

Final Report for Ofcom

Assessment of options for allocating
available spectrum within
VHF Band III (174–230MHz)
and L-Band (1452–1492MHz)

Analysys

•econ



Mason

3 September 2004

Amended 22 November 2004

Assessment of options for allocating available spectrum within VHF Band III and L-Band

Final Report for Ofcom

Contents

0	Executive summary	i
0.1	Introduction	i
0.2	Supply/demand for Band III and L-Band spectrum	ii
0.3	Recommended allocation/assignment strategy	viii
0.4	Suggested next steps for Ofcom	xiii
1	Introduction	1
1.1	Background	1
1.2	Study objectives	2
1.3	Summary of our approach	2
1.4	Structure of this document	3
2	Objectives in allocation and assignment	5
2.1	Underlying principles	5
2.2	The allocation and assignment process	7
3	Current usage of Band III and L-Band	15
3.1	VHF Band III (174–230MHz)	15
3.2	L-Band (1452–1492MHz)	19
4	Economic benefits from alternative uses of the spectrum	23
4.1	Introduction	23
4.2	Scope of the benefits assessment	25
4.3	Private Mobile Radio	26
4.4	Public Access Mobile Radio	29
4.5	T-DAB	30

4.6 T-DAB mobile and portable multimedia services	35
4.7 Summary of demand	36
5 Analysis of demand for the spectrum	41
5.1 Spectrum requirements of services in VHF Band III	41
5.2 Compatibility of services in VHF Band III	43
5.3 Demand for and value of services in VHF Band III	48
5.4 L-Band	50
6 Allocation options	55
6.1 VHF Band III: Sub-band 2	56
6.2 VHF Band III: Sub-band 3	60
6.3 L-Band	69
7 Assignment options	75
7.1 VHF-band III: Sub-band 2	76
7.2 VHF-band III: Sub-band 3	78
7.3 L-Band	83
8 Scenario analysis	87
8.1 Areas of uncertainty	87
8.2 High demand scenario for PMR/PAMR spectrum in London	93
9 Recommendations	95
9.1 Initial decisions	95
9.2 Allocation and assignment strategy for Band III and L-Band	96
9.3 Monitoring of future developments	100
9.4 Next steps	101
Annex A: Private mobile radio - benefit analysis	
Annex B: Public access mobile radio – benefit analysis	
Annex C: T-DAB – benefit analysis	
Annex D: T-DAB mobile and portable multimedia services – benefit analysis	
Annex E: PMSE usage of Band III	
Annex F: Interference analysis	

0 Executive summary

0.1 Introduction

Analysys Ltd (Analysys), Mason Communications Ltd (Mason) and DotEcon Ltd (DotEcon) have been retained by Ofcom to undertake an assessment of the options for allocating available spectrum in VHF Band III (174MHz–230MHz) and L-Band (1452MHz–1492MHz). This final report has been prepared as a summary of our findings and takes account of comments received from Ofcom.

In determining the appropriate process for distributing spectrum in VHF Band III and L-Band, Ofcom must make decisions about:

- *Allocation* – what type of services and/or technologies will be permitted to use the spectrum
- *Assignment* – who can use the frequencies
- *The distribution (assignment) mechanism(s)* – to what extent decisions on allocation and assignment should be determined administratively, or devolved to users through the use of market mechanisms.

Ofcom has identified five types of service which could be used in Band III and L-Band:

- terrestrial digital audio broadcasting (T-DAB) – national, regional, local or community radio services
- T-DAB-delivered mobile and portable multimedia services
- private mobile radio (PMR) – in addition to existing use in Band III
- transport communications (PMR-based) and passenger information services
- public access mobile radio (PAMR).

In addition, some spectrum in these bands is already allocated to programme making and special events (PMSE) and short-range devices.

In order to assess the most appropriate process for distributing Band III and L-Band spectrum, we undertook our assessment in three phases:

- In *Phase A* of the study, we investigated the demand for additional spectrum from the services listed above and quantified the economic benefits of allocating additional spectrum to each of these services.
- In *Phase B*, we identified and investigated the options available for allocating and assigning spectrum in VHF Band III and L-Band. In particular, we undertook a detailed review of the current services using Band III and the constraints impacting on future use (e.g. current band plan, Continental interference, and the nature of the spectrum required by each of the services).
- In *Phase C*, we analysed the robustness of our provisional Phase B findings under different market development scenarios. From this analysis, we developed our final recommendations.

0.2 Supply/demand for Band III and L-Band spectrum

0.2.1 Availability of Band III and L-Band spectrum

Band III is divided into three Sub-bands:

- *Sub-band 1 (174MHz–191MHz)*: Currently used for PMR, PAMR, common base stations, asset tracking (CDMA) and remote meter reading. Ofcom regards this band as being ‘full’ in London and the South East but further assignments can be made in most other parts of the country.
- *Sub-band 2 (193MHz–207MHz)*: This Sub-band is currently allocated to PMR and PAMR use. Ofcom estimates that around $2 \times 4.6\text{MHz}$ of this spectrum is available for new use (though only $2 \times 1.2\text{MHz}$ – that is, 95 paired PMR channels – is currently available on a contiguous basis).

- *Sub-band 3 (209MHz–215MHz)*: This Sub-band has notionally been allocated to ‘new technology systems’ but no assignments have been made to date. Ofcom estimates that in total $2 \times 2.7\text{MHz}$ of contiguous spectrum is available (216 paired 12.5kHz PMR channels). The remaining spectrum in this Sub-band is allocated either solely to programme-making and special events (PMSE)¹ or to both PMSE and short-range devices (SRDs). However, we understand from Ofcom that there are no SRDs currently utilising this spectrum.

The scope for interference between the UK and Ireland and the Continent means that not all of Band III can be used in all parts of the country.

L-Band spectrum (1452-1492MHz) has been internationally allocated to broadcasting (for T-DAB and Satellite DAB). Of the 40MHz of spectrum, 23.5MHz (1452MHz–1475.5MHz) has been allocated to T-DAB. This spectrum is divided into 16 blocks, each suitable for one T-DAB multiplex, in accordance with the CEPT Maastricht 2002 Allotment Plan. The remaining spectrum is unallocated.

0.2.2 Demand for Band III and L-Band spectrum

Our assessment indicated that the combination of radio propagation characteristics and equipment availability meant that L-Band would only be of use to two of the services under investigation: T-DAB radio and T-DAB mobile and portable multimedia. Band III spectrum is potentially useful to all five services.

Our analysis of the benefit of allocating additional spectrum in Band III to each of the five services revealed the following:

- *PMR (including transport PMR)*. Our modelling scenarios attached a positive value of up to GBP51 million (Net Present Value to 2014) to additional spectrum for PMR. Our baseline scenario attached a value of GBP29 million corresponding to allocating 6.6MHz ($2 \times 3.3\text{MHz}$) additional spectrum for PMR, although this additional demand is only required in London. A further 1MHz of spectrum would also be required on a

¹ PMSE Block 1 (207.4395–209.20626MHz) is used for shared radio microphones and co-ordinated radio microphones. PMSE Block 2 (207.4395–209.20626MHz) is used for the base receive part of TalkBack systems (this is paired with spectrum in Sub-band I). PMSE Block 3 (215.25625–217.5MHz) is used for shared radio microphones and point-to-point audio links. See Annex E for further details.

nationwide basis under this scenario, for the provision of real-time passenger information services on buses². We also modelled an alternative scenario corresponding to stronger demand for PMR spectrum (here demand for PMR spectrum is also strong but highly spectrally efficient digital technologies do not become available for Band III). This scenario attached a positive value of up to GBP51 million to allocating 9.1MHz ($2 \times 4.55\text{MHz}$) of additional spectrum in London, and 1.2MHz in other major urban areas.

- *PAMR*. Generally there is no additional value or demand for extra spectrum, though one scenario involving the migration of existing Dolphin customers to Band III PAMR networks could lead to a requirement of 1.2MHz of spectrum in London, with an associated value of GBP12.6 million.
- *T-DAB (including multimedia services)*. There is a positive social value of GBP28 million to GBP129 million associated with allocating up to seven or more additional T-DAB blocks which would require approximately 11.9MHz of additional spectrum. However, the incremental value created by additional blocks diminishes rapidly. For example, adding one extra national block accounts for over 33% of the total, whereas adding a fifth national block adds just 13%. Adding local multiplexes also adds less value than national ones, in large part because of the large amount of geographical spectrum that is sterilised in order to avoid interference between local radio stations.

There is one further specific source of demand for Band III spectrum. Up to 10MHz of spectrum may be required for public safety or national security purposes. Whether to allocate Band III spectrum for these purposes is an administrative decision that Ofcom will need to make – we estimate that the opportunity cost of making this allocation amounts to GBP25 million to GBP120 million.

² We estimated this could generate significant economic benefits (GBP852 million). However, our estimates are based on confidential information from London Buses and we have not been able to validate the market research methodology underlying this information.

0.2.3 Commercial and technical constraints

Band III

The nature of the existing usage of Band III, and the technical characteristics of each of the services, impose further constraints on the use of Band III:

- PMR/PAMR generally requires paired 12.5kHz channels with specific duplex spacing between base transmit and mobile transmit bands and a guard band between the base transmit and mobile transmit spectrum.
- T-DAB requires 1.536MHz channels (but with additional guard bands between channels). Additional T-DAB blocks need to be positioned at specific locations within Band III (in accordance with a CEPT band plan) to enable all T-DAB receivers to pick up these signals.
- There needs to be a 2.44MHz guard band between T-DAB and PMR base transmit spectrum in order to prevent harmful interference to PMR transmissions.
- As shown in Exhibit 0.1, existing assignments mean that in practice a maximum number of five T-DAB blocks can currently be allocated within Band III (using spectrum in Sub-band 3). Creating a sixth T-DAB block would involve the displacement of 1440 existing PMR assignments (of which 1319 are to Network Rail) and 6 existing PAMR assignments.
- Use of five T-DAB blocks would require existing PMSE users to be migrated to other frequencies – the cost of this would need to be considered further prior to any final allocation decision being made.
- Interference from television broadcast transmitters in Ireland and the Continent places severe constraints on the use of Sub-band 3 spectrum for PMR services.
- Usage of four of the five T-DAB blocks would be partially constrained (in terms of geographical availability) by the scope for causing harmful interference to television broadcasting in other countries.

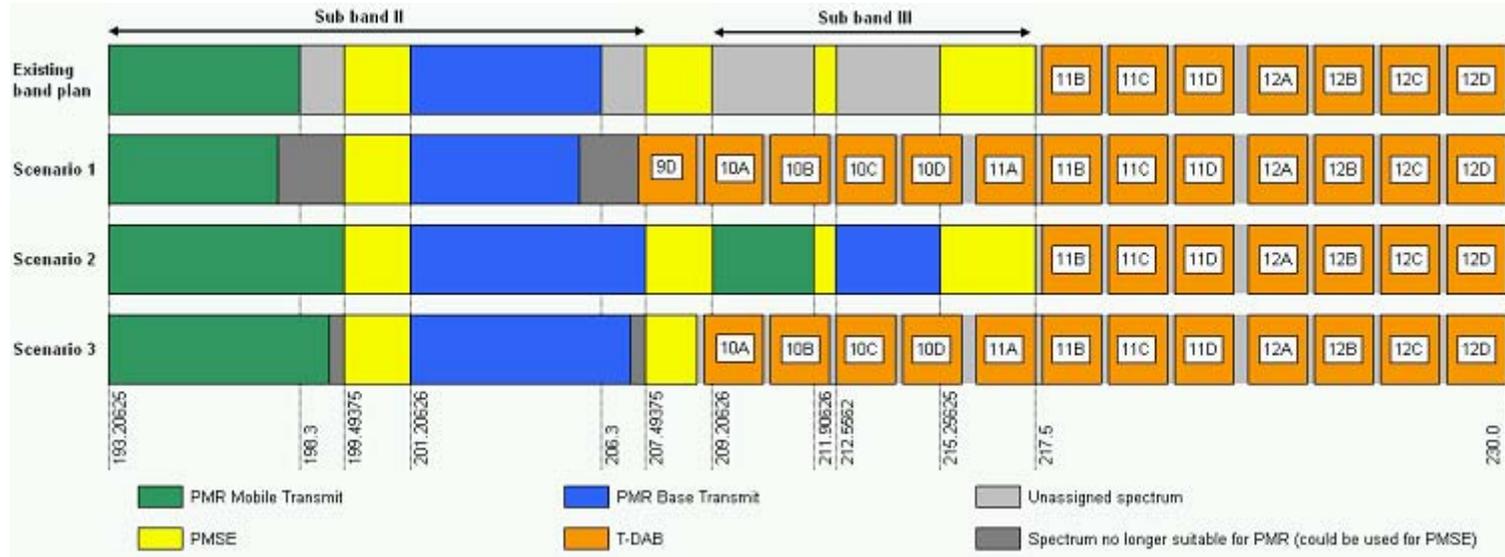


Exhibit 0.1: Selected allocation scenarios for VHF Band III

The allocation of five T-DAB blocks in Sub-band 3 would allow all of the unutilised Sub-band 2 spectrum to be allocated to PMR and PAMR, provided that one of the T-DAB blocks (10A) is not used within Greater London or the immediately surrounding areas (10km). Since some of the T-DAB blocks are to be used in certain regional areas, this should not be an insurmountable hurdle.

The unutilised Sub-band 2 spectrum ($2 \times 4.6\text{MHz}$) is sufficient for all future PMR/PAMR demand scenarios allowing demand for both PMR and T-DAB to be, for the most part, met. However, there is one scenario we have examined where this is not the case. This arises only if all of the following occur:

- there is strong continuing demand for the self-provision of mobile radio systems (i.e. strong demand for PMR spectrum in place of migration to public cellular networks)
- new spectrally efficient digital PMR technologies are not available in Band III
- UHF2 band re-alignment does not occur (thus only 50% of the potentially released spectrum for PMR in the 450-470MHz band does actually become available)
- there is additional demand for Band III PAMR spectrum in London – e.g. as a consequence of the migration of ex-Dolphin customers onto Band III public networks.

Under this low probability scenario, we estimate that an additional $2 \times 0.6\text{MHz}$ of spectrum would be required in London under this scenario – with an associated economic benefit of GBP5 million. This additional demand could be accommodated by allocating PMR to Sub-band 3 in the London area only. However, this would require the displacement of at least four of the proposed five new T-DAB blocks from the London area, at an estimated cost of GBP9 million to GBP17 million. Furthermore, our assessment of transmissions from Continental and Irish television broadcast sites indicates that such an option may not be viable due to interference constraints. Therefore, we recommend that Ofcom does not seek to reserve additional Sub-band 3 spectrum for PMR/PAMR in preference to T-DAB.

L-Band

The principal constraint on the usage of L-Band spectrum is ensuring that harmful interference is not caused to radio communications in neighbouring countries, in

accordance with international agreements. This places certain limits on the transmission levels that can be adopted in specific T-DAB blocks in various regions of the UK.

0.3 Recommended allocation/assignment strategy

0.3.1 Sub-band 2 of Band III

Allocation strategy

We recommend that the $2 \times 4.6\text{MHz}$ of spectrum that is available is allocated to PMR, PAMR or other compatible services. Whilst usage rights for this band already exist, these were generally designed with only PMR/PAMR in mind. Some adjustments may be appropriate to allow for alternative compatible use of the spectrum (e.g. by PMSE) and also future tradability.

<i>Spectrum endowment</i>	Continue to allocate spectrum in 12.5kHz pairs but with additional flexibility to facilitate other users (e.g. for PMSE)
<i>Geographical area</i>	Continue allocation on first-come-first-served basis according to the footprint requested by users
<i>Time of access</i>	Continue allocation on basis of 24 hours per day
<i>Duration</i>	Continuous rolling term but subject to revocation under specified conditions
<i>Interference constraints</i>	Set parameters to ensure harmful interference is not caused to other users (including spectrum users in other countries) but flexibility within an organisation's own holdings to reconfigure
<i>Other licence conditions</i>	Minimum possible, to avoid unnecessarily restricting deployment of new services or technologies
<i>Trading and liberalisation</i>	No restrictions, provided interference constraints are not breached

Assignment strategy

Assignment mechanism First-come-first-served basis

Pricing mechanism Administrative incentive pricing (AIP), taking account of potential alternative uses of the band, e.g. T-DAB

Timing of the assignment process As required by PMR and PAMR users

0.3.2 Sub-band 3 of Band III

Allocation strategy

We recommend that up to five additional T-DAB blocks are created in Sub-band 3. Two or three of these could be reserved for specific regional T-DAB multiplexes for local coverage in-fill purposes. Note that this recommendation assumes that the incremental value of additional blocks exceeds the cost of re-farming PMSE users in affected bands, which is subject to further verification.

Spectrum endowment Re-plan spectrum in accordance with Europe-wide band plan for T-DAB. This should not preclude reconfiguration by spectrum users

Geographical area National, except where Ofcom makes a decision to prioritise local coverage in-fill – these T-DAB blocks could be allocated on a regional basis

Block 10A should not be initially available for T-DAB coverage in London and surrounding areas (within 10km) due to potential interference with PMR/PAMR usage in Sub-band 2

Continental interference constraints also places limits on effective geographical area that can be used for T-DAB in Blocks 10A, 10B, 10C and 11A

Time of access 24 hours per day

<i>Duration</i>	Continuous rolling term, but subject to revocation under specified conditions
<i>Interference constraints</i>	<p>Require use of ‘stringent’ T-DAB mask where equipment is available</p> <p>Allow flexibility for users to reconfigure usage, provided harmful interference is not caused to other users</p> <p>Interference thresholds to be set for geographical boundaries to limit interference with other spectrum users and use of the spectrum in other countries</p>
<i>Other licence conditions</i>	No constraints on use of multiplex capacity for use for radio, multimedia or other services (except for any in-fill obligations in respect of local radio coverage)
<i>Trading and liberalisation</i>	No restrictions, provided interference constraints and public policy requirements are not breached
<i>Assignment strategy</i>	
<i>Assignment mechanism</i>	Simultaneous multiple round auction
<i>Pricing mechanism</i>	Set by the auction (amount of the winning bid). Ofcom may also wish to charge annual licence fees to cover associated administrative costs
<i>Timing of the assignment process</i>	Schedule auction as soon as practically possible, subject to resolving the issue of refarming PMSE users. Consider the use of an ‘overlay’ auction to facilitate efficient negotiations between PMSE and DAB users over PMSE migration

0.3.3 L-Band

Allocation strategy

We recommend that the 16 blocks currently allocated to T-DAB are made available to T-DAB or alternative compatible uses. The remaining spectrum could be allocated on the same basis; however, Ofcom may prefer to postpone a decision on allocation pending further consultation on potential sources of demand.

Spectrum endowment Maintain existing allocation of 16 blocks for T-DAB, and possibly allocate the remaining spectrum on the same basis. This should not preclude reconfiguration by spectrum users.

Geographical area Regional or national. Regional may be advantageous for the 16 blocks as it may encourage smaller companies to compete for the spectrum (but using larger regions than proposed in the Wiesbaden plan).

Interference with uses in other countries may impose some operational constraints on UK system coverage with the south-east of England.

Time of access 24 hours per day

Duration Continuous rolling term, but subject to revocation under specified conditions

Interference constraints Require use of ‘stringent’ T-DAB mask where equipment is available

Allow flexibility for users to reconfigure usage, provided harmful interference is not caused to other users

Interference thresholds to be set for geographical boundaries to limit interference with other spectrum users and use of the spectrum in other countries

Other licence conditions No constraints on use of multiplex capacity for use for radio, multimedia or other services (except for any in-fill obligations in

respect of local radio coverage)

Constraints on use of the spectrum if Ofcom wishes to ensure that some of this spectrum is made available for community radio applications for public policy reasons

Trading and liberalisation

No restrictions placed, provided interference constraints and public policy requirements are not breached

Assignment strategy

Assignment mechanism

Simultaneous multiple-round auction, possibly prefaced by a ‘demand evaluation contest’

Pricing mechanism

Set by the auction (amount of the winning bid). Ofcom may also wish to charge annual licence fees to cover associated administrative costs

Timing of the assignment process

Either combine the L-band auction with the VHF Sub-band 3 auction, or schedule the assignment process to take place after the Sub-band 3 auction

There may be a case for holding back some of the available spectrum until there is stronger evidence of demand from potential users.

0.3.4 Monitoring of demand

Following the allocation and assignment process for Band III and L-Band, we also recommend that Ofcom continues to monitor the demand for PMR/PAMR Band III spectrum in the medium term in order to:

- assess whether it is possible to remove the restrictions on the use of T-DAB Block 10A in Band III (i.e. prevention of use in London and the immediate surrounding area)
- assess whether it is possible to create new T-DAB block assignments in Band III by migrating existing users in the upper frequencies of Sub-band 2 to lower frequencies.

0.4 Suggested next steps for Ofcom

- Decisions need to be made on the allocation of spectrum for public safety and security, and prioritisation of local digital radio coverage in-fill for public policy reasons.
- Further investigation of the costs of refarming existing PMSE use in Sub-band 3. This could be a component of a wider review of the value of and availability of spectrum for PMSE.
- If local radio coverage in-fill is prioritised, further work on the use of specific frequency blocks in individual coverage areas to maximise efficient use of the available spectrum through an optimum frequency re-use plan.
- Development of the technical interference criteria that will facilitate the most flexible use of the spectrum in Band III and L-Band whilst ensuring other users and uses (both within the UK and in other countries) are adequately protected from harmful interference.
- Preparation of the detailed rules and regulations pertaining to the assignment processes i.e. the auction award processes proposed for Sub-band 3 of Band III and L-Band.
- Review of regulatory constraints on existing Band III PMR users of the spectrum, to ensure these are compatible with the terms and conditions associated with the new assignments.

1 Introduction

This report has been prepared by Analysys Consulting Ltd (Analysys), DotEcon Ltd (DotEcon) and Mason Communications Ltd (Mason) on behalf of the UK Office of Communications (Ofcom) as a summary of our analysis of the options for allocating spectrum within VHF Band III (174–230MHz) and L-Band (1452–1492MHz). The report incorporates comments received from Ofcom on the draft version.

1.1 Background

In 2003, the UK Radiocommunications Agency (RA) undertook a public consultation in respect of a number of alternative uses of the above frequency bands.³ The RA received a wide variety of responses to the consultation, although the responses from potential users associated with some of the uses of the spectrum (e.g. public mobile radio) were limited in number. Ofcom has consequently appointed a consortium comprised of Analysys, Mason and DotEcon to undertake an assessment of the options available for allocating the spectrum.

The principal alternative uses that Ofcom has identified for the above frequency bands are:

- terrestrial digital audio broadcasting (T-DAB) – national, regional, local or community radio services
- T-DAB-delivered mobile and portable multimedia services
- private mobile radio (PMR) – in addition to existing use in Band III
- transport communications (PMR-based) and passenger information services
- public access mobile radio (PAMR).

