Final Report for the Independent Audit of Spectrum Holdings

Spectrum demand for non-government services 2005–2025

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0 Executive summary

This document has been prepared by Analysys Consulting Limited (Analysys) and Mason Communications Limited (Mason) as part of a spectrum demand study for the Independent Audit of Spectrum Holdings (IASH) team.

0.1 Introduction

The principal objective of this study was to forecast the future demand for radio spectrum in the UK for commercial service (i.e. non-government) use within the frequency range 0–15GHz. Demand forecasts were to be developed for the next 20 years (2005–2025), but with a particular focus on the next 10 years (2005–2015).

We present below an overview of our approach. It is important that the objectives of the study and the approach we have adopted are both considered when interpreting our findings.

In particular, it should be appreciated that forecasts for individual services have been produced based only on the level of analysis necessary to support the generation of forecasts of overall demand for spectrum. Where these analyses make assumptions about future technology and market developments, it should be understood that such assumptions have been made to provide a tangible basis for the development of such forecasts; the use of any particular assumption should not be taken to imply that alternative developments are not equally likely, or that Analysys and Mason consider the assumed development to be the most likely.

Our assessment focuses on the main uses of spectrum in frequencies below 15GHz

The objectives of the study and the timescale available mean that we have taken a high-level assessment of the future demand for the spectrum. We have focused on the major users/uses of the spectrum with the intention of accounting for at least 80% of current commercial use of spectrum in frequencies below 15GHz. The specific services modelled in the study are cellular, fixed-links, broadband wireless access (BWA), satellite (fixed, mobile and broadcasting) and terrestrial television broadcasting.[1]

For each modelled service we have identified the key driver(s) underlying future demand

Our approach to the assessment involved the identification of the principal underlying driver(s) of future spectrum demand for each of the services under investigation (e.g. network traffic in the case of cellular networks, number/bandwidth of fixed-links, possible future satellite deployments in the case of mobile satellite spectrum, etc.) and projecting the future evolution of the drivers. These projections were then converted into demand for spectrum, taking account of potential future improvements in the spectral efficiency of the technologies supporting the delivery of individual services.

The exact methodology and approach used was specific to each service and is described in further detail in the relevant sections of this report.

In view of the uncertainties associated with each service, we have adopted a scenario-based approach

Spectrum demand projections are subject to a wide range of assumptions, particularly for future take-up and usage levels of individual services. We have therefore developed a series of scenarios for each of the modelled services. These scenarios aim to highlight the potential impact of variations in those assumptions to which our demand forecast is most subjective. We present an overview of each of the modelled scenarios below.

1 The forecasts presented in this study do not include uses of the spectrum such as private mobile radio (PMR), aeronautical and maritime services, programme making and special events and audio broadcasting (including DAB).

However, we have not been able to 'flex' all of the uncertainties associated with each service

Within the scope and time available for this study, we have not been able to model variations of all of the key parameters associated with the future demand for spectrum for each service. For example, in the case of cellular, we have made specific assumptions about the future of 2G networks and the deployment of HSDPA and 'systems beyond IMT-2000'. These assumptions have been made for modelling purposes and are not meant to preclude other possible outcomes (e.g. the deployment of a mobile version of WiMAX) as an alternative means of meeting demand.

Our study findings should therefore be interpreted in this light – in particular, this study is not a substitute for a comprehensive analysis of the specific issues associated with individual services.

We have assumed the supply of spectrum for individual services is available at current prices

For many of the proposed services, there is a trade-off between the use of additional spectrum and alternative options (e.g. deployment of additional transmitter sites). This trade-off depends on the availability and price of radio spectrum. We have therefore needed to make assumptions about the future pricing of spectrum to underlie our demand forecasts. For the purposes of this study, we have generally assumed that the prices/regime for payment of spectrum is comparable to the fees and environment currently in place for each individual service.

For cellular services, we have needed to make a specific modelling assumption about the future price of spectrum

For our modelling of future demand for cellular services, we have developed an operator cost model that can be used to assess the trade-off between the use of additional spectrum and the costs that would otherwise be incurred (additional capital and operating expenditures associated with the deployment of additional base station sites). For modelling purposes, we have made a specific assumption about where this trade-off lies, i.e. in relation to the future price of spectrum. We present our assumptions in the cellular section and note that if spectrum prices are higher or lower than our assumption, future demand for spectrum will be respectively lower or higher than we have forecast.

Our assessment of terrestrial television broadcasting and satellite services quantifies the future demand for spectrum from service providers rather than underlying end-user demand

Our approach focuses on quantifying the future demand for spectrum and, in the case of certain services (terrestrial television broadcasting and satellite services), we have focused on modelling potential future demand from users of the spectrum (e.g. broadcasters, satellite operators) rather than underlying end-user demand for downstream services.

For example, our assessment of future demand for mobile satellite spectrum is based on an assessment of demand from potential mobile satellite system operators. It is by no means certain whether there is sufficient end-user demand to warrant the deployment of all of the proposed competing systems. However, following discussions with the IASH team, our approach has been to quantify the demand from all these potential service providers in order to let the market determine the number of competing providers, rather than availability of spectrum being the determinant.

Likewise, in the case of terrestrial television broadcasting, we have not quantified end-user interest and take-up in new services (e.g. high definition television, mobile television), nor have we validated whether such services can be offered on an economic basis. This should be considered when interpreting our demand forecasts.

For each of the individual services we have modelled, we present below an overview of the modelling approach used and the results of our assessment. Further details can be found in the relevant sections and annexes of this report.

We have also developed three 'macro scenarios' which combine each of the service forecasts in order to take account of the principal linkages and interdependencies between the individual services. Further details of these are also presented below, following each of the relevant services.

0.2 Cellular services

0.2.1 Introduction

The UK cellular market is moving from 2G networks and services towards 3G. At this early stage in the 3G life cycle, it is currently difficult to gauge the take-up of 3G services and, as a result, there is a large amount of uncertainty about future traffic and spectrum demand.

In considering the demand for cellular services, we have developed two traffic scenarios to reflect the potential range in future demand: a low traffic and a high traffic scenario, which assumes aggressive growth in data traffic, resulting in 3G (and any systems beyond IMT-2000) traffic being dominated by data. These two forecasts were compared with forecasts developed by the UMTS Forum in its *Magic Mobile*[2] report. The forecast from the UMTS Forum is broadly in line with our high traffic scenario up to 2012, but, in respect of this study, we feel that the Magic Mobile forecast is overly aggressive in the later years and that our high traffic scenario represents a more likely upper bound to future demand.

Using a cost model for a typical 3G operator and the above traffic scenarios, we estimated the cost savings arising from obtaining additional spectrum (e.g. from deploying a smaller number of base stations). For the purposes of this study, we have assumed that if the cost saving from the use of an additional 2 x 5MHz block of spectrum were to be GBP5 million per annum or greater, the operator would demand this spectrum.[3]

As part of our approach, we also factored in anticipated improvements in spectral efficiencies arising from the deployment of new technologies (HSDPA/HSUPA and new systems beyond IMT-2000) to produce a spectrum demand forecast to 2025.

2 *Magic Mobile Future 2010–2020*, UMTS Forum, April 2005.

3 Cellular operators face a trade-off between acquiring additional spectrum and additional capital/operating expenditure. To model future spectrum demand, we therefore need to make an assumption about the level of this trade-off – essentially what the price of spectrum will be in the future. We do not regard the 2000 auction prices as a suitable benchmark as these were influenced by market conditions at the time of the auction. We have selected GBP5 million per annum as the threshold as this is in the same ballpark as Ofcom's current AIP-based price for 2G spectrum (approximately GBP3 million per annum for 2x5MHz) and the 1996 NERA/Smith assessment of the marginal value of mobile spectrum (GBP8 million per annum for 2x5MHz). If the true price of spectrum is significantly higher/lower than this assumption, our forecasts could overstate/understate future demand for spectrum, respectively.

It should be noted that our approach does not include a detailed assessment of the need for additional spectrum during any technology transition, to allow for parallel operation of the old and the new technologies, nor does it explicitly consider the requirement for additional spectrum to support new entrants into the market.

0.2.2 Results

Exhibit 0.1 and Exhibit 0.2 show the forecast 3G spectrum demand for the low traffic and the high traffic scenarios. In the low traffic scenario, spectrum demand initially falls as traffic is migrated onto the more efficient 3G networks. In both scenarios there is a step change in spectrum demand as the new system beyond IMT-2000 is introduced (in 2015 in urban areas and 2018 in rural areas). In the high traffic scenario, demand drops slightly in 2020–2022 as a further improvement to the system beyond IMT-2000 is introduced, before rising to a total of 1310MHz by 2025.

As discussed above, these results are based on the assumption that demand for additional mobile spectrum is driven by operators being able to make an additional cost saving of GBP5 million per annum from the use of each 2 x 5MHz block.

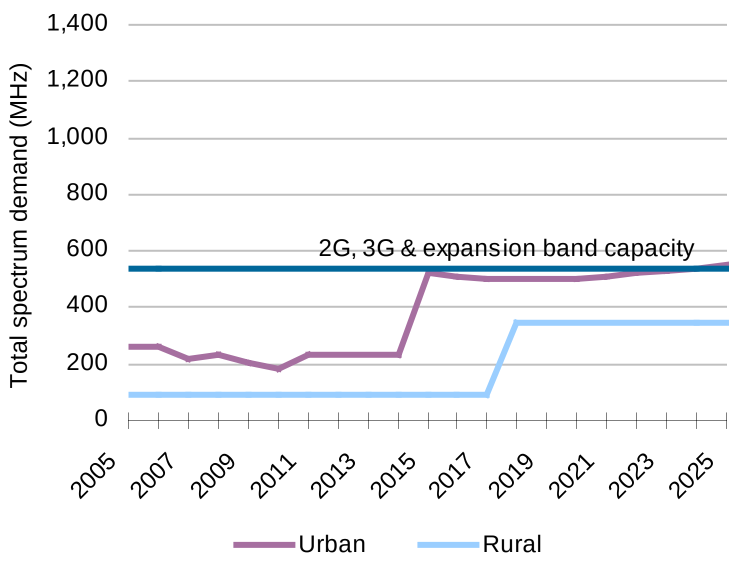

Exhibit 0.1: *Total spectrum demand – low traffic scenario [Source: Analysys, Mason, 2005]*

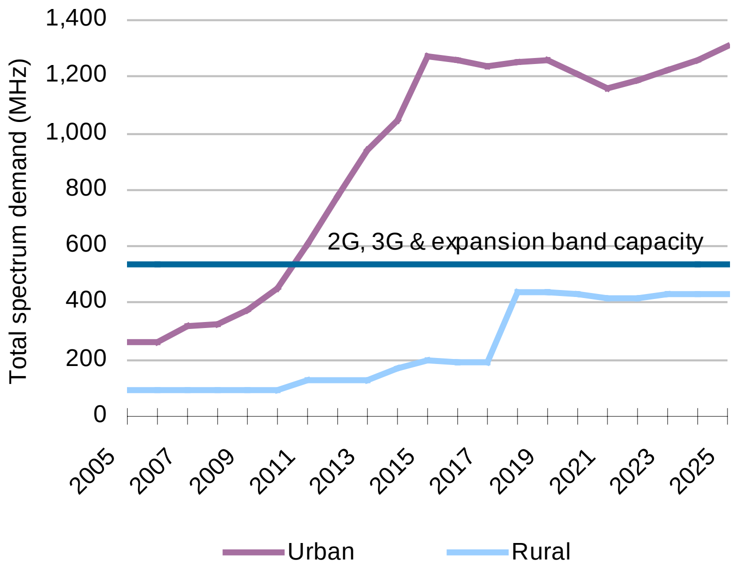

Exhibit 0.2: *Total spectrum demand – high traffic scenario [Source: Analysys, Mason, 2005]*

0.2.3 Conclusions

Under our low traffic assumptions, we expect that the spectrum demand in urban areas will be relatively constant until a new system beyond IMT-2000 is launched in 2015. Following this launch, the spectrum demand will increase to a total of 550MHz by 2025. In the aggressive, high traffic scenario we expect that spectrum demand in urban areas will reach a total of 1270MHz in 2015, rising to a total of 1310MHz by 2025. We forecast much less spectrum demand in rural areas; indeed we anticipate the minimum spectrum to operate UMTS (2 x 5MHz per operator) and a new system beyond IMT-2000 (modelled as being 2 x 30MHz per operator) should be sufficient under the low traffic scenario to 2025.

There is currently a total of 540MHz of spectrum that has been assumed to be available for cellular use and we forecast that this will be just enough to satisfy demand under our low traffic assumptions until 2025. However, if higher traffic scenarios materialise, additional spectrum will be required. In this case, there is likely to be considerable investment in research involving increasing the frequency range over which mobile technologies can operate – it is unlikely that sufficient spectrum can be found below 3GHz, so use will need to be made of higher frequencies. We understand that CEPT is currently seeking to identify spectrum up to 6GHz for use for future cellular systems.

Under our low traffic assumptions, the future demand for additional spectrum for cellular services is relatively modest. This is primarily as a consequence of the move to 3G technologies which are more spectrally efficient than GSM and the levels of interest and take-up of mobile data services. However, demand remains high from both existing operators and potential new market entrants for low-frequency spectrum (particularly spectrum under 1GHz) to facilitate the lower-cost deployment of cellular networks in less populated areas.

0.3 Terrestrial fixed-link service

0.3.1 Introduction

Terrestrial fixed-link services are used for a variety of purposes such as long-haul telecommunications trunked traffic and backhaul. Hence, the major users of fixed-links are the national fixed telecoms operators and the cellular operators. The strongest growth in demand for fixed-links in recent years has been driven by the cellular operators, which have made extensive use of fixed-links for their backhaul.

In this investigation the spectrum demand has been forecast for seven bands below 15GHz (1.4GHz, 4GHz, 6GHz lower, 6GHz upper, 7.5GHz, 13GHz and 15GHz bands, the 11GHz and 14GHz bands have been excluded from this study). In order to do this, it was first necessary to estimate current utilisation by band. This was achieved by calculating the fixed-link density by channel within each band by region (London, other urban areas and rural) and assuming that the highest density channel within each band is at capacity.

The fixed-link market is a highly concentrated market, with the top five users making up over 85% of currently used fixed-link occupied bandwidth (BT, Orange, T-Mobile, Cable & Wireless and H3G). The current trend of cellular operators switching to fixed-links means that Vodafone and O_2 may also become large users. Therefore, we have forecast future fixed-link occupied bandwidth individually for each of these seven companies. These forecasts were then used to trend forward to spectrum demand by band to 2025.

As part of these forecasts we have considered three scenarios focused around the potential options for the cellular operators when rolling out their 3G networks. **Please note that the assumptions of the future fixed-link demand for these companies have been made by Analysys and Mason for the purposes of this study and that this may not be consistent with the companies' own views.**

Conservative scenario

The assumptions behind this scenario are:

- Vodafone and O_2 do not switch to using fixed-links for their backhaul
- the cellular operators do not roll out 3G networks to rural areas.

Medium scenario

The assumptions behind this scenario are:

- Vodafone and O_2 will increase their percentage of sites served by fixed-links
- two cellular operators will roll out 3G networks to rural areas.

Aggressive scenario

The assumptions behind this scenario are:

- all five cellular operators use fixed-links in 75% of their sites by 2010
- all five cellular operators roll out 3G networks to rural areas.

0.3.2 Results

Exhibit 0.3 below shows the forecast utilisation and additional spectrum requirements by band for the medium scenario.

Band	Bandwidth (both up and down links)	Region	Utilisation (given current spectrum)				Additional spectrum required (MHz)			
			Today	2010	2015	2025	Today	2010	2015	2025
1.4GHz	50	London	22%	41%	56%	131%	0	0	0	27
1.4GHz	50	Urban	13%	22%	28%	56%	0	0	0	0
1.4GHz	50	Rural	11%	18%	25%	52%	0	0	0	0
4GHz	360	London	18%	18%	18%	18%	0	0	0	0
4GHz	360	Urban	56%	56%	56%	56%	0	0	0	0
4GHz	360	Rural	17%	17%	17%	18%	0	0	0	0
6GHz lower	485	London	32%	32%	32%	32%	0	0	0	0
6GHz lower	485	Urban	15%	16%	16%	16%	0	0	0	0
6GHz lower	485	Rural	10%	10%	10%	11%	0	0	0	0
6GHz upper	670	London	0%	0%	0%	0%	0	0	0	0
6GHz upper	670	Urban	7%	7%	8%	8%	0	0	0	0
6GHz upper	670	Rural	13%	13%	13%	14%	0	0	0	0
7.5GHz	454	London	78%	99%	97%	117%	0	76	62	172
7.5GHz	454	Urban	38%	53%	56%	81%	0	0	0	0
7.5GHz	454	Rural	11%	20%	23%	42%	0	0	0	0
13GHz	362	London	70%	93%	94%	124%	0	34	40	168
13GHz	362	Urban	66%	90%	92%	123%	0	20	28	162
13GHz	362	Rural	16%	31%	34%	66%	0	0	0	0
15GHz	240	London	67%	75%	80%	95%	0	0	0	27
15GHz	240	Urban	34%	55%	58%	94%	0	0	0	25
15GHz	240	Rural	7%	13%	15%	32%	0	0	0	0

Exhibit 0.3: *Forecast additional spectrum demand by band and region – medium scenario [Source: Analysys, Mason, 2005]*

0.3.3 Conclusions

We expect that, over the next 20 years, the growth in terrestrial fixed-links will be primarily driven by cellular operators. The majority of this growth will occur in bands above 15GHz, but some growth will occur in sub-15GHz bands.

Overall, under our medium scenario assumptions we expect that demand for fixed-link spectrum sub-15GHz in London (the area of highest demand) will rise from a total of 1170MHz in 2004 to 1440MHz in 2015, then to 1760MHz by 2025.

The current capacity for fixed-links sub-15GHz is 2620MHz (excluding the 11GHz and 14GHz bands), suggesting that there is sufficient capacity to cope with demand. However, demand is not uniform across the bands. The 7.5GHz, 13GHz and 15GHz bands are currently nearer capacity than the lower bands, and we expect the current trend towards use of higher bands to continue in the future. As a result, we expect in the medium scenario the 7.5GHz and the 13GHz bands to run out of capacity in London/urban areas before 2010;

and the 1.4GHz and 15GHz bands are projected to run out of capacity in London/urban areas by 2025. If further spectrum is not made available for these bands, we anticipate that increased demand will be placed upon the bands above 15GHz, and we already expect that these bands will experience significant growth in demand over the next 20 years.

0.4 Broadband wireless access services

0.4.1 Introduction

Our assessment focuses on long-range, high-power broadband wireless access (BWA) services since the spectrum requirement for short-range, low power services will be modest as frequencies can be repeatedly reused over short distances.

There is considerable uncertainty over whether BWA can compete with DSL and cable modems. Historically, operators deploying wireless local loop (WLL) technologies have failed to compete with incumbent operators as a result of high customer premises equipment (CPE) costs, technical performance issues and insufficient subscriber density to recover capital expenditure and operating costs. WiMAX could potentially result in considerable reductions in CPE costs, however, it is still far from clear whether WiMAX and subsequent technologies will be able to compete against wireline technologies such as DSL and fibre, where these are available.

We have therefore developed two scenarios which reflect the potential range of developments in the market, as described in the section below.

0.4.2 Results

Exhibit 0.4 below presents the scenarios modelled and the results of our assessment.

Scenario	*Description*	*Total urban spectrum demand (MHz)*	*Total rural spectrum demand (MHz)*
1	**Widespread deployment of BWA** – here we assume that a paradigm shift does occur in that BWA is a viable competitor to DSL and cable modem services and deployment of BWA services therefore occurs in both urban and rural areas	1800 (by 2015) 2800 (by 2025)	1000 (by 2015) 1700 (by 2025)
2	**BWA** limited to rural broadband coverage fill-in – under this scenario the underlying economics of BWA continue to be difficult and BWA deployment is therefore limited to providing DSL services in rural areas where a high-speed wireline service is not available – there will also be some BWA deployment in localised urban areas	Similar requirement to rural in localised areas	550 (by 2015) 850 (by 2025)

Exhibit 0.4: *Assessment of total future demand for BWA spectrum [Source: Analysys, Mason, 2005]*

0.4.3 Conclusions

Our projections indicate that for Scenario 1, a total of 1800MHz of spectrum for BWA services could be required in urban areas by 2015. If bandwidth growth trends continue, this requirement could grow to a total of 2800MHz by 2025. Under this scenario, the spectrum requirement in rural areas could be a total of 1000MHz in 2015. In view of the asymmetric nature of services, if technologies using unpaired spectrum (e.g. TDD) can be utilised, the spectrum requirement in urban areas could reduce to a total of 1200MHz in 2015. Shortages of spectrum in the 2–4GHz range will mean that higher frequency bands (e.g. 10GHz, 28GHz) will need to be used, particularly in urban areas.

In Scenario 2, the spectrum requirement in rural areas in 2015 is likely to be around a total of 550MHz. Under this scenario, we expect that there will also be certain localised deployments of BWA in various urban areas, and therefore it would be appropriate to allow for a similar spectrum requirement (total of 550MHz) in these areas.

These projections should be compared with the spectrum currently available for high-power, long-range fixed wireless applications. We estimate this to be around 333MHz.[4]

0.5 Satellite services

0.5.1 Introduction

Satellite services can be divided into three categories:

- Mobile satellite services (MSS), which provide a range of services to mobile users on land, at sea or in the air. A number of global and regional MSS systems have been deployed including Inmarsat, Iridium, Globalstar and Thuraya. We have modelled future growth in demand for spectrum by considering current spectrum shortages and future system deployments.

- Broadcast satellite services (BSS), used for the transmission of satellite broadcasting services such as Sky. We have modelled future growth in the number of television channels and the migration to high-definition television (HDTV) as this will drive future demand for transponder capacity and hence demand for spectrum.

- Fixed satellite service (FSS), which includes a variety of uses including VSATs for corporate connectivity and satellite feeder links. We have projected future growth in transponder use; the potential future growth in the number of VSATs and individual bandwidth required per link; and growth in mobile applications being supported by FSS, e.g. for long-haul aircraft, passenger ships and inter-city trains

There are considerable uncertainties associated with all three of the above services and we have therefore developed a number of scenarios for each service, as described in the following section.

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4 This estimate is based on 40MHz of spectrum currently used by UK Broadband, 168MHz of spectrum licensed to Pipex and 125MHz in the 5.8GHz band.

0.5.2 Results

Exhibit 0.5 below summarises the scenarios modelled and the results of our assessment.

Service	*Description*	*Total spectrum demand in 2015 (MHz)*	*Total spectrum demand in 2025 (MHz)*
MSS	Low – steady growth	120	230
	Medium – two new hybrid MSS systems	320	350
	High – as medium plus another new MSS system	380	440
BSS	Low – 2% p.a. growth in number of channels until 2010. 10% of channels on HDTV in 2015	1770	1960
	Medium - 10% p.a. growth in number of channels until 2010. 10% of channels on HDTV in 2015	2570	2840
	High – 10% p.a. growth in number of channels until 2010. 20% of channels on HDTV in 2015	3270	3610
FSS	Low – low transponder growth and no major new VSAT deployments; 25% of long-haul aircraft deploy mobile FSS solutions[5]	3840	4340
	Medium – 10 000 VSATS in 2012 and doubling of bandwidth per link; 50% of long-haul aircraft deploy mobile FSS solutions	4180	5190
	High – 10 000 VSATS in 2012 and trebling of bandwidth per link; 100% of long-haul aircraft deploy mobile FSS solutions	4540	6200

Exhibit 0.5: *Satellite scenario results [Source: Analysys, Mason, 2005]*

0.5.3 Conclusions

The MSS market is subject to significant uncertainty surrounding the future of existing systems and the possible launch of new ones. The results of our modelling suggest that, even in the most optimistic scenario, total MSS spectrum requirements in the long term

5 We also have incorporated passenger ships and inter-city trains although their contribution to the mobile FSS spectrum requirement is lower.

will be below a total of 500MHz. We are not convinced that there will be sufficient end-user demand to warrant the deployment of the new satellite systems included in our most aggressive scenario. Our least aggressive scenario is a more likely outcome, suggesting a total of 227MHz of spectrum would be required for MSS in 2025.

Our results for BSS suggest that the rapid growth in the number of satellite television channels (and, to a lesser extent, the move to dual HDTV/standard television broadcasting) could result in significant increases in demand for additional spectrum. Demand could increase from around the 1400MHz currently in use to a total of around 3600MHz by 2025 under our most aggressive scenario. However, in practice the deployment of new satellites in new orbital slots is likely to be a more appropriate means of providing additional BSS capacity, given constraints on spectrum availability.

Demand for FSS services is likely to lead to a requirement for additional spectrum in the longer-term, although the extent of this depends very much on the large-scale deployment of VSAT terminals, increases in average bandwidth per terminal, and spectrum re-use assumptions. We forecast that around 3400MHz of spectrum is used at present and under our most aggressive scenario this would rise to a total of 6200MHz by 2025. However, as for MSS, we are not convinced that there is sufficient end-user demand and therefore our least aggressive scenario is most likely to occur in practice. This suggests that there will be a modest growth in spectrum demand for FSS to a total of around 3850MHz by 2015 and to a total of around 4350MHz by 2025.

0.6 Terrestrial television broadcasting services

0.6.1 Introduction

Our analysis of the broadcast sector has focused on television as the major user of terrestrial broadcast spectrum (368MHz of spectrum in Bands IV/V). A major digital switchover (DSO) project is already underway within the UK for the roll out of a new digital terrestrial television (DTT) network and the shutdown of the analogue television network, which will determine the spectrum for fixed terrestrial television until around 2012.

We have assessed the likely range of future demand for spectrum for broadcast services by considering the possible increases in the number of terrestrial (standard definition) digital television programme channels available, as well as the possible introduction of new television services such as HDTV and mobile television.

0.6.2 Results

Fixed terrestrial television (e.g. traditional fixed or portable television receiving equipment)

Scenario	*Description*	*Total spectrum demand (MHz)*
1	This is the most aggressive scenario in which DTT becomes the dominant multi-channel platform of choice. There is an increase in the number of commercial SDTV channels that are available on the DTT platform as well as a widespread terrestrial HDTV implementation with most of the core DTT platform television channels also being available in HD format	632 (by 2015) 648 (by 2025)
2	This is a medium spectrum demand scenario where more commercial channels become available on the DTT platform and there is a limited terrestrial HDTV deployment	408 (by 2015) 416 (by 2025)
3	This assumes limited terrestrial HDTV deployment but that no new commercial SDTV channels are launched on the DTT platform	368 (by 2015) 368 (by 2025)
4	This scenario assumes that the DTT platform continues to operate but it is not developed any further. No new SDTV commercial channels are available on the DTT platform and HDTV is only available on other platforms	256 (by 2015) 256 (by 2025)

Exhibit 0.6: *Terrestrial television scenarios [Source: Analysys, Mason, 2005]*

Mobile television

There is currently a great deal of interest in mobile television, with a number of different technologies being proposed. Mobile television is still in its infancy in the UK and the eventual level of take-up and delivery platforms is not yet clear.

Scenario	*Description*	*Total spectrum demand (MHz)*	*Comment*
1	High spectrum demand scenario – Two DVB-H networks and two DMB networks are deployed by service providers[6]	74 (by 2015) 74 (by 2025)	Local content on three multi-frequency networks and national content on the other (single frequency) network
2	Low spectrum demand scenario – A single DVB-H network and a single DMB network are implemented	9.5 (by 2015) 9.5 (by 2025)	These are modelled as single frequency networks[7] with national content

Exhibit 0.7: *Mobile television scenarios [Source: Analysys, Mason, 2005]*

0.6.3 Conclusions

In the short to medium term, the DSO project will determine the spectrum demand for terrestrial fixed television broadcasting up to 2012. In the longer term, the spectrum demand for terrestrial television will largely depend upon whether there is significant demand for additional commercial channels and HDTV over the terrestrial platform. Our projections suggest that the total spectrum demand for fixed terrestrial television ranges from 256–648MHz, compared with the existing Bands IV/V allocation of 368MHz.

6 In practice, the economics of service provision may mean that the additional spectrum is used to broadcast additional programming (channels) rather than for a higher number of competing networks.

7 Potential service providers may prefer to deploy multi-frequency networks for mobile television, as these are apparently considerably less costly to deploy and operate. If this is the case, spectrum demand for mobile television services will be higher than modelled under this scenario but less than the demand forecast in Scenario 1. We have not explicitly modelled the deployment of two multi-frequency mobile television networks as an alternative scenario, since the total spectrum demand for mobile television is modest in comparison with fixed terrestrial television – and therefore is not critical to the overall study findings.

Mobile television is still in its infancy, with a number of potential technologies and delivery platforms, and at this stage its future market is still very uncertain. Our projections suggest that the total spectrum demand ranges from 9.5–66MHz in total.

Please note that we have not undertaken a detailed analysis of either end-user demand for these services or the underlying economics of each service in respect of its commercial viability. The actual demand for spectrum may therefore be limited by such factors.

Shortages of spectrum below 1GHz may mean that the expansion of terrestrial broadcasting services (including the introduction of mobile television) may need to be undertaken at higher frequencies – e.g. in the 1–2GHz range. The additional costs of using such frequencies to cover a given area in relation to Bands IV/V are considerable. As a result, this may restrict the coverage areas where services can be provided on an economic basis. In turn, this could cause increased migration to alternative delivery platforms (e.g. satellite).

0.7 Macro scenarios

0.7.1 Introduction

We have developed three macro scenarios that combine the scenario forecasts in each of the five services: an ‘economic-downturn’ scenario, a ‘base case’ scenario, and a ‘data-takes-off’ scenario. A brief overview of these scenarios is given in Exhibit 0.8 below.

	"Economic downturn"	*"Base case"*	*"Data takes off"*
Rationale	In this scenario we have considered the impact of an economic downturn on spectrum demand	The base case represents the most likely development of spectrum demand in the future	This scenario assumes an aggressive take-up of wireless data services and new TV services
Description	A downturn in spending inhibits the take-up of all services: • Modest growth in cellular 3G services • Cellular operators do not switch from leased lines to fixed links • BWA fails in urban areas • Weak demand for MSS • There is little demand for additional SDTV and HDTV channels (both terrestrial and satellite) • Moderate FSS growth through mobile FSS solutions, no new VSATs deployed • Mobile TV demand will be weak	This scenario assumes that: • Modest growth in cellular 3G services • Vodafone and O2 switch from leased lines to fixed links • BWA fails in urban areas • Weak demand for MSS • There is limited demand for additional DTT and HDTV on terrestrial but stronger demand on satellite • Moderate FSS growth through mobile FSS solutions, no new VSATs deployed • Mobile TV demand will be relatively strong	This aggressive scenario assumes: • Wireless data takes off, both in terms of cellular 3G services and broadband wireless access • All cellular operators use fixed links for majority of backhaul • Strong demand for MSS • There is strong demand for additional DTT and HDTV (both terrestrial and satellite) • Strong FSS growth through mobile FSS solutions, 14,000 new VSATs deployed by 2025 • Mobile TV demand will be relatively strong

Exhibit 0.8: *Overview of the three macro scenarios [Source: Analysys, Mason, 2005]*

0.7.2 Results

Our base case scenario forecasts that the five services modelled (cellular, terrestrial fixed-links, BWA, satellite and terrestrial television) will demand a total of 10.2GHz of spectrum below 15GHz and that demand will exceed the current 7.7GHz available for these services by 2011.

Exhibit 0.9 shows the breakdown of spectrum demand for the base case in urban regions by service. The demand for spectrum in rural areas is slightly lower than in urban areas.

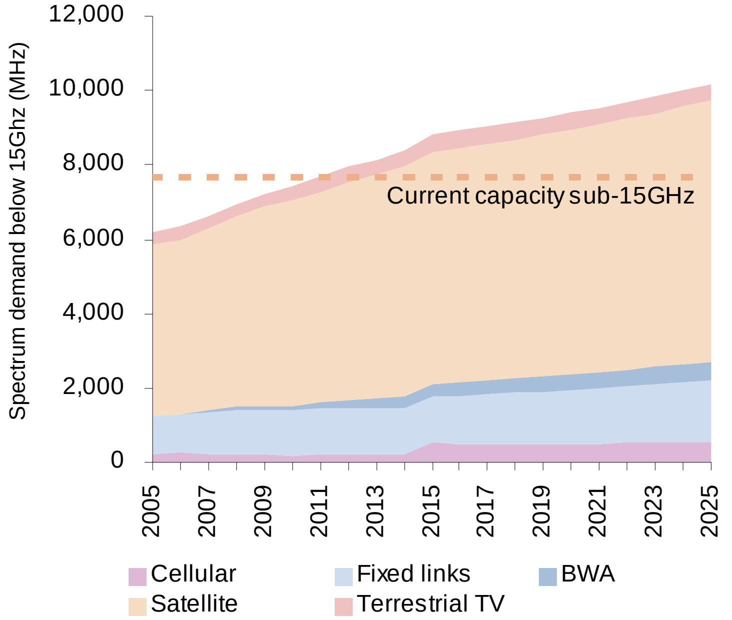

Exhibit 0.9: *Total spectrum demand breakdown – urban base case [Source: Analysys, Mason, 2005]*

Exhibit 0.10 shows the spectrum-demand results for the three scenarios for urban areas. In our most aggressive scenario ('data takes off'), total spectrum demand rises to over 15GHz in urban areas, whilst in our most conservative scenario ('economic downturn') total spectrum demand is below 9GHz.

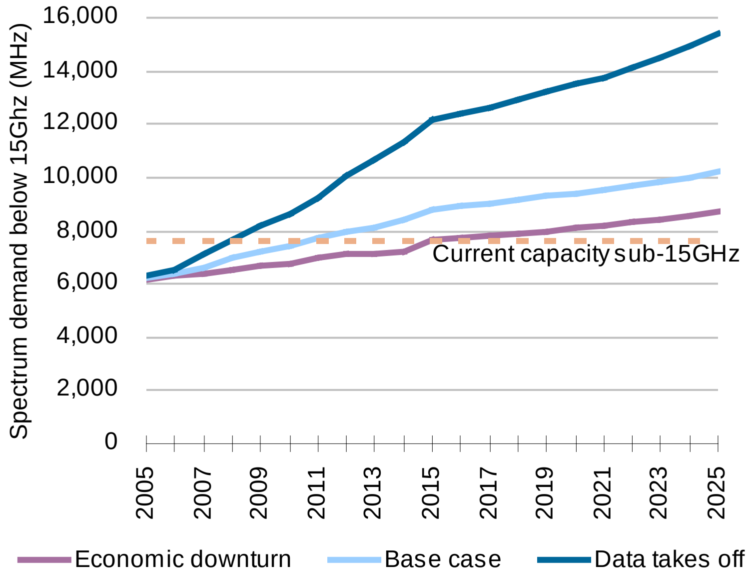

Exhibit 0.10: *Total urban spectrum demand forecast [Source: Analysys, Mason, 2005]*

Under all scenarios, the highest absolute levels of increased demand are for spectrum for satellite services. In particular, we project considerable additional demand for BSS spectrum in all our scenarios. In practice, the shortage of available spectrum may mean that the deployment of additional satellites in different orbital slots is a more viable solution for increasing BSS transponder capacity rather than the use of additional spectrum.

0.7.3 Conclusions

There is considerable demand for additional spectrum below 15GHz to support commercial services. Our 'base case' suggests around an additional 2.5GHz of spectrum could be required by 2025. Spectrum shortages are likely to be a constraint which could prevent the future optimal deployment and growth of a wide variety of services.

As expected, demand for additional spectrum in urban areas is considerably greater than demand for additional spectrum in rural areas (for many services, current rural spectrum allocations are likely to be sufficient through to 2025). One possibility, therefore, is for the IASH team to continue to explore the scope for government users releasing spectrum for use in the most-congested urban areas, whilst retaining use of the spectrum for government use in rural areas.

The nature of demand for spectrum also varies by frequency band, as discussed in Exhibit 0.11 below.

Frequency range	*Demand for additional spectrum*
0–1GHz	Spectrum in this range is in very high demand in view of the propagation characteristics – signals travel further, therefore reducing the cost of covering a given area. However, the low frequencies do mean that bandwidth in this band is limited – so it is less suited to services requiring a wide channel width. Furthermore, applications using this frequency range (broadcasting, mobile including cellular and private mobile radio) are among the uses of spectrum generating the greatest economic value Our study suggests that there may be high demand for additional spectrum for terrestrial broadcasting services. Additionally, although our overall projections for future demand for cellular spectrum are modest, there is likely to be high demand for spectrum below 1GHz in order to cover less populated areas is a more cost-effective manner Exploration of any potential means for releasing new spectrum in this range for commercial use should be prioritised
1–3GHz	Spectrum in the 1–3GHz range is increasingly being used as 'second choice' spectrum for applications such as cellular (and possibly terrestrial broadcasting in the future), due to shortages in the availability of spectrum below 1GHz. Additionally, the spectrum in this range also supports wider channel widths – and is therefore of use for the deployment of services such as BWA which need sufficient spectrum to provide acceptable end-user data rates In view of the shortage of spectrum below 1GHz, we expect to see moderate demand for additional spectrum in the 1–3GHz range to support commercial services such as cellular, BWA and possibly terrestrial broadcasting
3–6GHz	Demand for spectrum in this frequency range is likely to increase if BWA services are highly successful and/or if mobile cellular technologies can be developed which work in this frequency range (we understand that the CEPT is currently seeking to identify spectrum in this range for next-generation cellular systems)
6–15GHz	The highest absolute levels of additional demand for spectrum identified in our study are for applications within this frequency range including fixed satellite services, broadcast satellite services and specific fixed-link bands. Furthermore, there could be high demand from BWA services in urban areas if BWA is able to compete with wireline solutions as an acceptable means of providing broadband services In view of the high levels of demand for spectrum in this range, we recommend this should be among the priority areas for further research. However, future assessments should consider that alternative solutions might be possible for potential users in this band, e.g. the use of additional orbital slots as a means of creating additional BSS capacity in place of the use of additional spectrum

Exhibit 0.11: *Summary of future demand for spectrum below 15GHz [Source: Analysys, Mason, 2005]*

Finally, in addition to the overview and limitations of our approach that we presented at the start of this report, we would like to highlight a few further areas in relation to the importance of the correct interpretation of the findings of the study.

No consideration of economic value derived from use of the spectrum

The study has focused on assessing the potential future demand for spectrum without considering the economic value derived from its use by individual services. Care should therefore be exercised when interpreting the findings – for example, whilst our study suggests that the greatest demand for additional spectrum arises in higher frequency bands to support terrestrial fixed-links and satellite services, demand for spectrum below 1GHz typically comes from services (e.g. terrestrial broadcasting, cellular communications) that have historically generated the largest economic benefits.

Limitations of forecasting 20 years ahead

Our assessment of spectrum demand has obviously been based on our current understanding of prospective future developments. In view of the long duration of our forecasts (20 years), it should of course be remembered that fundamental changes may occur which change the nature of spectrum demand and supply. By their nature, it is impossible to predict what form these may take and what their impact could be – if this were possible, these could be factored into our analysis. An example of such a change which would not have been possible to predict in 1985 (20 years ago), for example, was the advent of the Internet and its implications for demand for spectrum to support wireless data communications services.

Interdependence of spectrum demand between services

There are various interdependencies between our forecasts for future spectrum demand for individual services, for example:

- increases in demand for one service may lead to an increase in demand for another (complementary) service – e.g. increase in usage of data on 3G networks will result in an increased demand for fixed-link spectrum for the backhaul connections from base stations on 3G networks as well as increasing demand for cellular spectrum
- increases in demand for a service may lead to a reduction in demand for another (substitute) service – e.g. strong take-up of satellite television may lead to less demand for additional spectrum for digital terrestrial television.

Care should therefore be exercised when aggregating the demand for spectrum for the individual services. We have sought to take account of the major linkages between services as part of our macro-scenario analysis, so these can be regarded as providing the best aggregate view of the future demand for spectrum.

Demand for spectrum may be artificially constrained by current availability

The underlying demand for spectrum from non-government users and uses that we have identified in this report may be artificially constrained by the current availability (or rather scarcity) of spectrum. Our assessment of individual services has identified several examples of cases where behaviour has been influenced by potential shortages of spectrum, for example:

- the prices paid for mobile and other spectrum (e.g. European 3G spectrum auctions) undoubtedly reflect spectrum scarcity and the need for access to specific radio spectrum bands in order to provide a high-value service
- fixed-link users automatically expect to migrate to higher frequencies in order to obtain high channels widths, even where use of lower frequencies would be preferred due to the additional range this would provide
- many service providers (e.g. terrestrial and satellite broadcasters) provide subscribers with user equipment designed to work in certain frequency ranges on the expectation that they are unlikely to be able to make use of other spectrum bands.

It is possible that, if spectrum availability changed, additional innovations using radio communications services could be developed using spectrum which is not currently available – which in turn could lead to further demand for spectrum.

1 Introduction

This document has been prepared by Analysys Consulting Limited (Analysys) and Mason Communications Limited (Mason) as part of a spectrum demand study for the Independent Audit of Spectrum Holdings (IASH) team.

This report is the main deliverable of the study and, in addition to presenting the results of our work, it also details the approach and methodologies used. This final version of the report takes account of feedback received from both the IASH team and Ofcom staff, although the analysis presented here is the work of Analysys and Mason alone.

