Final Report for Ofcom

International interference analysis for future use of 1452-1492MHz range

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Contents

Annexes

1 Introduction

This report has been prepared by Analysys Consulting Ltd (Analysys) and Mason Communications Ltd (Mason) on behalf of the UK Office of Communications (Ofcom) as a summary of our analysis of international interference constraints for the future use of the 1452–1492MHz spectrum band.

1.1 Background and objectives

The objective of this study was to analyse international interference constraints on the future use of the 1452–1492MHz spectrum band. The potential uses that we have considered include: digital radio (T-DAB), mobile multimedia (e.g. DVB-H, DMB), broadband wireless access (e.g. WiMAX, UMTS TDD), PMSE (e.g. digital wireless cameras) and satellite digital radio (S-DAB). We have identified the areas of the UK that would be affected by international interference constraints and calculated the corresponding populations affected.

The international interference constraints on this band are twofold:

Interference with European T-DAB services in the bottom 27.5MHz	The bottom 27.5MHz (1452–1479.5MHz) has been allocated to T-DAB in accordance with the CEPT Maastricht 2002 Special Arrangement (hereafter the 'Maastricht 2002 Plan'). The UK is not legally required to follow this arrangement in that it is free to use this spectrum for other services; however, it must respect the arrangement in terms of Continental coordination requirements. Since the agreement is specifically designed to protect T-DAB services from interference, this mean that if alternative uses are

deployed in the UK they must not cause any additional interference to (nor would they receive protection from) T-DAB services in neighbouring countries.

Interference with European S-DAB services in the top 12.5MHz

The upper 12.5MHz (1479.5-1492MHz) has been designated at a European level for possible use for satellite digital audio broadcasting services (see ECC Decision ECC/DEC/(03)02). However, the UK has not signed this decision and as a result there is no commitment on Ofcom's part to "reserve" the band for S-DAB use. Again, alternative uses of this spectrum can be deployed in the UK but based on the coordination agreement; users would be required not to cause interference with European satellite services and similarly would not receive protection from them.

1.2 Structure of this document

The remainder of this report is structured as follows:

- Section 2 describes our approach to the study
- Section 3 presents the interference thresholds for the different technologies being considered
- Section 4 assesses the restrictions on lower L-Band systems due to either receiving co-channel interference from, or causing such interference to Continental T-DAB systems also operating in the lower L-Band
- Section 5 assesses the restrictions on lower L-Band systems due to either receiving adjacent channel interference from, or causing such interference to Continental S-DAB systems in the upper L-Band
- Section 6 assesses the restrictions on upper L-Band systems due to either receiving adjacent channel interference from, or causing such interference to Continental S-DAB systems in the upper L-Band
- Section 7 discusses the implications of deploying the networks in such as way as to comply with the interference constraints discussed above
- Section 8 summarises the overall conclusions from the study.

In addition, this report has a number of supporting annexes (provided in a separate file):

- Annex A presents incoming interference charts by block
- Annex B presents outgoing interference charts by block
- Annex C presents side-by-side comparisons of outgoing and incoming interference for each block
- Annex D discusses the reference networks defined in the Maastricht 2002 Plan.

2 Approach

The ICS Telecom tool

Our approach was to model interference using the ATDI ICS Telecom tool, programmed with the relevant ITU-R propagation models for interference prediction, as referenced within the Maastricht 2002 Plan. Exhibit 2.1 below shows the ITU-R.P370.7 propagation model with the parameters shown.

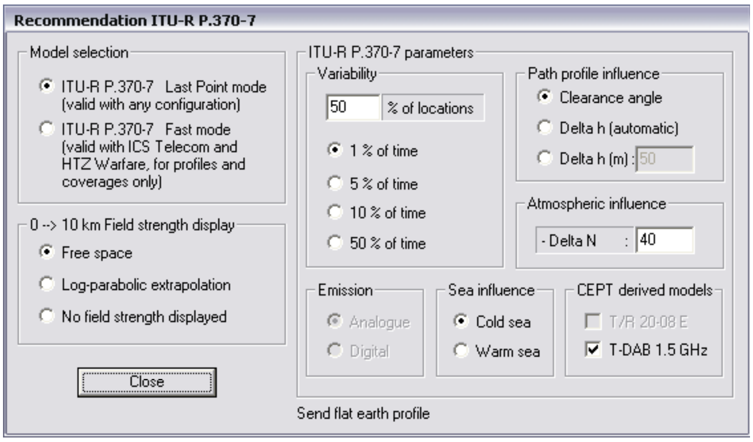

Exhibit 2.1:

Settings of the ICS Telecom propagation model [Source: Analysys, Mason]

The CEPT-derived model that we chose to use within the tool was developed specifically for 1.5GHz T-DAB and is described in detail within the Maastricht 2002 Plan. The tool was used to perform radio interference modelling for each of the scenarios under study. The results were then transferred into MapInfo to consider the area and population associated with each test point, and to produce thematic maps.

The L-Band frequency blocks under consideration

The lower 27.5MHz of the L-Band (1452–1479MHz) is divided into the following blocks:

T-DAB block number	Centre frequency (MHz)	Frequency range (MHz)
LA	1452.960	1452.192 - 1453.728
LB	1454.672	1453.904 - 1455.440
LC	1456.384	1455.616 - 1457.152
LD	1458.096	1457.328 - 1458.864
LE	1459.808	1459.040 - 1460.576
LF	1461.520	1460.752 - 1462.288
LG	1463.232	1462.464 - 1464.000
LH	1464.944	1464.176 - 1465.712
LI	1466.656	1465.888 - 1467.424
LJ	1468.368	1467.600 - 1469.136
LK	1470.080	1469.312 - 1470.848
LL	1471.792	1471.024 - 1472.560
LM	1473.504	1472.736 - 1474.272
LN	1475.216	1474.448 - 1475.984
LO	1476.928	1476.160 - 1477.696
LP	1478.640	1477.872 - 1479.408

Exhibit 2.2:

Frequency blocks in the lower L-Band

The upper 12.5MHz of the L-Band (1479–1490 MHz) is divided into the following blocks:

S-DAB block number	Centre frequency (MHz)	Frequency range (MHz)
LQ	1480.352	1479.584 - 1481.120
LR	1482.064	1481.296 - 1482.832
LS	1483.776	1483.008 - 1484.544
LT	1485.488	1484.720 - 1486.256
LU	1487.200	1486.432 - 1487.968
LV	1488.912	1488.144 - 1489.680
LW	1490.624	1489.856 - 1491.392

Exhibit 2.3:

Frequency blocks in the upper L-Band

Overview of our methodology

Our analysis proceeded as follows:

- Step 1: Calculate the interference thresholds of the technologies being considered.
- Step 2: Model co-channel interference to and from T-DAB systems in Belgium, France, Germany, the Republic of Ireland, Luxembourg, the Netherlands and Norway.[1]

1 Hereafter in this report we refer to these countries using the term ‘Continental’, for example ‘Continental T-DAB systems’.

- Step 3: Model adjacent channel interference between UK T-DAB networks and Continental S-DAB networks.
- Step 4: Model co-channel interference with Continental S-DAB services.
- Step 5: Analyse the additional impact on deploying these services or technologies in a way that complies with the interference constraints.

The following sections consider each of these in turn.

3 Interference thresholds for different technologies

Thresholds were calculated to determine the interference limit for an acceptable quality of service for the following technologies/services:

- T-DAB
- DMB
- DVB-H
- WiMAX
- UMTS TDD
- PMSE
- S-DAB

In each case, the most significant variable affecting the interference threshold is the basic type of device that the network is designed to cater for, rather than the underlying communications standard. This is because of the different coverage objectives of different devices and services (e.g. whether the device is intended for indoor or outdoor reception), and the characteristics of the receiving antenna. We considered five types of equipment:

- Fixed outdoor receiving equipment
- Hand-held outdoor equipment
- Hand-held indoor equipment
- Short-range PMSE equipment
- S-DAB equipment

3.1 Fixed outdoor receiving equipment

Examples of fixed outdoor receiving equipment are:

- WiMAX base stations (up link)
- UMTS TDD base stations (up link)
- PMSE base stations, to support outside broadcasts (up link).

Base stations are designed to be particularly sensitive, as they need to receive low field strength signals transmitted by hand-held battery powered devices. Hand-held devices have low gain omni-directional antennas and are usually in built-up urban areas or even in buildings, which adds further losses to the received signal. Base stations typically are installed at height, with high-gain sectored antennas assisted by masthead amplifiers. Taking the receiver gains and losses into account, a typical base station has an effective receive sensitivity of –110dBm.

3.2 Hand-held outdoor equipment

Examples of hand-held outdoor equipment are:

- DVB-H and DMB hand-held multimedia devices
- T-DAB hand-held radio
- WiMAX and UMTS TDD hand-held devices.

Hand-held devices are not as sensitive as fixed equipment. For this reason, networks designed to support them need to operate at a higher field strength. Taking the receiver gains and losses into account, a typical hand-held device has an effective receive sensitivity of –90dBm.

3.3 Hand-held indoor equipment

Examples are the same as the hand-held outdoor devices listed above. For indoor operation, however, additional signal strength is required to penetrate the fabric of buildings. Typically an uplift of 15dB is allowed for wall losses. This gives an effective receive sensitivity of –75dBm.

3.4 Short-range PMSE equipment

Short range PMSE equipment consists of low-power transmitters operating over short distances, typically around 50m, usually indoors. Examples of use include short-range video links used for uploading images from digital cameras. A typical receiver sensitivity for a video camera would be –75dBm, although the field strength is often well above this limit. Due to the short operating range of the equipment, these systems can tolerate quite a high degree of international interference, and they generate very low levels of outgoing interference themselves. In order for several such PMSE systems to operate at the same location, several channels are required, together with some mechanism for coordinating them.

3.5 S-DAB equipment

Satellites deliver a very consistent field strength within their target area due to an almost constant distance from all locations to the transmitter and a free space transmission path with no diffraction or multi-path losses. However, as satellites operate at a huge distance from the earth (36 000km for geo-stationary types) there are limits on the field strength that can be generated. The co-channel interference limit for satellite sound broadcasting stated within the Maastricht 2002 plan is shown in Exhibit 3.1 below. From this we observe that a satellite receiver has an effective receive sensitivity of –122.5dBm. Note that satellite systems may utilise space diversity, frequency diversity and time diversity to increase signal quality without increasing field strength.

	Satellite sound broadcasting Digital (1.5 GHz)	*Units*
Field strength to be protected	29	dBμV/m
C/I Ratio	13	dB
Interference Limit	16	dBμV/m

Exhibit 3.1: *Interference limit for S-DAB receivers [Source: Maastricht 2002, Annex 2, p.84]*

3.6 Summary

Exhibit 3.2 below shows the interference limits for devices of the types discussed above. A correction factor is added to the Effective Rx Sensitivity (except in the case of S-DAB) to allow for variations in filed strength. This factor ensures that the field strength is greater than the minimum required at 99% of locations. All figures are for 1.5m above ground height.

