz in UHF 1 and also the existing 2 x 5 MHz of public safety spectrum between 380–385 MHz paired with 390–395 MHz. The scenario below looks at how the Emergency Services as a sector can be an enabling factor in terms of making better use of the band between 420–470 MHz. As described below, this is not without its own set of challenges notwithstanding future Emergency Services requirements earmarked for this band and international agreements that will need to be considered.

In this scenario, two key areas are addressed:

- Maintaining existing and future capabilities in the band, and
- Potential to release or share spectrum in the UHF 1 & 2 bands.

#### 3.3.2 Future demand

The new applications or systems being introduced, or likely to be introduced in UHF 2 include:

- Breathing Apparatus (telemetry), which is temporarily using 869.5 MHz<sup>62</sup>, for the Fire Brigade. It is proposed that this will be used in the 450–470 MHz band between 469.875–470.000 MHz (50 kHz allocation providing a 25 kHz channel with 12.5 kHz guard bands on either side<sup>63</sup>) on a national basis. It is expected that around 25 forces will use the breathing apparatus this year (2014) and within 5 years all the forces in England, Wales, Scotland and Northern Ireland will be equipped with it.
- Home office system requiring around 100 kHz bandwidth.
- AGA (air to ground) communications as it is not feasible to use higher frequency bands and around 0.5 MHz paired will be required. This will be necessary to support those communications supported by the current TETRA network.

In addition there may be a need for a 650 kHz channel (approximately) to support slow scan video if this is not catered for on the new Emergency Services Network (ESN).

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<sup>62</sup> BA telemetry equipment operated in a licensed Emergency Services allocation at 862.9625 MHz but with Digital Switchover of TV broadcasting spectrum immediately below 862 MHz will be used by the uplink (i.e. handset transmissions) of 4G cellular and with a guard band of less than 1 MHz there was the potential for out of band emissions from the LTE handsets. The new allocation in the 450–470 MHz band was determined to be the most suitable.

<sup>63</sup> Tests were due to be completed shortly to confirm this spectrum requirement.

### 3.3.3 International developments

In Europe<sup>64</sup> ECC Decision ECC/DEC/(08)05 and the former ERC/DEC/(96)01 identified spectrum within the duplex bands 380–385 / 390–395 MHz for narrowband (up to 25 kHz channel spacing) digital PPDR (Public Protection and Disaster Recovery) applications. In ECC/DEC/(08)05 it states in Decides 3 that sufficient spectrum should also be made available for wideband digital PPDR within available parts of the 380–470 MHz frequency range.

Work is ongoing within ECC Project Team FM 49 to identify spectrum for broadband PPDR communications, focusing on medium term and long term (before year 2025)<sup>65</sup>. One of the frequency ranges considered is 400 MHz.

In document FM49(14)003rev2, the ECO summary of responses to a questionnaire on the use of the 400 MHz band, approximately one half of the respondents<sup>66</sup> (11 out of 25) did not see any possibility of making frequencies in the 400 MHz range available for BB PPDR networks. These administrations either provided no information or referred to the heavy usage of the band by other applications, predominantly by narrow and digital PMR/PAMR systems, and the difficulty of refarming.

Another 12 of the respondents considered there were possibilities of using parts of the 400 MHz sub-bands and in some cases both 410–430 MHz and 450–470 MHz in the future. In some instances this would include shared usage with commercial LTE networks.

At the time of writing, the draft Executive Summary in the PT's forthcoming ECC Report B, on "Harmonised conditions and spectrum bands for the implementation of future European broadband PPDR systems" includes a summary on the potential frequency bands for Wide Area Networks. The summary makes clear that the 700 MHz band is supported as the main candidate spectrum option by a majority of project team participants including user representatives. This band is also considered to have good physical propagation characteristics (although not as good as 400 MHz).

Therefore it is not currently considered that the 420–470 MHz band will be harmonised within Europe to provide Emergency Services broadband services.

### 3.3.4 General considerations

In this section we identify topics and issues that need to be taken into account when identifying potential solutions.

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<sup>64</sup> CEPT countries

<sup>65</sup> It is mentioned that 2 x 10 MHz is the minimum required for Broadband PPDR as calculated in ECC Report 199.

<sup>66</sup> CEPT administrations

In respect of this scenario, where it is addressing the potential to release spectrum, the following need to be considered:

1. Constraints on use of 410–412 / 420–422 MHz spectrum. Whilst the 410–412 / 420–422 MHz band is currently identified for use by the Department of Health it is not constrained<sup>67</sup> and could be used for commercial or private users or to meet the Emergency Services' needs that are currently addressed by using UHF 2 frequencies.
2. Emergency Services Network. There may be the potential to migrate some of the future requirements on to the new Emergency Services Network (ESN) once it is fully operational.

Also, whilst outside the scope of the Study, it is worth exploring the possibility of utilising part of the 380–385 / 390–395 MHz band to provide for a parking band or support commercial solution(s) in the longer term. Also, once the ESN is fully operational, this band could then be used to support changes in the UHF2 band or be used to support Emergency Service requirements from the existing UHF2 band.

### 3.3.5 Challenges

The challenges are:

- How to share the spectrum between the Emergency Services and incentivise migration to the new frequencies, especially considering the recent investments in equipment (e.g. the migration of HM prisons from on-site analogue to their own TETRA networks).
- Alignment of timing and how quickly spectrum sharing could be accomplished. A key consideration will be the timings for the service commencement of the ESN planned for late 2016 and ending of the Airwave contract at the end of December 2020.

### 3.3.6 Potential solutions

In this section we consider the potential solutions based on the general considerations and the challenges identified in the previous sections.

The possible options for releasing spectrum are:

1. Migrate the HM Prison current TETRA usage on to the Emergency Services Network once it is available and so releasing valuable paired spectrum.
2. Geographic sharing. Consider the potential use of the 410–412 / 420–422 MHz band, currently used by the Department of Health, on a geographic sharing basis. This could be by the migration of some of the existing and foreseen new services or networks (e.g. airborne applications, Fireground and Breathing Apparatus telemetry).

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<sup>67</sup> This band would be constrained by Fylingdales if band reversed.

3. Access to current TETRA network frequencies. Use of the Emergency Services spectrum in the 380–385 / 390–395 MHz band, on a temporary or permanent basis, could help facilitate band reversal if it was possible to gain access to the MOD spectrum. Alternatively it could also be used to support Emergency Services' requirements currently using UHF 2.

It is noted that this release of spectrum may be encouraged under the HMG spectrum release programme<sup>68</sup>.

### 3.3.7 Risks

The following are the likely risks identified with implementing spectrum sharing and release of spectrum:

1. Timing.
  - When will the Emergency Services Network (ESN) be available for use by HM Prisons and how quickly could the migration be undertaken?
  - The timings for access to the 380–385 / 390–395 MHz band may not match with any plans such as band reversal and may be delayed depending on how successful migration of voice services to the new Emergency Services network is.
2. Access to spectrum.
  - The 380–385 / 390–395 MHz spectrum is part of a core NATO band and they might not be willing to release / share it with non-Emergency Services or they might have other plans for the band.
  - Sharing between the identified services may not be feasible or it may not be possible to migrate all the users on to a common shared network. This would need further interference and compatibility studies.
3. Maintaining current capabilities in terms of applications and services both during the migration and in the final solution.
4. Cost of migration versus the benefits of undertaking such an exercise may be such it is not a viable option for the Emergency Services. There are a number of different users, a number who have recently migrated or are planning to migrate to new equipment and frequencies so a further investment may not be considered reasonable or viable.

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<sup>68</sup> For example see

[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/77429/Spectrum\\_Release.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/77429/Spectrum_Release.pdf)



### **3.3.8 Conclusions**

It is not expected that there will be any specific requirements to harmonise the use of the 400 MHz bands for broadband PPDR. The potential to consolidate systems and release frequencies is a very attractive option in terms of identifying additional spectrum for either band reversal or support of commercial networks and warrants further study and discussion with the users and departments involved. This should be followed up under the HMG spectrum release initiative.

### **3.4 Incumbent Growth leading to Band Reversal**

#### **3.4.1 Introduction**

In this Scenario the future capacity demand from existing users remains the same as forecasted in the “Incumbent Growth Scenario” and band reversal is seen as a means to allow the deployment of technologies, such as CDMA 450 and LTE, to meet these or alternative demands more efficiently.

Interference, from neighbouring countries, is considered sufficient to trigger the need for band reversal to align the UK usage of the 420 to 470 MHz bands with the rest of mainland Europe.

#### **3.4.2 Future demand**

In addition to the future demand identified in the “Incumbent Growth” scenario, band reversal could potentially support additional M2M deployments in the band.

Smart meters are likely to be one of the biggest M2M market sectors in terms of volume, with the Government aiming to complete national rollout by 2020. Three 15-year smart meter communication service contracts were awarded in 2013 covering the North, Central and Southern regions of the UK. The North region contract was awarded to Arqiva and the two other regions to Telefonica UK. Whilst Telefonica will be using their cellular (GPRS) network to support the wide area part of the service, Arqiva will be deploying a dedicated wireless advanced metering infrastructure (AMI) technology called Flexnet developed by US company Sensus and operating in the company’s existing licensed spectrum in the 410–430 MHz range.

In the future a number of recent standards innovations suggest there may be interest in the deployment of low power wide area (LPWA) M2M networks, which combine the attributes of today’s SRD and cellular technologies by allowing wide area coverage to be obtained from low power battery operated devices. UHF spectrum is potentially attractive for such networks because of the favourable propagation characteristics, although antenna size constraints for small embedded devices may favour higher bands such as 870–873 MHz.

The two principal LPWA technologies currently being promoted are Weightless and SIGFOX. Weightless is an open standard which uses frequency hopping spread spectrum with a very high spreading factor to enable low data rates to be transmitted over long distances (5 km) with low transmitter powers (4 W or less). The standard can in principle operate anywhere in the UHF range but currently the focus is on the TV white space frequencies where the 8 MHz channels enable the greatest benefit to be realised from the spread spectrum technology. The standard is also claimed to be suitable for operation in the cellular bands (where part of an operator’s existing spectrum could be re-purposed) or in licence exempt spectrum. Whilst the standard could be deployed in the 450 MHz range the Weightless Special Interest Group (SIG) responsible for the standards does not appear to be pursuing this option currently, although interestingly the SIG Chairman William Webb has

previously referred to possible sharing with the emergency services in the 380–450 MHz range (see his book “Understanding Weightless”, p.45).

The other standard, SIGFOX, has been developed by a French company of the same name and uses ultra narrow band technology to enable long range (up to 40 km) transmissions using low transmit powers. The focus is currently on the 868 MHz band although like Weightless the technology could be deployed in other bands if required. The narrow band technology requires as little as 200 kHz for a national cellular network, running at low bit rates (typically a few kbps or less).