³ Radiocommunications Agency: *Opportunities for future use of spectrum within VHF Band III (174-230MHz) and in the 1.5GHz band (1452-1492MHz)*, October 2003.

1.2 Study objectives

The principal objectives of the study were to:

- Quantify the potential economic benefit arising from allocating additional spectrum to each of the services (Phase A: assessment of service opportunities).
- Identify alternative options for allocating the spectrum to different services and alternative means of assigning spectrum within these allocations – making use of market mechanisms where appropriate (Phase B: formulation of options for allocating the spectrum).
- In view of the uncertainties associated with the development of the services (and hence their requirement for spectrum), to assess the robustness of the proposed allocation/assignment strategy(ies) under alternative market development scenarios (Phase C: scenario analysis of each option).

1.3 Summary of our approach

In determining the appropriate process for distributing spectrum in VHF Band III and L-Band, Ofcom must make decisions about:

- *Allocation* – what type of services and/or technologies will be permitted to use the spectrum.
- *Assignment* – who can use the frequencies.
- *The distribution (assignment) mechanism(s)* – to what extent decisions on allocation and assignment should be determined administratively, or devolved to users through the use of market mechanisms.

In Phase A of the study, we investigated the demand for additional spectrum from the range of services detailed above and quantified the economic benefits arising from allocating additional spectrum to each of the services.

In Phase B, we identified and investigated the options available for allocating and assigning spectrum in VHF Band III and L-Band. In particular, we have undertaken a detailed review of the current services using Band III and the constraints impacting on

future use (e.g. current band plan, nature of spectrum required by each of the services under investigation, co-ordination of interference with neighbouring countries).

In Phase C, we assessed the robustness of our proposed allocation and assignment options under different market development scenarios. This analysis was used to inform our final recommendations for allocation, assignment and appropriate distribution mechanisms for the available VHF Band III and L-Band spectrum.

1.4 Structure of this document

The remainder of this document is structured as follows:

- Chapter 2 discusses the principles underlying the allocation and assignment of spectrum and the broad policy options available to Ofcom
- Chapter 3 examines the current use of each of the bands and the key technical considerations associated with the use of VHF Band III and L-Band by each of the services under investigation
- Chapter 4 summarises the results of our analysis of the economic benefits arising from allocating additional spectrum to each of the services under investigation
- Chapter 5 provides further analysis of the demand for additional spectrum with reference to the availability of spectrum including current band allocation/assignments and interference constraints
- Chapter 6 presents the allocation options available to Ofcom for Band III and L-Band
- Chapter 7 discusses the assignment options for Band III and L-Band
- Chapter 8 contains our analysis of the allocation/assignment options under alternative scenarios
- Chapter 9 summarises our recommendations.

Supporting Annexes provide additional detail on key areas of our analysis:

- Annex A presents our analysis of the benefits of allocating additional spectrum to PMR services including our view of market developments, details of the quantification methodology we have utilised and the results of the economic benefit assessment
- Annex B contains our analysis of the benefits associated with allocating additional spectrum to PAMR services

- Annex C presents our assessment of the benefits from allocating additional spectrum to T-DAB
- Annex D discusses benefits from allocating spectrum for T-DAB portable and multimedia services
- Annex E details our analysis of the use of spectrum in Band III for programme-making and special events (PMSE) and our initial assessment of the potential costs of relocating users
- Annex F provides additional details on the interference scenarios that we have modelled as part of our assessment of the compatibility of the different services and co-ordination requirements with foreign broadcasters in VHF Band III.

[*Note:* All figures and Exhibits in this report are sourced from the study team (Analysys, DotEcon and Mason) unless otherwise stated.]

2 Objectives in allocation and assignment

2.1 Underlying principles

In determining the primary distribution of spectrum in VHF Band III and L-Band, Ofcom's core objective is to allocate and assign spectrum *efficiently*. This means distributing spectrum to the combination of uses and users that will maximise economic welfare for the UK, subject to taking account of social and public policy concerns that may not be reflected in the willingness to pay for spectrum by users.⁴

Ofcom's predecessor, the RA largely relied on administrative processes to allocate spectrum. Allocation decisions were made on the basis of industry consultation, cost-benefit analysis and international coordination. Most available spectrum was allocated to a particular service, often with further restrictions on the type of technologies that can be used. It was then divided into licences (or usage rights) and assigned to specific organisations on an 'exclusive use' basis. Many licences were also assigned by administrative decision (e.g. first-come-first-served or through beauty contests), although, recently the RA has increasingly favoured auctions and administered incentive pricing (AIP) as a way of assigning licences to those users with the highest value.

It is now widely recognised that the traditional emphasis on administrative central planning in allocation and assignment is inappropriate in a world of increasing spectrum scarcity and dynamic innovation in spectrum use. Administrative approaches are inherently inflexible; they respond too slowly to changing circumstances, are vulnerable to lobbying, and tend to focus disproportionately on avoiding interference between users and uses rather than

⁴

This is the economic definition of efficiency. It should not be confused with the more narrow use of the word 'efficiency' as a radio technical term, e.g. in terms of bit rates per Hz of bandwidth, etc.

maximising economic welfare derived from the spectrum. In general, markets rather than governments should be better placed to produce spectrum allocations and assignments that maximise welfare; market participants have better information about the potential uses of spectrum than governments. However, market mechanisms will not be appropriate in all circumstances, and administrative intervention may still be required to prevent incidences of market failure or to ensure that public policy goals are met.

In 2002, the independent Review of Radio Spectrum Management, commissioned by the Department of Trade and Industry (DTI) and HM Treasury, recommended a move away from “*the current central planning approach to one where more decisions on spectrum use are devolved to users facing incentives to economise.*”⁵ The Government broadly accepted the Review’s recommendations for “*extending and developing [the RA’s] policies on auctions, incentive pricing and spectrum trading*” and determined that, under Ofcom, “*licensing will be as flexible and technology neutral as possible*”.⁶ Subsequently, the RA and Ofcom have developed detailed policies for the introduction of spectrum trading and liberalisation of spectrum use.⁷

Reflecting this evolution in thinking on spectrum management, a number of underlying principles can be determined. Subject to Ofcom maintaining a regulatory framework that ensures that sufficient spectrum is available for essential public services, safeguards competition, minimises harmful interference and ensures compliance with international obligations:

- the market should be allowed to determine how the spectrum is used (allocation)
- the market should be allowed to determine who uses the spectrum (assignment)
- licences (usage rights) granted on an exclusive-use basis should be tradable and reconfigurable
- restrictions on current and future uses of the spectrum should be minimised.

These principles underpin our analysis of the allocation and assignment options for VHF Band III and L-Band.

⁵ Cave, Martin: *Review of Radio Spectrum Management*, March 2002, p.48.

⁶ DTI, RA and HM Treasury: *Government Response to the Review of Radio Spectrum Management*, October 2002, p.4.

⁷ RA: *Implementing Spectrum Trading*; July 2002; and Ofcom: *Spectrum Trading Consultation*, November 2003.

2.2 The allocation and assignment process

In determining the appropriate approach to allocation and assignment, there are four broad steps through which Ofcom should proceed. These are summarised in Exhibit 2.1.

As we explain below, the relative emphasis on the tasks described under each of these steps depends in large part on the extent to which it is perceived that the market could deliver an efficient outcome with minimal administrative intervention. Ofcom is pre-disposed to being a light-touch regulator and is moving towards liberalised spectrum markets (subject to international constraints etc.). Hence the need, for example, to do economic benefit assessments of alternative uses if spectrum should diminish in the future.

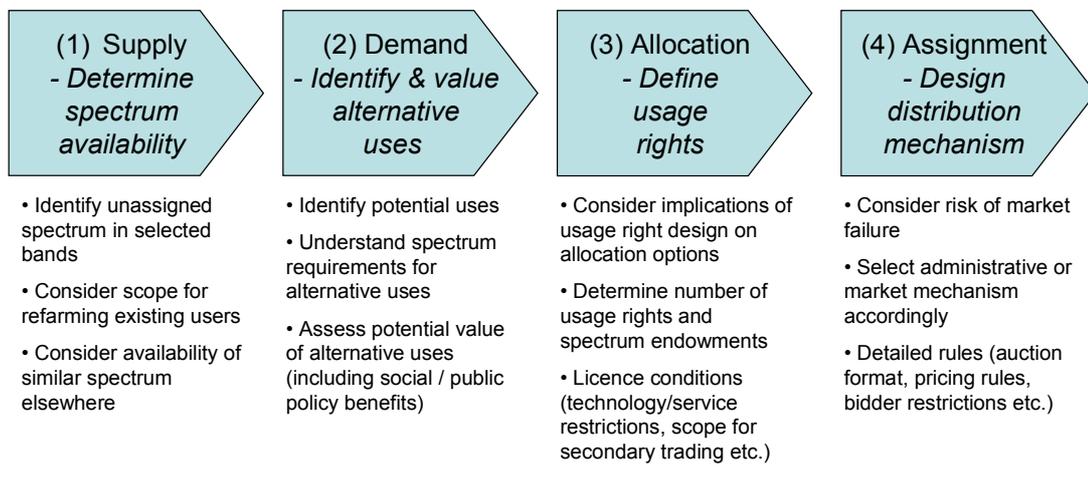


Exhibit 2.1: *Four main steps in allocation and assignment of spectrum*

In the following subsections, we explain each of these steps in relation to the underlying steps described above. Exhibit 2.1 provides a simplified illustration of our proposed methodology for linking these steps together to determine the options available to Ofcom for allocating and assigning spectrum in VHF Band III and L-Band.

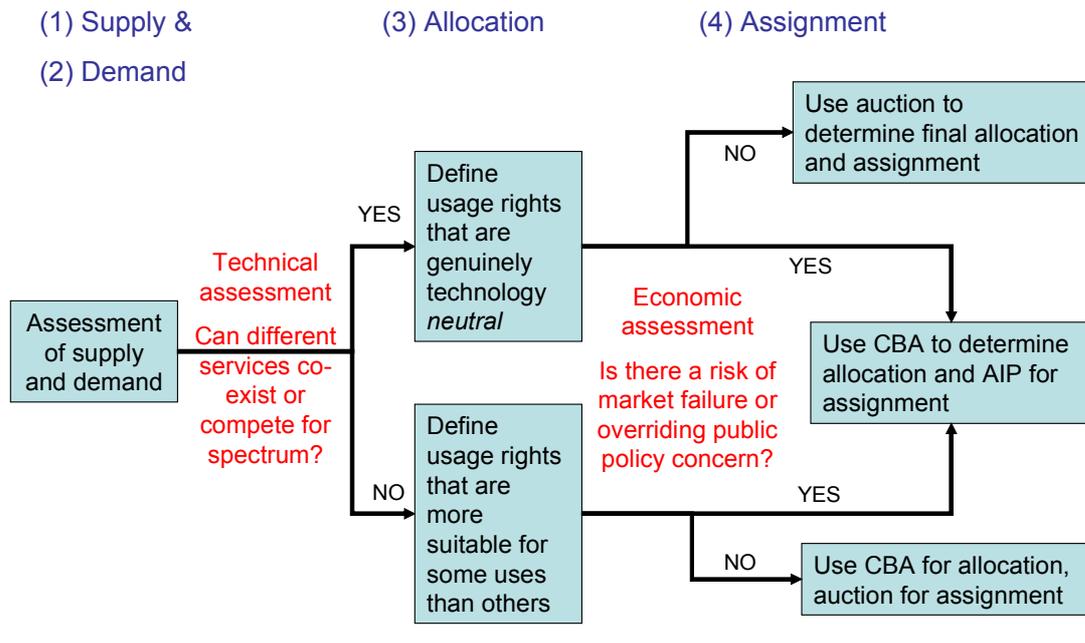


Exhibit 2.2: Simplified illustration of proposed methodology

2.2.1 Supply

The first two steps in any allocation and assignment process is to understand the supply of and demand for spectrum. These two steps are closely related, as technologies are generally designed to operate in specific frequency bands, and the availability of specific spectrum also influences the development of technologies to support service provision.

Spectrum availability is primarily a function of the amount of unallocated and/or unassigned spectrum in a selected band. However, supply conditions are also affected by the type of existing allocations and assignments in the band or adjacent bands, and the distribution of available spectrum within the band. Both these factors may impose constraints on future uses of the spectrum. Where spectrum is currently allocated to a specific use but not assigned, it may be desirable to change or relax the usage restrictions. Even if spectrum is already assigned, it may be possible to displace or reform (relocate) existing users; in this way, the amount of spectrum available may be increased, thus extending the scope for new and existing uses.

Wherever possible, spectrum should be made available in such a way that restrictions on its use imposed by existing allocations and assignments are minimised. However, this should

not be at the expense of causing undue interference or disruption to existing services. We discuss the supply of available spectrum in VHF Band III and L-Band in Section 3.

The availability of alternative spectrum in other bands is also a significant factor in allocation, as this may impact on demand from different types of uses. Spectrum is likely to be valued higher by users if it is in scarce supply i.e. alternative spectrum is not available in other bands or likely to become available in the future. Technology trends will also play a strong role since vendors may develop products for particular services that operate in a subset of available bands, depending on favourable conditions in that band relative to others (e.g. propagation, bandwidth and interference environment relative to services being supported). This will influence both supply and demand trends, since supply decisions must consider the characteristics of technologies that are available to use the spectrum, such that the spectrum offered is compatible with the range of potential products available to use the spectrum offered. For example, the amount of PMR spectrum available in UHF bands in areas such as London impact on the amount of demand for Band III PMR spectrum.

2.2.2 Demand

Notwithstanding the emphasis on market mechanisms to identify optimal uses and users, it is still important for Ofcom to have a good understanding of the potential competing uses for available spectrum, including their relative requirements for spectrum and protection from interference, the value they generate for society and the potential level of demand. This is because if the spectrum requirements of different uses are not sufficiently ‘compatible’, it may be difficult to package the spectrum in such a way that it can be used for all the alternative services. Key issues in this regard are the total bandwidth offered, and the type of radio channel (i.e. unidirectional or bi-directional transmission). There is an incompatibility in this sense between the spectrum required to support PMR services and that required to support T-DAB, in that the former requires narrowband channels in defined frequency pairs (to accommodate up and down links within the system) whereas the latter requires wider band channels that are unidirectional (since the T-DAB system does not include a return path since transmission is to the user only).

Lack of compatibility is not a reason per se why markets do not work – the market may be able to determine which of a number of possible exclusive uses is appropriate. However, if this is not the case, for example because there are concerns about possible market failure,

Ofcom may need to fall back on the assessments of demand and value generation in order to divide the spectrum between certain uses.

In the case of the VHF-band and L-Band, Ofcom has identified five potential types of use, although it is possible that other uses could also emerge. In Section 4 of this study, we assess the economic benefits of allocating the available spectrum to these five services. Section 5 discusses the relative demands for spectrum from these five services (and also PMSE), taking into consideration the result of the benefits analysis.

2.2.3 Allocation

The way that usage rights (licences) are defined can have a big impact on the type of use that is possible. Rights to transmit or receive signals over spectrum can be defined in relation to a number of parameters:

- *Spectrum endowment* – the frequency bandwidth to which access is granted. Different technologies and services require different bandwidths. Some services, such as broadcasting, require single contiguous blocks, while others, such as mobile, require paired spectrum for send and receive paths. Spectrum endowment also affects the number of usage rights available, which may have implications for the scale of entry in downstream service markets.
- *Geographical area* (e.g. an entire country, a region or a defined area around a base station).
- *Time of access* (e.g. access to spectrum throughout the entire day, or at a specific time of day).
- *Duration* (e.g. unlimited or defined-length usage rights). In general, Ofcom is in favour of granting usage rights with a continuous rolling term.⁸
- *Protection from interference* – the right to receive signals without harmful interference from other spectrum users, and the obligations not to cause such interference.
- *Other licence conditions* – these could include restrictions on the type of technology or service, or public service obligations tied to licences

⁸ Ofcom: *Spectrum Trading Consultation*, November 2003, p.33-34.

The design of usage rights will be influenced by the assessment of the demand profiles of potential users. Ideally, they should be designed in a way that maximises the range of possible uses. Even if different services/technologies have different demands for spectrum, geographical area, time of access, duration or protection from interference, it may be possible to design usage rights that can be aggregated or subdivided to accommodate different demands. Depending on how usage rights are defined, this could be done through a primary auction and/or through trading in a secondary market. Imposition of other licence conditions should generally be avoided, unless they are required to prevent market failure or to promote public policy goals.

We discuss the options for designing and allocating usage rights in VHF Band III and L-Band in Section 6.

2.2.4 Assignment

There are a variety of assignment and pricing mechanisms that Ofcom could use for distributing the VHF and L-Band spectrum. These are summarised in shaded area below. Where there is excess demand for the spectrum, Ofcom's default policy would normally be to use an auction for primary assignment, complemented by spectrum trading in the secondary market. However, in order to assess whether market mechanisms are appropriate, it is necessary to consider the risk of market failure (e.g. owing to the presence of many small local users incapable of grouping together to buy national or regional spectrum) and the presence of public policy concerns, such as broadcasting plurality. It may be possible to mitigate such factors through careful design of the usage rights and the assignment mechanism. If not, then it may be necessary to assign spectrum administratively, using AIP to ensure that users still have economic incentives to utilise their spectrum efficiently.

We discuss the options for assigning usage rights in VHF Band III and L-Band in Section 7.

Assignment and pricing mechanisms for radio spectrum

First-come-first-served (FCFS)

This is the most simple assignment mechanism. Applicants are awarded usage rights in the order that they request them. If current or anticipated demand for usage rights does not exceed supply, the assignment will be efficient. However, in other instances an FCFS assignment approach is unlikely to be desirable. In particular, it will probably not be appropriate if there is excess demand for licences or if use of part of the spectrum by one service will preclude another service from using other spectrum in the same band.

Comparative selection

Comparative selection or ‘beauty contests’ provide an administrative mechanism for differentiating between competing claims for scarce licences. The qualifications of competing applicants are examined to award licences where two or more have filed applications for the same spectrum and these demands cannot all be accommodated. Such procedures should result in a more efficient allocation than FCFS, assuming that the criteria for evaluating competing claims consider the economic value which rival bidders are expected to generate.

Comparative selection procedures allow governments considerable flexibility to evaluate bids on the basis of wide-ranging public-policy criteria, not just applicants’ willingness to pay. This may be justified where willingness to pay is perceived not to be a sufficiently good proxy for the social value of spectrum use. However, in recent years, the RA/Ofcom has favoured the use of market mechanisms (if possible), as these are considered to produce more efficient and transparent outcomes.

Auctions

The UK government has used auctions to assign scarce spectrum usage rights for a number of services, including mobile and FWA. Auctions offer a number of potential advantages over administrative processes:

- If well-designed, they should produce more efficient outcomes.
- They raise revenues, enabling the public to realise the full scarcity value of licences

through transfers from private operators.

- They are potentially transparent, robust to legal challenge, and can be quick and cost-efficient to run.

However, auctions are not appropriate for all types of spectrum. For example, assignment by auction may be perceived as conflicting with broader public policy goals, such as promoting new entry, rules on broadcasting plurality or use of spectrum for public safety services. An auction solely based on bidders' willingness to pay will not capture the impact of any social externalities, so may not be fully efficient.

Auctions also depend on there being sufficient competition for usage rights. If, for example, market conditions deteriorate suddenly or there are significant asymmetries between bidders, then competition may be ineffective. There is also a risk of market failure if there are many small users of spectrum who face high transaction costs from competing in an auction.

The detailed design of an auction is also important. Like a jigsaw puzzle, the pieces must be correctly assembled in order to generate appropriate incentives for bidders and efficient outcomes. There are a number of choices to be made with respect to key auction parameters, including the basic format, activity rules, transparency, round lengths and bid increments. Even small changes in auction rules can significantly affect outcomes, benefiting some parties at the expense of others. It is therefore critical to ensure that the assignment method adopted enables the allocating body to achieve its core objectives.

Administrative incentive pricing (AIP)

Administrative incentive pricing involves pricing licences to reflect the value of the spectrum used. With new assignments, the purpose is to price off lower-value users, mirroring the effects of a market mechanism in assigning licences to the users that value them most. Use of AIP on an on-going basis exposes users to the full opportunity cost of their spectrum use and should ensure that they have appropriate incentives to utilise their spectrum efficiently and do not tie up scarce resources unnecessarily.

Incentive pricing was pioneered in the UK. Ofcom calculates incentive pricing using the Smith-Nera methodology (the use of which was recently subject to a further study by

external consultants⁹), which identifies the marginal value of the spectrum as the minimal additional cost to the alternative user of using an alternative service, spectrum or technology, or not using spectrum at all. This provides an approximation of the clearing price that would be achieved in an open market.

The economic rationale for using AIP is strongest where market mechanisms are not practicable. However, it can also be applied alongside auctions and secondary trading, albeit at the expense of altering bidder behaviour. The main drawback of AIP is that it relies on administrative judgement to proxy market outcomes, which could lead to inefficient outcomes: if prices are set too *low*, inefficient users will not surrender spectrum, whereas if prices are set too *high*, scarce spectrum may remain unused.

Spectrum trading

Ofcom is committed to introducing both spectrum trading and liberalisation of use across a swathe of spectrum bands and licence types. Typically, this will involve the conversion of existing licences into flexible usage rights. For some bands and licence types, Ofcom envisages only allowing trading.

In general, both primary and secondary uses of markets are desirable and one does not remove the need for the other. Secondary trading provides a finer-grained ability to adjust spectrum assignment than can, for example, relatively infrequent auctions for block licences. The extent of benefits realisable from trading – both with and without change of use – depends significantly on the primary allocation and assignment systems that have already been used, especially the extent of technology and service restrictions within bands.

Restrictions on trading and/or liberalisation may be necessary if such activity could lead to disruption of existing services, either within the band concerned or other adjacent bands. It is also likely that spectrum trading should be ruled out where there are externalities so that individual users' willingness to pay does not reflect social benefits to the extent that auctions may not be appropriate for primary allocation.

⁹ Indepen, Aegis and Warwick Business School, February 2004, *An Economic Study to Review Spectrum Pricing*

3 Current usage of Band III and L-Band

This section provides a summary of the current usage of the two spectrum bands and an overview of the technical considerations in relation to their usage for providing each of the five services under assessment.

3.1 VHF Band III (174–230MHz)

3.1.1 Current availability

VHF Band III was previously used in the UK (until 1984) for broadcasting 405-line television. In other parts of Europe, including France, Belgium and Ireland, Band III is still extensively used for analogue television (vision and sound) carriers, and hence there are some constraints on the operation of UK services in the band owing to the potential scope for causing harmful interference to Continental television reception.