	S-DAB	*Outdoor Fixed*	*Hand Held Outdoor*	*Hand Held Indoor*	*Units*
Effective Rx Sensitivity	-122.5	-110	-90	-75	dBm
Location percentage correction factor (50% to 99%)	0	13	13	13	dB
Field strength to be protected	29	41.5	61.5	76.5	dBμV/m
C/I Ratio	13	10	10	10	dB
Interference Limit	16	31.5	51.5	66.5	dBμV/m

Exhibit 3.2: *Calculation of interference limits for different types of equipment [Source: Analysys, Mason 2006]*

4 Co-channel interference to and from Continental T-DAB systems

This section considers the restrictions on lower L-Band systems (in blocks LA to LP) due to either receiving co-channel interference from, or causing such interference to Continental T-DAB systems operating in the lower 27.5MHz of the band.

At the Maastricht 2002 CEPT T-DAB Planning Meeting, the administrations of certain European countries, including the UK, entered into an arrangement (the 'Maastricht 2002 Plan') regarding coordination of a comprehensive set of L-Band frequency block allotments appropriate for T-DAB services. The key points of the arrangement are to:

- Permit a level of interference from each frequency allotment that is equivalent to that would be produced by an appropriate T-DAB reference network, i.e. to set limits on *incoming* interference *from* T-DAB systems in Europe.

- To protect, by a process of coordination, these frequency allotments from interference generated by other networks, i.e. to set limits on *outgoing* interference *to* T-DAB systems.

The arrangement plans the boundary for each allotment, and specifies which of three reference network types should be used for planning purposes. Details of these reference networks are provided in Annex D.

We have considered the interference implications of deploying other services in the L-Band, namely T-DAB, DMB, DVB-H, WiMAX, UMTS TDD and PMSE. Note that we have not considered S-DAB, as this is only likely to be deployed in the upper part of the band.

Our analysis commenced with the construction of a reference network for each of the 370 L-Band allotments within 500km of the UK coastline. In total 3941 transmitters were modelled in accordance with the three reference network types, as shown in Exhibit 4.1 below.

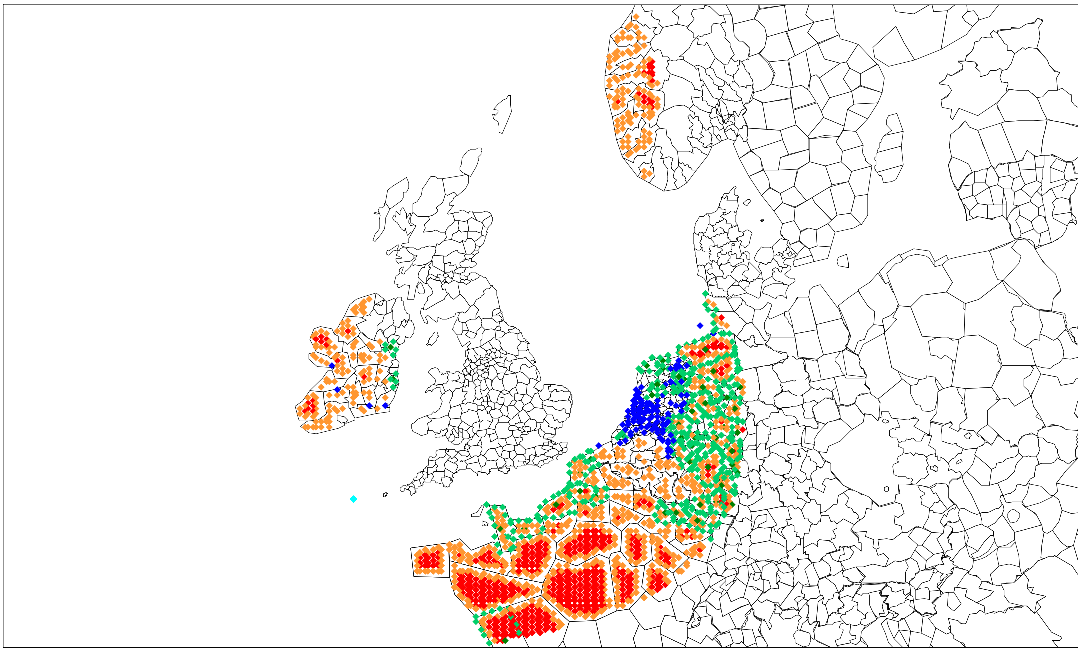

Exhibit 4.1: *Reference transmitters used to calculate incoming interference from Continental T-DAB systems [Source: Analysys, Mason 2006]*

4.1 Incoming co-channel interference from Continental T-DAB systems

4.1.1 Methodology used

Incoming co-channel interference was measured at 9610 test points in the UK, each point being positioned within a postal sector. A calculated proportion of the UK population was then assigned to each test point based on the number of domestic postal delivery addresses within each postal sector. The geographical area assigned to each test point was a polygon whose interior consisted of all points within the UK coastline which are closer to that test point than to any other. These areas are shown in Exhibit 4.2 below.

Note the UK allocation to Gibraltar has been excluded from this analysis.

Exhibit 4.2: *The UK's area divided amongst the 9610 test points [Source: Analysys, Mason 2006]*

For each of the 9610 test points in the UK, we measured incoming interference and calculated the interference received from each of the 3941 reference T-DAB transmitters using the ICS Telecom planning tool. Transmitters for each of the 16 T-DAB blocks were activated in turn and the analysis was repeated for each block (38 million calculations in all). Exhibit 4.3 below illustrates the tool calculating incoming interference for Block LE.

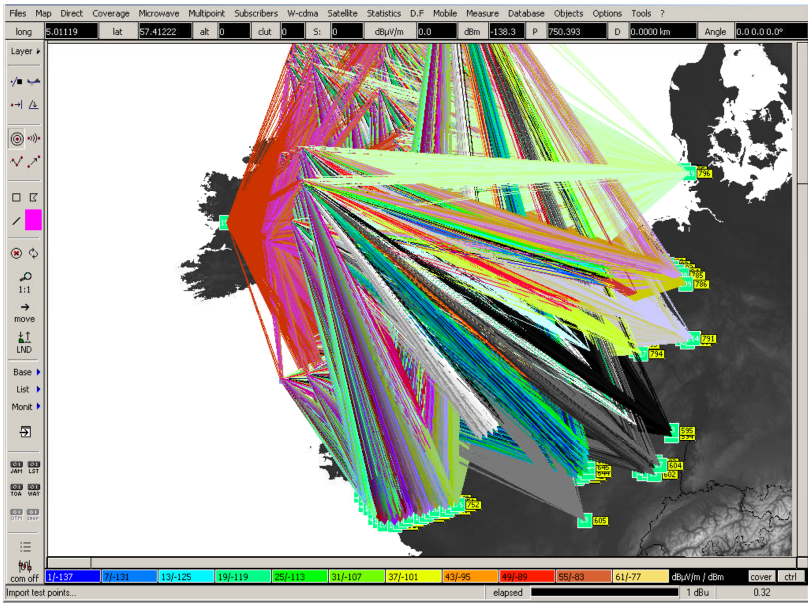

Exhibit 4.3: *Screen capture of ICS Telecom calculating incoming interference – Block LE [Source: Analysys, Mason 2006]*

Incoming field strengths were then summed (using the Bonn method) to determine the total interference contributed to each test point from all reference transmitters within each L-Band frequency block (LA to LP).

4.1.2 Summary of results

Exhibit 4.5 and Exhibit 4.6 below show, for each of the 16 T-DAB blocks in the lower part of the L-Band, a summary of the percentage of population and areas of the UK affected by incoming interference from Continental T-DAB systems. The following colour codes are used, showing which network types will have adequate signal quality. For reference, we provide in Exhibit 4.8 a conversion table that may be used to convert from dBW to Watts.

Green	WiMAX (duplex), UMTS TDD (duplex), PMSE (city-wide video links) as well as all the network types below
Yellow	T-DAB, DMB and DVB-H hand-held devices at 99% of locations, outdoor coverage
Orange	T-DAB, DMB and DVB-H hand-held devices at 99% of locations, indoor and outdoor coverage
Red	Short-range PMSE only

Exhibit 4.4: *Colour codes used in Exhibit 4.5 and Exhibit 4.6 below [Source: Mason, Analysys 2006]*

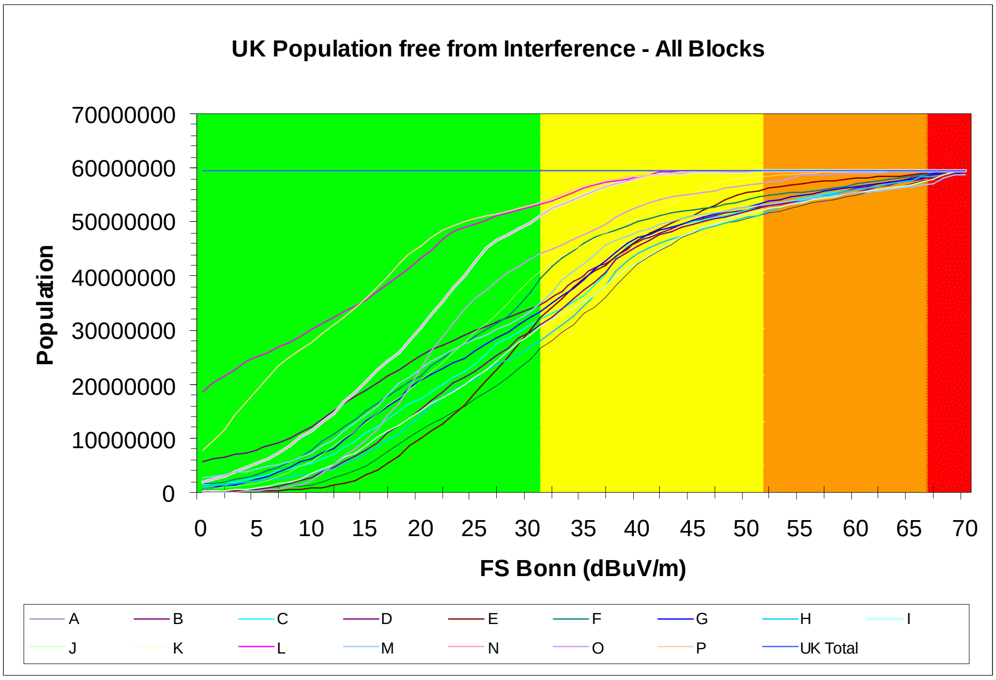

Exhibit 4.5: *UK population free from interference: T-DAB frequency blocks [Source: Analysys, Mason 2006] For colour coding, see Exhibit 4.1 above.*