1.1 Background to Independent Audit of Spectrum Holdings

The Chancellor announced in his December 2004 Pre-Budget Report that Professor Martin Cave would conduct an Independent Audit of Spectrum Holdings (IASH), to examine the efficiency of use of current holdings and ways of improving this. The terms of reference for the audit and the audit's consultation document can be found at www.spectrumaudit.org.uk.

The public sector is the single biggest user of UK radio spectrum, with many holdings dating back to a time of limited demand and relatively unsophisticated technologies. One aspect of the IASH's work will be to determine the scope for increased commercial access to this spectrum. It builds on the principles set out in Martin Cave's 2002 Review of Radio Spectrum Management, which set out the rationale for allocating the spectrum through market processes but did not examine specific spectrum allocations in any detail. As a result of the 2002 Review, Ofcom is currently implementing spectrum trading and liberalisation for private sector spectrum to increase efficiency and innovation – we have not identified any reasons why this should not continue during the course of this study.

The IASH will examine the impact of these changes on the public sector, looking mainly at frequencies below 15GHZ.

In order to inform the audit's recommendations in assessing current usage of this spectrum, likely pressure for commercial access to this spectrum and how current public sector use might be made more efficient, this study has been requested by the IASH team in order to obtain a high-level view of likely levels of future demand from the commercial sector for spectrum below 15GHz.

1.2 Objectives and approach

Study objective

The principal objective of the study was to forecast the future demand for radio spectrum in the UK for commercial service (i.e. non-government) use within the frequency range 0–15GHz. Demand forecasts were to be developed for the next 20 years (2005–2025), but with a particular focus on the next 10 years (2005–2015). The study will complement the IASH's own work in assessing future demand for spectrum to meet the needs of the public sector.

The objectives of the study and the timescale available mean that we have taken a high-level assessment of future demand for the spectrum. In particular, our assessment has focused on the major users/uses of the spectrum with the intention of accounting for at least 80% of current commercial use of spectrum in frequencies below 15GHz. This will enable the IASH team to determine the relative level of demand from the commercial sector for any spectrum that could be freed by existing government users.

Study approach and scope

The services covered in the study are:

- cellular
- fixed-links
- broadband wireless access (BWA)
- satellite (fixed, mobile and broadcasting)
- terrestrial television broadcasting.

Following discussions with the IASH team, the following services were explicitly excluded from the scope of work:

- private mobile radio (PMR)
- emergency services
- audio broadcasting (including DAB).

The study also excludes several other non-government services including programme making and special events (PMSE) and aeronautical and maritime services.

Our principal approach to the assessment involved the identification of the principal underlying driver of future spectrum demand for each of the services under investigation (e.g. cellular network traffic, number and bandwidth of fixed-links or wireless broadband subscribers and bandwidth requirements, number of television channels and resolution and future satellite system deployments) and the development of projections for this driver. These future service/traffic/subscriber/bandwidth projections were then converted into demand for spectrum, taking account of potential future improvements in the spectral efficiency of the technologies supporting the delivery of individual services.

In particular, it should be appreciated that forecasts for individual services have been produced based only on the level of analysis necessary to support the generation of forecasts of overall demand for spectrum. Where these analyses make assumptions about future technology and market developments, it should be understood that such assumptions have been made to provide a tangible basis for the development of such forecasts; the use of any particular assumption should not be taken to imply that alternative developments are not equally likely, or that Analysys and Mason consider the assumed development to be the most likely.

The exact methodology and approach used was specific to each service and is therefore described in further detail in the relevant sections of this report.

There were nonetheless several common elements to our approach for each of the services. In particular, we undertook a series of interviews with key Ofcom and industry personnel in each area, from which we gained valuable insight. Our approach also included extensive research of existing secondary forecasts.

Use of scenarios and modelling assumptions

Spectrum demand projections are subject to a wide range of assumptions, particularly in respect of future take-up and usage levels of individual services. We have therefore developed a series of scenarios for each of the modelled services. These scenarios aim to highlight the potential impact of variations in those assumptions to which our demand forecast is most subjective. We present an overview of each of the modelled scenarios for each service in the relevant section of this report.

Within the scope and time available for this study, we have not been able to model variations of all of the key parameters associated with the future demand for spectrum for each service. For example, in the case of cellular, we have made specific assumptions about the future of 2G networks and the deployment of HSDPA and 'systems beyond IMT-2000'. These assumptions have been made for modelling purposes and are not meant to preclude other possible outcomes (e.g. the deployment of a mobile version of WiMAX) as an alternative means of meeting demand.

Our study findings should therefore be interpreted in this light – in particular, this study is not a substitute for a comprehensive analysis of the specific issues associated with individual services.

Price of spectrum

For many of the proposed services, there is a trade-off between the use of additional spectrum and alternative options (e.g. deployment of additional transmitter sites). This trade-off depends on the availability and price of radio spectrum. We have therefore needed to make assumptions about the future pricing of spectrum to underlie our demand forecasts. For the purposes of this study, we have generally assumed that the prices/regime for payment of spectrum is comparable to the fees/environment currently in place for each individual service.

For our modelling of future demand for cellular services, we have developed an operator cost model which can be used to assess the trade-off between the use of additional spectrum and the costs that would otherwise be incurred (additional capital and operating expenditures associated with the deployment of additional base station sites). For modelling purposes, we have had to make a specific assumption about where this trade-off lies, i.e. in relation to the future price of spectrum. We present our assumptions below in the cellular section and note that if spectrum prices are in higher or lower than our assumption, then future demand for spectrum will be respectively lower or higher than we have forecast.

Demand for spectrum versus end-user demand

Our approach focuses on quantifying the future demand for spectrum and, in the case of certain services (terrestrial television broadcasting and satellite services), we have focused on modelling potential future demand from users of the spectrum (e.g. broadcasters, satellite operators) rather than underlying end-user demand for downstream services.

For example, our assessment of future demand for mobile satellite spectrum is based on an assessment of demand from potential mobile satellite system operators. It is by no means certain whether there is sufficient end-user demand to warrant the deployment of all of the proposed competing systems. However, following discussions with the IASH team, our approach has been to quantify the demand from all these potential service providers in order to let the market determine the number of competing providers, rather than availability of spectrum being the determinant.

Likewise, in the case of terrestrial television broadcasting, we have not quantified end-user interest/take-up in new services (e.g. high definition television, mobile television) nor have we validated whether such services can be offered on an economic basis. This should be considered when interpreting our demand forecasts.

Development of 'macro scenarios'

We have developed three 'macro scenarios' that combine each of the service forecasts in order to take account of the principal linkages and interdependencies between the individual services. Further details of these scenarios are also presented below.

1.3 Structure of document

The remainder of this document is structured as follows:

- *Section 2* describes our main research, demand modelling methodology and findings for cellular services
- *Section 3* outlines our main research, demand modelling methodology and findings for terrestrial fixed-link services
- *Section 4* summarises our main research, demand modelling methodology and findings for BWA services
- *Section 5* details our main research, demand modelling methodology and findings for satellite services (split into mobile satellite, broadcast satellite and satellite fixed-links)
- *Section 6* presents our main research, demand modelling methodology and findings for terrestrial television broadcasting services
- *Section 7* describes a number of macro scenarios, which combine the individual service forecasts to provide overall future-demand scenarios
- *Section 8* presents the overall conclusions from the study.

In addition, this document contains a number of supporting annexes:

- *Annex A* presents further details of the methodology, reasoning and assumptions for cellular services
- *Annex B* contains additional details of the methodology, reasoning and assumptions for terrestrial fixed-link services
- *Annex C* includes further details of the methodology, reasoning and assumptions for BWA services
- *Annex D* outlines further details of the methodology, reasoning and assumptions for satellite services
- *Annex E* provides further details of the methodology, reasoning and assumptions for terrestrial television services.

2 Cellular services

2.1 Introduction

The UK cellular market is moving from 2G networks and services towards 3G. At this early stage in the 3G life cycle, the full service portfolio remains unclear, and is likely to do so for a period of time until operators have passed the initial launch period and trends are more developed. Therefore, it is currently difficult to gauge the take-up of 3G services and, as a result, there is a large amount of uncertainty about future traffic and spectrum demand:

> "The main problem at the moment is that we have no idea how the market will develop. It is simply too early to say. In a year or two, people will have a much better idea".[8]

In addition to the uncertainties over the growth in traffic, there is also uncertainty over how spectral efficiency will improve over time. Many cellular operators are likely to invest in the deployment of high-speed downlink packet access (HSDPA) and high-speed uplink packet access (HSUPA) technologies in the next few years. However, beyond that, further improvements are less well defined (e.g. MIMO, systems beyond IMT-2000, etc.). It is also possible that a range of alternative technologies (e.g. 802.16e-WiMAX, Flarion Flash OFDM, IP Wireless UMTS TDD) may be deployed to replace or supplement HSDPA and/or systems beyond IMT-2000.

It should be noted that our approach does not include a detailed assessment of the need for additional spectrum during any technology transition, to allow for parallel operation of the

8 UK cellular operator, June 2005.

old and the new technologies, nor does it explicitly consider the requirement for additional spectrum to support new entrants into the market.

2.2 Review of secondary research

There has been a proliferation of reports written and discussion about the future demand for cellular services. However, few of these forecast out beyond the next few years. The most significant report in recent years that does this is *Magic Mobile Future 2010-2020* by the UMTS Forum in April 2005. A brief summary outlining its findings is given below:

- Traffic will increase by a factor of 23 between 2012 and 2020, rising to 36.39MB busy-hour traffic per subscriber (from 1.58MB in 2012).
- In 2020 the split of mobile traffic will be 55% mobile data, 24% machine-to-machine traffic and 21% mobile voice.
- Internet access will be the main driver of this growth. In 2020, voice is overtaken in terms of volume (Tbytes) by mobile Internet/extranet access which generates the highest traffic volumes.
- Voice will stay the predominant service. In 2012, voice is still the first service category in terms of daily traffic volumes.
- Other service traffic will grow including: person-2-person communications (such as MMS) thanks to the migration of text based MMS to photo / video-based MMS; infotainment traffic will increase due to higher use per subscriber; and location-based services will grow thanks to both subscriber growth and the frequency of use growth.

There has also been much written about the development of IMT-2000 (3G) networks and capabilities and those of potential systems beyond IMT-2000. Recommendation ITU-R M.1645, written by the ITU in 2003, discusses the future development of these systems. Its finding are summarised below:

"Recommendation ITU-R M.1645"

- This recommendation defines the framework and objectives for future development of IMT-2000 and systems beyond IMT-2000.

- In the medium term (to 2010) this report forecasts incremental/evolutionary enhancements to the capabilities of IMT-2000. These enhancements could increase the peak aggregate useful data rate to ~30Mbit/s by 2005.

- In the longer term, the report forecasts the deployment of a new system beyond IMT-2000 around 2015, which will have capabilities significantly beyond those of IMT-2000. The report states that peak data rates could be as high as 100Mbit/s for high mobility and 1Gbit/s for nomadic/local wireless access.

- Evolutions in technologies, inter-working between frequency bands and different access systems, and the improvement in spectrum efficiency associated with these new systems may reduce the amount of additional spectrum needed.

In conclusion, there has been much written that is bullish about the future of cellular networks and usage going forward. Our belief is that some of these views are overly optimistic, but for the purposes of this study it is important for us to understand what the impact on spectrum might be if cellular traffic does take off as some are anticipating.

2.3 Methodology

We have focused our forecasts on spectrum demand for 3G (and potentially systems beyond IMT-2000). Current 2G spectrum is located in the 900MHz and 1800MHz bands. We do not expect operators to require additional spectrum to provide 2G services. This is due to operators gradually migrating subscribers and traffic onto their 3G networks.

2.3.1 Scenarios

There are numerous uncertainties associated with the evolution of the cellular market and the future evolution of the cellular market. We have therefore developed two scenarios (low traffic and high traffic), which reflect a possible range of outcomes. These are detailed below. However, it should be noted that we have not been able to model alternative forecasts for all of the potential uncertainties within the scope/time available for this study (e.g. range of 2G to 3G subscriber migration profiles, alternative options for future of 2G networks). We regard this simplification as being necessary for the purposes of this study; however, this means that the analysis presented in this section should not be regarded as a substitute for a more comprehensive assessment of the cellular sector.

Low traffic scenario

The low traffic scenario represents a less aggressive view of the likely development of future traffic demand. In particular, it assumes a gradual growth in data traffic carried over 3G networks as take-up and usage of new applications steadily increases.

The low traffic scenario also assumes:

- the implementation of HSDPA/HSUPA will begin in 2007
- the next system beyond IMT-2000 will be implemented from 2015 in urban areas and 2018 in rural areas
- the 2G network will be decommissioned as the new system beyond IMT-2000 is deployed.

High traffic scenario

The high traffic scenario assumes a high take-up of data services with considerable growth in traffic (data traffic is forecast to increase 100 fold between 2005 and 2015). As a result, it assumes that cellular network traffic becomes dominated by data services.

The high traffic scenario also assumes:

- the implementation of HSDPA/HSUPA implementation will begin in 2007
- the next system beyond IMT-2000 will be implemented from 2015 in urban areas and 2018 in rural areas

- a further improvement to this system will be deployed in 2020
- the 2G network will be decommissioned as the new system beyond IMT-2000 is deployed.

Exhibit 2.1 and Exhibit 2.2 below show the forecast voice and data traffic for each of these scenarios.

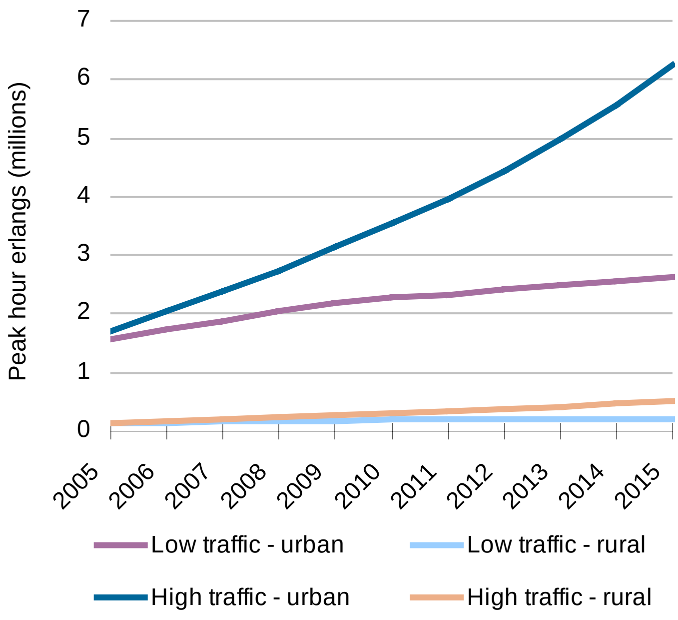

Exhibit 2.1:
Voice traffic forecasts [Source: Analysys, Mason, 2005]

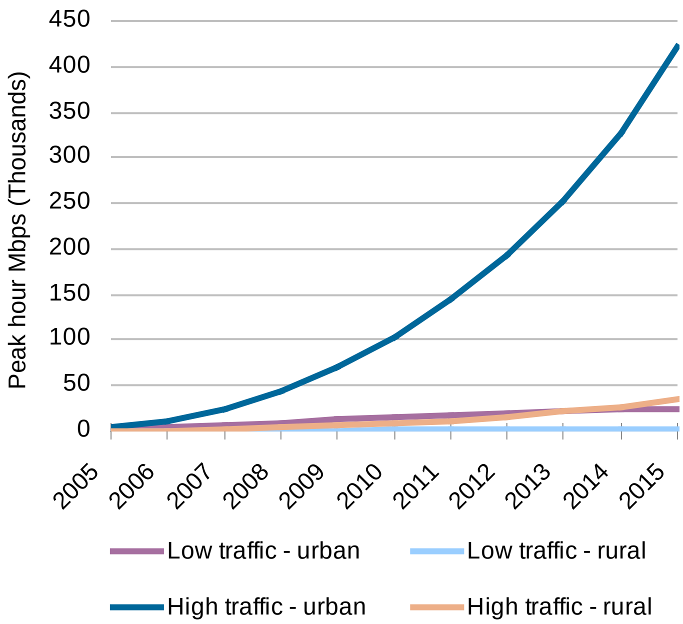

Exhibit 2.2:

Data traffic forecasts [Source: Analysys, Mason, 2005]

Although our scenarios focus on the deployment of UMTS/HSDPA and systems beyond IMT-2000, we do not preclude the deployment of alterative technologies (e.g. WiMAX) by mobile operators. Our expectation is that the technical capacity and spectral efficiency differences between such technologies is not likely to be as significant as the principal uncertainty regarding the future growth in demand for mobile data services, which has been modelled through the use of scenarios, as detailed above.

2.3.2 Comparison to *Magic Mobile Future 2010–2020* forecasts

Exhibit 2.3 below shows a comparison between the traffic forecast in our scenarios and the one forecast in the *Magic Mobile 2010–2020* report. In 2012, the traffic forecast in our high traffic scenario and in the Magic Mobile report are comparable. However, as you move further into the future, the Magic Mobile forecast becomes increasingly aggressive and by 2020 it is four times that of our high traffic scenario. In respect of this study, we feel that the Magic Mobile forecast is overly aggressive in the later years and that our high traffic scenario represents a more likely upper bound to future demand. Our low traffic scenario is significantly below both of the other two forecasts.

Forecast	*2012*	*2020*
Low traffic scenario	0.3	0.4
High traffic scenario	1.4	7.6
Magic Mobile forecast	1.6	36.4

Exhibit 2.3: *Busy-hour traffic per subscriber (MB) [Source: UMTS Forum, Analysys, Mason]*

2.3.3 Modelling overview

The analysis to forecast future spectrum demand for cellular services was undertaken at a high-level and as a result several simplifying assumptions have been made. These include:

- 2G spectrum is reused for 3G and other technologies at some point over the period modelled
- existing 2G networks are decommissioned once a new system beyond IMT-2000 is deployed.

Exhibit 2.4 below illustrates our approach to forecasting the future demand for spectrum for cellular services.

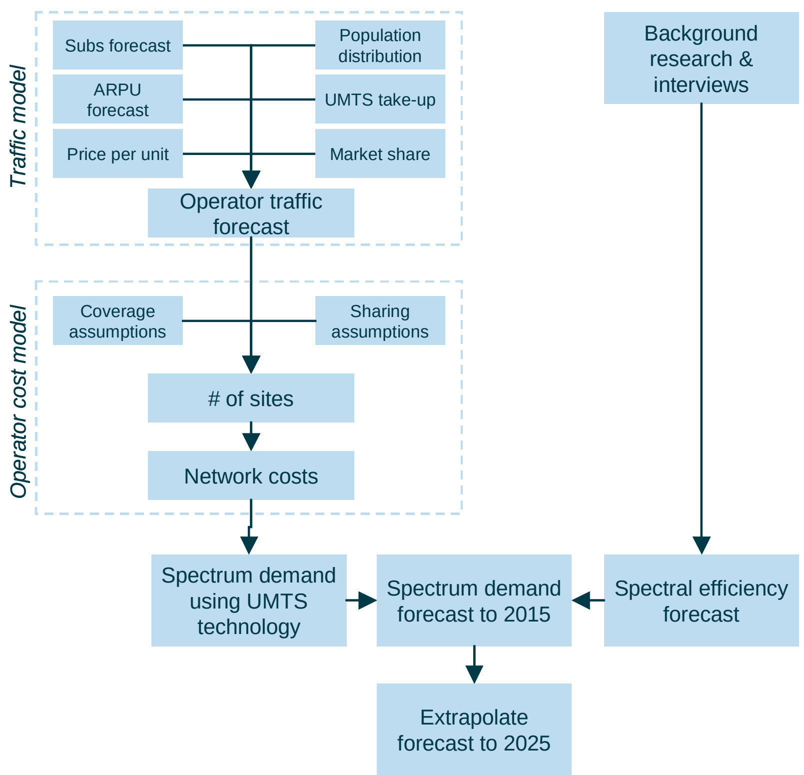

Exhibit 2.4: *Approach to forecasting spectrum demand for cellular services [Source: Analysys, Mason, 2005]*

The methodology for developing the cellular spectrum forecasts was a four-step process:

Forecasting spectrum demand given current technology

In order to forecast the spectrum demand for cellular services we have developed two models:

- **Traffic forecast model –** forecasts the traffic profile for a typical cellular operator by region (geotype regions) to 2015. It has the capability to produce profiles for different scenarios (e.g. high traffic scenario)
- **Cost model –** calculates the network requirements and costs (both capex and opex) for an operator for a given traffic profile and spectrum availability to 2015. The model assumes the use of current UMTS technology.

Further details of these models can be found in Annex A.

The primary driver for future spectrum demand will be potential cost savings that operators can make from acquiring additional spectrum.[9] Therefore, using the above two models we have calculated, for a given traffic forecast, the incremental saving that an operator can make from having additional 2 x 5MHz blocks of 3G spectrum. For the purposes of this study, we have assumed that if this saving were large enough (GBP5 million in any given year),[10] then the operator would wish to acquire an additional block of 2 x 5MHz spectrum.

Using this methodology we have forecast the demand that a typical operator will have for 3G spectrum, given current technologies and future spectral efficiency to 2015.

9 There are likely to be other drivers for spectrum acquisition by operators (e.g. for strategic purposes). However, we have assumed that cost saving is the primary driver.

10 Cellular operators face a trade-off between acquiring additional spectrum and additional capital/operating expenditure. To model future spectrum demand, we therefore need to make an assumption about the level of this trade-off – essentially what the price of spectrum will be in the future. We do not regard the 2000 auction prices as a suitable benchmark as these were influenced by market conditions at the time of the auction. We have selected GBP5 million per annum as the threshold as this is in the same ballpark as Ofcom’s current AIP-based price for 2G spectrum (approx GBP3 million per annum for 2x5MHz) and the 1996 NERA/Smith assessment of the marginal value of mobile spectrum (GBP8 million per annum for 2x5MHz). If the true price of spectrum is significantly higher/lower than this assumption, our forecasts could overstate/understate future demand for spectrum, respectively.

Our spectrum demand projections have been split between urban and rural demand. Exhibit 2.5 below shows our definition of 'urban' and 'rural' areas. They are based on an analysis of population density in individual postal districts and are the same areas as those used for our other spectrum forecasts (e.g. terrestrial fixed-links, BWA).

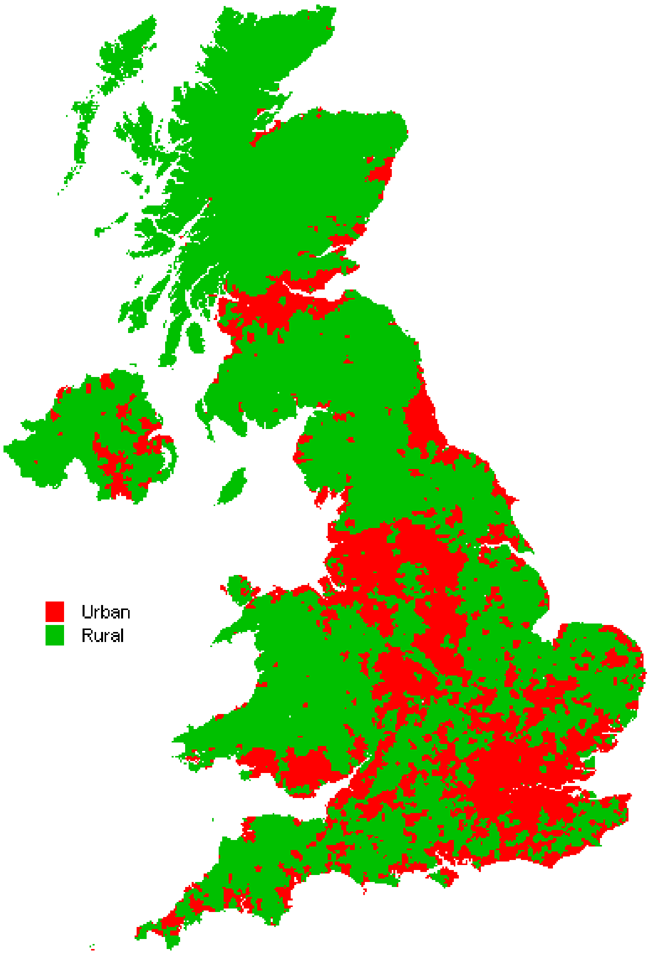

Exhibit 2.5: *Illustration of urban and rural areas for cellular assessment [Source: Analysys, Mason, 2005]*

Extrapolating the spectrum demand forecast to 2025

The spectrum demand forecasts given current spectral efficiency were then extrapolated for a further 10 years to 2025.

Forecasting spectral efficiency

Our forecasts assume current 3G spectral efficiency, however, they then overlay the following advances going forward:

HSDPA/HSUPA

Many of the cellular operators are in the process of developing and testing high-speed downlink packet access (HSDPA) and high-speed uplink packet access (HSUPA). We expect that it will be deployed in 2007.

We have assumed that HSDPA/HSUPA will improve data spectral efficiency by a factor of 1.5 compared to UMTS, but that there will be no improvement in voice spectral efficiency.

Systems beyond IMT-2000

We have assumed that the next generation of cellular network is launched by 2015 in urban areas. This is based on the historical time span between cellular network generations (of the order of 10 years).

However, we have assumed that this generation will not be deployed in rural areas until 2018. This is based on the expectation that 3G is likely to take two to three years from first launch to be rolled out to rural areas.

We forecast that this new system will give a 1.5 increase in data and voice spectral efficiency compared to HSDPA/HSUPA.

We forecast that each operator will require a minimum 2 x 30MHz of spectrum for the new system and that the 2G network will be switched off with the onset of the new system. We do not expect operators will wish to run three separate network technologies simultaneously – this is evidenced by the fact that the first generation analogue networks were decommissioned before 3G networks were launched.

Improvement to the system beyond IMT-2000

(high traffic scenario only)

We forecast that an improvement to the system beyond IMT-2000 will be deployed in 2020 for the high traffic scenario only. We have assumed that this is not deployed in our low traffic scenario due to low traffic growth.

We have assumed that this will improve spectral efficiency of data traffic by a factor of 1.5, but that there will be no improvement in voice spectral efficiency.

The spectral efficiency gains that we have forecast for the new system beyond IMT-2000 are conservative when compared to historical spectral efficiency gains between cellular generations. Exhibit 2.6 below shows the spectral efficiency gains for each generation advance.

Cellular generation advance	*Improvement in spectral efficiency*[11]
1G to 2G	7.0
2G to 3G	3.2
3G to "4G" forecast	1.8

Exhibit 2.6: *Spectral efficiency gains [Source: AEGIS, Analysys, Mason]*

Combining the forecasts

Finally, the spectrum demand forecast at current spectral efficiency was then combined with the spectral efficiency forecast to produce a spectrum demand forecast to 2025.

Comparison of spectrum demand forecasts with 'supply' of spectrum

In order to review our forecasts for future spectrum demand for cellular services, we have included the following spectrum in the 'supply' of spectrum:

11 Speech chain/MHz/sq km by generation was: TACS 1.82, GSM 12.66, UMTS 40.51. *[Source: AEGIS Spectrum Engineering]*

- 3G spectrum awarded during the 2000 auction (total of 140MHz)
- 3G expansion band spectrum (total of 190MHz) – although we note that Ofcom's intention that this award should be on a service and technology-neutral basis may mean that some of this spectrum could be used for services other than cellular
- current spectrum assigned to 2G operators (total of 210MHz) – noting that this spectrum could become available for use for other technologies (e.g. UMTS, systems beyond IMT-2000 and potentially other services) at some point in the future.

Please note the assumptions outlined above have been made for the purposes of this study, as it was not practical to model all future spectrum supply possibilities.

2.4 Results

Exhibit 2.7 and Exhibit 2.8 show the demand for cellular spectrum using current UMTS technology for the low traffic and high traffic scenarios. The main points of note are:

- in the urban low traffic scenario, spectrum demand initially falls as traffic migrates from 2G networks to the more spectrally efficient 3G networks. On the basis of our assumptions (involving a threshold of GBP5 million per annum of cost savings for an operator to demand more spectrum), no further spectrum is required before 2015, which is when the new system beyond IMT-2000 is deployed. There is then a step change in spectrum demand as 3G and the new system are run simultaneously. After 2015 there is a steady increase in demand for spectrum
- in the rural low traffic scenario, again no further spectrum is required on the basis of our assumptions before 2015, which is when the new system beyond IMT-2000 is deployed
- in the high traffic scenario, much more spectrum is required in urban areas (over 2.5GHz by 2020)
- in rural areas, demand will also increase to over 500MHz.

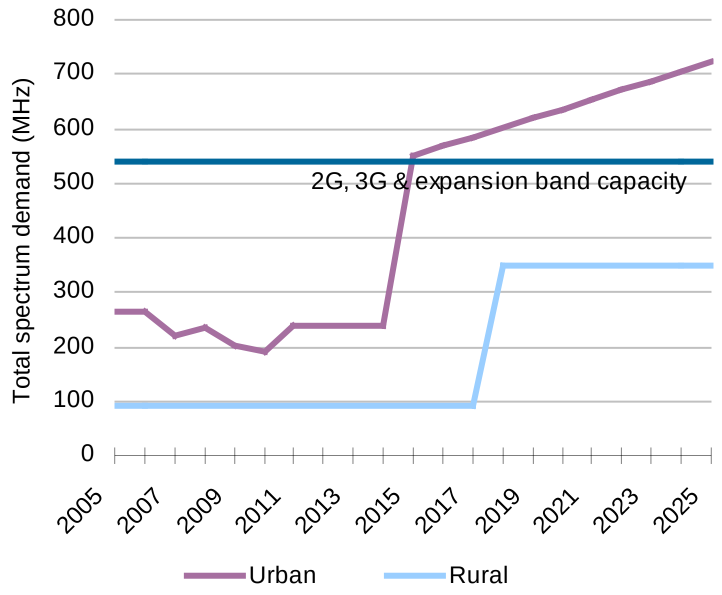

Exhibit 2.7: *Total spectrum demand using current technology – low traffic scenario [Source: Analysys, Mason, 2005]*

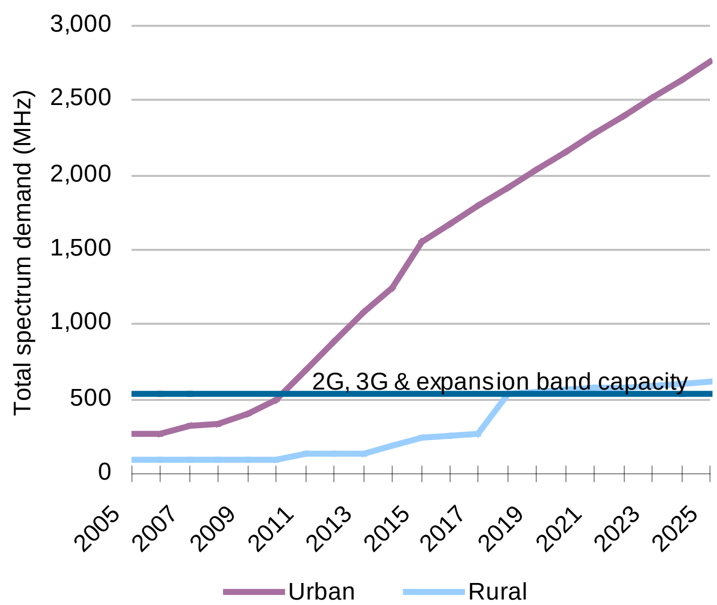

Exhibit 2.8: *Total spectrum demand using current technology – high traffic scenario [Source: Analysys, Mason, 2005]*

Once the forecast improvements in spectral efficiency from the deployment of new technologies are included, the forecast demand for spectrum falls. Exhibit 2.9 and Exhibit 2.10 below show the 3G spectrum demand for the low traffic and high traffic scenarios.

In the low traffic scenario, spectrum demand initially falls before there is a step change as the new system beyond IMT-2000 is introduced (in 2015 in urban areas and 2018 in rural areas). In urban areas, the demand then falls slightly as the new system beyond IMT-2000 is deployed over three years, before rising again. By 2025, the total spectrum demand is 550MHz, which is very close to the 540MHz of spectrum assumed to be available for future cellular use (the 900MHz, 1800MHz, 2GHz and 2.5GHz bands). In rural areas after 2018, the minimum spectrum (350MHz) is required to operate a 3G and a new system beyond IMT-2000 networks simultaneously.

In the high traffic scenario, the demand for spectrum is much higher in urban areas, passing the 540MHz assumed to be available for cellular services in 2011 and then rising to 1.3GHz in 2015. Demand then falls away slightly as spectral efficiency improvements from the new system beyond IMT-2000 and one further system improvement are deployed. Demand finally rises back to 1.3GHz by 2025. In rural areas, the demand is more than the minimum for operating the networks and rises to 430MHz in 2025.

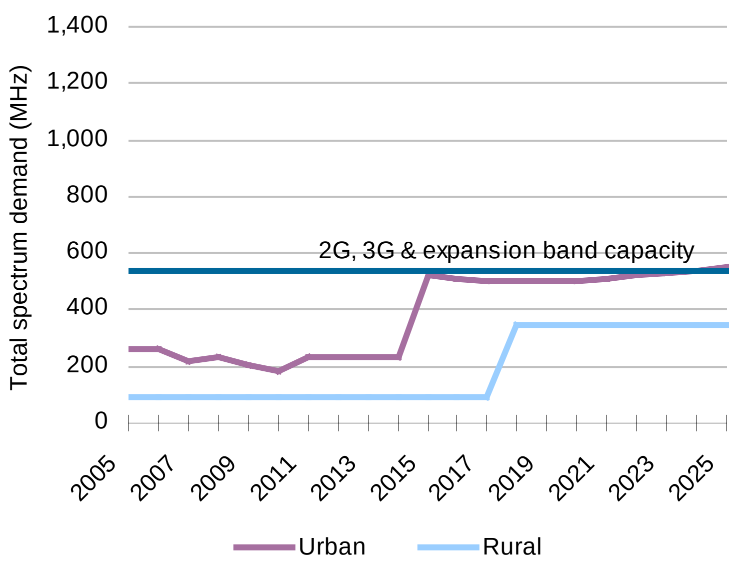

Exhibit 2.9: *Total spectrum demand – low traffic scenario – including spectrum efficiency assumptions [Source: Analysys, Mason, 2005]*

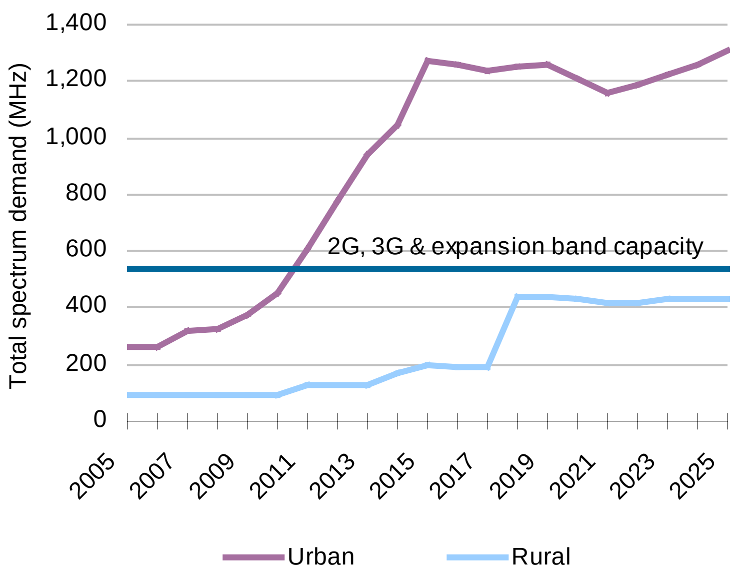

Exhibit 2.10:
Total spectrum demand – high traffic scenario – including spectrum efficiency assumptions [Source: Analysys, Mason, 2005]

If the traffic forecasts from the *Mobile Magic 2010-2020* report were used in the spectrum-demand forecasts (which are approximately four times higher than our high traffic scenario), the spectrum required would be significantly higher. However, if such demand does materialise, then further improvements in spectrum efficiency are likely to be developed (especially since our spectral efficiency improvement for 'systems beyond IMT-2000' is conservative in comparison with previous improvements) and the spectrum required would therefore not be four times larger.

2.4.1 Spectrum characteristics

In this section, we discuss the characteristics required for cellular spectrum.

Exclusive versus shared

We fully expect demand for spectrum from cellular operators to be for exclusive spectrum. The only possible exception to this would involve sharing on a geographical basis – particularly in view of the high level of demand in urban areas in comparison with much lower demand in rural regions.

Licensed versus licence-exempt

All cellular bands must be licensed in view of the considerable investment required in deploying a cellular network. Operators will wish to have security over their investment and also be sure that they can offer a high quality of service to customers. There may however be some scope for lighter licensing in certain specific areas: for example, low-power cellular applications such as small indoor picocells, etc.

Paired versus unpaired spectrum

Unpaired technologies are available (e.g. IP wireless TDD), but are not widely deployed. Therefore, we expect the demand initially to be for paired spectrum. If unpaired technologies were used, the amount of spectrum required could be reduced by up to 30% – e.g. by reducing the proportion of timeslots on a TDD system used for the uplink (mobile handset transmissions to the base station).

Harmonisation[12]

The use of common frequencies for cellular services at a European and a worldwide level is highly desirable to facilitate international roaming across Europe and the world. Additionally, the use of common frequency bands facilitates increased economies of scale, thereby lowering the cost of developing and manufacturing equipment. Harmonisation of spectrum bands has historically been undertaken by regulators, but market mechanisms could achieve similar benefits in the future.

In the long term, frequency-agile terminals may be developed which could reduce the importance of harmonisation of spectrum.

12 In this report we define harmonisation as the identification of common frequency bands across a region (e.g. Europe) for a particular application – and in some cases a particular technological standard. This does not necessarily imply exclusive access (the exclusive provision of frequency bands for a specific application or standard).

Spectrum bands

Current cellular spectrum is located in bands between 900MHz and 2GHz (2.5GHz if the expansion band is included). The lower end of this range is more attractive to the cellular operators than the higher end due to better propagation characteristics (signals travel further so less dense areas can be covered with fewer base stations). Therefore, we expect very high demand for spectrum below 1GHz. Additionally, at the higher frequencies, the frequencies that can be used are limited by mobility. Mobile technologies currently operate at spectrum up to 2.5GHz, though improvements could lead to bands up to 6GHz being used for cellular services in future. In summary, we expect:

- very high demand for spectrum below 1GHz
- continuing interest in spectrum from 1GHz to 3GHz in the short term
- an increase in interest in spectrum from 3GHz to 6GHz for mobile in the medium-term
- little interest in spectrum above 6GHz unless major technological enhancements occur.

Cellular is likely to need to compete with other services (e.g. broadcasting in bands below 1GHz, BWA in bands below 6GHz) for access to additional spectrum.

2.5 Conclusions

Under our low traffic scenario, we expect that the spectrum demand in urban areas should be relatively constant until a new system beyond IMT-2000 is launched in 2015. This is due to modest take-up of 3G services and improvements in spectral efficiency. With the deployment of this new system, total spectrum demand will increase to 550MHz by 2025.

In the aggressive, high traffic scenario we expect that total spectrum demand in urban areas will be 1270MHz in 2015, rising to 1310MHz by 2025.

We forecast much less spectrum demand in rural areas; indeed, the minimum spectrum required to deploy UMTS technology (2 x 5MHz per operator) and a new system beyond IMT-2000 (assumed to be 2 x 30MHz per operator) should be sufficient under the low traffic scenario to 2025. Total rural spectrum demand for the high traffic scenario is projected to be 430MHz by 2025.

In the short term, based on the assumption that there will be around 540MHz of spectrum available for cellular use (900MHz, 1800MHz, 2000MHz and 2500MHz bands), we forecast that this will almost be sufficient to satisfy demand under our low traffic assumptions until 2025.

However, if the traffic in our high traffic scenario (or indeed in the Magic Mobile forecast) materialises, more spectrum could be required. In the high traffic scenario, the spectrum demand passes 540MHz in 2011 and 760MHz of additional spectrum could be required by 2025. In this case, we expect there will be considerable investment in research involving increasing the frequency range over which mobile technologies can operate – it is unlikely that sufficient spectrum can be found below 3GHz, so use will need to be made of higher frequencies. We understand that CEPT is currently seeking to identify spectrum up to 6GHz for use for future cellular systems.

Regardless of the evolution of data traffic on cellular networks, we expect there will continue to be strong demand for lower frequency spectrum (below 1GHz in particular), in view of the beneficial propagation characteristics from the use of such frequencies. Existing mobile operators and new entrants are likely to continue to seek access to sub-1GHz spectrum in view of its properties.

3 Terrestrial fixed-link services

3.1 Introduction

Terrestrial fixed-link services, often referred to as point-to-point microwave links, are used for a variety of purposes such as long-haul telecommunications trunked traffic and backhaul within cellular or other wireless networks. Hence, the major users of fixed-links are the national fixed telecoms operators and the cellular operators.

The strongest growth in demand for fixed-links in recent years has been driven by the cellular operators, which have made extensive use of fixed-links for infrastructure support within cellular networks. This growth is likely to continue in the future with the roll out of 3G networks.

In terms of demand for fixed-links for trunked traffic, major national telecoms operators have adopted strategies in recent years to invest in fibre networks for high-capacity links, rather than using fixed-links. However, use of fixed-links can still offer a number of benefits for trunked transmission in some instances, for example to transmit over difficult terrain, or to provide alternative routing/back-up capacity.

