Consultation on future use of the 700 MHz band

Cost-benefit analysis of changing its use to mobile services

Consultation

Publication date:	28 May 2014
Closing Date for Responses:	29 August 2014

About this document

This document sets out our proposals to make spectrum in the 700 MHz band available for mobile broadband from 2022 or possibly up to two years earlier. It presents our assessment of the costs and benefits of such a change and invites comments on our proposals as part of a public consultation.

Digital terrestrial television (DTT) and Programme Making and Special Events (PMSE) services currently use the 700 MHz band as well as other frequencies. DTT provides UK viewers with high quality free to view television and PMSE underpins many important cultural and social activities.

The proposed change would involve moving parts of these services from the 700 MHz band to other frequencies. However, it should also result in significant benefits to citizens and consumers, such as improvements to mobile networks and cheaper mobile broadband services.

We need to ensure that any change that occurs safeguards the important benefits that DTT and PMSE services deliver to citizens and consumers. The document explains how it would be possible to make the 700 MHz band available to mobile broadband without compromising the benefits provided by DTT or PMSE, and without causing significant disruption to television viewers.

Following this consultation, we expect to reach decisions on any potential changes in use of the 700 MHz spectrum band in late 2014 or early 2015.

Alongside this consultation we are also publishing a statement on our mobile data strategy and a discussion document on the future of free to view TV.

Contents

Section 1

Executive summary

Making the 700 MHz band available for mobile broadband use would deliver significant benefits

1.1 Demand for mobile data services has been growing very rapidly and forecasts show substantial increases continuing in coming years, driven by uptake of smartphones and tablets. Although estimates vary widely, mobile data demand could be over 45 times greater than it is today by 2030. Ensuring that the mobile sector is able to meet this increase in demand is an important part of making sure that the UK stays at the forefront of digital services and that citizens and consumers can enjoy the mobile data services they want and need.

1.2 We believe that the mobile sector will need access to additional spectrum if it is to meet this projected increase in demand efficiently and effectively. One of our strategic priorities is to identify additional spectrum for mobile use. As part of our programme of work in this area, we have assessed the case for making spectrum at 694 to 790 MHz (the '700 MHz band') available for mobile broadband use. This spectrum offers a valuable opportunity to help meet demand for mobile data services, for three reasons:

a) first, low frequency spectrum such as the 700 MHz band has particularly favourable properties, as signals transmitted at these frequencies reach further and pass through walls and other obstructions more easily than spectrum at higher frequencies;

b) second, other countries across the world already use or plan to use the band for mobile services, which creates scope for economies of scale in the manufacture of equipment designed to operate at these frequencies and for early equipment availability; and

c) finally, the 700 MHz band is the only low frequency spectrum that is a candidate for widely harmonised mobile use for the foreseeable future.

1.3 Our analysis indicates that making the 700 MHz band available for mobile would result in significant benefits for citizens and consumers. We anticipate it would result in improved mobile network speeds and that it would help mobile network operators meet increases in demand for capacity in a more cost effective manner than without this spectrum. Because of the competitive nature of the mobile market, we would expect this to result in lower consumer prices for mobile data services than would otherwise be the case. For those benefits we can quantify, we estimate that the value to the UK of making the band available for mobile is between £900 million and £1.3 billion. These benefits would be greater if mobile use started earlier. There are also other benefits that are more difficult to quantify but offer scope for potentially large additional value. For example, the proposed change could result in improvements to mobile coverage and could facilitate improvements in the delivery of emergency services' communications requirements.

1.4 Although the 700 MHz band would be valuable for mobile services, other important services already use it. These are digital terrestrial television (DTT) and programme making and special events (PMSE) audio applications such as wireless microphones that artists use when performing live.

1.5 The DTT platform has an important role in providing low cost near-universal access to the public service TV channels and in sustaining viewer choice. Over 75% of households use it through Freeview and YouView, with 40% of households using it on their main TV set. As we explain in our discussion document, *Future of free to view TV*, we believe DTT is likely to retain a central role over the next decade, with a full switch to alternative technologies such as IPTV not appearing feasible until at least 2030. PMSE audio applications deliver significant benefits to citizens and consumers and make an important contribution to the cultural life of the UK, from theatre, pop concerts and sporting events to village fetes and church halls.

But by planning more efficiently we could re-purpose the band, while ensuring DTT and PMSE can continue to thrive

1.6 In this document, we propose to make the 700 MHz band available for mobile while simultaneously safeguarding the on-going delivery of the benefits which DTT and PMSE provide. Doing this would entail changing some of the frequencies at which DTT and PMSE operate.

1.7 Our analysis suggests that through more efficient frequency planning it would be possible to reconfigure the DTT network in the spectrum between 470–694 MHz without materially affecting the coverage or channel mix that viewers currently enjoy.[1] This would not require another TV switchover (like the switch from analogue to digital TV) and could be accomplished without causing significant disruption to TV viewers. Most DTT viewers would only need to retune their televisions and our assessment of costs reflects the time needed for viewers to do this. A small proportion (up to 0.5% of DTT households) would need to replace their rooftop aerials. In a very small number of cases, viewers might need to fit a simple filter to their televisions to avoid interference.

1.8 If we proceed with the proposed changes, we will work closely with Government, broadcasters, and new mobile operators to ensure that viewers receive appropriate information and support. Experience with recent programmes of change to broadcast infrastructure, for example digital switchover (DSO) and 800 MHz clearance, shows that with careful planning, appropriate financial and practical support and the right degree of cooperation between all parties, viewers can retune their TVs, replace aerials and deal with interference confidently and successfully.

1.9 For PMSE, we have considered the change as part of a broader review of the sector’s access to spectrum. We believe that by making other spectrum available for audio applications, we will be able to ensure that the sector can continue to provide the important benefits it delivers today.

[1] The exception to this would be the interim multiplex. As things stand, we believe that many of the channels carried on the interim multiplex that is currently operational could continue using the six national multiplexes, in particular the BBC’s multiplex B. However, it may not be possible to continue with all of the interim services on the six national multiplexes, at least not without switching off some existing channels.

1.10 We anticipate that from 2015 onwards white space devices (WSDs) will also use a range of frequencies that includes the 700 MHz band.[2] If the band were made available for mobile use in the 2020s, it would no longer be available for WSDs. However, WSDs will be able to continue operating in spectrum between 470 MHz and 694 MHz and potentially in other spectrum bands. We do not believe that the proposed change would materially reduce white space availability overall.

The change would involve substantial infrastructure costs, but overall the benefits outweigh the costs by a significant margin

1.11 The changes which we consider in this document would entail modifications to DTT transmission infrastructure, PMSE users replacing some of their equipment before the end of its life in addition to the impact for viewers. This would lead to material costs. We are currently working with Government to explore options for who might pay for the aspects of change highlighted in this document should we decide to proceed as proposed and what public funding, if any, might be appropriate.

1.12 As well as considering the costs of the transition process, we have considered the likely loss of value to existing uses from no longer having access to the band under the proposed change. Taken together, our assessment is that the costs of the transition process and the loss of value from change of use of the 700 MHz band could amount to a combined total of between £470 million and £580 million. Table 1, below, gives a breakdown of these costs. As we progress with further investigations of the potential changes, better design and planning information may lead to reductions in costs.

1.13 Several European Member States, including France, Sweden and Finland, have already decided to use the 700 MHz for mobile services and others are considering plans to do so. We will engage with our international neighbours to consider the implications of their decisions whether or not we ultimately decide to use 700 MHz for mobile services.

1.14 The nature of the changes to transmission infrastructure means it would take several years to complete a programme of change. We currently estimate that viewers would need to retune their sets from 2019 and that it should be possible to complete the programme by 2022. However, more detailed planning work may identify opportunities to reduce these timescales, possibly by as much as two years.

We propose to make the 700 MHz band available for mobile broadband as soon as possible

1.15 Overall, we believe that change of use of the 700 MHz band would deliver significant net benefits to the UK. This could arise alongside continued citizen and consumer benefits from existing uses of the band and any transitional impacts of change would be manageable. We are therefore proposing to proceed with change of use of the 700 MHz band on the earliest possible timescales, subject to discussions with Government regarding the costs of these changes and to us being able to reach necessary international spectrum planning agreements.

[2] WSDs are innovative new devices which are able to identify and make use of previously unused gaps in frequency bands.

1.16 Should we conclude, following consultation, that it is appropriate to go ahead with the proposed changes, we will initiate a programme of work to develop a detailed implementation plan. As we develop our plan we will also look for cost-effective opportunities to build in flexibility to adapt to any future developments in spectrum use, so that investments in this proposed change continue to deliver value over the longer term.

1.17 Consistent with our overall strategy for spectrum management, in the event of a change of use, we would expect to award licences to the 700 MHz band through an auction process. In previous cases where we have made spectrum available for mobile use, we have held auctions shortly before the spectrum became available. In this case, such an approach would imply an auction in around 2020. Through our consultation process, we are inviting respondents to comment on the potential timing of an award and the relative merits of holding it earlier, and possibly as early as 2016.

Table 1: Summary of estimated costs and benefits of change (2014 NPV)

<table>
<tr><th></th><th colspan="2">Costs of change</th><th colspan="2">Benefits of change</th></tr>
<tr><td rowspan="8">Elements that we have quantified</td><td>DTT infrastructure modifications (inc. programme management costs and consumer information scheme)</td><td>£370m-420m</td><td>Reduction in costs of meeting increased demand for mobile data capacity from having to build and to operate fewer network sites</td><td>£480m-770m</td></tr>
<tr><td>Consumer aerial replacements</td><td>£2m-4m</td><td rowspan="5">Improvement in the performance that mobile users would experience particularly deep indoors and in rural areas, also measured as the reduction in costs from having to build and to operate fewer network sites to achieve the improved performance</td><td rowspan="5">£390m-480m</td></tr>
<tr><td>Cost of consumer time retuning TVs</td><td>£7m-10m</td></tr>
<tr><td>Coexistence costs</td><td>£0-20m</td></tr>
<tr><td>PMSE equipment replacement</td><td>£6m - 18m</td></tr>
<tr><td>DTT loss of value net of operating cost savings</td><td>£80m-100m</td></tr>
<tr><td>PMSE loss of value</td><td>£10m-13m</td><td colspan="2">Reductions in consumer prices: a significant proportion of these network cost savings would likely be passed on to consumers</td></tr>
<tr><td colspan="2">Total: £470m-580m with potential for reduction as better information becomes available</td><td colspan="2">Total: £900m-1.3bn of quantified benefits</td></tr>
<tr><td rowspan="4">Elements that cannot be reliably quantified</td><td colspan="2" rowspan="3">WSD opportunity cost: current uncertainty over the deployment and take-up of WSDs does not support quantification and the change would be unlikely to have a material negative impact on white space availability overall</td><td colspan="2">Broader economic and social benefits from potential improvements in coverage if a 700 MHz award included a coverage obligation</td></tr>
<tr><td colspan="2">Access to new services: magnitude of benefits unclear. Could be very large, but could be zero</td></tr>
<tr><td colspan="2">Increases in capacity for delivery of emergency services communications: magnitude of benefits unclear. Could be significant</td></tr>
<tr><td colspan="2">Effect of unquantified costs: not material to total costs</td><td colspan="2">Effect of unquantified benefits: potential for significant upside over and above the quantified benefits</td></tr>
</table>