In Europe, the main focus of interest regarding M2M spectrum currently appears to be the existing 863–870 MHz SRD band for short range applications and it is noted that Ofcom has recently issued a statement on the release of spectrum in the 870 to 876 MHz and 915 to 921 MHz bands for Short Range Devices, which can be used for machine to machine (M2M) communications. 450 MHz is however attracting attention in some countries for potential deployment of CDMA450—the Netherlands being a case in point where there are plans to use this technology to support smart utility meters. In the UK this application, as noted earlier, is being served by existing networks (O2’s GPRS network and Arqiva’s Flexnet network) so there appears to be less opportunity for an alternative like CDMA. In the future LTE may cater for M2M and a scaled down version of the standard is currently under development (variously referred to as “low cost LTE for consumer equipment” or LTE category 0). Chip sets are expected to become available around 2017 but as requirements include the need for a simple receiver architecture it is questionable whether multi-band support would be included and whether there would be a sufficient business case to roll out additional infrastructure to support 450 MHz (with the associated large antennas), though serving the more mission-critical aspects of utility data communications (smart grids and telemetry) should make more of a case.

Beyond smart metering, the biggest markets for M2M communications are likely to be in the building automation, automotive and healthcare sectors. Building automation predominantly uses short range technologies which are likely to favour existing licence exempt bands (particularly 863–870 MHz). The automotive sector will require wide area coverage for which the UHF bands could in principle be very attractive, however the international nature of the automotive sector means that there will likely be a strong preference for internationally harmonised spectrum with extensive network coverage across all European countries. This would tend to favour use of existing LTE bands such as 800 MHz.

The likelihood that 700 / 800 MHz LTE will be adopted for public safety communications in Europe (either using dedicated networks or coverage-enhanced public networks) suggests that the case for LTE 450 to support mission critical M2M communications on coverage grounds would be diminished. We are therefore of the opinion that any expansion of M2M communication in the UHF bands is most likely to be driven by the utility sector, to provide a long term replacement for existing scanning telemetry systems and support the planned rollout of smart grid

distribution networks. It is likely that deployment of a single FDD carrier of 2 x 1.23 MHz (CDMA) or 2 x 1.4 MHz (LTE) would be sufficient to serve this requirement.

To conclude, whilst there is clearly potential to deploy M2M technology in the 450 MHz band (indeed this is already the case with utility and low power telemetry) this is not currently seen as one of the core bands for other types of future M2M systems. Interest is instead more focused on the internationally harmonised short range device and cellular bands and (to a lesser extent) the TV white spaces. Additional spectrum above 870 MHz may also prove attractive in the future particularly if this is harmonised at EU level.

### **3.4.3 International development**

There are no specific international developments relevant to this scenario but reference should be made to the scenario “introduction of LTE 450 in the band” where information is provided on the potential to deploy LTE and also “deployment of managed networks” where the deployment of CDMA 450 networks on mainland Europe are discussed and also Annex C.

### **3.4.4 General considerations**

In this section we identify topics and issues that need to be taken into account when identifying potential solutions.

#### **3.4.4.1 Meeting future demand for Utilities**

The huge challenge for the Utilities is finding sufficient spectrum to upscale their existing scanning telemetry networks. As the networks become denser they run the risk of drowning in self interference in a similar manner to the original analogue cellular networks. A more practical solution might be to find a gap for the Utilities to run a 1.4 MHz LTE network for the initial switch over and to cater for additional new sensors and then upgrade to a 3 MHz LTE system to support all their communications needs<sup>69</sup>. This approach would future proof the investment and ensure sufficient capacity and scope for increased amounts of data and other additions that are inevitable as the systems develop further. The service is uplink centric but the data amount is such that any of the IMT technologies could easily handle it. It could also meet the requirements for video surveillance of key points in the distribution networks. The use of LTE would also probably require less power at each point and at each concatenation point making back up power easier to provide than with the huge forecasted increase of the existing equipment.

Another option might be the use of CDMA 450 which could require less spectrum as each channel is 1.23 MHz and it is likely a maximum of 2 channels will be required.

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<sup>69</sup> Replace their Business Radio requirements as well as it is less likely that there will be a need for small form factor or terminals that support multiple frequency bands.

However for either option to be viable the band needs to be reversed as it is extremely unlikely that vendors will be willing to cater for the UK specific transmit and receive arrangement as the products are targeted towards large volume markets. Also the Utilities could end in an untenable single vendor / high cost situation.

#### 3.4.4.2 *Meeting demand for wideband PMR and other M2M*

Band reversal is also ideally necessary to meet the needs of deployment of wideband PMR and also any M2M solutions that might arise in the future.

#### 3.4.4.3 *Interference from and to mainland Europe*

It was noted in the “Incumbent Growth” scenario, under risks, that there are already instances of interference that are believed to be due to the changing use of the UHF bands in mainland Europe. This “new” interference is wideband and more challenging / impossible to escape from than the individual channel interference cases experienced in the past. Worsening the situation is that it is not the individual mobile that is suffering interference and unable to communicate but the base station receiver rendering the whole network of very little use.

Clearly any networks that are safety or business critical cannot be operated on frequencies where there is likely to be a loss of communications for any period of time. It has also been noted by some users that it is important that when a critical transmission is sent it must arrive at once without the need for multiple re-transmissions. Therefore with the potential for increasing use of the bands in Europe, in particular to provide high power wideband and broadband services (see Annex C), there is a need to investigate whether band reversal would help alleviate the impact of interference<sup>70</sup>.

To help understand the likely impact of interference from mainland Europe analysis has been undertaken looking at the potential for co-channel interference based on a number of scenarios and these are provided in Annex A.

As an example in Figure 19 below a simple analysis has been undertaken and the geographic area is shown where a single wideband co-channel transmitter located in France (at Calais) would degrade<sup>71</sup> the “normal service” in the UK for 1% of time. It was assumed that the EIRP towards the UK was 53 dBm / 100 kHz and the antenna was mounted at 30 m above ground level. The figure shows the interference areas when it is assumed that the threshold is 12 dBµV/m for 1% of

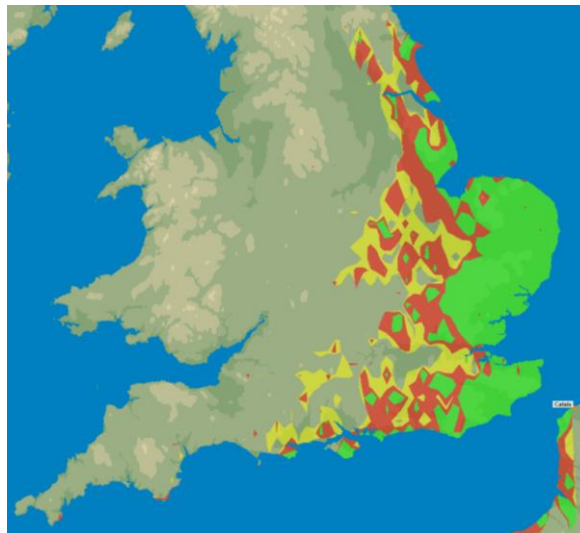
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<sup>70</sup> It is however impossible to identify the probability of interference now and how it will alter due to increasing use of the UHF bands in Europe as this will depend on so many assumptions about the level of take up of the European networks and the location and density of the transmitters.

<sup>71</sup> Any inbound interference above -116 dBm in 12.5 kHz will degrade the service as this is the planning threshold (defined at the receiver input) used for assignments and is defined in the Business Radio Technical Frequency assignment Criteria (TFAC).

time at antenna heights of 10 m (red contour) and 30 m (yellow contour) and 17 dB $\mu$ V/m (green contour) for 1% of time at 1.5 m antenna height<sup>72</sup>. The modelling tool took account of terrain data and used the ITU-R Rec. P.1812 propagation model which is developed for modelling point-to-area interference paths.

**Figure 19: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights (Threshold: 12 dB $\mu$ V/m in 25 kHz for 1% of time at 10 m & 30 m, 17 dB $\mu$ V/m in 25 kHz for 1% of time at 1.5 m, TX EIRP towards the UK: 53 dBm / 100 kHz)**



The modelling demonstrates that there is a significant geographic area of the UK where there is likely to be degradation to the service due to interference exceeding the  $-116$  dBm / 12.5 kHz planning threshold used by Ofcom. This is shown by the yellow and red contours which reflect the situation where the UK is band reversed as currently and the interference is base station transmitter in Calais into base station receiver in the UK.

In the case that the band was reversed then the interference would be from the base station transmitter in Calais into a mobile receiver, as shown by the green contour. The potential for interference into a mobile receiver is in reality expected to be even less than shown as it is more likely to be located within the clutter and so the 1% of time constraint is less likely to be exceeded<sup>73</sup>.

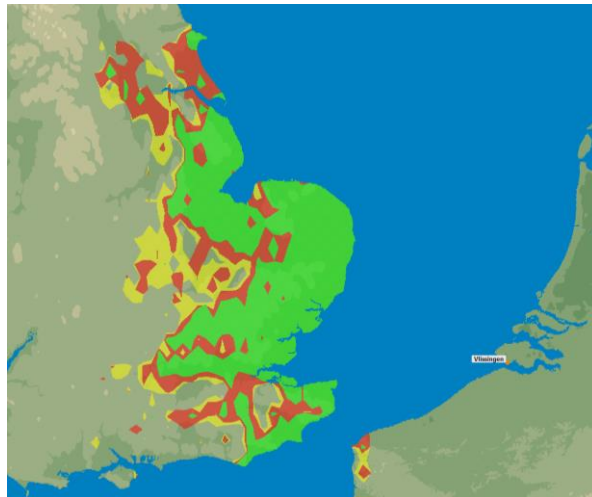
A similar outcome can be seen with a transmitter located in the Netherlands (at Vlissingen) as shown in Figure 20 below. Once again the interference areas for base station to base station interference, shown by the yellow and red contours are

<sup>72</sup> The threshold levels are based on the  $-116$  dBm / 12.5 kHz threshold, 10 m and 30 m antenna heights being for base stations, 1.5 m antenna height for the mobile terminal, 5 dBi gain for the base station antenna and 0 dBi gain for the mobile terminal antenna.

<sup>73</sup> Looking at the map it appears that the green area (band reversed interference) is roughly 50–60 % of the yellow area (current potential for interference).

greater than for the case with band reversal where the interference will be from a base station transmitter into a mobile receiver shown by the green contour.

**Figure 20: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
 (Threshold: 12 dBµV/m in 25 kHz for 1% of time at 10 m & 30 m,  
 17 dBµV/m in 25 kHz for 1% of time at 1.5 m,  
 TX EIRP towards the UK: 53 dBm / 100 kHz)



These results are just for a single base station and the situation is likely to become worse if there were a number of base stations located along or near the coastline in mainland Europe (France, the Netherlands etc.) as there is potential for interference levels to aggregate. In this case, the geographic area where the Ofcom assignment criterion would be exceeded would extend further inland.

Whilst we are aware it would be extremely helpful to be able to identify at what point interference would reach the trigger level where band reversal is needed it is impossible to derive this point due to a significant number of unknown input parameters including the level of take up of the European networks, the location and density of the transmitters and their deployment characteristics. The trigger level will also depend on whether these networks are co-ordinated in advance with the UK and so transmitter powers are reduced along, for example, the coast line pointing towards the UK.