The fixed-link market is a highly concentrated market, with the top five users making up over 85% of currently used fixed-link occupied bandwidth (BT, Orange, T-Mobile, Cable & Wireless and H3G). The current trend of cellular operators switching to fixed-links means that Vodafone and O_2 may also become large users. Therefore, we have forecast future fixed-link demand individually for each of these seven companies.

As part of these forecasts we have developed three scenarios (a conservative, a medium and an aggressive scenario) focused around the potential options for the cellular operators when rolling out their 3G networks.

3.1.1 Bands included in this study

There are nine fixed-link bands below 15GHz, as illustrated in Exhibit 3.1 below. In this study we have forecast the spectrum demand for each of these bands with the exception of the 11GHz and 13GHz bands, which are now closed to new assignments.

Band	*Frequencies*	*Comment*	*Included in this study?*
1.4GHz	1.375–1.517GHz		Yes
4GHz	3.600–4.200GHz	Shared with satellite, lower 85MHz reserved for Pipex	Yes
6GHz lower	5.925–6.415GHz	Shared with satellite	Yes
6GHz upper	6.425–7.125GHz	Shared with satellite	Yes
7.5GHz	7.425–7.900GHz		Yes
11GHz	10.700–11.700GHz	Closed	No
13GHz	12.750–13.250GHz		Yes
14GHz	14.250–14.500GHz	Closed	No
15GHz	14.500–15.350GHz		Yes

Exhibit 3.1: *UK fixed-link bands [Source: Ofcom]*

3.2 Review of secondary research

There have been relatively few reports written about the future demand for fixed-links and fixed-link spectrum. The most significant report in the last few years has been the *“Economic study to review spectrum pricing”* by Indepen, Aegis and Warwick Business School in February 2004. Despite the fact that it focuses on spectrum pricing and that it covers a number of services as well as fixed-links, it does give insights into future fixed-link spectrum demand.

A brief summary outlining the findings of this report regarding fixed-link spectrum demand is given below:

"Economic study to review spectrum pricing"

- The authors used RA's (now Ofcom) fixed-link database to calculate the fixed-link density in congested areas to understand whether bands were nearing their capacity.

- The report suggested that the bands below 14GHz were generally congested and one of the main causes of this is the low re-use potential of these bands (due to lower free space path loss).

- Administered Incentive Pricing (AIP) was introduced for sub-15GHz bands based on analysis carried out in 1997. Since then, demand is now greater in higher bands (23, 26 and 38GHz) and growth has been significantly higher in these bands. However, congestion has not yet been a problem in these bands due to higher re-use factors (congestion is likely in the future, especially in the 23GHz band).

- In bands below 13GHz demand has declined when account is taken of the bands formally exclusive to BT (4, 6 and 11GHz bands). Nevertheless, there continues to be congestion at the main nodes in trunk networks or in bands shared with satellite services.

In conclusion, this report suggests that many of the bands below 15GHz are congested. However, this may be eased somewhat by the majority of future fixed-link growth being in bands above 15GHz.

3.3 Methodology

This section presents an overview of the methodology used to forecast future fixed-link spectrum demand. A detailed description of the methodology is included in Annex B.

3.3.1 Overview of the methodology

Exhibit 3.2 below illustrates the approach that we have used to forecast the spectrum demand for fixed-links:

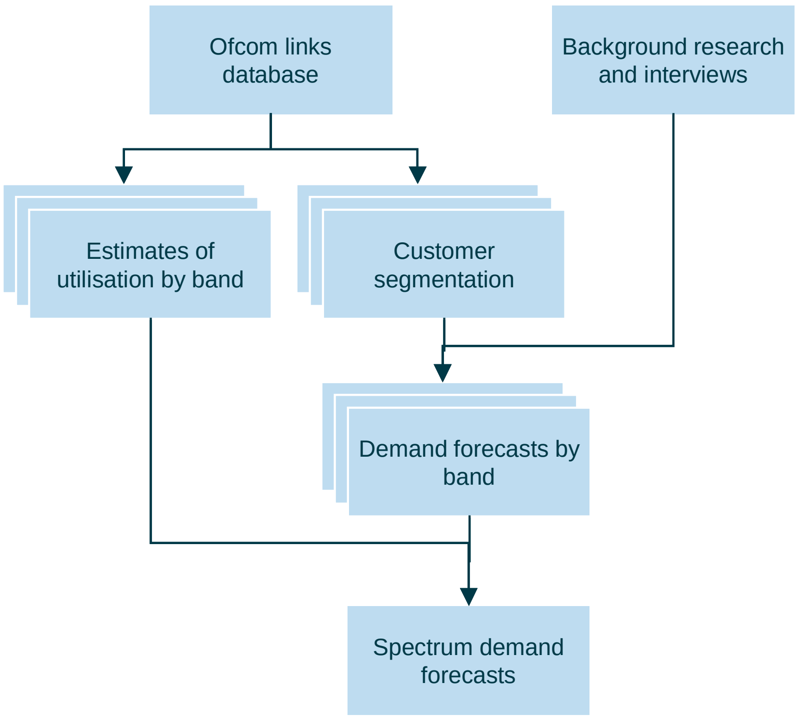

Exhibit 3.2: *Approach to forecasting fixed-link spectrum demand*

The methodology for creating the fixed-link spectrum forecast was a four-step process:

Estimating current fixed-link utilisation

Before even beginning to consider forecasting future spectrum demand for fixed-links, it is first necessary to establish the current utilisation. Calculating the current utilisation is a non-trivial task:

- channels can be reused by fixed-links in several different geographical locations
- it is not obvious how many bands can be fit into a given area
- demand for bands is concentrated in urban areas, which means that they may hit capacity before rural areas.

However, the methodology that Ofcom uses to assign links has enabled us to estimate current utilisation. Ofcom assigns links to the channels at either end of each band first, meaning that the channels at either end of each band are likely to be at capacity (at least in urban areas). Therefore, we have calculated the density of links in each channel and assumed that the channels with the highest link density are at capacity.

As urban areas (including London) are much more densely populated with fixed-links than rural areas, it is necessary to split these regions out when calculating capacity. Therefore, for the purposes of this study the UK has been split into three areas:

- London – defined as being within the M25
- other urban areas
- rural – covering all other areas.

Exhibit 3.3 below shows our definition of ‘urban’ and ‘rural’ areas. These are based on an analysis of population density in individual postal districts and are the same areas as those used for our other market forecasts (e.g. for spectrum demand for cellular services).

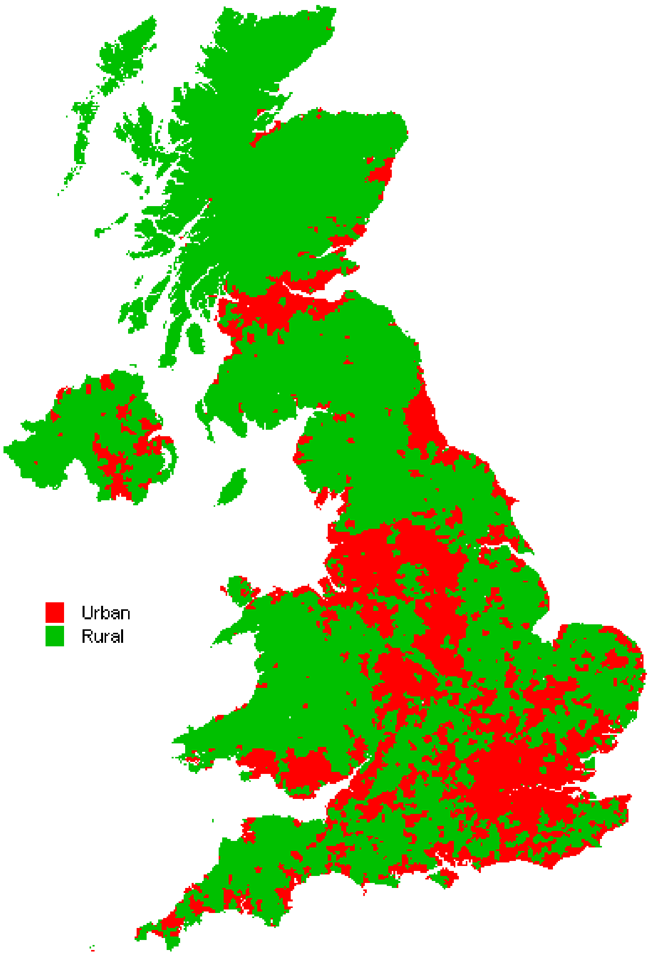

Exhibit 3.3:
Illustration of urban and rural areas for fixed-link assessment [Source: Analysys, Mason, 2005]

The channel link density was calculated for each channel and band in each of these three regions; the maximum channel density in any of these regions was then used as a proxy for the channel capacity of the band. Once the capacity for each channel (in terms of density of links) is known, it is possible to calculate the utilisation of the whole band.

Forecasting fixed-link occupied bandwidth demand to 2015

Occupied bandwidth forecasts were developed by band and region (London, other urban areas and rural areas) for the largest five users (BT, Orange, T-Mobile, Cable & Wireless and H3G) plus the other two cellular operators (Vodafone and O_2), which we have identified as potential future big users of fixed links. The remaining users were grouped into three segments (telecoms operators, utilities/oil and gas, and others)[13] based on their current fixed-link usage, and occupied bandwidth demand forecasts were developed for each of these. An overview of the assumptions behind the forecasts of each of these users/segments is given below – a more detailed description is provided in Annex B.

Please note that these forecasts of the future fixed-link demand for these companies have been made by Analysys and Mason for the purposes of this study, and that this may not be consistent with the companies' own views.

► *Forecasting occupied bandwidth – cellular operators*

We have used four drivers to forecast the demand for **fixed-link**s from cellular operators:

- **Number of sites –** we have used the model developed to project future demand for spectrum for cellular services in order to forecast the number of sites that a typical operator will require. For the purposes of this study, our medium scenario assumes that just two of the cellular operators will roll out 3G to rural areas – alternative scenarios model all/none of the existing 3G operators deploying 3G coverage to rural areas.

- **The percentage of sites served by fixed-links –** using Ofcom's fixed-link database and estimates of the number of sites for each operator, we have calculated the current proportion of sites served by fixed-links for each operator. There is an expectation that cellular operators will move from using leased lines for backhaul to fixed-links. This is primarily driven by the fact that fixed-links are cheaper.

"We expect that most operators will be moving toward fixed-links in the future." *UK cellular operator, 2005*

Therefore, for the medium scenario we have assumed the following:

13 The "others" segment includes wireless broadband providers, broadband access for businesses and any new segments that may develop in the future; these may include mobile and terrestrial television. See Annex B for more for a detailed description of the forecasts for this segment.

Orange	Orange already uses fixed-links for the vast majority of its sites. Therefore, we have assumed that its percentage of sites served by fixed-links will remain constant.
T-Mobile	T-Mobile currently uses a combination of leased lines and fixed-links. We have assumed that its percentage of sites served by fixed-links will be constant for three years before growing to 75% by 2012.
Vodafone	Vodafone currently does not use fixed-links for any of its backhaul. We have assumed that it will increase its percentage of sites served by fixed-links to 75% by 2010.
O_2	O_2 currently does not use fixed-links for any of its backhaul. We have assumed that it will increase its percentage of sites served by fixed-links to 25% by 2010.
H3G	H3G uses fixed-links for the majority of its backhaul. We have assumed that its percentage of sites served by fixed-links will remain constant.

- **Channel width per individual fixed-link –** historically, the channel width per link for cellular operators has risen over time. In order to forecast future channel width per link we have trended forward the historical channel width per link for Orange and T-Mobile. However, we have included a step increase in channel width per link with the introduction of HSDPA/HSUPA and potential mass-market take-up of 3G in 2007/8.

- **Mix of frequency bands –** in recent years there has been a trend towards higher frequency bands. This has occurred both as a result of regulatory pressure (for example, the introduction of minimum link length policy by the RA, encouraging use of higher frequency bands for shorter links) and technology improvements, such as the introduction of higher-level modulation schemes providing higher-capacity links in the higher-frequency bands. Therefore, we have extrapolated forward this migration to higher bands into the future.

Extrapolating the occupied bandwidth demand forecasts to 2025

These occupied bandwidth forecasts by users/segment were then aggregated at a band and region level and trended forward to 2025.

Translating the occupied bandwidth demand forecasts to spectrum forecasts

As the occupied bandwidth forecasts were developed for fixed-link occupied bandwidth, they inherently assume that any historical improvements in spectral efficiency (i.e. Mbit/s per MHz) will continue into the future. Therefore, we have assumed that there is a direct relationship between the total occupied bandwidth and spectrum demand.

3.3.2 Scenarios

As the largest influence on the future spectrum demand is likely to be the requirements posed by the cellular operators, we have focused our scenarios around their potential 3G roll-out options. We have considered the following three scenarios:

Conservative scenario

The assumptions behind this scenario are:

- Vodafone and O_2 do not switch to using fixed-links for their backhaul
- the cellular operators do not roll out 3G networks to rural areas.

Medium scenario

This scenario represents our best view of fixed-link spectrum demand for the next 20 years. The assumptions behind this scenario are:

- Vodafone will increase its percentage of sites served by fixed-links to 75% by 2010
- O_2 will increase its percentage of sites served by fixed-links to 25% by 2010
- two cellular operators deploy 3G networks to rural areas, but all five operators share these networks.

Aggressive scenario

The assumptions behind this scenario are:

- all five cellular operators use fixed-links in 75% of their sites by 2010.
- all five cellular operators roll out 3G networks to rural areas.

The objective of the above scenarios is to take account of the principal factors affecting future spectrum demand. However, we have not been able to vary all underlying variables affecting demand within the time available for this study, and have had to make specific assumptions for these variables for the purposes of our assessment. **Again, please note that the above assumptions have been made by Analysys and Mason for the purposes of this study and may not reflect the companies' own views/plans.**

3.4 Results

3.4.1 Current band utilisation

Band utilisation was calculated for the seven bands below 15GHz in each of the three regions, as shown in Exhibit 3.4 below:

Band	*London*	*Urban*	*Rural*
1.4GHz	22%	13%	11%
4GHz	18%	56%	17%
6GHz lower	32%	15%	10%
6GHz upper	0%	7%	13%
7.5GHz	78%	38%	11%
13GHz	70%	66%	16%
15GHz	67%	34%	7%

Exhibit 3.4: *Band utilisation by region [Source: Analysys, Mason, 2005]*

Our results suggest that the higher bands (7.5GHz, 13GHz and 15GHz bands) are nearing capacity in either London or the other urban areas (the utilisation being above 60%). None of the bands are near capacity in rural areas. The most heavily utilised band is the 4GHz band, with 17% utilisation in rural areas.

Please note that this analysis does not account for the fact that the 4GHz, 6GHz lower and 6GHz upper bands are shared with satellite services and that this might limit their usage in some areas. Thus, it may not be possible to reach 100% utilisation in these bands.

3.4.2 Occupied bandwidth demand forecasts

In our medium scenario we forecast that although demand for occupied bandwidth will rise in the sub-15GHz bands, we expect that the vast majority of future demand will be in bands above 15GHz. Exhibit 3.5 below shows the forecast fixed-link occupied bandwidth for the sub-15GHz bands and the other bands (note that the other bands include all bands above 15GHz plus the 11GHz and 14GHz bands).

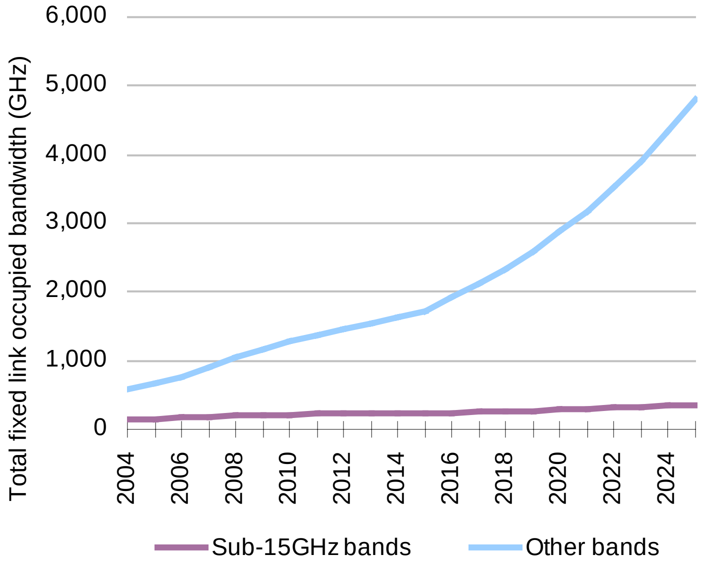

Exhibit 3.5: *Forecast total fixed-link occupied bandwidth (all regions – medium scenario) [Source: Analysys, Mason, 2005]*

Exhibit 3.6 shows the forecast occupied bandwidth by band to 2025 for the medium scenario. Within the sub-15GHz bands, the majority of the growth is forecast in the higher bands (7.5GHz, 13GHz and 15GHz bands). We have forecast very little growth in the 4GHz, 6GHz lower and 6GHz upper bands as these are largely occupied by legacy BT links.

Band	*2005*	*2010*	*2015*	*2020*	*2025*
1.4GHz	1	1	1	2	3
4GHz	15	15	16	16	16
6GHz lower	11	11	11	12	12
6GHz upper	14	15	15	15	15
7.5GHz	20	30	33	42	53
13GHz	83	127	133	170	220
15GHz	12	18	20	27	36
Other bands	681	1285	1732	2871	4800
Total	838	1503	1961	3154	5155

Exhibit 3.6: *Forecast total occupied bandwidth by band (GHz) – medium scenario [Source: Analysys, Mason, 2005]*

3.4.3 Spectrum-demand forecasts

Exhibit 3.7 shows the total spectrum-demand forecast for the sub-15GHz bands by region for the medium scenario. Please note that this analysis excludes the 11GHz and 14GHz bands, in which no new assignments are being made. As expected, demand is higher in London and the other urban areas than in rural areas. There also appears to be enough spectrum available to meet demand to 2025.

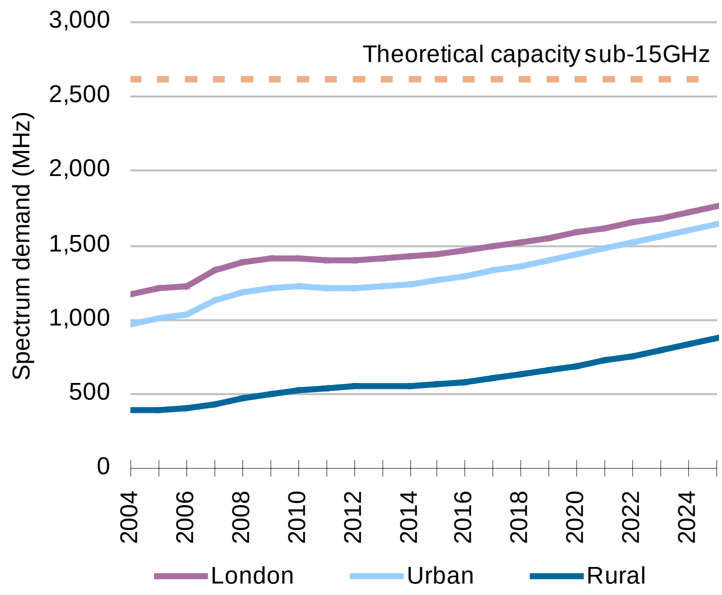

Exhibit 3.7: *Total spectrum demand forecast (sub-15GHz – medium scenario) [Source: Analysys, Mason, 2005]*

However, we forecast that the demand for spectrum will not be uniform across all of the bands. Exhibit 3.8 below shows the forecast utilisation and additional spectrum requirements by band for the medium scenario. We expect that the 7.5GHz and the 13GHz bands will reach capacity before 2010, and the 1.4GHz and 15GHz bands before 2025.

Band	Bandwidth (both up and down links)	Region	Utilisation (given current spectrum)				Additional spectrum required (MHz)			
			Today	2010	2015	2025	Today	2010	2015	2025
1.4GHz	50	London	22%	41%	56%	131%	0	0	0	27
1.4GHz	50	Urban	13%	22%	28%	56%	0	0	0	0
1.4GHz	50	Rural	11%	18%	25%	52%	0	0	0	0
4GHz	360	London	18%	18%	18%	18%	0	0	0	0
4GHz	360	Urban	56%	56%	56%	56%	0	0	0	0
4GHz	360	Rural	17%	17%	17%	18%	0	0	0	0
6GHz lower	485	London	32%	32%	32%	32%	0	0	0	0
6GHz lower	485	Urban	15%	16%	16%	16%	0	0	0	0
6GHz lower	485	Rural	10%	10%	10%	11%	0	0	0	0
6GHz upper	670	London	0%	0%	0%	0%	0	0	0	0
6GHz upper	670	Urban	7%	7%	8%	8%	0	0	0	0
6GHz upper	670	Rural	13%	13%	13%	14%	0	0	0	0
7.5GHz	454	London	78%	99%	97%	117%	0	76	62	172
7.5GHz	454	Urban	38%	53%	56%	81%	0	0	0	0
7.5GHz	454	Rural	11%	20%	23%	42%	0	0	0	0
13GHz	362	London	70%	93%	94%	124%	0	34	40	168
13GHz	362	Urban	66%	90%	92%	123%	0	20	28	162
13GHz	362	Rural	16%	31%	34%	66%	0	0	0	0
15GHz	240	London	67%	75%	80%	95%	0	0	0	27
15GHz	240	Urban	34%	55%	58%	94%	0	0	0	25
15GHz	240	Rural	7%	13%	15%	32%	0	0	0	0

Exhibit 3.8: *Forecast additional spectrum demand by band and region – medium scenario [Source: Analysys, Mason, 2005]*

3.4.4 Scenario results

In the medium scenario, we forecast that sub-15GHz spectrum demand (excluding the 11GHz and 14GHz bands) will rise to 1440MHz in 2015. However, in our conservative assumption (in which Vodafone and O_2 do not switch to fixed-links for backhaul and none of the cellular operators roll out 3G into rural areas), we expect this to be just 1260MHz by 2015. In the aggressive scenario (in which all cellular operators use fixed-links for 75% of their sites by 2010 and they all roll out 3G into rural areas), we expect this to be as high as 1540MHz by 2015.

Exhibit 3.9 shows the total sub-15GHz spectrum demand (excluding the 11GHz and 14GHz bands) for London for the three scenarios. Exhibit 3.10 shows the spectrum demand by region for the three scenarios.

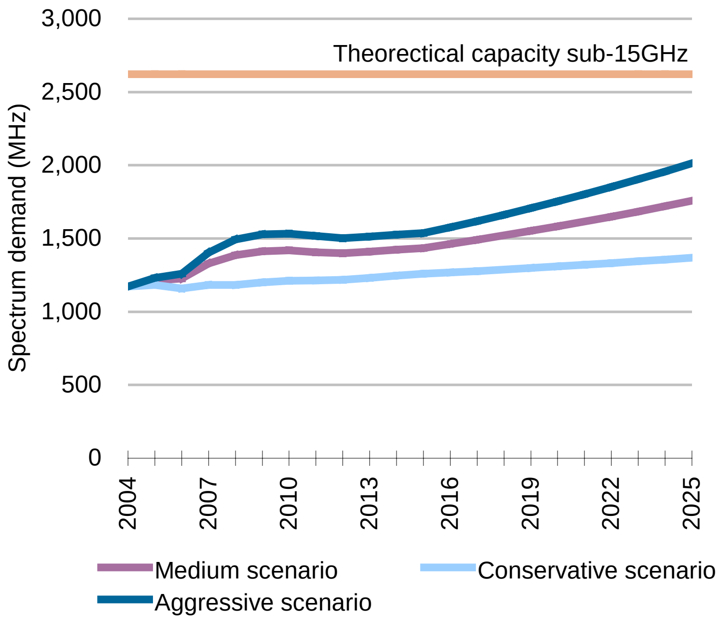

Exhibit 3.9: *Total spectrum demand by scenario (London, sub-15GHz) [Source: Analysys, Mason, 2005]*

Region	*Scenario*	*2005*	*2010*	*2015*	*2020*	*2025*
London	Conservative	1182	1212	1259	1309	1370
London	Medium	1215	1419	1435	1583	1757
London	Aggressive	1231	1533	1536	1754	2014
Urban	Conservative	987	1028	1090	1155	1226
Urban	Medium	1015	1219	1259	1435	1647
Urban	Aggressive	1030	1321	1352	1600	1914
Rural	Conservative	386	427	460	504	557
Rural	Medium	393	525	560	690	871
Rural	Aggressive	398	653	700	1004	1506

Exhibit 3.10: *Sub-15GHz total spectrum demand by scenario and region (MHz) [Source: Analysys Mason, 2005]*

3.4.5 Spectrum characteristics

In this section, we discuss the characteristics of the spectrum required for terrestrial fixed-links.

Exclusive versus shared

Some of the fixed-link bands are currently shared with satellite services. As each fixed-link is specific to a particular geographical location, we see no reason why fixed-link bands cannot continue to be shared as long as adequate measures are in place to avoid interference.

Licensed versus licence-exempt

We expect that future demand will be for licensed spectrum. The majority of links require high quality-of-service levels and therefore the protection from interference that comes from licensed bands is essential.

Paired versus unpaired spectrum

All current fixed-link bands sub-15GHz are paired. Fixed-link spectrum could potentially be used on an unpaired basis using time division multiplex (TDD) technology. However, the vast majority of fixed-links in the UK are used for backhaul, which requires continuous transmission in both directions. Therefore, unpaired spectrum/TDD is not appropriate. TDD technology may be possible for corporate access services, but these make up a very small proportion of links. Therefore, it is reasonable to assume that future bands should be paired.

Harmonisation[14]

The demand for regionally harmonised spectrum will be moderate. As fixed-link equipment can be adapted to work in different frequency bands, there is no technical need for harmonisation of individual frequency bands – provided there is sufficient overlap and the frequencies do need to be within a reasonable range.

The UK market may not be sufficiently large for manufacturers to develop specific equipment for it. In particular, in the current environment, major manufacturers may only develop new equipment for a band once it has been harmonised (by regulators and/or the market) at a European or global level.

Spectrum bands

We forecast that the vast majority of demand will occur in bands above 15GHz. However, in sub-15GHz bands we expect that there may be a shortage of capacity, in particular in the 7.5GHz and 13GHz bands. There may also be competing demand for use of these frequencies for satellite services and possibly BWA services.

3.5 Conclusions

We expect that, over the next 20 years, the growth in terrestrial fixed-links will be primarily driven by cellular operators. This will be due to the roll out of 3G networks and those operators that currently have backhaul supplied by leased lines switching over to fixed-links. As discussed above, the majority of this growth will occur in bands above 15GHz, but some growth will occur in sub-15GHz bands. In contrast, we forecast that BT and Cable & Wireless's demand for the sub-15GHz bands will be relatively constant going forward, as we anticipate they will maintain any existing legacy links. As for the other segments, we expect that growth will be modest for the other telecoms operators and the utilities/oil and gas companies, but the "other segment" (which includes corporate access services and wireless broadband providers) will experience significant growth.

14 In this report we define harmonisation as the identification of common frequency bands across a region (e.g. Europe) for a particular application – and in some cases a particular technological standard. This does not necessarily imply exclusive access (the exclusive provision of frequency bands for a specific application or standard).

Overall, under our medium scenario assumptions, we expect that demand for fixed-link spectrum sub-15GHz in London (the area of highest demand) will rise from 1170MHz in 2004 to a total of 1440MHz in 2015, then to a total of 1760MHz by 2025. Other urban areas will see slightly lower demand, rising to a total of 1260MHz by 2015 and a total of 1650MHz by 2025, and demand in rural areas will be much lower, rising to a total of 560MHz by 2015 and a total of 880MHz by 2025.

In our conservative scenario, spectrum demand will rise to just a total of 1260MHz in London in 2015; in our aggressive scenario it will reach a total of 1540MHz.

The current capacity for fixed-links sub-15GHz is 2620MHz (excluding the 11GHz and 14GHz bands), suggesting that there is sufficient capacity to cope with demand. However, demand is not uniform across the bands. The 7.5GHz, 13GHz and 15GHz bands are currently nearer capacity than the lower bands, and we expect the current trend towards higher bands to continue in the future. As a result, we expect the 7.5GHz and the 13GHz bands to run out of capacity in London/urban areas in our medium scenario before 2010; and the 1.4GHz and 15GHz bands are projected to run out of capacity in London/urban areas by 2025. If further spectrum is not made available for these bands, we anticipate that increased demand will be placed upon the bands above 15GHz, and we already expect these bands to experience significant growth in demand over the next 20 years.

4 Broadband wireless access services

4.1 Introduction

Broadband wireless access (BWA) services can be divided into two categories:

- short-range, low-power services using technologies such as WiFi (variants of IEEE 802.11), Bluetooth, etc. – primarily used for localised 'distribution' (e.g. within a residence) to individual PCs, PDAs, etc.

- long-range, high-power services using specialist fixed wireless access (FWA) technologies (e.g. WiMAX) or existing mobile technologies (e.g. IMT-2000 W-CDMA, IP Wireless UMTS TDD) – typically used for providing 'backhaul' connectivity, e.g. to a residence, although services could, over time, be direct to individual user equipment (laptop PC, etc.).

Our analysis and forecasts of the demand for spectrum for BWA services in the future focuses on the second category – long-range, high-power services. This is because the nature of short-range, low-power services means that frequencies can be extensively re-used as the signals travel over a limited distance. Although as such services (e.g. home WiFi networks) get increasingly deployed there will be a requirement for additional spectrum, this increase in demand is likely to be very limited in comparison with the potential requirement for additional spectrum to support long-range applications.

In respect of these applications, there has been considerable recent interest in the use of FWA technologies for providing telecommunications services, including broadband, to both residential users and SMEs. In the UK, UK Broadband is currently offering broadband services using IP Wireless's UMTS TDD technology and a variety of other technologies (e.g. Flarion OFDM, Navini, IMT-2000 CDMA2000 at 450MHz, IMT-2000 W-CDMA) are under deployment in various markets around the world. Greatest interest has arisen in relation to the potential for WiMAX (heavily backed by Intel) to fundamentally change the economics of BWA service provision, as we discuss below.

Historically, there have been numerous previous attempts to create viable FWA businesses, including:

- first-generation FWA (voice) in the late 1990s: Ionica, Lanka Bell, Tele2, Atlantic Telecom
- second-generation FWA (LMDS) circa 2000: Broadnet, NextLink, Teligent, Winstar.

These propositions have generally failed to compete against incumbent fixed operators for one or more of the following reasons:

- high customer premises equipment (CPE) costs, leading to higher upfront charges for customers or high subscriber acquisition costs for the operator
- technical performance issues, e.g. insufficient network throughput/peak data rates to compete with fixed providers, which can simply ‘ramp up’ basic DSL rates until they exceed the capabilities of fixed wireless systems
- insufficient subscriber density to recover the upfront capital expenditure and ongoing operating expenditure of each base station.

WiMAX could potentially result in considerable reductions in CPE costs – in particular, Intel’s backing of WiMAX could considerably change the paradigm as a result of potential CPE volumes, especially if WiMAX does become an integral component within the majority of laptops. However, it is still far from clear whether WiMAX and subsequent technologies will be able to compete against wireline technologies such as DSL and fibre.

In summary, although FWA systems have historically been proven to be uneconomic to deploy, we cannot rule out a paradigm shift over the next 20 years.

4.2 Review of secondary research

Our research of existing projections for broadband FWA systems in the UK has revealed a lack of information in this area.

Several reports and industry articles have been published on the future take-up of broadband FWA systems, however, these mainly focus on a qualitative description of the future potential for WiMAX deployment and, where quantitative forecasts are available, these are primarily for the US or occasionally the European market as a whole. Examples of these reports include:

- *'WiMAX and Wi-Fi: Unwiring the World'*, Pyramid Research, November 2003.
- *'A (Sub-11Ghz) Worldwide Market Analysis and Trends 2005–2010'*, Maravedis Inc., February 2004.
- *'WiFi, WiMAX and 802.20: The Disruptive Potential of Wireless Broadband'*, BWCS and Senza-Fili Consulting, April 2004.
- *'Broadband Wireless-Last Mile Solutions'*, ABI research, April 2004.
- *'Fixed Wireless, WiMAX, and WiFi Market opportunities, Market Forecasts, and Market Strategies, 2005–2010'*, Wintergreen Research, May 2005.

Our literature review has not revealed any existing third-party detailed projections for future broadband FWA systems deployment or take-up in the UK. Whilst there is significant hype over the potential for WiMAX, as discussed above, third-party forecasts have generally tended to concentrate on the US market, where the potential for such deployments is greater due to density of residences located away from the location of telephone exchanges.

Additionally, we have not been able to identify any existing future forecasts for spectrum requirements in the UK or any other market.

As a consequence of the limited information (and considerable 'hype') in this area, we have sought to develop our own projections of future BWA service deployment and take-up, using the methodology detailed in the following section.

4.3 Methodology

This section presents an overview of the methodology underlying our analysis of the future demand for BWA spectrum. Section 4.3.1 discusses the range of scenarios we have modelled; Section 4.3.2 provides details of the methodology we have used; and Section 4.3.3 illustrates our geographical modelling in respect of 'urban' and 'rural' areas.

4.3.1 Modelled scenarios

In view of the considerable uncertainties over the economic viability and future deployment of BWA systems, as discussed above, we have developed two scenarios which reflect the potential range of developments:

- **Scenario 1: Widespread deployment of BWA** – here we assume that a paradigm shift does occur in that BWA is a viable competitor to DSL and cable modem services and deployment of BWA services therefore occurs in both urban and rural areas.

- **Scenario 2: BWA limited to rural broadband coverage in-fill** – under this scenario, the underlying economics of BWA continue to be difficult and BWA deployment is therefore limited to providing DSL services in rural areas where a high-speed wireline service is not available.

We also considered the development of a third scenario – **broadband coverage in full in urban areas**. Under this scenario, in addition to BWA deployments in rural areas (as per Scenario 2), we considered the potential deployment of BWA in urban areas to cover those residences, etc., lying outside the viable range over which wireline technologies (e.g. DSL) can provide high-speed broadband services. We initially undertook a geographical analysis of these households but rapidly reached a conclusion that the density of such users was too small to warrant network deployment. Whilst individual localised solutions may be developed for certain 'clusters' of users, the spectrum requirement of such users is likely to be limited to being less than the requirement for spectrum in the most dense rural areas. We have therefore not sought to explicitly model this scenario.

4.3.2 Spectrum-demand-forecast methodology

In view of the lack of reliable third-party forecasts for future spectrum demand or take-up of BWA services, we have developed a detailed methodology for this assessment, as shown in Exhibit 4.1 below. We developed detailed forecasts of BWA traffic and spectrum requirements up to 2015 – and then extend these forecasts to derive the full 20-year demand profile.

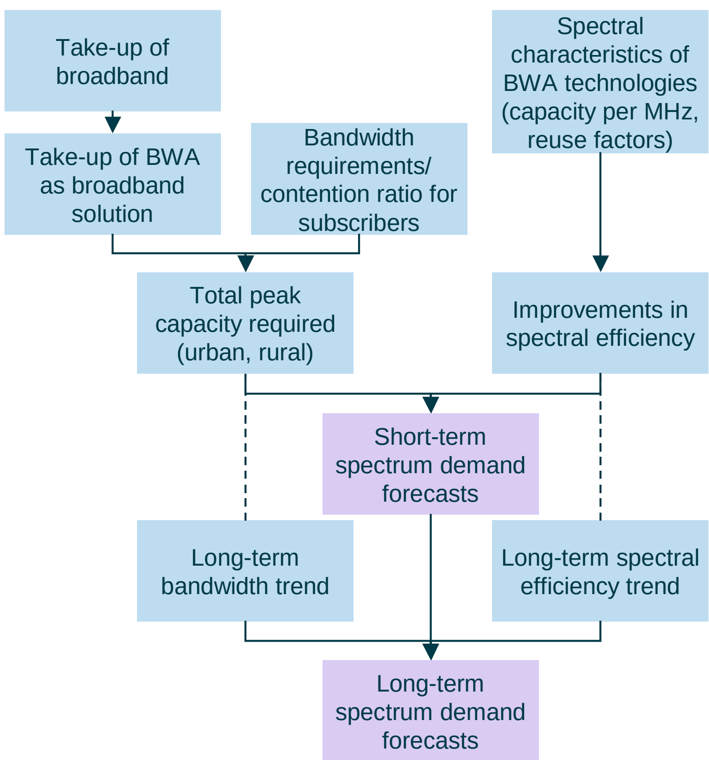

Exhibit 4.1: *Approach to estimation of demand for BWA spectrum [Source: Analysys, Mason, 2005]*

Our spectrum-demand forecasts from 2005-2015 are based upon:

- an assessment of the take-up of broadband services – this is primarily based on forecasts developed by our sister company, Analysys Research Limited

- an assessment of the number of households and SMEs taking-up BWA services as a proportion of those taking up broadband services

- an assessment of the bandwidth required to serve these subscribers – assessed by considering the uplink and downlink bandwidths required by each subscriber and the contention ratio that the service provider will need to offer

- current spectral efficiency of BWA technologies (capacity per MHz and areas over which individual frequencies can be re-used) and future evolution of these parameters.

We have extrapolated our forecasts to 2025 by considering potential future growth in bandwidth requirements and improvements in spectral efficiency.

In the following section we discuss the key assumptions that underlie each of the key stages of the methodology.

4.3.3 Urban and rural areas

Exhibit 4.2 below shows our definition of 'urban' and 'rural' areas. These are based on an analysis of population density in individual postal districts and are the same areas as those used for our other market forecasts (e.g. for spectrum-demand for cellular services).

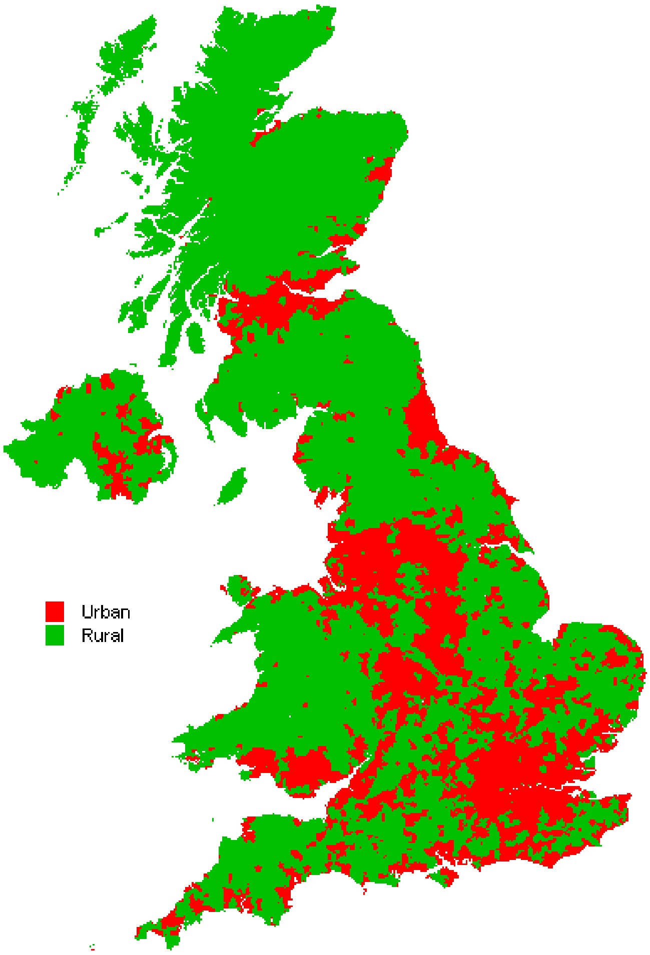

Exhibit 4.2: *Illustration of urban and rural areas for BWA assessment [Source: Analysys, Mason, 2005]*

Under Scenario 1 (widespread deployment), our assessment of the demand for spectrum in urban areas is based on consideration of the demand for spectrum in the densest urban region (amounting to 2% of the area of the urban region). Demand for spectrum in rural areas is driven by demand in the densest regions in rural areas (amounting to 20% of the area of the rural region).

Under Scenario 2 (rural coverage in-fill), BWA is not deployed in urban regions – except for certain specific locations (hotspots). For rural demand, we consider the take-up by subscribers located in the densest regions in rural areas, but located away from BT exchanges (i.e. beyond the reach of DSL technologies).

4.4 Key assumptions

Exhibit 4.3 below presents an overview of the key assumptions which correspond with the key stages of the methodology as detailed in the section above. Further details of the assumptions are also presented in Annex C and we advise the reader to review the annex in conjunction with this section.