Section 2

Introduction and background

This consultation assesses the case for making the 700 MHz band available for mobile broadband use

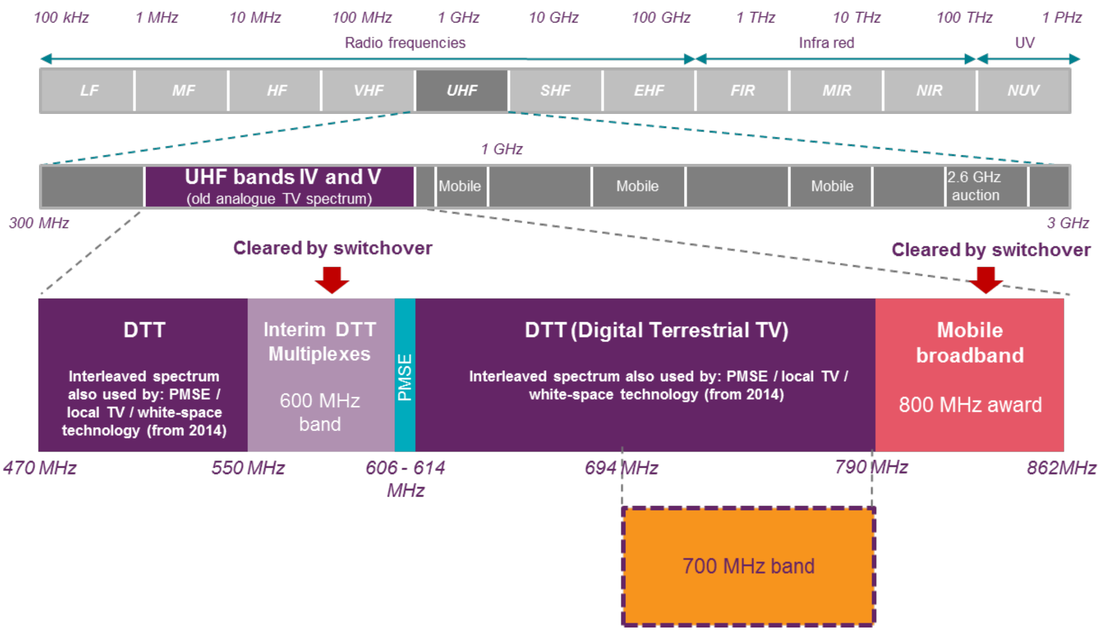
2.1 Frequencies between 694 MHz and 790 MHz (the '700 MHz band') constitute an important part of spectrum used for the provision of DTT and PMSE audio applications, as Figure 1 illustrates. We anticipate that from 2015 onwards WSDs will also use these frequencies.

2.2 This document considers whether there is a case for changing the use of the 700 MHz band and for making it available for mobile broadband. In order to evaluate this case, we have assessed whether the benefits of using the 700 MHz band for mobile would exceed the sum of:

- the costs of implementing the change; and
- the loss of value from existing uses no longer having access to the band.

2.3 The document consults on the findings of this analysis and on our proposals for the future of the 700 MHz band. Our analysis takes account of stakeholder responses to the Call for input on the 700 MHz band which we published in April 2013 (the '*2013 CFI*').

Figure 1: Current allocations in UHF bands IV and V



Our proposals build on our UHF strategy statement

2.4 This consultation takes forward the decisions which we reached in our *UHF strategy statement* (published in November 2012). The *UHF strategy statement* set out our assessment of the challenges associated with balancing the future spectrum needs of mobile broadband, DTT and services sharing spectrum with DTT. It outlined our intention to pursue the dual strategic objectives of providing more low frequency spectrum for mobile broadband, while also securing the on-going delivery of benefits provided by DTT. To achieve this we said we would:

- support the international process and seek to enable a harmonised release of the 700 MHz band for mobile broadband use; and
- seek to ensure that the DTT platform can access the 600 MHz band assuming change of use at 700 MHz takes place.

The consultation is part of a broader programme of work on mobile data

2.5 As discussed in more detail in Section 4 of this document, demand for mobile data services is growing sharply, driven by the increased uptake of smartphones and tablets. This growth is forecast to continue for the foreseeable future.

2.6 Enabling industry to serve this growing mobile demand could deliver significant benefits to citizens and consumers. In the light of this, addressing future mobile data demand is a priority for Ofcom[3] and part of the solution is likely to include making additional spectrum available for mobile data services. We discuss our wider programme of work in this area in more detail in our *Mobile data strategy statement*[4], which we are publishing alongside this consultation.

2.7 Our analysis of the case for making the 700 MHz band available for mobile broadband therefore forms a key part of our broader programme of work on mobile spectrum.

Our broader strategic thinking on the future of free to view TV and PMSE informs the analysis in this consultation

2.8 The 700 MHz band is an important part of the spectrum used to deliver DTT and PMSE services.

2.9 As outlined in our discussion document on the *Future of free to view TV*[5], DTT plays a central role in delivering a number of key policy objectives, including:

- providing near universal low cost access to public service TV channels;
- contributing to inter-platform competition; and
- giving viewers choice for how to receive TV services.

2.10 We believe it will continue to play this role for the foreseeable future. Were we to make the 700 MHz band available for mobile broadband, we would therefore seek to do so in a manner which safeguards the on-going delivery of the benefits that DTT

[3] As set out in our *Spectrum management strategy*: http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf
[4] http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/statement/
[5] http://stakeholders.ofcom.org.uk/consultations/700MHz/ftv/

provides. This is reflected in our assessment of the steps that we would need to take in order to make the band available for mobile.

2.11 We also recognise that the use of wireless microphones and other PMSE applications delivers significant cultural benefits to the UK. As set out in our *Spectrum management strategy statement*[6], ensuring that the PMSE sector has access to an appropriate amount of spectrum in the future is a high priority for Ofcom. Just as we are committed to safeguarding the benefits DTT provides, so we are committed to ensuring that the PMSE sector remains capable of delivering the important benefits associated with it if we make the 700 MHz band available for mobile. Once again, this is factored into our assessment of the steps that we would need to take in order to implement the change under consideration.

White space devices

2.12 The analysis in this document also considers the impact of making the 700 MHz band available for mobile on the availability of spectrum for white space devices (WSDs). WSDs are designed to identify and access unused frequencies. As part of our broader programme of work on spectrum sharing, we are currently exploring the possibility of permitting WSDs to operate in unused spectrum within the frequency ranges assigned to DTT (so-called TV white spaces)[7]. Change of use of the 700 MHz band would affect the total amount of TV white spaces potentially available. We discuss this further in Section 8.

There is an important international dimension to debates about the 700 MHz band

2.13 Our focus is on securing the optimal use of spectrum for UK citizens and consumers and this is set in the broader context of international harmonisation and coordination. There are several strands to the international debate about the future of the 700 MHz band.

2.14 First, part of the reason why the band is potentially attractive as a source of mobile spectrum is that a wide range of countries across the globe have either committed to use it for mobile broadband or are in the process of doing so. For example, countries across Latin America and the Asia Pacific region have decided to make the 700 MHz band available for mobile as have a number of European countries including France, Sweden and Finland. The impetus for change in Europe was prompted by a strong desire by several African countries to use the 700 MHz band for mobile. Therefore we anticipate that a large number of African countries will follow suit. This is important because mobile spectrum needs to be used on an international basis to provide the economies of scale required to ensure a wide availability of devices at reasonable cost.

2.15 Second, we would need a number of international agreements to be in place before we could make the 700 MHz band available for mobile broadband. These include the following:

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[6] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf
[7] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

- **The International Telecommunications Union (ITU)[8] would need to amend the radio regulations to confirm a co-primary allocation for mobile and broadcasting in the 700 MHz band in ITU region 1 (Europe, the Middle East and Africa).** The radio regulations are the rules which govern international use of spectrum and satellite orbits. They stipulate the permitted uses of each spectrum band. The regulations are reviewed at World Radiocommunication Conferences (WRCs) which take place every three to four years. The latest WRC in 2012 (WRC-12) resulted in a decision to agree a co-primary allocation for mobile and broadcasting in the 700 MHz band in ITU region 1, subject to a number of studies on technical and regulatory conditions. Without this co-primary allocation, there would be significant international constraints on using the 700 MHz band for mobile services. The decision is expected to be implemented in the radio regulations at WRC-15, which will take place in November 2015. Ofcom takes the lead for the UK in WRC negotiations under direction from the Government. We are therefore actively engaged in UK, European and international preparations for WRC-15.

- **Agreement of a DTT frequency plan**: We would need to agree a revised DTT frequency plan with neighbouring states in order to manage the impact of interference between services in different countries. We discuss this in more detail in Section 5.

- **Agreement of a mobile band plan:** The European Conference of Postal and Telecommunication Administrations (CEPT)[9] would need to agree a mobile band plan, stipulating how frequencies within the 700 MHz band can be used for mobile in European countries. CEPT has considered the options and has decided to move forward with a 2x30 MHz arrangement. In addition, it has opted for 20 MHz of supplemental downlink in the centre gap, and national options for the use of PMSE or public safety applications in remaining parts of the 700 MHz band. Ofcom is actively engaged in these discussions. See Annex 6 for further detail.

2.16 Finally, the European Commission could also have a significant influence on any change of use of the 700 MHz band. For example, it could adopt a binding decision requiring member states to release the band for mobile services by a certain date. There are also broader discussions taking place about the future of the UHF band (470 to 790 MHz). The Radio Spectrum Policy Group (RSPG)[10] plans to work in 2014 on a long-term strategy on the future of the 470 to 790 MHz band in the EU. In addition, the Commission has set up an advisory group involving senior industry figures to report on a long term strategy for 470 to 790 MHz in the EU by July 2014.

2.17 Ofcom will monitor and actively engage in discussions on the 700 MHz band. We will also continue to engage in discussions on the long term future of the UHF band and to review any impact they may have on implementation options for a 700 MHz change of use. We are seeking to ensure that consumers and citizens can continue to enjoy the benefits delivered by DTT and PMSE.