Band III is divided into three Sub-bands:

- Sub-band 1 (174–191MHz): This is currently used for PMR, PAMR, common base stations, asset tracking (CDMA) and remote meter reading. Ofcom regards this band as being ‘full’ in London and the South East but further assignments can be made in most other parts of the country.
- Sub-band 2 (193–207MHz): This Sub-band is currently allocated to PMR and PAMR use. Ofcom estimates that around $2 \times 4.6\text{MHz}$ of this spectrum is available for new use (though only $2 \times 1.2\text{MHz}$ – that is, 95 paired PMR channels – is currently available on a contiguous basis).

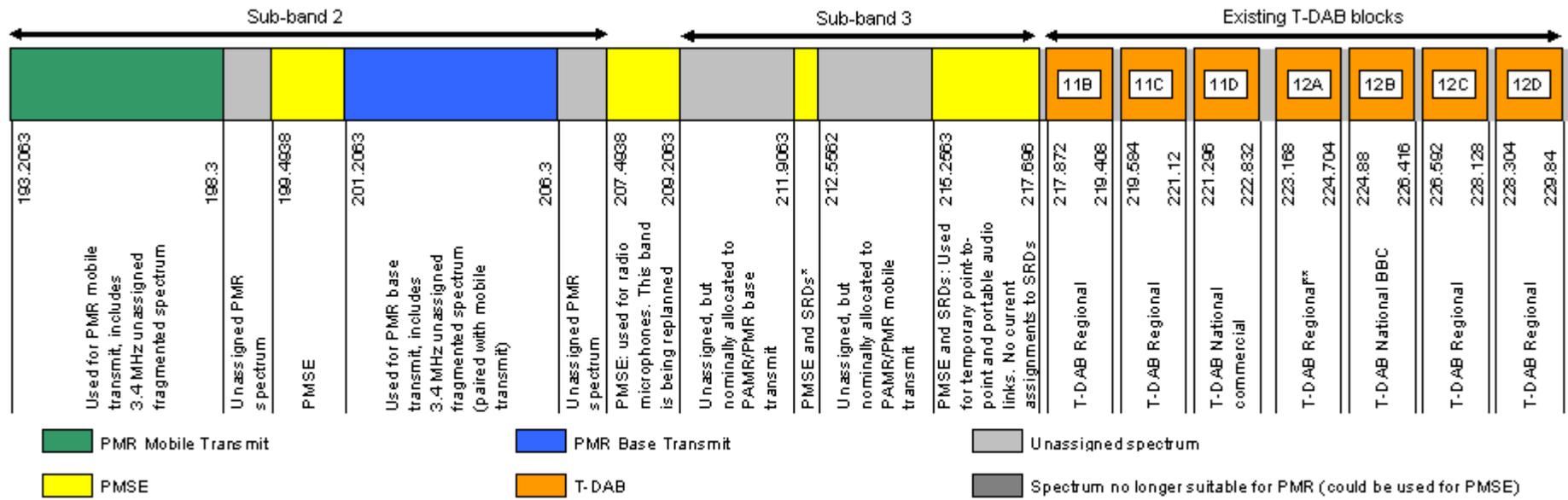
- Sub-band 3 (209–215MHz): This Sub-band has notionally been allocated to ‘new technology systems’ but no assignments have been made to date. Ofcom estimates that in total $2 \times 2.7\text{MHz}$ of contiguous spectrum is available (216 paired 12.5kHz PMR channels). The remaining spectrum in this Sub-band is allocated either solely to programme-making and special events (PMSE)¹⁰ or to both PMSE and short-range devices (SRDs). However, we understand from Ofcom that there are no SRDs currently utilising this spectrum.

The frequencies above Band III (217-230MHz) are allocated to national and local T-DAB multiplexes, which are spaced in accordance with CEPT agreements. All available T-DAB channels are in use; however, in the case of local multiplexes, much of the spectrum is unused on a regional basis, in order to prevent interference between local radio stations. In addition, some designated regional multiplexes have not yet received an application. A small amount of the T-DAB spectrum is shared with PMSE, on a no-interference basis, although we understand that PMSE is no longer using this spectrum.

The spectrum between the Sub-bands is allocated to PMSE (also SRDs in some cases, although Ofcom tells us that there are no SRD users).

The structure of the spectrum allocated to the services in Band III is very different. PMR and PAMR services use ‘paired’ spectrum: two channels, one for sending signals from the base to mobile devices (base transmit) and one for the reverse path (mobile transmit). These must be spaced at fixed intervals. The normal convention in mobile systems is ‘base high’ i.e. that the base transmit channels form the upper frequencies in the pair, although in parts of Band III, this convention is reversed. T-DAB multiplexes use a single contiguous block of spectrum. PMSE devices use a mixture of single channels and paired channels, depending on the specific application. Exhibit 3.1 below summarises the existing allocations and assignments in Sub-bands 2, 3 of VHF Band III and higher frequencies.

¹⁰ 207.4395–209.20626MHz is used for shared radio microphones and co-ordinated radio microphones. 207.4395–209.20626MHz is used for the base receive part of TalkBack systems (this is paired with spectrum in Sub-band I). 215.25625–217.5MHz is used for shared radio microphones and point-to-point audio links. See Annex E for further details.



Notes:

* Used for PMSE talkback (duplex frequency for wide area use). No current assignments to SRDs.

** PMSE at 224.00625-224.49375 MHz allocated to temporary point-to-point audio links on a no interference basis.

Exhibit 3.1: Allocation and assignment of spectrum in VHF Band III [Source: Ofcom, 2004]

The scope for interference between the UK and neighbouring countries means that not all of Band III can be used in all parts of the country without constraints due to the need to overcome imported interference effects, or avoid exported interference above defined regulatory field strength limits.¹¹ Ofcom's Band III assignments are therefore co-ordinated with use of the spectrum in France, Ireland, Belgium and the Netherlands in order to ensure harmful interference does not arise.

In summary, the following spectrum is available for allocation and assignment to existing or new uses and users:

- 2 × 1.2MHz contiguous spectrum in Sub-band 2
- 2 × 3.4MHz spectrum fragmented across Sub-band 2
- 2 × 2.7MHz contiguous spectrum in Sub-band 3.

These allocations could potentially be augmented by refarming spectrum currently in use, most obviously some of the spectrum currently used for PMSE in Sub-band 3.

3.1.2 Alternative uses

Band III spectrum could be of use to all of the services under investigation in this study:

- PMR and PAMR: as discussed above, these services already have assignments in this band and a range of equipment is available – the available spectrum in Band III is suitable for accommodating an expansion in PMR and PAMR spectrum demand.
- T-DAB (both audio and multimedia/portable services): the band is adjacent to the current main T-DAB allocation (217.5–230MHz) – we understand that the majority of receivers in the market should be able to re-tune to use the additional Band III frequencies. The principal drawback of this band for use for multimedia/portable services is the antenna size (length) that is required for optimum reception.

The favourable radio propagation characteristics of VHF spectrum relative to higher frequency bands mean that it is ideal for covering wider areas (particularly in comparison with L-Band spectrum) – this means a given area can generally be covered with a smaller number of radio

¹¹ This is primarily a consequence of both the 'high-power, high-tower' nature of broadcast transmissions and the high susceptibility of television receivers to interference.

sites (and hence lower capital and operating costs for service providers). However the propagation characteristics also mean that the minimum frequency re-use distance is generally much greater than with L-Band to avoid co-channel interference effects. Band III spectrum is therefore not as well suited for highly localised low-power coverage as higher bands.

In line with Ofcom's general plans to introduce spectrum trading and liberalise use of the radio spectrum where appropriate¹², this band could potentially be used to provide services other than those which are under investigation in this study.

3.2 L-Band (1452–1492MHz)

3.2.1 Current availability

L-Band spectrum has been internationally allocated to broadcasting (for T-DAB and Satellite DAB) since WARC-92 however, to date the UK has not made any specific assignments to broadcasting users. The band has been allocated for T-DAB in some other countries (e.g. Germany). Instead, current uses of the band in the UK include:

- fixed links (1450–1467.5MHz) – although existing users are required to move by 2007 to facilitate the deployment of T-DAB or other future systems
- PMSE (1488–1491MHz) – the spectrum is used for audio links. We are not aware of Ofcom having any specific plans to migrate these users.

Once migration of the fixed links has taken place, a bandwidth of up to 40MHz will be available for allocation to new services (less any spectrum that continues to be used for PMSE). Of the 40MHz of spectrum, 23.5MHz (1452MHz–1475.5MHz) has been allocated to T-DAB. This spectrum is divided into 16 blocks, each suitable for one T-DAB multiplex, in accordance with the CEPT Maastricht 2002 Allotment Plan (see Exhibit 3.2 below). The remaining spectrum is unallocated.

No spectrum in L-Band has been assigned to new users. Ofcom is not obliged to allocate and assign spectrum in accordance with the Maastricht Plan, although if it permits alternative uses, these would not be allowed to cause any additional interference to T-DAB

¹² Ofcom and Radiocommunications Agency: Spectrum Trading Consultation, November 2003.

services in neighbouring countries. Therefore, in principle, all spectrum in L-Band is available to be allocated and assigned to new uses and users.

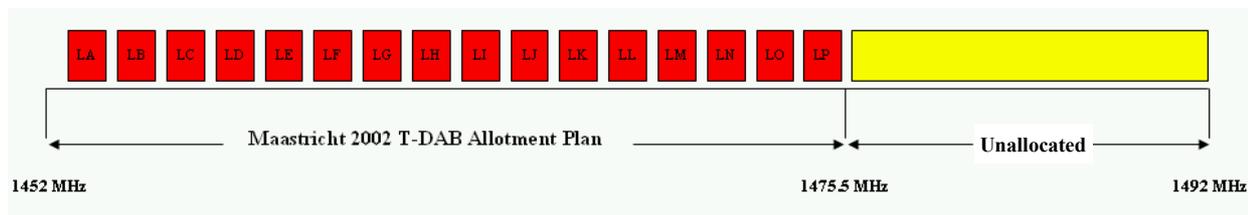


Exhibit 3.2: L-Band band plan [Source: Ofcom, 2004]

3.2.2 Alternative uses

Amongst the five services categories examined, L-Band spectrum is only likely to be useful for T-DAB (audio and T-Dab multimedia/portable services). For technical and commercial reasons, it does not appear suitable for any type of PMR or PAMR application.¹³ There may also be alternative uses for L-band spectrum other than those that we were asked to examine in this study. For example, spectrum at this frequency would be suitable for deployment of a wireless broadband data network or cellular network provision. These were not included in our assessment of economic benefits as any analysis would be highly speculative at this stage. We do, however, consider the possibility of alternative sources of demand in our analysis of allocation and assignment options in Chapters 6 and 7.

L-Band spectrum has been internationally allocated to broadcasting, including T-DAB (although this does not preclude alternative uses in the UK). Despite L-Band being used to provide T-DAB in certain other markets such as Germany, most existing T-DAB receivers are not able to operate in L-Band. It is likely, however, that many receivers will in future be dual-band, especially as some European countries (e.g. Germany) have plans to use L-band more extensively for digital radio than is likely to be the case in the UK. As discussed

¹³ We are not aware of any currently available PMR and PAMR equipment for this band nor any plans to specify equipment for use at frequencies above 1GHz. The propagation characteristics of L-Band mean that a large number of base station sites would be required to cover a given area (potentially 30–100 times as many base station sites as for PMR in Band III). In view of the small number of users on individual PAMR or PMR networks, there is unlikely to be sufficient income or benefit to warrant deployment at L-Band even if equipment were to be made available in the future.

above, L-Band spectrum is most suitable for covering smaller areas (e.g. very local radio broadcasts).

One variant of the use of L-Band for broadcasting is the potential use of the spectrum for terrestrial in-fill of a satellite digital radio service (e.g. similar to the services offered by Worldspace in other parts of the world). This may use a technology other than T-DAB.

4 Economic benefits from alternative uses of the spectrum

4.1 Introduction

This section presents a summary of the work undertaken in Phase A of the study, which examined the relative scale of economic benefits from alternative uses of available spectrum in VHF band III and L-band. The specific objectives of this phase of work were to:

- Qualitatively assess how the availability of additional Band III and L-Band spectrum is likely to impact on each of the services (e.g. change in take-up, value arising from the service, cost of service provision, etc.).
- Quantify the net consumer and producer benefits arising from the availability of additional spectrum to each of the services.
- Assess how the economic benefits are likely to vary with the amount of spectrum that is made available to each service.
- Identify the level of uncertainty associated with each of the projections (including a sensitivity analysis of key assumptions).
- Use the findings of this assessment to support the work undertaken in Phases B and C of the study, examining allocation and assignment options and scenarios.

We have undertaken our assessment through a combination of:

- *Desk research* – in view of the limited timescale for the study, in line with Ofcom's ITT, we have made extensive use of secondary research undertaken in the respective areas. In particular, we have reviewed a variety of industry papers such as Digital

Radio Development Board market research, Federation of Communications Services PMR demand projections and radio audience figures as well as previous demand and economic studies undertaken by the RA. We have also undertaken a detailed review of the responses received by the RA to the October 2003 consultation.

- *Telephone interviews* – we have held 12 telephone discussions with a variety of organisations including users and potential end users of the services, service suppliers, equipment manufacturers and industry bodies, in order to gain a detailed understanding of their perspectives and to validate our initial analysis.
- *Analysis and modelling* – we have developed service demand forecasts, corresponding spectrum requirement forecasts and economic assessment analyses to provide a quantitative underpinning to our assessment.

The remainder of this section is structured as follows:

- *Section 4.2* explains the scope of our benefits assessment, and the rationale for focusing on particular uses and bands
- *Section 4.3* summarises our analysis of the benefits of allocating additional spectrum to private mobile radio
- *Section 4.4* highlights our analysis of the benefits of allocating additional spectrum to public access mobile radio
- *Section 4.5* presents our analysis of the benefits of allocating additional spectrum to T-DAB
- *Section 4.6* details our analysis of the benefits of allocating additional spectrum to T-DAB mobile and portable multimedia services
- *Section 4.7* provides a summary of our findings.

In addition, a number of supporting annexes provide additional detail of the methodologies we have used for the benefit assessment, and further details of the results (including sensitivity analysis of key variables):

- *Annex A* – private mobile radio
- *Annex B* – public access mobile radio
- *Annex C* – T-DAB
- *Annex D* – T-DAB mobile and portable multimedia services.

4.2 Scope of the benefits assessment

Of the services and uses which Ofcom indicated we should examine in this study, there is likely to be demand for L-Band spectrum only for T-DAB audio and multimedia/portable services, as well as possible use for terrestrial in-fill of satellite radio.

Whilst deployment of a national/regional multiplex in L-Band is widely considered to be uneconomic, a combination of L-Band and Band III could be deployed to extend the local multiplex coverage, albeit at higher costs of deployment than utilising Band III alone. For example, a study by GEC-Marconi for the Radio Authority in 1997 estimated that between seven to ten L-band transmitters would be required to cover the Reigate and Crawley independent local radio region, whereas only three transmitters would be required were VHF band to be used. If we apply a similar scaling to extending local multiplex coverage by, for example, 13% of population using L-band instead of VHF, we estimate this could result in additional capital expenditure costs in the order of GBP24 million. In practice, the additional cost is likely to be much higher as some of the areas that are required to be covered will be sparsely populated and so the propagation disadvantage of L-band will be more pronounced.

L-Band is also well suited for community radio services, which could be served by the allocation of a single block.

The propagation characteristics of L-Band (and resulting implications for economics of network build through required density of base stations) and low probability of availability of PMR and PAMR equipment at frequencies above 1GHz mean that deployment of PMR and PAMR in L-Band is in our opinion very unlikely, particularly whilst more favourable options remain available.

In summary, our initial assessment indicated that the combination of radio propagation characteristics and equipment availability meant that L-Band would only be of use to two of the services (T-DAB radio and T-DAB mobile and portable multimedia) and that spectrum allocation between these two services is an issue which can be resolved directly by the market. Band III spectrum is potentially useful to all five of the service categories – consequently our work has focused on assessing the trade-offs and incremental value of allocating different amounts of Band III spectrum to each of the services.

4.3 Private Mobile Radio

PMR spectrum is used by organisations to operate their own mobile communications networks for private use. Whilst the general demand for PMR assignments has fallen over the last ten years as users have migrated to cellular networks, certain areas of PMR and types of user are exhibiting strong growth (including demand from local government organisations for wide-area PMR assignments in existing parts of Band III which are allocated to PMR).

Demand for Band III spectrum is likely to arise from a variety of users:

- transport users: railways, bus and coach, trams, underground
- general PMR: taxis and courier firms, local government, other wide area commercial users, on-site communications, common base stations.

To take account of market uncertainties, we have developed three scenarios for the development of the PMR market in Band III:

- *Baseline scenario*: users continue to operate private networks and spectrally efficient digital PMR equipment becomes available
- *Scenario A*: users continue to utilise private networks but availability of advanced digital technologies in Band III is poor
- *Scenario B*: the migration to public networks such as cellular continues.

Additionally, one further key issue is the amount of spectrum that is likely to be available for PMR in other bands, particularly in geographic regions where there are high levels of demand (e.g. London and the South East). The availability of UHF spectrum for PMR (e.g. in UHF Band 2 - 450-470MHz) depends on whether band re-alignment is to occur (in particular Ofcom has indicated double the amount of spectrum would be made available if the band were fully re-aligned). Ofcom has recently announced that it does not intend to manage the band re-alignment process and now intends to leave this to the market. In view of the uncertainty over whether band re-alignment will occur, we have also undertaken assessments of the demand for PMR spectrum in the cases where UHF2 band re-alignment does and does not occur.

For each scenario, we have developed forecasts for the future requirement for Band III spectrum and assessed the net economic benefit associated with use of this spectrum. This has been determined using two methodologies:

- For general demand, we have assessed growth in terms of the increase in numbers of mobile terminals and the consumer surplus associated with each terminal (based on existing research undertaken by the RA.¹⁴)
- For the special case of real-time passenger information services on buses, using data from London Buses, we have modelled the surplus arising from passengers' willingness to pay for this information over the costs of service provision.

As for all other services, we have modelled demand over the period from 2004 through to 2015 (assuming that additional spectrum is not available until 2005) and have taken the net present value (NPV) of consumer surplus using a discount rate of 5.5% in line with UK Treasury guidance on investment appraisal and target rates of inflation.

The results of our general demand assessment (for the case where UHF2 band re-alignment occurs) are summarised in Exhibit 4.1 below. Please note that the division of results by region (London, Major Urban and Other) is not precise since (i) it is dependent on our 'best guess' estimates about the current availability of PMR spectrum in different regions and (ii) the propagation characteristics of Band III mean that spectrum used in urban areas prevents further use across a wide area surrounding the urban area (depending on topography).

¹⁴ 'The Economic impact of radio', Radiocommunications Agency, February 2001.

Baseline scenario

Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	25,078,718	6.5	3,845,433
Major urban	0	-0.3	0
Other	0	-6.8	0
Nationwide	25,078,718	6.5	3,845,433

Scenario A: Moderate PMR growth, limited availability of digital equipment

Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	38,306,223	8.3	4,599,857
Major urban	6,651,183	0.8	8,049,477
Other	0	-6.4	0
Nationwide	44,957,406	8.3	5,398,539

Scenario B: Migration to public networks

Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	95,390	0.2	460,998
Major urban	0	-3.7	0
Other	0	-7.8	0
Nationwide	95,390	0.2	460,998

Exhibit 4.1:

PMR general demand scenario analysis results (UHF2 band re-alignment occurs)

We have also undertaken an assessment of the requirement for additional spectrum in the event that re-alignment of the 450-470MHz (UHF2) band does not occur. The results are summarised in Exhibit 4.2 below.

Baseline scenario			
Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	29,039,667	6.6	4,406,946
Major urban	0	-0.3	0
Other	0	-6.8	0
Nationwide	29,039,667	6.6	4,406,946

Scenario A: Moderate PMR growth, limited availability of digital equipment			
Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	42,625,676	9.1	4,678,468
Major urban	8,214,617	1.2	6,878,887
Other	0	-6.4	0
Nationwide	50,840,294	9.1	5,580,080

Scenario B: Migration to public networks			
Area	NPV to 2014 (GBP)	Net additional spectrum (MHz)	NPV/MHz (GBP)
London	95,390	0.2	460,998
Major urban	0	-3.7	0
Other	0	-7.8	0
Nationwide	95,390	0.2	460,998

Exhibit 4.2:
Demand and economic benefits from additional PMR spectrum under scenario where UHF2 band realignment does not occur [Source: Analysys, 2004]

In the case of real-time passenger information services on buses, we estimate that this will require 1MHz of spectrum nationwide, with an economic benefit of GBP852 million (NPV to 2014). Please note that this estimate has been based on assumptions derived from confidential information from London Buses – we have not been able to validate the market research methodology underlying the information provided to us by London Buses.

4.4 Public Access Mobile Radio

PAMR is a commercial offering providing similar service features as PMR (e.g. push-to-talk, group calling, etc) but on a public network. Demand for PAMR has fallen considerably, particularly over the past two years, as users have increasingly migrated to cellular networks. There are several PAMR networks in operation that use Band III spectrum (national and regional) – these are based on older analogue technologies and have been downscaled to reflect the reduced demand.

We envisage three scenarios for the development of the PAMR market:

- *Scenario 1:* gradual closedown of PAMR networks, releasing the existing spectrum that is used for PAMR

- *Scenario 2: continuation of operations* – resulting in no net change to the overall spectrum position
- *Scenario 3: partial Dolphin migration* – migration of circa 30% of users from Dolphin (a digital PAMR provider using UHF spectrum, whose operations are set to close at the end of July 2004). We estimate that an additional 1.2MHz of Band III spectrum could be required in London to support this additional demand.

We have assessed the net economic benefits arising in Scenario 3 using a similar approach to that for assessing the benefits for PMR. We estimate the benefit in this instance amounts to GBP12.6 million (NPV to 2014).

4.5 T-DAB

Following the launch of T-DAB services by the BBC in September 1995, take-up and availability of radios has been limited. However, recently, large reductions in equipment price (to sub-GBP100), the launch of new models and marketing campaigns run by broadcasters have led to significant increases in sales – the industry now expects strong growth and forecasts that 10.2 million sets in total will have been sold in the UK by 2008.¹⁵

Our assessment of the economic benefit arising from additional spectrum allocations to T-DAB in Band III takes account of the availability of L-Band spectrum (i.e. the benefits of Band III spectrum over and above the available L-Band spectrum). To determine the economic benefit associated with T-DAB, we have utilised the results of a stated preference (SP) survey by Aegis Systems Ltd. for the RA in 2000, which aimed to measure the value of a proposed digital radio service.

The assessment of the economic benefit arising depends on the purpose for which Band III spectrum is used, namely:

- *Additional national multiplexes* – we have assessed the ‘value’ to T-DAB listeners of having access to a greater number of national stations, and the benefits associated with the relatively small number of additional T-DAB listeners attracted by the increased number of stations.