Parameter	*Scenario 1 (widespread deployment*	*Scenario 2 (rural coverage in-fill)*
Broadband take-up	• 80% of households in urban areas and 75% of households by 2015 • 80% of SMEs in urban areas and 70% of SMEs in rural areas by 2015	
BWA take-up	• 20% market share of broadband household in urban areas by 2015 and 15% in rural areas • 10% share of broadband SMEs in urban areas by 2015 and 25% in rural areas	• 50% share of broadband households and SMEs in rural areas outside coverage of BT exchanges in rural areas
Subscriber bandwidth requirements (downlink)	• 1Mbit/s (2005) growing to 4Mbit/s (2010) and 11Mbit/s (2015) for residential subscribers in urban areas • 0.5Mbit/s (2005) growing to 2.5Mbit/s (2010) and 8Mbit/s (2015) for residential subscribers in rural areas2Mbit/s (20050 growing to 8Mbit/s (2010) and 22Mbit/s (2015) for SME subscribers in urban areas • 0.5Mbit/s (2005) growing to 5Mbit/s (2010) and 16Mbit/s (2015) for SME subscribers in rural areas • 20% per annum growth in bandwidth post-2015 • Uplink bandwidth 10-25% of downlink rates (varies between user categories) • Contention ratio of 50:1 for residential subscribers and 30/40:1 for SMEs (urban/rural)	
Radio network deployment	• 100% of dense urban areas – assumed cell radius of 1km • 80% of the highest density rural area (which is itself 30% of overall rural area) – assumed base station cell radius of 7.5km	• 60% of highest density rural area 9which is itself 30% of overall rural area) – assumed base station cell radius of 7.5km
Equipment spectral efficiency	• 1.9Mbit/s/MHz for urban deployments and 0.8Mbit/s/MHz for rural deployments based on WiMAX Forum estimates and pre-WiMAX equipment – assumed to increase at 15% per annum	

***Exhibit 4.3**: Key spectrum demand modelling assumptions [Source: Analysys, Mason, 2005]*

4.5 Results

The results of our analysis are shown in the Exhibits below. Exhibit 4.4 and Exhibit 4.5 show, respectively, the demand for spectrum in urban and rural areas under Scenario 1, whereas Exhibit 4.6 shows the demand for spectrum in rural areas under Scenario 2.

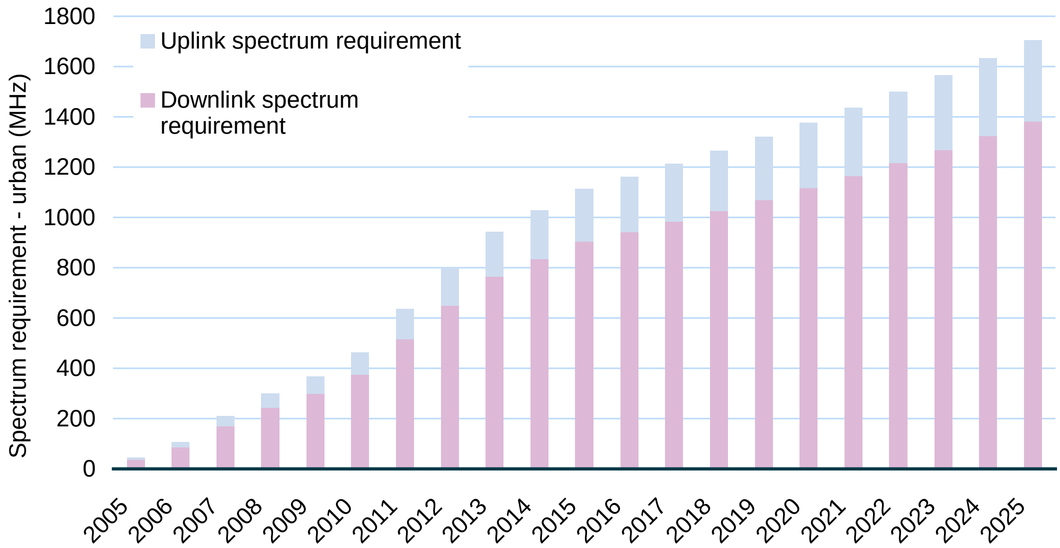

Exhibit 4.4: *Scenario 1 – Total demand for spectrum in urban areas [Source: Analysys, Mason, 2005]*

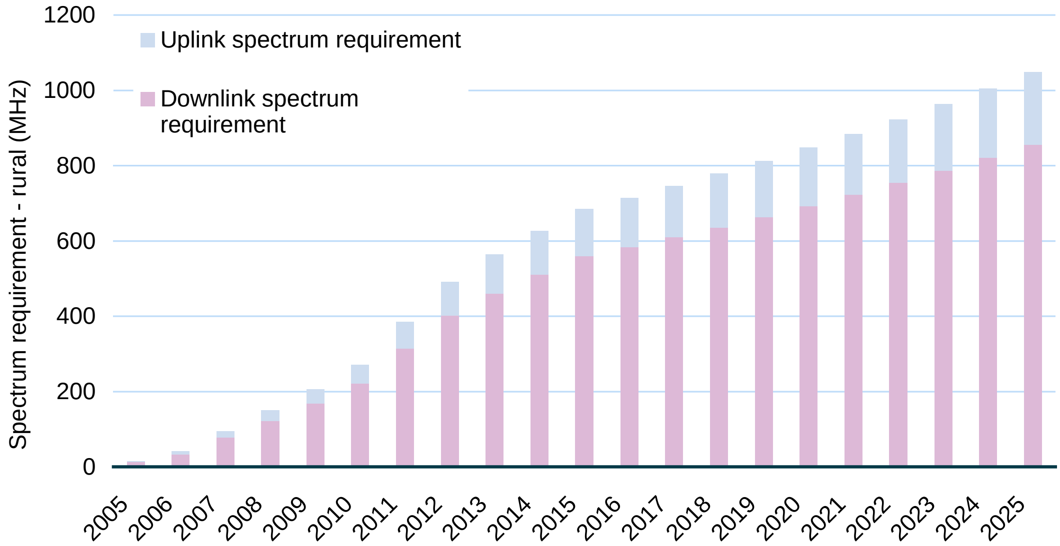

Exhibit 4.5: *Scenario 1 – Total demand for spectrum in rural areas [Source: Analysys, Mason, 2005]*

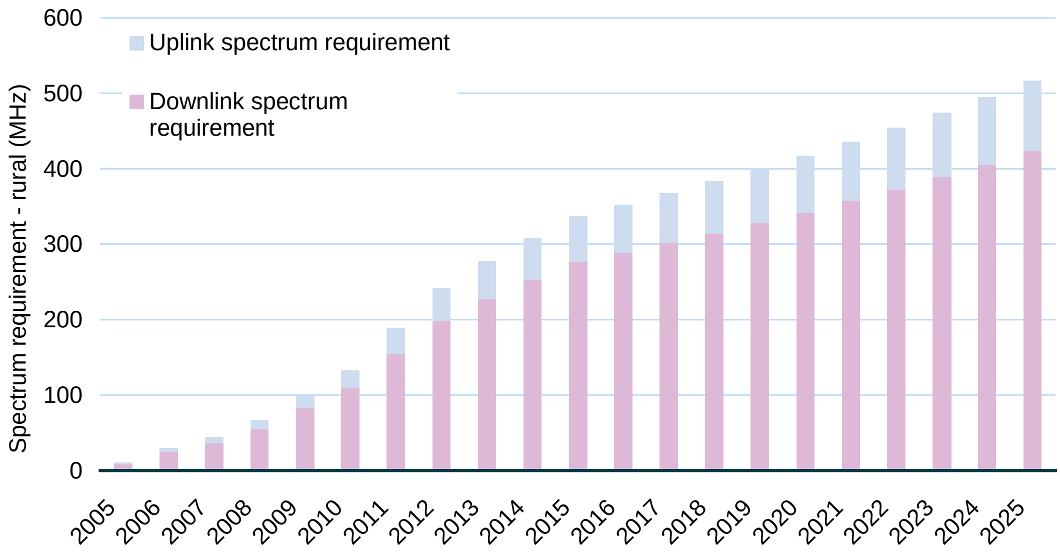

Exhibit 4.6: *Scenario 2 – Total demand for spectrum in rural areas [Source: Analysys, Mason, 2005]*

As expected, Scenario 1 leads to the greatest demand for spectrum – a total of 1100MHz of spectrum in urban areas in 2015 and a total of 700MHz of spectrum in rural areas in 2015. By 2025, this requirement grows to a total of 1700MHz of spectrum in urban areas and a total of 1100MHz of spectrum in rural areas.

Under Scenario 2, a total of 350MHz of spectrum is required in rural areas in 2015 rising to a total of 500MHz of spectrum by 2025. As previously discussed, there is also likely to be some demand for spectrum in certain 'localised areas' in urban regions.

4.5.1 Spectrum characteristics

In this section, we discuss the characteristics of the spectrum required for BWA.

Exclusive versus shared

We believe that spectrum could be shared with other services (e.g. fixed-links, satellite), whilst BWA remains a niche offering. Under Scenario 1, however, we would anticipate that operators would seek exclusive spectrum for ease of spectrum management.

Licensed versus licence-exempt

We expect that increasing use could be made of licence-exempt spectrum in rural areas – perhaps rising to as much as 70% of the spectrum requirement in the long run. For the highest forecast use scenario (Scenario 1), the high density of use coupled with the high network deployment costs are likely to mean that operators will require licensed spectrum in urban areas – perhaps only 20% of the spectrum demand in urban areas could be met from unlicensed spectrum.

Paired versus unpaired spectrum

Technologies (e.g. TDD) utilising unpaired spectrum would represent the most efficient use of spectrum in view of the asymmetric nature of data usage. We expect increasing use to be made of unpaired spectrum due to the asymmetric nature of Internet traffic.

Exhibit 4.7 below illustrates the potential impact of use of unpaired (e.g. TDD) technologies versus paired (e.g. FDD) technologies on the overall demand for spectrum in urban areas under Scenario 1. Note that we have assumed that imperfections in 'dynamically' allocating spectrum between downlink and uplink channels means that the use of unpaired spectrum provides only 80% of the spectrum saving that a theoretically 'perfect' unpaired solution would provide.

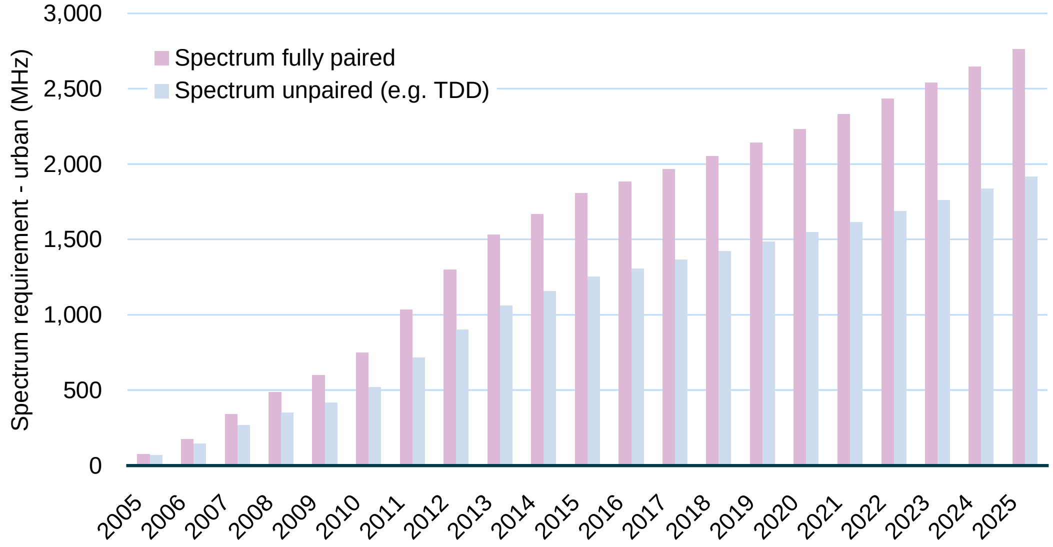

Exhibit 4.7: *Illustration of total spectrum demand under Scenario 1 for urban areas – use of paired versus unpaired spectrum [Source: Analysys, Mason, 2005]*

Harmonisation[15]

Demand for harmonised spectrum for BWA services on a European/international basis will be low to medium. The UK has some scope for autonomy as equipment can be adapted to work in individual frequency bands. However, the low cost of equipment (e.g. from a global market) is likely to be a key factor affecting whether BWA deployment follows Scenario 2 rather than Scenario 1. The realisation of Scenario 1 could be dependent on global economies of scale being realised – which is dependent on regulatory or market-led harmonisation of bands for BWA. In the medium to long term, the development of frequency-agile radios could reduce the need for harmonisation of specific frequency bands.

15 In this report we define harmonisation as the identification of common frequency bands across a region (e.g. Europe) for a particular application – and in some cases a particular technological standard. This does not necessarily imply exclusive access (the exclusive provision of frequency bands for a specific application or standard).

Spectrum bands

We expect that demand for BWA spectrum will be greatest in the 1–3GHz and 3–6GHz spectrum ranges. This is because these bands generally provide a good balance between range and capacity. However, there may be considerable demand for this spectrum from other services (e.g. cellular).

Higher frequencies (e.g. 10GHz band) can also be used in metropolitan areas. The major problem with the use of such frequencies is that the 'subscriber density' is insufficiently high in comparison with the limited range of a base station. Under Scenario 1, however, where spectrum demand is greatest, it should be possible to make use of higher frequency bands in view of the higher density of users. It may also be possible to make use of frequencies above 15GHz (e.g. existing 28GHz band) in such urban areas, although our interview programme suggested that current providers of BWA services remain concerned about the economic viability of such high frequencies. Again, there will also be other services that wish to use these higher frequency bands (e.g. satellite services and fixed links).

Lower frequencies (e.g. 450MHz) are useful for covering very rural areas due to propagation range. CDMA450 networks are being deployed in Eastern Europe, for example, to provide broadband services – though at lower data rates than we have projected in our model. There may therefore be some demand for frequencies below 1GHz, but we expect this to be limited.

4.6 Conclusions

There is considerable uncertainty over the future demand for BWA spectrum, in view of whether the economics of BWA systems can be made to work in areas where alternative solutions (e.g. DSL) are available.

Our projections indicate that a total of 1800MHz of spectrum for BWA services could be required in urban areas by 2015 if the economics of BWA deployment can be made to work. If bandwidth growth trends continue, this requirement could grow to a total of 2800MHz by 2025. Under this scenario, the spectrum requirement in rural areas could be a total of 1000MHz in 2015. In view of the asymmetric nature of services, if technologies using unpaired spectrum (e.g. TDD) can be utilised, the spectrum requirement in urban areas could reduce to a total of 1200MHz in 2015. Shortages of spectrum in the 2–4GHz range will mean that higher frequency bands (e.g. 10GHz, 28GHz) will need to be used, particularly in urban areas.

A more likely outcome is that BWA services are primarily offered in rural areas outside the reach of conventional broadband technologies (DSL, cable modem, etc.). In this case the spectrum requirement in rural areas in 2015 is likely to be around a total of 550MHz. Under this scenario, we expect that there will also be certain localised deployments of BWA in various urban areas, and therefore it would be appropriate to allow for a similar spectrum requirement (total of 550MHz) in these areas.

These projections should be compared with the spectrum currently available for high-power, long-range FWA applications. We estimate this to be around 333MHz.[16]

In the short-to-medium term there is likely to be increasing interest in the use of licence-exempt spectrum for BWA service provision. We note Ofcom's plans (as outlined in its *Spectrum Framework Review*[17]) to steadily increase the spectrum available on a licence-exempt basis – currently 125MHz of spectrum is available in the 5.8GHz band for higher-power applications. However, under Scenario 1, we note that it is likely that BWA operators will seek dedicated licensed spectrum, particularly in urban areas, to mitigate against any quality-of-service issues arising from potential interference and also to protect their business investments.

16 This estimate is based on 40MHz of spectrum currently used by UK Broadband, 168MHz of spectrum licensed to Pipex and 125MHz in the 5.8GHz band.

17 http://www.ofcom.org.uk/consult/condocs/sfr/sfr2/?a=87101.

5 Satellite services

5.1 Introduction

In this section we consider the demand for spectrum for the purposes of delivering satellite services. Satellite services are a significant user of the spectrum below 15GHz. We look at mobile satellite services (MSS), broadcast satellite services (BSS) and fixed satellite services (FSS) separately due to the very different nature of each of these services and the frequencies in which they operate.

It is important to understand that because of the very wide coverage area of satellites the consideration of satellite spectrum demand for the UK alone in this study must be considered in the international context. Spectrum and orbital positions have been planned carefully to avoid interference and to ensure that adequate separations are maintained between satellites. Due to the international nature of satellite services, much of this co-ordination takes place within a framework of international rules administered by the ITU, a treaty-based body formed under the auspices of the United Nations.

The ITU Radio Regulations, which have the force of an international treaty, contain procedures for the notification, co-ordination and registration of satellite space stations and networks and place certain rights and obligations on ITU member states. These are designed to ensure that satellite networks operate without interference and that orbital positions are efficiently utilised.

MSS operators provide a range of services to mobile users on land, at sea or in the air. Historically voice, low speed data and, for maritime users, safety services, have been the mainstay of MSS. However, recent developments including the launch of Inmarsat's first fourth-generation satellite (Inmarsat-4) for its BGAN service, mean that higher speed global mobile data services are now available.

The number of MSS systems is expected to remain relatively static in the future. Growth could materialise in both increasing number of subscribers and increasing usage per subscriber both of which could be enabled by more capable systems such as Inmarsat's BGAN and Thuraya's DSL services. Given that the MSS is relatively niche it is likely that increasing usage per subscriber will be the main growth driver.

The BSS market is a potentially large user of spectrum. Currently in the UK the Sky platform supports around 400 television channels. Over time, this may increase, which may be a driver of spectrum, as will the planned shift to high-definition television which requires more bandwidth per channel.

In the FSS market VSATs are typically used in rural or remote areas of developed countries or more generally in developing countries as part of a large corporate network solution. They are also used to provide connectivity for semi-permanent business units such as those associated with oil, gas and mineral extraction.

In recent years growth in the FSS sector as a whole has been limited, due in part to the increasing coverage of terrestrial networks from incumbent operator broadband strategies and, in some cases, public sector intervention projects primarily in Europe. Euroconsult[18] estimates that in 2003 the market 'remained difficult' with a 2.2% growth in transponder use with traditional services such trunking in decline; satellite asset utilisation averaged 75% over the last 10 years, but was 70% in 2003; and finally asset utilisation will increase after 2005 as demand increases and fewer satellites are planned for launch. One UK specialist satellite consultancy we interviewed said it expects that there to be some consolidation in the FSS market over the next few years, with perhaps three or four players left – this is perhaps an indication of the challenging conditions in this market.

However, there are prospects for growth, e.g. in many markets high capacity terrestrial infrastructure remains limited geographically and some argue that the businesses' increasing reliance on broadband connectivity will further stimulate the FSS market, potentially via an increase in the number of VSATs and usage per terminal.

18 World Satellite Communications & Broadcasting Markets Survey 2004 Edition.

Furthermore, there is growing interest in FSS supporting mobile applications, e.g. broadband services to aircraft, ships and trains. Boeing's 'Connexion' is an example of such an aeronautical service. In these environments, the FSS bands are usable because relatively high-gain antennas can be used; the bands are not suited to hand-held terminals of the kind supported by MSS.

5.2 Review of secondary research

There is a limited amount of publicly available research on the future demand for satellite spectrum. In addition to reviewing the output from recent WRCs we used two reports as background for this work.

The Advanced Satellite Mobile Systems Task Force (a trade association of MSS operators and manufacturers supported by ESA/EC), has published a '*Forecast of MSS traffic and spectrum requirements to 2010'*. The report states that total MSS traffic is expected to grow due to increases in use of data services, with land-based mobile telephony seeing significant growth; broadcast/multicast services are also expected to generate new traffic. The forecasts assume two global multimedia systems, two global non-multimedia systems, one regional multimedia system and one multicast system. The report concludes that additional spectrum will be needed for MSS with 2 × 151.2MHz being required by 2010, compared with the current allocation of 2 × 79.5MHz (it should be noted that the ASMS excludes the additional 12MHz allocated at WRC-03).

We understand that a revised version of this report may become available shortly.

As to the FSS market, Euroconsult's *'World Satellite Communications & Broadcasting Markets Survey 2004'* includes predictions for the growth of FSS services. It concludes that:

- in 2003 the market remained 'difficult' with a 2.2% growth in transponder use. Traditional services (e.g. trunking) are in decline
- satellite asset utilisation has averaged 75% over the last 10 years, but fell to 70% in 2003
- asset utilisation will increase after 2005 as demand increases and fewer new satellites are launched.

Due to the limited amount of published research in this market our views have been informed substantially by interviews with organisations operating in the MSS, BSS and FSS segments.

Regarding mobile applications provided over FSS, WRC 2000 and WRC 2003 decisions enabled aircraft to transmit in the 14–14.5GHz band,[19] and also for earth stations on vessels (ESVs) to use the 5.925–6.425GHz and the 14–14.5GHz band with restrictions in coastal waters. ETSI has set up groups to develop technical and operational standards to guide the manufacture and installation of the terminals for aircraft, ships and trains; a draft standard for an Airborne Earth Station (AES) is currently pending approval by the ECC, a draft standard for a Ku-band ESV is nearing the end of the Public Enquiry phase; a draft standard for a C-band ESV is almost ready to enter the Public Enquiry phase; and a meeting to start the development of a draft standard for an earth station on a train (EST) is scheduled to take place early in September.

5.3 Bands included in this study

The bands used for satellite services considered in this study are as follows:

- MSS – 1–3GHz (L-band/S-band)
- BSS – 11.7–12.5GHz (Ku-band)
- FSS – 3.6–4.2GHz and 5.85–7.075GHz (C-band) and 10.7–11.7GHz, 12.5–13.25GHz, 13.75–14.0GHz, 14.0–14.5GHz (Ku-band).

The Ka-band (27.5–31GHz uplink and 18.3–18.8GHz/19.7–20.2GHz downlink) is not included in because it is above the 15GHz threshold for this study.

The following sub-sections consider each service in more detail.

19 Note that some European countries limit this to the lower half of the band.

5.3.1 Mobile satellite services (MSS)

The main MSS operators relevant to this study are Inmarsat, Iridium and Globalstar. Inmarsat is a geostationary orbit (GSO) system whereas Iridium and Globalstar are low Earth orbit systems, often termed 'Big LEOs'. These three systems use frequencies in the L-band at 1.5–1.6GHz and provide voice and low speed data services. Inmarsat provides a more comprehensive service portfolio and later this year is expected to launch its BGAN service which will provide bandwidth up to 432kbit/s per user (following the introduction of its Regional BGAN service using leased capacity on the Thuraya satellite). Inmarsat also uses frequencies in C-band for its feeder links at 3.6–4.2GHz – this is shared with fixed satellite services.

In addition there are other GSO MSS systems that are regional rather than global, such as Thuraya (Europe, North/Central Africa and a large part of Asia), Mobile Satellite Ventures – MSV (North and Central America and Northern South America), Asia Cellular Satellite – ACeS (Central/Eastern Asia) and several others. These systems provide voice and low-speed data services. Thuraya has recently introduced a service called 'DSL' offering up to 144kbit/s to the end-user in direct competition with Inmarsat's Regional BGAN.

ICO's original medium Earth orbit (MEO) system is on hold – although one satellite has been in orbit since 2001 no commercial service is available. We understand that the company has applied to Ofcom for launch of a GSO satellite which would cover the Americas. Plans for Europe are not known. However, other organisations have proposed alternative uses of the 2 x 30MHz spectrum assigned to ICO.[20] Both Alcatel and Astrium have proposals for a hybrid system in Europe incorporating an 'ancillary terrestrial component' (ATC) – this is where the same frequencies are used for satellite and terrestrial communications. Each of these systems is believed to require 2 x 15MHz initially which would fully replace the spectrum currently allocated to ICO. Similar systems have been proposed in the US for example by MSV which has recently been awarded patents for hybrid satellite-terrestrial services. Another example is SDMB in Japan.

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20 The system was co-ordinated over 2 x 30MHz to allow flexibility to accommodate national/regional differences, although only 10-12MHz is required for operation.

Other MSS systems include 'little LEOs' such as Orbcomm and Omnitracs/Euteltracs. These do not operate in the MSS allocations in L-band – Orbcomm operates at 137/148MHz for its communications links, and Omnitracs/Euteltracs operates at 11/14GHz (1GHz and 1.4GHz are used for feeder links). These systems are typically used for asset tracking, remote monitoring and messaging applications which require low data rates. There appears to be little evidence for significant growth in this part of the MSS market at the CEPT level.

Globally, MSS bands are used by nine GSO MSS operators, and it is generally accepted that the 1626.5–1660.5/1525–1559MHz band is congested. In particular we understand that spectrum is very congested where Inmarsat and Thuraya footprints overlap. We also expect that Iridium may be requesting additional spectrum. In response to the congestion issues the WRC-03 allocated an additional 2 x 7MHz of spectrum in L-band, although only 12MHz of this is available for satellite (1518–1525MHz downlink and 1670–1675MHz uplink) due to the lower 2MHz of uplink frequency being used for radio astronomy in Europe.

Currently, allocations for MSS in the 1–3GHz range total 171MHz (2 x 79.5MHz + 5+7GHz), as shown below.

Uplink (MHz)	Downlink (MHz)	Bandwidth (MHz)	Current use
1610-1626.5	2483.5-2500	2 x 16.5	Iridium, Globalstar
1626.5-1645.5 & 1646.5-1660.5	1525-1544 & 1545-1559	2 x 33	Inmarsat, Thuraya
1670-1675	1518-1525	5 + 7	None at present
1980-2010	2170-2200	2 x 30	ICO (& other filings)
		2 x 79.5 + (5+7)	

Exhibit 5.1: *Current MSS allocations and use [Source: Ofcom, Analysys, Mason, 2005]*

These allocations exclude 2 x 20MHz (2670–2690MHz uplink and 2500–2520MHz downlink) and 2 x 15MHz (2655–2670MHz uplink and 2520–2535MHz downlink). These were initially identified for terrestrial or satellite components of IMT-2000 – however, in CEPT countries, the MSS allocation has since been given up in favour of terrestrial (3G expansion) use.

5.3.2 Broadcast satellite services (BSS)

In the UK, BSkyB operates the Sky TV satellite platform that delivers direct to home (DTH) reception of satellite television. BSkyB's subscriber numbers in the UK reached 7 349 000 in the UK at the end of Q1 2005. This platform delivers television (and radio) channels from both Sky as well as those from third parties such as the BBC. Therefore our forecasts are based on the expansion of the Sky platform.

The actual BSS allocation is 11.7–12.5GHz. For historical reasons, ASTRA launched its service distributing broadcasting content and subsequently offered DTH services within the 10.7–11.7GHz band. This band is allocated to FSS and FS.

For this reason, we use the 10.7–11.7GHz and 11.7–12.5GHz bands as the basis for our BSS forecasts.

We have not considered the demand for satellite audio broadcasting (e.g. SDAB), as the spectrum requirement will be very low in comparison with satellite television broadcasting.

5.3.3 Fixed satellite services (FSS)

Fixed satellite services are used extensively in the UK by organisations such as broadcasters, cruise and ferry operators, airlines and national lottery, multi national corporations and fuel stations and supermarkets. Fixed satellite services have important business, social and scientific applications and offer a unique ability to deliver communications capacity to many parts of the World not adequately served by other means.

We consider the full range of frequencies in C-band and Ku-band that are allocated to FSS use. These are shown in Exhibit 5.2 below.

GHz	Bandwidth (MHz)
3.6-4.2	600
5.85-7.075	1,225
10.7-11.7	1,000
12.5-12.75	250
12.75-13.25	500
13.75-14.0	250
14.0-14.25	250
14.25-14.3	50
14.3-14.4	100
14.4-14.47	70
14.47-14.5	30
C-band total	**1,825**
Ku-band total	**2,500**

Exhibit 5.2:

FSS allocations

[Source: Ofcom, Analysys, Mason, 2005]

We understand that the shared civil/military 13.75–14GHz band will be made available for VSATs and have included this in our forecasts.

5.4 Methodology

5.4.1 Overview of methodology

The general approach used for forecasting satellite spectrum demand for each service is as follows:

- For MSS spectrum demand is driven on a top-down ‘system’ basis. We have not attempted to model end-user demand in this study although this may warrant further investigation in future. However, given the fact that in absolute terms MSS spectrum requirements are relatively small when compared other satellite services (BSS and FSS) we believe this approach is appropriate. Other studies, such as the one undertaken by ASMS[21], have modelled traffic developments, in this case to 2010 (see later). We have not explicitly modelled the impact of aeronautical services. We would expect demand in absolute terms to be relatively small when compared with land and maritime services and believe aeronautical spectrum requirements are catered for in our assumptions for increasing demand for total spectrum in the scenarios described below.

21 The Advanced Satellite Mobile Systems Task Force – Forecast of MSS Traffic and Spectrum Requirements to 2010 (version 2.1, 12 November 2003).

- For BSS spectrum, we have modelled growth in the total number of television channels and projected trends for the broadcasting of high definition (HD) television, namely the proportion of channels broadcast in HDTV and the required bandwidth per channel (both HDTV and standard definition (SDTV)), as shown in Exhibit 5.3 .

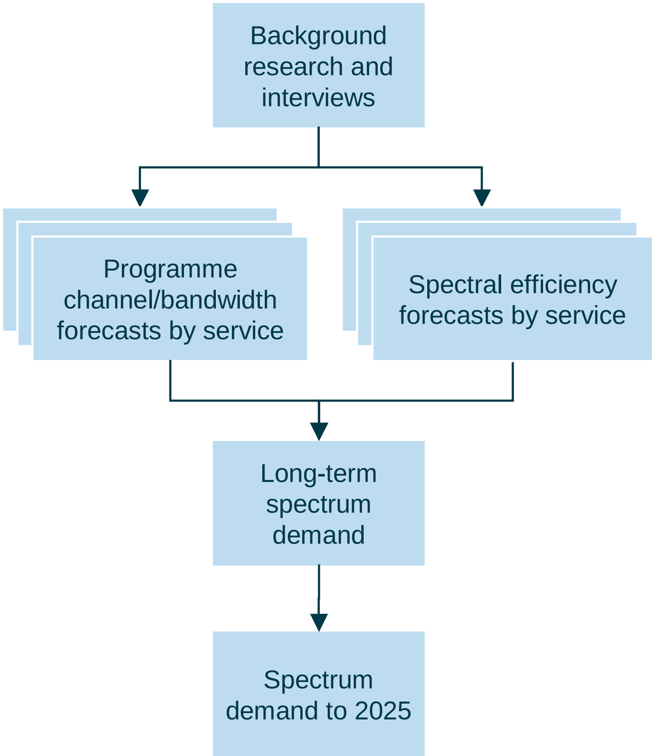

Exhibit 5.3
Approach to forecasting BSS satellite service spectrum demand [Source: Analysys, Mason, 2005]

- For FSS spectrum we model C-band and Ku-band separately. For C-band we assume future growth in FSS transponder use based on historical figures, as reported by Euroconsult. For Ku-band we have also modelled the impact of additional VSAT deployments and different developments in the average bandwidth per VSAT terminal. Finally, we have modelled the introduction of mobile services supported by FSS to long-haul aircraft, passenger ships and inter-city trains.

We have developed scenarios around the potential outcomes of each of these issues.

5.5 Modelled scenarios and key assumptions

We have developed a set of scenarios for each satellite which are further described in this section. **Please note that these forecasts represent Analysys and Mason's view of the future demand for these companies, and that this may not be consistent with the companies' own view.**

5.5.1 MSS

For the MSS scenarios the key developments to consider are:

- the success of Inmarsat's BGAN and other higher capacity services such as Thuraya's DSL service
- the future of Iridium and Globalstar, e.g. whether they are replenished
- whether or not a new system or systems is/are launched
- ICO's future and use of its 2 x 30MHz allocation
- the introduction of hybrid terrestrial/satellite ATC systems.

The three MSS scenarios are summarised below.

MSS Scenario 1

We assume the following for Scenario 1:

- Modest growth in spectrum requirements for GEO systems – we assume 2 x 7MHz of spectrum is required every 6 years starting in 2006 and coinciding with the WRCs. For Inmarsat and Thuraya, which operate with 2 x 33MHz, this represents around a 20% increase from the current allocation every 6 years, and is required to meet increasing demands for higher bandwidth services such as Inmarsat BGAN and Thuraya DSL.

- Iridium continues and is replenished on an as-needed basis. Globalstar is not replenished and Iridium makes use of the freed up spectrum for future growth. No additional spectrum is required for the Big LEOs.

- ICO continues to hold its 2 x 30MHz allocation but there is no need for future growth (either because the system remains as it is today or changes configuration, launches service but shows not additional spectrum requirements).

- No hybrid ATC system is launched.

MSS Scenario 2

As Scenario 1 with the additional requirements for spectrum:

- two hybrid ATC systems commence commercial service in 2012, requiring 2 x 30MHz each. The service date is set to take account of design, build and launch lead-time required for new systems.

MSS Scenario 3

As Scenarios 1 and 2 but with:

- 2 x 14MHz required every six years rather than 2 x 7MHz, due to greater demand for higher capacity services – this models greater penetration and higher usage per subscriber than Scenario 1.

In addition:

- one new MSS system is launched in 2015 requiring 2 x 16.5MHz (the same as Iridium and Globalstar today).

5.5.2 BSS

For the BSS scenarios the key developments to consider are:

- the growth in the number of television channels
- the rate of deployment of HDTV services

- the extent of dual (SD/HD) transmission.

There are a finite number of satellite transponders that can be used to broadcast television channels to UK households using the Sky platform, based on the satellite orbit, polarisation and frequency. Detailed information on the leasing of specific transponders on individual satellites is commercially sensitive and therefore we have had to estimate current utilisation.

For all scenarios we assume the following:

- we estimate that the currently around 70 (nominally 33MHz) transponders are used to provide around 400 standard definition (SD) television channels and 100 radio channels for the Sky platform
- satellite HDTV will be launched in 2006 (based on industry discussions)
- compression technology – bandwidth requirement of HD/SD ratio falls from four to two throughout the period
- there is sufficient capacity within the existing transponders until the end of 2006
- estimated current spectrum utilisation is 1362MHz.

Scenario-specific assumptions are summarised below.

BSS Scenario 1

- 2% initial growth in television channels for 10 years
- by 2015, 10% of all television channels will be transmitted as HDTV – 75 HDTV channels
- no dual transmission of SD and HD.

BSS Scenario 2

- 10% growth in total television channels (SD and HD) over the next five years, then continued slower growth thereafter

- by 2015, 10% of all television channels will be transmitted as HDTV – 75 HDTV channels
- no dual transmission of SD and HD.

BSS Scenario 3

- 10% growth in total television channels (SD and HD) over the next five years, then continued slower growth thereafter
- by 2015, 20% of all television channels will be transmitted as HDTV – 151 HDTV channels
- dual transmission of SD and HD throughout the period.

5.5.3 FSS

For the FSS scenarios the key developments to consider are:

- the extent to which recent historical trends in transponder demand are a guide to future spectrum requirements
- the demand for corporate networking (VSAT) versus terrestrial alternatives, characterised by additional deployment of VSAT terminals and increasing average bandwidth per terminal
- the extent to which long-haul aircraft, passenger ships and inter-city trains deploy FSS technology capable of supporting mobile applications.

Note: bandwidth per VSAT terminal is modelled on an average basis across all VSAT terminals. This current average tends to be low because most VSATs are used for low data rate applications like point-of-sale (POS) or automatic teller machine (ATM) applications. However, some VSATs within the installed base may in fact be operating at much higher bandwidths. We do not foresee mass deployment of multi-Mbit/s VSAT terminals since in many countries the increasing footprint of DSL will cater for many needs, although we have modelled DSL-like bandwidth in the mid- to long term in our forecasts as we expect this to become a minimum for corporate networks supported by satellite.

For all scenarios we assume the following:

- estimated current spectrum utilisation is 70% for C band and 85% for Ku band. This is projected to grow at 1% and 3% per annum for C and Ku band respectively.

Scenario-specific assumptions are summarised below.

FSS Scenario 1

- no major new VSAT deployment occurs
- 25% of long-haul aircraft, 19% of passenger ships and 12% of inter-city trains deploy mobile FSS solutions by 2025

FSS Scenario 2

- 10 000 new VSATs are deployed by 2012, increasing steadily to 14 000 new VSATs by 2025
- we assume current average bandwidth for these VSAT terminals is 64kbit/s and this grows to 1Mbit/s in 2015 and 2Mbit/s in 2025
- 50% of long-haul aircraft, 37% of passenger ships and 24% of inter-city trains deploy mobile FSS solutions by 2025.

FSS Scenario 3

- 10 000 new VSATs are deployed by 2012, increasing steadily to 14 000 new VSATs in 2025
- we assume current average bandwidth for these VSAT terminals is 64kbit/s and this grows to 2Mbit/s in 2015 and 4Mbit/s in 2025
- 100% of long-haul aircraft, 74% of passenger ships and 47% of inter-city trains deploy mobile FSS solutions by 2025.

5.6 Results

5.6.1 MSS

The results for the three MSS scenarios are shown in Exhibit 5.4.

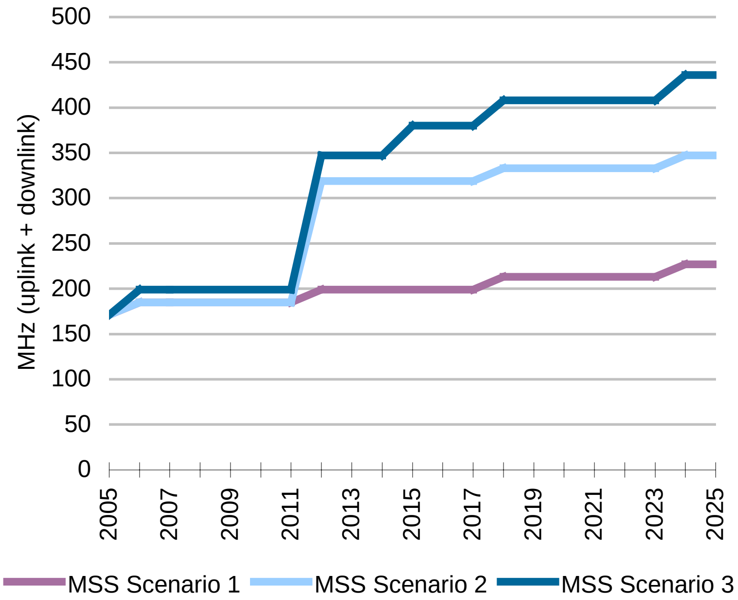

Exhibit 5.4: *Total projected MSS spectrum demand [Source: Analysys, Mason, 2005]*

MSS Scenario 1 shows a modest growth in spectrum demand from the 171MHz estimated to be currently used to a total of 199MHz by 2015 and 227MHz by 2025.

MSS Scenario 2 requires a total of 319MHz of spectrum by 2015 and 347MHz of spectrum by 2025. The big increase in spectrum demand in 2012 is caused by launch of two hybrid ATC systems.

MSS Scenario 3 requires a total of 380MHz of spectrum by 2015 and a total of 436MHz of spectrum by 2025. The big increase in spectrum in 2012 is caused by launch of two hybrid ATC systems and there is a further increase in demand in 2015 with the launch of a new MSS system.

The results for 2012 for Scenarios 2 and 3 are reasonably in line with ASMS's projections of 2 x 151MHz being required by 2010, based on a bottom-up traffic projection. It should be noted however that ASMS's assumptions for systems development are different to ours.

5.6.2 BSS

The results for the three BSS scenarios are shown in Exhibit 5.5. These are based on the case that all of the transponder demand is satisfied by using more spectrum. Once the existing spectrum allocation has been fully utilised, there are three main ways that additional transponder capacity can be made available:

- allocate additional spectrum below 15GHz
- use existing/new allocations in Ka band (which is above 15GHz)
- re-use the existing spectrum in other orbits (e.g. in an orbit between 3 and 9 degrees away).

Only the first option requires additional spectrum below 15GHz and therefore this represents the highest requirement for additional spectrum demand.

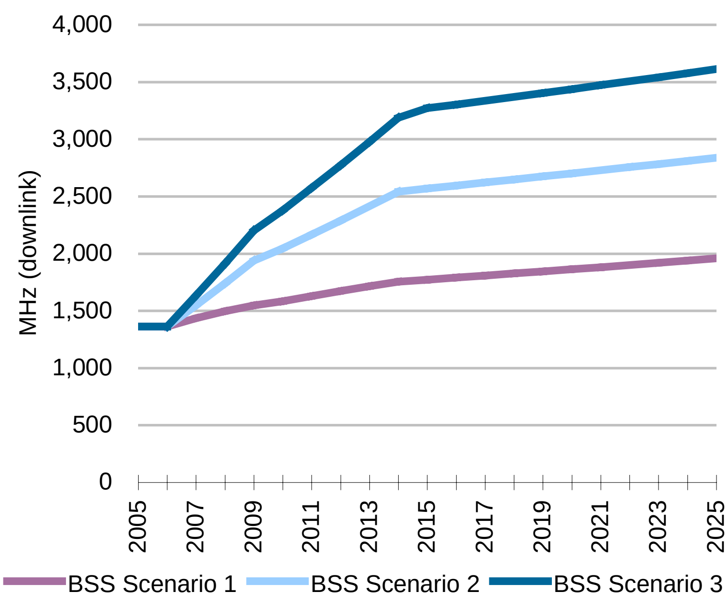

Exhibit 5.5: *Total projected BSS spectrum demand [Source: Analysys, Mason, 2005]*

Scenario 1 shows a modest growth from the current estimated 1362MHz usage of spectrum to a total of 1773MHz by 2015 and 1959MHz by 2025.

Scenario 2 requires a total requirement of 2571MHz of spectrum by 2015 and 2840MHz by 2025.

Scenario 3, which is the most aggressive, requires a total of 3272MHz of spectrum by 2015 and 3614MHz by 2025.

The number of television channels is a key driver of growth in all scenarios shown rather than the impact of HDTV.

As discussed above, there is scope for techniques such as the use of new orbital slots as an alternative means of achieving additional capacity.