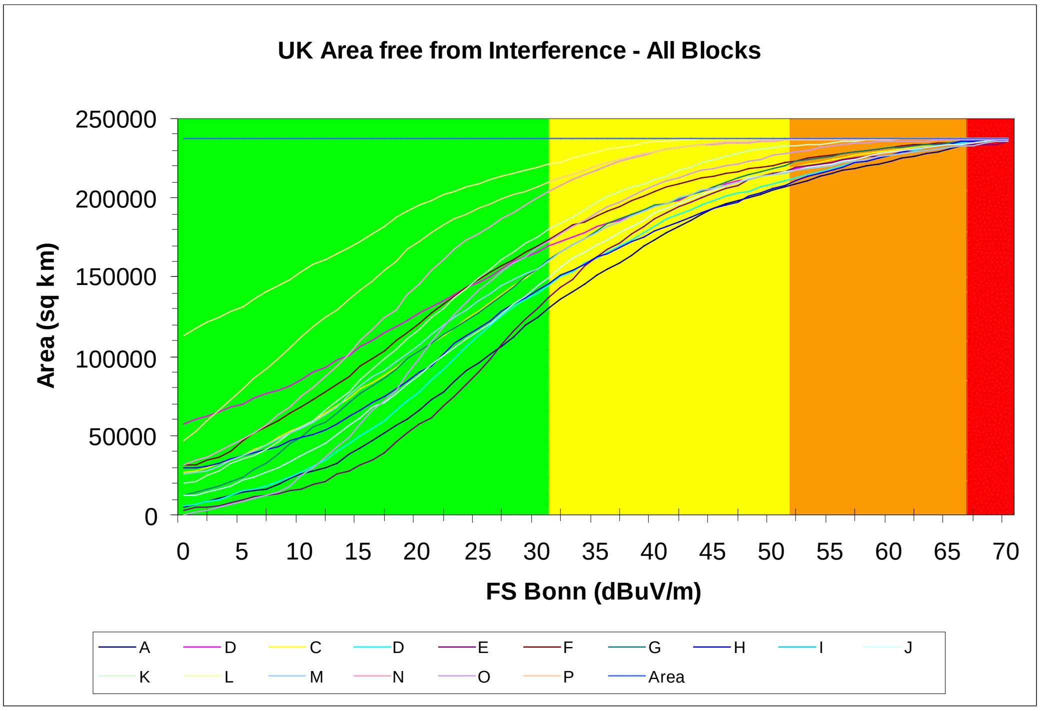

Exhibit 4.6: *UK area (km^2) free from interference: T-DAB frequency blocks [Source: Analysys, Mason 2006] For colour coding, see Exhibit 4.1 above.*

Exhibit 4.7 shows in tabular form the percentages of the population and area that are free from such interference. Further details are provided in Annex A, including maps and charts for each T-DAB Block.

Channel	*Interference levels low enough for all network types*	*Interference low enough for Networks providing Coverage for Outdoor Hand Held Devices*	*Interference low enough for Networks providing Indoor Coverage for Hand Held Devices*
LA	44.7% (55.0%)	85.8% (87.1%)	96.8% (97.9%)
LB	58.4% (71.4%)	88.8% (91.2%)	97.6% (98.9%)
LC	53.8% (67.3%)	88.5% (91.8%)	98.6% (99.4%)
LD	52.1% (60.9%)	88.4% (88.8%)	98.1% (98.8%)
LE	54.3% (57.9%)	94.0% (91.3%)	99.3% (98.1%)
LF	66.6% (73.2%)	91.8% (93.6%)	98.6% (99.3%)
LG	56.4% (67.8%)	89.6% (92.8%)	97.7% (99.2%)
LH	47.2% (61.4%)	86.2% (87.6%)	98.2% (99.1%)
LI	86.1% (86.0%)	99.9% (99.5%)	100.0% (100.0%)
LJ	51.6% (63.1%)	87.4% (91.2%)	96.7% (98.7%)
LK	68.9% (75.8%)	98.1% (97.9%)	100.0% (100.0%)
LL	89.7% (93.0%)	100.0% (100.0%)	100.0% (100.0%)
LM	58.7% (67.5%)	89.2% (91.0%)	95.4% (98.0%)
LN	86.1% (86.0%)	99.9% (99.5%)	100.0% (100.0%)
LO	74.2% (72.7%)	96.0% (96.0%)	99.6% (99.6%)
LP	90.1% (88.4%)	100.0% (99.7%)	100.0% (100.0%)

Exhibit 4.7: *For each T-DAB frequency block, percent of population and of area (in brackets) that are free from the effects of incoming interference from Continental T-DAB systems: [Source: Analysys, Mason 2006]*

The following conversion table may be used to convert from dBW to Watts.

dBW	Watts	Comments
37	5,012	Typical Omni T-DAB, DMB, DVB-H
36	3,981	
35	3,162	
34	2,512	
33	1,995	
32	1,585	
31	1,259	Low Power Omni T-DAB, DMB, DVB-H
30	1,000	
29	794	
28	631	
27	501	
26	398	Low Power Offset Antennas T-DAB, DMB, DVB-H
25	316	
24	251	
23	200	
22	158	
21	126	Sectorised (Back) T-DAB, DMB, DVB-H
20	100	
19	79	
10	10	Low Power Applications (Short Range PMSE)

Exhibit 4.8:

Conversion from dBW to Watts

4.2 Outgoing co-channel interference to Continental T-DAB systems

4.2.1 Methodology

We employed essentially the same methods as those described above to calculate outgoing co-channel interference to European T-DAB systems, with the following differences:

- transmitters were placed in typical network configurations across the UK
- test points were located across the relevant Continental countries within T-DAB allotments
- the receive antenna height and protected field strength were in accordance with the Maastricht 2002 Plan.

The field strength to be protected is specified as 69dBμV/m. The C/I protection ratio is 10dB. This gives a total limit for interference of 59dBμV/m for the Bonn sum of all interference. We assume that no more than a quarter of this interference total comes from a single transmitter, leaving the other three-quarters of the interference for the remaining transmitters in the network. The maximum interference from a single transmitter is therefore 53dBμV/m.

In order to calculate the maximum transmitter power, the power at each site was reduced until the interference generated at the relevant test point dropped below 53dBμV/m.

4.2.2 Summary of results

Exhibit 4.10 and Exhibit 4.11 below show, for each of the 16 T-DAB blocks in the lower part of the L-Band, a summary of the maximum allowable transmitter ERP (in dBW) in the direction of the nearest European test point, if interference to Continental T-DAB systems is to remain within limits. The following colour codes are used, showing the transmitter power limits required to ensure that the signal quality of European T-DAB networks is not affected.

	Typical omni directional transmitter for T-DAB, DMB and DVB-H
	Low-power omni-directional transmitter for T-DAB, DMB and DVB-H
	Sectorised (back) transmitter for T-DAB, DMB and DVB-H. Plus tri-sectored antennas for WiMAX and UMTS TDD
	Low-power, short-range PMSE applications only

Exhibit 4.9: *Colour codes used in Exhibit 4.10 and Exhibit 4.11 below [Source: Mason, Analysys 2006]*

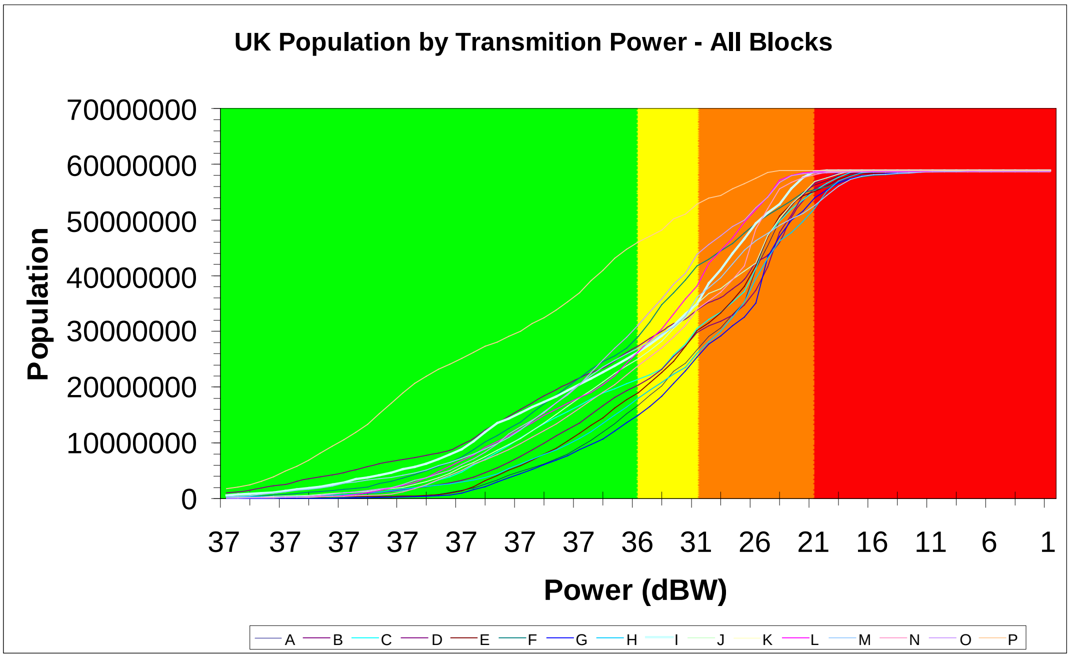

Exhibit 4.10: *Maximum allowable transmitter strength by UK population: T-DAB frequency blocks [Source: Analysys, Mason] For colour coding, see Exhibit 4.9 above*

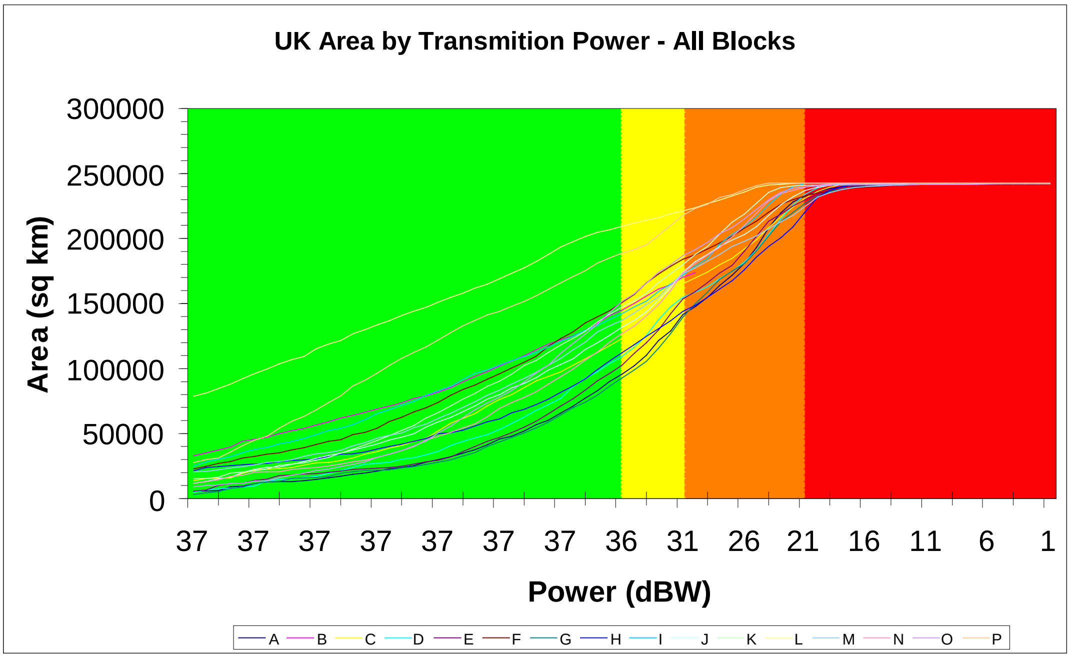

Exhibit 4.11: *Maximum allowable transmitter strength by UK area: T-DAB frequency blocks [Source: Analysys, Mason] For colour coding, see Exhibit 4.9 above*

Exhibit 4.12 shows in tabular form the percentage of the UK population and area that do not cause outgoing interference to Continental T-DAB systems. Further details are provided in Annex B, including maps and charts for each T-DAB Block.