¹⁵ Source: Oliver and Ohlbaum Associates Ltd: *The Market Impact of BBC's Digital Radio Services*, March 2004.

- *Additional regional multiplexes* – a T-DAB frequency block could be used to provide regional stations (e.g. to Scotland, Wales, Northern England), albeit at the expense of some of the population at regional boundaries who would not be able to access this service. No respondents to the RA’s consultation on Band III and L-Band raised a preference for this type of T-DAB multiplex – we believe the decision to use a national multiplex for regional stations can be left to the market.
- *Local multiplex coverage completion* – between two and five T-DAB Band III spectrum blocks could be used to extend the layer of local multiplexes from 90% population coverage to virtually 100%. We have assessed the net economic benefits of this by considering the increase in T-DAB listeners as a consequence of the availability of local radio stations as well as the benefit to existing listeners of national T-DAB stations in these areas who will subsequently have access to more local radio stations.
- *Community radio broadcasting* – spectrum could be allocated for community radio services for public policy reasons. We therefore suggest that Ofcom considers this in terms of the opportunity cost of the spectrum (i.e. the loss of economic value from the other uses for which the spectrum could be used).

The results of our analysis are summarised in Exhibit 4.3.

Additional national multiplex			
Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
Nationwide	First national multiplex	25.1	42.9
Nationwide	Second national multiplex	10.0	17.2
Nationwide	Third national multiplex	4.0	6.9
Nationwide	Fourth national multiplex	1.6	2.7
Nationwide	Fifth national multiplex	0.6	1.1

Five local coverage expansion using five VHF blocks			
Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
Localised	First VHF block	6.9	11.8
Localised	Second VHF block	7.6	13.0
Localised	Third VHF block	8.3	14.1
Localised	Fourth VHF block	7.7	13.1
Localised	Fifth VHF block	9.8	16.8

Local coverage expansion using three VHF blocks			
Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
Localised	First VHF block	8.6	14.7
Localised	Second VHF block	9.5	16.3
Localised	Third VHF block	9.4	16.1

Local coverage expansion using two VHF blocks			
Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
Localised	First VHF block	9.9	17.0
Localised	Second VHF block	11.2	19.1

Local coverage expansion using three VHF blocks & L-band			
Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
Localised	First VHF block	6.9	11.8
Localised	Second VHF block	7.4	12.6
Localised	Third VHF block	8.9	15.2
Localised	L-band	-	10.2

Exhibit 4.3: *Economic benefit from allocation of additional spectrum for T-DAB – baseline scenario*

In some cases, the value of VHF blocks allocated for the provision of local multiplexes increases as blocks are allocated despite the fact that the greatest proportion of unserved area will be served using the first blocks. This is due to the inclusion in the above figures of

an estimate of the additional value arising from the use of the blocks to provide a second local multiplex to areas already served, in addition to covering certain areas for the first time. As the amount of unserved area is lower for subsequent blocks, the potential for re-use elsewhere in the country is greater and so they may have a higher value as a result.

Note they are based on the conservative assumption that the additional surplus to a consumer from acquiring a T-DAB radio remains unchanged over time; in practice, as DAB is an “experience good”, it is quite likely that value could increase over time. However, we also make the more optimistic assumption that the benefits from T-DAB will not only accrue to the purchaser of the radio but also to other listeners of the radio, who have not had to pay for it. We have also modelled a scenario where take-up of T-DAB radios is lower than in the baseline projection. The result of both of these downwards adjustments are shown in Exhibit 4.4.

Additional national multiplex				
Additional spectrum (Mhz)	Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
1.712	Nationwide	First national multiplex	5.4	9.2
1.712	Nationwide	Second national multiplex	2.2	3.7
1.712	Nationwide	Third national multiplex	0.9	1.5
1.712	Nationwide	Fourth national multiplex	0.3	0.6
1.712	Nationwide	Fifth national multiplex	0.1	0.2

Five local coverage expansion using five VHF blocks				
Additional spectrum (Mhz)	Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
1.712	Localised	First VHF block	1.5	2.6
1.712	Localised	Second VHF block	1.6	2.8
1.712	Localised	Third VHF block	1.8	3.1
1.712	Localised	Fourth VHF block	1.6	2.8
1.712	Localised	Fifth VHF block	2.1	3.6

Local coverage expansion using three VHF blocks				
Additional spectrum (Mhz)	Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
1.712	Localised	First VHF block	1.9	3.2
1.712	Localised	Second VHF block	2.1	3.5
1.712	Localised	Third VHF block	2.0	3.5

Local coverage expansion using two VHF blocks				
Additional spectrum (Mhz)	Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
1.712	Localised	First VHF block	2.2	3.7
1.712	Localised	Second VHF block	2.4	4.2

Local coverage expansion using three VHF blocks & L-band				
Additional spectrum (Mhz)	Area Required	Allocation	NPV/MHz (GBP million)	Total NPV Benefit (GBP million)
1.712	Localised	First VHF block	1.3	2.2
1.712	Localised	Second VHF block	1.5	2.6
1.712	Localised	Third VHF block	1.6	2.7
-	Localised	L-band	-	3.3

Exhibit 4.4: Economic benefit from allocation of additional spectrum for T-DAB – lowest value scenario

Examining both of the above exhibits, we can see that the total value of T-DAB (assuming two blocks assigned for national multiplexes and five for local multiplexes) could range from GBP28 million in the lowest value scenario to GBP129 million in the base case.

There are also a number of possible further sources of benefit from T-DAB use not captured in our results, which suggest that they may be an underestimate of full benefits from T-DAB radio, namely:

- Multiplex providers may generate producer surplus from the provision of capacity to radio stations (and also multimedia services – see below). Producer surplus will only be zero if the market for providing T-DAB capacity is fully competitive.
- There may be additional benefits to advertisers from the availability of radio stations on a digital platform. Notably, advertisers may benefit from the availability of new stations which allow them to reach specific target markets.
- Migration of radio stations to digital could potentially free up existing analogue spectrum in the FM band for alternative use. This is potentially a very large benefit. However, as analogue switchover is not anticipated within the timescale of this analysis, it would not be appropriate to include this potential benefit.

4.6 T-DAB mobile and portable multimedia services

T-DAB can be used to transmit multimedia/data services to mobile devices. For example, the existing national commercial multiplex owner Digital One has recently signed a contract with BT Wholesale to use a portion of its multiplex for such services. The main industry momentum, however, is behind the use of DVB-H (a variant of the digital terrestrial TV standard) for providing broadcast services to handsets.

The economic benefits associated with T-DAB mobile and portable multimedia services is therefore very much dependent on the success of the technology in comparison with DVB-H. As this service is in the earliest stages of development, we simply provide an indication of how large the benefits may be, by comparing the cost effectiveness of T-DAB as a delivery mechanism for such content compared with 3G networks. For video clip downloading, the use of T-DAB could result in an NPV benefit of GBP 33 million arising from the cost saving over providing a similar service on a 3G network. This benefit could rise to over GBP 200 million if a live video streaming service were offered as the cost savings associated with broadcasting would be leveraged to a greater extent.

While there is a high degree of uncertainty over the amount of benefit that would arise from a T-DAB multimedia service, it has been shown in Annex D that the benefits are

potentially very significant. It is likely that the market will be able to determine whether to utilise T-DAB multiplex capacity for providing additional radio stations as against using it for providing multimedia services to mobile and portable devices – provided Ofcom does not place any specific regulatory constraints on usage of the multiplex capacity.

4.7 Summary of demand

Exhibit 4.5 below summarises the demand for Band III spectrum (including spectrum current allocated to PMSE and short-range devices¹⁶) for use for T-DAB and PMR, together with the net economic benefit from its use (NPV over the period 2005–2014). We have shown the PMR demand and net economic benefit associated with the baseline case here. Please also note that the economic benefits associated with T-DAB are shown for T-DAB radio only – use of the spectrum for the provision of mobile and portable multimedia services could provide a further upside to the indicated results.

¹⁶ The chart shows the potentially available spectrum in Sub-bands 2 and 3 of Band III. This has been calculated by considering the unassigned spectrum in Sub-band 2 (2 x 4.6MHz) and the spectrum from the upper edge of Sub-band 2 (207.49375MHz) up to T-DAB block 11B (centre frequency 218.64MHz), but subtracting the guard band spectrum that would be required between T-DAB and PMR (3MHz from the centre frequency of the T-DAB transmission - see Annex F for further details). This gives a total of 17.35MHz of 'available' spectrum (note that this includes current allocations to PMSE and SRD).

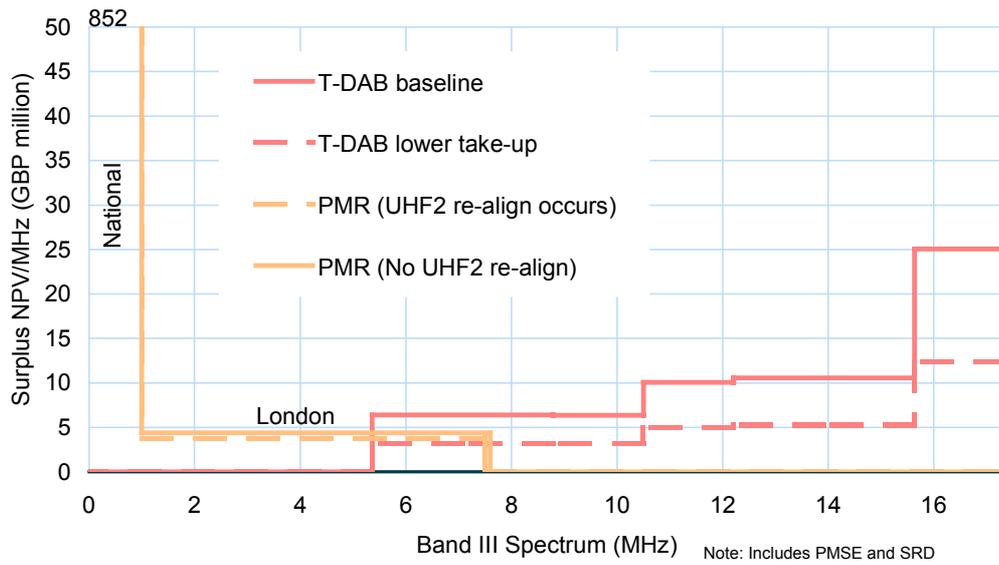


Exhibit 4.5: Demand/net economic benefit for usage of Band III spectrum – PMR baseline scenario

It can be seen that there is demand for PMR spectrum in London and the South East which also overlaps with demand from T-DAB to enhance local coverage. One key issue is whether these requirements can be covered using the same frequency block.

Exhibit 4.6 and Exhibit 4.7 show the results for PMR demand Scenarios A and B, respectively.

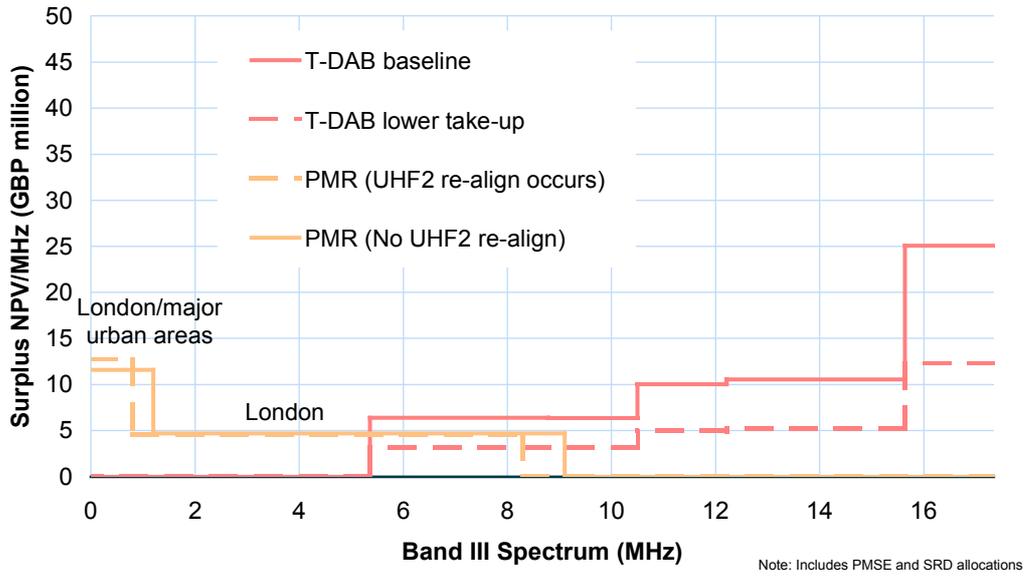


Exhibit 4.6: Demand/net economic benefit for usage of Band III spectrum – PMR Scenario A

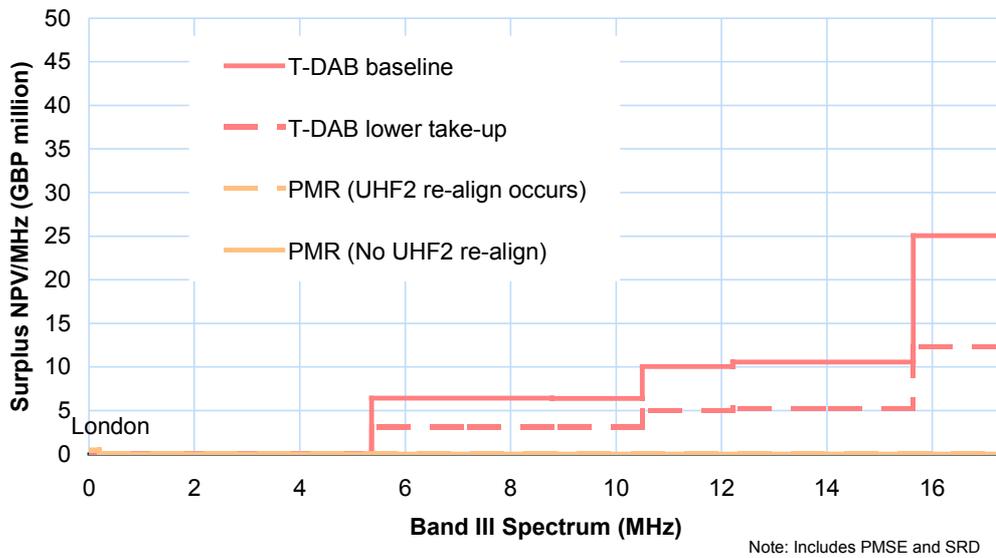


Exhibit 4.7: Demand/net economic benefit for usage of Band III spectrum – PMR Scenario B

In the case of Scenario A, the ‘overlap’ in requirement for spectrum between PMR and Band III is where PMR is being used in London and the major urban areas. The requirement for T-DAB is for providing a local multiplex to small proportions of the population. Again there may be potential for both uses to co-exist. However, given the

propagation characteristics of Band III, use in major areas of the UK may mean that spectrum is effectively ‘sterilised’ across a large part of the country’s population – scope for use for T-DAB may therefore be limited.

We have also considered the impact if spectrum is required for PAMR services. Exhibit 4.8 below consequently shows the demand/net economic benefit arising from usage of the spectrum for PMR, PAMR and T-DAB. We have shown the results for PMR demand Scenario A as this represent the greatest demand for additional PMR spectrum.

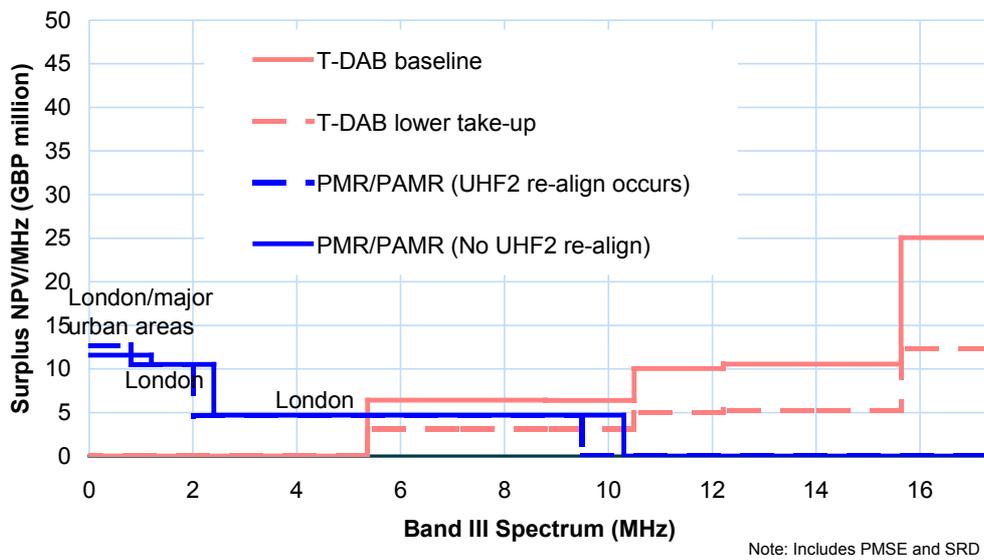


Exhibit 4.8: Demand/net economic benefit for usage of Band III spectrum – PMR Scenario A and PAMR

4.7.1 Other services: identification of opportunity costs

The above summary assessments can also be used for making other key ‘opportunity cost’ determinations:

- we understand that there may be a requirement for 10MHz (2 × 5MHz) of spectrum for public safety communications. Band III may be a potential source for all or part of this spectrum requirement. Using the assessment detailed above, the economic value generated from services that would be lost can be assessed.

- prioritising extending T-DAB local station availability (coverage) – in cases where there is not sufficient spectrum for additional T-DAB national multiplexes and enhancing local coverage, trade-offs can be made between utilising spectrum which would otherwise be used for a national multiplex versus spectrum which would otherwise be used for PMR for this purpose.

5 Analysis of demand for the spectrum

We have identified a number of different services that could use available spectrum in VHF Band III, including PMR/PAMR, T-DAB and PMSE. We wish to understand whether spectrum can be allocated in a service/technology-neutral fashion, that allows all or some of these service groups to compete for the spectrum, or whether an administrative decision is required to divide up available spectrum between services. To do this, we need to examine their relative requirements for spectrum and consider the extent to which these may be ‘compatible’. We also need an understanding of likely demand for and value of spectrum for the different services to inform any administrative decisions that are required. We consider these issues in the subsections below.

The situation in L-Band, which we address in Section 5.4, is more straightforward. Amongst the services that we have been asked to consider, only T-DAB radio or multimedia services are likely to have demand for the spectrum. However, we must also consider the possibility that alternative uses for the spectrum could emerge in the future.

5.1 Spectrum requirements of services in VHF Band III

Spectrum in VHF Band III is currently allocated to a mixture of land mobile (PMR/PAMR), T-DAB, PMSE and short-range devices. These applications have very different demands for spectrum, which impose constraints on their positioning within the band:

T-DAB

T-DAB multiplexes each require a single channel of a nominal bandwidth of 1.536MHz. In principle, these could be positioned anywhere in the VHF Band III. However, in practice, Ofcom informs us that each block must conform to the Europe-wide frequency band plan

for effective receiver operation. Many existing digital radios are only designed to pick up channels broadcast using these specific frequency blocks; others would need to be retuned. In addition, any attempt to re-plan UK T-DAB blocks could be complicated by the need to co-ordinate with television broadcasters in Belgium, France and Ireland, who use the same spectrum.

T-DAB is transmitted using relatively high-power signals designed to reach large areas of population. In order to ensure that radio users enjoy high quality reception (which is a key attribute of T-DAB radio), broadcasters require exclusive use of spectrum in their footprint (although there may be some scope for sharing with short-range devices on a no-interference basis). A guard band of 0.176MHz is planned between T-DAB blocks for coordination between adjacent multiplexes; but larger spacing may be required where T-DAB is adjacent to other services, owing to the characteristics of the T-DAB emissions mask. Substantial geographic spacing is also required between regional/local multiplexes using the same spectrum.

Land mobile

Analogue PMR and PAMR operate using discrete narrowband channels, each of 12.5kHz, for sending signals from the base to mobile devices (base transmit) and vice versa (mobile transmit). The equipment works using specific paired channels, which must be spaced at fixed intervals (duplex spacing). For example, existing PMR users in Band III use duplex pairs spaced 8MHz apart. A spacing of less than this is feasible but is ultimately limited by the duplex filter performance (a minimum gap is required to avoid interference between the transmit and receive paths in the equipment). Land mobile systems use more modest power signals than broadcasting but may still cover quite extensive areas. No separation is typically required between channels being used for transmitting signals in the same direction. However, a gap is required between the base and mobile spectrum (the duplex spacing in the case of existing PMR spectrum in VHF Band III is 1.7125MHz). Guard bands are also required to prevent adjacent channel interference from high-power systems operating in adjacent bands. For example, we estimate that a minimum separation of 2.44MHz is required between the central frequency of a PMR channel and a T-DAB channel (see Annex F for an explanation).

PMSE

PMSE use VHF spectrum for a variety of functions, including radio microphones, TalkBack (push-to-talk mobile systems for voice communication), and temporary or portable audio links. These operate using small channels (200 kHz or less), but sufficient spectrum is required to facilitate deployment of multiple devices at special events. Some equipment is retunable across the VHF band, but other devices are designed to operate only in specific ‘spot’ frequencies based on existing allocations. TalkBack requires paired spectrum.

PMSE devices transmit low-power signals over short distances, so there is limited scope for them to interfere with other services in neighbouring frequencies. This means that they can be deployed in the guard bands between PMR base and mobile transmit, and between PMR/PAMR and T-DAB. However, they are vulnerable, to varying degrees, to interference from high-power devices (such as T-DAB) operating in neighbouring frequencies or areas. Thus, the extent to which they can utilise guard band spectrum may be constrained, especially at the edges.

Short-range devices

Short-range devices, such as alarms and key fobs, use only small spectrum endowments and send low-power signals over very short distances. This limits the scope for them to cause interference with other applications. However, as they are unlicensed and there are no controls over their location, they could interfere with PMR handsets or T-DAB radio receivers on a localised basis. They are also potentially vulnerable to interference from high-power applications.

5.2 Compatibility of services in VHF Band III

In this subsection, we discuss the compatibility of allocations for potential services in VHF Band III, in light of the comparison of their spectrum requirements above.