5.6.3 FSS

The results for the three FSS scenarios are shown in Exhibit 5.6.

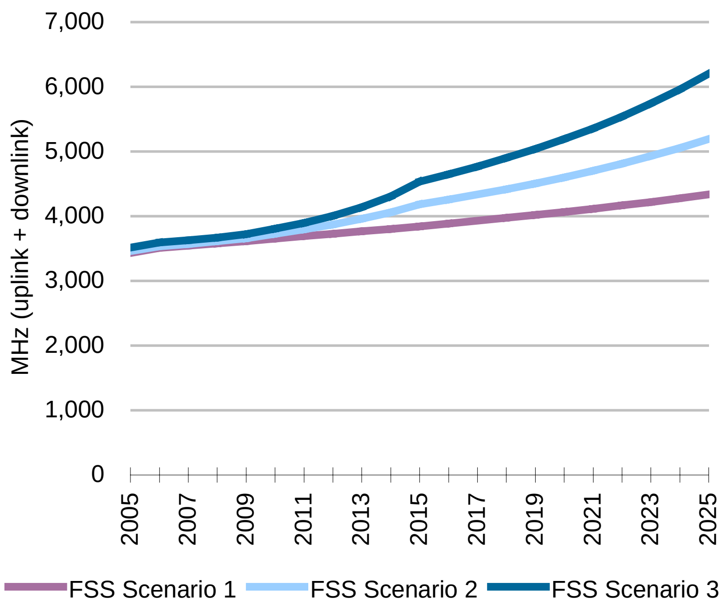

Exhibit 5.6: *Total projected FSS spectrum demand [Source: Analysys, Mason, 2005]*

Scenario 1 shows a modest growth in spectrum use from 3431MHz today, to 3841MHz by 2015 and 4335MHz by 2025. Scenario 2 requires 4180MHz by 2015 and 5193MHz by 2025. Scenario 3 requires 4535MHz by 2015 and 6202MHz by 2025.

The mobile FSS contribution to the overall FSS spectrum requirement by 2025 in Scenarios 1, 2 and 3 is 3%, 5% and 9% respectively.

5.6.4 Spectrum characteristics

In this section, we discuss the characteristics of the spectrum required for satellite services.

Exclusive versus shared

There is some scope for sharing satellite spectrum with other services (e.g. fixed-links, FWA). Spectrum for earth-space links can be shared provided that the overall interfering power-density reaching the satellite is limited, while space-earth links can be shared through the establishment of protection/co-ordination zones around earth stations– although it is noted that in the South and South East of England there is such a density of terrestrial fixed-links that that co-existence is very difficult.

Spectrum for BSS in the space-earth direction is a special case, given that there are currently more than 7 million domestic satellite television receiving installations throughout the UK. There has been an issue with interference from terrestrial fixed-links in the 11GHz band into domestic satellite television receivers which has lead to the closing of the 11GHz band to new terrestrial applications.

Licensed versus licence-exempt

Spectrum will generally need to utilise licensed spectrum due to the investment involved in satellite deployment (and therefore security of spectrum use is a necessity).

Paired versus unpaired

All satellite service spectrum is paired. Increasing usage of data (fixed VSATs and mobile terminals) could theoretically result in spectrum savings from the use of technologies such as TDD; however, the practicalities of implementing such technologies (i) over such long distances and (ii) bands shared with other uses means that unpaired usage is unlikely to be utilised.

BSS spectrum is inherently unpaired (although feeder links to the satellite are also required – these are classified as FSS links).

Harmonisation[22]

Satellite operators will seek an internationally agreed allocation of spectrum for services in view of the international nature of satellite usage. This is because the satellite is susceptible to receiving signals across a wide area, and reception of satellite signals on the ground is often heavily susceptible to interference from other users due to the low power signals that are received. As a consequence, earth-space links (and space-earth links near geographical borders) that operate in shared bands require the other uses of the band to be managed across international borders to ensure harmful interference levels are avoided.

Spectrum bands

It is much more favourable for systems to be allocated additional spectrum in the same frequency bands as existing operations. For example, we understand the 5+7MHz recently allocated to MSS will not be usable by Inmarsat's I-4 satellite, which is already in orbit. We do not however take into account such technical constraints in this study.

For MSS the 2 × 7MHz provides some capacity for expansion in the short term. The fact that the MSS allocations at 2670–2690MHz and 2500–2520MHz downlink have been

[22] In this report we define harmonisation as the identification of common frequency bands across a region (e.g. Europe) for a particular application – and in some cases a particular technological standard. This does not necessarily imply exclusive access (the exclusive provision of frequency bands for a specific application or standard).

designated for terrestrial cellular use (3G expansion band) may become an issue for MSS in the longer term should our most optimistic scenarios materialise. Demand for spectrum below 6GHz from cellular providers and BWA providers will compete with any requirement for additional spectrum for MSS.

The existing Ku-bands work well for BSS as it is today. It has been suggested that from a technical point of view the 12.5–12.75GHz band could be used for expansion as it can be used by existing household appliances (set-top boxes, etc.). However, in practice, this is unlikely to be achievable since this band is already heavily used by VSATs. The re-use of existing spectrum from other orbits is attractive from a spectrum efficiency point of view but will require households to obtain new receiving equipment. A move to Ka-band is a possibility but this band is more susceptible to rain fade and again will require households to obtain new receiving equipment. Securing additional spectrum will be difficult in view of the limited amount of spectrum available in this frequency range and the demand from other services (e.g. fixed links).

For FSS the bands used for VSAT are heavily utilised. This situation will be eased somewhat if additional spectrum around the 14GHz band is made available subject to agreement with the MOD.

Finally, hybrid Ku/Ka systems may emerge that require spectrum both below and above 15GHz. As above, securing additional spectrum could be challenging in view of spectrum shortages and competing demand from other services (e.g. fixed links).

5.7 Conclusions

The MSS market is subject to significant uncertainty surrounding the future of existing systems and the possible launch of new ones. Our ‘system-driven’ modelling suggests that even in the most optimistic scenario total MSS spectrum requirements in the long term will be below 500MHz in total, compared with the 171MHz used today. We are not convinced that there will be sufficient end-user demand to warrant the deployment of the new satellite systems included in our most aggressive scenario. A more likely outcome is our least aggressive scenario, suggesting that a total of 227MHz of spectrum would be required for MSS in 2025.

Our modelling for BSS suggests that the rapid growth in the number of satellite television channels, and to a lesser extent the move to dual HDTV/standard television broadcasting, could result in significant increases in demand for additional transponder capacity. This would result in an increase in demand for spectrum from around the 1400MHz currently in use to a total of around 3600MHz by 2025 under our most aggressive scenario. In the short term, some additional transponder capacity within existing spectrum allocations is likely become available in 2007 (subject to co-ordination). Once the existing spectrum allocation has been fully utilised, there are alternative options available for providing additional capacity. For example, new satellites could be deployed in different orbital slots, thereby allowing the re-use of existing spectrum. At this time it is difficult to predict how the additional transponder capacity will be provided in the medium to long term, but given constraints on the availability of additional spectrum, the use of additional orbital slots may be the only practical solution.

Our analysis suggests that FSS is also likely to suffer from spectrum shortages in the longer term. The extent of these shortages depends on the large-scale deployment of Ku band terminals, increases in the average bandwidth per terminal, and usage/take-up of mobile satellite applications on FSS systems. We forecast that around 3400MHz of spectrum is used at present, and under our most aggressive scenario this would rise to a total of 6200MHz by 2025. However, as for MSS, we are not convinced that there is sufficient end-user demand and therefore our least aggressive modelled scenario is most likely to occur in practice. This suggests that there will be a modest growth in spectrum demand for FSS to a total of around 3850MHz by 2015 and around 4350MHz by 2025.

6 Terrestrial television broadcasting services

6.1 Introduction

This section discusses the future demand for spectrum for the terrestrial broadcasting of television (satellite delivery of television is covered in Section 5).

Our analysis of the broadcast sector has focused on television as the major driver of demand for spectrum for terrestrial broadcast services. It was agreed with IASH that radio/audio broadcasting, which uses a small proportion of the spectrum allocated to terrestrial broadcasting, would be excluded from this study. Terrestrial television currently uses 368MHz of spectrum in Bands IV and V.

Television is currently delivered to UK households by a number of different platforms such as:

- cable (cable television or ADSL)
- satellite (subscription or free-to-air (FTA))
- terrestrial broadcast network (both traditional analogue FTA television as well as digital television including Freeview). Analogue television and Freeview currently reach around 98.5% and 73% of households respectively.

In this report we use the term 'fixed terrestrial television' to mean traditional fixed or portable television receiving equipment, and 'mobile television' to mean television reception on mobile or portable devices such as cellular handsets.

Changes to terrestrial broadcast television occur relatively slowly due to the long lead times associated with the changeover of household televisions, frequency co-ordination with Europe and the physical roll out of new transmission networks, e.g. for digital terrestrial television (DTT).

A major digital switchover (DSO) project is already underway within the UK for the roll out of a new DTT network and the shutdown of the analogue television network. It is anticipated that this programme will be completed by 2012 (but this date is yet to be confirmed by government) and consequently no other major changes to the spectrum requirement for fixed terrestrial television in the UK are expected until after 2012.

We consider the future demand for spectrum for terrestrial broadcasting in terms of:

- increases in the number of terrestrial (standard definition) digital television programme channels – which could generate increased demand for spectrum from 2012
- the introduction of high definition television (HDTV) – which may generate increased demand for spectrum after 2012
- the introduction of mobile television – which could generate increased demand for spectrum before 2012.

6.2 Review of secondary research

A review of secondary research was carried in the early part of this study and a list of the main documents is provided in Annex E. Some of the key findings of these documents are given below.

Digital switchover

- Ofcom concluded[23] that the market alone will not deliver switchover and that it was time to move from planning to implementation.

23 *Driving Digital Switchover – a report to the Secretary of State* (Ofcom April 2004).

- The government set two conditions for switchover back in 1999: first, that all households that can currently get the main public service broadcasting (PSB) channels (BBC1, BBC2, ITV and Channel 4) in analogue form can receive them on digital systems; and, second, that digital television would be affordable for the vast majority of households. The *anticipated* date for the completion of DSO is 2012, but there are still important questions that need to be resolved before the government will announce the final timetable for switchover.

- The plan for DSO is well developed but will depend upon satisfactory frequency co-ordination being reached within Europe.

- New digital PSB channels will reach broadly the same percentage of households as today's analogue television (around 98.5% of households). Commercial channels will be able to determine their own levels of coverage, but this must be at least as widespread as digital DTT coverage today.[24]

- DTT must be planned in the context of digital television more generally such that appropriate technological neutrality is maintained between different platforms. Ofcom is committed to achieving switchover in the UK to the agreed timetable on a multiplatform basis.

- It is anticipated that a 'digital dividend' of 112MHz of spectrum could become available after DSO has been completed[25] – this is the existing spectrum used for analogue broadcasting that could be released, although it is important to note that there are other existing uses for some of this spectrum (e.g. for programme-making and special events) and potential future alternative uses.

- In terms of future development of DTT, worthwhile spectrum efficiency gains would require DTT to move to newer and more efficient compression standards, however, neither of these would be 'backwards compatible' to the 5+ million existing DTT receivers, so achieving these efficiency gains would be challenging.

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24 Large parts of the UK (particularly rural areas) do not currently have access to DTT. Ofcom estimates that around 73.1% of households have access to *all* current DTT services – however, a greater proportion of households will have access to a smaller number of multiplexes.

25 The release of this spectrum is subject to the successful conclusion of RRC06, and even then not all of the released spectrum will be available across the whole of the UK due to interference from (and necessary protection of) continental and Irish television broadcasts.

HDTV

- Although DTT programming is likely to start in standard definition format, it looks inevitable that some high-definition programming will be broadcast soon afterwards. The question is: how much and when?

- The main UK broadcasters have already committed to begin broadcasting in HDTV in the near future:
  - BSkyB has announced that it is to start broadcasting HDTV channel in 2006
  - BBC has announced that it is to produce all programme material in HDTV by 2010.

- The migration to HDTV could also result in additional spectrum being required for programme-making activities[26] due to the need to increase the quality (bandwidth) of the original recordings, etc.

Mobile television

- UK trials using two different technologies, DVB-H and DMB, are either underway or are being planning – the former by O_2 and Arqiva (formerly NTL Broadcast) in the Oxford region and the latter by BT, GWR and Virgin Mobile inside the M25.

- Alongside DMB and DVB-H, there are several other potential delivery platforms including satellite (S-DMB) and 3G (e.g. Orange has launched a mobile television service over its existing 3G network). However, to date, no real favourite has emerged.

26 Quantification of the future spectrum demand for programme-making falls outside the scope of this study.

6.3 Key developments

6.3.1 DSO project

It is anticipated that DSO will be completed by 2012 (subject to government confirmation) and this will deliver three PSB multiplexes (offering similar coverage to today's analogue PSB channels) and three commercial multiplexes with a lower level of coverage.

A key feature of the switchover plan is to maximise the ability for households to continue to use their existing rooftop antennas by retaining existing analogue transmitter sites for DTT transmissions.

The current DSO plan anticipates releasing 112MHz of spectrum, but this is subject to detailed planning and agreement at the 2006 regional radio conference (RRC06).

6.3.2 Post-DSO developments

Looking ahead from 2012, it is important to consider the likely developments (if any) of the DTT platform (comprising the DTT transmitter network itself as well as the associated household receiving equipment), as these will be the main drivers for future demand for spectrum for terrestrial broadcast services.

As part of the DSO, some households may be forced to obtain new equipment (e.g. set top boxes (STBs)) to continue to receive terrestrial broadcasts, and there may also be issues with ancillary equipment such as video recorders. Therefore, it is likely to be unacceptable to once again impose forced migration to a new technology/platform for some considerable time after DSO has been completed. We anticipate that any new services (such as HDTV) that are introduced on to the DTT platform will have to be either backwards-compatible with household DTT equipment or there will be continued simulcasting of existing DTT transmissions.

Given that the completion of DSO is still at least seven years away, and that many issues with DSO are still to be resolved, there is little third-party research or predictions as to what might happen. Therefore, we have adopted a scenario-based approach based on the most likely developments. The main drivers for spectrum demand for terrestrial television that are considered in this study are:

- an increase in the number of (standard definition) channels available
- the introduction of terrestrial HDTV
- the introduction of mobile television.

For each of these services, the type and level of coverage will also influence the total spectrum demand.

We also note that there may be potential demand for spectrum for community or local television in the future. As well as being highly uncertain, we regard this spectrum requirement to be relatively modest (e.g. depending on how 'local' the coverage area is, it may be possible to fit this within the spectrum used for multi-frequency networks), so we have not explicitly modelled this as part of our analysis.

Please note that we have not undertaken a detailed analysis of end-user demand for these services, nor have we analysed in detail the underlying economics of each service in respect of its commercial viability. The demand for spectrum in practice may therefore be limited by such factors.

Increase in the number of standard definition channels

There is currently keen commercial interest in additional channel capacity on the existing Freeview DTT platform. Since its re-launch as an FTA service, Freeview has become increasingly popular. Recent research[27] suggests that Freeview now accounts for nearly one-third of homes equipped with digital television, and media reports suggest that, as a consequence, commercial channel 'slots' on the Freeview platform are becoming more expensive because of a greater commercial interest by broadcasters – for example, ITV plc has recently acquired SDN Limited (holder of the licence to operate Multiplex A on DTT) for GBP134 million. If Freeview was to overtake Sky as the dominant multi-channel platform, then this could increase demand for commercial terrestrial digital television channels even further.

27 Source: *Digital Television Update Q1 2005*, Ofcom.

For new commercial DTT channels, we believe that it is also important to consider the ability for households to receive new channels using their existing DTT equipment. If potential viewers have to buy new equipment to receive these new channels, then this is a potential barrier to take-up. This is likely to mean that demand for additional spectrum will primarily be for spectrum in the existing Bands IV/V.

Introduction of HDTV

There is strong interest in HDTV today and it is possible that over time the HDTV format will become the dominant picture format within Europe, although predicting the exact timeframe and delivery platforms is difficult. One UK satellite broadcaster has suggested that 30% of its customers will be using high-definition services by 2011, rising to 70% by 2016. Others are more cautious and suggest that the introduction of HDTV is more akin to the protracted change from black and white to colour television, which took from 1967 to 1985 for the majority to switchover.

The expectation is that once viewers are accustomed to the high-definition format on other platforms (e.g. DVD), they are likely to expect it to be available on broadcast television as well.

Type of network

DTT networks using the digital video broadcast (DVB) standard can be implemented as either single frequency networks (SFN) or multi-frequency networks (MFN) and the type of network influences the demand for spectrum. Both types have advantages and disadvantages, which are explained in more detail in Annex E. In particular, we note that MFN is required for the transmission of localised content. The historical nature of broadcasting local content (on the BBC and ITV) to viewers means that MFN will be required to facilitate the continuation of local content broadcasting (as required by the obligations on broadcasters under the Broadcasting Act), as well as facilitating the carriage of local advertising.

The individual scenarios below describe which type of network has been assumed.

Level of coverage

The metric for national coverage of PSB channels on the new DTT platform is likely to be around 98.5% of households, and in order to achieve this most, or all, of today's (more than 1150) transmitter sites will need to be used. Commercial channels will be able to determine their own levels of coverage which, as a minimum, must be at least as good as digital DTT coverage today (around 73% of households). We have assumed that it will not be cost-effective to provide commercial television coverage to more than 90% of households. For new services, various different levels of coverage are described in the scenarios, including London and urban coverage.

6.3.3 Mobile television

There is currently a great deal of interest in mobile television, with a number of different technologies being proposed. A fundamentally different approach to traditional fixed terrestrial television, which is optimised for reception at fixed locations at the standard television definition of 625 lines, is required for mobile television.

The two main technologies that are either being or are about to be trialled for mobile television in the UK are digital multimedia broadcasting (DMB) and digital video broadcasting handheld (DVB-H). Both DVB-H and DMB use the same multiplexing scheme; their roots, however, are somewhat different, with DMB being evolved from digital audio broadcasting (DAB) and DVB-H evolving from the terrestrial DVB standard that is currently being used to deliver (DVB-T). In addition there are other technologies which could be deployed (e.g. Qualcomm's MediaFLO system). For the purposes of our modelling, we have focused on the deployment of DVB-H and DMB systems; however, this should not be taken as to preclude the use of an alternative technology such as MediaFLO.

As discussed above, we also note that there are other potential delivery platforms for mobile television include satellite (S-DMB) and 3G.

6.4 Methodology

This section presents an overview of the methodology underlying our analysis of the future demand for terrestrial broadcast television.

6.4.1 Overview of methodology

Our approach for the forecast of the spectrum demand for terrestrial television is illustrated in Exhibit 6.1 below:

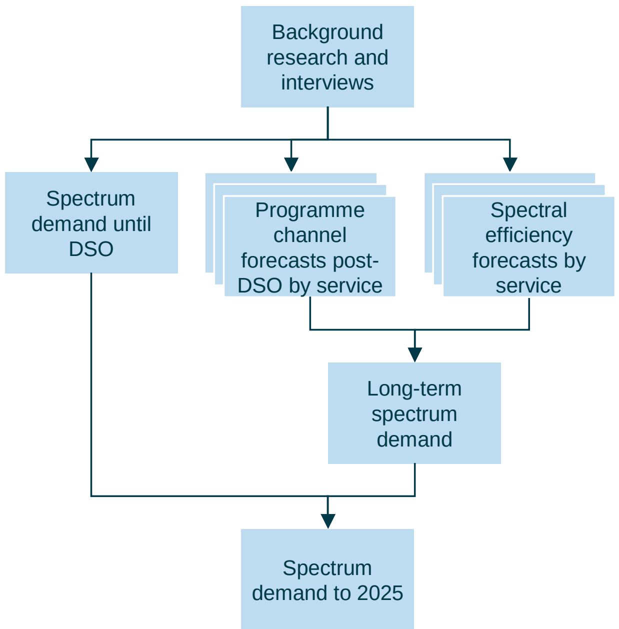


Exhibit 6.1: *Approach to forecasting demand for spectrum for terrestrial television services [Source: Analysys, Mason, 2005]*

One of the key findings of the study is that the short-term availability of spectrum for fixed terrestrial television services in the UK is effectively determined by the DSO plan, and this situation is not expected to change until after the DSO has been completed (expected to be in 2012). Mobile television could potentially be deployed in advance of this, and therefore we have considered the demand for fixed and mobile television in separate scenarios.

Our forecasts for channel and service growth are based on industry interviews and high-level Web-based research. These channel forecasts have been combined with spectral efficiency forecasts to produce spectrum demand forecasts for three regions: London, urban and rural.

Again, it should be noted that we have not undertaken a detailed analysis of end-user demand for these services, nor have we analysed in detail the underlying economics of each service in respect of its commercial viability. The demand for spectrum in practice may therefore be limited by such factors.

All scenarios assume that the DTT platform continues to operate up to 2025, for some scenarios this implies a period of simulcasting. If the need for simulcasting could be reduced (by deployment of new HDTV-compatible STBs to all households), then this could free up a significant amount spectrum that could be used to either introduce more television services or to release spectrum for other purposes.

6.4.2 Introduction to scenarios

We have considered four scenarios (1–4) for fixed terrestrial television and two scenarios (1 and 2) for mobile television. These are described in Exhibit 6.2 below and in further detail in Annex E.

Fixed Terrestrial TV		***Standard definition (SDTV)***			***High definition (HDTV)***	
Scenario	*Concept*	**DSO channels** (PSB≈ 98.5% HH, Comm. ≈ 90% HH)	**London commercial**	**'Urban' commercial**	**PSB** (≈ 98.5% HH)	**Commercial** (≈ 90% HH)
1: High spectrum demand	DTT becomes the dominant multi-channel platform of choice with an aggressive take-up of commercial SDTV channels to centres of population as terrestrial TV competes with Sky/cable for advertising revenue. Widespread HDTV implementation as HDTV becomes the de facto medium	Yes	80 TV channels	30 TV channels	15 TV channels	15 TV channels
2: Medium spectrum demand	Limited HDTV implementation with national coverage of most PSB channels. Some deployment of commercial SDTV channels to centres of population	Yes	30 TV channels	15 TV channels	6 TV channels	9 TV channels
3: Limited HDTV deployment	Concept is to locate as many HDTV channels as possible in band 4/5 spectrum (e.g. to ease migration to HDTV), but this squeezes out any new commercial SDTV channels	Yes	–	–	6 TV channels	6 TV channels
4: Low spectrum demand	The post-DSO DTT network continues to operate but is not developed any further. HDTV is only available on other platforms	Yes	–	–	–	–

Mobile Terrestrial TV		***DVB-H***			***DMB***		
Scenario	*Concept*	**London**	**Urban**	**Rural**	**London**	**Urban**	**Rural**
1: High spectrum demand	Two DVB-H networks and two DMB networks are implemented. Local content on three networks (MFN) with national content on the other network (SFN)	20+20 TV channels	20+20 TV channels	20+20 TV channels	5+5 TV channels	5+5 TV channels	5+5 TV channels
2: Low spectrum demand	Single DVB-H (SFN) and a single DMB network (SFN) are implemented, both with national content	20 TV channels	20 TV channels	-	5 TV channels	5 TV channels	-

Exhibit 6.2: *Summary of terrestrial television scenarios [Source: Analysys, Mason, 2005]*

Please note that we have not modelled whether there will be sufficient end-user demand or generated revenues from the underlying services (e.g. mobile television) to warrant the deployment of multiple networks. As discussed in Section 8, our approach has been to ascertain the possible range of demand in the future for spectrum from service providers, and to allow the market to determine the number of viable providers of the service.

6.4.3 Key assumptions

Exhibit 6.3 below lists the key assumptions used to evaluate scenarios. Further details of the assumptions are also presented in Annex E and we advise the reader to review this annex in conjunction with this section.

Parameter	*Assumption*
HDTV impact	HDTV becomes the de facto TV format within Europe and is universally available by 2025
Compression	Compression technology improves to allow three HDTV channels to be carried per 8MHz multiplex by 2012 In order to maintain backward-compatibility with current set-top boxes and digital TVs, current MPEG2 compression is maintained[1] for all SDTV channels
Multiplex capacity	It is assumed that the **average** capacity of a single 8MHz multiplex is 6 SDTV channels, based on the implementation of 64-QAM on all multiplexes (as per Ofcom's preferred Option 3[2])
Introduction of new SDTV commercial TV channels	Additional commercial channels are introduced using the existing SDTV format
Network spectrum requirements	Each national multi-frequency network (MFN) requires a block of six 8MHz channels A single frequency (SFN) network can be used for limited commercial coverage of the main urban area. If this proves not to be the case, then a multi-frequency network may be required which will increase the spectrum demand

1: It might be possible to include support for the use of more advanced compression in new set-top boxes that would assist the introduction of more capacity in the future. For example, a move to MPEG4 compression could double the channel capacity. A clear view of the evolution of the post-DSO market could encourage manufacturers of set-top boxes to include such a facility

2: 'Planning Options for Digital Switchover – Ofcom statement issued on 1 June 2005

Exhibit 6.3: *Summary of key assumptions for terrestrial television demand scenarios [Source: Analysys, Mason, 2005]*

6.5 Results

In this section we present an overview of the scenarios modelled and the results. Further details, such as the specific assumptions underlying each of the scenarios, can be found in Annex E of this report.

Terrestrial television Scenario 1 – high spectrum demand

This is the most aggressive scenario in which DTT becomes the dominant multi-channel platform of choice. There is an increase in the number of commercial SDTV channels that are available on the DTT platform as well as a widespread terrestrial HDTV implementation with most of the core DTT platform television channels also being available in HD format.

Consumers will need an high definition television set and/or new/updated STBs and aerials in order to receive HDTV, with the assumption that they are willing to pay for this in order to receive the new HDTV service. In order to maintain compatibility with the SDTV DTT platform transmissions, it is necessary to simulcast both HDTV and SDTV for a period.

Breakdown of spectrum demand

Band IV/V spectrum for DSO DTT services	256MHz
Spectrum for additional commercial SDTV channels	112MHz
Spectrum for HDTV	280MHz
Overall spectrum requirement	648MHz

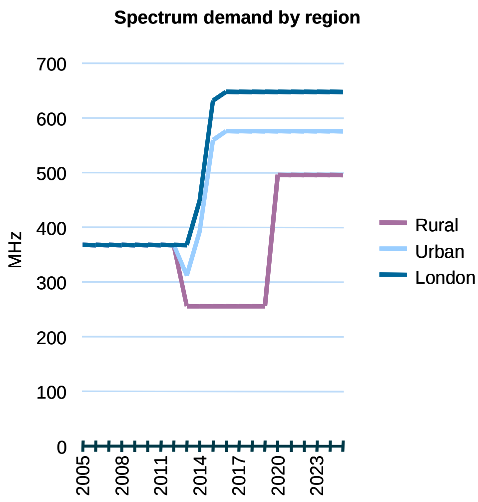


Exhibit 6.4: *Terrestrial television Scenario 1 spectrum demand [Source: Analysys, Mason, 2005]*

The resulting spectrum demand is:

- **Planned DTT platform** – 256MHz of spectrum is required.
- **New commercial SDTV services** – 112MHz of spectrum is required. As discussed above, spectrum in the existing Bands IV/V would be preferred for compatibility with existing DTT receiving equipment.
- **New HDTV services** – 280MHz of spectrum is required. There is greater scope for this demand to be met using spectrum outside Bands IV/V since new receiving equipment will be required anyway.

Terrestrial television Scenario 2 – medium spectrum demand

This is a medium spectrum demand scenario where more commercial channels become available on the DTT platform and there is a limited terrestrial HDTV deployment.

Consumers will need an HDTV set and/or new/updated STBs and aerials in order to receive HDTV. In order to maintain compatibility with the SDTV DTT platform transmissions, it is necessary to simulcast both HDTV and SDTV for a period.

Breakdown of spectrum demand

Band IV/V spectrum for DSO DTT services	256MHz
Spectrum for additional commercial SDTV channels	40MHz
Spectrum for HDTV	120MHz
Overall spectrum requirement	416MHz

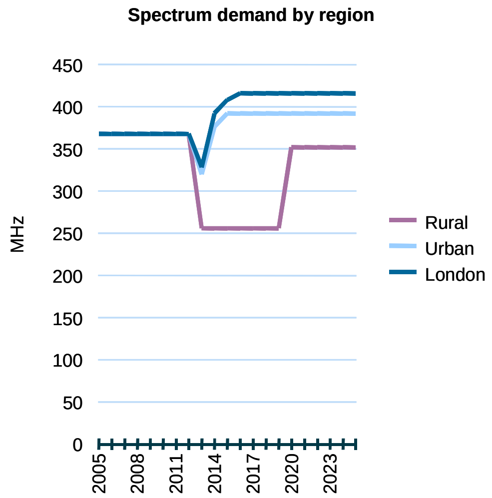


Exhibit 6.5: *Terrestrial television Scenario 2 spectrum demand [Source: Analysys, Mason, 2005]*

The resulting spectrum demand is:

- **Planned DTT platform** – 256MHz of spectrum is required.
- **New commercial SDTV services** – 40MHz of spectrum is required. As discussed above, spectrum in the existing Bands IV/V would be preferred for compatibility with existing DTT receiving equipment.
- **New HDTV services** – 120MHz of spectrum is required. Again, there is greater scope for this demand to be met using spectrum outside Bands IV/V since new receiving equipment will be required anyway.

Terrestrial television Scenario 3 – limited HDTV deployment

This scenario assumes limited terrestrial HDTV deployment; however, it also assumes that no new commercial SDTV channels are launched on the DTT platform.

Breakdown of spectrum demand

Band IV/V spectrum for DSO DTT services	256MHz
Spectrum for additional commercial SDTV channels	0MHz
Spectrum for HDTV	112MHz
Overall spectrum requirement	368MHz

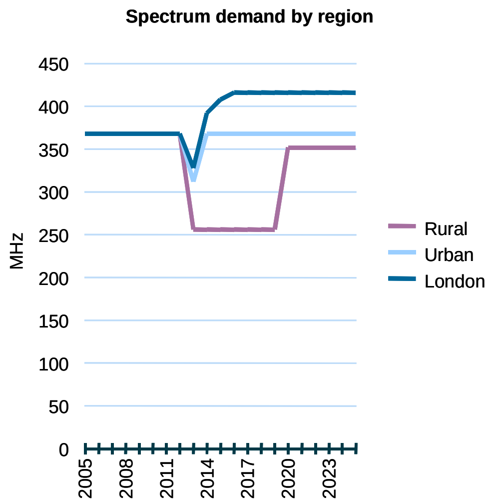


Exhibit 6.6: *Terrestrial television Scenario 3 spectrum demand [Source: Analysys, Mason, 2005]*

The resulting spectrum demand is:

- **Planned DTT platform** – 256MHz of spectrum is required.
- **New commercial SDTV services** – no spectrum is required.
- **New HDTV services** – 112MHz of spectrum is required.

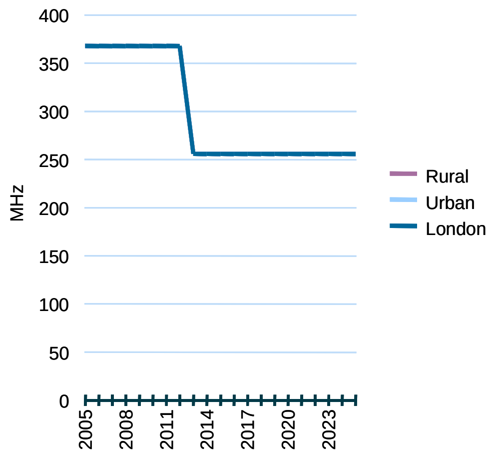
Terrestrial television Scenario 4 – no DTT development

This scenario assumes that the DTT platform continues to operate, but it is not developed any further. No new SDTV commercial channels are available on the DTT platform and HDTV is only available on other platforms.

Breakdown of spectrum demand

Band IV/V spectrum for DSO DTT services	256MHz
Spectrum for additional commercial SDTV channels	0MHz
Spectrum for HDTV	0MHz
Overall spectrum requirement	256MHz

Spectrum demand by region



Note: In the chart, the urban and rural lines are the same as for London, and are therefore hidden

Exhibit 6.7: *Terrestrial television Scenario 4 spectrum demand [Source: Analysys, Mason, 2005]*

Under this scenario, a total of 256MHz of spectrum is required after DSO is completed in 2012.

Mobile television Scenario 1 – high demand

This is our high demand scenario for mobile television spectrum, and it assumed that both DMB and DVB-H networks are implemented on a widespread basis. In practice, the spectrum requirement we have modelled may actually arise for additional programming (channels) on a smaller number of mobile television networks (as detailed in Scenario 2), rather than for a larger number of competing networks.

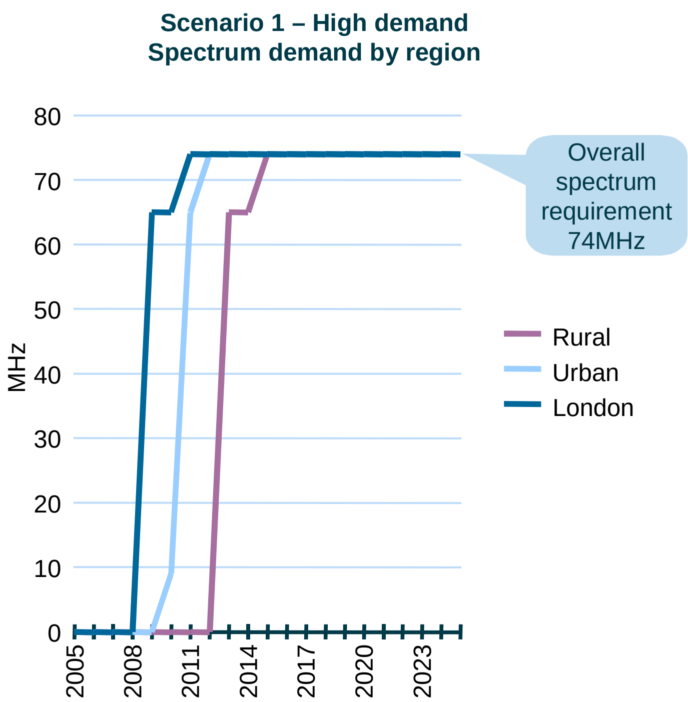


Exhibit 6.8:
Mobile television Scenario 1 total spectrum demand [Source: Analysys, Mason, 2005]

Under this scenario there is a demand for a total of 74MHz of spectrum.

Mobile television Scenario 2 – low demand

This is our low demand scenario for spectrum for mobile television, where we assume that two single frequency networks are implemented. We note that potential service providers may prefer to deploy multi-frequency networks for mobile television, as these are apparently considerably less costly to deploy and operate. If this is the case, spectrum demand for mobile television services will be higher than modelled under this scenario, but lower than the demand forecast estimated under Scenario 1. We have not explicitly modelled the deployment of two multi-frequency mobile television networks as an alternative scenario, since the total spectrum demand for mobile television is modest in comparison with fixed terrestrial television – and therefore it is not critical to the overall study findings.

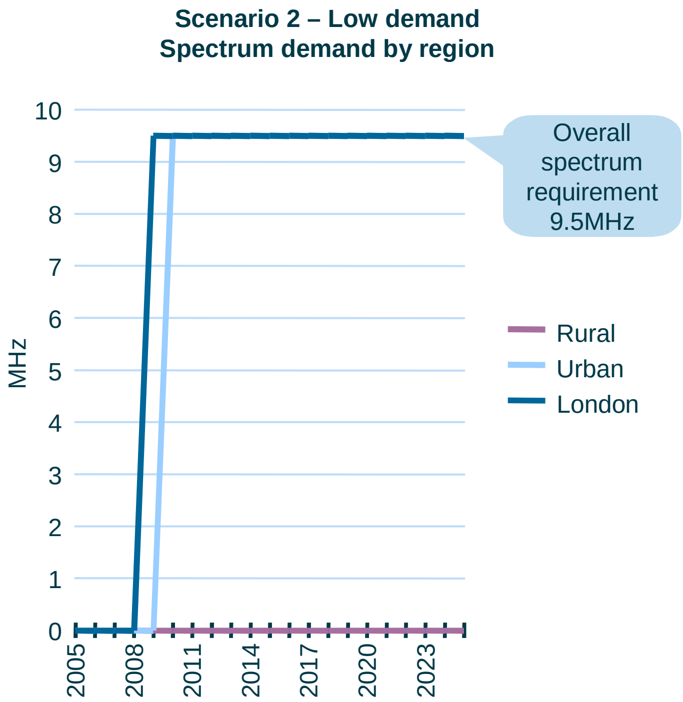


Exhibit 6.9: *Mobile television Scenario 2 total spectrum demand [Source: Analysys, Mason, 2005]*

Under this scenario there is a demand for a total of 9.5MHz of spectrum.

6.5.4 Spectrum characteristics

In this section, we discuss the characteristics of the spectrum required for terrestrial broadcast television.

Exclusive versus shared

Spectrum used for broadcasting is primarily exclusive. The high-power nature of broadcasts means that it is difficult to share spectrum with other high-power applications. Geographical sharing is possible where non-national multiple frequency multiplexes are deployed, e.g. interleaving with programme-making and special events. A mixture of single frequency networks and multi-frequency networks will also facilitate sharing of the spectrum with other services such as programme-making and special events.

Licensed versus licence-exempt

Spectrum will need to be licensed due to the high-power characteristics of broadcast terrestrial television and the need for co-ordination with high-power broadcast transmissions from neighbouring European countries.

Paired versus unpaired spectrum

Broadcast spectrum is inherently unpaired.

Harmonisation[28]

Harmonisation of spectrum used for terrestrial broadcasting could facilitate European/global economies of scale for equipment. However, the UK market is sufficiently large that most of the scale economies would still be realised in the advent of non-harmonised spectrum being used for broadcasting – for example, the use of different schemes (PAL, SECAM, etc.) for analogue broadcasting does not mean that television receiver costs are much higher than would be the case under a unified scheme.

For mobile television, there is likely to be greater demand for harmonised frequency bands due to the global nature of the mobile phone market and the high R&D costs associated with developing receivers for specific bands, given the power and space constraints particular to mobile terminals.

In the medium to long term, the development of frequency-agile radios could reduce the importance of harmonisation of individual frequency bands.

28 In this report we define harmonisation as the identification of common frequency bands across a region (e.g. Europe) for a particular application – and in some cases a particular technological standard. This does not necessarily imply exclusive access (the exclusive provision of frequency bands for a specific application or standard).

Spectrum bands

We expect that demand for spectrum for terrestrial television services will be greatest in Bands IV/V given that this band is already used for television both in the UK and Europe, both for compatibility with existing television receiver equipment and ease of co-ordination with Europe for the high-power transmitter sites.

For both fixed terrestrial television and mobile television, demand for additional spectrum will be primarily focused on frequencies below 1GHz in view of the propagation characteristics of the band (lower cost of covering a given area as the signals travel further). There will be heavy demand for the 112MHz of spectrum that is expected to be released as a result of DSO – especially from cellular network operators (current and potential new entrants).

Spectrum immediately above 1GHz (e.g. L-Band) may be an alternative (e.g. for earlier deployment of mobile television services); however, the economic case for the use of higher frequencies is by no means certain in view of the higher coverage costs. Again, this spectrum could also be in heavy demand from cellular network operators, and possibly from BWA providers.

6.6 Conclusions

In summary, the longer-term spectrum demand for terrestrial television will largely depend upon whether there is significant demand for additional commercial channels and HDTV:

- In the short to medium-term, the DSO project will primarily determine the spectrum demand from terrestrial fixed television broadcasting services up to 2012.
- In the longer term, spectrum demand for the terrestrial television platform is more uncertain, given the competition from other platforms such as satellite, cable and perhaps broadband in the future. If terrestrial HDTV is introduced, it will generate the majority of demand for additional spectrum.

- Our projections suggest that spectrum demand for fixed terrestrial television ranges from:
  - **648MHz** – where DTT becomes the dominant multi-channel platform of choice – this is a very significant amount of spectrum
  - **416MHz** – where there is a more limited introduction of HDTV and additional commercial SDTV channels
  - **368MHz** – where there is a limited deployment of HDTV and no increase in the availability of SDTV channels on the DTT platform
  - **256MHz** – where the post-DSO DTT platform remains static.

Mobile television is still in its infancy and its future market is still very uncertain

- Mobile television is still very much within its infancy in the UK and there are a number of competing technologies. The level of take-up of mobile television is not yet clear, nor is the platform that will be used to deliver it.

- Our projections suggest that the spectrum demand ranges from:
  - **9.5MHz** – for two networks with a single operator each, offering coverage only in urban areas
  - **74MHz –** for an aggressive roll out of mobile television where there are three networks with widespread coverage and regional content.

Please note that we have not undertaken a detailed analysis of end-user demand for these services, nor have we analysed in detail the underlying economics of each service in respect of its commercial viability. The actual demand for additional spectrum for terrestrial broadcasting services may therefore be limited by such factors.

Shortages of spectrum below 1GHz may mean that the expansion of terrestrial broadcasting services (including the introduction of mobile television) may need to be undertaken at higher frequencies – e.g. in the 1–2GHz range. The additional costs of using such frequencies to cover a given area in relation to Bands IV/V are considerable. As a result, this may restrict the coverage areas where services can be provided on an economic basis. In turn, this could cause increased migration to alternative delivery platforms (e.g. satellite).