In addition we have analysed the implications of meeting the cross-border interference threshold level when interference from the UK is considered<sup>74</sup>. It was found that a typical base station located at Dover or Ashford would exceed the cross

<sup>74</sup> In the case of CEPT Recommendation T/R 25-08 (May 2008) the recommended threshold level is 20 dBµV/m at the border for land mobile radio frequencies between 400 and 606 MHz. This level is for bandwidths up to 25 kHz, co-channel interference, 50% of locations, 10% of time and 10 m receiver height. For wideband land mobile applications the threshold is increased by  $6 \times \log(\text{Channel BW} / 25 \text{ kHz})$ .

border coordination threshold in the simulated area over France, whereas the same transmitter located in Maidstone would satisfy the coordination threshold. In the case of a mobile transmitter there is the potential to locate it close to the coast without exceeding the threshold. Therefore alignment with mainland Europe will provide greater deployment flexibility.

#### 3.4.4.4 *Previous work on band reversal*

There have been previous proposals for band reversal and these have not been progressed. This in part is a reflection of the improved interference environment which resulted from the closure of the former analogue cellular networks that operated in the band but is now under threat due to the emergence of new digital networks such as CDMA450. Also the costs were considered to outweigh the benefits at the time. Industry does need to see the benefits of band reversal and the process needs to be as simple as possible and executed within short timescales. Band reversal can only be instigated by Ofcom as they ultimately are responsible for the efficient and effective use of the spectrum.

#### 3.4.5 **Challenges**

The major challenge is how the process of band reversal can be achieved. It has to be recognised that the only way is likely to be through regulatory intervention, since many of the licensees who already have access to spectrum are unlikely to “buy-in” to something that costs money and from which they see no concrete benefits.

#### 3.4.6 **Potential solutions**

In this section we consider the potential solutions to facilitate band reversal based on the general considerations and the challenges identified in the previous sections.

1. Availability of parking band. Band reversal ideally would use suitable spare spectrum to act as a parking space and if this can be identified it should facilitate the re-planning of the UHF 1 and 2 bands to match with T/R 25-08. There is no minimum amount of spectrum that is required as band reversal could potentially be achieved on a phased basis over smaller coverage areas. It was identified in the scenario on the Emergency Services that rather than an expansion in their use of the bands there might be the potential to reduce its use and so release spectrum for commercial use on a permanent or time limited basis. In the case of the latter this might be an attractive option if in return they receive contiguous spectrum later. Another option might be to remove the Radioamateurs for a limited period.
2. Migration of users to other spectrum or solutions. Band reversal would be easier if those users that can and would wish to migrate to other frequency bands (such as VHF) or to other solutions such as cellular or managed networks do so at an early date. This would also have the added benefit of addressing increasing demand and should be encouraged anyway by Ofcom and not be predicated on band reversal.



3. Development of plan. It will be necessary for Ofcom to develop and deliver a clear plan and associated timescales. There may be a need for a mix of approaches such as licence cancellations, increased fees or specific requirements placed on Ofwat and Ofgen that lead to the required investments outside of their usual finance cycles. The issue of the costs of band reversal and how to ensure the necessary human resource is available to undertake, for example, any site re-engineering will also have to be addressed.

### 3.4.7 Risks

1. Implementation issues. In previous consultations on band reversal, concerns were raised about lack of skilled field staff (riggers and equipment installers), lack of space at sites to install additional equipment etc. These issues are still relevant.
2. Suitable parking bands. Important considerations are the availability, timeliness and suitability of parking bands / replacement frequencies or network solutions. If no suitable parking bands are available then it might still be feasible to achieve band reversal by considering smaller geographic areas and isolating and identifying what spectrum is needed for these specific areas. In other words do it in phases (might just be weeks apart).
3. Costs. A Study undertaken by PA Consulting in June 2004 estimated the total cost of UHF2 band alignment, assuming that each user will require a single frequency change, to be between £260M and £310M. A short high level review of the key considerations in this study are provided in Annex B. Due to the likely difference in costs since 2004 it is proposed that this study, or at least parts of it, would need to be repeated. However as an initial indication these figures are probably reasonable to understand the likely costs of band reversal.
4. Funding. An important consideration is how band reversal would be funded and how it could be implemented cost effectively. There are implications for business cycles, for example Ofwat has a 5 year finance cycle and in the worst case it could be up to 10 years before anything was possible, this however could be different if funding were available.
5. Interference. Even with band reversal interference could still be a problem but the UK will be in a position to fully comply with the cross border Harmonised Calculation Method (HCM) and would place the UK in a stronger position should there be incoming interference.

The Republic of Ireland is currently aligned with the UK and they would also need to band reverse to avoid new interference issues. For example, ComReg has recently decided to adopt a channel plan for scanning telemetry based on the current UK plan<sup>75</sup>.

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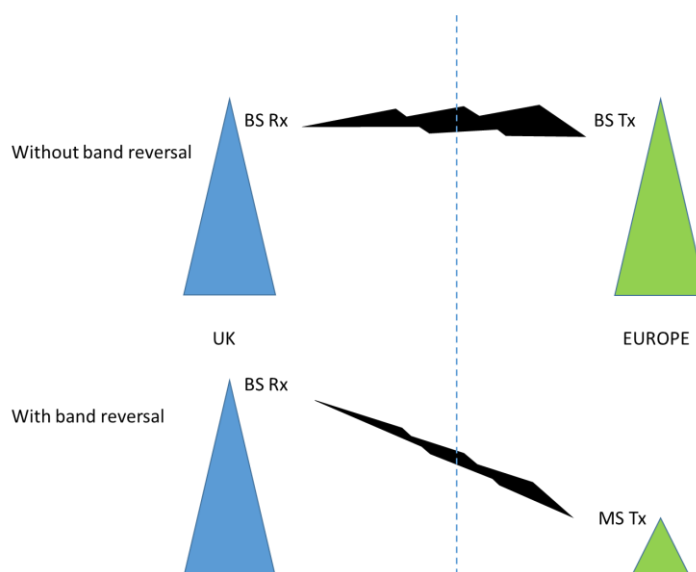
<sup>75</sup> See ComReg document 13/77.

### 3.4.8 Conclusions

Band reversal is necessary to provide the opportunity for wideband PMR and allow for the introduction of more efficient technologies, such as CDMA 450 and LTE 450 to address the increasing demands from the Utilities. The European Directives that impact on the communications solutions used by the Utilities indicate that there are some major investment decisions needed in the immediate future. The Emergency Services are already addressing such decisions. There are trials underway in Europe looking at the use of CDMA 450 to meet the Utilities requirements as well as network roll out in the Netherlands. It is not considered an option to deploy CDMA 450 or LTE without the UK harmonising with the rest of Europe to ensure availability of reasonably priced equipment / networks. It is not possible for just one sector to align as that effectively moves the European interference impact closer to home and exacerbates the problem for other users. This, however, would be the start of the “snowball” effect.

In addition there is the potential for increasing use of the bands in Europe, in particular to provide high power wideband and broadband services, with the likely increase of interference into the UK. Band reversal can decrease the potential for interference as indicated in the figure below. The current situation is there is increased risk of interference as base stations on mainland Europe, with higher transmitter powers and antenna heights, are more likely to cause interference into base station receivers in the UK. The interference risk is much lower if the UK is aligned with Europe as the interference into base station receivers in the UK will be from mobile transmitters normally deployed at lower heights with the potential to be hidden in the clutter and transmitting with lower powers.

**Figure 21: Comparison of cross-border interference scenarios (Europe into UK)**



Also if both the UK and neighbouring countries deploy networks using IMT technologies it should be feasible for the network operators to coordinate their deployments, similar to the situation now with cellular networks operating on the same frequencies in neighbouring countries.

It is likely that the only way band reversal can be achieved is through regulation instigated by Ofcom, since many of the licensees who already have access to spectrum are unlikely to “buy-in” to something that costs money and from which they see no concrete benefits. Ofcom will need to make the decision on the basis of efficient and effective use of the spectrum and whether they can provide the market (industry and users) with the required usable spectrum to meet developing needs.

## **3.5 Deployment of Managed Networks in the Band**

### **3.5.1 Introduction**

This particular scenario is considering the introduction of new networks based on technologies such as TETRA, CDMA 450 and LTE that target the existing business users of the UHF1 & 2 bands.

### **3.5.2 Future demand**

There is no clarity as to likely future demand for access to spectrum in the 420 to 470 MHz band to support managed networks<sup>76</sup> in the UK. However it is understood that some existing UK providers would like to extend their existing UHF systems across the main conurbations but lack of frequencies is an issue. Coverage provided by existing managed networks outside the main conurbations is limited and unlikely to be sufficient for many Business Radio users<sup>77</sup>. Provision of national coverage in the UK is challenging compared to countries like Belgium or Holland, which are much smaller and have much flatter terrain. However if providers prove their business case in other European countries, for example Entropia in the Netherlands and Belgium, then it is possible that they will look to provide similar networks elsewhere in Europe including the UK. This has two implications—the potential for existing users to migrate to an alternative solution to meet their communications requirements and the risk of increased interference from neighbouring countries.

### **3.5.3 International developments**

There is at least one example of the implementation of an extensive network to provide managed services to end users. Entropia is running TETRA in Holland (they appear to be operating as a MVNO on KPN's TETRA-NED) and also in Belgium. It is understood that in the Netherlands they will have nationwide coverage (> 95% geographic coverage) in June 2014. The TETRA networks are being used in Belgium and the Netherlands by several public and private (security) organisations and also the Utilities where they are providing telemetry and PMR.

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<sup>76</sup> Managed networks will typically provide a complete solution to the user including mobiles, hand terminals, and if required the base radio equipment for the office. Typical market sectors that are addressed include taxi, bus and coach companies, maintenance engineers, docks and port operations and distribution organisations.

<sup>77</sup> For example Mercantile Radio offers PAMR services in the London and North West regions and Fleetcomm covers much of the south-east, Midlands and South Pennine regions. Maxxwave Ltd. offers fully managed base station installation and maintenance, site sharing and access to a range of sites across the country. There are some other local systems such as London Radio Networks (LRN) that own and operate a Trunked Radio System infrastructure in London and the surrounding areas. LRN operate two separate networks—one for hand portable radio coverage and the other for those using Trunked Mobile Radios fitted in their vehicles.

Entropia claim that such users have pushed them towards a high mission critical TETRA network.

### 3.5.4 General considerations

In this section we identify topics and issues that need to be taken into account when identifying potential solutions.

1. Availability of spectrum. There will need to be suitable and sufficient contiguous spectrum to support the likely technologies. It is envisaged that there will need to be around 2 x 4.5 MHz for a TETRA network<sup>78</sup> and possibly 3 carriers, each of 1.23 MHz, for a CDMA 450 network<sup>79</sup>.
2. User demand. There are likely to be current Business Radio licensees that will see an advantage in moving to a managed network as it saves investment and maintenance of their own network and sites. Potential users that cannot obtain a licence in Metropolitan areas may find it a more acceptable option compared with using cellular or light licences. If the network can support wideband it may be an attractive option to those users whose services are currently restricted to voice and narrowband data.