Channel	*Low Power Short Range Applcations*	*Sectorised (Back) T-DAB, DMB, DVB-H.*	*Low Power T-DAB, DMB, DVB-H*	*Typical omni T-DAB, DMB, DVB-H*
LA	100% (100%)	94.7% (95.9%)	44.9% (58.3%)	28.2% (39.4%)
LB	100% (100%)	93.6% (96.3%)	56.9% (70.2%)	46.1% (59.7%)
LC	100% (100%)	93.0% (95.3%)	51.3% (68.2%)	36.0% (50.8%)
LD	100% (100%)	95.2% (96.5%)	50.1% (63.9%)	34.3% (45.1%)
LE	100% (100%)	92.8% (94.8%)	50.7% (63.3%)	32.0% (42.4%)
LF	100% (100%)	93.2% (96.0%)	70.2% (75.9%)	48.9% (62.2%)
LG	100% (100%)	90.9% (93.7%)	42.7% (57.6%)	25.2% (38.3%)
LH	100% (100%)	87.6% (90.9%)	43.8% (59.4%)	30.3% (46.2%)
LI	100% (100%)	98.7% (99.9%)	58.7% (70.9%)	44.3% (58.7%)
LJ	100% (100%)	95.8% (97.8%)	58.8% (71.7%)	42.3% (54.3%)
LK	100% (100%)	98.6% (99.4%)	64.2% (74.2%)	44.4% (60.8%)
LL	100% (100%)	99.0% (100.0%)	86.9% (91.3%)	79.0% (86.4%)
LM	100% (100%)	88.5% (92.6%)	60.7% (71.3%)	45.4% (56.6%)
LN	100% (100%)	97.7% (98.8%)	57.1% (71.5%)	40.1% (52.4%)
LO	100% (100%)	98.3% (98.9%)	73.7% (77.0%)	52.5% (62.4%)
LP	100% (100%)	99.0% (100.0%)	88.8% (89.9%)	77.5% (77.8%)

Exhibit 4.12: *For each T-DAB frequency block, percent of UK population and area (in brackets) that do not cause outgoing interference to Continental T-DAB systems [Source: Analysys, Mason 2006]*

4.3 Comparison of incoming and outgoing interference

In Annex C we provide a side-by-side comparison of outgoing and incoming interference. Note that incoming interference was calculated using industry typical field strengths at 1.5m above ground level, whilst outgoing interference was assessed in accordance with the Maastricht Plan 2002, as the test points in Europe enjoy protection under this agreement. The consequence is that outgoing interference is likely to be the limiting factor when designing a broadcast network within the UK (T-DAB, DMB or DVB-H) whilst incoming interference will be the limiting factor for duplex WiMAX and UMTS TDD networks, due to the interference received at the network base stations.

5 Adjacent channel interference between lower L-Band systems and Continental S-DAB systems

This section considers the restrictions on lower L-Band systems (in block LO and LP) due to either receiving adjacent channel interference from, or causing such interference to Continental S-DAB systems operating in the top 12.5MHz of the band.

Our approach was to consider the spectrum mask for L-Band DAB transmitters defined in ETSI TR 101 496-3 for use in areas where adjacent channel interference is critical (see Exhibit 5.1). This was compared with typical satellite parameters for *incoming* interference, and the protection figures at various frequency offsets described in the Maastricht 2002 Plan for *outgoing* interference.

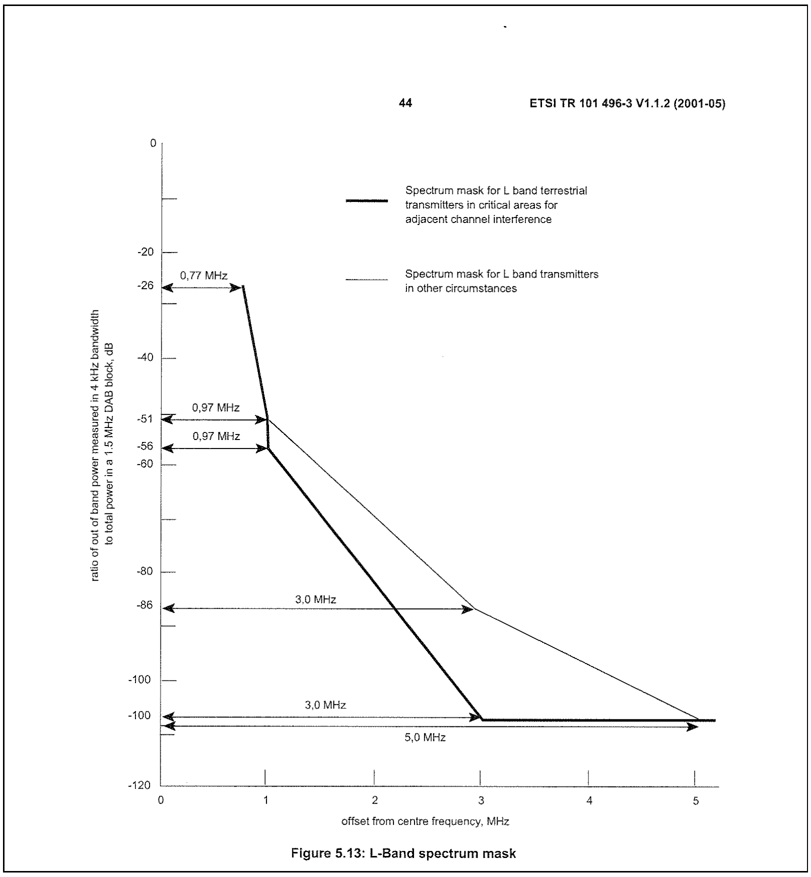

Exhibit 5.1:
Spectrum mask for L-Band T-DAB specified in ETSI TR 101 496-3

5.1 Incoming adjacent channel interference from Continental S-DAB systems

This section considers the restrictions on lower L-Band systems (in block LP) from incoming interference from Continental S-DAB systems operating in the top 12.5MHz of the band.

The separation between Blocks LP and LQ is 1.712 MHz. By applying the spectrum mask of a 1.5MHz DAB block to a typical field strength generated by a satellite system, we can calculate the field strength within the adjacent channel.

The protected field strength for a digital audio satellite broadcast is 29dBμV/m (see Exhibit 3.1 on page 9 above). However, in practice satellite systems often operate at a higher field strength than this, so for the purpose of assessing adjacent channel interference it is prudent to calculate a more typical field strength. Using more typical figures, the link budget can be calculated as shown in Exhibit 5.2 below.

	S-DAB	
Typical Satellite Power Output	24.0	dBW
Typical Satellite Antenna Gain	29.0	dBi
EIRP	53.0	dBW
Altitude	36000	km
Free Space Loss	186.9	dB
Nominal Receive Power	-133.9	dBW
Nominal Receive Power	-103.9	dBm
Typical Field Strength (Co Channel)	36.7	dBμV/m
FS Centre Freq. +/- 0.97MHz	-14.3	dBmV/m
FS Centre Freq. +/- 3.0MHz	-49.3	dBmV/m
FS Centre Freq. +/- 5.0MHz	-63.3	dBmV/m

Exhibit 5.2: *Incoming adjacent channel interference from Continental S-DAB satellites [Source: Analysys, Mason 2006]*

Comparing this with Exhibit 3.2 above, we see that even the highest adjacent channel interference from Continental S-DAB satellites at 0.97MHz will not affect any of the classes of equipment we have considered.

5.2 Outgoing adjacent channel interference to Continental S-DAB systems

This section considers the restrictions on lower L-Band systems (in block LO and LP) from causing outgoing interference to Continental S-DAB systems operating in the top 12.5MHz of the band.

5.2.1 Methodology used

Exhibit 5.3 shows the protection ratios and the limits of permissible interference (dBμV/m 1%) at various offsets from the centre frequency for S-DAB services, as specified in the Maastricht 2002 Plan.

Satellite sound broadcasting - digital (1.5 GHz)							
Service identifier	Field strength to be protected in dB(µV/m)					Receiver height (m)	
ZA	29.0					10	
Δ f (MHz)	-3.324	-1.712	-0.856	0.000	0.856	1.712	3.324
PR (dB) 1%	-55.8	-13.1	13.0	13.0	13.0	-13.1	-55.8
dB (µV/m) 1%	84.8	42.1	16.0	16.0	16.0	42.1	84.8

Exhibit 5.3: *Limits for adjacent channel interference to S-DAB services [Source: Maastricht 2002 Plan (Annex 2, p.84)]*

The above spectrum mask limits are illustrated graphically in Exhibit 5.4 below, along with the masks for the two adjacent T-DAB channels, LP and LO. The T-DAB masks are shown at a typical field strength sufficient to provide indoor coverage for hand-held devices. As can be seen, there is a considerable overlap between the two masks.