7 Macro scenarios

7.1 Introduction

We have developed three macro scenarios that combine the scenario forecasts in each of the five services: an 'economic-downturn' scenario, a 'base case' scenario and a 'data-takes-off' scenario. A brief overview of these scenarios is given in Exhibit 7.1 below.

	"Economic downturn"	*"Base case"*	*"Data takes off"*
Rationale	In this scenario we have considered the impact of an economic downturn on spectrum demand	The base case represents the most likely development of spectrum demand in the future	This scenario assumes an aggressive take-up of wireless data services and new TV services
Description	A downturn in spending inhibits the take-up of all services: • Modest growth in cellular 3G services • Cellular operators do not switch from leased lines to fixed links • BWA fails in urban areas • Weak demand for MSS • There is little demand for additional SDTV and HDTV channels (both terrestrial and satellite) • Moderate FSS growth through mobile FSS solutions, no new VSATs deployed • Mobile TV demand will be weak	This scenario assumes that: • Modest growth in cellular 3G services • Vodafone and O2 switch from leased lines to fixed links • BWA fails in urban areas • Weak demand for MSS • There is limited demand for additional DTT and HDTV on terrestrial but stronger demand on satellite • Moderate FSS growth through mobile FSS solutions, no new VSATs deployed • Mobile TV demand will be relatively strong	This aggressive scenario assumes: • Wireless data takes off, both in terms of cellular 3G services and broadband wireless access • All cellular operators use fixed links for majority of backhaul • Strong demand for MSS • There is strong demand for additional DTT and HDTV (both terrestrial and satellite) • Strong FSS growth through mobile FSS solutions, 14,000 new VSATs deployed by 2025 • Mobile TV demand will be relatively strong

Exhibit 7.1: *Overview of the three macro scenarios [Source: Analysys, Mason, 2005]*

7.2 Results

Our base case scenario forecasts that the five services modelled (cellular, terrestrial fixed-links, BWA, satellite and terrestrial television) will need a total of 10.2GHz of spectrum below 15GHz by 2025. We forecast that by 2011, demand in urban areas will exceed the 7.7GHz of spectrum that is currently available for these services. Exhibit 7.2 and Exhibit 7.3 show the spectrum demand for the base case in urban and rural regions. Note that the difference in demand between the urban and rural spectrum demand forecasts is small. This is due to the fact that, although the forecasts for cellular, terrestrial fixed-links and terrestrial television are all lower in rural areas, the demand for satellite, which is constant throughout all areas, dominates.

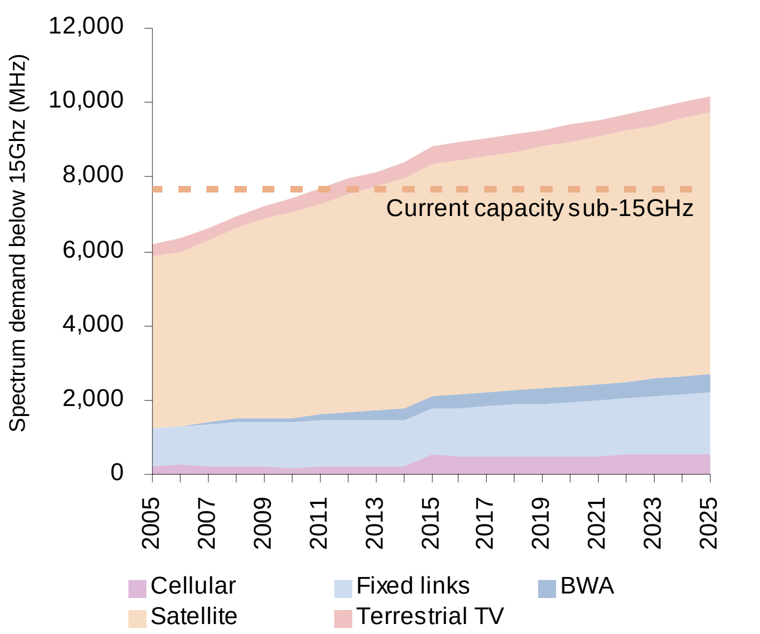


Exhibit 7.2:

Total spectrum demand breakdown – urban base case [Source: Analysys, Mason, 2005]

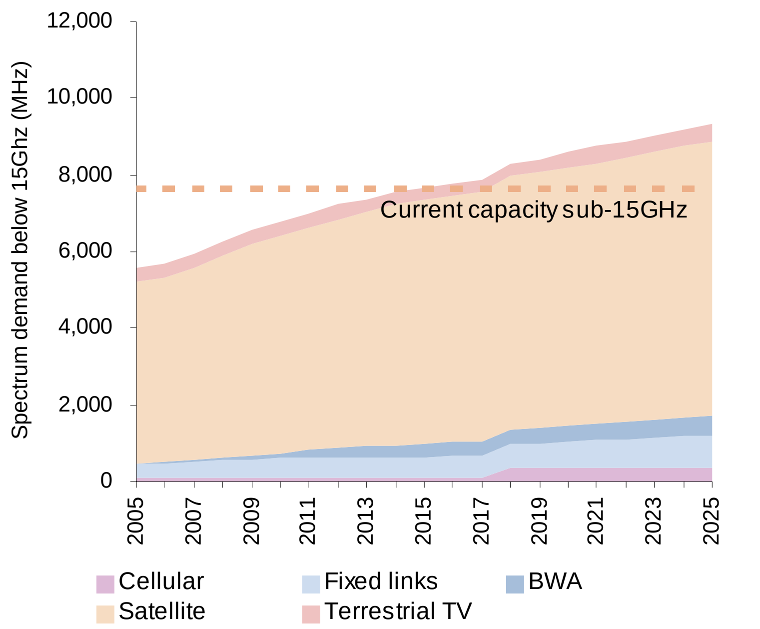


Exhibit 7.3: *Total spectrum demand breakdown – rural base case [Source: Analysys, Mason, 2005]*

Exhibit 7.4 and Exhibit 7.5 below show the spectrum demand results for the three scenarios for both urban and rural areas. In our most aggressive scenario ('data takes off'), spectrum demand rises to a total of over 15GHz by 2025 in urban areas and over 13GHz by 2025 in rural areas. In our most conservative scenario ('economic downturn'), spectrum demand is below a total of 9GHz in both urban and rural areas.

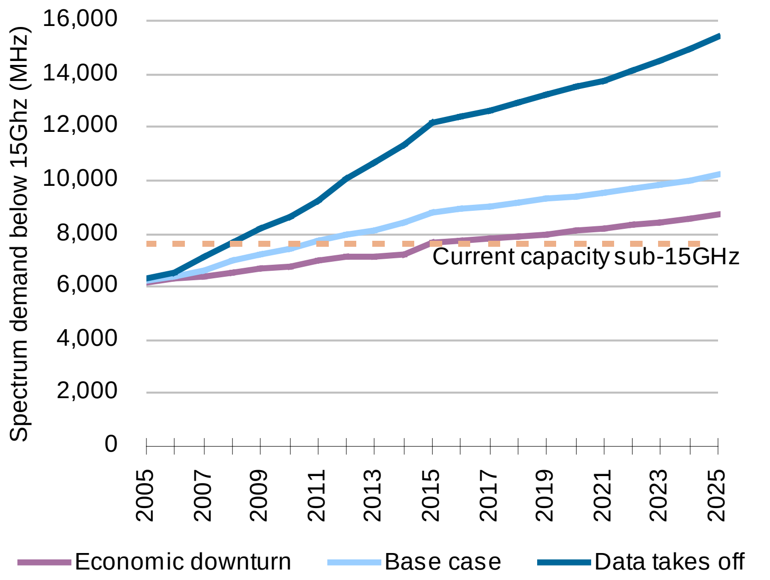


Exhibit 7.4: *Total urban spectrum demand forecast [Source: Analysys, Mason, 2005]*

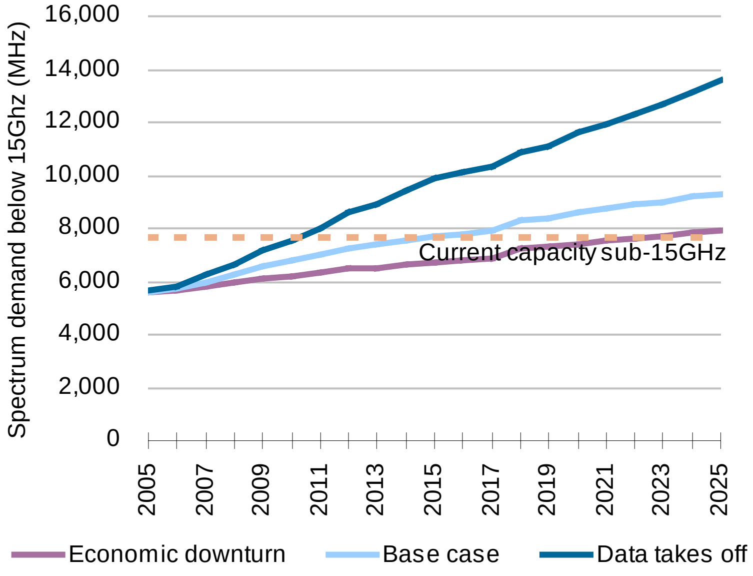


Exhibit 7.5: *Total rural spectrum demand forecast [Source: Analysys, Mason, 2005]*

Under all scenarios, the highest absolute levels of increased demand are for spectrum for satellite services. In particular, we project considerable additional demand for BSS spectrum in all our scenarios. In practice, the shortage of available spectrum may mean that the deployment of additional satellites in different orbital slots is a more viable solution for increasing BSS transponder capacity rather than the use of additional spectrum.

7.3 Future demand by sub-band

The overall analysis presented in this section does not highlight the variation in demand across the whole range of spectrum up to 15GHz. In this section, we provide comments on the demand for additional spectrum in 'sub-bands' across this wide spectrum range – in particular, we highlight that whilst the overall aggregate demand for additional spectrum in "raw MHz" terms may be at higher frequencies (for satellite services primarily and also fixed-links), there is also considerable demand for low frequency spectrum (below 1GHz). This is due to its propagation characteristics and the economic value generated from services seeking spectrum in this band (e.g. terrestrial television broadcasting and cellular). Overall, when examining spectrum at a more granular level, there can be greater imbalances between future demand versus supply than is suggested by a review of the 0–15GHz spectrum band as a whole.

0–1GHz

Spectrum in this range is in very high demand due to the propagation characteristics – the signals travel further, therefore reducing the cost of covering a given area. The low frequencies do mean that bandwidth in this band is limited – so it is less suited to services requiring a wide channel width.

Our study suggests that there may be high demand for additional spectrum for terrestrial broadcasting services. Additionally, although our overall projections for future demand for cellular spectrum are relatively modest, there is likely to be high demand for spectrum below 1GHz in order to cover less densely populated areas is a more cost-effective manner.

Applications that use this frequency range (broadcasting, mobile including cellular and private mobile radio) generate some of the greatest economic value among the uses of spectrum. Exploration of any potential means for releasing new spectrum in this range for commercial use should be prioritised.

1–3GHz

Spectrum in the 1–3GHz range is increasingly being used as ‘second choice’ spectrum for applications such as cellular (and possibly terrestrial broadcasting in the future). This is due to shortages in the availability of spectrum below 1GHz. Additionally, the spectrum in this range also supports wider channel widths, and it is therefore of use for the deployment of services such as BWA which need sufficient spectrum to provide acceptable end-user data rates.

In view of the shortage of spectrum below 1GHz, we expect to see moderate demand for additional spectrum in the 1–3GHz range to support commercial services such as cellular, BWA and possibly terrestrial broadcasting.

3–6GHz

Demand for spectrum in this frequency range is likely to increase if BWA services are highly successful and/or if mobile cellular technologies that work in this frequency range can be developed. We understand that the CEPT is currently seeking to identify spectrum in this range for next-generation cellular systems.

6–15GHz

The highest absolute levels of additional demand for spectrum identified in our study are for applications within this frequency range, including fixed satellite services, broadcast satellite services and specific fixed-link bands. Furthermore, there could be high demand from BWA services in urban areas if BWA is able to compete with wireline solutions (DSL, cable modem) as an acceptable means of providing broadband services.

In view of the high levels of demand for spectrum in this range, we recommend this should be among the priority areas for further research. However, future assessments should consider that alternative solutions might be possible for potential users in this band, e.g. the use of additional orbital slots as a means of creating additional BSS capacity in place of the use of additional spectrum.

8 Conclusions

8.1 Summary of study findings

There is considerable demand for additional spectrum below 15GHz to support commercial services. Our 'base case' suggests around an additional 2.5GHz of spectrum could be required by 2025. Spectrum shortages are likely to be a constraint which could prevent the future optimal deployment and growth of a wide variety of services.

As expected, demand for additional spectrum in urban areas is considerably greater than demand for additional spectrum in rural areas (for many services, current rural spectrum allocations are likely to be sufficient through to 2025). One possibility, is for the IASH team to continue to explore the scope for government users releasing spectrum for use in the most-congested urban areas, whilst retaining use of the spectrum for government use in rural areas.

The nature of demand for spectrum also varies by frequency band. For example:

- terrestrial broadcasting and cellular services require spectrum below 1GHz in order to coverage large areas with fewer broadcast transmission/mobile base station sites
- fully mobile services cannot currently be deployed in spectrum above 3–4GHz (this range may increase in future), due to technological limitations
- BWA, fixed-links and satellite services require access to large channel widths and therefore higher frequency spectrum is often utilised. For rural areas, however, lower frequencies would be preferred for fixed-links and BWA services because of the improved range, however such spectrum is often in short supply.

A summary of our findings in relation to each of the services investigated in the study is shown in Exhibit 8.1 below.

Service	*Summary of study findings*
Cellular	Under our low traffic scenario, current/future planned spectrum allocations (including the 3G expansion band) should be sufficient to meet demand through to 2025. In a more aggressive high traffic scenario, however, there could be demand for an additional 0.8GHz of spectrum by 2025
Fixed-links	Most of the growth will occur in bands above 15GHz – spectrum below 15GHz allocated to fixed-links should be sufficient overall. However, in our medium scenario, the 7.5GHz and 13GHz bands may run out of capacity in urban areas before 2010 and the 1.4GHz and 15GHz bands are projected to run out of capacity in urban areas by 2025
Broadband wireless access	We expect that there will be demand for an additional 0.2GHz of spectrum under our less aggressive scenario – this will primarily be in rural areas, but could also be required in certain localised urban hotspots. Our more aggressive scenario, which assumes BWA is an effective competitor to DSL/ cable modems, could lead to a requirement for up to an additional 2.5GHz of spectrum in urban areas and an additional 0.7GHz in rural areas by 2025
Satellite services	Additional spectrum requirements for mobile satellite services are modest – amounting to 0.3GHz in the most aggressive scenario. Broadcast satellite services could require significant increases to support the introduction of HDTV, leading to an additional requirement of between 0.6–2.3GHz of spectrum by 2025 under our scenarios – however, the deployment of satellites in new orbital slots could reduce this additional demand considerably. Fixed satellite services will require an additional 0.9–2.8GHz of spectrum by 2025 – we expect the lower end of the range is the most likely outcome
Terrestrial television	0.4GHz of additional spectrum (over the 2012 post-DSO allocation of 256MHz) could be required by 2014 in order to support a large increase in the number of digital terrestrial television channels and the widespread introduction of HDTV services. By comparison, the spectrum requirements for mobile television are relatively modest (a total of 70MHz from 2010). Note that we have not modelled the economic viability or end-user demand of these services – these factors may constrain actual levels of demand

Exhibit 8.1: *Summary of study findings for each service [Source: Analysys, Mason, 2005]*

8.2 Interpretation of the forecasts

In addition to the overview and limitations of our approach that we presented in Section 1 of this report, we would like to highlight a few further areas in relation to the importance of the correct interpretation of the findings of the study.

No consideration of economic value derived from use of the spectrum

The study has focused on assessing the potential future demand for spectrum without considering the economic value derived from its use by individual services. Care should therefore be exercised when interpreting the findings – for example, whilst our study suggests that the greatest demand for additional spectrum arises in higher frequency bands to support terrestrial fixed-links and satellite services, demand for spectrum below 1GHz is typically from services which have historically generated the largest economic benefits (e.g. terrestrial broadcasting, cellular communications).

Limitations of forecasting 20 years ahead

Our assessment of spectrum demand has obviously been based on our current understanding of prospective future developments. In view of the long duration of our forecasts (20 years), it should of course be remembered that fundamental changes may occur which change the nature of spectrum demand and supply. By their nature, it is impossible to predict what form these may take and what their impact could be – if this were possible, these could be factored into our analysis. An example of such a change which would not have been possible to predict in 1985 (20 years ago), for example, was the advent of the Internet and its implications for demand for spectrum to support wireless data communications services.

Interdependence of spectrum demand between services

There are various interdependencies between our forecasts for future spectrum demand for individual services, for example:

- increases in demand for one service may lead to an increase in demand for another (complimentary) service – e.g. an increase in usage of data on 3G networks will result in an increased demand for fixed-link spectrum for the backhaul connections from base stations on 3G networks, as well as increasing demand for cellular spectrum

- increases in demand for a service may lead to a reduction in demand for another (substitute) service – e.g. strong take-up of satellite television may lead to less demand for additional spectrum for digital terrestrial television.

Care should therefore be exercised when aggregating the demand for spectrum for the individual services. We have sought to take account of the major linkages between services as part of our macro-scenario analysis, so these can be regarded as providing the best aggregate view of the future demand for spectrum

Demand for spectrum may be artificially constrained by current availability

The underlying demand for spectrum from non-government users and uses that we have identified in this report may be artificially constrained by the current availability (or rather scarcity) of spectrum. Our assessment of individual services has identified several examples of cases where behaviour has been influenced by potential shortages of spectrum, for example:

- the prices paid for mobile and other spectrum (e.g. European 3G spectrum auctions) undoubtedly reflect spectrum scarcity and the need for access to specific radio spectrum bands in order to provide a high-value service
- fixed-link users automatically expect to migrate to higher frequencies in order to obtain high channels widths, even where use of lower frequencies would be preferred due to the additional range this would provide
- many service providers (e.g. terrestrial and satellite broadcasters) provide subscribers with user equipment designed to work in certain frequency ranges on the expectation that they are unlikely to be able to make use of other spectrum bands.

It is possible that, were spectrum availability to change, additional innovations using radio communications services could be developed using spectrum which is not currently available – which in turn could lead to further demand for spectrum.

Annexes to Final Report for the Independent Audit of Spectrum Holdings

Spectrum demand for non-government services 2005–2025

1 September 2005

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Contents

Annex A: Cellular services

This annex presents further details of our assessment of future demand for spectrum for cellular services and should be read in conjunction with Section 2 of the main report.

A.1 Overview of methodology

Exhibit A.1 below summarises our overall approach to forecasting the demand for spectrum services.

We have developed a 'traffic model' which projects the future growth in busy-hour traffic on cellular networks, and an operator cost model which projects network costs to provide sufficient network coverage/capacity for a given level of traffic, taking account of the amount of spectrum available. These models forecast the demand for spectrum to 2015, based on the use of UMTS technology.

We then take account of the impact of introducing new (more spectrally efficient technologies) such as HSDPA/HSUPA and systems beyond IMT-2000, and extrapolate our forecasts to 2025.

It should be noted that our approach does not include a detailed assessment of the need for additional spectrum during any technology transition, to allow for parallel operation of the old and the new technologies, nor does it explicitly consider the requirement for additional spectrum to support new entrants into the market.

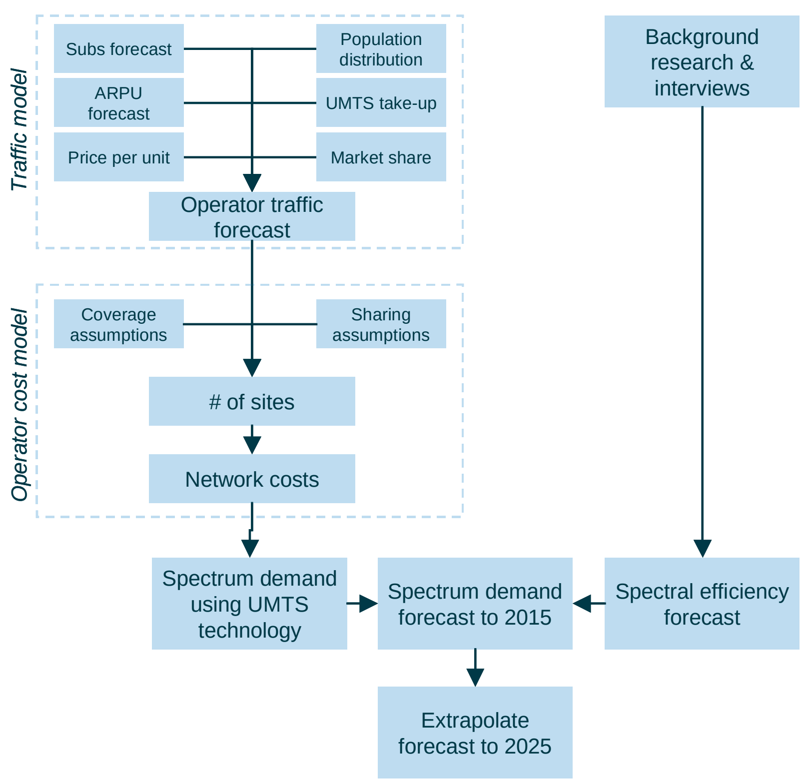


Exhibit A.1: *Approach to forecasting spectrum demand for cellular services [Source: Analysys, Mason, 2005]*

A.2 Traffic model

The traffic model forecasts busy-hour traffic for a typical UK operator by service and network generation (GSM vs. UMTS). There is considerable uncertainty regarding future traffic on 3G networks, and bottom-up approaches of estimated usage levels of individual services have led to over-estimates of future traffic levels (as well as the future revenues generated from new 3G services).

We have therefore adopted an approach of projecting 3G subscriber numbers, future average revenues per user (ARPU) from voice and data services, and unit price evolution (price per minute, price per message, price per MB, etc.). We have modelled these for individual market segments, including large corporate, small and medium-sized businesses, consumer postpaid and consumer prepaid.

From these results, we can then derive total traffic forecasts and convert these total traffic forecasts into busy-hour traffic forecasts by operator. As a check, we have also calculated the total revenues generated from 3G services and benchmarked these (as well as our individual subscriber, ARPU and unit price benchmarks) against analyst forecasts.

Forecasts have been developed covering a 10-year time period to 2015. As discussed above, we have developed forecasts for beyond this period by extrapolating the 2006–2015 forecast.

Exhibit A.2 outlines the flow of calculation in the traffic model.

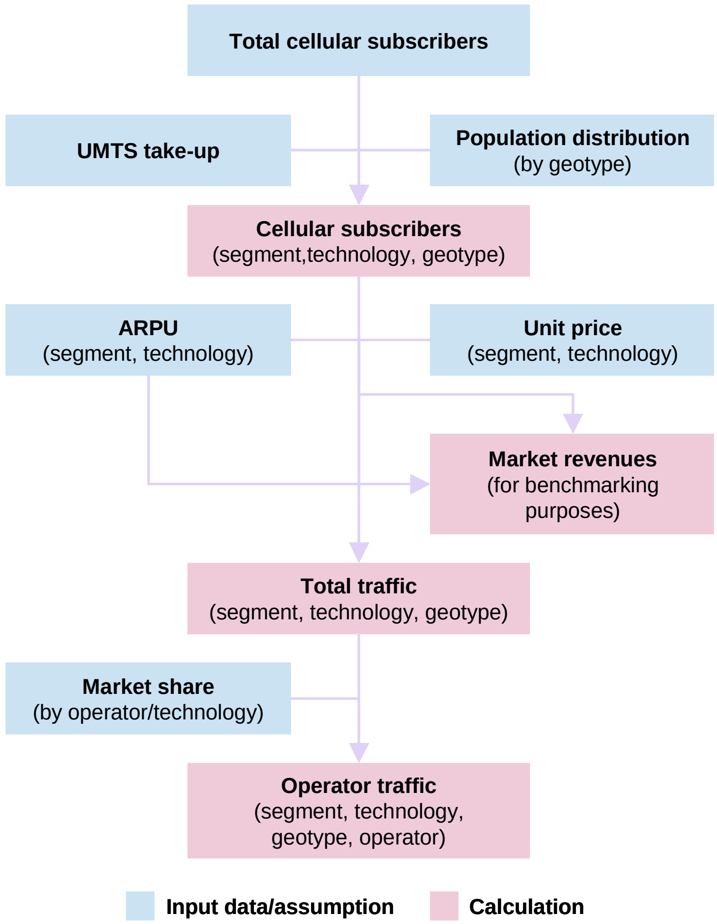


Exhibit A.2: Traffic model calculation flow [Source: Analysys, Mason, 2005]

In developing our traffic projections, we note that there are numerous uncertainties associated with the evolution of the cellular market and the future evolution of the cellular market. As discussed in Section 2, we have therefore developed two scenarios (low traffic and high traffic) which reflect a range of outcomes. It should be noted, however, that we have not been able to model alternative forecasts for all of the potential uncertainties underlying the future demand for spectrum within the scope/time available for this study (e.g. range of 2G to 3G subscriber migration profiles, alternative options for future of 2G networks). We regard this simplification as being necessary for the purposes of this study; however, this means that the analysis presented in this section should not be regarded as a substitute for a more comprehensive assessment of the cellular sector.

The result of the traffic model is busy-hour traffic by service (in Mbit/s) by geotype.[29] These busy-hour traffic forecasts are then used in the operator cost model to calculate the required infrastructure and associated costs given a certain amount of spectrum.

Exhibit A.3 and Exhibit A.4 below show the peak hour voice and data traffic forecasts for our two modelled scenarios (low traffic and high traffic).

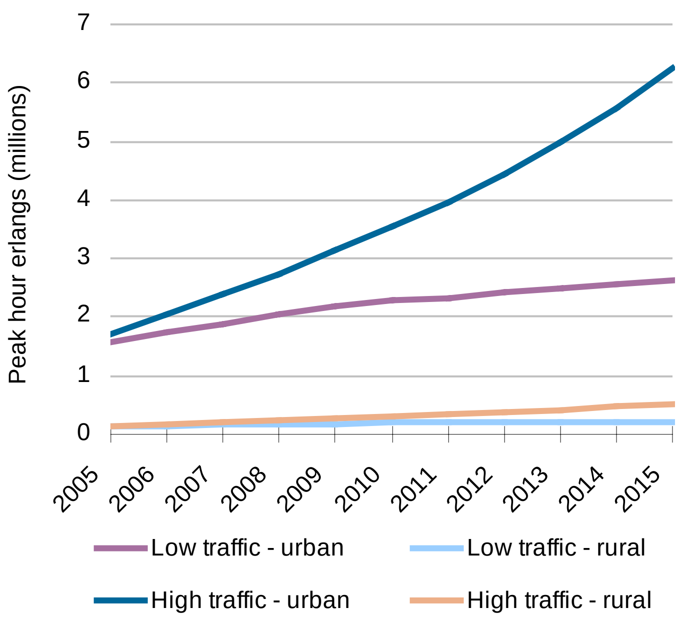


Exhibit A.3:
Voice traffic forecasts [Source: Analysys, Mason, 2005]

29 Subscriber forecasts are broken down by geotype to enable more accurate modelling of costs in the operator cost model in areas with different types of geographical characteristics and population densities.

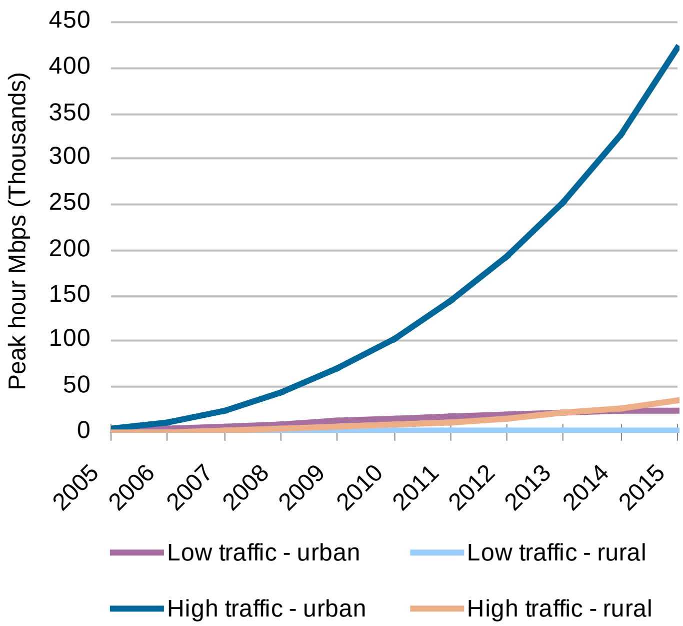


Exhibit A.4:
Data traffic forecasts [Source: Analysys, Mason, 2005]

We have compared these traffic forecasts against the projections contained in the UMTS Forum's *Magic Mobile 2010–2020* report. In 2012, the traffic forecast in our high traffic scenario and in the Magic Mobile report are comparable. However, as we move further into the future, the Magic Mobile forecast becomes increasingly aggressive and by 2020 it is four times higher than that of our high traffic scenario. We are concerned that the Magic Mobile forecast may be unrealistic in the later years and suggest that our high traffic scenario represents a more likely upper bound to future demand. Our low traffic scenario is significantly below both of the other two forecasts.

A.3 Operator cost model

The operator cost model simulates the elements of a mobile network whose cost vary depending on the amount of spectrum that is available.

The costs that have been considered in the model are:

- **Included** (costs varying with amount of spectrum available): Radio equipment (node B, transmitter), site (acquisition and rental), backhaul and network maintenance.

- **Excluded** (costs largely independent of amount of spectrum available): Core network (MSC, GGSN, SGSN, HLR, VMS, SMSC, billing system, prepaid server, MGW, etc.), other operating costs (interconnect, roaming, IP transit, customer acquisition and retention costs, staff costs, advertising and marketing, customer care, billing costs, bad debt costs, etc.).

The first step in modelling radio network costs is to forecast the number of sites deployed for a typical UMTS network. Calculating the number of sites required is key to understanding the potential savings arising from an operator having access to additional spectrum. In areas where the number of sites is driven by usage (rather than coverage), if an operator can obtain more spectrum, then they need not build as many sites. Therefore, there is a trade-off between the amount of spectrum that an operator has and its costs to build additional sites.

We have predicted the number of sites required based on the level of UMTS coverage required and the traffic forecasts from the traffic model.

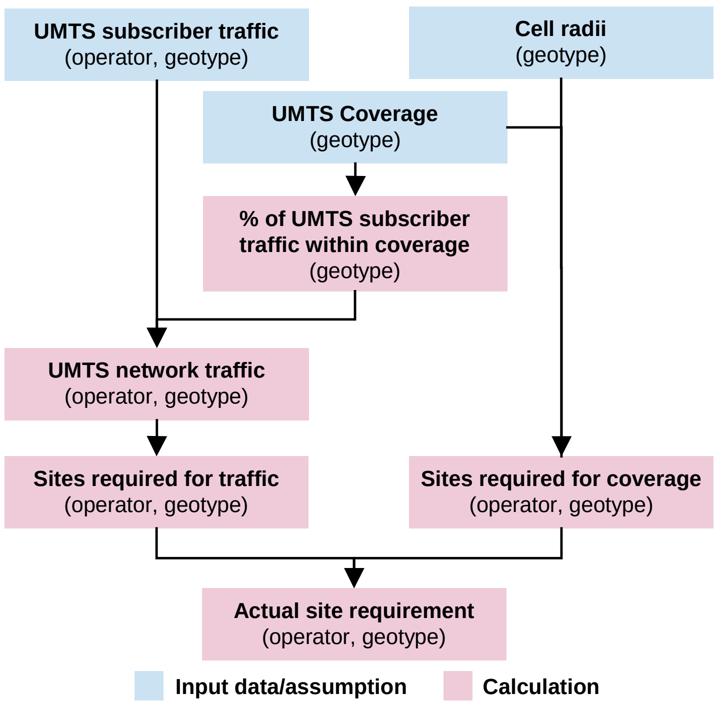


Exhibit A.5: *UMTS site forecasting methodology [Source: Analysys, Mason, 2005]*

In a given geotype, site numbers will either be driven by the number of sites required for coverage or the number of sites required for traffic. It is expected that in urban areas, substantially more base stations will be required to handle the high levels of traffic compared to the number required to simply offer coverage. In this case, base stations are limited by their capacity for handling traffic. Conversely, in sparsely populated rural areas, it is expected that there will be areas where the minimum number of base stations required to cover an area will be deployed. In these areas, base station numbers are limited by the size of each cell (cell radius).

Lastly, the amount of network equipment of different types required to support the forecast number of sites and level of traffic is calculated. The associated capex and opex is also calculated.

Key assumptions

The role of the operator cost model is to understand how an operator's costs vary with the amount of spectrum available. In order to do this, there are two key parameters used:

- The *traffic capacity of each site*: This determines how many sites are required to meet the traffic demand. It is important to understand how the maximum traffic capacity at each site varies depending on the amount of spectrum that is available.

- *Other network costs*: Many of the other network costs vary with the number of sites. Therefore, it is important to understand the relationship between these costs and the number of sites.

Site traffic capacity

The number of UMTS sites required to meet the traffic demand is calculated using the following calculation:

> Number of sites = Busy-hour traffic / (UMTS site capacity per carrier * Number of carriers)

The busy-hour traffic represents the traffic (in Mbit/s) during the peak hour of the day. It is the key output from the traffic model.

The UMTS site capacity per carrier (in Mbit /s) represents the maximum busy-hour traffic that a site can handle per carrier. It has been calculated as follows:

> UMTS site capacity per carrier = Sectors * useful channels * full voice rate * actual carrier utilisation factor

The following points have been assumed when calculating the UMTS site capacity per carrier:

- three sectors per cell
- 43.3 useful channels per sector (based on 80 channels, 30% allowance for soft handover, which gives 56 channels, 1% blocking probability gives 43.3 useful channels)
- full voice rate of 0.013Mbit /s
- a theoretical to actual channel utilisation factor of 60% – this takes account of practical factors such as the fact that traffic demand will not necessarily fall evenly across a whole geotype.

The resulting UMTS site capacity per carrier that we have assumed is 1.01Mbit/s.

The number of carriers is dependent on the amount of spectrum available to the operator. With each additional 2 x 5MHz block of spectrum available, the operator can deploy an extra carrier, thus reducing the number of sites required to meet the traffic demand. It is this input that is flexed in this model to understand the cost impact of having additional spectrum.

Other network costs

There are several costs that vary with the number of sites (and therefore with the amount of spectrum available). The major types of cost which vary with the number of sites are site (acquisition and rental), radio equipment (node B, transmitter), backhaul and network maintenance.

Site costs	The site costs (acquisition, rental and operational costs) have been benchmarked against industry cost data
Radio equipment	The capex for each incremental site (node B, transmitter) has been benchmarked against industry cost data. We have forecast that the cost of UMTS equipment will erode at a similar rate to GSM equipment following its development. It has been assumed that an incremental RNC is required per 150 UMTS carriers and that the practical utilisation per RNC is 80%.
Backhaul	For modelling purposes, all backhaul is assumed to be microwave. This is due to the general industry trend of cellular operators to use microwave links over leased lines (for more details refer to the terrestrial fixed link section). All traffic generated on the network is assumed to pass from BTS/Node B to the BSC/RNC layer, and the number of backhaul links (of each type) is dimensioned on the basis of TRXs and carriers installed. It is assumed that 1.3 'hops' are needed per backhaul link, and that practical maximum utilisation of the links is 60%.
Network maintenance	Incremental network maintenance costs have been modelled as 3% of cumulative capex to date.

Annex B: Terrestrial fixed-link services

This annex contains further details of the models that we have developed to forecast future demand for spectrum for terrestrial fixed-link services.

B.1 Detailed methodology

B.1.1 Estimating fixed-link spectrum utilisation

Estimating fixed-link capacity

Ofcom's approach of assigning links to channels creates an opportunity to measure the capacity of each band:

- The user first of all requests a link, stating the location, length and bit-rate (sometimes they will request a certain band and channel).
- Ofcom has a "minimal path length policy". This states that each link should be placed in the highest band possible given its length and required bit rate.
- Ofcom then assigns the link to a channel within the band. It starts at either end of the band and attempts to place the link in the highest/lowest frequency channel. If this is unsuccessful for interference reasons, it then tries the next channel in, and so on until a channel is found.

The result of this process is that the outside channels in each band are likely to be near to capacity (at least in urban areas). Therefore, we have calculated the density of links in each channel and assumed that the channels with the highest link density are at capacity.

As urban areas (including London) are much more densely populated with fixed-links than rural areas, it is necessary to split these regions out when calculating capacity. Therefore, for the purposes of this study, the UK has been split into three areas:

- London – defined as being within the M25
- other urban areas
- rural – covering all other areas.

However, it is possible for a link to have an A-end within an urban area but the B-end within a rural area. In these instances half a link is counted in each area.

The channel link density was calculated for each channel and band in each of these three regions and the maximum channel density in any of these regions was then used as a proxy for the channel capacity of the band.

For a subset of the bands, namely the 4GHz, 6GHz lower, 6GHz higher bands and 15GHz, this approach was not valid. One would expect that the link density capacity would increase as the frequency of the band increases, due to higher reuse factors. However, using the above approach, the 4GHz, 6GHz lower, 6GHz higher and 15GHz bands have lower than expected capacities (see Exhibit B.1 below). This is due to a combination of three factors:

- These bands are mainly occupied with old BT fixed-links and are a legacy from when BT controlled these bands. BT may or may not have followed the same assignment procedure of filling the outside bands and, as a result, our methodology may not be applicable.
- These bands are shared with satellite services and therefore fixed-links may not be permitted in some geographical locations in order to prevent interference. This means that fixed-link density is lower than it otherwise would be.
- None of the channels in the band are actually at capacity. We suspect that this is the case with the 15GHz band.

For these bands, the channel capacity was adjusted upwards to be in line with the other bands. This means that this approach does not account for the fact that the 4GHz, 6GHz lower and 6GHz upper bands are shared with satellite services.

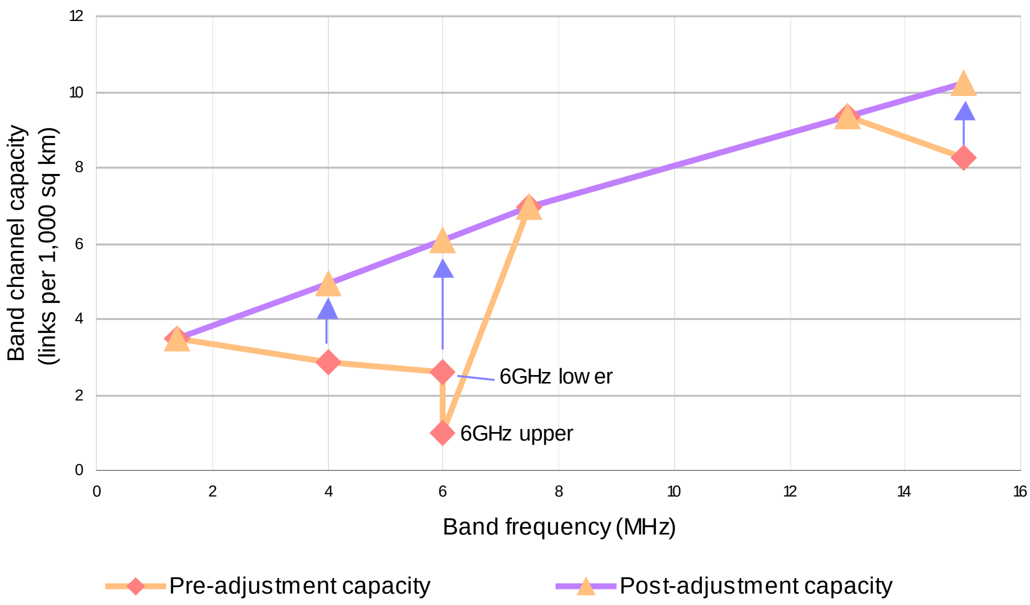


Exhibit B.1: *Fixed-link band capacity [Source: Analysys, Mason, 2005]*

The different channel plans that Ofcom runs for each band made the process of calculating the channel link density more complex. In each band a link could be on a number of different channel plans. For example, the 7.5GHz band has three channel plans (D, E and F). A link in channel plan D occupies 28MHz, whilst a link in channel plan E occupies just 14MHz. Therefore, the bandwidth of each link and the channel location in the band needed to be considered when calculating the channel link density. A detailed description of this adjustment is given below.

► *The use of channel plans by Ofcom*

Ofcom splits up each band into a number of channels. For example, the 7.5GHz channel is split up into 8 x 28MHz channels, 16 x 14MHz channels, or 32 x 7MHz channels. Each of these formats of channels is called a channel plan. Each band has a number of channel plans enabling Ofcom to fit links of different bandwidths into the same band.