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[8] The ITU is the United Nations specialised agency for information and communication technologies. Among other things, it is responsible for the allocation of radio spectrum and satellite orbits.
[9] CEPT is the European regional organisation for postal and telecommunications issues. Membership is made up of the postal and telecommunications administrations of 48 European countries.
[10] The RSPG is a high-level advisory group assisting the European Commission in the development of radio spectrum policy in the Community. Its members are representatives of member states and the Commission.

The emergency services may also have an interest in using the 700 MHz band

2.18 The analysis in this document focuses principally on the possibility of using the 700 MHz band for the provision of commercial mobile services. However, debates about the future of the 700 MHz band are also linked to discussions about the communications technologies which the emergency services use.

2.19 The emergency services rely heavily on wireless communications to contribute to the delivery of safety-of-life services, which are of critical importance to UK citizens. Developments in mobile broadband are creating opportunities for the delivery of enhanced, data-rich public protection and disaster recovery (PPDR) applications. This is generating debate in the UK and internationally over whether, and how, governments and regulators should make additional spectrum capacity available for emergency service communications. Both the UK Government and other national administrations are considering the possibility of using spectrum in the 700 MHz band for broadband PPDR communications applications.

2.20 Decisions regarding PPDR spectrum assignments are a matter for Government. Therefore, this consultation does not seek to reach a view on the merits of using the 700 MHz band for PPDR. However, it takes note of the on-going debate insofar as it will impact on our analysis of the costs and benefits of change of use of the 700 MHz band. We provide further details in Section 4.

The structure of this consultation

2.21 The remainder of this consultation is structured as follows:

- **Section 3** outlines the relevant legal framework.
- In **section 4** we consider the benefits that could be realised from using the band for mobile broadband services.
- A change of use of the 700 MHz band would have significant implications for the current DTT platform. In **section 5** we set out the changes that may be needed and provide estimates of the associated costs and timelines. We also consider the benefits associated with DTT retaining access to the spectrum.
- **Section 6** describes the impact that change of use would have on DTT viewers and gives an early consideration of where viewer-support measures might be needed in the event that we proceed with change of use. Finally, it sets out the pre-emptive actions we are taking to ensure that, as far as possible, consumer equipment sold today is capable of operating should there be a 700 MHz change of use.
- **Section 7** outlines our assessment of the impact a change of use would have on PMSE users as well as the actions we have identified to mitigate this impact.
- **Section 7** sets out the impact a 700 MHz change of use would have on the availability of spectrum for WSDs.
- **Section 9** explains our approach to discounting and calculating equipment replacement costs.

- **Section 10** sets out our proposals.
- In **section 11** we consider funding for a potential 700 MHz change of use.
- **Section 12** identifies the next steps we are intending to take.

2.22 In addition, we include a number of annexes which provide further detail of our approach to the cost-benefit analysis and implications of a 700 MHz change of use. To develop our proposals, we also used analysis from a number of reports, most of them prepared by independent consultants. Annex 16 provides a list of these reports.

2.23 We invite stakeholders' comments on our analysis and proposals.

Section 3

Legal framework

3.1 In making the proposals set out in this consultation, and when considering subsequent decisions, Ofcom acts within a framework defined by both EU and UK law. In the context of considering the future use of the 700 MHz band, Ofcom has specific duties and powers related to the management of radio spectrum.

3.2 More particularly, Ofcom has a number of general and specific statutory duties derived from the European regulatory framework, the Communications Act 2003, and the Wireless Telegraphy Act 2006. These Acts recognise that, on occasion, Ofcom will need to exercise its discretion in terms of the weight given to different considerations when taking decisions. Ofcom must also have regard to the rights and obligations of the UK as a matter of the UK's international obligations – for instance, in relation to spectrum arrangements with our international neighbours. In this regard Ofcom has been directed by the Government to represent UK interests in negotiations within the main spectrum-related institutions, including the International Telecommunications Union (ITU), the European Conference of Postal and Telecommunications Administrations (CEPT), and spectrum committees, of the European Union.

3.3 Article 8 of the Framework Directive (Directive 2002/21 – as amended) sets out the objectives that national regulatory authorities must take all steps to achieve. These include:

- the promotion of competition in the provision of electronic communications networks and services by, among other things, encouraging efficient investment in infrastructure and promoting innovation, and encouraging efficient use of radio frequencies; and

- contributing to the development of the internal market by, among other things, removing obstacles to the provision of electronic communications networks and services at a European level, encouraging the interoperability of pan-European services and ensuring that, in similar circumstances, there is no discrimination in the treatment of undertakings providing electronic communication networks and services.

3.4 Section 3(1) of the Communications Act 2003 sets out Ofcom's general duties, including its principal duty:

- to further the interests of citizens in relation to communications matters; and

- to further the interests of consumers in relevant markets, where appropriate by promoting competition.

3.5 Pursuant to this general duty, section 3(2) of the Communications Act provides that Ofcom is required in carrying out its functions to secure, among other things:

- the optimal use for wireless telegraphy of the electro-magnetic spectrum;

- the availability throughout the United Kingdom of a wide range of electronic communications services;

- the availability throughout the United Kingdom of a wide range of television and radio services which (taken as a whole) are both of high quality and calculated to appeal to a variety of tastes and interests; and

- the maintenance of sufficient plurality of providers of different television and radio services.

3.6 Section 3(3) of the Communications Act 2003 provides that, in performing its duties, Ofcom must have regard in all cases to the principles of transparency, accountability, proportionality and consistency, as well as ensuring that actions are targeted only at cases where they are needed.

3.7 Section 3(4) of the Communications Act 2003 requires that Ofcom has regard, in performing its duties to a range of factors, as appear to be relevant in the circumstances, including the desirability of:

- promoting the fulfilment of the purposes of public service television broadcasting in the United Kingdom;

- promoting competition in relevant markets;

- encouraging investment and innovation in relevant markets; and

- encouraging the availability and use of high speed data transfer services throughout the United Kingdom.

3.8 Section 3(4) also requires Ofcom to have regard to the different needs and interests of all persons who may wish to use the electro-magnetic spectrum for wireless telegraphy.

3.9 Section 4 of the Communications Act requires Ofcom to act in accordance with the six Community requirements. These requirements give effect to the requirements of Article 8 of the Framework Directive.

3.10 When carrying out functions related to the management of radio spectrum, section 3(1) of the Wireless Telegraphy Act 2006 imposes a number of further duties. Ofcom is required to have regard to:

- the extent to which the electromagnetic spectrum is available for use, or further use, for wireless telegraphy;

- the demand for use of the spectrum for wireless telegraphy; and

- the demand that is likely to arise in future for the use of spectrum for wireless telegraphy.

3.11 Section 3(2) of the Wireless Telegraphy Act 2006 provides that Ofcom must also have regard to the desirability of promoting the efficient management of radio spectrum, the economic and other benefits that may arise from the use of wireless telegraphy, the development of innovative services and competition in the provision of electronic communications services.

3.12 Taking into account each of the above duties, we consider that our principal duty to further the interests of citizens and consumers, where appropriate by promoting competition, is of particular importance in considering the future use of the 700 MHz band. Moreover, we consider that our duties relating to the following are particularly relevant in this context:

- securing the optimal use of spectrum taking into account current and future demand;
- the desirability of encouraging investment and innovation in relevant markets;
- the desirability of encouraging the availability and use of high speed data transfer services throughout the United Kingdom;
- the need to have regard to the different needs and interests of all persons who may wish to make use of spectrum; and
- the availability throughout the United Kingdom of a wide range of television and radio services and the maintenance of sufficient plurality of providers of different television services.

Impact assessment

3.13 The analysis presented in this document constitutes an impact assessment as defined in section 7 of the Communications Act 2003.

3.14 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practice policy-making. This is reflected in section 7 of the Communications Act 2003, which means that generally we have to carry out impact assessments where our proposals would be likely to have a significant effect on businesses or the general public, or when there is a major change in Ofcom's activities. However, as a matter of policy Ofcom is committed to carrying out impact assessments in relation to the great majority of our policy decisions. For further information about our approach to impact assessments, see the guidelines, "Better policy-making: Ofcom's approach to impact assessment", which are on our website.

Equality Impact Assessment

3.15 We conducted an Equality Impact Assessment to understand if change of use at 700 MHz could disproportionately affect any particular group of consumers or raise specific issues for groups that are protected under equality laws. We looked at the composition of the DTT audience to understand whether any change of use might cause greater impacts on one group over another.

3.16 Ofcom data[11] show that the DTT audience is likely to include a comparatively higher share of viewers from older age groups. One of the impacts of a potential change of use could be that a small number of households may need to change their rooftop aerials or to add a filter to their television equipment to address interference (see Section 6 of this document). The practical steps involved in some of the changes that viewers may need to carry out are likely to raise challenges for disable people.

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[11] *Communications Market Report 2013*, August 2013: http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr13/2013_UK_CMR.pdf and *Public Service Broadcasting Annual Report 2013*, August 2013: http://stakeholders.ofcom.org.uk/broadcasting/reviews-investigations/public-service-broadcasting/annrep/psb13/

3.17 Older and disabled people are protected groups under equality law and the Communications Act 2003 also requires Ofcom to consider these groups specifically. We conducted consumer research published alongside this document to get an understanding of how these groups would be affected to help inform any potential consumer support campaign. Due to their greater use of the DTT platform and potential challenges from dealing with TV equipment modifications, e.g. relating to mobility issues, these two groups could experience a greater impact from the proposed change.

3.18 More generally, we have identified that the benefits of the change under consideration would flow to users of mobile data services and that some categories of DTT viewers are less likely to use these services. Section 6 outlines our broader thinking around consumer impacts and our view that a consumer support campaign would be required to mitigate these. Subject to responses to this consultation, further work on a programme of change would include detailed proposals for how best to design and to plan consumer support, including for protected groups.

Section 4

Benefits of change of use of the band

4.1 This section considers our analysis of the benefits that could be realised from changing use of the 700 MHz band from DTT and PMSE to the provision of mobile broadband services. The approach we have taken for the purposes of this analysis is to model the benefits of a change of use over a 20 year period starting in 2022. We have used 2022 as the start of the modelling period because initial analysis indicates that this is a realistic date by which the 700 MHz band could be made available for mobile broadband on a national basis.

4.2 We have identified various types of benefit, some of which are more amenable to quantification than others. We have specifically quantified the benefits of improved network performance and network cost savings (which we expect to lead to lower prices to consumers) and estimate them to be between £900 million and £1.3 billion.[12] However, because some of the benefits are not amenable to quantification, this estimate may understate the total benefit of change of use of the band. The benefits of change are likely to be greater the sooner that change occurs.