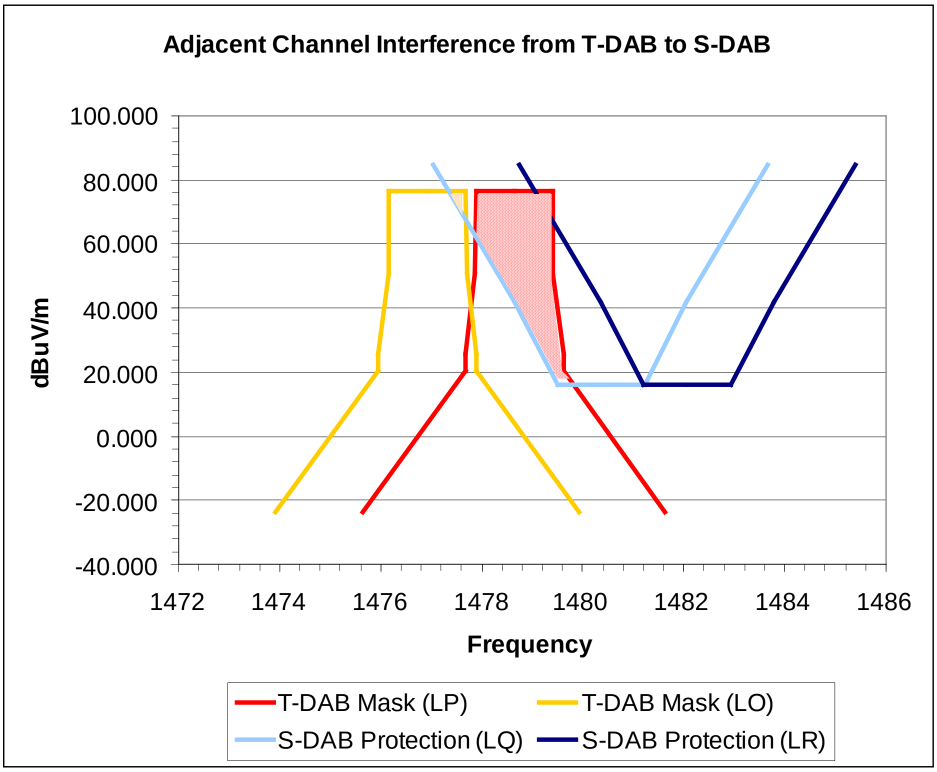

Exhibit 5.4: *Outgoing adjacent channel interference to S-DAB users [Source: Analysys, Mason 2006]*

In order to remove this interference, the field strength of T-DAB transmissions at the border with S-DAB regions will need to be reduced as shown in Exhibit 5.5 below.

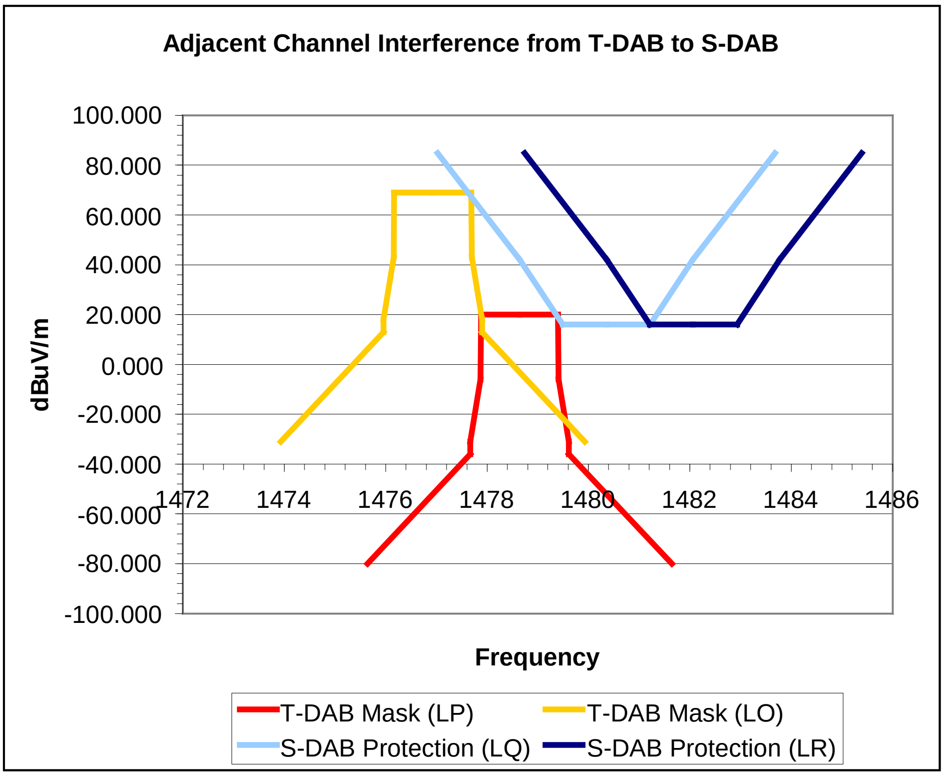

Exhibit 5.5: *Reduction in field strength required to mitigate risk of adjacent channel interference S-DAB users [Source: Analysys, Mason 2006]*

Adjacent channel interference from T-DAB Block LP to S-DAB Block LQ

As can be seen from the above Exhibits, interference from T-DAB Block LP to S-DAB Block LQ is very significant. The T-DAB field strength must be reduced from 75.6dBμV/m to 20dBμV/m at the boundary with S-DAB in order to conform to the protection limit agreed in the Maastricht 2002 Plan. In our view these restrictions appear conservative and the permissible field strength may well be higher in reality. Indeed, this limit is 39dB *lower* than the co-channel interference limit for T-DAB to T-DAB services (69 PFS – 10PR = 59dBμV/m). As a consequence, the use of T-DAB Block LP could be severely restricted if Continental countries claim protection for S-DAB services in Block LQ.

Within the UK, adjacent channel interference from T-DAB Block LP to S-DAB Block LQ is also likely to require coordination.

Adjacent channel interference from T-DAB Block LP to S-DAB Block LR, and from T-DAB Block LO to S-DAB Block LQ

In both these cases, we have calculated that a field strength reduction of 7.5dB (from 76.5 down to 69dBμV/m) is required to avoid adjacent channel interference. This is a manageable reduction in level since, for example, this will occur as a matter of course for signals crossing the English Channel, even at its narrowest point. However, at the land boundary between Ireland and Northern Ireland the necessity to reduce field strength could affect in-building reception in areas close to the boundary with S-DAB regions. It will also be necessary to ensure that the T-DAB transmitters are carefully positioned in the border region; where transmitters are sited such that cell coverage would spill over the border, directional antennas will be required to ensure that the field strength is reduced to no more than 69dBμV/m on the border.

Granting these concessions, we consider that there is no fundamental reason why Blocks LO and LP cannot be used right up to a boundary with S-DAB Blocks LQ and LR respectively.

5.2.2 Results

The following maps show the restrictions on lower L-Band systems (in block LP) due to causing adjacent channel interference to Continental S-DAB users when the protection defined in the Maastricht 2002 Plan is applied. Exhibit 5.6 shows the effect of all restrictions combined, while Exhibit 5.7 to Exhibit 5.13 show the effects for each of the countries considered. Exhibit 5.14 shows in tabular form the percentage of the UK's population and area that would remain unaffected by the restrictions.

As we note in Section 6.2 below, the restrictions on upper L-Band systems due to causing co-channel interference to Continental S-DAB systems in the upper 12.5MHz of the band are identical to those in regard to adjacent channel interference.

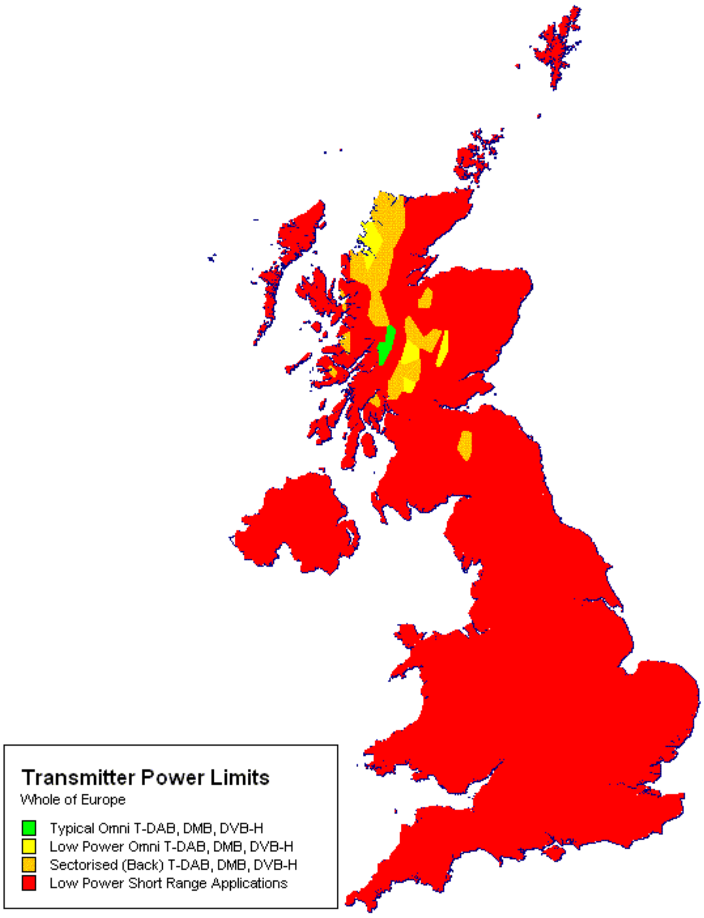

Exhibit 5.6:
UK area affected by concessions to S-DAB users in all Continental countries considered [Source: Analysys, Mason 2006]

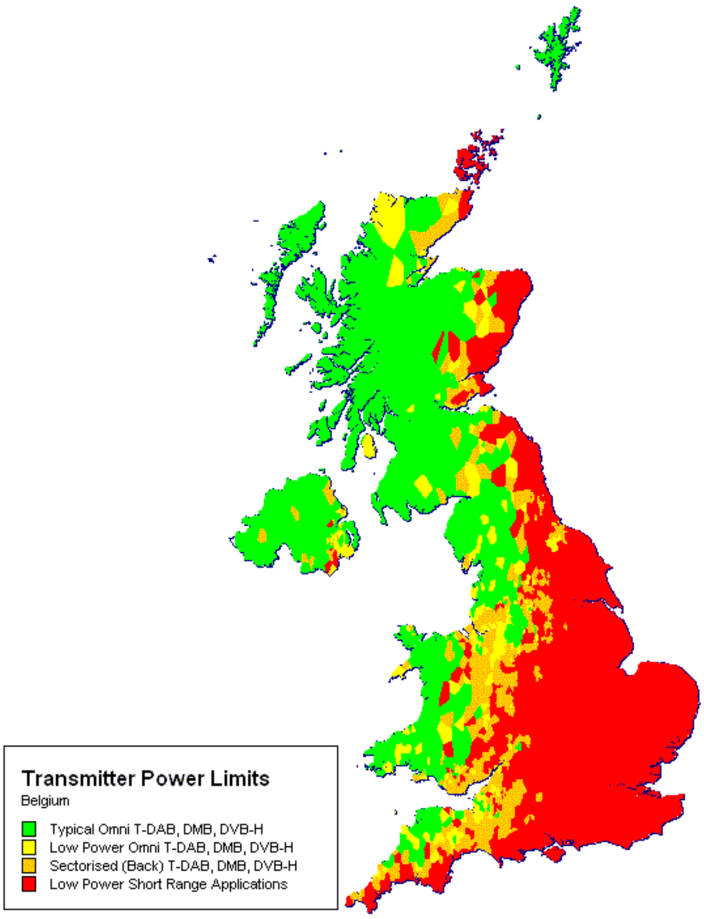

Exhibit 5.7:
UK area affected by concessions to S-DAB users in Belgium [Source: Analysys, Mason 2006]