### 3.5.5 Challenges

The availability of suitable spectrum is not only a consideration but also a significant challenge. There are TETRA solutions that are available that are band reversed to meet the needs of the UK market. However it is our view that deployment of CDMA 450 will require band reversal and this will have implications in terms of interference on the other uses and users in the band as well as available spectrum.

### 3.5.6 Potential solutions

In this section we consider the potential solutions based on the general considerations and the challenges identified in the previous sections.

Release of spectrum by the Emergency services may provide some if not all of the required spectrum as described in the earlier scenario, see section 3.3.

### 3.5.7 Risks

1. Market exit. Managed networks to date have not been a success in the UK (e.g. Arqiva and Dolphin) and those networks that do exist (e.g. Fleetcomm) have limited coverage, so it is questionable whether they could be an alternative to running own networks which need significant coverage. The main demand

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<sup>78</sup> The problem with planning TETRA is the self interference between cells which makes it difficult to provide in-fill to take account of capacity requirements. This leads to considerably more spectrum being required than might be first envisaged.

<sup>79</sup> The latter is the situation in the Netherlands but this includes provision of high density smart metering services.

from Business Radio users is for on site licences and the Utilities and Emergency Services require high levels of resilience (24/7 operation and 3 day power back-up) and in the case of the Utilities there is low traffic demand. These considerations could lead to the business case not being viable and market exit. It is also worth noting that the business case in countries like the Netherlands and Belgium seems to be largely predicated on serving the large market for smart utility meters, which is already being addressed by other means in the UK.

Also if a system is to support critical communications there are two key requirements—if something is sent it must arrive at once and no multiple call attempts. So to attract mission and / or business critical users the network must have the capacity as well as speed to meet the users' requirements. Service support is also a critical consideration—if a user loses an hour of communications they could lose considerably more than they would save in moving to a managed network (for example we are aware of one large Business Radio user who could lose £2.5M in just an hour). For a Managed Network solution to be a viable option it will be essential that from Day 1 that reliability, availability and coverage meet users' expectations.

## 2. Semi success

If a network is established and just enough users migrate to make it financially viable, the amount of spectrum used may provide for less users than if the spectrum had been used for individual users i.e. the network is not loaded to provide any real trunking efficiency. The other risk is that the network is established using for example a TETRA network matching the current band plan and hence may be blocking for band reversal for many years.

### 3.5.8 Conclusions

The potential for a managed network to be a viable option to a user running their own network is not proven in the UK. Any such network will need to have capacity as well as speed, resilience to outages and excellent service support to attract users. The biggest challenge will be for Ofcom to identify suitable and sufficient spectrum—possibly from the release of Emergency services spectrum, discussed earlier, or the MOD? Ideally any network should have the capability to support both narrowband and wideband applications which in turn would require band reversal.

## **3.6 LTE 450 Scenario**

### **3.6.1 Introduction**

In this scenario the possible uses of a LTE 450 network are considered taking into account international developments and technology considerations.

### **3.6.2 Future demand**

There is, as far as we are aware, no expressed demand to deploy LTE 450 in the UHF bands. Demand for LTE450 services internationally is currently driven by the need to extend rural broadband coverage using fixed or nomadic wireless terminals (see Brazilian example below). It is doubtful such a market would be sufficiently large in the UK<sup>80</sup> and therefore the most likely demand is likely to arise from Utilities requiring resilient data connectivity on a national basis, e.g. for the rollout of smart grid distribution networks. Such demand is currently being addressed by other mobile technologies elsewhere (notably CDMA450).

### **3.6.3 International developments**

The most significant international development is the identification of the 450 to 470 MHz band at WRC-07 for IMT. It has been claimed<sup>81</sup> that the reason for identifying this band for IMT in 2007 was the rising number of IMT networks being deployed in the band and that the deployments were using CDMA2000 technology which was approved by the ITU for IMT-2000.

In June 2012 ANATEL, the Brazilian regulator, auctioned licences for fourth generation (4G) systems for the 450 MHz<sup>82</sup> (451 MHz to 458 MHz and 461 MHz to 468 MHz band) and 2.6 GHz bands<sup>83</sup>. As a direct consequence of the 4G auction, the 450 MHz band was split over four geographical areas, each one assigned to a main carrier already operating in the Brazilian market. The intention was the 450 MHz band would be used to provide Fixed Wireless Access services in rural areas. TIM Brasil has revealed plans to launch LTE services in the 450 MHz band in 2015 and Huawei has announced it expects to have CPE (customer premises equipment) available in 2014.

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<sup>80</sup> The countries where CDMA 450 has been deployed or where LTE 450 is being considered or implemented typically consist of vast geographic areas with very low population density or, as in Scandinavia, have a high density of summer houses and boats. This is not necessarily the situation in the UK.

<sup>81</sup> CDMA Development Group (CDG) ([www.cdg.org](http://www.cdg.org)).

<sup>82</sup> Also referred to as Band 31.

<sup>83</sup> It is understood that no-one bid for the 450 MHz spectrum so the Government required the 2.6 GHz winners to also build out using 450 MHz. Coverage obligations were set but the operators could achieve these through either frequency band although the expectation was it would make economic sense to also use the 450 MHz band.

In September 2012 a 3GPP work programme was initiated to cover LTE 450 in Brazil and in July 2013 Release 12 of the 3GPP Standard was completed that included the 450 MHz band. The standardised band arrangement is 452.5–457.5 MHz (uplink) paired with 462.5–467.5 MHz (downlink) providing 2 x 5 MHz of spectrum. We understand trials of LTE450 are also underway or planned in Russia and Belarus.

As far as we are aware there are currently no other countries planning to use the 450 MHz band for LTE but countries that already use the 450 MHz band for CDMA networks (e.g. Ukraine, Argentina and most of the CITE<sup>84</sup> countries) could potentially migrate to LTE technology to upgrade their Fixed Wireless Access (FWA) networks. For example a news release from the Ministry of Transport and Communications in Finland from 2011<sup>85</sup> mentioned the possibility of transitioning to CDMA in the 450 MHz band and transitioning to 4<sup>th</sup> generation mobile networks in the band and “the importance of collaboration between the countries (i.e. with the Russian Federation) in order to create a sufficiently large and appealing market area, which would be attractive to both network operators and device manufacturers, thus ensuring the necessary supply of 4G devices on the market”. However the Finnish 450 MHz operator (Datame Oy) closed its network at the end of 2013 as the parent company became insolvent. CDMA 450 is also widely deployed for FWA in many African countries and the Far East.

At the ITU JTG 4-5-6-7 meeting (Oct 2013) Brazil submitted an input document proposing to identify the 410–430 MHz as an IMT band. There was not much support, or to be more precise, not much interest for this subject at the time. As the band already is a primary mobile service band it should not be difficult to identify it for IMT and it is already possible to allocate the band to IMT on a national basis.

#### 3.6.4 General considerations

In this section we identify topics and issues that need to be taken into account when identifying potential solutions.

1. Technology. There are a couple of important considerations in respect of LTE 450 that may have implications on how it might be used. The first is that whilst the propagation characteristics of the 450 MHz band will make it attractive to achieve rural coverage the same propagation characteristics will increase the interference into neighbouring cells and reduce the traffic that can be carried over the network. This is because the LTE network is limited by self interference as the air interface is specified as a single frequency network (SFN) reuse technology and the same channel is reused on every sector of every LTE

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<sup>84</sup> CITE<sup>L</sup>—Inter-American Telecommunications Commission: see <https://www.citel.oas.org/en/Pages/default.aspx>

<sup>85</sup> See <http://www.lvm.fi/pressreleases/1228664/finland-and-russia-negotiate-frequencies-and-roaming-charges>



Base Station. This is very different from the traditional Business Radio noise limited network designs.

It is considered highly unlikely that the 450 MHz band will be included in “mainstream” mobile handsets for a number of reasons, including:

- The addition of frequency bands will inevitably add extra costs which either have to be recouped via higher handset costs or higher sales volumes and the latter can only be realised if the new band adds consumer value to the device.
- There are already a number of higher priority frequency bands that need to be included (e.g. digital dividend bands).
- A typical performance degradation of 1 dB may result from the addition of 450 MHz to handsets and this performance loss will apply across all the bands in handset.
- Handset antennas should ideally be at least a quarter wavelength long at the frequency of operation to operate efficiently. This would preclude the use of small form factor devices and limit the appeal to the general public.
- Deployment of MIMO antenna configurations is likely to be particularly difficult at 450 MHz due to the physical size of the antennas and the large separation that would be required between MIMO antennas.

It is not therefore anticipated, based on the handset considerations, that LTE 450 will be used for improved mobile coverage such as to fill in not-spots or provide better road coverage. Its use will be better suited where user terminals are not required to support multiple frequency bands and form factor is far less important.

2. Availability of 3GPP standards (release 12). The availability of standards relating to the 450 MHz band will provide the opportunity for the development of standardised equipment. Vendors, if they decide to develop equipment for this band will be actively seeking further markets. The Study Team is already aware of approaches made by Huawei to a number of African countries re introduction of LTE for rural broadband.

### 3.6.5 Challenges

LTE 450 (or even CDMA 450 for that matter) appears to be an attractive solution to meet the future demand for the Utilities. However Government needs to encourage them to work together to develop a suitable self-managed network that meets their operational needs and can be used as a replacement to meet the existing and future network monitoring and control and communication requirements. Even in this situation it is possible that an alternative, more established technology such as CDMA may be preferred, this however may have limited longevity if countries around the globe start to update to LTE FWA.

The other consideration is identifying spectrum to allow the band to be used for LTE. This is particularly challenging because of the need to both reverse the duplex configuration and find sufficient spectrum with the necessary 10 MHz duplex spacing within the proposed channel plan for LTE.

### 3.6.6 Potential solutions

In this section we consider the potential solutions based on the general considerations and the challenges identified in the previous sections.

Band reversal and the migration of some existing users to alternative spectrum would be necessary to support the introduction of LTE 450 in the band (already covered in previous scenarios).

### 3.6.7 Risks

1. Release of spectrum. The introduction of LTE in the 450 to 470 MHz band could require a significant release of spectrum even if only 2 x 1.4 MHz is made available initially as it will be necessary to deploy guard bands<sup>86</sup> to protect adjacent services and to ensure the spectrum has the necessary 10 MHz duplex configuration. In addition to free up this spectrum the existing users, whose spectrum demand is increasing and in many cases are critical to UK infrastructure, will need to be migrated elsewhere in the band or to different technical solutions if that is possible.
2. Interference into SRDs. There have been issues of interference from LTE user equipment (UE) into SRDs operating in the adjacent 800 MHz band (i.e. at 863 MHz and above). There might be similar problems in the UHF 2 band with SRDs operating in UK only spectrum adjacent to UEs in the proposed LTE up-link of 452.5 to 457.5 MHz.