4.3 In considering the benefits of change of use of the 700 MHz band we commissioned Analysys Mason to examine the network cost savings and performance benefits from using the band for mobile. This report has been published alongside this consultation.[13]

We expect significant growth in demand for mobile services to continue

4.4 Mobile services are an important part of the UK economy, generating revenues of £15.3 billion in 2012, and delivering large consumer benefits. Analysys Mason estimated that in 2011 the total economic value of mobile services was £30 billion.[14]

4.5 Demand for mobile broadband services is growing rapidly. Data traffic carried by UK mobile networks increased by approximately 50% between June 2012 and June 2013 and more than doubled between March 2011 and June 2012.[15]

4.6 Growth in demand is expected to continue into the future as take-up of smartphones and other devices, and the data demands of the applications used on these devices, continues to increase. In our November 2012 *UHF strategy statement* we quoted a forecast from a technical study by Real Wireless which predicted that, as a mid-range estimate, mobile data traffic 'before offload' (i.e. before allowing for the fact that a proportion of traffic will be offloaded onto Wi-Fi networks) would increase 80-fold from 2012 to 2030. Separately, Analysys Mason forecasts that mobile data traffic

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[12] Assessed over a 20 year period from 2022 and discounted back to 2014 using the Spackman method (explained in more detail in Section 10) and a social discount rate of 3.5%.
[13] Analysys Mason, May 2014, *Assessment of the benefits of a change of use of the 700MHz band to mobile:* http://stakeholders.ofcom.org.uk/consultations/700MHz/
[14] Analysys Mason, November 2012, *Impact of radio spectrum on the UK economy and factors influencing future spectrum demand*: https://www.gov.uk/government/publications/impact-of-radio-spectrum-on-the-uk-economy-and-factors-influencing-future-spectrum-demand
[15] *Infrastructure Report: 2013 update*, October 2013: http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2013/

could increase by a factor of 45 before offload, with the traffic carried on mobile networks 'after offload' (i.e. after allowing for traffic offloaded to Wi-Fi networks) increasing 25 times between 2014 and 2030. A large part of this apparent reduction is that Real Wireless compares traffic in 2012 with forecast traffic in 2030, whereas Analysys Mason compares 2014 and 2030. Given the significant growth in traffic between 2012 and 2014 this makes a large difference.

4.7 Table 2 highlights the uncertainty over forecasts of demand. Although the 2030 'before offload' Analysys Mason forecast is around double the Real Wireless forecast, the 'after offload' forecasts are broadly similar. Analysys Mason assume Wi-Fi offloading grows from 60% in 2014 to 77% in 2030, while Real Wireless assume offloading is much lower and only reaches 50% in 2035. It is 'after Wi-Fi offload' traffic that drives demand for additional spectrum for mobile networks. Actual 'after Wi-Fi offload' traffic was 19 PB in June 2012 and 28 PB in June 2013.

Table 2: Monthly UK mobile traffic in petabytes[16]

	2012	2014	2020	2030
Before Wi-Fi offload				
Analysys Mason mid case	34	104	1,421	4,938
Real Wireless mid case	31	57	560	2,506
After Wi-Fi offload				
Analysys Mason mid case	17	42	374	1,133
Real Wireless mid case	19	33	316	1,303

4.8 Meeting this increase in demand could deliver significant benefits to consumers, through new and improved mobile data services. It could also promote competition and lower consumer prices by reducing the marginal cost of serving additional traffic and lowering capacity constraints in the mobile sector. In addition it could sustain wider growth in the economy by improving the capability of the UK's mobile infrastructure.

4.9 Apart from using more spectrum, mobile operators have a range of options for increasing mobile data capacity and coverage including: using more efficient technologies; deploying more mobile sites; and encouraging greater use of Wi-Fi and femtocell data offloading. All of these techniques will be important for meeting future demand growth if it is as strong as predicted. Sub-1GHz spectrum such as the 700 MHz band is particularly important for increasing capacity in hard to serve locations (e.g. deep indoors and rural areas).

Using 700 MHz for mobile services would bring significant benefits

4.10 We have published a statement regarding our future strategy relating to provision of mobile data (the *Mobile data strategy statement*). The statement identifies a number of spectrum bands which could potentially be made available for mobile data use.

4.11 The 700 MHz band is an important part of this strategy, particularly given (a) the propagation advantages of sub-1 GHz spectrum; (b) that it is harmonised across many regions in the world and further harmonisation is in progress; and (c) strong international momentum behind making the band available for mobile use.

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[16] 1 PB = 1,073,741,824 MB

4.12 We have identified a number of benefits of changing use of the 700 MHz band. These include:

- **Mobile network cost savings from deploying fewer base stations.** Analysys Mason estimates the potential savings are between £480 million and £770 million, based on a 20 year analysis from 2022.

- **Improvements in mobile performance in hard to serve locations**. Analysys Mason estimates the reduced cost of delivering performance improvements to be between £390 million and £480 million.

- **Potential for lower consumer prices**. Millions of consumers could benefit from lower mobile tariffs, because we expect a significant proportion of the network cost savings to be passed through to consumers.

- **Extending data coverage**. The possibility of extending data coverage beyond the current footprint, possibly through the use of a coverage obligation, could deliver significant social and economic benefits.

- **Potential for new services or technology to be deployed in the band**. The 700 MHz band will be the only sub 1GHz band across such a large international footprint and this could support development of new services or technologies.

- **Benefits of using the centre gap.** Depending on the band plan adopted up to 25 MHz of spectrum in the centre gap could be available for other uses. The most likely uses are either PMSE or supplemental downlink (SDL) use.

- **Possibly making some of the spectrum available for emergency service use**. No decision has yet been taken on PPDR use in the 700 MHz band. Our analysis assumes – conservatively – that it is not used for PPDR and that any decision to use the band for PPDR would only be taken on the basis that the benefits of doing so outweighed the cost of displaced mobile use.

4.13 The first three benefits identified above are linked, in that mobile network operators can use additional spectrum to deliver services using fewer mobile sites and some of this network cost saving may be passed onto consumers in the form of lower prices; or alternatively, in the extreme, operators might decide not to reduce the number of new sites built and instead use the spectrum to improve the performance and coverage consumers receive in hard to serve locations. More likely, we would see a combination of these benefits – Analysys Mason has modelled one specific combination (in a way that minimises the risk of double-counting between different types of benefit).

4.14 We do not think that a robust quantification is possible for all potential citizen and consumer benefits arising from 700 MHz release. In addition, such forward-looking assessments require careful interpretation, recognising that there are different paths that the future can take and that we need to exercise judgment in estimating which developments are more likely on the basis of today’s information.

4.15 We have therefore sought to:

- Quantify the network cost savings from using the band for mobile services and the reduced cost of delivering improved performance. Taken together, we estimate these benefits are between £900 million and £1.3 billion in 2014 NPV terms. To reflect the uncertainty of modelling over such a long period we have considered a range of benefits rather than a point estimate.

- Qualitatively examine the savings that could be passed onto consumers in lower tariffs. As well as other potential benefits that are difficult to quantify and in some case seem more uncertain, but could be additional to the benefits we have quantified.

4.16 While the modelling approach we have adopted focuses on network cost savings as a way of quantifying the benefits of 700 MHz change of use it is not the case that the benefits of these savings will accrue entirely to mobile network operators. We would expect that a significant proportion of the savings would either be transferred to Government as auction receipts, or passed on to consumers in lower tariffs (than might otherwise arise) or through improved performance and coverage.

4.17 We discuss each of these benefits in more detail below.

Network cost savings could be between £480 million and £770 million

4.18 The main options for meeting growing demands for mobile capacity are to use more spectrum, deploy more sites, or to adopt more advanced technologies that achieve a higher data throughput in a given amount of spectrum. Mobile operators can also reduce traffic on their macro network by encouraging offload to Wi-Fi or femtocells.

4.19 Using the 700 MHz band for mobile services would allow mobile operators to deploy fewer sites to meet a given level of traffic. We commissioned Analysys Mason to estimate the network cost savings that could result from a reduction in new site build. Its approach and results are set out below.

4.20 The Analysys Mason model is based on three previous models created by, or for, Ofcom. These are:

- a previous Analysys Mason model used to report on the opportunity cost of spectrum used by DTT and digital audio broadcasting.

- a model constructed by Real Wireless for its 2012 report for Ofcom on techniques for increasing the capacity of wireless broadband networks; and

- an Ofcom model used to carry out an assessment of compliance with the coverage obligation in Telefónica's 800 MHz licence.

4.21 In its consolidated model, Analysys Mason calculates network cost savings based on an assessment of the number of sites that a generic operator could avoid building if it could use an additional 2 x 10 MHz of spectrum (in the 700 MHz band). Analysys Mason has considered a number of different scenarios to give an estimated range for the network cost savings. Figure 2, below shows Analysys Mason's estimation of the number of network sites required in both the with-700 MHz and without-700 MHz scenarios to meet forecast mobile data traffic over the modelling period. In 2041, it estimates that 1,671 more sites will need to be built in the without-700 MHz network than in the case where 700 MHz carriers are deployed (in its central-high scenario)[17].

[17] The assumptions driving the different scenarios are explained in the Analysys Mason report. We have used the central-high scenario as an example. The central-low scenario has 17,500 starting

The cost saving of avoiding building these extra sites with change of use of 700 MHz is Analysys Mason's calculated network cost saving. Figure 2 illustrates how a relatively small proportion of the total number of sites drives a large value for the estimated network cost savings. This is because of the substantial capital and operating costs associated with deploying additional macro sites relative to adding a carrier to an existing site.[18]

Figure 2: Analysys Mason's estimate of the number of network sites required in the central high scenario for a generic operator

4.22 The year-on-year network costs are calculated from the assumed date of change of use until 2041, with and without change of use of the 700 MHz band. The difference in the present value of these costs represents the network cost savings to the generic operator from holding 2x10 MHz of 700 MHz spectrum. We multiply this saving across three generic operators to get a value for the overall industry network cost saving from change of use of the 700 MHz band.[19]

4.23 This estimate takes account of other methods of meeting a given level of traffic over the time period including release of other spectrum bands, improvements in spectral efficiency and increases in Wi-Fi offloading.

4.24 Given the timescales involved, there is naturally significant uncertainty over a number of inputs into the Analysys Mason model. For example, forecasts of future demand for mobile data services vary widely depending on the source and it is not certain what other spectrum bands mobile operators will have access to in the future. Given this uncertainty, Analysys Mason provides two ranges of results which vary depending on the assumptions used. The assumptions driving the differences between these ranges are shown in Table 3 below; these are explained more fully in the Analysys Mason report.

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sites, but the difference in number of sites between the with- and without-700 MHz spectrum states of the world would be smaller.

[18] For example, in 2014 the capex associated with deploying a new site is approximately £100,000, whereas the capex associated with deploying a new carrier is approximately £6,000.