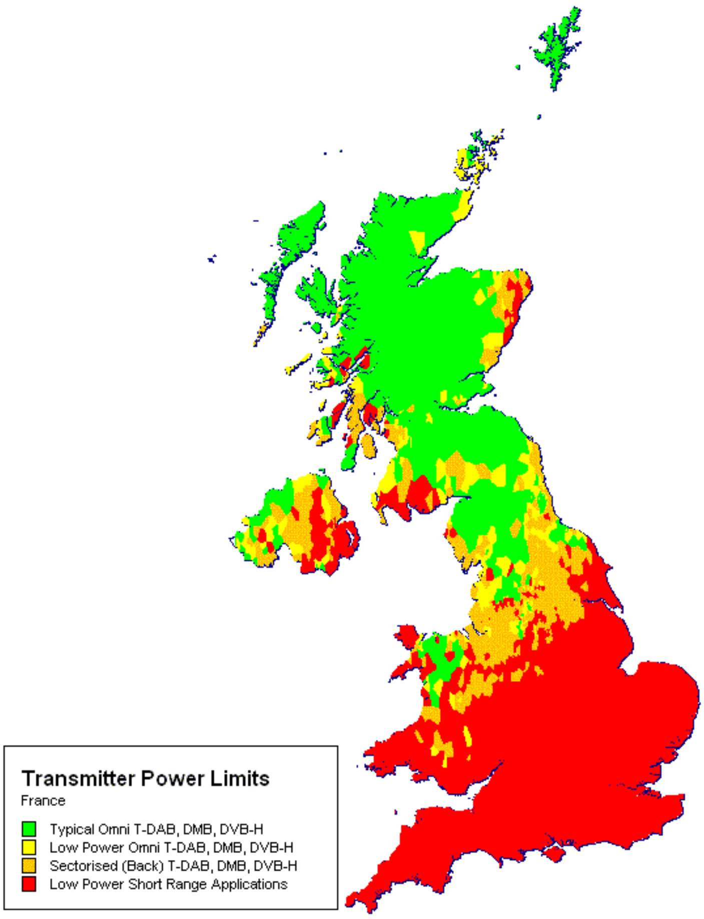

Exhibit 5.8:

UK area affected by concessions to S-DAB users in France [Source: Analysys, Mason 2006]

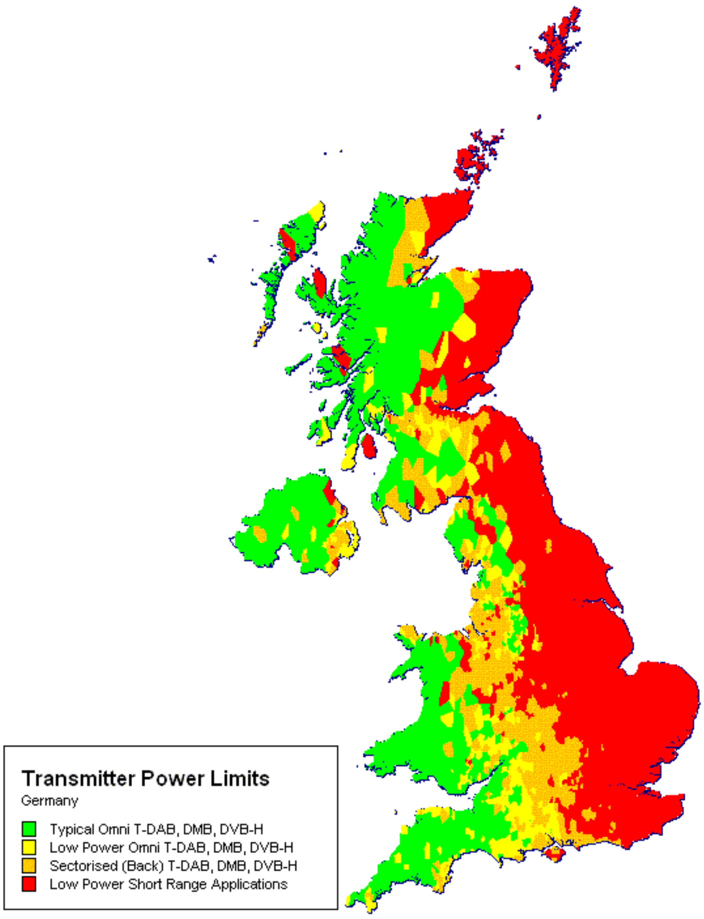

Exhibit 5.9:

UK area affected by concessions to S-DAB users in Germany [Source: Analysys, Mason 2006]

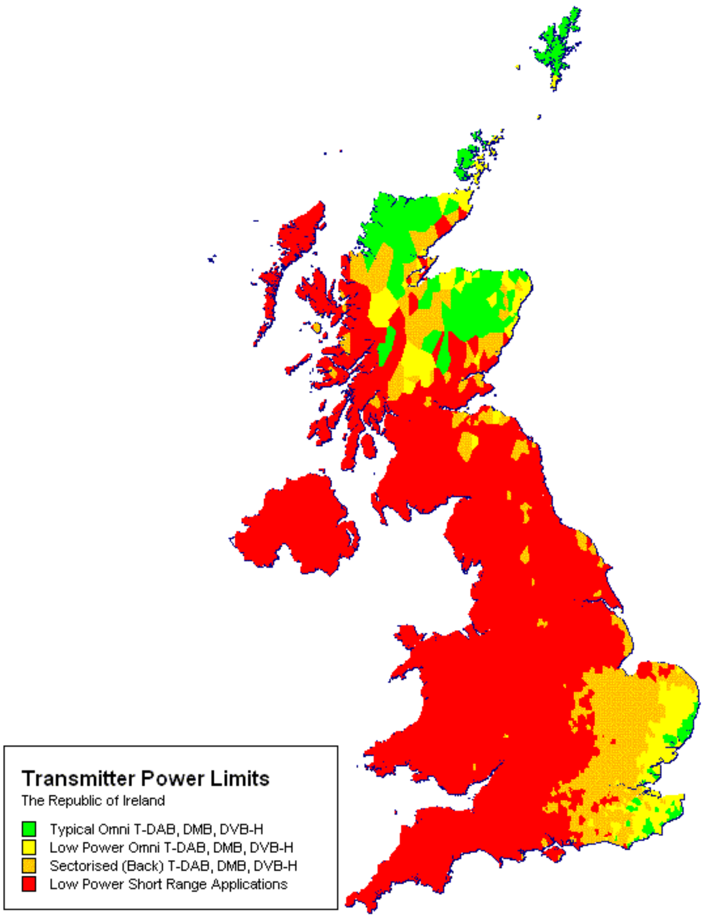

Exhibit 5.10:

UK area affected by concessions to S-DAB users in the Republic of Ireland [Source: Analysys, Mason 2006]

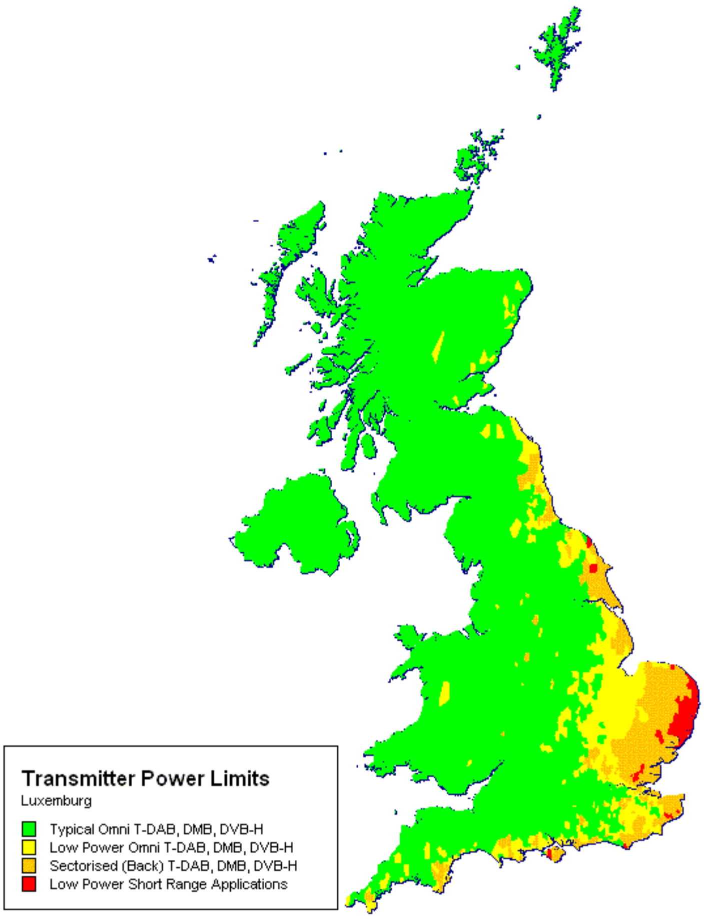

Exhibit 5.11:

UK area affected by concessions to S-DAB users in Luxembourg [Source: Analysys, Mason 2006]