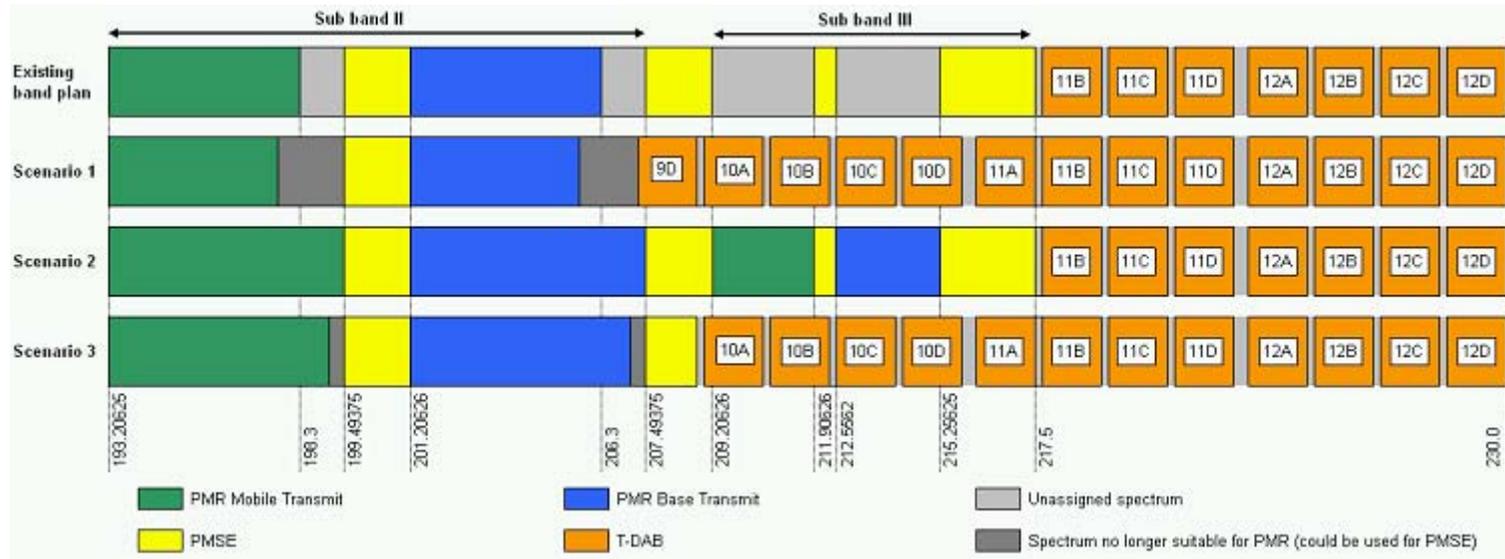


Exhibit 5.1: Selected allocation scenarios for VHF Band III

Exhibit 5.1 shows the current band plan for Sub-bands II and III of VHF Band III. It also illustrates a number of possible future allocation scenarios:

- *Scenario 1:* There are six new T-DAB blocks, located in contiguous spectrum, adjacent to the existing T-DAB allocation. Some PMSE and PMR users are refarmed to accommodate T-DAB.
- *Scenario 2:* All available spectrum is allocated to PMR; there are no new T-DAB blocks. PMSE users are unaffected.
- *Scenario 3:* There are five new T-DAB blocks, located in contiguous spectrum, adjacent to the existing T-DAB allocation. Remaining available spectrum is allocated to PMR and/or PMSE users. Some PMSE users are refarmed to accommodate the new T-DAB blocks.

Our comparison of these scenarios and analysis of spectrum requirements for the different services produces a number of significant observations:

- The available spectrum in Sub-band 3 can be used for *either* land mobile (PMR/PAMR) or T-DAB, *not* both. It is not realistic to configure the spectrum in a way that allows allocations to both services, owing to the separation required between the services and conflict between the requirement of PMR for duplex spectrum and T-DAB for unidirectional blocks in fixed locations.¹⁷
- Additional T-DAB blocks would clash with existing PMSE bands. Specifically, blocks 10D and 11A clash with PMSE in 215.25625–217.5MHz, Block 10B clashes with PMSE in 207.4395–209.20626MHz, and Blocks 9D and 10A clash with PMSE in 207.4395–209.20626MHz. Only Block 10C does not clash with PMSE spectrum, although it is immediately adjacent to a PMSE band, so may also cause interference. Note, however, that as some T-DAB blocks may be used for local radio stations, it may still be possible to have PMSE on a local basis. Thus any allocation proposal that envisages additional T-DAB blocks would need to take into account the cost of displacing PMSE users.

17

In theory, it would be possible to accommodate one additional T-DAB block (11A) at the expense of existing PMSE users, and still allocate most of the remaining spectrum in Sub-band 3 to PMR. However, this is most unlikely to be desirable given our understanding of relative demand for spectrum across different service categories (see Section 4).

- Additional T-DAB blocks would also clash with some existing SRD allocations; however, this is not an obvious concern, as these allocations are not currently used.
- Unlike T-DAB, PMR is more compatible with PMSE. PMSE users would not be affected if additional spectrum in Sub-band 3 was used for PMR, since new PMR assignments could be planned around existing PMSE channels.
- The available spectrum in Sub-band 2 could be used either for PMR or displaced PMSE. It could not be used for T-DAB without displacing existing PMR users. Specifically, allocating a sixth T-DAB block (9D) would potentially interfere with 1440 existing PMR assignments at the upper end of Sub-band 2 (1319 of which are to Network Rail) and 6 existing PAMR assignments. Exhibit 5.2 illustrates the geographical distribution of the assignments, which would have to be re-farmed to avoid interference. Thus, the opportunity cost of allocating a sixth T-DAB block appears prohibitive.
- Allocating a fifth T-DAB block (10A) in Sub-band 3 would reduce available spectrum for PMR in Sub-band 2 by $2 \times 0.56\text{MHz}$ in order to maintain adequate separation between the two services to prevent interference. However, this PMR spectrum is not currently used. Furthermore, the spectrum would not be sterilised, as it could be used, for example, for PMSE, or possibly PMR on a regional basis.

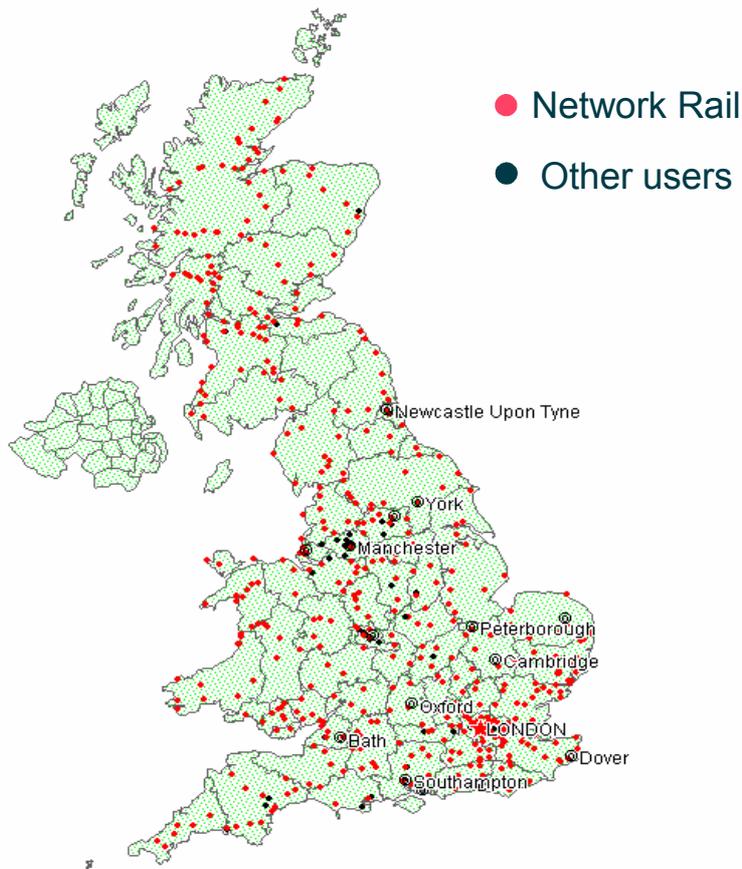


Exhibit 5.2: PMR and PAMR assignments that would be affected by a sixth DAB block (9D) [Source: [Ofcom, Analysys, 2004]

In summary, it is apparent that demand for spectrum for different services in VHF Band III is not easily reconcilable. The main problem area is Sub-band 3, where spectrum could either be allocated to PMR/PAMR¹⁸ or T-DAB, but not both. If T-DAB is favoured, then this would require displacement of PMSE. Sub-band 2 is more straightforward, as this is only likely to be suitable for PMR/PAMR or displaced PMSE, as the cost of re-farming existing PMR users to make sufficient spectrum available for T-DAB appears prohibitive.

Thus, for Sub-band 3, Ofcom must either develop an allocation process that is capable of allowing the market efficiently to chose between PMR/PMSE and T-DAB, or make an administrative allocation that favours one or the other. As we explain in Section 6, in our view it is not possible in this case to develop such an allocation process. Thus an

¹⁸ Note however that usage of Sub-band 3 for PMR is likely to be highly constrained. As detailed in Annex F, television broadcast transmissions from Ireland and the Continent place severe constraints on the geographic areas where Sub-band 3 spectrum can be used for PMR services.

administrative decision is required, based on an assessment of current and potential demand for the spectrum from the different services, and any additional social benefits they generate for the UK.

5.3 Demand for and value of services in VHF Band III

A thorough understanding of the relative value generated by different services using spectrum is essential to facilitate administrative choices between allocations or to design efficiently assignment mechanisms that allow the market to determine the final use. Phase A of the study examined the relative value to society (consumer surplus) of a number of different services over the next ten years. The key findings were:

- *PMR (including transport PMR)*. Our modelling scenarios attached a positive value of up to GBP51 million (Net Present Value to 2014) to additional spectrum for PMR. Our baseline scenario attached a value of GBP29 million corresponding to allocating 6.6MHz (2×3.3 MHz) additional spectrum for PMR, although this additional demand is only required in London. A further 1MHz of spectrum would also be required on a nationwide basis under this scenario for the provision of real-time passenger information services on buses¹⁹. We also modelled an alternative scenario corresponding to stronger demand for PMR spectrum (here demand for PMR spectrum is also strong but highly spectrally efficient digital technologies do not become available for Band III). This scenario attached a positive value of up to GBP51 million to allocating 9.1MHz (2×4.55 MHz) of additional spectrum in London, and 1.2MHz in other major urban areas.
- *PAMR*. Generally no additional value or demand for extra spectrum, however one scenario involving the migration of existing Dolphin customers to Band III PAMR networks could lead to a requirement of 1.2MHz of spectrum in London with an associated value of GBP12.6 million.
- *T-DAB (including multimedia services)*. There is a positive social value of GBP28million–GBP129 million associated with allocating up to seven or more additional T-DAB blocks. However, the incremental value created by additional blocks

¹⁹ We estimated this could generate significant economic benefits (GBP852 million). However, our estimates are based on confidential information from London Buses and we have not been able to validate the market research methodology underlying this information.

diminishes rapidly. For example, adding one extra national block accounts for over 33% of the total, whereas adding a fifth national block adds just 13%. Adding local multiplexes also adds less value than national ones, in large part because of the large amount of geographical spectrum that is sterilised in order to avoid interference between local radio stations.

These estimates are useful because they give us an indication of the result that a hypothetical market-based contest for spectrum between PMR, PAMR and T-DAB might produce. They also give us some idea of the opportunity cost of allocating spectrum to a particular service to the exclusion of others. However, a number of further factors should be taken into account:

- A market-based contest is determined by relative demand for spectrum. In interpreting the results described above, it is important to consider that these figures are not estimates of demand, but rather the value to consumers of allocating spectrum to specific services. In the case of PMR and PAMR, this should provide a good indication of future incremental demand for spectrum, as demand is driven directly by potential users' valuations. However, in the case of T-DAB, the linkage is more complicated. Demand for T-DAB spectrum depends on the demand for spectrum from the BBC and commercial broadcasters. This in turn is linked to take-up of T-DAB sets by consumers, but also to the demand for advertising.
- Evidence of significant social value attached to T-DAB cannot necessarily be interpreted as an indication of future demand for spectrum and for channels on multiplexes (as this value is derived from consumer surplus to radio listeners, rather than the value to radio stations and their advertisers). Indeed, amongst existing T-DAB assignments, there was only one applicant for the national commercial channel, while some local multiplexes remain unassigned. Recently, however, there has been a significant take-off in sales of T-DAB radios, which is likely to make digital broadcasting more attractive. A number of respondents to Ofcom's consultation on the use of spectrum in VHF Band II and L-Band indicated interest in acquiring spectrum, especially for nationwide or large regional multiplexes.
- Our methodology necessarily focused on economic value to consumers, as reflected in their purchasing decisions. There may be additional sources of social value not captured in this approach. For example, existing local T-DAB multiplexes only reach around 90% of the population, and many regions (e.g. Oxford, Ipswich, Derby and the

northern Home Counties) do not have their own dedicated spectrum. This situation may be considered iniquitous from a political standpoint.

- Phase A of the study did not consider the social value of spectrum for PMSE or short-range devices currently allocated spectrum in VHF Band III. In the case of short-range devices, no actual assignments have been requested, so we may reasonably suppose that this value is low, possibly even zero. However, in the case of PMSE, it is apparent that there is extensive use of spectrum in VHF Band III. In making decisions on allocation, we must therefore consider the opportunity cost of any impact on PMSE users. This equates to the cost of either refarming users to alternative frequencies or ending specific services completely, whichever is the smaller.
- Within the scope of this project, it has not been possible to fully cost the impact of moving PMSE to accommodate additional T-DAB blocks. In Annex E, we summarise current PMSE activity in VHF Band III. The total value of equipment being used in this band is uncertain but may exceed GBP40 million; however, a significant proportion may be retunable to alternative bands at UHF or in the lower VHF bands. We note, however, that PMSE spectrum is also under pressure in the UHF band, owing to digital switchover and potential UHF2 alignment. There may, therefore, be a case for a strategic review of spectrum for PMSE across bands.
- It is also important to consider that there may be possible future sources of demand for the spectrum that we have not considered. Ideally, the spectrum should not be allocated in such a way that these services cannot get access to spectrum, if they value it more highly than alternative uses.

5.4 L-Band

T-DAB broadcasting and multimedia services are the main candidate services for L-Band spectrum, amongst those analysed. If these were the only services with demand for the spectrum, then this would mean that there should not be any significant compatibility problems between services in allocating the spectrum. There may, however, be alternative uses in the future for this spectrum, for example wireless broadband, public mobile services and satellite radio. The extent to which spectrum demand from these services would be compatible with T-DAB depends very much on the specific use in question.

As with VHF spectrum, L-Band multiplexes require contiguous blocks of frequency. In this case, each block is approximately 1.712MHz, including spacing between T-DAB blocks.

As L-Band signals generally propagate over quite short distances relative to VHF, they are ideal for small area broadcasting networks. They are much less suitable than VHF for rolling out multiplexes for national or large local radio networks, owing to the larger number of transmitter sites required. Possible T-DAB uses for L-Band spectrum include:

- In-fill or extension of radio station footprints, where VHF is unsuitable (e.g. owing to risk of interference with other radio stations).
- Community radio or small-scale commercial radio, especially in dense urban areas.
- For the provision of multimedia services to mobile and portable devices – the antennas required for L-band are more suited to such applications than for Band III.

Demand for spectrum could come directly from users or from a band manager that licenses spectrum to small users. Most likely, community radio stations will prefer to buy T-DAB services from an organisation running a multiplex, rather than trying to run a multiplex themselves and reselling excess capacity. The expected model is important, as the implications for allocation with respect to the degree of geographical division of usage rights is very different with micro users versus a band manager operating across multiple areas.

There is already a band plan provisionally in place for T-DAB in L-Band (see Exhibit 3.2 above and Exhibit 5.3 below). This envisages 16 blocks, each used to provide channels in small areas spread across the country, such that each area only has one channel. This plan was effective in ensuring that the UK broadcasting industry has access to as many blocks as possible unencumbered by constraints on interference with neighbouring countries. However, it is doubtful that it represents a particularly efficient structure for rolling out services, for two reasons:

- The plan was drawn up with only partial reference to potential geographical distribution of demand. Actual demand may not fit with the areas and geographical boundaries selected. Moreover, one block may not be sufficient for some high-population areas. For example, just one block is assigned to Greater London.

- The plan is very wasteful of spectrum, as any one block is only being used in a few small areas of the country. It is doubtful whether all 16 blocks are really required to accommodate demand in this way. It is quite possible that demand could be accommodated with a smaller number of blocks and with some regions enjoying access to a number of multiplexes.

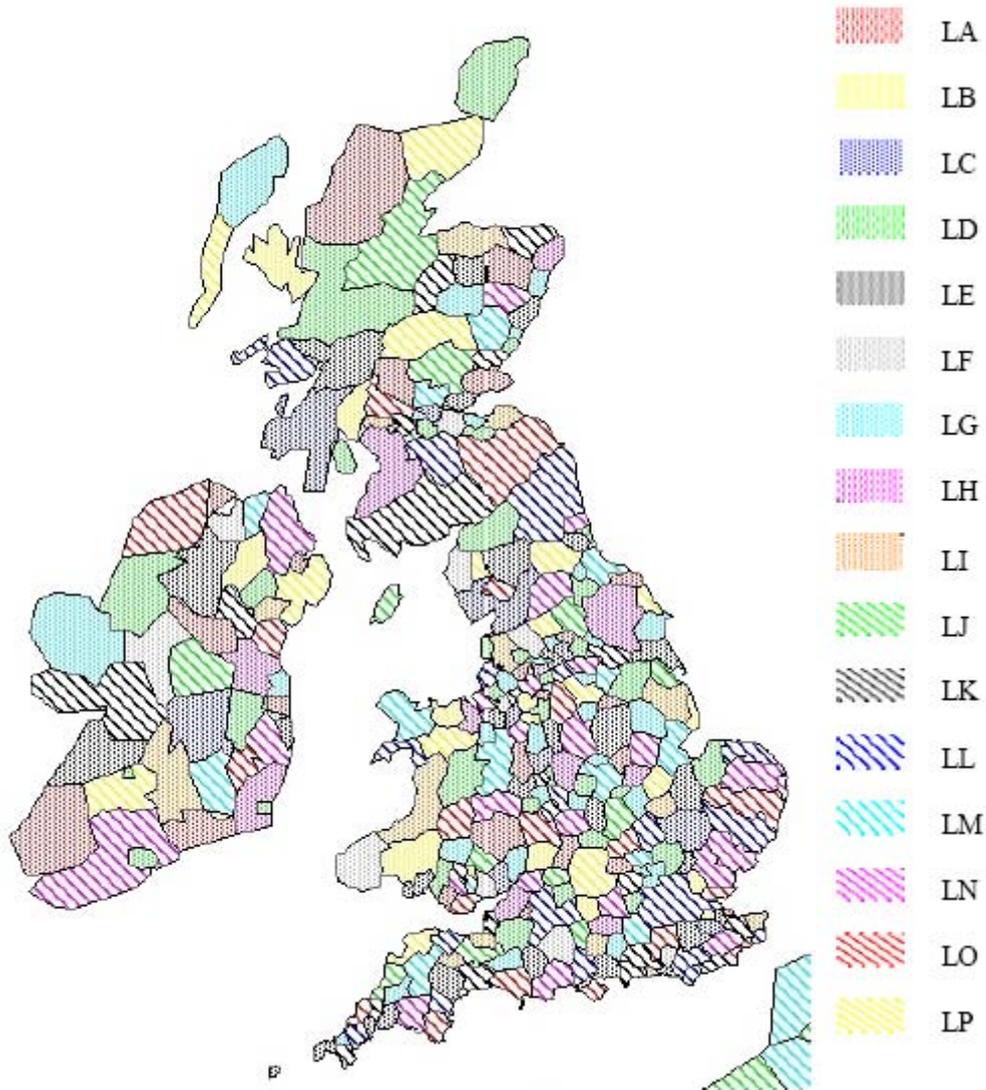


Exhibit 5.3: T-DAB allotment plan for L-Band in UK and Ireland [Source: Radiocommunications Agency, 2003]

There is little evidence of demand for L-Band spectrum for T-DAB services in the UK at present. However, there *is* evidence of significant latent demand for community radio as is

evidenced by recent activity to establish a framework for licensing community radio in the UK. Looking forward, demand for this spectrum could increase significantly over the next decade if continental markets which use L-band develop and dual-band radios become standard in the UK.

6 Allocation options

In this section, we describe the main options available for allocating spectrum in VHF Band III and L-Band. A key observation is that there is no efficient way of defining usage rights in the context of existing allocations in VHF Band III that allows both T-DAB and land mobile users to compete with each other in a market contest. Therefore, a level of administrative decision is required. Based on our assessment of the relative value of the spectrum for different services, our main recommendations are as follows:

In VHF Band III:

- Available spectrum in the existing PMR bands in Sub-band 2 continues to be allocated to PMR or compatible services.
- Up to five additional T-DAB blocks are created in Sub-band 3; two or three of which are reserved for specific local T-DAB multiplexes. This assumes that the incremental value of additional blocks exceeds the cost of re-farming PMSE users in affected bands, which is subject to further verification.

In L-Band:

- The 16 blocks currently allocated to DAB are made available for T-DAB or alternative compatible uses.
- The remaining spectrum is either allocated on the same basis or a decision on allocation is postponed, pending further consultation on potential sources of demand.

We consider, in turn, the cases of Band III Sub-band 2; Band III Sub-band 3; and L-Band. We regard this separation as being appropriate, as the allocation challenges in each of these frequency bands are distinct. To the extent that they are related, this is discussed below.

Both Band III Sub-band 3 and L-Band are candidate frequencies for T-DAB services. However, they do not appear to be particularly close substitutes. Multiplex operators offering service to national radio stations and local stations covering rural areas are unlikely to consider L-Band for wide area roll-out, owing to the large additional cost of erecting multiple additional transmitters. Overlap is thus likely to be limited to local radio stations or multimedia services in urban and suburban areas. We also note that most existing T-DAB radios in the UK are VHF and so dual band receivers would be required to operate across both VHF and L bands.

6.1 VHF Band III: Sub-band 2

6.1.1 Allocation choices

Total available spectrum in Sub-band 2 amounts to 2 x 4.6MHz, but only 2 x 1.2MHz is contiguous. Realistically, spectrum in this band can only be used by existing PMR/PAMR type applications or compatible services, such as PMSE. This is because there is not enough available contiguous spectrum to fit in a T-DAB block without refarming many existing PMR and PMSE users. Our analysis indicates that refarming significant amounts of spectrum in Sub-band 2 would be very disruptive to existing users and carry a high opportunity cost.

For example, in Section 4.2, we considered the example of creating a T-DAB block 9D, and identified that this would require the displacement both of PMSE users and, owing to the need for a 2.44MHz separation between PMR and T-DAB, a large number of existing PMR users, including many Network Rail licences. Note that PMR users would be effectively displaced from both the mobile and base parts of their paired spectrum, even though only the base spectrum would actually be affected by the T-DAB block. Creating T-DAB blocks below 9D would be result in further disruption and expense.