[19] This is based on a 2x30 MHz band plan where spectrum is awarded to three operators each winning 2x10 MHz. The band plan is discussed in more detail below. If the spectrum were awarded to more than three operators, e.g. two operators are awarded 2x5 MHz, then the total network cost savings would tend to increase, under the modelling assumptions adopted by Analysys Mason.

Table 3: Assumptions in the AM model

Key parameter	Explanation
Traffic forecast	Level of traffic before offload to Wi-Fi networks. Higher traffic drives larger network cost savings as more sites need to be deployed to meet additional traffic. For modelling purposes the level of traffic is assumed to be the same both with and without access to the 700 MHz band. The base case assumption is an increase in traffic between 2014 and 2030 of x45.
Offloading assumption	Proportion of traffic that is offloaded onto Wi-Fi networks. Higher offload assumptions reduce the network cost savings, as less network build would be needed to meet forecast traffic levels without 700 MHz spectrum. In the base case offloading grows from 60% in 2014 to 77% in 2030.
Traffic distribution across sites	Traffic is not distributed evenly across sites. A small proportion of sites deliver a large proportion of busy hour traffic. The steeper the distribution, i.e. the more traffic is concentrated in a small number of sites, the larger the network cost saving as it is more likely a given site will hit the capacity limit.
Traffic served by sub-1 GHz spectrum only	The model assumes that a proportion of traffic can only be served using sub 1GHz spectrum. This varies between 18% and 22%. The higher the percentage the higher the network cost savings.[20]
Starting number of sites	This assumption determines the number of sites at the end of 2017. A larger number of starting sites means fewer sites need to be built later without access to 700 MHz spectrum, and reduces the network cost saving.
Proportion of shared new build sites	This is the proportion of new sites where costs are shared with another operator. If a higher proportion of sites are shared the cost of deploying new sites falls and therefore the network cost savings are lower.
Unit cost of sites	This is the cost of building a new site. The higher the build costs the greater the network cost savings.
Proportion of new sites that are six sector	The majority of sites today are three sector sites. If more sites are capable of being upgraded to six sectors there is less need to deploy additional sites and therefore the network cost savings fall.
Spectral efficiency forecast	Spectral efficiency determines how much capacity can be delivered with a given amount of spectrum. If spectral efficiency is higher there is less need to deploy sites and therefore network cost savings from 700 MHz fall.
Future spectrum availability	Availability of other spectrum bands potential reduces the benefits of using the 700 MHz band. In the benefit range considered below 700 MHz is the only new sub-1 GHz band made available.

4.25 Analysys Mason estimates that 700 MHz change of use would deliver mobile network cost savings of £480 million to £770 million. This is a “central range” estimate. The upper and lower limits of this range are based on alternative assumptions as to the value of key parameters. Analysys Mason has also generated a “wide range” of the benefits from £190 million to £930 million. However values outside the central range appear less likely and values towards the extremes of the wider range are particularly unlikely. For example, for network costs to be at the bottom of the wide range would require one set of factors (including mobile traffic growth, peakiness of traffic distribution, and cost of network build) to be at the bottom of their plausible range of

[20] This is a stylised modelling approach that attempts to capture the importance of sub 1 GHz spectrum to a generic operator. The rationale behind the range we have used is explained in the Analysys Mason report. We recognise that this stylised approach is a less accurate representation of some specific operators, e.g. there are operators offering mobile broadband services today using little or no sub 1 GHz spectrum. But we consider it reasonable to adopt a model suitable for a generic operator rather than developing separate models to reflect the individual circumstances of specific operators.

values, and would simultaneously require other factors (including spectral efficiency and starting number of sites) to be at the top of their plausible range of values.

4.26 All of the estimates above are based on a 2x30 MHz mobile band plan. For the purpose of quantifying benefits we have assumed that a 2x30 MHz band plan aligned with APT will be supported in all new global handsets from 2018 due to economies of scale, opportunities for global roaming and potential handset-design complications associated with the 2x40 MHz plan.

4.27 It is still possible that European negotiations might result in a 2x40 MHz mobile band plan being implemented in Europe. This might arise if differences between out of band emissions standards in Europe and the Asia-Pacific region existed and materially diminished the harmonisation benefits associated with the 2x30 MHz plan. In this case, the network cost savings would be calculated by multiplying the savings to the generic operator by four rather than three. This would increase the savings in the central range by £160 million (lower bound) to £260 million (upper bound). However, there would be costs associated with supporting the 2x40 MHz plan, principally in terms of additional mobile handset costs. We have not attempted to quantify this cost but it could result in a significant increase in mobile terminal costs. The 2x30 MHz plan also supports a larger centre gap; we discuss this in more detail below.

4.28 These values correspond to a change of use of 700 MHz in 2022 as this is when Arqiva has estimated change of use could be completed. Over time it may become possible to move this forward, particularly if replanning of the DTT network takes less time than Arqiva has initially estimated. As discussed in Section 10 we are exploring ways to make the band available at the earliest possible date.

4.29 We consider that there would be additional benefits from earlier change of use. The Analysys Mason model estimates that an earlier change of use in 2020 would increase the network cost saving benefits by between £10 million and £50 million in the central range as it would result in a reduction in the number of sites being built to meet increasing demand where the network cannot otherwise support it and a longer period over which benefits accrue. Conversely, a later change of use of 700 MHz would reduce the benefits with more sites likely to be built in the meantime (or lower consumer benefits from reduced performance) and benefits over a reduced period of time. For example, change of use in 2026 would reduce the network cost savings by £50 million to £80 million compared to 2022.

Performance and coverage improvements

4.30 The propagation characteristics of sub 1 GHz spectrum make it particularly useful for serving users in rural areas and deep indoors. Although the 800 MHz and 900 MHz bands are available now for mobile broadband use there may be a need for further low frequency spectrum in the future. The 700 MHz band is currently the only low frequency band that is a candidate for widely harmonised mobile use.

4.31 The importance of sub 1 GHz spectrum is reflected in our network cost saving modelling. However, there is likely to be a further benefit to performance, beyond what is captured in the network cost modelling, and Analysys Mason has sought to capture this effect, as we discuss below. As well as improvements in performance in those areas already served there are potential benefits from extending data coverage beyond the current footprint, we have not attempted to quantify this benefit but discuss it below.

Extending data coverage

4.32 Mobile data services have enabled a range of new applications that are increasingly important to consumers including social networking, accessing public services on mobile devices and mobile banking. As such, ubiquitous data coverage is becoming more important for digital inclusion, both from a social and economic perspective.

4.33 We expect rollout of services using the 800 MHz band to cover a substantial proportion of the population (for example, Telefónica's coverage obligation requires it to serve 98% of indoor areas and other operators have made announcements to deliver a similar level of coverage).

4.34 In propagation terms the 700 MHz band is similar to the 800 MHz and 900 MHz bands. Therefore we may not expect mobile operators to extend data coverage for commercial reasons beyond the footprint provided by the rollout of 800 MHz services. However, release of the 700 MHz band could be combined with other incentives or obligations to extend mobile coverage to more remote areas including roads and railway lines. For example, as mentioned above the award of the 800 MHz band included a licence with a coverage obligation.

4.35 If coverage increases beyond that enabled by mobile use of other sub-1GHz bands as a result of 700 MHz change of use, there are potentially significant benefits. This includes the possibility that more ubiquitous coverage may enable or strengthen new types of mobile applications, for example, related to M2M technology and the internet of things. Extended coverage could also promote benefits associated with social inclusion of citizens and network effects associated with those citizens currently unable to access mobile services in certain locations.

4.36 We have not identified a basis for quantifying these benefits, but they could be significant if geographic coverage is extended beyond what would be achieved with rollout of other sub-1 GHz bands under their current obligations.

Improving performance

4.37 As well as extending coverage beyond the current footprint, use of the 700 MHz band could improve performance at the edge of existing network coverage i.e. deep indoors and in rural areas.

4.38 Improvements in performance would increase the mobile broadband speeds that end users receive. This could allow users to consume new services, e.g. HD video on the move, or improve the overall user experience, e.g. by reducing mobile download times.

4.39 The network cost saving calculation set out above is based on meeting traffic demand in terms of busy hour capacity. However, in some areas there may be additional benefits from deploying 700 MHz carriers which would allow the network to deliver higher speeds.

4.40 The value of this effect depends both on the amount by which speed would improve as a result of 700 MHz, and the extent to which consumers valued such improvements. Analysys Mason's analysis using the Ofcom coverage model indicates that a network with 700 MHz carriers deployed on all sites could deliver average speeds up to 20% faster for some users (compared to a network of the same size without 700 MHz) and that speed improvements could be greater at the cell edge.

4.41 It is more difficult to determine how much consumers value improved mobile services. However evidence from consumer research and take-up of LTE services shows some consumers place a substantial value on improved performance. For example, consumer research, commissioned for our *UHF strategy consultation*, showed that 73% of consumers would be willing to pay £10 a month more for improved mobile coverage and more data capacity.

4.42 An alternative approach to estimating the benefit of improved performance is to estimate the cost mobile operators would face if they were to provide faster speeds without access to the 700 MHz band, i.e. by building more sites (additional to those needed to meet capacity requirements).

4.43 Analysys Mason has estimated that a network without access to 700 MHz would need between 2,050 and 2,650 additional sites (in the central range) in order to provide the same capacity and performance as could be achieved if 700 MHz carriers were available on all sites. Of these sites between 1,180 and 1,670 are needed to provide the same capacity and between 870 and 980 are needed to provide the same performance. Its estimate of performance benefits from 700 MHz is the avoided cost of building these 870 to 980 additional sites, which it calculates to be between £390 million and £480 million (central range).[21]

4.44 This estimate is based on 700 MHz change of use in 2022. If change of use happens in 2020 we estimate the performance benefits would increase by between £10 million and £20 million (central range). If change of use were delayed until 2026 the estimated performance benefits would fall by between £70 million and £90 million (central range).

4.45 There is a risk that this approach overestimates the benefit as consumers may not value the improvements in performance up to the cost of additional sites. Alternatively it could understate the benefits if consumers valued the improvement significantly more than the cost of additional sites but operators were unable to monetise this value and, therefore, would not have an incentive to provide the higher performance in the without-700 MHz scenario.

4.46 An additional risk is that this method does not consider performance benefits in the without-700 MHz network. Without access to the 700 MHz band Mobile Network Operators (MNOs) would need to deploy additional sites in certain areas rather than 700 MHz carriers (this is what drives the network cost savings above). However, adding a new site increases capacity by more than adding a 700 MHz carrier to an existing site. This could mean the without-700 MHz network may deliver faster speeds than the with-700 MHz network in a few areas. An additional site without 700 MHz will only deliver a performance benefit which is greater than a single site with a 700 MHz carrier if the with-700 MHz site is near full capacity. This is because if the with-700 MHz site was not near full capacity, it could match the higher speeds provided by the additional site without 700 MHz. Based on the distribution of traffic across sites we expect the number of areas where there is a performance benefit in the without-700 MHz case to be limited.