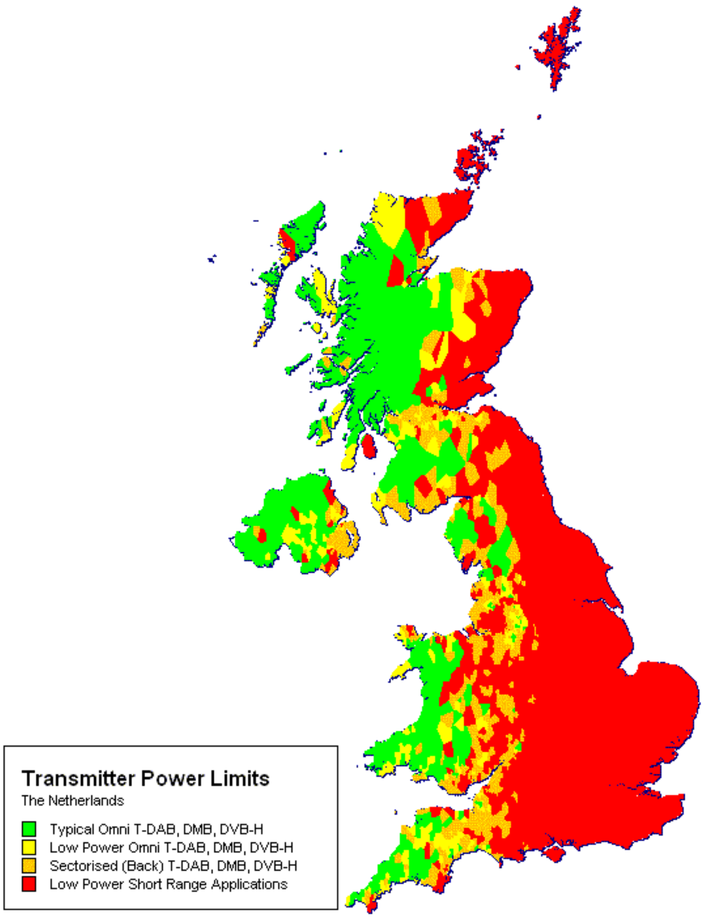

Exhibit 5.12:
UK area affected by concessions to S-DAB users in the Netherlands [Source: Analysys, Mason 2006]

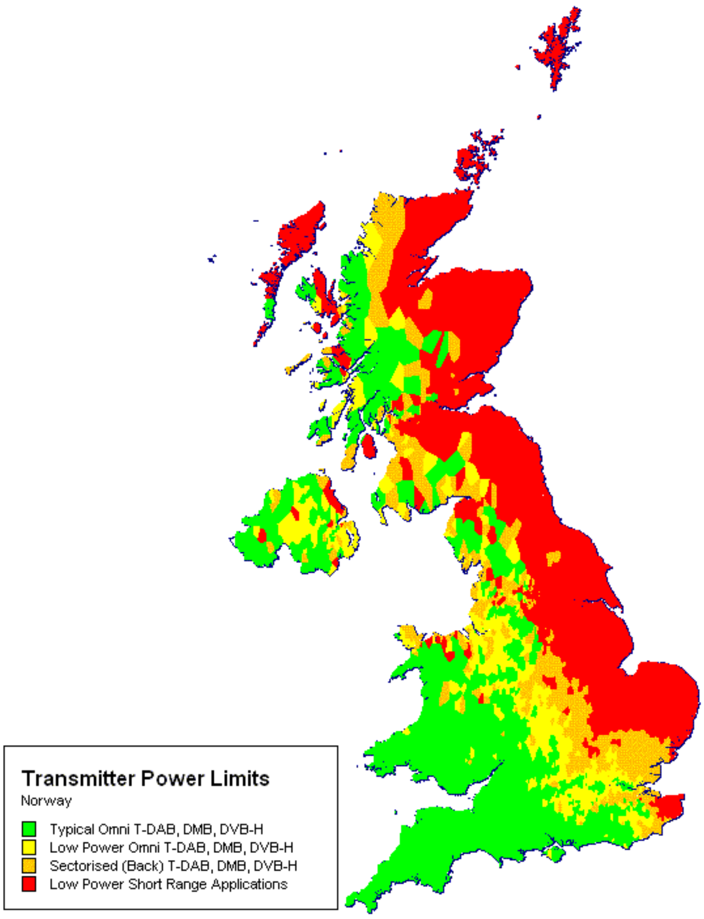

Exhibit 5.13:
UK area affected by concessions to S-DAB users in Norway [Source: Analysys, Mason 2006]

Channel	*Low Power Short Range Applcations*	*Sectorised (Back) T-DAB, DMB, DVB-H.*	*Low Power T-DAB, DMB, DVB-H*	*Typical omni T-DAB, DMB, DVB-H*
Belgium	100% (100%)	39.2% (58.4%)	24.7% (46.1%)	19.2% (40.0%)
Germany	100% (100%)	44.5% (59.3%)	24.9% (43.0%)	17.1% (35.1%)
France	100% (100%)	33.5% (51.2%)	15.8% (38.0%)	11.5% (32.3%)
The Netherlands	100% (100%)	29.2% (46.7%)	13.3% (33.8%)	8.8% (27.5%)
The Republic of Ireland	100% (100%)	30.3% (28.5%)	7.4% (14.0%)	2.5% (8.7%)
Luxemburg	100% (100%)	98.1% (98.9%)	88.2% (91.0%)	76.1% (83.0%)
Norway	100% (100%)	72.4% (62.6%)	54.7% (47.6%)	34.3% (38.8%)
TOTAL	100% (100%)	0.1% (4.9%)	0.0% (1.1%)	0.0% (0.7%)

Exhibit 5.14: *Percentage of UK's population and area (in brackets) not affected by concessions to Continental S-DAB users [Source: Analysys, Mason 2006]*

As can be seen from these maps, the effect is widespread due to the conservative assumptions in the Maastricht 2002 Plan. If these maps where to show the protection required by a satellite service that is no more sensitive to adjacent channel interference than a T-DAB service of the same field strength, then we would see that the concessions required would be greatly reduced and would be most significant in the vicinity of UK transmitters located close (10km) to the land border with Ireland. Hence, in practice the restrictions required to prevent actual interference to S-DAB systems are likely to be much less severe than indicated in Exhibit 5.6.

6 Co-channel interference to and from Continental S-DAB systems

This section considers the restrictions on upper L-Band systems due to either receiving co-channel interference from, or causing such interference to Continental S-DAB systems also in the upper 12.5MHz of the band.

For this analysis we have focused on the more significant interference from the satellite systems, rather than the less significant interference from terrestrial infill systems that may also be deployed in this band.

We have considered the interference implications of using other services in the upper part of the L-Band, namely T-DAB, DMB, DVB-H, WiMAX, UMTS TDD and PMSE. Note that we have not considered S-DAB, as any deployment of S-DAB is likely to be Europe-wide and hence the operator would manage the interference between different countries. If country-specific services were deployed, we assume that operators would co-ordinate their use of the spectrum.

6.1 Incoming co-channel interference from Continental S-DAB systems

We have assumed that any satellite providing coverage to the Continental countries considered[2] will cover 100% of the UK with a similar field strength. (Note that unlike the lower band there are no block allotments.) Depending on the specification of the satellite system, this could create co-channel interference within any of the blocks LQ to LW of between 36dBμV/m (vehicle coverage) and 29dBμV/m (fixed dish coverage).

2 Belgium, France, Germany, the Republic of Ireland, Luxembourg, the Netherlands and Norway.

When we compare these two figures to the interference limits specified in Exhibit 3.2, on page 10 above, it would appear that 36dBμV/m might have the potential to cause interference to outdoor fixed receivers such as WiMAX and UMTS TDD base stations. However, we must also take into consideration the fact that these base stations will typically have a further 10dB of antenna elevation pattern loss, as the antennas are most sensitive to signals within a few degrees of the horizon. The precise level of antenna elevation pattern loss will depend upon how high above the horizon the satellite appears from the location of the base station. In the case of geo-stationary satellites, the elevation is greater the closer the observer is to the equator, giving the best protection in the South of the UK. In the case of high elliptic obit satellites the point of greatest elevation is more typically to be found at latitudes between 50º and 70º, corresponding to areas in Scotland. Once the antenna elevation pattern loss is taken into account, we see that the level of interference will in fact be below the limit for WiMAX and UMTS TDD base stations.

As for the mobile units for these two technologies, particularly hand-held equipment for use indoors, such devices are far less sensitive and therefore will not be susceptible to satellite interference. In the case of hand-held devices for T-DAB, DMB and DVB-H services, it is clear from Exhibit 3.2 that satellite interference is well below their interference limits.

6.2 Outgoing co-channel interference to Continental S-DAB systems

Outgoing interference to Continental S-DAB systems is a more significant constraint. If European S-DAB users are to be given the level of protection called for in the Maastricht 2002 Plan then the concessions required would be identical to those discussed in regard to adjacent channel interference in Section 5 above. This is because of the low co-channel interference limit (16dBμV/m) called for in the Maastricht 2002 Plan (see Exhibit 5.3 on page 24 above).

The concessions required to avoid outgoing interference are therefore identical to those shown in Exhibit 5.6 to Exhibit 5.13 on pages 27–34. This would preclude the use of high field strength broadcast applications such as T-DAB, DMB and DVB-H hand-held devices. Even if the satellite service could operate at a more typical field strength, the interference limit would still be as low as 23.7dBμV/m.

Low field strength services, such as WiMAX and UMTS TDD, should be able to operate within the constraints imposed in at least part of the country (the green and yellow areas shown in Exhibit 5.6 to Exhibit 5.13).

It should again be noted that the S-DAB interference limit specified in the Maastricht 2002 Plan appears conservative, and that in practice the restrictions required to prevent actual interference to S-DAB systems are likely to be much less severe.

7 Impact on deployment

This section discusses how the deployment of each of the services discussed in this report may need to be altered to avoid interference. We have assumed that operators deploy services in the lower 27.5MHz using just one frequency channel. It may be possible for operators to acquire more than one block, and in this case they may be able to acquire blocks that have different interference constraints in different areas of the UK, thus minimising the impact of the constraints. We have also assumed that operators roll out their services nationally to both urban and rural areas.

7.1 Wireless digital video and audio links for PMSE

In the Programme Making and Special Events (PMSE) sector there are two distinct applications of wireless digital video/audio links: short range and city-wide.

Short-range video links are generally used for connecting a digital camera to local PMSE equipment. The wireless camera gives the camera operator more freedom to move around without the risk of tripping over camera flexes: the camera receiver is placed in a discreet location as close as practical to the area where filming is taking place. Such a system may include a sound channel, but more often sound is dealt with separately.

Short-range systems can tolerate quite high levels of incoming international interference; in the worst case the operating range of the equipment may be reduced. Where several such wireless cameras are used at the same event (possibly by different organisations) the users may need to coordinate with each other to ensure that devices in close proximity operate on different channels.

Because of the short transmission distances involved and indeed the close proximity of people to the transmitters, the power output of these systems is limited to a few watts or less (typically 100mW). Such a low transmission power will not generate international co-channel or adjacent channel interference.

City-wide video links are typically used by news-gathering organisations to support outside broadcasts. Systems are set up to serve areas that are a frequent source of news stories, such as Westminster, the whole of Central London or a region like Greater Manchester. In this case the link carries both video and audio, and links the outside broadcast team with the broadcasting studio. The base station at the studio needs to be sensitive enough to receive a signal over a distance of several miles. Both the outside unit and the base station may use some type of manoeuvrable directional antenna. If a single base station is to cover a wide area, then the outside broadcast unit may employ a van with a pump-up mast which is used to clear local clutter and achieve a better propagation path.