### 3.6.8 Conclusions

LTE 450 could provide a solution for meeting the Utilities future demand and is an attractive option in terms of spectrum efficiency and flexibility to expand as additional monitoring points are implemented. With future developments of LTE it could also potentially support the Business Radio communications as well. However the need for the Utilities to agree on and share a self-managed network to meet their operational needs may be very difficult to achieve without Government intervention. Access to the required spectrum in the 450 to 470 MHz band is likely to be difficult and will require band reversal.

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<sup>86</sup> It is impossible without undertaking sharing studies with users in the adjacent spectrum to identify the necessary guard bands.

## 3.7 Introduction of a Band Manager

### 3.7.1 Introduction

This is not a scenario but has been included to consider whether a Band Manager could be an enabler for band reversal.

### 3.7.2 General considerations

1. Costs. There are significant costs associated with establishing a Band Manager (e.g. big upfront costs in systems and marketing) and in addition there will be a need to incentivise existing users to migrate / move so the use of the available spectrum can be maximised. In other words a Band Manager would need to be equipped with sufficient powers to make the necessary changes in the interest of efficient use of the spectrum for this to work. Also the duration of managing the band, under these difficult conditions, must be long enough to carry through the decisions and reap some of the benefits or it is not going to happen.
2. Facilitate band reversal. The introduction of a Band Manager may facilitate band reversal as existing users are likely to require financial encouragement and this could be a way of achieving this.
3. Business case / benefit for potential Band Manager. There would need to be either a business case and / or a benefit for any potential Band Manager. The benefit, for example, could be increased access to spectrum in the case of the Utilities.

### 3.7.3 Challenges

The biggest challenge is to find a suitable business model for a Band Manager as it will need to be a profitable business and the relevant terms and conditions will need to provide them with sufficient flexibility to maximise the use of the UHF bands including band reversal<sup>87</sup>. This is likely to require significant legal effort from both parties to ensure a satisfactory arrangement for all parties (Ofcom, the Band Manager and the existing users of the spectrum).

### 3.7.4 Risks

Band Manager promotes own interests. One reason to take on the role of Band Manager is to maximise the benefit of existing assets such as systems and also to obtain access to further spectrum for own use. This may not necessarily be to the benefit of other existing users.

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<sup>87</sup> Whilst there is no guarantee a Band Manager will be able to implement band reversal there is the potential that they can provide financial incentives to the users to move. It is also considered that any Band Manager will need to cover all the commercial services in the UHF 1 & 2 bands to make such changes possible and also have support from Ofcom.

### **3.7.5 Conclusions**

It is considered highly unlikely that it will be possible to establish a Band Manager for the UHF bands with the required flexibility (powers) to make any impact on band reversal and for there to be a viable long term business case in managing the spectrum. It is highly probable that existing users will need to move frequencies within the band or invest in new solutions and Ofcom is likely to be the only organisation that can require such changes to be implemented in a timely way.

## 4 CONCLUSIONS

The outcome of the Scenarios on incumbent growth (see Section 3.2) indicates a need for further spectrum to support growth in demand from existing users:

- All Business Radio licence products are predicted to show continued growth and Light licences in particular show significant future demand and there are also indications of an unmet demand for wideband systems. It has been estimated that there is likely to be a need for a further 1.4675 MHz of spectrum by 2023 to support the current voice and narrowband user requirements.
- The Governmental requirements on the Utilities, leading to a huge increase in the number of monitoring points in their networks, will require substantial additional spectrum. The Joint Radio Company has indicated that there is a need for 2 x 3 MHz of additional spectrum for SCADA focused over the period 2015 to 2020.
- PMSE will continue to require a significant amount of spectrum and as a minimum will need to retain their current allocations to meet the demand for frequencies.
- Emergency Services, whilst they have identified the need for continued access to existing spectrum holdings in UHF2 to support new applications, may be in a position to release some of their current frequencies if they can consolidate systems and / or share some existing allocations with the Department of Health and move some users onto the new Emergency Services network. However the viability and timescales of this would need to be investigated.

This scenario also notes there might be the possibility to free up spectrum through a review of the licensing approach and the potential migration<sup>88</sup>, of some users to other frequency bands or solutions (e.g. cellular or a managed network). It is however unclear how effective this might be on its own. As an overall consideration, it is likely to be difficult to find sufficient 'useful' spectrum, especially any contiguous frequencies, to meet the growth in demand without a severe re-engineering of the 420 to 470 MHz band because of the fragmented use. It is also noted that the potential for increasing interference from mainland Europe could impact on the use of the UHF 1 and 2 bands for critical and resilient applications.

The scenario on LTE 450 considers alternative technologies that might be deployed in the bands and concludes that LTE 450 would not be a suitable solution to provide

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<sup>88</sup> It may be necessary to force some users to migrate from the spectrum by not renewing licences beyond a specified date. This approach has been used by other regulators—for example Industry Canada has had to "claw back" frequencies to award them to more urgent / higher importance services—see their Inventory Report.

ubiquitous cellular coverage for network operators in the UK. However the scenario on incumbent growth with band reversal opines that LTE 450 or CDMA 450 might better meet the demands of the Utilities increased monitoring requirements whilst at the same time providing the potential to support their video and communications needs as well. This assumes the Utilities are combined on a single self-managed network and the existing SCADA is replaced. Band reversal and contiguous spectrum would be necessary as it is not expected that vendors would be willing to support a UK only solution or lead to a high cost / single vendor situation making it non-viable. There are implications for Business Radio and PMSE as they would need to be supported within the remaining spectrum.

The requirement to support the currently un-met demand for wideband Business Radio would also require band reversal.

The scenario addressing incumbent growth and band reversal recognises that band reversal also has the potential to minimise the risks of interference from mainland Europe. There are indications of increased use of the UHF 1 and 2 bands in neighbouring countries and also reports of interference from this use. With the current band configuration there is a higher risk of interference as base stations on mainland Europe, with higher transmitter powers and antenna heights are more likely to cause interference into base station receivers in the UK. The interference risk is much lower if the UK is aligned with Europe as the interference into base station receivers in the UK will be from mobile transmitters normally deployed at lower heights with the potential to be hidden in the clutter and transmitting with lower powers.

Band reversal is a significant exercise and for UHF 2 was estimated to cost between £260M and £310M in 2004. For most users there is no perceived need to undertake such re-engineering as their spectrum requirements are met and there is no risk of interference. It is assumed that the only way band reversal may be achieved is through Ofcom intervention, who will need to make the decision on the basis of efficient and effective use of the spectrum and whether they can provide the market (industry and users) with the required usable spectrum to meet developing needs.

The potential for the Emergency Services to release or share spectrum, see the scenario in Section 3.3, may provide additional frequencies for existing users and / or support the process of band reversal. It will be important to investigate further the likely timescales for release as the longer it takes to implement any changes (e.g. re-organisation or band reversal) to the UHF 1 and 2 bands the more likely it is that other uses and users may want access to the spectrum because of its attractive propagation characteristics.

## A. CROSS-BORDER INTERFERENCE MODELLING

### A.1 Introduction

The potential for co-channel interference has been examined for a number of scenarios using Aegis interference modelling tool which takes account of terrain effects and employs the ITU-R Rec. P.1812 propagation model developed for modelling point-to-area interference paths using two different criterion.

- **Interference Scenario 1:** Co-channel interference from an example single wideband PMR transmitter (at an assumed 30 m (agl) antenna height) located in Calais (France) has been analysed assuming that the EIRP towards the UK is 200 W in 100 kHz (i.e. 53 dBm / 100 kHz). It is assumed that the victim receiver antenna heights are 1.5 m, 10 m and 30 m.
- **Interference Scenario 2:** Interference Scenario 1 calculations have been repeated by assuming that the transmitter is located in Vlissingen (Netherlands).
- **Interference Scenario 3:** Co-channel interference from an example single wideband PMR transmitter (at an assumed 30 m antenna height) located in Dover (UK) has been examined assuming that the EIRP towards the continent is 200 W in 100 kHz (i.e. 53 dBm / 100 kHz). It is assumed that the victim receiver antenna height is 10 m. This is height with which the cross border interference threshold is associated. The location of the transmitter has been modified towards inland until the cross border interference threshold is satisfied.
- **Interference Scenario 4:** Interference Scenario 3 calculations have been repeated by assuming that the interfering terminal is at 1.5 m height and its EIRP towards the continent is 1 W in 25 kHz (i.e. 30 dBm in 25 kHz).

The impact of interference has been assessed by using two interference criteria.

- **Criterion 1 (CEPT Recommendation T/R 25-08, May 2008):** The recommendation specifies a coordination threshold level of 20 dBµV/m at the border for a receiver bandwidth of up to 25 kHz. The criterion is defined for 10% of time and 10 m receiver antenna height. To examine the impact of different practical deployment scenarios, the same threshold level has also been assumed for 1.5 m and 30 m receiver antenna heights and 1% of time.
- **Criterion 2 (Ofcom Business Radio Technical Frequency Assignment Criteria, December 2008):** The TFAC specifies a receiver threshold level of -116 dBm in 12.5 kHz<sup>89</sup>. Assuming that the receiver antenna gain is 5 dBi for base stations and 0 dBi for mobile terminals, the interference threshold levels

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<sup>89</sup> Service from a base station is planned by Ofcom to a level of -104 dBm and the sterilised limit is considered to be -116 dBm. Any incoming interference that exceeds -116 dBm will erode the 12 dB SINAD and degrade the UK users' service.

are 12 dB $\mu$ V/m for a base station (for the assumed 10 m and 30 m antenna heights) and 17 dB $\mu$ V/m for a mobile terminal (for the assumed 1.5 m antenna height) in 25 kHz receiver bandwidth. It is assumed that these field strengths are associated with 1% of time.

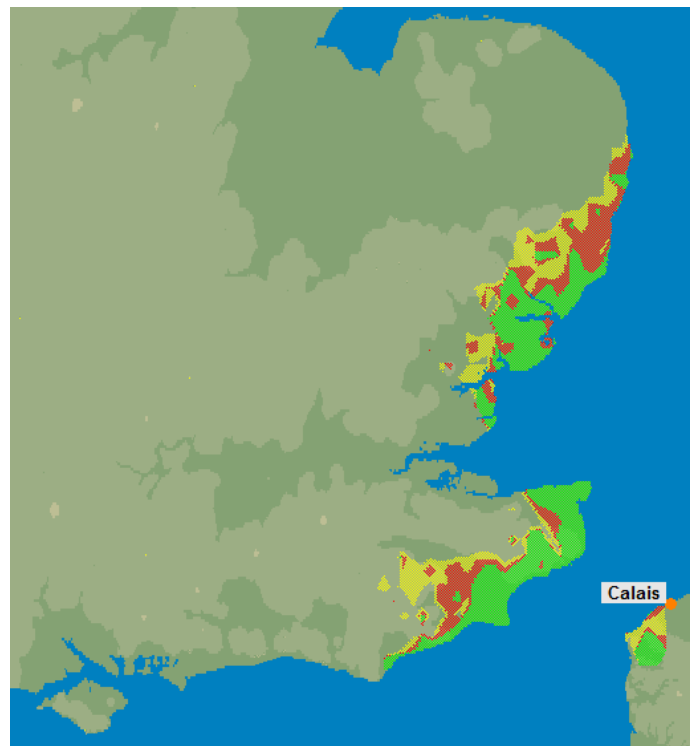
## A.2 Analysis of Interference Scenario 1

### A.2.1 With CEPT Rec. T/R 25-08 Criterion

The following figure shows the areas where the cross border coordination threshold is exceeded in the simulated area over southern and eastern UK when a transmitter with an EIRP of 53 dBm / 100 kHz is located at Calais (France).