4.47 The methodology behind estimating the performance benefit is discussed in more detail in section 3.3 and section 5.2 of the Analysys Mason report.

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[21] Analysys Mason refers to this estimate as the adjusted technical value less the network cost savings. The same assumptions drive the central range as in the network cost saving calculation. The wider range of the performance benefits is between £180 million and £660 million.

4.48 Overall we think there are a number of areas where there could be a benefit from deploying 700 MHz to improve performance. We believe the Analysis Mason estimate, of between £390 million and £480 million, provides a good approximation of this performance benefit although it may overstate it to a small extent.

Consumer pricing benefits

4.49 Given the competitiveness of the UK mobile market we believe that a change of use of 700 MHz would result in significant benefits for consumers in the form of lower mobile tariffs. This could encourage take-up of new services and reduce the monthly cost consumers pay for mobile services.

4.50 Hazlett and Muñoz (2009)[22] offer support for the view that additional spectrum allocations reduce consumer prices. Their empirical model uses econometric analysis to study the relationship between frequencies allocated to cellular services and retail prices for twenty-eight countries between 1991 and 2003, finding that larger quantities of spectrum are associated with lower prices. A limitation of the Hazlett and Muñoz study in the context of change of use of the 700 MHz band is that it considers the effects of increased spectrum allocations on mobile voice and text services, not the provision of mobile data services.[23] However, it provides empirical support for the type of effect relevant to consumer pricing benefits.

4.51 Consistent with the findings of Hazlett and Muñoz, we consider there to be a number of different mechanisms through which an increase in spectrum being made available for mobile use could reduce consumer prices. Below, we consider two possibilities; a reduction in the marginal costs of providing mobile services and an easing of capacity constraints.

A reduction in the marginal cost of providing mobile broadband

4.52 An operator that gains some 700 MHz spectrum as a result of change of use is likely to experience a reduction in the marginal cost of serving additional traffic, all else being equal. This is because, absent this extra spectrum, the operator would be required to build out its network to meet increasing demand for mobile data services (as discussed above). The expected costs which operators would incur from the building of new sites to cater for this increasing demand or more customers without 700 MHz would increase the marginal cost (compared to the lower marginal cost of providing additional traffic capacity with 700 MHz). A change of use of 700 MHz would therefore reduce the marginal cost compared to the counterfactual.

4.53 We recognise that it is likely that a change of use of 700 MHz would result in substantial costs to operators winning the spectrum (for example through an auction). Therefore, even though the marginal costs of providing mobile data to consumers may fall with access to 700 MHz, it is unclear whether their total costs will fall. [24]

4.54 However, even in the case where operators' total costs do not fall with change of use, there may be a consumer pricing benefit associated with a change in the cost

[22] Hazlett, T.W. and Muñoz, R.E. (2009), *Welfare analysis of spectrum allocation policies,* The RAND Journal of Economics, 40: 424-545

[23] We have been unable to extend the Hazlett and Muñoz study to include mobile data due to limitations in the availability of the required evidence.

[24] It is quite possible that total costs will be lower, particularly in a second-price auction where the winner pays the value of the next-highest bids, which might be substantially below its own valuation.

structures of mobile operators. This is because the spectrum acquisition fees are to some degree fixed costs.[25] Standard economic theory suggests that competitive firms' pricing decisions should be informed by the relationship between demand and marginal costs. In general, a reduction in marginal costs tends to lead to a reduction in prices.

4.55 The extent to which any marginal cost saving will be passed through to consumers in this way depends on a number of factors including (i) whether the reduction in marginal costs is experienced by a specific firm or more widely and (ii) the market structure and competitiveness of the industry.

4.56 We also consider that a reduction in the marginal costs of mobile operators could lead to greater competitive intensity between operators. This is because operators will find it more attractive to compete for new consumers where the cost of serving them is reduced. We would expect any increase in competitive intensity in the mobile market to provide further pricing benefits to consumers.

An easing of capacity constraints

4.57 Spectrum is an essential input for the provision of mobile broadband and mobile providers hold a finite amount. With their existing spectrum holdings, the four national mobile networks are able to meet current traffic demands. However, given the forecasted growth of mobile data traffic this might not continue to be the case in the medium term.

4.58 In many cases, operators may look to meet increased demand by investing in building new mobile sites on their networks, as explained in our discussion of network cost savings. However, absent access to more spectrum, operators are likely to run into localised capacity[26] constraints where the practicality of building additional new mobile sites restricts their ability to meet increased demand (for example, protected areas or where planning permission cannot be obtained).

4.59 Our analysis of network cost savings focuses on whether operators are able to deploy macro sites in order to overcome capacity constraints in the absence of additional available spectrum. This is a simplifying assumption for the purposes of modelling and we expect that going forward MNOs will increasingly use small cells to meet localised capacity constraints. Analysys Mason considers that small cells and macrocells have similar costs per unit of capacity and forecasts that macrocells will be slightly more cost effective than small cells.[27] Therefore, although Analysys Mason's modelling approach may overstate the number of macrocells deployed, the overall cost of deploying a large number of small cells to meet some of this demand is likely to be similar or greater than Analysys Mason estimate.

4.60 We would expect that capacity constraints would tend to reduce the incentives for operators to compete: in general a firm is unlikely to reduce its prices to win new

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[25] Fixed costs do not vary with output. Spectrum licences acquired in an auction, are tradable but spectrum is only likely to be sold in material block sizes (such as 2x5 MHz or 2x10 MHz), and spectrum trades are expected to occur infrequently, so that in practice costs of spectrum acquisition are significantly less variable than network costs and, to some degree, fixed with respect to additional traffic.
[26] We are using the term "capacity" here in the general sense of the ability to serve customers.
[27] Analysys Mason, May 2014, *Assessment of the benefits of a change of use of the 700MHz band to mobile,* section 3.2.6*:* http://stakeholders.ofcom.org.uk/consultations/700MHz/

customers if it does not have the capacity to serve them. A reduction in prices by an operator in this situation would simply reduce the operator's revenues rather than increase their customer base since they would be unable to serve additional subscribers.

4.61 A change of use of the 700 MHz band would offer mobile operators the opportunity to acquire additional spectrum. This could prevent consumers from experiencing lower levels of service in certain areas (localised capacity constraints), helping to maintain competitive intensity in the industry. Thus, resulting in lower prices for mobile broadband services than would be expected if capacity constraints were allowed to develop in some areas.

Potential scale of consumer pricing benefits

4.62 Although we consider that significant consumer benefits would arise from a change of use of 700 MHz, we have concerns that an estimation of these potential benefits would involve a substantial degree of double counting of our network cost savings estimate. While the approach used to estimate network cost savings is reasonable on its own terms, it relies on certain assumptions (e.g. taking consumer demand as given) which do not allow for additional modelling of pricing outcomes in the market (which would require us to treat demand as a function of prices).

4.63 Because of the difficulty of identifying consumer pricing benefits which could, with confidence, be taken as additional to the network cost savings, we do not attempt to quantify the consumer pricing benefits described above. However, in practice a significant proportion of the benefits which we have quantified as network cost savings could in practice be realised by consumers through lower prices (than they otherwise would have in the absence of change of use of 700 MHz). Given our duties to consumers and citizens, we consider these benefits to be particularly important.

4.64 As an illustrative calculation of the benefit of lower prices, we have considered what percentage reduction in consumer prices would lead to an increase in consumer surplus broadly similar in magnitude to the network cost savings estimate, described above. Using traffic and pricing data from Analysys Mason, we estimate that a 1% reduction in consumer prices (operator mobile data ARPU) could result in an increase in consumer surplus of around £700 million (over a 20 year period from 2022). This is a value towards the upper bound of Analysys Mason's central range in its network cost savings estimate. However, we stress that the consumer pricing estimation is purely indicative and its magnitude reflects the scale of the mobile market.

New services and technology

4.65 If there is international consensus, the 700 MHz band will be unique as a sub 1GHz spectrum band harmonised across most regions of the world (with the exception of a few countries including the US). We would expect this to mean that the band would be supported by the majority of new mobile handsets worldwide. This may have implications on how new services, which could have significant value for consumers and citizens, could be deployed using the 700 MHz band. As a result of global harmonisation there could be new services exclusive to the 700 MHz band, increasing the consumer benefits for all countries which adopt the band for mobile use.

4.66 At this stage, we are unaware of any specific innovation that could be uniquely suited to a globally harmonised 700 MHz band. This is not surprising given the timeframes involved and the unpredictability of future technological change. But new services, potentially exclusive to the 700 MHz band, could develop between now and a change of use of the 700 MHz band. Alternatively, the 700 MHz band could support earlier development of certain services than would be possible in other bands.

4.67 It is difficult to estimate the size of this potential benefit since these possible future services are, as yet, unknown. The potential benefits range from the hundreds of millions if highly-valued services are launched exclusively in this band and taken-up by millions of users, or zero if new services can be accessed without the 700 MHz band.

4.68 As well as the possibility of new services, the 700 MHz band might also be used to deploy a new mobile technology. This could be a future release of LTE or a new technical standard.

4.69 Depending on the timing of release of the 700 MHz band and the availability of new technologies, release of the band could either:

- avoid the need to re-farm other low frequency spectrum. This could avoid costs associated with re-farming and/or reduce the time needed to roll out a new network; or

- result in faster roll out and/or improved coverage if higher frequency spectrum was the only alternative for deploying this new technology.

4.70 At present it appears the technology most likely to be deployed using the 700 MHz band is some variant of LTE. It also appears that the timing of change of use would be too late to be one of the first bands to use a future LTE release, such as later flavours of LTE-Advanced.

4.71 However the long lead times mean that by 2022 the 700 MHz band might be important for deploying a new technology in Europe just as the 800 MHz band was for LTE. Given the uncertainty we have not placed much weight on this benefit but recognise it as a potential upside.

Benefits of using the centre gap

4.72 As discussed in paragraph 5.26 the benefits quantified above are based on a 2x30 MHz band plan. This band plan involves a centre gap (the gap between the uplink and downlink spectrum) of 25 MHz which could be used for other services.

4.73 The most likely use of the spectrum would be either PMSE use or supplemental downlink use:

- If the centre gap was used for PMSE this would reduce the impact, and associated costs, of changing use of the 700 MHz band on the PMSE community.