The channels within each channel plan are numbered 1 to n, with channel 1 being the lowest frequency channel. This makes the calculation of link density of the channel more complex as a channel in one channel plan will be in a different part of the band as the same number channel in a different plan. For example, in the 7.5GHz band, channel 8 in the 28MHz channel plan (channel plan D) is at the very high end of the band, but channel 8 in the 14MHz channel plan (channel plan E) is in the middle of the band. Furthermore, a channel in the 28MHz channel plan will take up twice as much spectrum as the 14MHz. The diagram below illustrates the three channel plans in the 7.5GHz band:

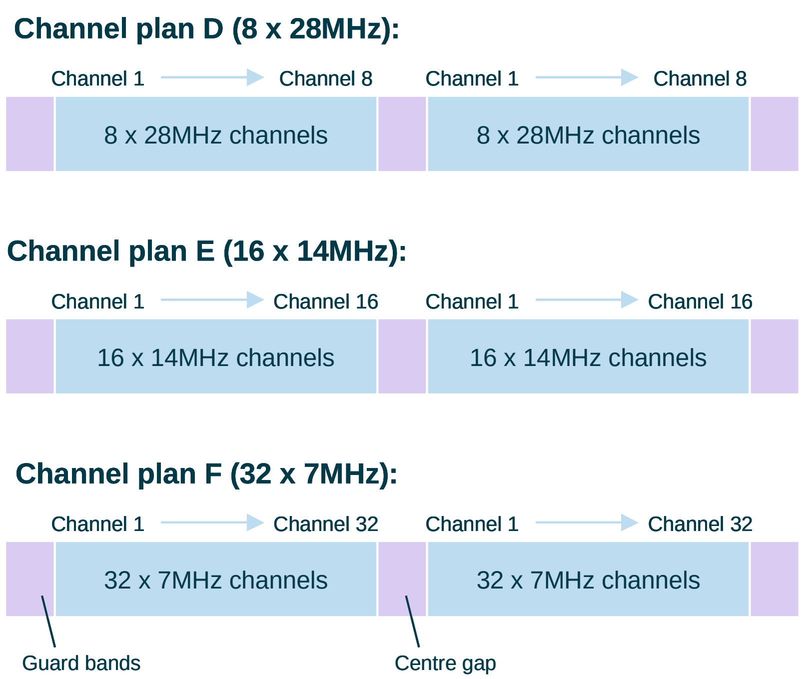


Exhibit B.2:

Channel plans for the 7.5GHz band

[Source: Ofcom]

In order to calculate the channel link density each band was split into "buckets" that corresponded to the most disaggregated channel plan (in the case of the 7.5GHz band this was 32 buckets). Then, the number of links assigned to each "bucket" was counted. For example, a link in channel 1 in channel plan D (8 x 28MHz channels) was counted in buckets 1, 2, 3 and 4 as the link spans all of these buckets. A link in channel 1 in channel plan E (16 x 14MHz channels) was counted in buckets 1 and 2. Therefore, channel link density was then calculated as the number of links per 1000km^2.

Calculating utilisation

Once the capacity for each channel (in terms of density of links) is known, it is possible to calculate the utilisation of the band. It is the sum of the fixed-link density by channel divided by the sum of the capacity of each channel.

For example, Exhibit B.3 illustrates the fixed-link density for a theoretical band with 6 channels:

Channel	*Fixed link density*
Channel 1	10 links per sq km
Channel 2	8 links per sq km
Channel 3	4 links per sq km
Channel 4	3 links per sq km
Channel 5	7 links per sq km
Channel 6	9 links per sq km

Exhibit B.3: *Fixed-link density for a theoretical band with 6 channels [Source: Analysys, Mason, 2005]*

The channel capacity for this band would be 10 links per sq km and the estimated utilisation would be:

$$(10 + 8 + 4 + 3 + 7 + 9) / (6 * 10) = 41 / 60 = 68\%$$

This approach assumes that each channel could have 10 links and no more per 1000 sq km.

The band utilisation has been calculated for Greater London, other urban areas and rural areas for each band.

Calculating capacity and utilisation example: the 13GHz band

The 13GHZ band has four channel plans:[30]

30 There is also a 128 x 1.75MHz channel plan but there are currently no links assigned using this plan.

- Channel plan D: 8 x 28MHz channels
- Channel plan E: 16 x 14MHz channels
- Channel plan F: 32 x 7MHz channels
- Channel plan G: 64 x 3.5MHz channels.

In order to calculate the capacity of the band, we have split it up into 64 "buckets" (an equivalent number to the most disaggregated channel plan – channel plan G), each of 3.5MHz. Each of the current links was then allocated to these buckets depending on which channel plan and channel they were assigned to. This was done for the three areas, namely London, other urban areas and rural, separately. These results were then divided by the area of the region to produce a link density by bucket. The exhibits below illustrate the link density results by bucket for the 13GHz band. The maximum fixed-link density for any of the buckets and any region is the first bucket in the urban region where there are 9.4 links per 1000 sq km. This figure has then been used as a proxy for the capacity of each channel.

The resulting utilisation for the 13GHz band for the three regions is:

- London: 70%
- other urban areas: 66%
- rural: 16%.

As expected, the utilisation is higher in London and urban areas than in rural areas.

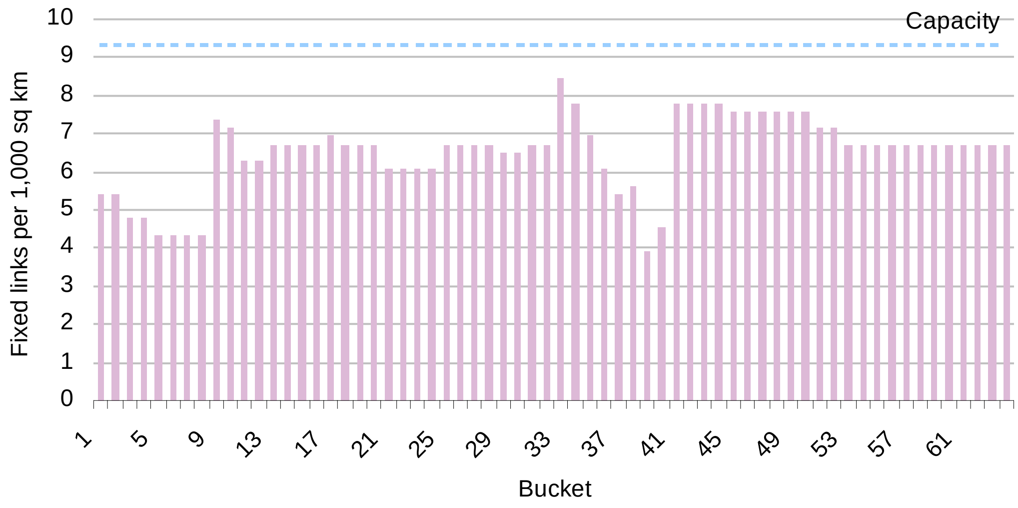


Exhibit B.4: *Fixed-link density by bucket – 13GHz band, London [Source: Analysys, Mason, 2005]*

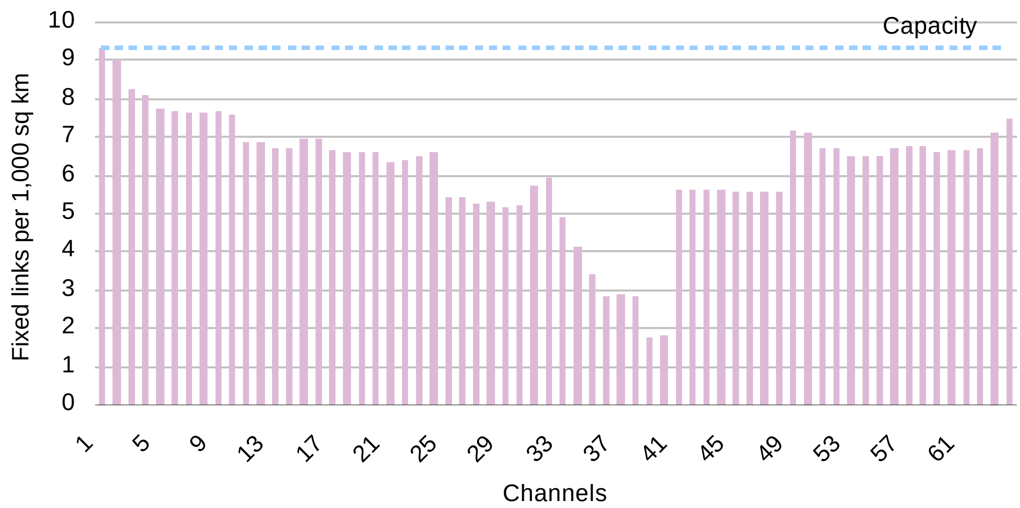


Exhibit B.5: *Fixed-link density by bucket – 13GHz band, other urban areas [Source: Analysys, Mason, 2005]*

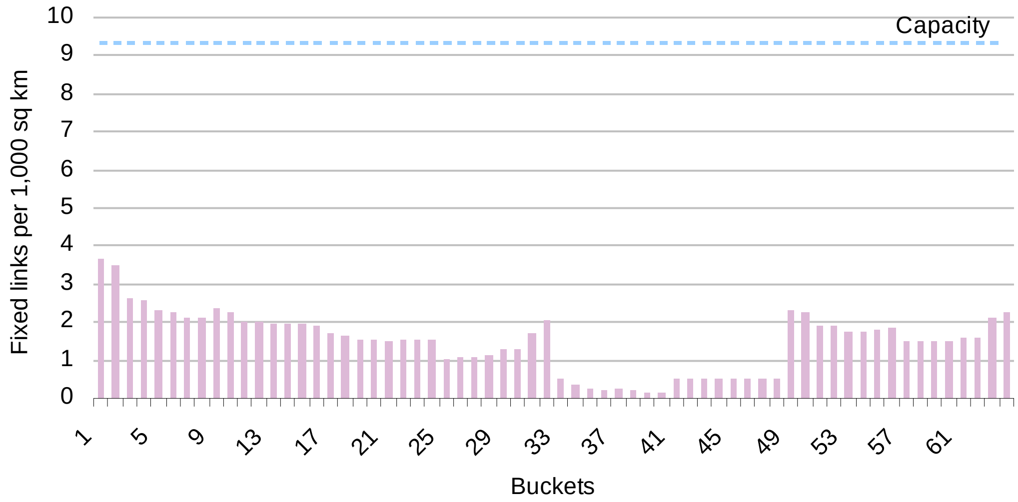


Exhibit B.6: *Fixed-link density by bucket – 13GHz band, rural areas [Source Analysys, Mason, 2005]*

B.1.2 Forecasting fixed-link occupied bandwidth demand to 2015

There are 357 users of fixed-link spectrum in the UK. However, the top five users account for over 85% of the fixed-link cumulative bandwidth. It is a highly concentrated usage.

Customer	*Fixed links*	*Total bandwidth (MHz)*	*Avg bandwidth per link (MHz)*	*Cumulative bandwidth*
BT	11,583	234,514	20.25	32%
ORANGE	10,994	176,517	16.06	56%
T - MOBILE	5,849	114,345	19.55	71%
HUTCHISON 3G	4,202	49,098	11.68	78%
CABLE AND WIRELESS	3,837	61,172	15.94	86%
Other	7,419	101,417	13.67	100%

Exhibit B.7: *Fixed-links assignments by user (all bands) [Source: Ofcom fixed-link database]*

In order to forecast the demand for fixed-links, these largest five users have been considered individually. The remaining users have then been segmented into three groups: telecoms companies, utilities/oil and gas companies and others. This segmentation was based on their current use of the fixed-link bands (e.g. utilities and oil and gas companies have the majority of their links in bands of less than 15GHz).

Fixed-link forecasts have also been made for the two other UK cellular operators (Vodafone and O_2). There is currently a trend for the cellular operators to switch from using leased lines for backhaul to fixed-links. Therefore, Vodafone and O_2 may become major users of fixed links in the future.

In our link-demand forecasts we considered the cellular operators, BT/Cable & Wireless and the remaining segments separately.

Current user segment characteristics

► *Occupied bandwidth by band*

In the UK, 67% of fixed-link occupied bandwidth is in bands with frequencies higher than 15GHz. However, this mix of occupied bandwidth above and below 15GHz is not equal across the segments. The mobile operators, especially Hutchison 3G, have little occupied bandwidth below 15GHz. In contrast, the utilities and oil companies have a much higher proportion of their links below 15GHz (69% of occupied bandwidth). The telecoms operators sit between these two extremes.

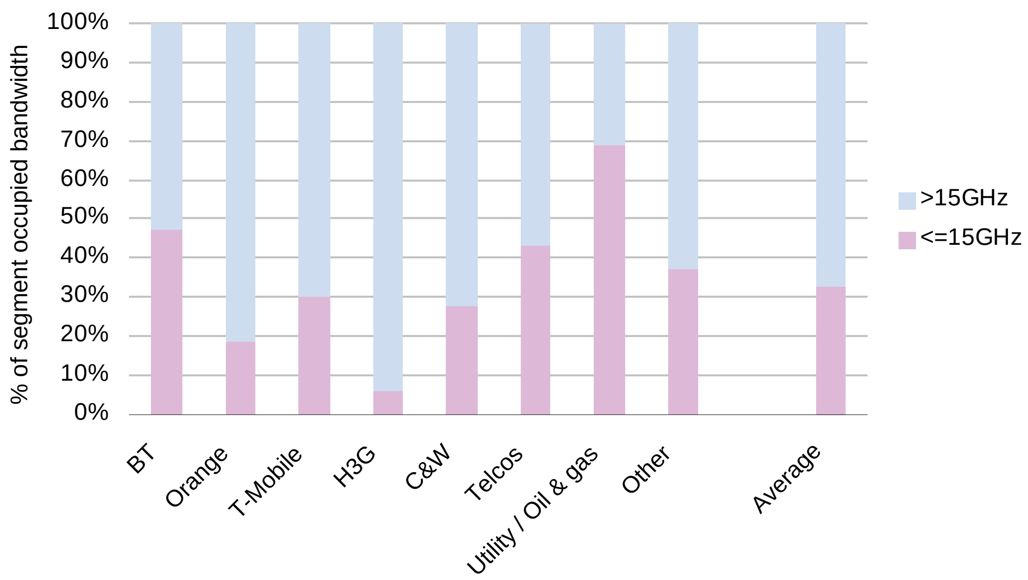


Exhibit B.8: *Segment breakdown by band [Source: Ofcom fixed-link database]*

► *Occupied bandwidth by region*

The split of fixed-links between London, other urban areas and rural areas varies by segment. BT, the telecoms operators and the utilities/oil and gas companies have a large proportion of their fixed-links in rural areas. Meanwhile, the cellular operators (especially H3G) have relatively few links in rural areas. We would expect this for H3G as the company has not yet rolled out its 3G network to rural areas and it does not have a 2G network. Cable & Wireless has a high proportion of their links in London and relatively few in rural areas.

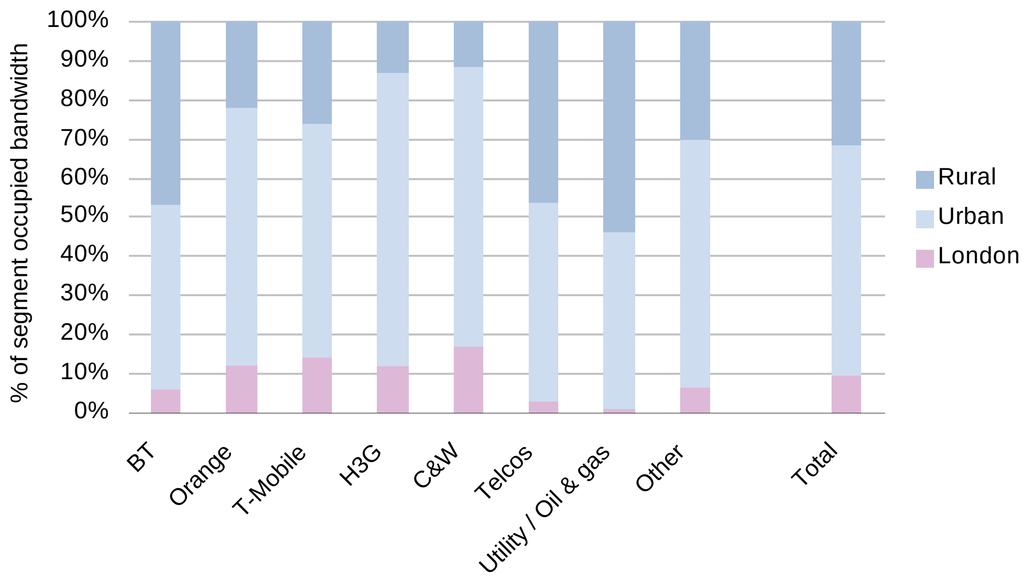


Exhibit B.9: *Segment breakdown by region – all bands [Source: Ofcom fixed-link database]*

Occupied bandwidth forecasts – the cellular operators

Fixed-link bandwidth demand forecasts have been created for the five cellular operators (O_2, Vodafone, Orange, T-Mobile, H3G) until 2015. We have used four drivers to develop these forecasts: the number of sites, the percentage of sites served by fixed-links, channel width per link and the mix of bands.

Please note that the assumptions of the future fixed-link demand for these companies have been made by Analysys and Mason for the purposes of this study and that this may not be consistent with the companies' own views.

► *The number of sites*

For this assessment, we have used the model developed for the cellular spectrum demand forecasts (for details see Annex A).

Using this model we have forecast the number of sites that a typical UK cellular operator will require until 2015. Our medium scenario has then assumed that just two of the operators will roll out 3G networks in rural areas and that areas will be shared with the other three operators. Exhibit B.10 illustrates the total forecast sites by region to 2015.

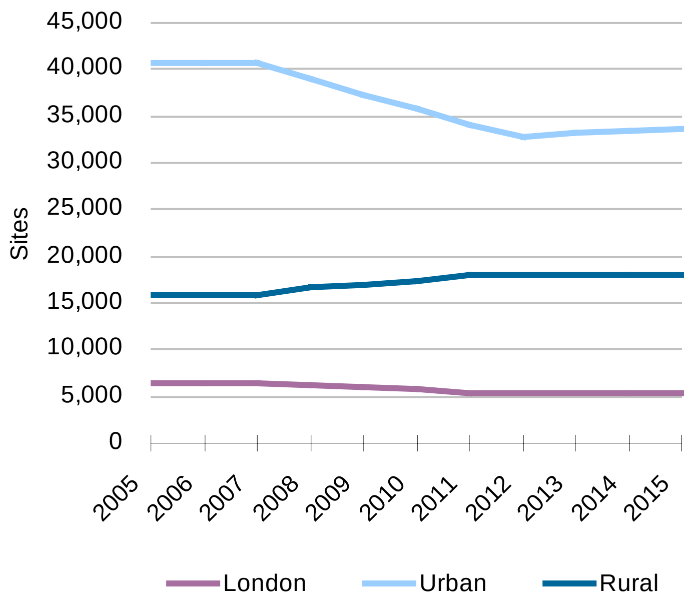


Exhibit B.10: *Forecast total number of sites [Source: Analysys, Mason 2005]*

► *The percentage of sites served by fixed-links*

Using Ofcom's fixed-link database and estimates of the number of sites for each operator, we have estimated the current proportion of sites served by fixed-links. There is an expectation that cellular operators will move from using leased lines for backhaul to fixed-links. This is primarily driven by the fact that fixed-links are cheaper.

"We expect that most operators will be moving toward fixed-links in the future." *UK cellular operator*

Therefore, for our medium scenario we have assumed the following:

Orange	Orange already uses fixed-links for the vast majority of its sites. Therefore, we have assumed that its percentage of sites served by fixed-links will remain constant.
T-Mobile	T-Mobile currently uses a combination of leased lines and fixed-links. We have assumed that its percentage of sites served by fixed-links will be constant for three years before growing to 75% by 2012.
Vodafone	Vodafone currently does not use fixed-links for any of its backhaul. We have assumed that it will increase its percentage of sites served by fixed-links to 75% by 2010.
O_2	O_2 currently does not use fixed-links for any of its backhaul. We have assumed that it will increase its percentage of sites served by fixed-links to 25% by 2010.
H3G	H3G uses fixed-links for the majority of its backhaul. We have assumed that its percentage of sites served by fixed-links will remain constant.

Exhibit B.11 shows the forecast for the percentage of sites served by fixed-links by operator.

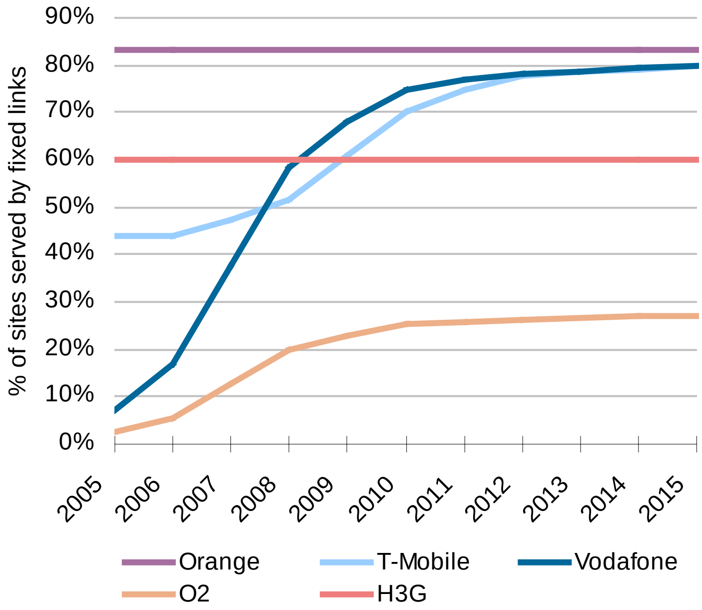


Exhibit B.11: *Forecast proportion of sites served by fixed-links [Source: Analysys, Mason 2005]*

► *Channel width per link*

Historically, the channel width per link for cellular operators has risen over time. In order to forecast future channel width per link, we have trended forward the historical channel width per link for Orange and T-Mobile. However, we have included a step increase in channel width per link with the introduction of HSDPA/HSUPA and the mass-market take-up of 3G in 2007/8.

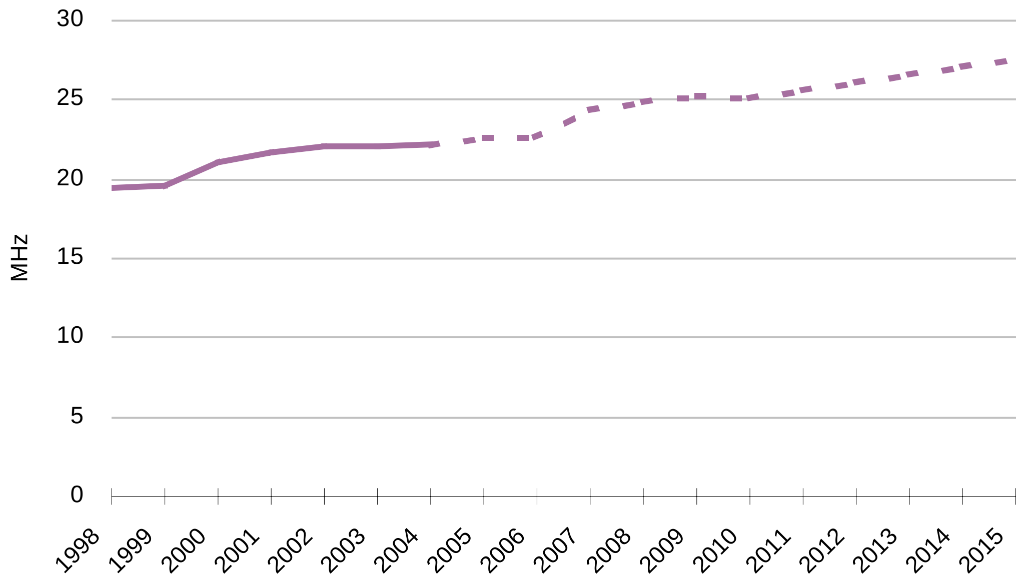


Exhibit B.12: *Average channel width per fixed-link [Source: Analysys, Mason 2005]*

► *Mix of bands*

In recent years there has been a trend towards higher frequency bands. This has occurred both as a result of regulatory pressure (for example, the introduction of minimum link length policy, encouraging use of higher frequency bands for shorter links) and technology improvements, such as the introduction of higher-level modulation schemes providing higher capacity links in the higher frequency bands. Therefore, we have extrapolated forward this migration to higher bands into the future.

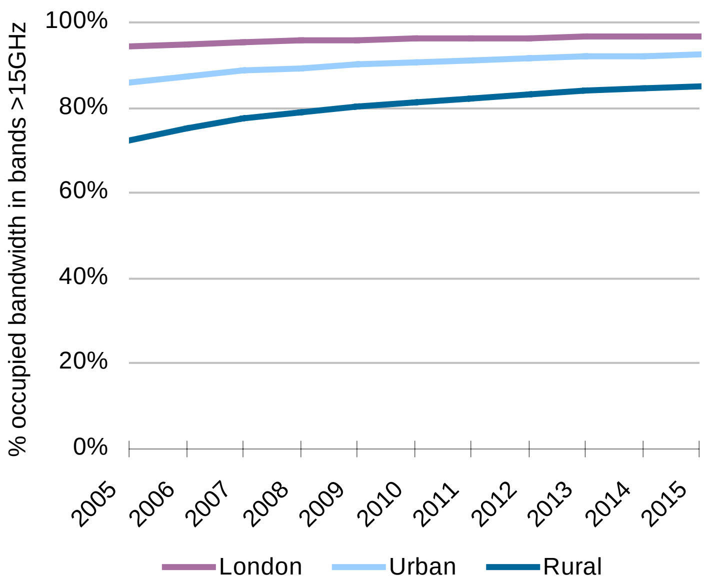


Exhibit B.13: *Forecast proportion of occupied bandwidth in bands greater than 15GHz [Source: Analysys, Mason 2005]*

Occupied bandwidth forecasts – BT and Cable & Wireless

We have forecast that all the future growth for BT will occur in bands above 15GHz. This growth will be to provide cellular operators with fixed-links (typically in the 38GHz band) and for broadband access for business users (typically in the 18GHz band).

Fixed-links that BT has in sub-15GHz bands are generally a legacy from before the availability of fibre (many of which are in the 11GHz band). Therefore, it is unlikely to add any significant number of fixed-links in the future in these bands. The only exceptions to this would be in areas of rough terrain or for links over water; these are likely to be few and far between. However, BT is unlikely to replace these with links in higher bands as its network equipment (towers, etc.) is optimised for these bands. A change would be very expensive. Therefore, we expect that the number of links that BT has in sub-15GHz bands to be constant.

We have also assumed similar growth for Cable & Wireless:

- growth in the >15GHz bands
- the sub-15GHz bands to be stable.

Occupied bandwidth forecasts – the other segments

The remaining three segments (telecoms operators, utilities/oil and gas and the other segment) make up only 13% of the current fixed-link occupied bandwidth. In order to forecast their future occupied bandwidth, we have simply trended forward their historical growth. Exhibit B.14 shows the forecast occupied bandwidth for these segments.

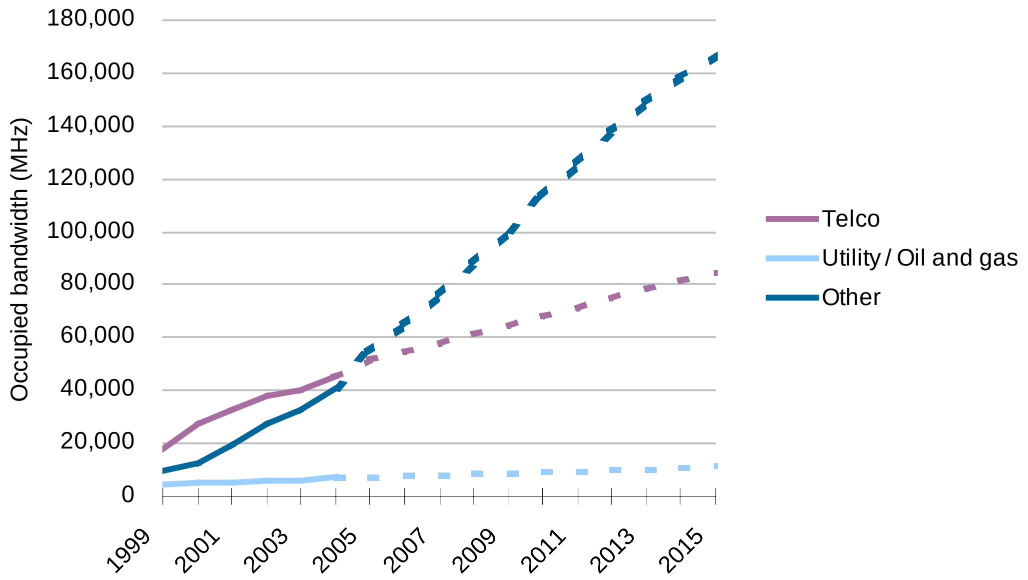


Exhibit B.14: *Forecast occupied bandwidth by segment (all bands) [Source: Analysys, Mason 2005]*

Historically, the utilities/oil and gas companies have seen little growth and we have forecast this forward. We have forecast that the most growth will come from the "other" segment. This segment includes wireless broadband providers and links for broadband access for businesses, and also any new segments that may develop in the future. These may include backhaul for mobile and terrestrial television or other applications. Historically this segment has experienced relatively high growth below 15GHz and we forecast this to continue.

The forecast for this segment is consistent with Scenario 2 of our BWA forecasts (BWA limited to rural broadband coverage fill-in). We expect that the increased demand in BWA will produce demand in fixed-links for backhaul. However, the majority of this is likely to be in bands above 15GHz. Furthermore if Scenario 1 (Widespread deployment of BWA) does materialise, then we expect that the vast majority of this incremental demand to fall in urban areas and thus the backhaul requirements are likely to be met through leased lines or fixed-links in bands above 15GHz.

The impacts of the new pricing algorithm

The new pricing algorithm was introduced on 13 June 2005. Previously there was no obvious progression of pricing for fixed-links across length, bandwidth, etc. The algorithm prices each link at GBP88 per MHz for two directions. Adjustments are then made for which band the link is in, etc.

The new algorithm is likely to increase costs for users with old links that do not use the spectrum efficiently and those with links in low frequency bands that should be in higher bands (due to the path length policy).

The algorithm will have greatest impact on BT (and possibly Cable & Wireless). However, for the purposes of this study, we have assumed that these organisations will not move many of their links in these bands due to the infrastructure they have in place for these bands:

> "Despite the fact that our links in the low bands will cost us more, it is unlikely that we will move to higher bands, we have a network of established infrastructure with towers optimised these low bands." *UK fixed operator*

B.2 Extrapolating the bandwidth demand forecasts to 2025

The occupied bandwidth forecasts by band and region to 2015 were aggregated across the segments. These forecasts were then extrapolated to 2025 using the average annual growth rate between 2005 and 2015. Exhibit B.15 below shows the extrapolated occupied bandwidth forecasts for each region.

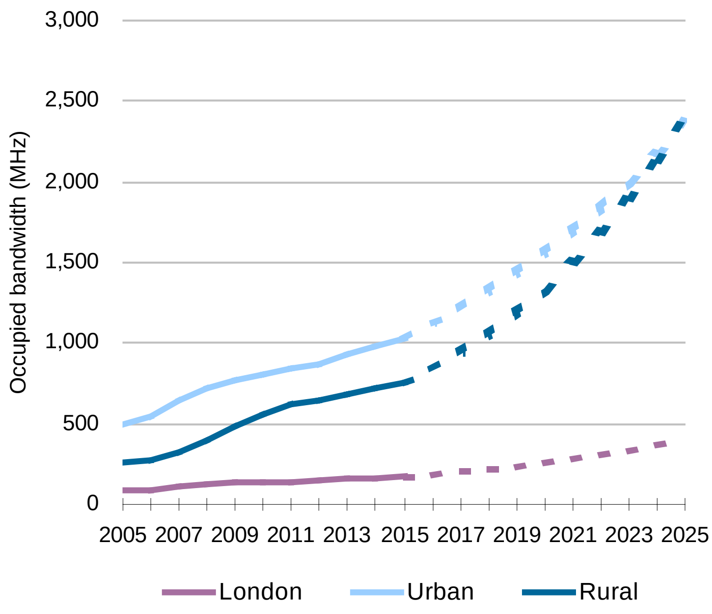


Exhibit B.15: *Forecast occupied bandwidth by region to 2025 [Source: Analysys, Mason, 2005]*

B.2.1 Translating the occupied bandwidth demand forecast to spectrum forecasts

As the demand forecasts have been developed for occupied bandwidth, they assume that any historical improvements in spectral efficiency (i.e. Mbit/s per MHz), caused by improvements in modulation, etc., will continue in the future. Therefore, the spectrum required is directly related to the demand for occupied bandwidth. Therefore, we have forecast the current spectrum usage (calculated as the utilisation of the band multiplied by the bandwidth) using the occupied bandwidth forecasts.

Annex C: Broadband wireless access services

This annex contains further details of the assumptions underlying the development of forecasts for spectrum required for BWA services – and should be read in conjunction with Section 4 of the main report.

C.1 Key assumptions

This section provides further details of the assumptions underlying our BWA spectrum demand modelling work.

UK demographics

The basic demographic parameters underlying our assessment are shown in Exhibit C.1 below, including the geotypes used for our analysis. For urban areas, we consider the demand for spectrum in the densest urban region (Dense Urban); for rural areas, we consider the demand for spectrum in the densest rural region (Rural).

Geotype	Urban/ Rural	Households	% of Households	Area (km2)	% of Area	Small business (<100)	Medium business (100-500)
Dense Urban	Urban	1,490,119	6.0%	336	0.1%	167,502	1,562
Urban	Urban	7,413,525	30.0%	3,991	1.6%	1,321,916	19,501
Semi-urban	Urban	8,100,512	32.8%	11,842	4.8%	261,033	3,322
Semi-rural	Urban	5,236,420	21.2%	47,454	19.4%	273,263	2,433
Rural	Rural	1,729,823	7.0%	56,819	23.3%	167,610	1,129
Remote	Rural	494,235	2.0%	33,547	13.7%	114,830	643
Very Remote	Rural	247,118	1.0%	90,304	37.0%	93,483	533

Exhibit C.1: *Geotypes used for modelling [Source: UK Statistics Office, Analysys, Mason, 2005]*

Addressable market for BWA services in rural areas under Scenario 2

Under Scenario 2, we assume that the addressable market for BWA services is limited by the deployment of wireline broadband services. For the purposes of our assessment, we assume that residences and SMEs located within 4km of an exchange are not addressable by BWA, primarily in view of DSL's higher data rates, as shown in Exhibit C.2 below. Additionally, it is likely that DSL services will also be priced at a lower level.

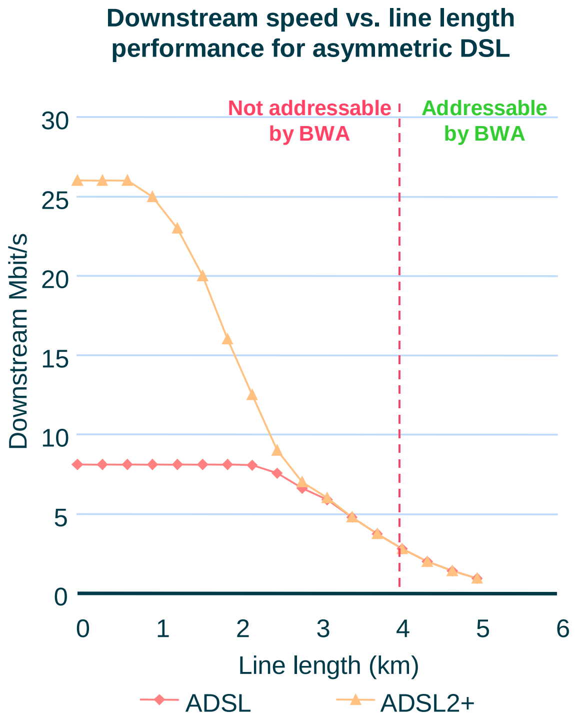


Exhibit C.2:
ADSL downstream speed versus line length [Source: Analysys, 2005]

The addressable market for BWA under Scenario 2, therefore, consists of residences and SMEs located over 4km from a BT exchange. Whilst it is likely that the performance of DSL will improve over time (i.e. greater speeds at a given distance from an exchange), it is also likely that user requirements for data rates will also increase over this time.

Broadband take-up

Our projections for the take-up of broadband services for residential users and SMEs are shown in Exhibit C.3 and Exhibit C.4 below.

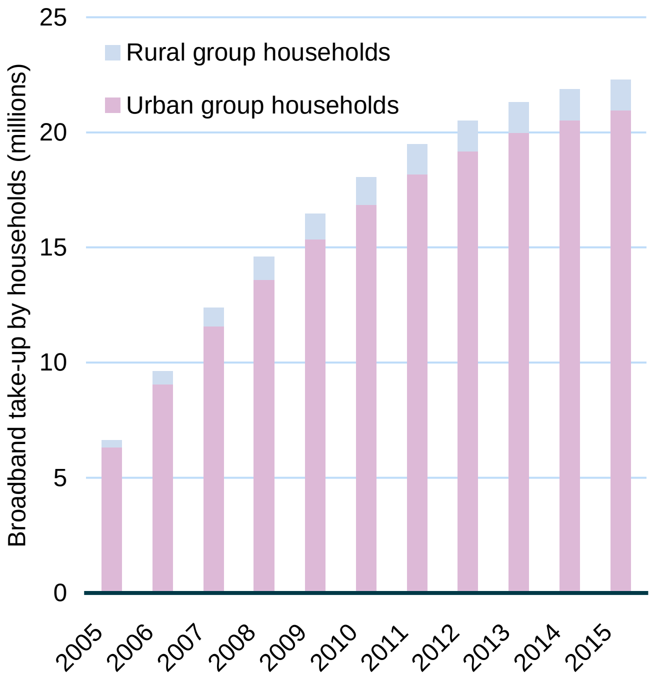


Exhibit C.3: *Broadband take-up by households [Source: Analysys, Mason, 2005]*

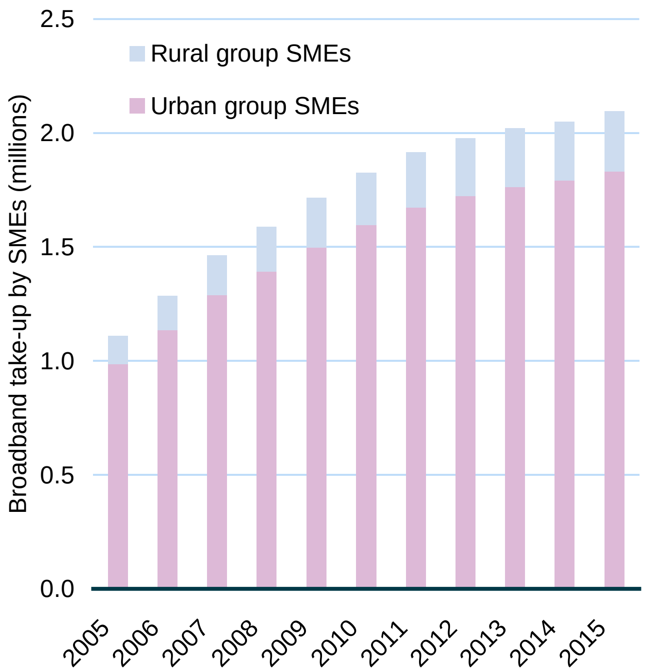


Exhibit C.4: *Broadband take-up by SMEs [Source: Analysys, Mason, 2005]*

For Scenario 1, in addition to household and SME take-up of broadband services, we also consider the potential use of broadband as a leased line replacement solution for medium-sized businesses. We consider that a total of 10 000 (2005) to 22 000 (2015) medium-sized business could adopt either a wireline or BWA leased-line replacement solution.

BWA take-up – Scenario 1

Our projections for the take-up of BWA services by broadband residential users and SMEs under Scenario 1 are shown in Exhibit C.5 and Exhibit C.6 below.

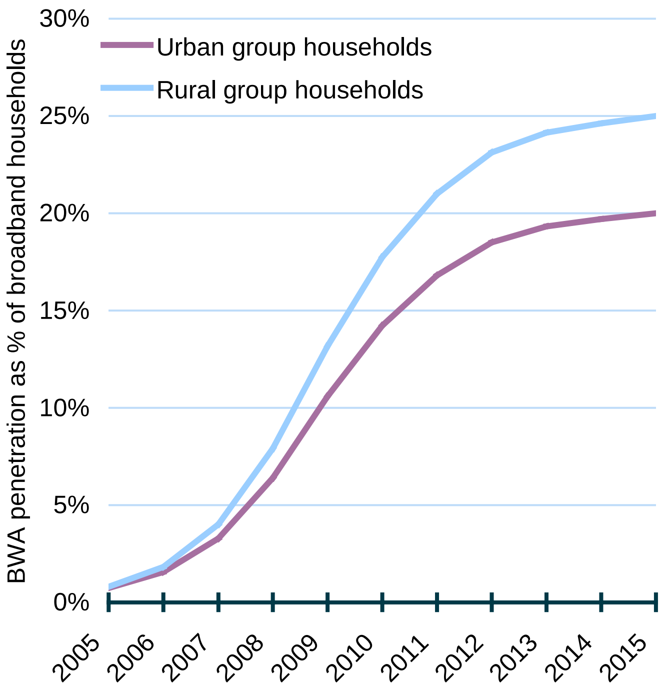


Exhibit C.5:

Scenario 1 – BWA take-up by broadband households [Source: Analysys, Mason, 2005]

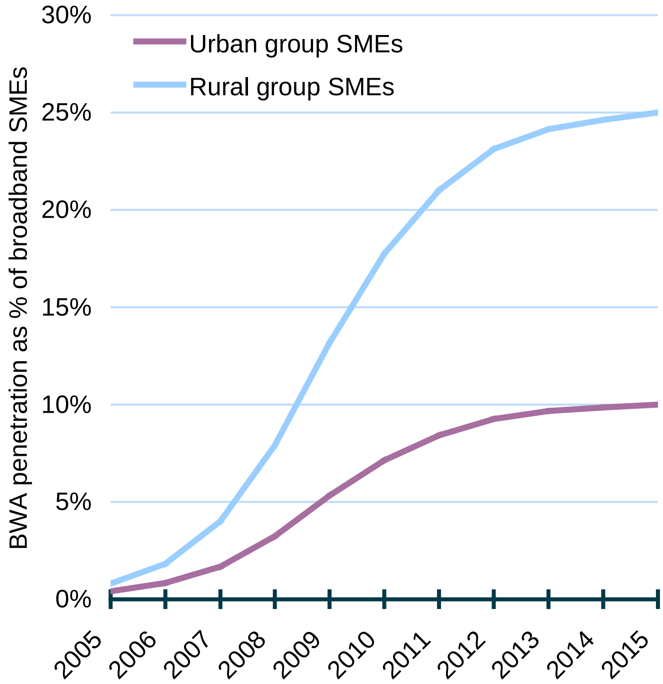


Exhibit C.6:

Scenario 1 – BWA take-up by broadband SMEs [Source: Analysys, Mason, 2005]

In respect of BWA as a leased line replacement solution, we assume a long-term penetration of 5% of those medium-sized businesses requiring a wireline or wireless solution in urban areas and 12.5% in rural areas.