In the figure, the interference threshold level of 20 dB $\mu$ V/m (10% of time) is associated with 30 m (yellow contour), 10 m (red contour) and 1.5 m (green contour) receiver antenna heights.

**Figure 22: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
(Threshold: 20 dB $\mu$ V/m in 25 kHz for 10% of time,  
TX EIRP towards the UK: 53 dBm / 100 kHz)



As a next step, the EIRP of the base station transmitter has been reduced iteratively until the cross border coordination threshold value (20 dB $\mu$ V/m for 10% time at 10 m height) is satisfied. It is noted that the threshold is satisfied when the EIRP level towards the UK is reduced from 53 dBm / 100 kHz (i.e. 200 W) to 12 dBm / 100 kHz (i.e. 16 mW).

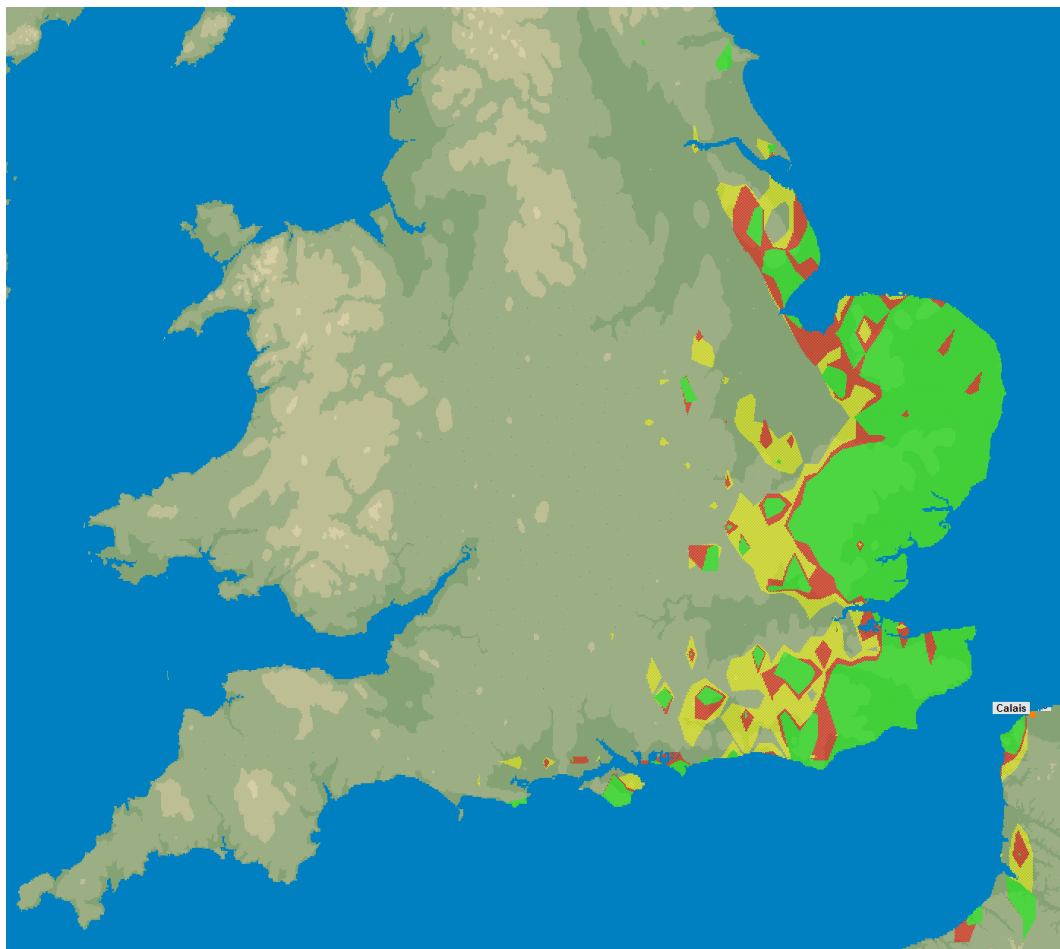
This result indicates that the cross border coordination threshold level of 20 dB $\mu$ V/m, applicable to FM / TETRA / CDMA base station receivers, is only



satisfied when the base station EIRP towards the UK is restricted significantly. This means that if these wideband networks are deployed without any co-ordination with the UK then there could be significant cases of interference into the southern and eastern areas of the UK due to the base station into base station interference.

To examine the impact of interference in more practical deployment scenarios, simulations have been repeated by assuming that the threshold level is associated with 1% of time.

**Figure 23: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
(Threshold: 20 dBµV/m in 25 kHz for 1% of time,  
TX EIRP towards the UK: 53 dBm / 100 kHz)

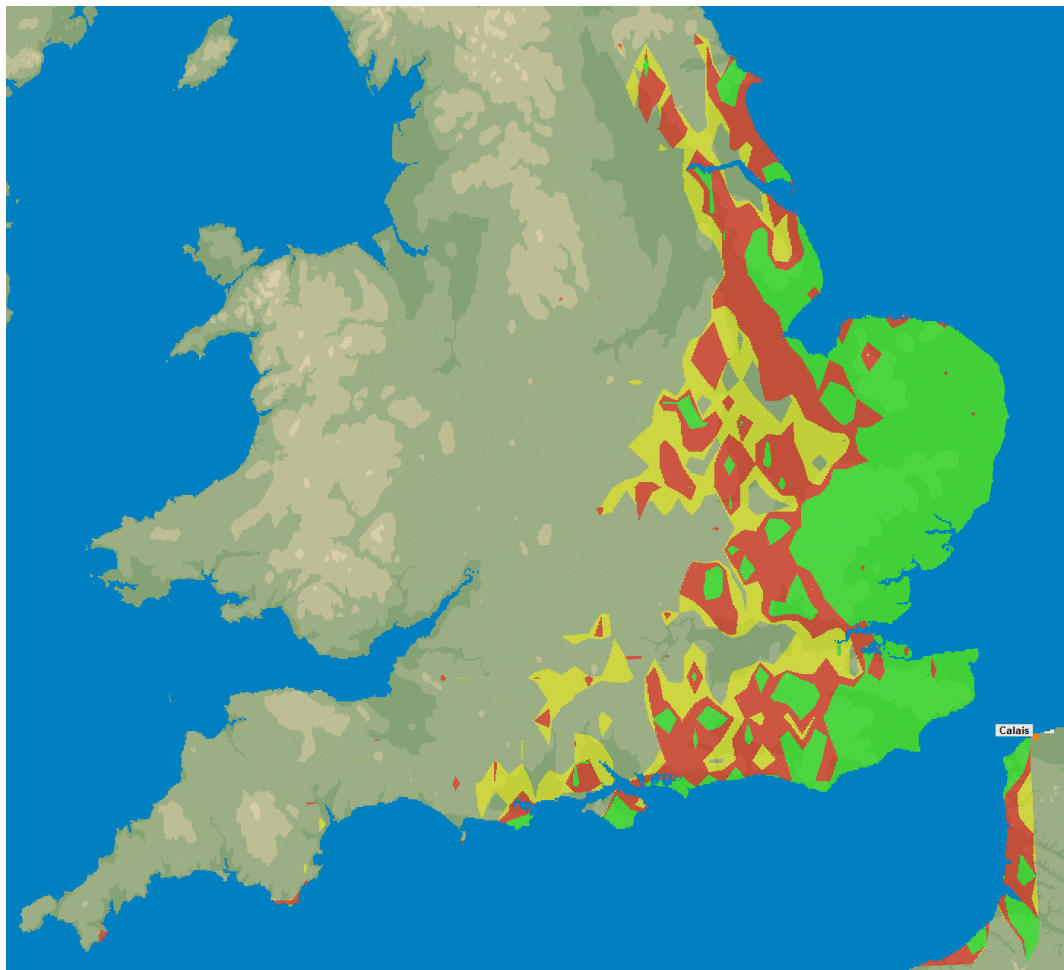


In this case, the interference areas are expanded significantly. It is noted that the EIRP towards the UK needs to be reduced to 9 dBm / 100 kHz to satisfy the cross border interference threshold (20 dBµV/m at 10 m height for 1% of time).

#### **A.2.2 With Ofcom TFAC Criterion**

The figure below shows the interference areas when it is assumed that the threshold is 12 dBµV/m for 1% of time at antenna heights of 10 m (red contour) and 30 m (yellow contour) and 17 dBµV/m (green contour) for 1% of time at 1.5 m antenna height.

**Figure 24: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
 (Threshold: 12 dB $\mu$ V/m in 25 kHz for 1% of time at 10 m & 30 m,  
 17 dB $\mu$ V/m in 25 kHz for 1% of time at 1.5 m,  
 TX EIRP towards the UK: 53 dBm / 100 kHz)



As expected, more stringent criteria used to derive the above contours result in larger affected areas.

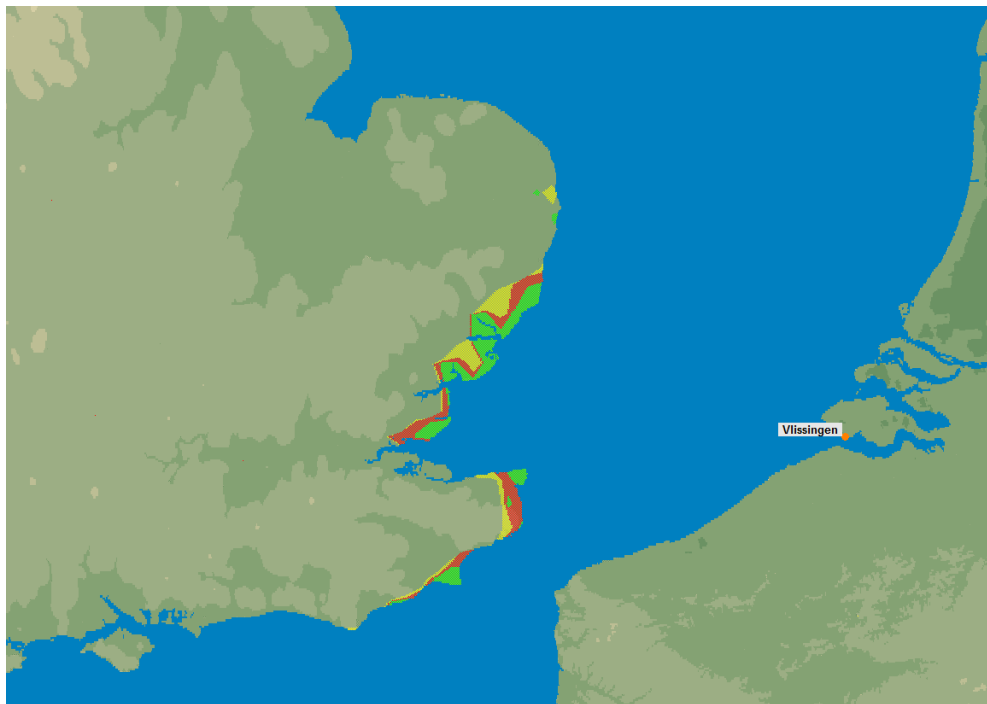
### A.3 Analysis of Interference Scenario 2

In this section, the interference areas have been re-calculated when the interfering transmitter is assumed to be located in Vlissingen (Netherlands).