This spectrum in Sub-band 2 provides significant flexibility for possible future expansion in PMR and PAMR demand. Our analysis in Section 4 indicated potential additional demand for PMR/PAMR over the next ten years of up to 2 x 5.15MHz in London and 2 x 0.6MHz in other urban areas. This could be almost entirely accommodated within the available spectrum in Sub-band 2 (importantly PMR systems can make use of the available 12.5kHz duplex channels that are fragmented across the band).

Meanwhile, T-DAB demand can more easily be accommodated through allocation of spectrum in Sub-band 3 (see below). Our benefit analysis found that there is a very low incremental value to having a sixth (or more) T-DAB block, so that provided T-DAB demand is accommodated in Sub-band 3, the opportunity cost of not making Sub-band 2 spectrum available to T-DAB is low.

Ideally, it would be preferable to put this analysis to the test by having a competitive contest between PMR and T-DAB for the spectrum. However, we do not believe that it is possible under current conditions to design an auction that could efficiently distinguish between competing demand from potential users of PMR and T-DAB. There are two main reasons for this:

- It is impractical to design usage rights that could reconcile the conflicting spectrum demands of PMR (small duplex pairs for geographical areas of varying size) and T-DAB users (large, contiguous blocks, nationwide or local). This means that any usage rights designed to enable PMR will indirectly restrict other services such as T-DAB due to incompatibility, even if no explicit restriction is placed on the service that can be used.
- Demand for PMR is fragmented across many small users, which creates practical problems in bringing their demand together in an auction. This raises the risk of market failure.

Both these problems would be eased if PMR users were represented by ‘band managers’ who administered large blocks of spectrum on their behalf. This is essentially the system that already operates for T-DAB radio (PMSE also has a band manager, albeit with limited management functions). The promotion of band managers in the PMR sector may be a practical way for Ofcom to facilitate future competitive contests for spectrum between PMR and other uses. However, unless and until such band managers emerge, it is likely to be impractical to use auctions for allocate spectrum for PMR.

We therefore recommend that available spectrum in Sub-band 2 continues to be made available to PMR/PAMR. However, Ofcom should also consider the scope for other relatively compatible services, such as PMSE, to use some of this spectrum, especially the 2 x 1.2MHz contiguous. Although the design of usage rights (if based on current PMR usage rights) would place an indirect restriction on the uses of the spectrum, this need not preclude uses other than PMR/PAMR.

6.1.2 Definition of usage rights

Usage rights (licences) for available spectrum in Sub-band 2 already exist. However, these were design only with PMR/PAMR in mind. Some adjustments may be appropriate to allow for alternative compatible use of the spectrum (e.g. by PMSE) and also future tradability. Ideally, any changes should also apply to existing licences, to ensure that all users have appropriate incentives to use spectrum efficiently.

Spectrum endowment

Available spectrum in Sub-band 2 is currently allocated in 12.5KHz pairs, as required by PMR users. This should continue. However, in relation to the 2 x 1.2MHz continuous spectrum, some flexibility would be appropriate to allow PMSE users to acquire this spectrum for alternative uses. For example, it should be possible for a PMSE user to combine multiple channels and potentially to use each half of the duplex pair for different services.

Geographic area

Spectrum in Sub-band 2 is currently allocated on a first come first served basis according to the geographical footprint requested, which may be national or highly localised. This approach can be maintained. However, it should be appreciated that primary allocation of spectrum in this way, which results in fragmented geographical use across large numbers of small users does create barriers to future tradability. The introduction of private band managers who can buy spectrum on a national or local basis and then allocate spectrum to users in a secondary process could potentially increase future efficiency in allocation – especially as the band becomes more congested.

Time of access

Most potential users require access to spectrum 24 hours a day, and therefore licences should be allocated in this way. To the extent that there is demand for access to PMR systems for shorter periods each day, this could be resolved through sub-leasing arrangements in a secondary market.

Duration

In its consultation on the introduction of spectrum trading, Ofcom declared a preference for the implementation of usage rights with continuous rolling terms, but subject to revocation under exception conditions.²⁰ This policy appears appropriate for usage rights in this band. In return for the security of tenure associated with such rights, users should be charged the full opportunity cost of their spectrum use (see discussion of incentive pricing in Section 7).

Interference

Ofcom currently has responsibility for coordinating PMR users in Sub-band 2, in order to prevent harmful interference between regional allocations or across channels. This role will remain important.

If alternative services or technologies are deployed in this spectrum, then this should be on a no-interference basis with existing PMR users, and should not restrict future PMR use in any unassigned channels. However, within their own assignments, users should have flexibility to determine their own interference thresholds between the services and technologies that they deploy.

Other licence conditions

Other licence conditions should be kept to a minimum, in order to avoid unnecessarily restricting deployment of new technologies or services.

Trading and change of use

There appears no obvious reason to restrict the trading or reconfiguration of licences in the secondary market.

The existing band plan imposes considerable constraints on the scope for change of use, but this should be permissible provided users respect their licence conditions.

²⁰ Ofcom, *Spectrum Trading Consultation*, November 2003, p.33-34

6.2 VHF Band III: Sub-band 3

6.2.1 Allocation choices

This spectrum could be used for either PMR/PAMR or for T-DAB. However, given that there is sufficient available spectrum in Sub-band 2 to accommodate almost all potential PMR/PAMR demand even under the most extreme of our scenarios, the case for allocating this spectrum to T-DAB appears much stronger. Additionally, as detailed in Annex F, television broadcast transmissions from Ireland and the Continent place severe constraints on the use of Sub-band 3 for PMR services – in particular usage in London (which is the main area where additional spectrum for PMR/PAMR may be required) does not appear to be possible. The main opportunity cost of making Sub-band 3 spectrum available to T-DAB arises not from exclusion of PMR/PAMR but rather from the potential displacement of PMSE services from Sub-band 3.

Up to five T-DAB blocks could be created in Sub-band 2, as described under scenario 3 in Section 4.2. These are described in Exhibit 6.1 below, which also highlights the opportunity cost of each block in terms of the impact on PMSE. Some of these blocks are encumbered by non-interference obligations in relation to foreign broadcasters, which will affect their value to potential T-DAB users. The only block unencumbered by foreign coordination is 10D, which suggests that this is an ideal candidate for a new national multiplex.

<i>Possible new T-DAB blocks</i>	<i>Restrictions owing to foreign coordination</i>	<i>Opportunity cost in terms of impact on PMSE and PMR</i>
10A	Restrictions on use in southern and eastern England owing to use in Belgium and France	Very small overlap with PMSE band used for radio microphones. Some unoccupied PMR spectrum in Sub-band 2 affected.
10B	Restrictions on use in south-east England, Northern Ireland and west coast of Wales and England owing to use in Belgium and Ireland	Partly overlaps with PMSE band used for TalkBack systems
10C	Restrictions on use in Northern Ireland and west coast of Wales and England owing to use in Ireland	Immediately adjacent to PMSE band used for TalkBack systems
10D	No restrictions	Partly overlaps with PMSE band used for radio micro-phones and audio links
11A	Restrictions on use in southern England owing to use in France	Fully overlaps with PMSE band used for radio micro-phones and audio links

Exhibit 6.1: *Impact of creating new T-DAB blocks in Sub-band 3*

Unlike PMR and T-DAB, there is some scope for PMSE and T-DAB to co-exist in Sub-band 3. Although the band plan would need to be redrawn to accommodate potential T-DAB demand, PMSE could potentially occupy some of these blocks. Also, as two or three of the T-DAB blocks would be used for local multiplexes, there may be scope for PMSE to make use of T-DAB spectrum in regions where T-DAB is not being broadcast. It should be feasible for the PMSE band manager, JFMG, or possible future new band manager to compete with T-DAB multiplex providers for blocks in primary assignment or sub-lease spectrum in a secondary market.

Allocating a fifth T-DAB block (10A) in Sub-band 3 would reduce available spectrum for PMR in Sub-band 2 by 2 x 0.56MHz. However, unlike the creation of a block 9D, the opportunity cost of this appears modest. This PMR spectrum is not currently used, so no existing users would be displaced. The spectrum could still be used for PMSE, possibly as part compensation for loss of spectrum in Sub-band 3. In future, the only likely source of demand for this spectrum for PMR/PAMR is in London; this could potentially still be accommodated if 10A was used for local T-DAB outside London.

In summary, we recommend that the allocation plan for Sub-band 3 is redrawn such that it can accommodate up to five T-DAB blocks. PMSE and any other compatible uses should be given the opportunity to compete for these blocks in a competitive contest. It is likely

that this would result in displacement of some existing PMSE use, and Ofcom will need to give due consideration to compensation arrangements (if appropriate) and the timing of re-farming.

6.2.2 Definition of usage rights

In order to facilitate implementation of the allocation options outlined above, Ofcom will need to define new usage rights (licences) for spectrum in Sub-band 3, which allow for the introduction of T-DAB.

Spectrum endowment

Available spectrum in Sub-band 3 will need to be re-planned into five blocks suitable for T-DAB (broadcast and/or multimedia), as illustrated in Exhibit 5.1). These should follow the Europe-wide band plan for T-DAB. Note, however, that dividing up the spectrum in this way does not preclude them from being used for other services, which would have the option of reconfiguring the spectrum.

Geographic area

If the blocks are used for T-DAB, then they could be used for either national or local multiplexes. From a commercial perspective, national blocks will tend to have a higher value, as there is a potential to reach a much larger audience (because local licensing necessitates sterilising large areas around each locality). This may mean that if the market is allowed to determine how the T-DAB blocks are used, many of the new blocks would be used for national channels.

An outcome favouring national multiplexes may be undesirable, because availability of local radio (in addition to national) may be considered to offer significant social benefits. At present, not all parts of the country have access to a local T-DAB multiplex; this may also be considered politically iniquitous. Therefore, there may be a public policy case for setting aside some blocks for multiplexes that serve specific regions.

There are a number of options for allocating spectrum to local T-DAB multiplexes; this could be done using 2, 3, 4 or 5 T-DAB blocks. Two blocks would facilitate provision of

multiplexes to all un-served parts of the country, but would require that some existing radio regions are merged, some boundaries redrawn and there is additional investment in frequency coordination at boundaries. Granting five local multiplexes would allow all existing radio regions to have their own multiplexes, without any changes; however, this would carry a very high opportunity cost. i.e. the preclusion of any additional national multiplexes.

Exhibit 6.2 illustrates the trade off between allocating national and local multiplexes, based on our estimates of their relative social value. In the case of the local multiplexes, we have assumed that these would include allocations to all unserved regions, along the lines described above, with the remaining geographic spectrum allocated to additional local multiplexes in a way that maximizes their value to consumers. This analysis suggests that the optimal number of blocks to be allocated to additional local multiplexes is either two or three.

The opportunity cost of allocating an additional block for local multiplex use in this way is the higher of: (a) the loss of benefit from foregoing an additional national multiplex; or (b) the loss of benefit from foregoing an alternative configuration of local multiplexes unrestricted by the need to reach unserved regions. We estimate that the social value of having a third local multiplex is roughly equivalent to that of a third extra national multiplex. It is possible that an even higher social value could be generated from having additional local multiplexes configured in a different way (i.e. one that does not necessarily take account of unserved regions), but this would require detailed investigations of local preferences.

It is unlikely that market forces alone would achieve the projected social benefits from having additional local multiplexes.

- Willingness to pay for multiplex licences is not determined directly by the value to consumers, but rather by the value which multiplex suppliers can generate from commercial radio stations, which in turn is linked to prospects for advertising spend.
- Multiplex capacity for national or large regional radio stations is more commercially attractive than capacity for small local radio stations. Even when the incremental social value created by additional national channels is very low, there is still potential for any

individual new station to grab a large audience and advertising revenues at the expense of existing rivals. Put differently, even though society might benefit more from having local radio, this effect may be outweighed by the greater scope for commercial gain from having more national radio.

- The fact that having local stations results in spectrum in surrounding areas being sterilised and potentially requires complex site roll-out to address interference coordination at boundaries tends to reinforce the commercial bias towards multiplexes serving large areas.

In summary, we note that there is a possible public policy case for reserving some multiplexes to reach unserved regions; this would also enable many other regions to gain second or third local multiplexes. This could be achieved using two or three multiplex blocks. Provided that two or three additional blocks are also available for national use, reserving blocks for local use in this way appears to be beneficial in terms of generating social value. If, however, the national blocks were not used for T-DAB, then reserving remaining blocks for local rather than national T-DAB would no longer be socially desirable. In all cases, there will be a commercial opportunity cost from intervention; this could potentially be observed from the losing bids in an auction of the national multiplex usage rights.

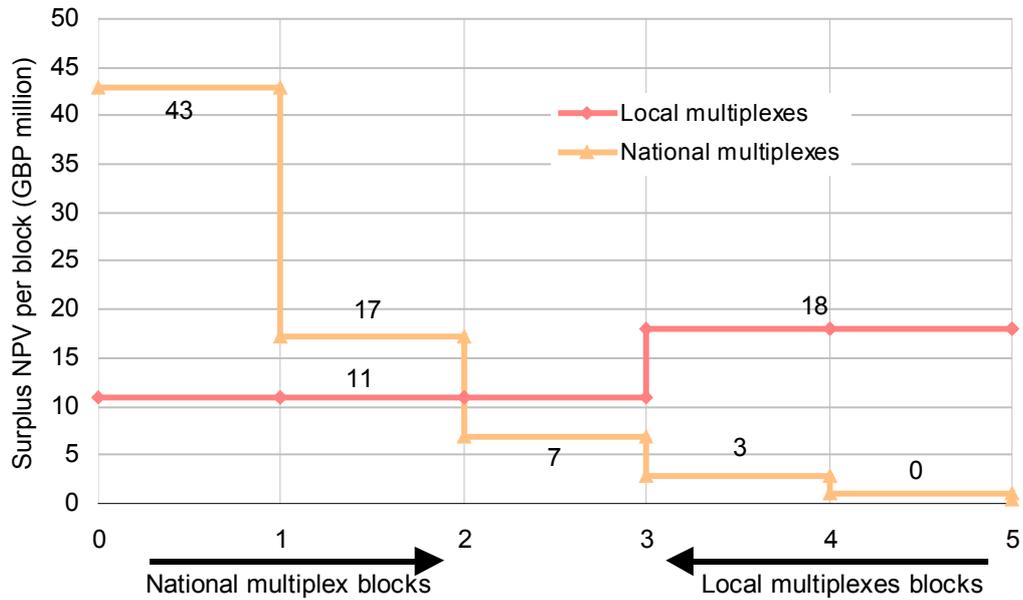


Exhibit 6.2: Trade-off in terms of additional social value between allocation of additional local and national multiplexes

Some of the potential T-DAB blocks are subject to transmission restrictions owing to requirements for coordination with continental broadcasters. These blocks are likely to be the most appropriate ones for local multiplexes, as they carry a lower opportunity cost in relation to denying national multiplexes. A possible allocation plan in the event that three blocks were allocated to local services is described in Exhibit 6.3.

<i>Block</i>	<i>Allocation*</i>	<i>Proportion of population*</i>	<i>Restrictions</i>
10A	W.Surrey/ E.Hants; Salisbury; Barnstaple; Bury St Edmonds/ Ipswich; Northampton; Gloucester/ Cheltenham; Ceredigion; York; Chester/ Wrexham	5.6%	Coordination with Belgium and France Also coordination with PMR use in UK Sub- band 2
10B	National multiplex (or alternative use)	<100%	Coordination with Belgium and Ireland
10C	N.Home Counties (inc. Milton Keynes); Stratford-upon-Avon; Pembrokeshire; Lincoln; Kent coast	5.3%	Coordination with Ireland
10D	National multiplex (or alternative use)	100%	None
11A	NE.Surrey/ N-Mid Sussex; Somerset; Oxfordshire (incl. Aylesbury); Hereford/ Worcester; Carmarthen; Kings Lynn; Derby; Caernarfon; Harrogate	2.8%	Coordination with France

* Note that local blocks could be used to provide second or third multiplexes for many other parts of the country, therefore reaching a much larger proportion of the population than stated in the table

Exhibit 6.3: *Possible allocation plan if three blocks are allocated for local multiplexes*

Allocation of local blocks to unserved regions under either the two or three block scenarios described would leave unallocated spectrum across large parts of the country. This could be used to provide additional local multiplexes for certain other parts of the country, or for alternative services, such as PMSE. For example, under the band plan described in Exhibit 5.1, it would be possible to allocate an additional local multiplex for the north of England and Scotland in 11A.

Allocation of other blocks on a national basis would not preclude them being broken up into regions, if there is a business case for this. For example, it may be commercially attractive to separate England and Scotland. This could be done in the secondary market, so

its is probably unnecessary for Ofcom to attempt to anticipate the structure of such divisions.

Time of access

Multiplex providers require access to the spectrum 24 hours per day, therefore the licences should be allocated on this basis. Radio stations may be broadcast for portions of the day, but this decision should be devolved to the owners of the multiplexes.

Duration

The duration of licences should be sufficient to allow owners of the usage right to make long-term investments in service provision. Ofcom's proposal under spectrum trading for continuous rolling licence terms is likely to be a more appropriate way of achieving this than the current approach for existing T-DAB licences, which is 12-year terms.

Interference

The allocation options presented above will potentially displace existing PMSE use, as described in Annex E. There is also the potential for adjacent channel interference (ACI) to existing PMR systems in Sub-band 2, arising from T-DAB block 10A. The severity of ACI effects will depend on the T-DAB spectrum mask and whether the basic ETS300041 mask or the more stringent mask is applied. Our analysis of ACI effects (see Annex F for a full description) suggests that the stringent mask should be mandated by Ofcom within the technical conditions associated with the multiplex licence, for spectrum efficiency reasons. Our analysis suggests that the frequency offset that exists between T-DAB block 10A and the highest PMR channel in Sub-band 2 is 2.44 MHz. With the stringent T-DAB mask applied, this offset should be sufficient to avoid ACI to PMR, assuming that PMR and T-DAB coverage areas are not co-located, without the need for an additional geographical exclusion zone. If T-DAB transmissions do not fall within the stringent mask, a geographical exclusion zone would be required to avoid ACI effects. Our analysis suggests that a exclusion zone of around 10km between the PMR and T-DAB coverage areas would be required in this case.

If there stringent mask is in use, there would be a benefit to the PMR community as PMR channels can be assigned within Greater London up to the boundary of Sub-band 2 (207.29375 MHz), adjacent to T-DAB block 10A used for local coverage outside of London, without the need for guard channels and/or geographical exclusion zones being required for coordination.

Tests undertaken by Ofcom indicated that existing T-DAB equipment did not fully conform to the stringent T-DAB mask – we therefore recommend Ofcom maintains the 10km exclusion zone around London unless this does not prove to be required in practice.

As discussed above, blocks 10A, 10B, 10C and 11A are also encumbered by restrictions on transmissions in some areas, owing to the need to co-ordinate with foreign broadcasts (see Annex F).

If one of the blocks is used for a service other than T-DAB, this should be on a no-interference basis with adjoining T-DAB blocks.

Other licence conditions

If some of the new T-DAB blocks are allocated to local multiplexes, there may be public policy reasons for ensuring that existing local radio stations in specific regions have access to this spectrum. There may therefore be a case for imposing obligations for ‘must carry’ or provision of local access on ‘fair and reasonable terms on the owners of the multiplex’. Such measures necessarily restrict the flexibility of the usage rights holder, and therefore must be justified in light of their opportunity cost in terms of alternative uses of the spectrum foregone.

Other licence conditions should be kept to a minimum, in order to avoid unnecessarily restricting deployment of new technologies or services. For example, there is no obvious reason to dictate whether national T-DAB channels are used for radio or multimedia services.

Trading and change of use

In principle, the usage rights should be fully tradable and reconfigurable. Change of use should also be allowed, except where there are public policy requirements for the spectrum to be used for certain types of radio service.

6.3 L-Band

6.3.1 Allocation choices

The L-Band includes 16 blocks of spectrum which have been allocated for T-DAB use. Our study has not identified any specific alternative uses for this spectrum, although we note that the spectrum is potentially suitable for deployment of wireless broadband or mobile services. Ideally, the spectrum should be allocated in a way that is suitable for T-DAB use but also leaves open the possibility of alternative use. This point is given added weight by the fact that demand for this spectrum for T-DAB is uncertain, given that most T-DAB radios currently available do not receive L-Band transmissions.

If the spectrum is used for T-DAB, it is anticipated that demand will be from local and community radio stations, covering small geographical areas. This suggests two main options for allocation:

- Division of each block of spectrum into many small multiplex service areas.
- Allocation of national or large regional blocks, which can then be subdivided by a band manager, for the purpose of supplying local and community radio stations or multimedia T-DAB.

There are a number of problems with the first approach:

- It requires Ofcom to second guess the geographical demand structure for L-Band T-DAB. Such an administrative approach is unlikely to generate an optimal outcome.
- It would make it more difficult for alternative services that require national spectrum to aggregate the necessary usage rights.

By contrast, the technology format of T-DAB, with up to ten radio stations and multimedia channels sharing a single multiplex, lends itself to the band manager approach. Indeed, this

has been the approach adopted by commercial radio stations in the VHF band. We therefore recommend that Ofcom proceeds with the second approach of allocating spectrum either by national licence or large area regions (see discussion below).

Under the Maastricht plan, the Radio Authority divided the UK into a large number of geographical areas. Each area has been allocated to just one of the 16 blocks. This approach appears unnecessarily restrictive for the purposes of defining actual use. There appears no reason why a band manager should not be permitted to develop their own geographical structure for multiplexes, in response to market demand. The band manager should have a commercial self-interest to ensure that its allocations do not create harmful interference. It would likely require a number of blocks covering the same wide geographical area, so as to have flexibility in the deployment of multiplexes across overlapping and adjacent areas.

In addition to the 16 T-DAB blocks, there is also an additional 16.5MHz unallocated spectrum. This additional spectrum could be divided into usage rights and allocated on the same basis as the 16 blocks. However, we note that it seems unlikely that this spectrum will be required for T-DAB in the foreseeable future, and that alternative uses – which may have very different spectrum demands – for this spectrum have not been clearly identified. There may therefore be a case for delaying allocation of this additional spectrum pending a further consultation on possible sources of demand.

6.3.2 Definition of usage rights

In order to facilitate implementation of the allocation options outlined above, Ofcom will need to define new usage rights (licences) for L-Band spectrum which allows for the introduction of T-DAB or alternative services.

Spectrum endowment

The current allocation of 16 T-DAB blocks can be maintained. Although plausible alternative uses, such as mobile or wireless broadband, would require larger spectrum endowments, this could be achieved by acquiring multiple contiguous blocks. For example, many existing wireless broadband systems require 5MHz contiguous blocks, which is

essentially equivalent to three contiguous T-DAB blocks. On this basis, it may be appropriate to allocate the additional 16.5MHz in the same way.