- SDL allows mobile networks to provide additional downlink only capacity. This could have a number of benefits including additional network cost savings and the ability to offer faster downlink speeds. Up to 15 MHz of spectrum could be made available for SDL under European harmonisation options. This spectrum would be utilised in a subset of devices and therefore there is a risk this spectrum could be less valuable than harmonised paired spectrum. As an illustration we have estimated the value of an additional 15 MHz of downlink spectrum using the

Analysys Mason model, the total benefit is between £60 million and £110 million.[28] However as explained this risks overstating the benefit if the centre gap was used for SDL.

4.74 We have not quantified the benefits of using the centre gap for either of the above uses. However, we note that any use of this spectrum would have a net benefit. Given the uncertainty over future use at this stage it is difficult to estimate the magnitude of this benefit.

Emergency service use

4.75 In the UK, the PPDR service used by the police, fire and ambulance services is currently provided by Airwave and based on the ETSI TETRA (terrestrial trunked radio) standard. The Airwave service operates in a number of bands between 380 and 470 MHz. Approximately 14 MHz (2 x 7 MHz) is assigned to Airwave to support its service, although additional bandwidth is made available in certain locations to provide extra capacity.

4.76 Airwave provides robust and secure voice and narrowband data messaging services. The system offers radio functionalities tailored for the emergency services, such as group calling, nationwide roaming and direct mobile to mobile calls without network infrastructure support.

4.77 The current PPDR network cannot deliver high speed mobile broadband services. A number of options are under consideration in the UK and internationally for deploying next generation PPDR networks. There is a possibility that the 700 MHz spectrum could be used for PPDR by the emergency services, whether by securing capacity on mobile networks or by using part of the band directly with specific or shared spectrum.

4.78 Use of high speed mobile broadband networks by the emergency services could deliver significant benefits. Example uses include fire fighters being able to download high resolution building plans in order to navigate safely in darkness or smoke. Another possible use is the ability to upload high quality videos and photos from a crime scene in real time.

4.79 However, at this stage it is unclear what role the 700 MHz band will play in the future delivery of PPDR services. Decisions on whether and how the 700 MHz band might become part of the delivery of PPDR communications are a matter for Government. We are noting them here as alternative use of part of the spectrum could affect the benefits of change of use of the band.

4.80 Using some of the spectrum for PPDR use could potentially reduce the spectrum available for consumer mobile broadband services and some of the benefits identified above.[29]

4.81 However, if 700 MHz spectrum were to be released for PPDR, it would be on the expectation that there would be a net benefit from doing so above using it for consumer mobile broadband. That is, the benefits of PPDR use would be greater

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[28] This is based on three operators winning an additional 2 x 5 MHz of 700 MHz spectrum.
[29] This depends on how the band would be made available for PPDR use. Some options may not reduce the total spectrum available for mobile use.

than the benefits that could have been achieved from mobile use alone. We have not quantified this potential additional benefit.

Question 1: Do you have any comments on Analysys Mason's approach to quantifying the network cost savings and performance benefits?

Question 2: Do you have any comments on the other benefits we have identified including the likely magnitude or how they may be quantified?

Question 3: Do you agree with our assessment of the likely benefits of changing use of the 700 MHz band?

Section 5

Implications for the DTT platform and resulting costs

5.1 Having discussed the benefits that could be associated with change of use of the 700 MHz band, we now move on to consider the costs that could arise as a result of such a change. This section sets out our assessment of the implications for the DTT platform of a change of use of the 700 MHz band.

5.2 The section starts by summarising who the existing DTT users of the 700 MHz band are. It then describes the changes to the DTT frequency plan that would need to be made in the event of change of use of the 700 MHz band. Finally, it discusses the changes to broadcast infrastructure that would need to be made in order to enable change of use of the 700 MHz band and consider the costs and timescales that could be associated with these changes.

5.3 The section sets out the following provisional views.

a) Change of use of the 700 MHz band would require changes to be made in the frequencies used to transmit DTT services.

b) We believe it is possible to plan and implement these changes in such a way as to safeguard the on-going delivery of the important benefits provided by the platform. Specifically the changes will retain:

   - near-universal coverage for public service broadcasting (PSB) services;

   - a broad range of services on six national DTT multiplexes with coverage broadly matching that achieved today; and

   - local TV services and the Northern Ireland multiplex (again with coverage broadly matching today).

c) We consider that the current mix of transmission technologies would support achieving these objectives[30].

d) DTT transmission infrastructure would require changes to allow it to operate at revised frequencies. We estimate the costs associated with these modifications to be between £350 million and £390 million (2014 NPV), based on Arqiva's advice to date. We use these figures for the analysis in this document, but believe there may well be scope to reduce costs below this range.

e) We estimate that the reduction in value from the loss of access to the band for existing DTT services is between £80 million and £100 million.

[30] I.e. continuing with five DVB-T multiplexes and one DVB-T2 multiplex nationally, and the Northern Ireland multiplex using DVB-T2 and probably the local TV multiplex using DVB-T. We note however that changing the transmission standard to DVB-T2 in some locations might have benefits in the case of the local TV multiplex.

A number of parties provide services on the DTT platform

5.4 There are six UK-wide DTT multiplexes and a local television multiplex using spectrum in the 700 MHz band (694-790 MHz) in addition to other frequencies at 470 to 694 MHz. Three of the UK-wide multiplexes we classify as PSB multiplexes (Multiplexes 1, 2, B) and three of which we classify as commercial multiples (Multiplexes A, C, D).

5.5 Each of these multiplexes bar one has two licences – a Broadcasting Act 1996 licence and a Wireless Telegraphy Act 2006 licence. The basic division between the licences is that the Broadcasting Act licences create an obligation on the multiplex operators to provide a service on the terms of that licence. The Wireless Telegraphy Act licences authorise the establishment, installation and use of radio equipment on certain frequencies for broadcasting in accordance with the terms of the Broadcasting Act licences. The exception is Multiplex 1, owned by the BBC, which only has a Wireless Telegraphy Act licence. The obligations that would otherwise be covered by the Broadcasting Act licence are included in the BBC's Charter and Framework Agreement.

5.6 In addition, there are two short term multiplexes using spectrum in the 600 MHz band, and two 'Geographic Interleaved' multiplexes which are licensed under the Wireless Telegraphy Act only.

5.7 These licences all contain general provisions regarding their possible variation or revocation with appropriate notice[31].

a) PSB multiplexes – there are three multiplexes provided by the BBC and Digital 3 and 4 that broadcast from a network of over 1,100 transmitters and are available to 98.5% of households.

b) Commercial multiplexes - there are three commercial multiplexes licensed to Arqiva and SDN that broadcast from the largest 80 transmitters achieving coverage of around 90% of households.

c) Geographical Interleaved (GI) spectrum licences – two portions of spectrum that can be used to provide a DTT multiplex in Manchester and Cardiff.

d) Northern Ireland multiplex – one multiplex that broadcasts RTÉ and TG4 from three transmitters and covers approximately 78% of households in Northern Ireland.

e) Local television multiplex - Comux holds licences to broadcast the local TV multiplex which has launched recently and has set out plans to broadcast from 40-60 transmitter sites and achieve coverage of up to 50% of households. The award of this licence specifically referred to the possibility of change of use of the 700 MHz band[32]. Since Comux won its licence, Ofcom has been awarding

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[31] For example, in the case of Wireless Telegraphy Act, revocation can occur for spectrum management reasons subject to five years' notice. DTT Broadcasting Act and Wireless Telegraphy Act licences are available at: http://licensing.ofcom.org.uk/tv-broadcast-licences/current-licensees/multiplex/

[32] Invitation to Apply for a local TV multiplex licence, 10 May 2012: http://licensing.ofcom.org.uk/binaries/tv/local-tv/archive/Invitation.pdf see for example paragraphs 5.15 to 5.24 including "In the longer term, these developments could lead to a change in the use of the 700 MHz band, with TV broadcasting being cleared from that spectrum in countries that decide to

licences for local TV services in various locations to be carried on this multiplex and this process is continuing.

f) Interim multiplexes - Ofcom awarded the 600 MHz spectrum band (550 to 606 MHz) to Arqiva on an interim basis by granting a single licence for the establishment of temporary DTT multiplexes using DVB-T2/MPEG4 technology. This service is authorised through a Wireless Telegraphy licence. The basis on which we made it available was to support short term use[33] and the terms of the award set out specifically that we would revoke the licence to enable change of use of 700 MHz if we made a decision in favour of such a change[34].

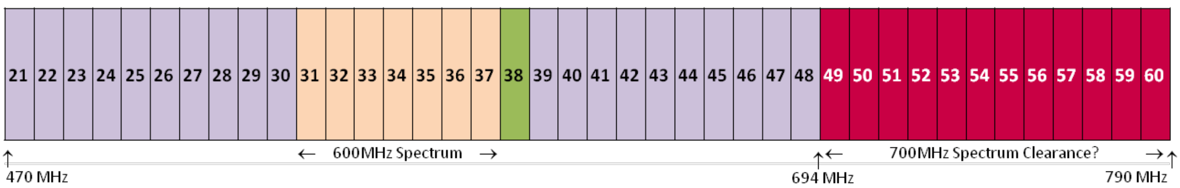
Change of use of the 700 MHz band would require revisions to the DTT frequency plan

5.8 These DTT services all operate in the spectrum between 470-790 MHz[35]. As shown in Figure 3, the 700 MHz band constitutes an important part of this frequency range.

5.9 Ensuring that all of the services can satisfy their coverage objectives without causing interference to each other in a limited amount of spectrum involves careful planning of the frequencies used at each transmitter.

5.10 If there were a change of use of the 700 MHz band, DTT services would no longer be able to operate at these frequencies. This means that the DTT frequency plan currently in use (which outlines the frequencies used at individual transmitter sites) would have to be modified so that that all current DTT allocations which fall into the 700 MHz band would be reallocated into the broadcasting spectrum below the 700 MHz band.

Figure 3: Frequencies from 470 to 790 MHz



We wish to safeguard the benefits associated with the DTT platform

5.11 The DTT platform performs important roles in providing low cost near-universal access to PSB services and in sustaining viewer choice of services, platforms and equipment. We are committed to safeguarding the on-going delivery of these benefits. As outlined in the *UHF strategy statement*, we consider that the delivery of these objectives can continue in case of changes to the 700 MHz band.

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do so. If this happens, then there could be a need to rearrange the frequencies used by TV broadcasting in the UK, which would have an impact on the use of GI spectrum by the planned new local multiplex service as well as the established national DTT multiplexes.”
[33] UHF strategy statement: http://stakeholders.ofcom.org.uk/binaries/consultations/uhf-strategy/statement/UHF_statement.pdf, paragraphs 1.47-1.58.
[34] See our statement on the award of the interim 600 MHz licence at http://stakeholders.ofcom.org.uk/binaries/consultations/600 MHz-award/statement/600_MHz_Statement.pdf, for example at paragraphs 1.3 and 2.46 to 2.68.
[35] With the exception of 606-614 MHz (channel 38) which is used exclusively by PMSE.