If the base station is operated in an uplink-only mode (with the outside broadcast unit transmitting and the studio receiving), then the system will generate very little outgoing interference. However, the base station may be susceptible to incoming interference, particularly when the direction of the outside broadcast unit aligns with a Continental transmitter. To mitigate this, several base stations may be deployed, perhaps using sectorised antenna to increase sensitivity to the outside broadcast whilst rejecting incoming international interference.

7.2 UMTS TDD and WiMAX in the lower L-Band

For Blocks LA to LO, the limiting factor is incoming co-channel interference from Continental T-DAB networks. Networks could be rolled out unaffected in the areas coloured green in the maps shown in Annex A, but in the yellow areas, base stations would need to use sectored antennas that face away from the source of the interference. As shown in Exhibit 7.1, this would result in a 100%–200% increase in the number of base stations required in those areas.

Block LP will be limited by adjacent channel interference with Continental S-DAB systems in Block LQ within the upper L-Band. The impact on the deployment of UMTS

TDD and WiMAX systems using this block will be the same as for those operating in the upper 12.5MHz of the L-Band (see next section).

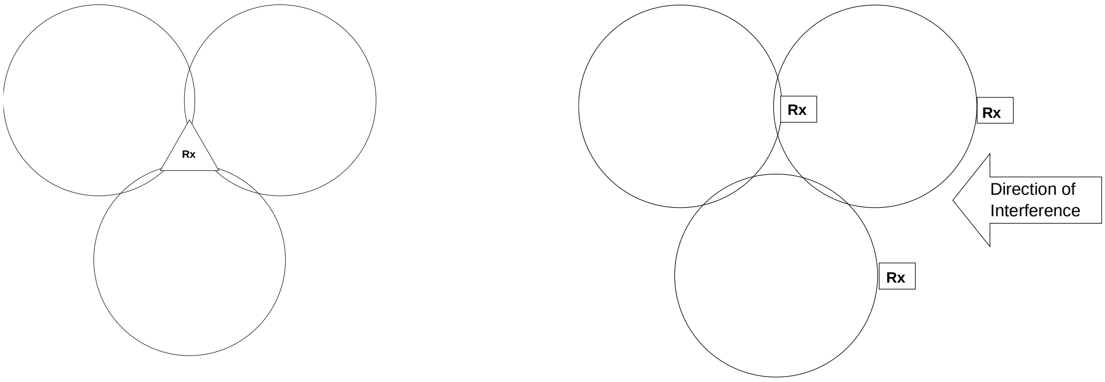

Exhibit 7.1: *A conventional tri-sectored base station, and three single sector base stations facing away from a source of incoming interference [Source: Analysys, Mason 2006]*

7.3 UMTS TDD and WiMAX in the upper L-Band

The upper part of the L-Band is better suited to UMTS TDD and WiMAX services as there is far less incoming interference. In addition, the base stations will ignore reject interference from elevations more than 10 degrees or so above the horizon (see Section 6.1 above). The lower transmission power will have a less significant effect on S-DAB users than broadcast services. Networks should be fine in the areas coloured green and yellow in the maps shown in Exhibit 5.6 to Exhibit 5.13 (see pages 27–34), but will require careful sectorisation in the other areas, and a consequential increase in the number of base stations.

The interference from mobile UMTS TDD and WiMAX devices will be negligible when measured in Continental countries.

7.4 T-DAB, DMB and DVB-H in the lower L-Band

Blocks LA to LO are the part of the L-Band most suited to T-DAB, DMB and DVB-H services. For these services the most significant impact in these blocks is that of outgoing interference. The effects vary from block to block (see Annex B), and the implications of avoiding causing interference also vary widely:

- At best (Blocks LI and LL), a small amount of the network would need low-power sites rather than high-power ones (in the areas coloured yellow in the maps shown in Annex B). Typically these sites will cover only 25% of the area covered by a high-power site positioned on a high hilltop, and as a result more sites would be required in total.

- In areas colour-coded orange, sectorised sites will be required, which will cover no more than 15% of the area covered by a high hilltop high power site.

- In the areas shown as red, it is unlikely that it will be possible to achieve indoor coverage within the interference limits imposed by the Maastricht 2002 Plan.

Services in Block LP will be limited by adjacent channel interference with European S-DAB users in Block LQ of the upper L-Band. The impact on deployment within this channel will therefore be the same as for the upper L-Band (see Section 7.5 below).

7.5 T-DAB, DMB and DVB-H in the upper L-Band

In our opinion the use of T-DAB, DMB and DVB-H in the upper 12.5MHz of the L-Band is unlikely be viable. The combination of high-field-strength broadcast services in the UK and protected low-field-strength satellite services on the Continent would not work at all. The area that would be affected by concessions covers nearly the whole of the UK, as was shown in Exhibit 5.6, reproduced below.

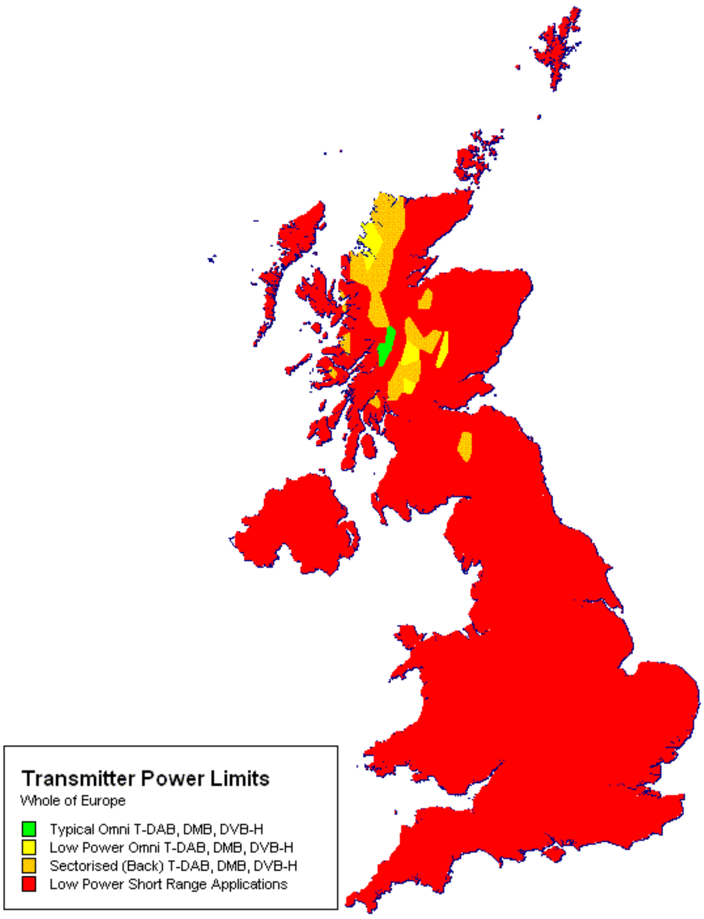

Exhibit 7.2:

UK area affected by concessions to S-DAB users in all Continental countries considered [Source: Analysys, Mason 2006]

8 Conclusions

There are potentially a wide range of services that could use spectrum in the 1452–1492MHz band, for example T-DAB, DMB, DVB-H, WiMAX, UMTS TDD and PMSE. Potential future users of the L-Band will, however, need to adhere to interference constraints with regard to both Continental T-DAB and S-DAB users. The interference restrictions are different for the various frequency blocks, and could result in either reduced revenues (e.g. through reducing the population coverage possible) or increased costs of deploying solutions to overcome the interference-related problems.

Exhibit 8.1 and the following paragraphs summarise the degree to which the services under consideration would be affected by interference restrictions. Note that we have only considered the use of S-DAB in the UK in the upper L-Band; we assume that S-DAB operators in the UK and the Continent will co-ordinate their use of the spectrum.

Type of equipment affected		*Fixed outdoor equipment*	*Hand-held outdoor equipment*	*Hand-held indoor equipment*	*Short-range PMSE equipment*
Type of interference	Incoming interference from T-DAB	**Medium** (Blocks LA–LO)	Low	Low	Low
	Outgoing interference to T-DAB	Low	**Medium** (Blocks LA to LO)	**Medium** (Blocks LA to LO)	Low
	Incoming interference from S-DAB	Low	Low	Low	Low
	Outgoing interference to S-DAB	**High** (Blocks LP and LQ–LW)	**High** (Blocks LP and LQ–LW)	**High** (Blocks LP and LQ–LW)	Low
Services affected		*WiMAX, UMTS TDD and city-wide PMSE*	*DVB-H, DMB, T-DAB, WiMAX and UMTS TDD*	*T-DAB, DMB and DVB-H*	*Short-range PMSE video links*

Exhibit 8.1: *Level of restrictions that would apply to different services in the L-Band due to restrictions relating to different types of interference [Source: Analysys, Mason 2006]*

Incoming interference from Continental T-DAB systems

Incoming interference from Continental T-DAB users would primarily affect fixed outdoor receiving equipment, and as a result this form of interference would be the limiting factor for WiMAX, UMTS TDD and city-wide video links in the lower L-Band (excluding Block LP).

The population of the UK that could be served without taking mitigating measures varies by block, from less than 50% (Block LA) to over 95% (Block LL). It might be possible to avoid the interference constraints by using sectorised antennas, but this would mean that more antennas would be required in total.

For indoor hand-held devices (T-DAB, DMB and DVB-H), the interference restrictions would be less. At worst (in Block LA), incoming interference might make it difficult to provide a service for up to 3% of the population. However, in some blocks (such as Block LL) there would be no restrictions at all.

Outgoing interference to Continental T-DAB systems

Outgoing interference to Continental T-DAB systems would be the limiting factor for indoor handheld devices (T-DAB, DMB and DVB-H). At worst, in Block LA it would only be possible to cover 28% of the population using high-power omni-directional antennae. Other blocks would be less affected: for example, it would be possible to cover 79% of the population using Block LL.

In order to mitigate these effects, lower power omni-directional antennae or sectored antennae could be used. However, this would require a large number of additional sites.

Incoming interference from Continental S-DAB systems

We do not envisage that incoming interference from Continental S-DAB systems (either co-channel interference in the upper L-Band, or adjacent channel interference in Block LP) would restrict the use of the L-Band in the UK. Even if a Continental service were to completely cover the UK, the field strength would not be strong enough to cause interference to any of the services considered in this study.

Outgoing interference to Continental S-DAB systems

The Maastricht 2002 Plan is very restrictive about the levels of interference that can be caused to S-DAB users in the upper 12.5MHz of the L-Band: the maximum interference level permitted is just 16dBμV/m. This renders the use of other services in this part of the band problematic.

The same is true for Block LP in the lower 27.5MHz of the band, due to the equally restrictive adjacent channel interference constraints that apply.

It should be noted that the S-DAB interference limit specified in the Maastricht 2002 Plan appears conservative, and that in practice the restrictions required to prevent actual interference to S-DAB systems are likely to be much less severe.