Geographic area

The spectrum could be allocated in national blocks or in large area regions, or possibly a mixture of the two. In theory, it should not matter which approach Ofcom adopts, as the secondary market should allow participants to aggregate or sub-divide usage rights according to prevailing demand. However, there may be a case for starting with a regional structure, as this may encourage smaller companies wishing to facilitate T-DAB services to compete for the spectrum. It should be noted that greater spectrum efficiency is achieved with larger regions rather than the very small regions proposed in the Maastricht plan, since larger regions provide for better frequency re-use.

If Ofcom decides to allocate licences on a large-area regional approach, then a possible candidate structure would be the 14 regions used for the auction of personal fixed wireless access (PFWA) licences in the 3.5GHz band.²¹

The case for allocating the additional 16.5MHz spectrum using a regional usage right structure is much weaker than with the first 16 blocks. It is particularly uncertain what this spectrum will be used for, and there are no specific reasons to suppose that there will be regional demand in addition to or instead of national demand.

Time of access

Multiplex providers require access to the spectrum 24 hours per day, therefore the licences should be allocated on this basis. Radio stations may be broadcast for portions of the day, but this decision should be devolved to the owners of the multiplexes.

²¹ The 14 regions were: Greater London; Liverpool & Manchester; West Midlands; Berkshire, Hampshire & Oxfordshire; Buckinghamshire, Essex & Hertfordshire; East Anglia; East Midlands; Kent, Surrey & Sussex; Yorkshire; North England; South West England; Scotland; Wales; and Northern Ireland.

Duration

The duration of licences should be sufficient to allow owners of the usage right to make long-term investments in service provision. Ofcom's proposal for continuous rolling licence terms should be an appropriate way of achieving this.

Interference

T-DAB users would be obliged to conform to spectrum masks, as envisaged under the CEPT plan. As discussed above, it is suggested that the stringent T-DAB mask should be mandated through regulation if possible, since this improves adjacent channel compatibility with other services.

If some or all blocks are allocated on a regional basis, basic rules may be required to determine spectrum masks in border areas. These should be subject to renegotiation by usage rights holders, to ensure that no border areas are unnecessarily sterilised.

If one or more of the blocks is used for a service other than T-DAB, this should be on a no interference basis with adjoining T-DAB blocks. This constraint should not preclude a firm from buying up a number of contiguous blocks to deploy an alternative service, although it may mean that an alternative user would need to acquire sufficient spectrum to create its own guard bands.

Other licence conditions

There may be public policy reasons for ensuring that at least some of this spectrum is made available for community radio. The government may therefore wish restrict use for a proportion of the available blocks. Such measures necessarily restrict the flexibility of the usage rights holder, and therefore must be justified in light of their opportunity cost in terms of alternative uses of the spectrum foregone.

Other licence conditions should be kept to a minimum, in order to avoid unnecessarily restricting deployment of new technologies or services.

Trading and change of use

In principle, the usage rights should be fully tradable and reconfigurable. Change of use should also be allowed, except where there are public policy requirements for the spectrum to be used for certain types of radio service.

7 Assignment options

In this section, we describe the main options available for assigning spectrum in VHF Band III and L-band, in light of our recommendations for allocation described in Section 6. Our main recommendations are that:

- In Band III:
 - Spectrum in Sub-band 2 allocated to PMR and compatible services or to PMSE is made available on a first come, first served basis, and subject to administrative incentive pricing (AIP) as appropriate.
 - Spectrum in Sub-band 3 be allocated to T-DAB and assigned with national and local T-DAB usage rights by simultaneous multiple round auction. Existing unsold local T-DAB usage rights should be included in the auction. After completion of the auction, any unsold usage rights should be available on a first come, first served basis.

- In L-band:
 - Usage rights are assigned using a simultaneous multiple round auction. This may be prefaced by a ‘demand evaluation contest’, which would determine whether it is necessary to run an auction.
 - There may be a case for holding back some of the available spectrum until there is stronger evidence of demand from potential users.

As with our analysis in Section 6, we consider the cases of Sub-bands 2 and 3 of VHF band III and L-band separately. However, to the extent that there are synergies or substitution effects between T-DAB blocks in Sub-band 3 and L-band, there is a case for either combining or coordinating these auctions.

7.1 VHF-band III: Sub-band 2

In Section 6.1, we proposed that available spectrum in Sub-band 2 continues to be made available for PMR use, but that other compatible services, such as PSME, should be allowed access to the spectrum on a no interference basis. Below, we discuss options for assigning and pricing this spectrum to users.

7.1.1 Choice of assignment mechanism

PMR spectrum in Sub-band 2 is currently assigned on a first-come, first-served basis. This is appropriate given that there is available spectrum across all parts of the country.

We recommend that this first come, first served approach be maintained. Given that the current situation is one of spare capacity, there is no need for a market mechanism to distinguish between the competing demands of users. Further, it would be difficult to design a primary auction that could accommodate the very varied demands for regional spectrum of PMR users, unless these were amalgamated by ‘band managers’ representing groups of users.

One possible drawback of first-come-first-served is that it may perpetuate the current fragmented ‘ownership’ structure of PMR spectrum. This may make the future emergence of band managers less likely, as band managers would ideally want access to contiguous spectrum, so as to maximise their future flexibility. Although introducing trading would allow an aspiring band manager to acquire spectrum from multiple users, this is clearly a more challenging task than acquiring large spectrum blocks from Ofcom. This drawback, however, does not obviously provide justification from holding back spectrum from individual applicants in the absence of any evidence of current demand from band managers.

Looking forward, it is possible that Sub-band 2 could become increasingly congested on a regional basis. Our scenarios for the development of the PMR/PAMR markets (see Section 4) indicate that additional spectrum could be required in the London area from 2010. Available spectrum for PMR may also be constrained if PMSE or other users enter the band. At this point, of course, all spectrum in the band in congested areas would be assigned; so ideally we should look to the secondary market to resolve any inefficiencies in assignment.

7.1.2 Pricing mechanism

PMR spectrum is subject to administrative incentive pricing (AIP). This is based on calculating the marginal private value of the spectrum for the current or alternative use, which should equal the opportunity cost of that spectrum use.²²

In the case of Sub-band 2, there is currently excess capacity and this is expected to continue in the near term under our proposed allocation recommendations. This implies that the opportunity cost of denying alternative users within the proposed allocation regime is currently zero (although this may change if the band becomes congested in the future). However, it should be considered that the proposed allocation carries an opportunity cost in terms of the alternative uses incompatible with PMR that have been denied access to the spectrum. In this case, an alternative use for Sub-band 2 is more national T-DAB channels, in addition to those in Sub-band 3.

AIP should be set as the higher of:

- The opportunity cost of denying the spectrum to T-DAB (or other use should one emerge). This can potentially be derived from the marginal losing bids in an auction for national T-DAB blocks in VHF Sub-band 3. Note that if there is not excess demand for T-DAB blocks in Sub-band 3, then the AIP would be zero.
- The marginal private value for the current use, in the event that geographical areas in the Sub-band become congested.

AIP should be levied across all users in Sub-band 2, not just those who are assigned spectrum that is currently not being used.

In their review of spectrum pricing policy, Indepen, Aegis Systems and Warwick Business School recommended that AIP for each band be reviewed “about every five years”.²³ We recommend applying this approach, with an initial review following allocation of T-DAB blocks in Sub-band 3 (see below).

²² Indepen, Aegis and Warwick Business School, February 2004, *An Economic Study to Review Spectrum Pricing*, p.6

²³ Indepen, Aegis and Warwick Business School, February 2004, *An Economic Study to Review Spectrum Pricing*, p.12

7.2 VHF-band III: Sub-band 3

In Section 5, we proposed that up to five additional T-DAB blocks are created in Sub-band 3. Two or three of these blocks would be broken up into local usage rights suitable for T-DAB local radio, with the remainder allocated on a national basis. These usage rights would also be available for services other than T-DAB, although Ofcom may decide to reserve some of the local usage rights for T-DAB radio on public policy grounds. Below, we discuss options for assigning and pricing this spectrum to users.

7.2.1 Choice of assignment mechanism

Previous assignments of licences for T-DAB national and local multiplexes were on the basis of comparative selection. In practice, however, competition was limited which reflected in part the embryonic nature of the DAB market in 1998 when commercial licences were first made available. Since then, take-up of T-DAB radios has grown considerably, which in turn implies diminished risk for investors in multiplexes. The responses to Ofcom's consultation on the VHF and L-band indicate that there is potential significant demand for new national T-DAB multiplexes.

Given the possibility of excess demand for additional T-DAB multiplexes, it would not be appropriate to hand out the new usage rights on a first come, first served basis. Rather, there should be a competitive contest which allocates the usage rights to the users with the highest values. The proposed national and local usage rights appear to be very suitable candidates for auction. There appears to be little risk of market failure in relation to the use of a market mechanism; to the extent that there may be concern that some local T-DAB usage rights may offer social benefits which would not be reflected in private valuations, this could be resolved by obliging holders of these rights to provide local T-DAB radio services on public policy grounds.

Some existing analogue local radio areas are not covered by local multiplexes. In addition, some spectrum in existing local T-DAB blocks could be used to create new local multiplexes for regions that already have access to at least one multiplex. This spectrum should be included in any auction of new usage rights in Sub-band 3. This is appropriate in order to allow bidders to realise any complementarities or substitution effects between this spectrum and the new usage rights.

It is quite likely that some usage rights, such as those for covering smaller geographical regions, may not be sold in the auction. These usage rights could be made available on a first-come, first-served basis after the auction.

7.2.2 Auction format

The auction format chosen for Sub-band 3 must be suitable for assigning multiple, discrete usage rights.²⁴ There are a variety of auction formats that can do this and the most appropriate choice depends primarily on the nature of demand for the spectrum. There are two main demand scenarios that we should consider:

- a reasonable level of competition is expected, or
- the level of competition is uncertain and could be low, and there are concerns about incumbency advantages.

There are currently ten different commercial companies running local multiplexes but only one (DigitalOne) running a national commercial multiplex. In the responses to Ofcom's consultation, a number of companies – including some of the current local operators – expressed interest in acquiring a national multiplex. This implies that we are probably in the first scenario above. However, there may be a case for further demand evaluation by Ofcom prior to selection of an auction format.

On the basis that a reasonable level of competition is expected, it would be appropriate to use an open auction format. We recommend using a simultaneous multiple round auction (SMRA). This format, which has been widely used for spectrum auction in the United Kingdom and elsewhere,²⁵ enables bidders to pursue multiple usage rights – both national and local – at the same time, and switch between usage rights on the basis of their relative price. The auction would continue over multiple rounds until activity on all usage rights had ended.

²⁴ Some spectrum auctions assign abstract lots, where there are multiple usage rights available that are essentially identical. This is not an option for Sub-band 3, as there are significant differences between all the lots, for example in terms of geographic area or foreign coordination constraints.

²⁵ SMRAs have been widely used in Europe and the United States to assign mobile and FWA licences. In the UK, the RA used SMRA-style auctions for the assignment of 3G, BFWA and PFWA licences.

It is likely that some bidders would have ‘synergies’ between usage rights, which reflect, for example, anticipated economies of scale in network roll-out and contract management with radio stations. In a standard SMRA, such bidders would be exposed to aggregation risks.²⁶ Aggregation risks can be mitigated by allowing combinatorial bidding, whereby bidders can link together their demand for a number of usage rights in a combined bid. However, combinatorial bidding can make auctions more complex, especially when there are many lots, as would be the case with Sub-band 3.

In the case of T-DAB multiplexes, synergies between blocks are probably quite modest; it is likely that even one local multiplex can offer a viable business proposition; and any unwanted licences won could be traded in a secondary market. Therefore, combinatorial bidding may not be required. Aggregation risks can anyway be eased by applying activity rules to the standard SMRA format. We would anticipate that this would include the use of ‘eligibility points’ linked to bids on specific usage rights to determine participant’s bidding rights, and also a limited number of withdrawals.²⁷

What if we were under the second demand scenario described above? In this case, the use of an open auction format may not be appropriate. With limited competition, there is a risk that new entrants may be discouraged from participating by the expectation that they will simply be overbid by the incumbent national multiplex operator. This could lead to usage rights being assigned at artificially low prices. Incumbency advantages can be offset by using a single round, sealed bid auction instead of an open contest; this creates uncertainty for incumbents over what they should bid and thus gives entrants greater hope of outbidding incumbents.²⁸

A considerable downside of using a single round, sealed bid is that it deprives bidders of the opportunity to manage substitution and aggregation risks by shifting demand between

²⁶ Aggregation risks result from uncertainty over what to bid for a lot when willingness to pay is contingent on winning other lots whose price is also uncertain.

²⁷ The UK PFWA and BFWA auctions both featured eligibility points and withdrawals as part of their activity rules. In these cases, eligibility points were identical for each regional licence, regardless of population size. However, given the much larger population disparities between national and regional usage rights in an auction of Sub-band 3 spectrum, consideration should be given to varying eligibility by region. This is the approach used for regional spectrum licensing in US and Canadian SMRAs.

²⁸ Klemperer, P, 2002a, ‘What really matters in auction design,’ *Journal of Economic Perspectives*, 16(1), 169-189

licences in response to relative price movements. This problem can potentially be addressed by using a sealed bid combinatorial auction.²⁹

Pricing mechanism

Under the current system, T-DAB licence holders are charged a non-refundable application fee and an annual licence fee. These represent a nominal contribution to Ofcom's cost of administering the spectrum: for example, the annual fee paid by DigitalOne for its national multiplex is GBP10 000 per annum, while Score Digital pay just GBP100 per annum for its Edinburgh licence; the applications fee paid by Score for the Edinburgh licence was GBP15 000.

To the extent that the annual licence fees represent a useful contribution to covering Ofcom's administrative costs, they could be maintained for the new usage rights. It should be appreciated that the imposition of large annual fees would have a knock-on impact on bidders' willingness to pay in an auction; however, current fee levels are too low to have a meaningful impact.

Non-refundable application fees are not typically imposed on participants in spectrum auctions, as they could deter participation, especially by entrants that face competing with stronger incumbents. Rather, bidders provide deposits linked to their bidding rights, which are refundable in the event that they are unsuccessful. Winning bidders may be charged an upfront administrative fee in addition to the amount of their winning bid; as with annual fees, it should be appreciated that charging large upfront fees would have an impact on participation in the auction.

A key aspect of an auction is that winning bidders should pay an amount related to their winning bids in the auction. This would normally be their own winning bids or a marginal price, based on the amount bid by the highest losing bidder. If either an SMRA or sealed bid combinatorial auction is used for assigning this spectrum, we recommend that Ofcom uses the amount of the winning bids. Marginal pricing adds no significant value to a standard SMRA format with discrete rather than abstract lots. It would also be inappropriate in this case for a sealed bid combinatorial auction, as it would favour

²⁹ Kolboldt, C, Maldoom, D and Marsden, R, 2003, 'The first combinatorial Spectrum Auction - Lessons from the Nigerian auction of fixed wireless access licences', DotEcon DP No. 03/01, available at www.dotecon.com/publications.

incumbents, enabling them to bid high in the knowledge that they would never pay more than the next highest bid.³⁰

A reserve price is normally set for usage rights in a spectrum auction. In principle, the reserve price in this case should reflect the opportunity cost of refarming existing PMSE users, as this is the next best alternative use of the spectrum. In practice, this would be difficult to implement, as the creation of the different T-DAB blocks encumbers PMSE users to different degrees, and setting too high reserve price for local usage rights could result in them unnecessarily going unassigned.

Competition concerns

Availability of spectrum for T-DAB is limited to VHF Band III and the L-band, and the latter spectrum is less attractive for rolling out large area networks. This raises the possibility of future competition concerns if a small number of companies were to acquire a ‘dominant’ position in the provision of channels on T-DAB multiplexes, especially at a national level. For the foreseeable future, such concerns are probably mitigated by the availability of many alternative platforms for radio station delivery, including analogue, satellite, digital television and the Internet. To the extent that these concerns could become material in the future, existing competition law should be sufficient to prevent the emergence of market power. For example, competition law could be used to oblige a company to divest some of its multiplexes in response to such concerns. Therefore, it is probably not necessary to place any restrictions on bidders in an auction of T-DAB spectrum.

Timing of the auction

As there is evidence of existing unsatisfied demand for additional T-DAB multiplexes, the auction should ideally be scheduled as soon as practically feasible. There is a significant opportunity cost to delaying the auction. However, the potential need to refarm existing PMSE users represents a practical obstacle to rapid deployment of T-DAB in this spectrum. PMSE users will need to be given sufficient time to vacate the spectrum.

³⁰ Klemperer, P, 2002a, ‘What really matters in auction design,’ *Journal of Economic Perspectives*, 16(1), pp169–189.

One way of approaching the issue of PMSE relocation would be to run an ‘overlay’ auction, with T-DAB channels encumbered by the need to respect PMSE allocations for a defined time period. Should T-DAB operators wish to deploy their services more quickly, they would need to negotiate with PMSE users over appropriate compensation. Note, however, that as T-DAB channels and existing PMSE allocations are not directly aligned, this may require a number of T-DAB multiplex operators to negotiate together. PMSE users would also need to be represented by one or more band managers, in order to ensure that transaction costs are manageable. Although PMSE users do have a band manager, JFMG, this body plays a limited, largely technical role and does not currently have the powers to undertake this type of negotiations on behalf of its members.

7.3 L-Band

In Section 6.3, we proposed allocating 16 blocks for T-DAB or compatible services. Ofcom also has the option of allocating the remaining 16.5MHz spectrum in the same way. These blocks could either be allocated on a national basis or broken into large area regions. Ofcom may wish to reserve a proportion of these blocks for T-DAB ‘community’ radio on public policy grounds. Below, we discuss options for assigning and pricing this spectrum to users.

7.3.1 Choice of assignment mechanism

Like the VHF Sub-band 3, L-band channels appear suitable for assignment by auction. However, an auction is only necessary if demand exceeds supply. In the case of L-band, demand is particularly uncertain, and it may be possible to assign spectrum on a first come, first served basis.

One way of determining whether there is sufficient demand to justify an auction is to run a ‘demand evaluation contest’.³¹ Bidders would be invited to submit binding applications for usage rights at (low) reserve prices. If aggregate demand exceeded supply, then the bidders would proceed to an auction stage. If all demand could be accommodated, then the usage

³¹ This was the approach used for assigning spectrum in the Nigerian auction of fixed wireless access licences in 2002. See Kolboldt, C, Maldoom, D and Marsden, R, 2003, ‘The first combinatorial Spectrum Auction - Lessons from the Nigerian auction of fixed wireless access licences’, DotEcon DP No. 03/01, available at www.dotecon.com/publications.

rights would be assigned accordingly and no auction would be required. Remaining usage rights could then be made available on a first come, first served basis.

Demand evaluation contests are easiest to implement when the usage rights within a distinct category are essentially identical. In this case, usage rights can be assigned on an abstract basis, i.e. users apply for a number of identical usage rights, rather than specifying individual usage rights. The assignment of physical licences is then determined by the administrator on the basis of pre-stated rules. This approach works much less well if there are lots of discrete usage rights which are nevertheless close substitutes; in this case, it is usually more appropriate to go straight to an auction format that allows bidders to distinguish their relative preferences for the usage rights based on their different attributes.

Unlike Sub-band 3, where all the usage rights had different characteristics, many of the usage rights for L-band would be essentially identical. For example, if all the blocks were divided up into 14 identical geographical regions, then there would essentially be 14 different types of licences, and 16 licences of each type. Unfortunately, this is complicated by the existence of foreign coordination obligations in relation to a minority of usage rights, which would mean that a few of the usage rights would have a lower value than the others, so could not be treated as identical.

The use of abstract blocks also raises some other complications. For example, T-DAB bidders for local blocks could be expected to place higher value on having adjacent geographical usage rights at the same frequency, so as to reduce the need for coordination at boundaries. Bidders wishing to use the spectrum for non-T-DAB services (if there are any) may also place additional value on contiguous spectrum, either in terms of frequency or geography. These problems may, however, be resolvable through administrative coordination once the assignment of abstract lots is complete.

7.3.2 Auction format

The choice of auction format (if required) is also determined by whether it is possible to use abstract lots or if Ofcom has to define multiple discrete lots:

- With discrete lots, we recommend the use of a standard simultaneous multiple round auction, using the same format as Sub-band 3. As with Sub-band 3, there is a possible case for using an SMRA with combinatorial bidding to address aggregation risks;

although the use of activity rules, such as eligibility points and withdrawals would probably be sufficient to ensure a reasonably efficient outcome. As there are no obvious concerns about incumbency advantages in relation to L-band, there should be no reason to prefer a sealed bid over an open process.

- With abstract lots, a variant of the standard SMRA can be used, in which bidders specify bids in terms of the number of usage rights of a particular type that they require. The price of usage rights in each category increases over multiple rounds until demand and supply are balanced. As with a standard SMRA, the auction ends when there is no activity in any of the usage right categories. This type of auction offers some potential advantages over an SMRA with discrete lots, namely: identical licences always sell for identical prices; and there may be less risk of fragmented outcomes in terms of spectrum contiguity. It is also easier to introduce combinatorial bidding with abstract lots, as the number of potential combinations is significantly reduced.

A final decision on the relative merits of these two approaches would require a decision on any geographical division of the licences, a detailed investigation of the impact of any foreign co-ordination obligations on the available usage rights and identification of whether there are any non-T-DAB bidders for the spectrum.

7.3.3 Pricing mechanism

The price paid for usage rights would be determined by the amount bid in the auction. A low reserve price is appropriate, given the uncertain nature of demand. However, setting too low a reserve price might risk attracting purely speculative bidders who have no intention of rolling out services.

In addition, Ofcom may wish to levy an upfront fee and/or an annual fee per usage right to cover administrative costs. Annual fees could be a useful tool for deterring speculative bids; however, if set too high, they might also deter legitimate participation.

7.3.4 Timing of the assignment process

Whereas VHF T-DAB broadcasters have access to a substantial and rapidly growing base of digital radio owners, the current listener base with L-band receivers is negligible.

Bidders for L-band spectrum who wish to roll out T-DAB multiplexes face uncertainty over the speed to which dual band receivers will penetrate the market. There is a ‘chicken and egg’ problem here, in that demand for dual band receivers is unlikely to take-off significantly until services are widely available, or at the least, there are good reasons to believe that services will soon become widely available.

This level of uncertainty may well translate into low demand and low prices for L-band spectrum, if an auction is held in the next 12 months. This may mean that much of the spectrum, if it is sold, is bought either for speculative reasons or to provide an option for expansion that won’t be required for many years. Note, however, that this should not be a problem from an efficiency perspective, provided that the design of usage rights is sufficiently flexible to accommodate future sources of demand as they emerge.

If there are good reasons to believe that much of the spectrum is not required in the medium term, and there are no valuable alternative uses identified, then it may be appropriate only to assign some of the L-band spectrum now, and set aside the rest for later allocation and assignment, once the prospects for L-band T-DAB and alternative uses of the spectrum are more certain. Such a two-step strategy is effectively what will have taken place with the VHF spectrum, if new T-DAB blocks are created in Sub-band 3.