BWA take-up – Scenario 2

We assume no take-up of BWA in urban areas for the purpose of our modelling (though as discussed in the main report, there may be localised 'islands' of deployment of BWA in urban regions).

Our geographical analysis indicates that the number of addressable households (i.e. those lying beyond 4km of a BT exchange) in rural areas is around 18.6% of the total number of households in the area. We assume that BWA services are taken-up by 50% of the broadband subscribers in these areas in the long run (2015), applying a similar take-up curve as for Scenario 1. We also apply these assumptions to the SME market, although we note that the addressable market may be slightly lower in practice as SMEs may be clustered closer to BT exchanges than households. We do not consider this approximation to be material in respect of our overall evaluation.

Subscriber bandwidth requirements

The projected downlink and uplink bandwidth requirements of household subscribers are shown in Exhibit C.7 and Exhibit C.8 respectively. Please note that these bandwidth projections can be considered to be relatively conservative in comparison with potential developments of wireline bandwidths – this is one of the reasons why we place a low probability on the prospect of BWA being able to challenge DSL and other wireline broadband solutions in urban areas.

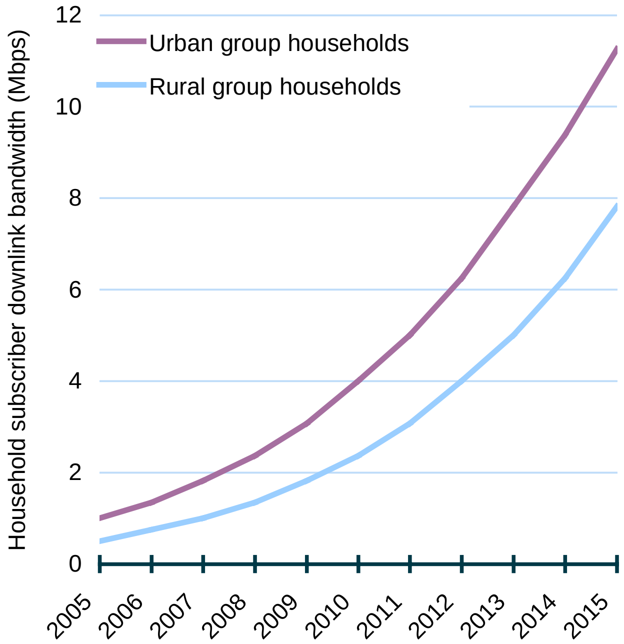


Exhibit C.7: *Household subscriber downlink bandwidth [Source: Analysys, Mason, 2005]*

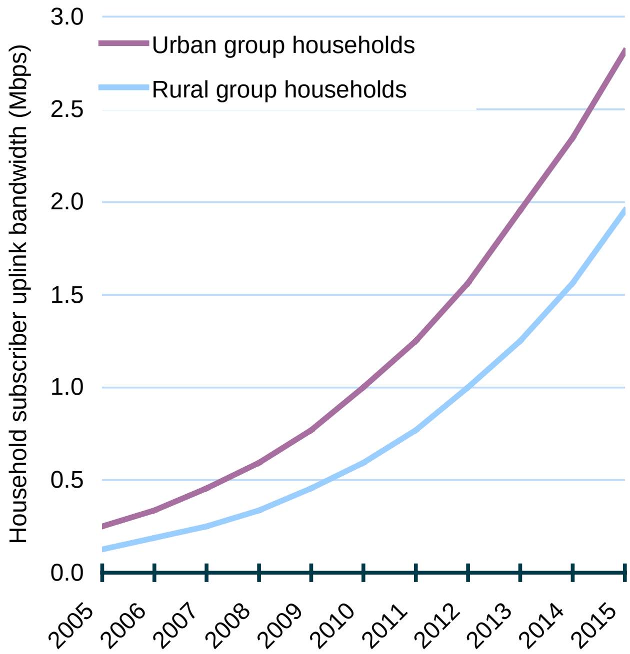


Exhibit C.8: *Household subscriber uplink bandwidth [Source: Analysys, Mason, 2005]*

We assume that household users will require service at a contention ratio of 50:1.

For SMEs, the downlink and uplink bandwidth requirements are shown in Exhibit C.9 and Exhibit C.10 respectively. Again, these requirements can be regarded as being fairly conservative.

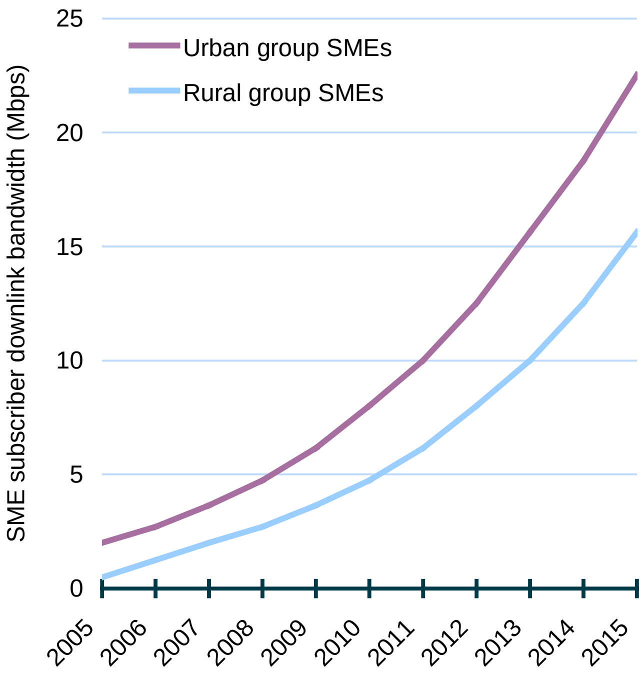


Exhibit C.9: *SME subscriber downlink bandwidth [Source: Analysys, Mason, 2005]*

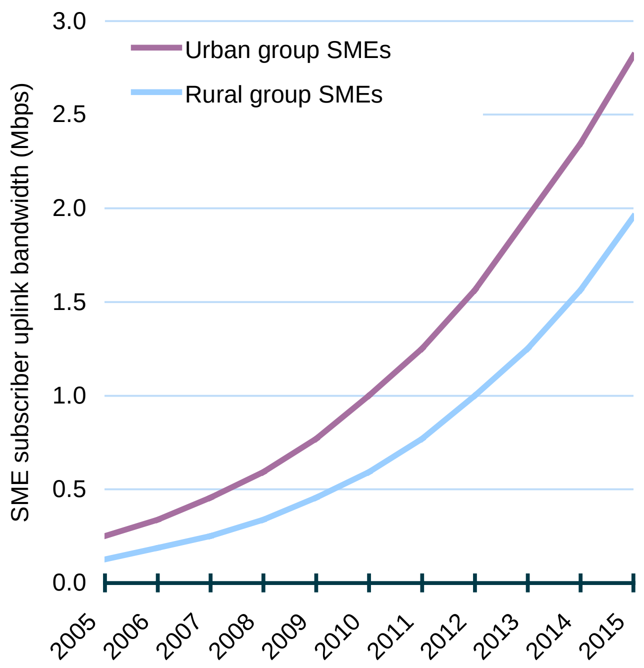


Exhibit C.10: *SME subscriber uplink bandwidth [Source: Analysys, Mason, 2005]*

We have assumed that SME broadband subscribers in urban areas will require a contention ratio of 30:1, whilst rural users will require a ratio of 40:1.

For leased-line replacement services, we assume that urban users require symmetric bandwidth of 1Mbit/s (2005) growing to 4Mbit/s (2015) in urban areas, with rural user requirements growing from 0.5Mbit/s (2005) to 3Mbit/s (2015). A contention ratio of 1:1 is assumed to be required in all cases, as the service is a leased-line replacement.

Radio network deployment

With the scope of the study, we have not been able to develop a detailed network cost model to assess the trade-off between access to additional spectrum and the number of base stations that an operator deploys. We have therefore had to make a series of simplified assumptions in relation to the base-station density that it is likely for operators to be able to deploy services economically. Whilst on first glance these may be considered as being 'broad brush' assumptions, they are in fact based upon several detailed fixed wireless access deployment models that Analysys has constructed for clients.

Under Scenario 1, we assume that:

- for the urban region, a 100% of the dense area is covered using cells with a range of 1km (although we assume a higher cell radius – 3km – in earlier years, due to the lower density of subscribers and lower bandwidth requirements of individual subscribers)

- for the rural region, 80% of the highest density rural areas are covered over time, assuming a base-station cell radius of 7.5km.

Under Scenario 2, we assume that 60% of the highest density rural areas are covered, again assuming a cell radius of 7.5km. Please note that this coverage requirement is lower than that under Scenario 1, since under this scenario we assume that households located within 4km of a BT exchange are not users of the BWA service, due to the superior characteristics (e.g. data rates, cost) of a wireline broadband solution.

Spectral efficiency

Our spectral efficiency calculations are based on data published by members of the WiMAX Forum.

For urban deployments, we assume a bandwidth of 2.7Mbit/s per MHz. This is based on WiMAX Forum estimates of a channel capacity of 9.5Mbit/s for a 3.5MHz channel for cell radii up to 1.5/2km in urban/suburban areas, respectively – see Exhibit C.11 below. We also assume a conventional cellular frequency re-use pattern of 12.

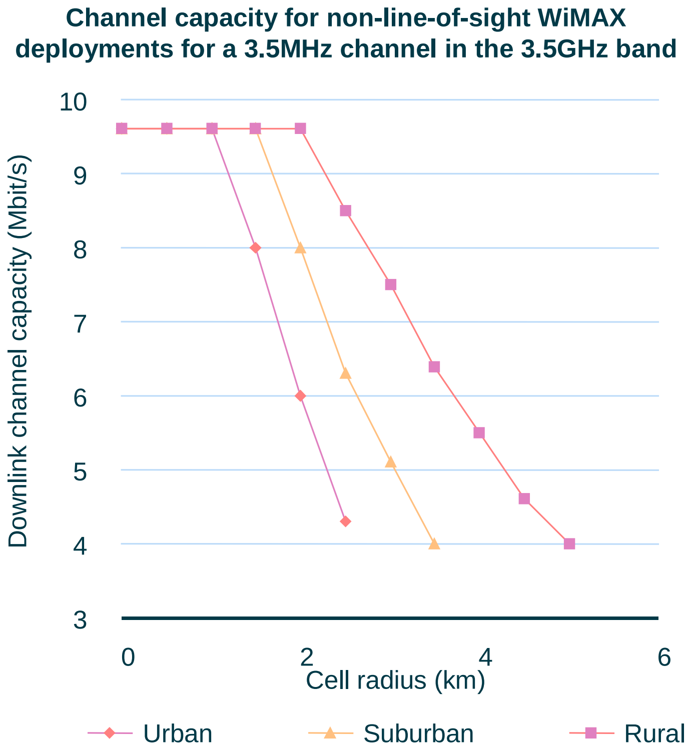


Exhibit C.11:

WiMAX urban channel capacity [Source: WiMAX Forum based on theoretical propagation model by Erceg et al]

The projected channel capacities are for a 'typical' non-line-of-sight WiMAX deployment:

- assumes mid-performance WiMAX-compliant equipment, operating in frequency division duplex (FDD) mode
- externally mounted antenna
- subscribers are uniformly distributed over the cell area
- 3.5MHz channel bandwidth
- use of the 3.5GHz band.

For rural coverage deployments, we assume a supported bandwidth of 1.2Mbit/s per MHz. This is based on a combination of:

- pre-WiMAX line-of-sight equipment supporting 24Mbit/s per 20MHz channel at a 10km range
- WiMAX Forum estimates of the performance of non-line-of-sight equipment (see Exhibit C.11 above) indicating a data rate of 4Mbit/s with a 3.5MHz channel at a range of 5km.

For both urban and rural areas, we have assumed:

- an 'efficiency factor' of 70% of the actual bandwidth per MHz calculated above, in order to take account of the imperfect spread of demand across the 'dense urban' and most dense rural areas modelled
- an improvement in spectral efficiency of approximately 15% per annum from 2005 to 2015 – this broadly corresponds to a doubling of spectral efficiency every five years.

Key long-term forecast assumptions

► *Traffic-demand projections*

We have assumed an annual growth of 20% in total traffic to be carried by BWA deployments between 2015 and 2025.

► *Spectral efficiency projections*

We have assumed an improvement in spectral efficiency of 15% per annum from 2015 to 2025. Again, this corresponds to a doubling of spectral efficiency every five years.

Annex D: Satellite services

This annex presents further details of our assessment of future demand for spectrum for satellite services and should be read in conjunction with Section 5 of the main report.

D.1 Existing BSS spectrum allocation

In the UK, BSkyB operates the Sky TV satellite platform that delivers direct to home (DTH) reception of satellite television. BSkyB's subscriber numbers reached 7 349 000 in the UK at the end of Q1 2005. The Sky TV platform delivers television (and radio) channels from Sky as well as those from third parties such as the BBC. Broadcasts are transmitted from a number of satellites operating in the 28.2°and 28.5° East orbits and using spectrum in the 10.7–12.5GHz band.

Frequency co-ordination for satellites is carried out by the ITU in terms of maximum permitted power limits for orbital positions. In bands shared with terrestrial services satellite emissions are constrained to a power flux density at the surface of the Earth which may not be exceeded.

Transponders on satellites compatible with the Sky platform can currently cover the whole of the 10.7–12.75GHz band. The breakdown of this band is given in Exhibit D.1.

Band (GHz)	*Sharing issues*	*Comments*
10.7 – 11.7	Co-ordination with terrestrial fixed-links in 11GHz band is required	No new terrestrial fixed-link allocations are being made in 11G band
11.7 – 12.5	None (exclusive BSS band)	
12.5 – 12.75	Primary allocation is for fixed satellite (FSS) which itself has sharing issues with MoD	Used extensively for VSATs in the UK

Exhibit D.1: *Usage of 10.7–12.75GHz band in the UK [Source: Ofcom, Analysys, Mason, 2005]*

The use of the 10.7 –11.7GHz band for BSS is a special case, as this band is designated for FSS use shared with terrestrial fixed-links. Fixed-link receivers are protected from space-to-earth interference by limiting the permissible power flux density that the broadcast satellite can generate, as defined in Article 21 of the Radio Regulations. However, this arrangement does not protect household satellite television receive-only installations from any harmful interference from terrestrial fixed services.

DTH Satellite capability

EUTELSAT and SES Astra have reached an intersystem co-ordination agreement for Europe which means that, for the UK, they have split the 10.7–12.5GHz band between themselves, as shown in Exhibit D.2 below. As indicated above, any use of frequencies in the 10.7–11.7GHz band in the UK is also subject to co-ordination with terrestrial fixed services.

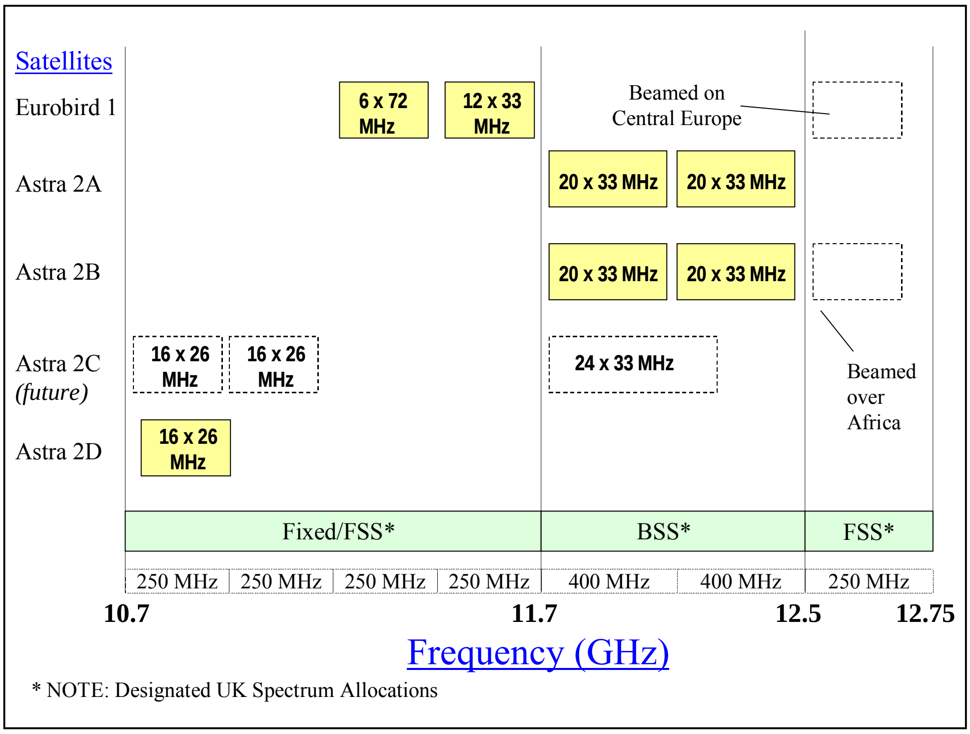


Exhibit D.2: *Current UK DTH BSS satellite spectrum utilisation [Source: Analysys, Mason 2005]*

Looking at the 10.7–12.5GHz band as a whole, there are potentially a total of 80 (nominal 33MHz bandwidth) transponders that could provide channel capacity for the UK Sky platform. We estimate that, at present, some 70 of these transponders are being used to provide television channels for the Sky platform with the other 10 transponders being either used for other services or not available because of limited satellite on-board transponder capacity (on some satellites there are less transponders than frequency channels and so all channels cannot be used simultaneously).

Future capacity

The 10.95–11.2GHz portion of the 10.7–12.5GHz band is not currently used. SES Astra intends to move its Astra 2C satellite to the 28.2° East orbit in 2007 to use this part of the band. Therefore this will provide an additional 16 transponders in the short term that could possibly be used (subject to co-ordination with terrestrial services) for additional capacity on Sky.

In terms of the medium-to-long-term demand, a number of possible measures have been suggested in order to provide additional capacity:

Proposal	*Impact on spectrum*	*Impact on household receiving equipment*	*Comment*
Use of 12.5 to 12.75 band (currently allocated for FSS)	None - existing FSS allocation	None	This is an FSS designated band which is already heavily used for VSATs in UK. Difficult to see where spare capacity can be found
Deploy newer satellites in the 10.7–12.5GHz band (with more efficient transponder plans)	None	None	Some current satellites have less transponders than available channels
Use of adjacent orbital slots	None	New dish and LNB and STB	Co-ordination with other satellite operators' slots required
Use of the Ka band (actually above 15GHz)	None - existing allocation	New dish and LNB and STB	Ka band currently little used – can be subject to rainfade

D.2 FSS modelling assumptions

For modelling additional VSAT demand (FSS Scenarios 2 and 3) we assume growth in:

- the number of VSATs deployed – 10 000 by 2012 and 14 000 by 2025
- average bandwidth per terminal – reaching 1Mbit/s in 2015 and 2Mbit/s in 2025 (FSS Scenario 2); 2Mbit/s in 2015 and 4Mbit/s in 2025 (FSS Scenario 3).

We also assume a bandwidth management efficiency of 10:1 aimed at modelling 'pre assigned multiple access' systems. In addition to this, we also assume frequencies can be re-used three times for a given VSAT network.

For mobile applications delivered over FSS, we modelled three main markets:

- aeronautical – long-haul aircraft only
- maritime – passenger ships
- railway – inter-city trains.

Demand for spectrum for these services arises for several reasons:

- Growth in the total number of long-haul aircraft in operation – assumed to rise from 5000 in 2005 to 7400 in 2025 (a CAGR of 2%); we assume the number of passenger ships remain constant (4000), as do the number of inter-city trains (for which we assume there are 7500).

- The percentage of the fleet in use at any one time – assumed to be 70%, 60% and 80% for aircraft, ships and trains respectively.

- Growth in penetration of mobile services:
  - Long haul aircraft – rising to 100% by 2025, reflecting the business market on board
  - Ships and trains – rising to 50% by 2025.

- Growth in bandwidth per unit – from 1Mbit/s in 2005 to 16Mbit/s in 2025 for haul aircraft (15% CAGR); from 0.5Mbit/s in 2005 to 8Mbit/s in 2025 for ships and trains (CAGR 15%). The difference reflects the higher concentration of business use on aircraft.

- Contention ratio – assumed to be 20:1 for aircraft and 50:1 for ships and trains. The difference reflects the higher concentration of business use on aircraft.

- The minimum number of transponders required for coverage – assumed to be 25 for aircraft and ships, and 10 for trains (lower because of narrower geographical focus).

- Frequency re-use – we have assumed FSS frequencies can be re-used five times in each of 3 major regions around the world e.g. through the use of spot beam technologies.

- For simplicity we have assumed the spectrum forecasts resulting from the above assumptions are incorporated into the main FSS scenarios on a proportionate basis, namely:

  - FSS scenario 1 includes 25% of the spectrum forecast from mobile FSS applications
  - FSS scenario 2 includes 50% of the spectrum forecast from mobile FSS applications
  - FSS scenario 3 includes 100% of the spectrum forecast from mobile FSS applications.

Annex E: Terrestrial television broadcasting services

This annex contains further details of the of background research, issues and methodology used to forecast the spectrum demand for terrestrial television broadcast services – and should be read in conjunction with Section 6 of the main report.

E.1 List of secondary research documents

The main documents and reports that were reviewed are listed in Exhibit E.1 below.

Ref.	*Document*	*Source*	*Date*
1.	Planning options for digital switchover – statement	Ofcom	1 June 2005
2.	Driving digital switchover: a report to the Secretary of State	Ofcom	5 April 2004
3.	Spectrum framework review: implementation plan	Ofcom	13 Jan 2005
4.	Digital television update Q1 2005	Ofcom	10 June 2005
5.	Report of the digital TV Project	Digital Television Project	26 Nov 2004
6.	Study on spectrum management in the field of broadcasting. Final Report: Implications of digital switchover for spectrum management	Indepen/Aegis/IDATE	June 2004
7.	Progress towards achieving digital switchover: a BBC report to the government	BBC	April 2004
8.	IDS research briefing – HDTV	IDS	April 2005
9.	Euro HDTV: slow but steady	Cable & Satellite International	Jan/Feb 2005
10.	Technologies for efficient emission of HDTV across Europe – White Paper WHP 104	S.B. Gauntlett BBC R&D	Jan 2005
11.	Why HDTV will flourish	IEE Communications Engineer	April/May 2005
12.	Mobile TV the next big 'killer app' in wireless?	3G Americas	July 2005

Exhibit E.1: *List of main secondary research documents*

E.2 Further details of key areas for terrestrial television

E.2.1 DSO project

The DSO plan provides for six multiplexes:

- three PSB multiplexes offering similar DTT coverage to current analogue television from around 1150 sites
- three commercial multiplexes offering a lower level of coverage from around 200 sites.

A key feature of the switchover plan is to maximise the use of existing household rooftop antenna installations by retaining existing analogue transmitter sites and frequencies for DTT transmissions. If a wholesale replacement/re-alignment of antennas to around 25 million households was required, then this would hugely complicate and delay the switchover plan and could cause considerable disruption to viewers during the changeover period. It has been suggested[31] that no realignment or replacement of antennas is expected for 90% of households.

The current DSO plan anticipates retaining 32 channels (256MHz) to provide the coverage/programming as detailed above, and releasing a total of 14 channels (amounting to 112MHz of spectrum), but this is subject to detailed planning and agreement at the 2006 regional radio conference (RRC06). Some low-power local television services, such as community television, may also be able to be accommodated within the frequency plan.

Future changes to terrestrial broadcast television will occur relatively slowly because of the long lead times associated with:

- the pace of changeover of television receiving equipment by consumers in the approximately 25 million households in the UK
- the co-ordination required with the rest of Europe for the agreement to changes to high-power broadcast transmitters from analogue to digital transmissions
- the implementation of the new DTT transmitter network (currently there are more than 1100 analogue television transmitter sites), and the need to minimise the disruption to existing analogue transmissions prior to switchover.

The earlier conversion from black and white television to colour in the UK could be seen as a similar switchover project. Colour television broadcasts of BBC2 started in 1967 but 10 years later it was estimated that only 55%[32] of households had colour televisions and simulcasting of black and white and colour programmes continued until 1985.

31 *Report Of The Digital TV Project*, November 2004.

32 Source: BBC.

E.2.2 Post DSO developments

This section provides additional information on potential future developments of digital terrestrial television, and should be read in conjunction with our overview of developments presented in Section 6.3.

HDTV

There is currently strong interest in HDTV:

- The BBC has announced that it intends to produce all programmes in HDTV format by 2010.
- The BBC has demonstrated the non-real time delivery of HDTV. The system works by downloading programmes during the night to a hard disc where they are stored until the standard definition version is broadcast.
- Sky has announced that it is to start broadcasting HDTV services in 2006.
- Sales of large flat-screen televisions are increasing, and the latest models are HDTV compatible.
- A high density DVD format is expected soon.
- Of the main gaming platforms, Playstation 3 and Xbox will have high density gaming content in future models.

In relation to the requirement for HDTV-compatible equipment, it has been suggested by industry representatives that more clarity in the future development of the DTT platform could stimulate at least some 'future proofing' of new DTT STBs by including future compatibility modes (perhaps for very little incremental cost) that would ease the future introduction of new services.

Type of network

DTT networks using the digital video broadcast (DVB) standard can be implemented as two types of networks: either single frequency networks (SFNs), or multi-frequency networks (MFNs).

- SFNs transmit exactly the same frequency and programme content from each broadcast site; the standard DVB orthogonal frequency division multiplexing format allows transmissions from different sites to be combined in the receiver provided that they are all received within a guard interval. However, transmissions from longer distances can exceed the guard interval and cause interference and, therefore, for wide-area networks careful network planning and RF engineering is required. The guard interval used in SFNs results in the multiplex having less capacity for programming – thereby reducing the magnitude of the spectral efficiency benefits arising from the use of SFNs.

- MFNs are similar to the current analogue television networks whereby a pool of channels is re-used across the coverage area – typically a pool of six channels would be used for DTT. While this is theoretically more spectrally inefficient than the use of SFNs for transmitting the same content, the use of MFNs can be more spectrally efficient for the broadcasting of regional and local content (SFNs would require all regional variants of BBC1, ITV, etc. to be broadcast across the whole country – and may possibly require the use of encryption technology (e.g. as used by ITV on BSkyB) to ensure regional content is only available in the area in which reception is intended). Current broadcasting law mandates the provision of such regional content. Additionally, current transmitter network sites, etc. are all configured for multi-frequency broadcasting.

Simulcasting

Where new television services are introduced that are not compatible with the existing DTT platform, then a period of simultaneous broadcasting (simulcasting) may be required, which has a significant impact on spectrum demand. It may be possible to design future STBs with a backwards-compatibility mode that can convert HDTV transmissions into SDTV format which could potentially reduce the need for simulcasting. However, this would not address the installed base of around five million STBs and digital televisions – which are not HDTV compatible.

E.2.3 Discussion of key areas for mobile television

The main differences between traditional fixed terrestrial television broadcasting and mobile television are:

- mobile devices have much smaller screens than televisions
- power consumption is a major factor because of battery rather than mains operation
- mobile reception is much more challenging, with the antenna at street rather than rooftop level.

Two technologies that are being, or are about to be, trialled in the UK for mobile television are digital multimedia broadcasting (DMB) and digital video broadcasting handheld (DVB-H):

- DVB-H is a variant of standard DTT but optimised for mobile devices. It uses standard 8MHz bandwidth carriers and each carrier can typically support up to 30 low-resolution television channels. It is best suited to applications that require many television channels. O2 and Arqiva (formerly NTL Broadcast) have announced that trials of DVB-H are being held in Oxford in the summer of 2005.

- DMB is a variant of digital audio broadcasting (DAB). It uses 1.5MHz carriers and each carrier can typically support four to six low-resolution television channels. It is well integrated with DAB radio and offers a flexible multiplex structure. It is best suited to applications requiring a few television channels. Trials are planned within the M25 in the summer of 2005 by BT, GWR and Virgin Mobile.

Depending upon the application, it may be possible to use caching for non real time content in order to reduce spectrum demand.

E.3 Further details of scenarios

E.3.1 Terrestrial television Scenario 1

In this scenario, there is an increase in the number of commercial SDTV channels:

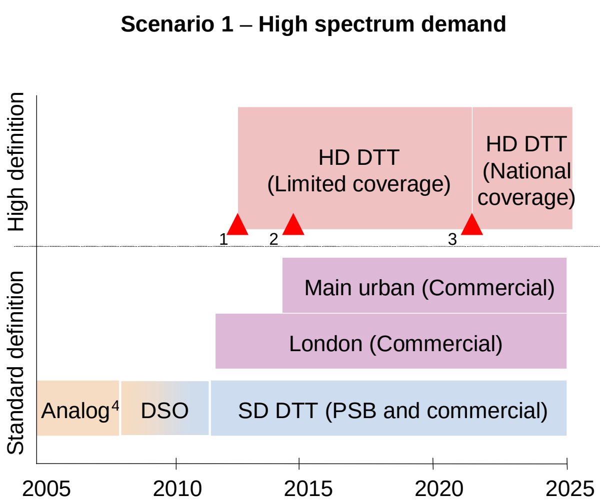
- London – a total of 80 new television channels, supported on the basis of the very high population density and the fact that relatively few transmitter sites would be required.
- Urban – a total of 30 new television channels.

Given that the coverage is not contiguous, we have assumed the use of single frequency networks for the new commercial SDTV channels.

Terrestrial HDTV is also introduced, with the total number of channels broadly equivalent to the number of Freeview channels currently available:

- 15 new HDTV channels with national coverage (equivalent to national DTT coverage), using a multi-frequency network with six 8MHz carriers – this will support regional content
- 15 new commercial HDTV channels with coverage limited to urban areas, using a single frequency network with one 8MHz carrier. This will have national content – although regional content may be possible in urban areas where there is no overlapping coverage from other more distant urban areas.

The timeline for this scenario is given in Exhibit E.2.



1. HD coverage from main broadcast sites (2012)
2. HD coverage equivalent to Freeview today (2015)
3. National HD coverage (2022)
4. Freeview currently shares Band IV/V spectrum

Exhibit E.2: *Terrestrial television Scenario 1 timeline [Source: Analysys, Mason, 2005]*

E.3.2 Terrestrial television Scenario 2

In this scenario, there is a more limited increase in the number of commercial SDTV channels:

- London – a total of 30 new television channels, supported on the basis of the very high population density and the fact that relatively few transmitter sites would be required
- Urban – a total of 15 new television channels.

Given that the coverage is not contiguous, we have assumed the use of single frequency networks for the new commercial SDTV channels.

Terrestrial HDTV is also introduced but with only a sub-set of the core DTT channels being available in HDTV format:

- six new HDTV channels (four core public service broadcast channels plus two others) with national coverage (equivalent to national DTT coverage), using a multi-frequency network with six 8MHz carriers. This will support regional content
- nine new commercial HDTV channels with coverage limited to urban areas, using an SFN with one 8MHz carrier. This will have national content – although regional content may be possible in urban areas where there is no overlapping coverage from other more distant urban areas.

The timeline for this scenario is given in Exhibit E.3 below.

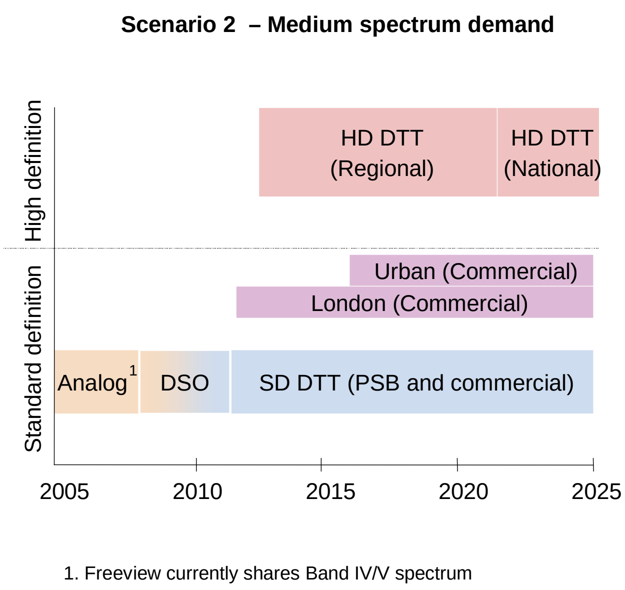


Exhibit E.3: *Terrestrial television Scenario 2 timeline [Source: Analysys, Mason, 2005]*

E.3.3 Terrestrial television Scenario 3

In this scenario, we assume that HDTV services are introduced on the digital terrestrial platform but no additional SDTV channels are introduced.

Terrestrial HDTV is also introduced but with only a sub-set of the core DTT channels being available in HDTV format:

- six new HDTV channels (four core public service broadcast channels plus two others) with national coverage (equivalent to national DTT coverage), using a multi-frequency network with six 8MHz carriers. This will support regional content
- six new commercial HDTV channels with coverage limited to urban areas, using an SFN with one 8MHz carrier. This will have national content – although regional content may be possible in urban areas where there is no overlapping coverage from other more distant urban areas.

The timeline for this scenario is given in Exhibit E.4.

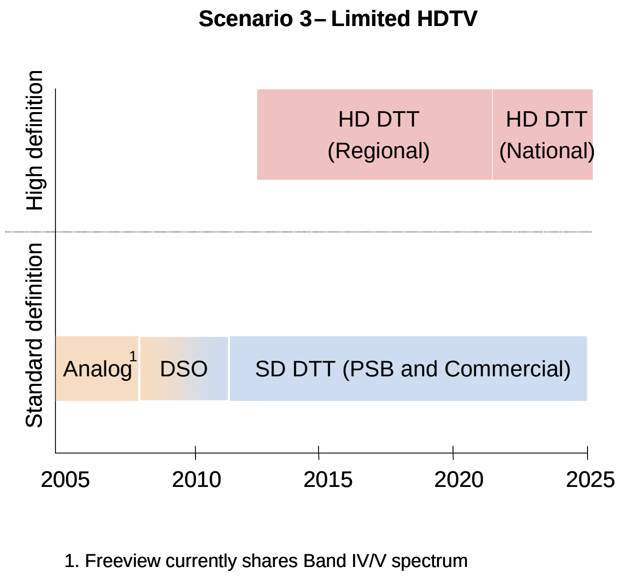


Exhibit E.4: Terrestrial television Scenario 3 timeline [Source: Analysys, Mason, 2005]

E.3.4 Terrestrial television Scenario 4

In this scenario, the DTT platform continues to operate until 2025 but there is no further development of the DTT platform (beyond 2012) in terms of the introduction of HDTV or additional SDTV channels. HDTV services are only available on other platforms.

The timeline for this scenario is given in Exhibit E.5.

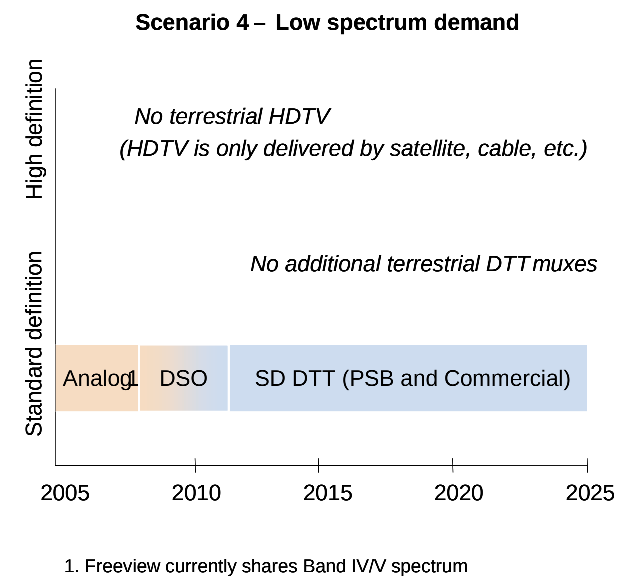


Exhibit E.5: Terrestrial television Scenario 4 timeline [Source: Analysys, Mason, 2005]

E.3.5 Mobile television Scenario 1

This is the first mobile television scenario and it assumes that there is widespread implementation of mobile television, with the DVB-H and DMB platforms being complementary. The DVB-H network offers a premium mix of channels whilst the DMB network offers fewer channels but is more integrated with DAB radio.

In practice, the spectrum requirement we have modelled may actually arise for additional programming (channels) on a smaller number of mobile television networks (as detailed in Scenario 2), depending on the economics of service deployment relative to generated service revenues.

DVB-H

- One national MFN with 20 television channels and local content.
- One national SFN with 20 television channels with national content. Regional content may be possible in urban areas where there is no overlapping coverage from other more distant urban areas.

DMB-H

- Two national multi-frequency networks with five television channels each, both with regional content.

The timeline is given in Exhibit E.6.

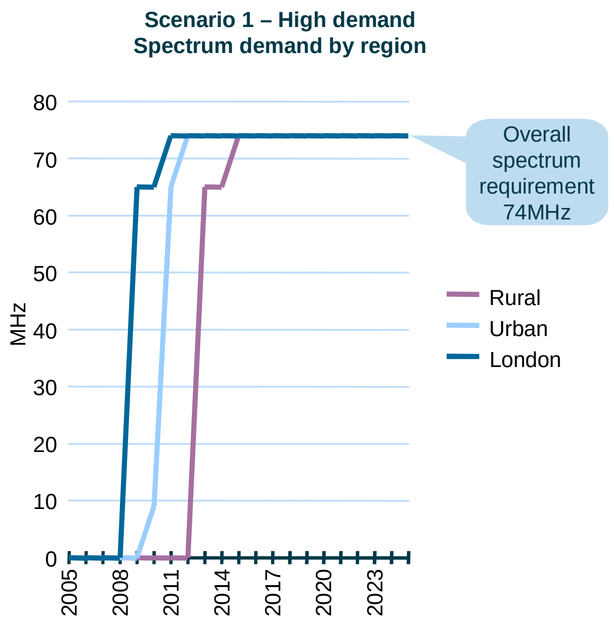


Exhibit E.6:

Mobile television Scenario 1 timeline [Source: Analysys, Mason, 2005

E.3.6 Mobile television Scenario 2

In this scenario, one DVB-H and one DMB network are implemented. Each network is a SFN providing coverage to London and urban areas only. This will have national content – although regional content may be possible in urban areas where there is no contiguous coverage from other more distant urban areas. The timeline is provided in Exhibit E.7.

As discussed in Section 6.5, we note that potential service providers may prefer to deploy multi-frequency networks for mobile television as these are apparently considerably less costly to deploy and operate. If this is the case, spectrum demand for mobile television services will be higher than modelled under this scenario but less than the demand forecast estimated under Scenario 1. We have not explicitly modelled the deployment of two multi-frequency mobile television networks as an alternative scenario since the total spectrum demand for mobile television is modest in comparison with fixed terrestrial television – and therefore it is not critical to the overall study findings.

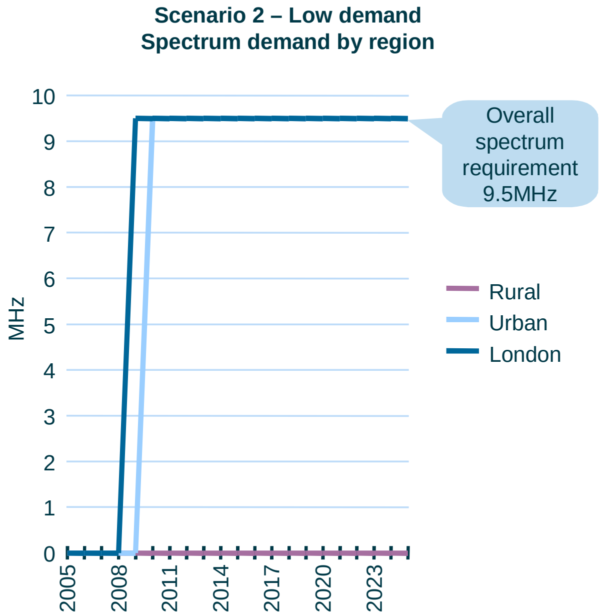


Exhibit E.7:

Mobile television Scenario 2 timeline

[Source: Analysys, Mason, 2005]