#### A.3.1 With CEPT Rec. T/R 25-08 Criterion

As before, in the following figure, the interference threshold level of 20 dB $\mu$ V/m (10% of time) is associated with 30 m (yellow contour), 10 m (red contour) and 1.5 m (green contour) receiver antenna heights.

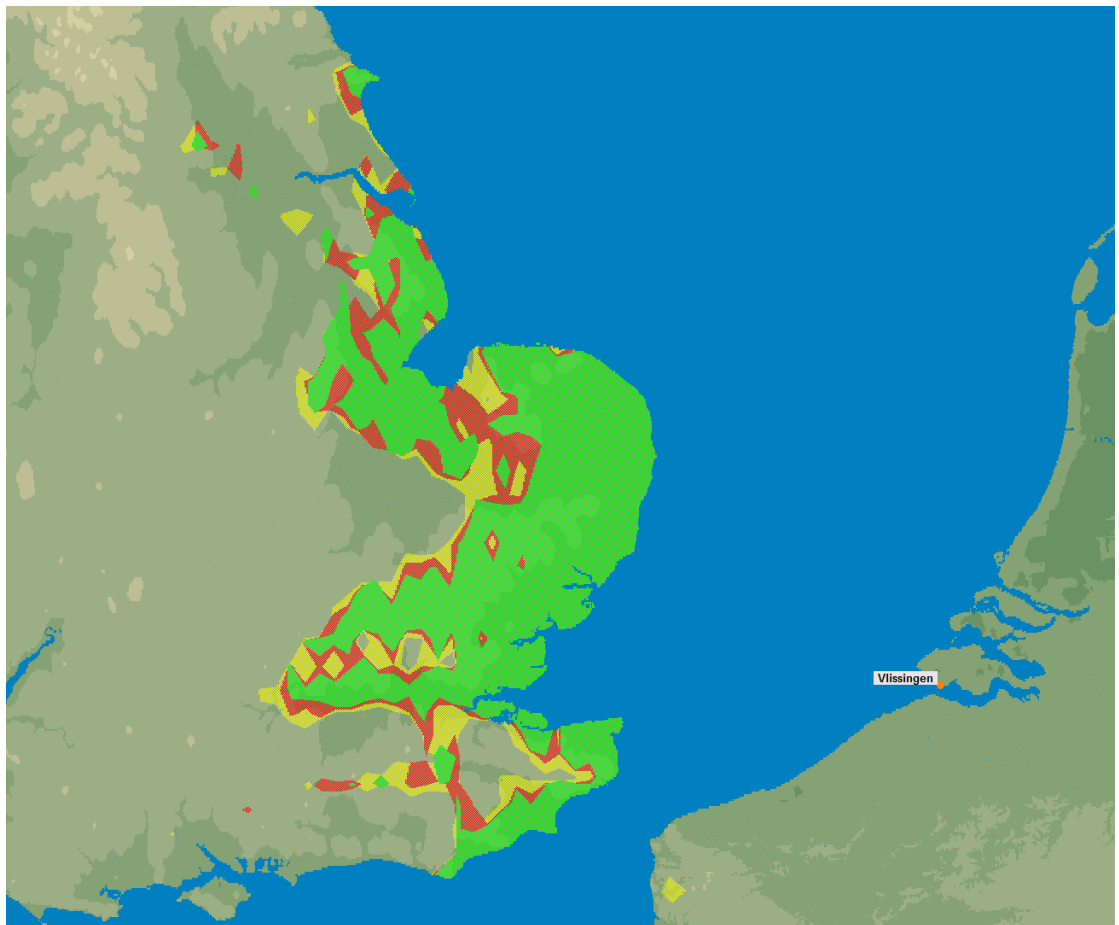
**Figure 25: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights  
(Threshold: 20 dB $\mu$ V/m in 25 kHz for 10% of time,  
TX EIRP towards the UK: 53 dBm / 100 kHz)**



Further analysis has indicated that the threshold (i.e. 20 dB $\mu$ V/m at 10 m height for 10% of time) is satisfied when the EIRP level towards the UK is 43 dBm / 100 kHz (i.e. 20 W in 100 kHz).

The following figure shows the interfered areas when it is assumed that the cross border threshold applies for 1% of time.

**Figure 26: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
 (Threshold: 20 dBµV/m in 25 kHz for 1% of time,  
 TX EIRP towards the UK: 53 dBm / 100 kHz)

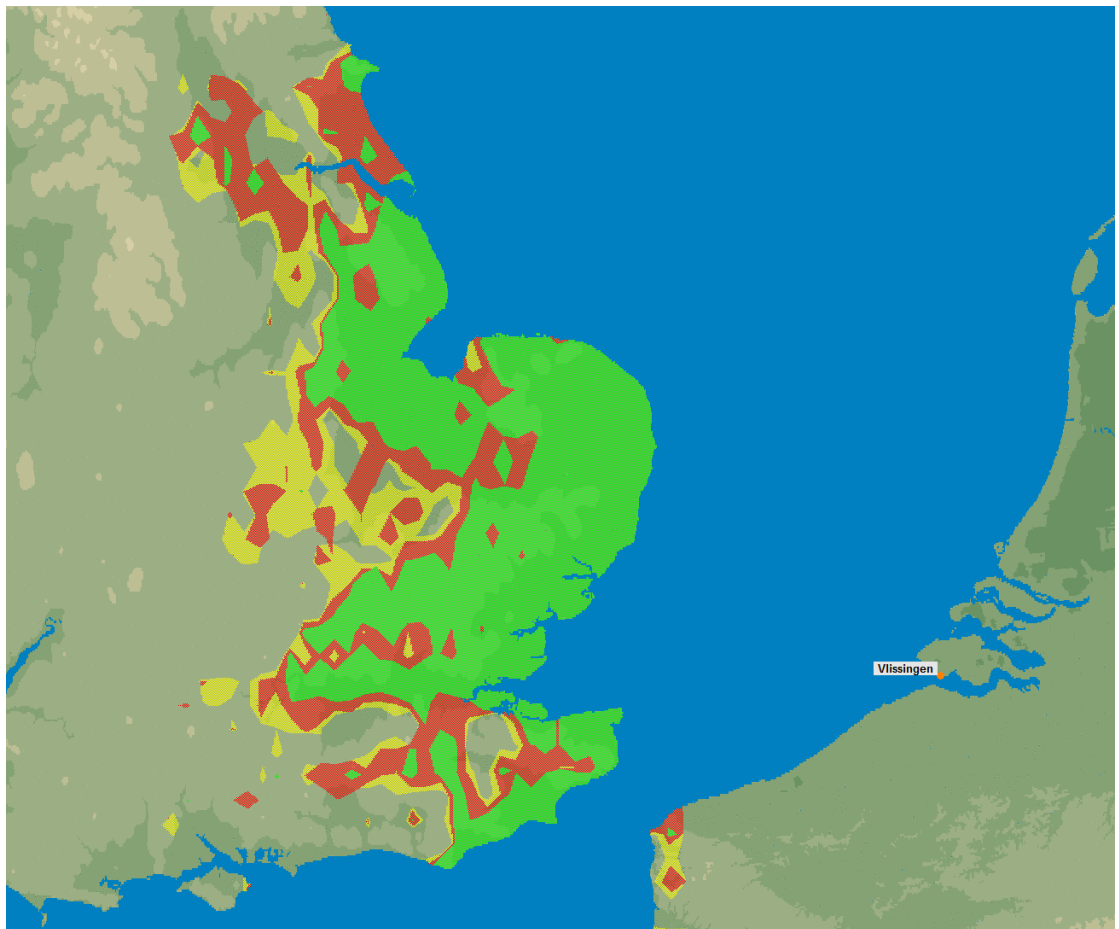


It is also noted that the EIRP towards the UK needs to be 21 dBm / 100 kHz (i.e. 125 mW / 100 kHz) to satisfy the 20 dBµV/m threshold for 1 % of time at 10 m height.

### **A.3.2 With Ofcom TFAC Criterion**

Using the Ofcom TFAC criteria, the following areas have been calculated.

**Figure 27: Interference Areas for 30m, 10m & 1.5m Receiver Antenna Heights**  
(Threshold: 12 dBµV/m in 25 kHz for 1% of time at 10 m & 30 m,  
17 dBµV/m in 25 kHz for 1% of time at 1.5 m,  
TX EIRP towards the UK: 53 dBm / 100 kHz)

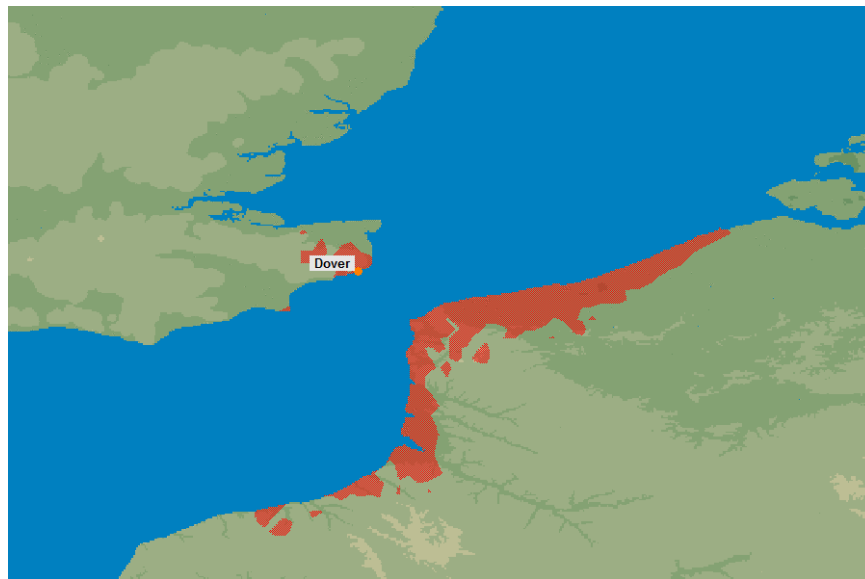


#### **A.4 Analysis of Interference Scenario 3**

In this scenario the implications of conforming to cross border requirements are examined.