There is a potential relationship between demand for VHF and L-band spectrum for T-DAB. Although L-band spectrum is not a viable alternative for most national and local radio stations, it is potentially suitable for some local radio stations with small geographical footprints but covering dense population areas. L-band spectrum could also be used to augment footprints of some radio stations on VHF T-DAB. These relationships suggest that there is a modest case for linking together the L-band and Sub-band 3 auctions. If they are not linked, the L-band auction should take place after the Sub-band 3 auction, as it is an inferior substitute.

Multiplex owners in the VHF T-DAB channels are natural candidates to run multiplexes in the L-band, as they have the expertise required and also access to many transmitter sites. This suggests potential benefits from holding the L-band auction after the Sub-band 3 auction, once the new market structure for VHF T-DAB multiplex providers has been established.

8 Scenario analysis

This section discusses the robustness of our proposed allocation and assignment recommendations in respect of the various uncertainties that remain. Section 8.1 presents details of these uncertainties and discusses the impact of these on our proposed allocation/assignment process whilst Section 8.2 discusses one potential market development scenario where our recommended allocation of Band III spectrum to PMR and PAMR may not be sufficient.

8.1 Areas of uncertainty

We have identified a number of key areas of uncertainty in relation to the assessment of the appropriate allocation and assignment strategy for Band III and L-Band spectrum. These were refined as part of a scenario planning workshop with Ofcom and the final list of areas (and the principal potential outcomes in each area) is summarised in Exhibit 8.1 below.

Fluid world	Principal uncertainties	Tablets of stone
		
Trading with liberalisation	<i>Political (policy/regulatory)</i> Spectrum trading/liberalisation	Trading only
Additional spectrum released	UHF2 band re-alignment	Release of spectrum
	<i>Economic</i>	
Mass migration	PMR/PAMR migration to cellular	Self-build continues
Low cost/ease of refarming	Spectrum refarming	Significant cost of refarming
High demand for T-DAB radio channels	T-DAB audio demand	Low demand for T-DAB radio channels
High demand for T-DAB multiplexes	DVB-H/T-DAB multimedia	Low demand for T-DAB multiplexes
	<i>Social</i>	
Localisation more important	Regionalisation/localisation	Current balance – London concentration
Security requirement for flexibility	Public safety/security requirement	Needs met in other spectrum
	<i>Technological</i>	
Digital world - lower spectrum demand	Digital PMR technologies	Analogue continues – demand maintained

Exhibit 8.1: Key areas of uncertainty [Source: Analysys, Ofcom, 2004]

We discuss each of these areas in turn below, in respect of our recommended allocation and assignment strategy.

8.1.1 Spectrum trading/liberalisation

This uncertainty is in relation to (i) to what degree will liberalisation be implemented in Band III and L-Band and (ii) to what extent will trading/liberalisation migrate spectrum to the user/use from which the greatest economic benefit is derived.

Our allocation recommendations include proposals for Ofcom to allow secondary trading of spectrum in these bands and facilitate liberalisation of individual channels provided such liberalisation does not result in the UK breaching its continental interference obligations and additional harmful interference is not caused to others users of the radio spectrum (unless agreement has been reached between the users concerned to allow this). Such an approach provides the flexibility to allow spectrum rights to migrate to other users/uses over time.

The one area where social economic issues may occur is in respect of any allocation of spectrum for the provision of local radio coverage. If Ofcom were to decide to prioritise T-

DAB spectrum blocks for local coverage in-fill, it would be appropriate to retain such regulations on the use of spectrum blocks, even if change of ownership occurred through secondary trading. Provided that obligations specified by Ofcom were being met, spectrum rights holders should nonetheless be free to utilise any remaining spectrum (e.g. in different geographical areas) in a liberalised manner.

8.1.2 UHF2 band re-alignment

Ofcom has announced that the RA's proposed plans for realignment of the 450–470MHz band are withdrawn and that instead it hopes that the market will itself manage a transition to improved usage of the spectrum. Ofcom has indicated that band re-alignment would have released approximately double the spectrum in UHF2 that would otherwise be released through the emergency services migrating to the 380-400MHz band. This would reduce the overall levels of demand for Band III spectrum from 2010 onwards.

However as Ofcom anticipates/hopes that the market will move towards realignment of its own accord in any case, some of the additional spectrum which would be released through Ofcom-initiated band realignment may be released nonetheless. There is therefore a remaining uncertainty over how much Band III spectrum will be required to act as a substitute for UHF2 spectrum.

Our recommended approach of allocating Sub-band 2 of Band III to be used for PMR and PAMR services meets almost all our projected PMR and PAMR demand scenarios (including those where UHF2 band re-alignment does not occur). However there is one scenario where Sub-band 2 spectrum would be insufficient – this is discussed further in Section 8.2 below.

8.1.3 PMR/PAMR migration to cellular

As discussed in Annex A, there has been a general trend to make increasing use of public cellular networks in place of either self-provisioned PMR networks or using a digital or analogue public access mobile network. Nonetheless many users value the specific features offered on PMR/PAMR networks for voice calls (e.g. push-to-talk, emergency calls and group calls) as well as the control, security and reliability of self-provision. It is therefore uncertain as to whether the general trend towards use of public cellular networks will

continue (e.g. cellular operators may start to offer quality of service guarantees on their 3G networks) and what impact this will have on demand for PMR (as the organisations which have up-to-now highly valued PMR/PAMR are likely to continue to do so – furthermore there are also specific instances of users who have migrated to cellular moving back to self-provision).

Our recommended approach of allocating Sub-band 2 of Band III to be used for PMR and PAMR services meets almost all our projected PMR and PAMR demand scenarios (including those where there is strong demand for Band III spectrum). However there is one scenario where Sub-band 2 spectrum would be insufficient – this is discussed further in Section 8.2 below.

8.1.4 Spectrum refarming

Our proposed allocation of up to five T-DAB blocks in Band III will require the refarming of existing PMSE users. As discussed in Section 7, this could potentially be achieved through an overlay auction. Alternatively Ofcom could set the reserve prices for the auction of T-DAB blocks on the basis of recovering the refarming costs faced by existing PMSE users in the band.

8.1.5 T-DAB audio demand

One key factor affecting the demand for T-DAB radio channels is the take-up rate of DAB radios. As discussed in Annex B, we have modelled alternative scenarios for this take-up and hence identified the range of economic benefits arising from allocating additional spectrum to T-DAB.

As discussed in Section 6, whilst there is considerable availability of spectrum for T-DAB in L-Band, existing usage of Sub-band 2 of Band III for PMR and the need for a guard band to protect PMR users currently restricts the amount of Band III spectrum that can be used to provide T-DAB services. Our recommendations therefore propose that Sub-band 2 remains allocated for PMR and PAMR use. Should additional demand for T-DAB occur over time, if additional demand for PMR/PAMR channels is not realised, it may be possible to migrate PMR existing users in the higher frequencies of Sub-band 2 of Band III to lower frequencies, thereby releasing additional spectrum for T-DAB. Additionally the

introduction of spectrum trading and liberalisation across Band III will also facilitate a migration to T-DAB in the event that demand picks up and T-DAB is a more economically valuable use of the spectrum than existing PMR/PAMR services.

8.1.6 T-DAB multimedia demand

The demand for capacity on T-DAB multiplexes for mobile and portable multimedia services is highly uncertain at present – especially in view of the competing industry standards (e.g. DVB-H). Our allocation recommendations suggest that the market should be left to make the decision on how the spectrum and multiplex capacity is utilised – should demand for T-DAB multimedia services take-off – and this were a more economically valuable use of the spectrum – T-DAB multiplex operators could switch existing radio channel capacity over. Furthermore, the success of T-DAB multimedia may increase the overall demand for spectrum for T-DAB multiplexes. The introduction of spectrum trading and liberalisation in Band III and L-Band will enable additional spectrum to be used for T-DAB if it is the most economically advantageous use of the spectrum.

One issue for Ofcom that remains is the protection of any spectrum that is reserved for local radio coverage infill. If this requirement forms part of the conditions of use of the spectrum, then provided spectrum owners continue to meet their obligations in this regard, the remaining spectrum can be used for multimedia, audio or other services as required by the market.

8.1.7 Regionalisation/localisation

The importance of localisation (especially in respect of digital radio) is a key uncertainty. Whilst historically local radio has been very popular, to an extent this may have been as a consequence of the limited availability of commercial national radio stations on FM radio. Our allocation approach allows spectrum to be reconfigured by the market for national, regional or local usage (i.e. allows the market to make this choice). Local radio coverage in-fill is the one area where Ofcom may wish to impose obligations on the use of radio spectrum. Should local radio prove not to be as important as currently perceived, Ofcom should retain the flexibility to remove these obligations at a later date.

8.1.8 Public safety/security requirements

There is a requirement for additional spectrum for public safety/security. Should this spectrum be required in Band III, our allocation recommendations are not compatible with this need. In this instance, it will be necessary to forgo the use of up to 10MHz of spectrum for PMR, PAMR, T-DAB and PMSE use. Our benefit analysis indicates that the opportunity cost of this spectrum is likely to amount to GBP25 million to GBP120 million.

8.1.9 Digital PMR technologies

The availability of digital PMR technologies in Band III is a further uncertainty – it is not clear whether manufacturers will be willing to adapt existing digital technologies (e.g. TETRA, Tetrapol) for use in Band III or whether the Digital Mobile Radio (DMR) standards currently being developed by ETSI will be implemented in practice. This has considerable impact on the demand for Band III spectrum – both in terms of demand for spectrum for new services which can be offered using the advanced data facilities of digital PMR technologies and also in respect of the amount of spectrum required for carrying existing services (such as push-to-talk speech).

Our recommended approach of allocating Sub-band 2 of Band III to be used for PMR and PAMR services meets almost all our projected PMR and PAMR demand scenarios (including those where additional spectrum due to the lack of availability of spectrally efficient digital technologies). However there is one scenario where Sub-band 2 spectrum would be insufficient – this is discussed further in Section 8.2 below.

8.1.10 Summary

In general it can be seen that our recommended allocation strategy is robust in respect to the identified areas of uncertainty, with two possible exceptions:

- high-demand scenario for PMR and PAMR spectrum in London – this is discussed further in Section 8.2 below
- the need to allocate up to 10MHz of Band III spectrum for public safety/security purposes – this is an administrative decision Ofcom will need to make – we estimate

the opportunity cost of allocating this spectrum to public safety/security uses to be GBP25 million to GBP120 million over the period 2005-2014.

8.2 High demand scenario for PMR/PAMR spectrum in London

As discussed above, there is one specific market demand scenario where the allocation of the currently available Sub-band 2 Band III spectrum to PMR/PAMR may not be sufficient in London. This scenario arises if all of the following occur:

- there is strong continuing demand for the self-provision of mobile radio systems (i.e. strong demand for PMR spectrum in place of migration to public cellular networks)
- new spectrally efficient digital PMR technologies are not available in Band III
- UHF2 band re-alignment does not occur (thus only 50% of the potentially released spectrum for PMR in the 450-470MHz band does actually become available)
- there is additional demand for Band III PAMR spectrum in London – e.g. as a consequence of the migration of ex-Dolphin customers onto Band III public networks.

In such an instance the 2 x 4.6MHz of additional PMR/PAMR spectrum in Sub-band 2 of Band III may not be sufficient – we estimate that 2 x 5.2MHz of additional spectrum would be required in London under this scenario.

Our recommended allocation approach would mean that only 2 x 4.6MHz of spectrum was available. In this situation, we estimate that around GBP5 million of economic benefits (NPV over the period 2005–2014) would be foregone.

However this concern should be set aside against two other key factors:

- the cost of setting-aside additional spectrum for PMR/PAMR in Band III would be the displacement of at least four of the five T-DAB blocks from the London area.. We estimate that the economic benefits foregone in this instance would amount to around GBP9 million to GBP17 million
- the probability of the above PMR/PAMR requirement scenario occurring – based on an assessment of the probabilities of each of the individual factors outlined above, we estimate the overall likelihood of such a demand scenario occurring to be <10%.

Furthermore, our assessment of transmissions from Continental and Irish television broadcast sites indicates that allocating Sub-band 3 spectrum to PMR in the London region is unlikely to be viable due to interference constraints (see Annex F for further details).

Given the difference in foregone benefits and the low probability of the additional demand scenario for PMR/PAMR spectrum arising, we recommend that Ofcom does not seek to reserve additional Sub-band 3 spectrum for PMR/PAMR to supplement the additional 2 x 4.6MHz in Sub-band 2 of Band III. However, it is recognised that this decision may result in the additional PMR/PAMR demand, if this arises, having to be accommodated within other existing PMR bands, which are themselves already considered to be congested in London and other urban areas.

9 Recommendations

This section summarises the principal findings from the study in the form of our recommendations for Ofcom. We have structured our recommendations as follows:

- Section 9.1 discusses the initial key decisions which Ofcom will need to make
- Section 9.2 presents our recommended allocation and assignment strategy for Band III and L-Band
- Section 9.3 contains a series of recommendations on areas which Ofcom should monitor in the medium-term
- Section 9.4 summarises the next steps we recommend Ofcom take.

9.1 Initial decisions

There are two key initial decisions which we believe Ofcom will need to make:

- Allocation of spectrum for public safety/security – Ofcom has indicated that there is a potential requirement for up to 10MHz of spectrum for the above applications. Ofcom will need to make a decision on whether to allocate spectrum within Band III to fully or partially meet this requirement. The results of our study indicate the opportunity cost to Ofcom of allocating 10MHz of spectrum for public safety/security purposes to be of the order of GBP25 million to GBP120 million.
- Prioritisation of T-DAB local coverage in-full. Left to market forces alone, spectrum for T-DAB services may be used for national multiplexes, additional local stations in areas already served, T-DAB mobile and portable multimedia services rather than providing local stations in areas which are not currently covered (as a result of potential for interference to other local regions) by existing T-DAB spectrum allocations. If Ofcom wishes to make this a priority, this will have an impact on the

allocation processes described in the following section as Ofcom should seek to place obligations on the rights holders of spectrum prioritised for local coverage in-fill.

9.2 Allocation and assignment strategy for Band III and L-Band

Our recommendations for Band III are divided into recommendations for Sub-bands 2 and 3.

9.2.1 Sub-band 2 of Band III

Allocation strategy

We recommend that the 2 x 4.6MHz of spectrum that is available is allocated to PMR, PAMR or other compatible services. Whilst usage rights for this band already exist, these were generally designed with only PMR/PAMR in mind. Some adjustments may be appropriate to allow for alternative compatible use of the spectrum (e.g. by PMSE) and also future tradability.

<i>Spectrum endowment</i>	Continue to allocate spectrum in 12.5kHz pairs but with additional flexibility to facilitate other users (e.g. for PMSE)
<i>Geographic area</i>	Continue allocation on first come, first served basis according to the geographical footprint requested by users
<i>Time of access</i>	Continue allocation on basis of 24 hours per day
<i>Duration</i>	Continuous rolling term but subject to revocation under specified conditions
<i>Interference constraints</i>	Set parameters to ensure harmful interference is not caused to other users (including spectrum use in other countries) but flexibility within an organisation's own holdings to reconfigure
<i>Other licence conditions</i>	Minimum possible to avoid unnecessarily restricting deployment of new services or technologies
<i>Trading and liberalisation</i>	No restrictions placed provided interference constraints are not breached.

Assignment strategy

Assignment mechanism First-come, first-served basis.

Pricing mechanism Administrative incentive pricing (AIP) taking account of potential alternative uses of the band e.g. T-DAB.

Timing of the assignment process As required by PMR and PAMR users.

9.2.2 Sub-band 3 of Band III

Allocation strategy

We recommend that up to five additional T-DAB blocks are created in Sub-band 3; two or three of which could be reserved for specific regional T-DAB multiplexes for local coverage in-fill purposes. Note that this recommendation assumes that the incremental value of additional blocks exceeds the cost of re-farming PMSE users in affected bands, which is subject to further verification.

Spectrum endowment Re-plan spectrum in accordance with Europe-wide band plan for T-DAB. This should not preclude reconfiguration by spectrum users.

Geographic area National except where Ofcom makes a decision to prioritise local coverage in-fill – these T-DAB blocks could be allocated on a regional basis.

Block 10A should not be initially available for T-DAB coverage in London and surrounding areas (within 10km) due to potential interference with PMR/PAMR usage in Sub-band 2.

Continental interference constraints also places limits on effective geographical area that can be used for T-DAB in Blocks 10A, 10B, 10C and 11A.

Time of access 24 hours per day.

Duration Continuous rolling term but subject to revocation under specified

	conditions.
<i>Interference constraints</i>	<p>Require use of ‘stringent’ T-DAB mask where equipment is available.</p> <p>Allow flexibility for users to reconfigure usage provided harmful interference is not caused to other users.</p> <p>Interference thresholds to be set for geographical boundaries to limit interference with other spectrum users and use of the spectrum in other countries.</p>
<i>Other licence conditions</i>	No constraints on use of multiplex capacity for use for radio, multimedia or other services (except for any local radio coverage in-fill obligations).
<i>Trading and liberalisation</i>	No restrictions placed provided interference constraints and public policy requirements are not breached.
<i>Assignment strategy</i>	
<i>Assignment mechanism</i>	Simultaneous multiple round auction.
<i>Pricing mechanism</i>	<p>Set by the auction (amount of the winning bid).</p> <p>Ofcom may also wish to charge annual licence fees to cover associated administrative costs.</p>
<i>Timing of the assignment process</i>	Schedule auction as soon as practically possible, subject to resolving the issue of refarming PMSE users. Consider the use of an ‘overlay’ auction to facilitate efficient negotiations between PMSE and DAB users over PMSE migration

9.2.3 L-Band

Allocation strategy

We recommend that the 16 blocks currently allocated to T-DAB are made available to T-DAB or alternative compatible uses. The remaining spectrum could be allocated on the same basis; however, Ofcom may prefer to postpone a decision on allocation pending further consultation on potential sources of demand.

We recommend that the 16 blocks currently allocated to T-DAB are made available to T-DAB or alternative compatible uses. We also recommend that the remaining spectrum in this band remains unallocated pending further consultation on other sources of demand.

Spectrum endowment Maintain existing allocation of 16 blocks for T-DAB, and possibly allocate the remaining spectrum on the same basis. This should not preclude reconfiguration by spectrum users.

Geographic area Regional or national. Regional may be advantageous for the 16 blocks as it may encourage smaller companies to compete for the spectrum (but using larger regions than proposed in the Wiesbaden plan). Interference with uses in other countries may impose some operational constraints on UK system coverage with the south-east of England.

Time of access 24 hours per day.

Duration Continuous rolling term but subject to revocation under specified conditions.

Interference constraints Require use of ‘stringent’ T-DAB mask where equipment is available.

Allow flexibility for users to reconfigure usage provided harmful interference is not caused to other users.

Interference thresholds to be set for geographical boundaries to limit interference with other spectrum users and use of the spectrum in other countries.

Other licence No constraints on use of multiplex capacity for use for radio,

<i>conditions</i>	<p>multimedia or other services (except for any local radio coverage in-fill obligations).</p> <p>Constraints on use of the spectrum if Ofcom wishes to ensure that some of this spectrum is made available for community radio applications for public policy reasons.</p>
<i>Trading and liberalisation</i>	<p>No restrictions placed provided interference constraints and public policy requirements are not breached.</p>
 <i>Assignment strategy</i>	
<i>Assignment mechanism</i>	<p>Simultaneous multiple round auction possibly prefaced by a ‘demand evaluation contest’.</p>
<i>Pricing mechanism</i>	<p>Set by the auction (amount of the winning bid).</p> <p>Ofcom may also wish to charge annual licence fees to cover associated administrative costs.</p>
<i>Timing of the assignment process</i>	<p>Either combine the L-band auction with the VHF Sub-band 3 auction, or schedule the assignment process to take place after the Sub-band 3 auction.</p> <p>There may be a case for holding back some of the available spectrum until there is stronger evidence of demand from potential users.</p>

9.3 Monitoring of future developments

We recommend that Ofcom generally monitors the development of demand for PMR/PAMR and T-DAB spectrum in the medium-term, with a specific review in two to four years time to ascertain the level of demand for PMR/PAMR spectrum in order to:

- Assess whether the restrictions on the use of T-DAB Block 10A in Band III (i.e. prevention of use in London and the immediate surrounding area) can be removed – if the highest demand scenarios for PMR/PAMR are not realised, it should be possible to remove this restriction.

- Assess whether there is sufficient spectrum within Sub-band 1 and lower frequencies in Sub-band 2 of Band III to migrate existing users in the upper frequencies in Sub-band 2 (e.g. Network Rail) to new frequencies. This could potentially occur if the demand for additional Band III PMR/PAMR spectrum is modest and/or from the introduction of spectrally efficient PMR technologies. This would allow additional spectrum to be released for T-DAB or other alternative services.

In the longer term, the introduction of spectrum trading and liberalisation should allow the market to reconfigure the spectrum for the most economically beneficial uses. There is however a risk that some degree of ‘market failure’ may arise as a consequence of the highly fragmented nature of demand for PMR spectrum. Ofcom may need to take action to address this at a later date. One possible solution could be the promotion of band managers for PMR, as already exist in the PMSE and broadcasting sectors.

9.4 Next steps

There are a number of key next steps for Ofcom:

- Decisions need to be made on the key issues outlined in Section 9.1, namely the allocation of spectrum for public safety/security and prioritisation of local digital radio coverage in-fill for public policy reasons.
- If local radio coverage in-fill is prioritised, further work on the use of specific frequency blocks in individual coverage areas to ascertain the minimal amount of spectrum required and maximising the availability of geographical areas in which the spectrum can be used for other purposes.
- Further examination of potential demand for L-band spectrum to consider the extent to which demand exists for the use of L-band to provide services which were outside the scope of this study.
- Development of the technical interference criteria that will facilitate most flexible use of the spectrum in Band III and L-band whilst ensuring other users/uses (both within the UK and in other countries) are adequately protected from harmful interference.

- Further investigation of the costs of refarming existing PMSE use in Sub-band 3. This could be a component of a wider review of the value of and availability of spectrum for PMSE.
- Preparation of the detailed rules and regulations pertaining to the assignment processes i.e. the auction award processes proposed for Sub-band 3 of Band III and L-Band.
- Review of regulatory constraints on existing users of the spectrum to ensure these are compatible with the terms and conditions associated with the new assignments – for example any unnecessary restrictions on liberalisation of other Band III PMR spectrum could be removed and restrictions on the use of T-DAB multiplexes (e.g. limitations on proportion of capacity to be used for the provision of data services) should be reviewed – whilst still ensuring public policy objectives continue to be met.