The following results show that a base station located at Dover or Ashford exceeds the cross border coordination threshold in the simulated area over France. Further analysis showed that the same transmitter located in Maidstone satisfies the coordination threshold.

**Figure 28: Interference Area for UK Transmitter at Dover**  
(Threshold: 20 dB $\mu$ V/m in 25 kHz at 10 m for 10% of time,  
TX EIRP towards the Continent: 53 dBm / 100 kHz, TX Height: 30 m)



**Figure 29: Interference Area for UK Transmitter at Ashford**  
(Threshold: 20 dB $\mu$ V/m in 25 kHz at 10 m for 10% of time,  
TX EIRP towards the Continent: 53 dBm / 100 kHz, TX Height: 30 m)



## A.5 Analysis of Interference Scenario 4

This scenario assumes that the UK is aligned with T/R 25-08. In this case, a mobile transmitting at normal power (e.g. 1 W / 25 kHz) at 1.5 m height in Dover and Whitfield would result in interference areas shown in the following figures.

**Figure 30: Interference Area for UK Mobile Transmitter at Dover**  
(Threshold: 20 dB $\mu$ V/m in 25 kHz at 10 m for 10% of time,  
TX EIRP towards the Continent: 30 dBm / 25 kHz, TX Height: 1.5 m)



**Figure 31: Interference Area for UK Mobile Transmitter at Whitfield**  
(Threshold: 20 dB $\mu$ V/m in 25 kHz at 10 m for 10% of time,  
TX EIRP towards the Continent: 30 dBm / 25 kHz, TX Height: 1.5 m)



Further analysis showed that if the mobile transmitter was located at Aylesham (near Canterbury) then it would satisfy the cross-border interference threshold.

## **B. COST OF BAND REVERSAL**

PA Consulting undertook a study on issues determining the cost for 450–470 MHz band alignment in 2004. The study considered key cost issues for a number of user categories. These included PBR, Paging, PMSE, Telemetry and Network Operators. In addition, the cost implications associated with site engineering were also examined.

In deriving cost figures for each user category, a range of parameters were taken into consideration. For example, cost parameters for PBR users included equipment re-tuning and replacement, project management, maintaining business continuity through equipment hire and training for new equipment. In the case of telemetry users, additional parameters considered were site visits, spare equipment purchase, planning and liaison costs and management software updates. For network operators, modem replacement in large fleets as well as potential lost revenue were included in the calculations. Site engineering costs were attributed to factors including duplicate site installation, multi-user / multi-frequency equipment installation, site planning and 20% contingency.

The baseline total cost figures were calculated to be £67M for PBR, 9M for Paging, 13M for PMSE, 23M for Telemetry, 94M for Network Operators and 7M for Site Engineering. These figures result in an estimated total cost of £277M. A further statistical analysis was then applied to examine the variation of different parameters used in the baseline cost calculation. The analysis results suggested that the total alignment cost would be between £260M and £310M.

As summarised above, estimates given in the PA Consulting report are calculated in 2004 and include wide range of factors. In 2014, it is reasonable to expect that, for example, the total cost associated with the re-tuning of Business Radio equipment is less of an issue as modern equipment is more amenable to being re-tuned within the UHF bands than the older kit, in digital equipment there are no duplexers and antenna equipment is likely to cover wider frequency ranges. However any engineering costs associated with the replacement of antennas and RF equipment in TV outside broadcast vans, for example, are likely to be higher. It is therefore not possible to provide a quick update on the total cost without exploring at least the dominant factors (e.g. Business Radio, Network Operators and Site Engineering costs) in detail.



## C. USE OF 450 MHZ IN EUROPE

In the following information is provided on use of the 450 MHz band in nearby European countries. It demonstrates the use of the 450 MHz for Fixed Wireless Access and the potential for interference into the UK.

In **Finland** the 450 MHz broadband network operator (Datame Oy) has ceased services despite providing 99.9% population coverage. Datame Oy took over the 450 MHz licence from Digita Oy who announced that it would end its @450 broadband network operations in 2010. The network licence was changed to technology neutral for Datame Oy to allow them to replace the non-serviceable out-of-date Flash-OFDM<sup>90</sup> to CDMA or LTE technologies for broadband services.

In **Sweden, Norway and Denmark** CDMA 450 systems have been deployed in the 450 MHz band to provide FWA to a (Wi-Fi) router with either an internal or external antenna. Ice is operating in Norway whereas Net 1 is in Sweden and Denmark. These networks work together and there is no roaming charge. They also provide coverage over the sea around the countries. This is intentional as they have purposely increased the power towards the sea to achieve coverage of about 100–120 km compared with the typical 60 km. It appears that they are using CDMA EVDO rev B and at least in Norway and Sweden they are still adding new base stations to the network to increase the coverage and capacity. In Denmark they have around 85% geographic coverage. In Sweden Net 1, which has been providing services since 2003, claims that they provide broader network coverage than its mobile competitors—for example in Sweden they claim 90% coverage of the land mass compared with 50% provided by the mobile network operators.

Ice.net has 103,950 subscribers in Norway as of September 2013, according to Informa's WCIS Plus service. Ice.net in Norway focuses on M2M and portable fixed wireless broadband, rather than handset connectivity in the rural areas where they have around 30 percent of the market<sup>91</sup>.

In Scandinavian countries it is very popular to have leisure huts in very rural areas like mountains, beaches, forests and ski resorts. To provide coverage for these areas and for leisure/fishing vessels all with no telephone lines or mobile coverage CDMA 450 is the only financially viable connection possibility.

In **Ireland** Ripplecom is operating FWA on a CDMA450 network bought from Ice net and a couple of other companies. The current coverage can be seen at <http://www.ripplecom.net/broadband-coverage-map> . It focuses on delivery of broadband internet connectivity to rural as well as urban and semi-urban Ireland.

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<sup>90</sup> See [https://www.viestintavirasto.fi/attachments/Markkinakatsaus\\_1\\_2011\\_EN.pdf](https://www.viestintavirasto.fi/attachments/Markkinakatsaus_1_2011_EN.pdf)

<sup>91</sup> Source: <http://www.telecoms.com/204371/norways-mystery-spectrum-winner-named-as-ice-net-parent/>

In **Holland** Liander<sup>92</sup> and KPN<sup>93</sup> are planning a CDMA 450 network for the M2M market. Entropia is running TETRA in Holland (they appear to be operating as a MVNO on KPN's TETRANED) and in **Belgium** and claim to be planning to start a DMR trunked net in the UK<sup>94</sup>. It is understood that in the Netherlands they will have nationwide coverage (> 95% geographic coverage) in June 2014. The TETRA networks are being used in Belgium and the Netherlands by several public and private (security) organisation and also the Utilities where they are providing telemetry and PMR. Entropia claim that such users have pushed them towards a high mission critical TETRA network.

In respect of the CDMA 450 usage, in the BRIG meeting notes of April 2013, it is specifically noted that CDMA interference was measured on the East Coast around 464 MHz and that blocks of "raised noise" were identified in 1.4 MHz segments that led Ofcom to think that this was due to interference from the Nordic countries. It was also noted that Holland in addition to the Scandinavian countries were looking to introduce CDMA 450. The increased power levels to provide off shore coverage could increase the impact of these networks in terms of interference to the UK.

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<sup>92</sup> Source JRC

<sup>93</sup> Source: PA Consulting Group, Study on comparability of frequency bands in different business models for Ministerie van Economische Zaken, September 2010.

<sup>94</sup> Source: Entropia's founder's LinkedIn site

## D. TECHNOLOGIES

There are a number of technologies that can potentially be deployed in the 400 MHz spectrum. Ignoring those that have a limited lifetime the following list provides some of the options.

Standard analogue PMR will be around for a few years to come but is increasingly being overtaken by the newer digital technologies and some manufacturers have already stopped making analogue equipment<sup>95</sup>.

Currently the available digital technologies are;

- dPMR a FDM solution using two 6.25 kHz channels in a 12.5 kHz allocation
- DMR two timeslot TDM in a 12.5 kHz channel
- TETRA 4 timeslot TDM in a 25 kHz channel
- LTE in 1.4, 3, 5, 10, 15 and 20 MHz channels OFDMA
- CDMA 450 in 1.25 MHz channels

The latter two were developed as an additional band to the main standard originally designed for the more traditional cellular bands around the globe.

In addition to the above there are specialised versions of PMR and other equipment used for a variety of applications like SCADA, fixed links and paging Base Stations.

Are the modern digital equipment more frequency efficient than analogue PMR?

The ability to take a channel and get two (voice or data carriers) out of it is attractive in terms of spectrum utilisation but it does come at a price. The reuse distance for the frequency increases because of a much increased required co-channel rejection ratio compared to analogue and ACLR and ACLS are also degraded. In addition, trying to make these individual narrowband systems operate in a denser environment will also start to produce a high amount of transmitter and receiver intermodulation based interference. This is something that inherently is taken care of as part of the design of multichannel cellular networks but is not easy to deal with between single or a low number of channels individually assigned to separate systems. Trying to deal with this often leads to a large proportion of the spectrum being underutilised. So from an overall frequency efficiency per MHz point of view the introduction of the narrower channel systems probably has not changed anything.

TETRA of course has the same 'narrow band' characteristics as the two digital PMR technologies mentioned above and 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

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<sup>95</sup> Recently Motorola announced the stop of analogue PMR equipment.

deployments this value will approach 49. Hence, like other trunked networks, it will not deliver improved frequency efficiency for smaller systems.

LTE and CDMA both have a frequency reuse of 1 but this also comes at a price in that both require a considerable amount of guard bands. This again means that these are not anywhere as frequency efficient for the relatively narrow allocations they can obtain in this spectrum compared to the much larger allocations they were designed for.

In summary, the only real frequency efficiency improvement that can be obtained in this spectrum is from the trunking effect for those services/applications where this is feasible and these need to be large scale with a high number of users and/or huge amounts of data to have any real effect.

Notwithstanding all of the above, these PMR type technologies are important to their particular applications/market segment so trunking is not going to solve the congestion although it may help ease it to a certain extent. The wider band technologies may help solve the anticipated rapid growth of the Utilities remote sensing/telemetrics/smart grid requirements both in terms of numbers of data gathering points and the amount of data transmitted simply because of the huge data capabilities offered by these technologies which is something that could not be done with the existing technology without excessive amounts of spectrum. From the now ceased analogue cellular networks we already know that PMR technology does not scale up gracefully but ends up with a tremendous amount of self interference requiring a huge amount of spectrum to avoid this. As an example, two LTE networks adjacent in frequency—one for all the Utilities and another for PPDR—would provide a far better frequency efficiency than could ever be achieved by narrow band technology. Making these adjacent in frequency would also negate one set of guardbands increasing the overall efficiency. These wider band technologies also have long range capabilities similar to existing fixed or scanning telemetry.

It is noted that the narrow band technologies dPMR and DMR are both capable of operating in the 68–88 MHz (some manufacturers), 138–174 MHz and UHF bands whereas TETRA, LTE and CDMA only operate in the UHF bands and above.