5.12 If we were to proceed with change of use of the 700 MHz band, we would seek to develop a revised frequency plan which would provide for the continued delivery of:

- near-universal coverage for PSB services;
- a broad range of services on six national DTT multiplexes with coverage broadly matching that achieved today;
- a similar range of local TV services to those that the platform is capable of delivering today; and
- the services carried on the Northern Ireland multiplex.

5.13 We would also seek to ensure that the PSB multiplexes retained the ability to broadcast programming specifically for the UK Nations and English regions. We would not, however, seek to ensure the continued delivery of the interim multiplexes that were licensed on an interim basis with the possibility of revocation from 2018 set out at the time of award. This issue is discussed in more detail further on in this section.

An updated DTT frequency plan would require international coordination

5.14 Radio signals do not stop at international borders which means that UK DTT transmitters can cause interference abroad, and viewers in the UK can be affected by interference from international transmitters. International agreements are therefore required when deploying or replanning high power services such as broadcasting, so as to manage the impact of interference between services in different countries.

5.15 The UHF spectrum band is currently primarily used for DTT broadcasting services as allocated in the ITU Radio Regulations and the Geneva 2006 Agreement (GE06 Plan), the relevant regional agreement to which the UK is a party. The GE06 Plan documents all registered broadcasting assignments for Europe and the surrounding countries and the agreements that govern the conditions under which they can operate. However these plans are relatively high-level, i.e. they only include allocations for each country's largest transmitters. They have been subject to subsequent bilateral agreements, for neighbouring countries to identify additions or modifications to existing plans for transmitters not specifically covered in the GE06 Plan.

5.16 In order to implement a change of use of the 700 MHz band, the UK and its neighbouring countries would need to negotiate a revised set of agreements governing high power DTT transmissions. This could be achieved either through a mixture of bilateral and multi-lateral meetings, or a larger scale planning conference as was put in place to achieve agreement for the GE06 Plan. If we were to proceed with change of use of the 700 MHz band, our current preference would be to pursue an approach to DTT replanning based on bilateral and multilateral co-ordination meetings, as opposed to a large-scale planning conference. Based on exploratory discussions to date, we believe the majority of neighbouring administrations also favour such an approach.

5.17 In our view an approach to international frequency co-ordination based on bilateral negotiations would likely yield quicker agreements than a planning conference. A conference is likely to take a long time to plan and arrange and any agreements reached would likely require modification through subsequent bilateral agreements. Nonetheless, irrespective of which approach is taken, we anticipate that the international co-ordination process (and therefore the development of a revised DTT frequency plan) would take a number of years to complete.

5.18 The outcome of international frequency co-ordination negotiations would determine the coverage and number of multiplexes the DTT platform was able to deliver following change of use of the 700 MHz band. As discussed below, the agreements reached at an international level would also be an important determinant of the specific modifications to DTT infrastructure in different locations across the network and, as a result, of the number of consumer aerial changes that might be needed if change of use of the band occurred.

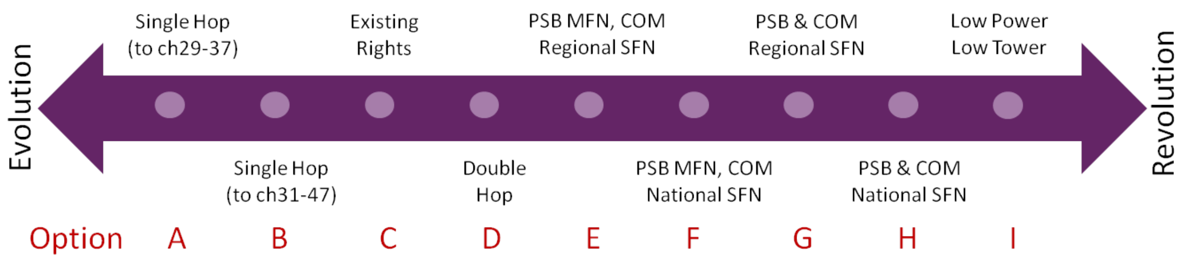
We would favour an evolutionary approach to DTT replanning

5.19 If we were to proceed with the changes discussed in this document, engaging internationally on the DTT frequency plan with a view to securing optimal outcomes for UK citizens and consumers would be a high priority for Ofcom. Consistent with the approach set out in our *UHF strategy statement*, we are already engaging in exploratory discussions with our neighbours.

5.20 In order to inform these discussions with our neighbours and to help us assess the implications of change of use of the 700 MHz band, the DTT Frequency Planning Group (DFPG)[36] has put together a range of options for DTT frequency plans which could be put in place in the event of change of use of the 700 MHz band.

5.21 The options identified by the DFPG range from evolutionary (moderate changes to the current DTT band plan) to revolutionary (entirely new DTT band plans) as shown in Figure 4 below.

Figure 4: DTT band plan options



5.22 Annex 8 provides a fuller description of the wide range of options we have been considering and of their implications. Our view is that it would be beneficial for UK citizens and consumers, and probably for our neighbours as well, to seek to secure an option involving changes that are relatively limited, i.e. options A or B which seek to minimise the number of affected transmitters and the number of frequency changes involved[37]. This would support securing our objectives for the DTT platform. At paragraph 6.52, we provide our assessment of infrastructure costs resulting from

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[36] The DFPG is chaired by Ofcom and has replaced the Joint Frequency Planning Project (JPP). DFPG comprises representatives from each of the DTT multiplex licensees, the BBC and transmission company Arqiva.

[37] We use the terminology 'single hop' to describe a plan where the DTT multiplexes in the 700 MHz band are moved directly to their final frequencies in the 600 MHz band,

changes to the frequency plan. We reflect the risk of not reaching a coordinated agreement on the basis of option A or B, through a consideration of option E.

We believe it would be possible to develop a frequency plan which allowed for the continued delivery of the benefits provided by DTT

5.23 In its response to our *2013 CFI*, Digital UK suggested that:

> 'Ofcom's cost-benefit analysis needs to take into account the potential loss of consumer and citizen benefit that would arise were the DTT platform to be weakened as a result of any 700 MHz clearance process – this would include the potential loss not only of DTT services, but also the wider competition and innovation benefits identified in Digital UK's discussion of the benefits conferred by the DTT platform.'[38]

5.24 We agree that securing the on-going delivery of the benefits currently provided by the DTT platform to citizens and consumers will be an important objective if any change of use of the 700 MHz band takes place, and have carried out our analysis with that objective in mind.

5.25 As set out in Annex 8, the assessment undertaken by the DFPG indicates that if we were to proceed with change of use of the 700 MHz band, it should be possible to develop a frequency plan which allows for the continued delivery of PSB coverage, reach and range of services similar to today through six national multiplexes.

5.26 Providing the potential coverage and number of services similar to today for the local TV multiplex following change of use of the 700 MHz band would be more challenging. However, there are a range of techniques that we believe could be used to address these challenges. These include considering the local TV multiplex in the frequency planning process from the outset, in contrast to the way in which it was initially planned as a service that fitted around pre-existing services, reviewing its operating parameters alongside those of other multiplexes, with a view to optimising performance, or potentially considering in some locations the role of a transmission mode that is more robust in the presence of densely packed services (i.e. a potential option of DVB-T2 where relevant when the multiplex currently transmits using DVB-T in all locations). On balance, we therefore believe that it would be possible to plan in such a way as to enable the continued availability of local TV services, as well as the services carried on the NI mux.

5.27 Some stakeholders have mentioned the role that DVB-T2 might play in maintaining coverage of the national DTT multiplexes, should a replan of the 700 MHz band occur[39]. In principle, we agree that there is some risk of a reduction in DTT coverage resulting from a replan to move services using 700 MHz to 600 MHz and that this is an issue to which we should be particularly attentive.

5.28 Our analysis to date indicates the following.

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[38] http://stakeholders.ofcom.org.uk/binaries/consultations/700mhz-cfi/responses/Digital_UK_members.pdf

[39] For example, Digital UK argued that 'even with an optimal international outcome, none of the planning scenarios currently under consideration would maintain the same DTT coverage as today without a migration of Freeview to DVB-T2 broadcast standards'.

- **The risk appears to be small**: as set out above, we have developed a number of candidate DTT band plans in the event of a change of use of the 700 MHz band. Early indications are that with two of these plans it should be possible to achieve our objectives for DTT coverage, broadly matching existing coverage for the six national multiplexes, using the current mix of transmission technologies.

- **It is not clear that greater use of DVB-T2 would be an effective mitigation for any potential coverage reduction**. Coverage calculations from the DFPG indicate that a DVB-T2 migration would only offer a small offset against coverage losses.

- **DVB-T2 upgrade[40] is costly**: as set out in the Ofcom discussion document *Future of free to view TV,* there are significant consumer costs associated with a DVB-T2 upgrade. While these costs would need to be balanced against the benefits from such an upgrade, we expect that the scope for DVB-T2 to address a potential coverage loss from 700 MHz change of use would be, at most, limited in scale relative to the other benefits and the costs associated with DVB-T2 upgrade.

5.29 As indicated above, it might be that a transition to DVB-T2 for local TV services could, in some locations, play a role in securing coverage objectives. However, this is only one of several means to secure continued benefits from the delivery of local TV and it is not clear that use of DVB-T2 in locations presenting particular challenges would be sufficiently effective in improving coverage to make it a useful option. For the avoidance of doubt, a move to use DVB-T2 for local TV in some locations would not require other national multiplexes to migrate to DVB-T2.

5.30 Based on the above considerations, our view is that change of use of the 700 MHz band could be achieved without further migration to DVB-T2. We have conducted our cost-benefit analysis on this basis.

5.31 We recognise that our assessment of the coverage and services (as supported by a number of multiplexes) that the DTT platform would be able to deliver following a potential change of use of the 700 MHz band is to some extent contingent upon the outcome of international frequency co-ordination negotiations. If these negotiations were to progress in such a way that it appeared that we could not achieve our objectives in relation to coverage and number of multiplexes, we would need to consider carefully the reasons for that progress and whether it might justify revisiting some of the proposals set out in this document. However, at present we believe the likelihood of having to do so is low.

DTT infrastructure would need to be modified in the event of change of use of the 700 MHz band

5.32 In the event that we were to proceed with change of use of the 700 MHz band, DTT transmission infrastructure would need to be modified to allow it to operate at revised frequencies. In the following paragraphs we describe the infrastructure that is used for DTT transmission and then set out the modifications that would be needed to this infrastructure and the associated costs.

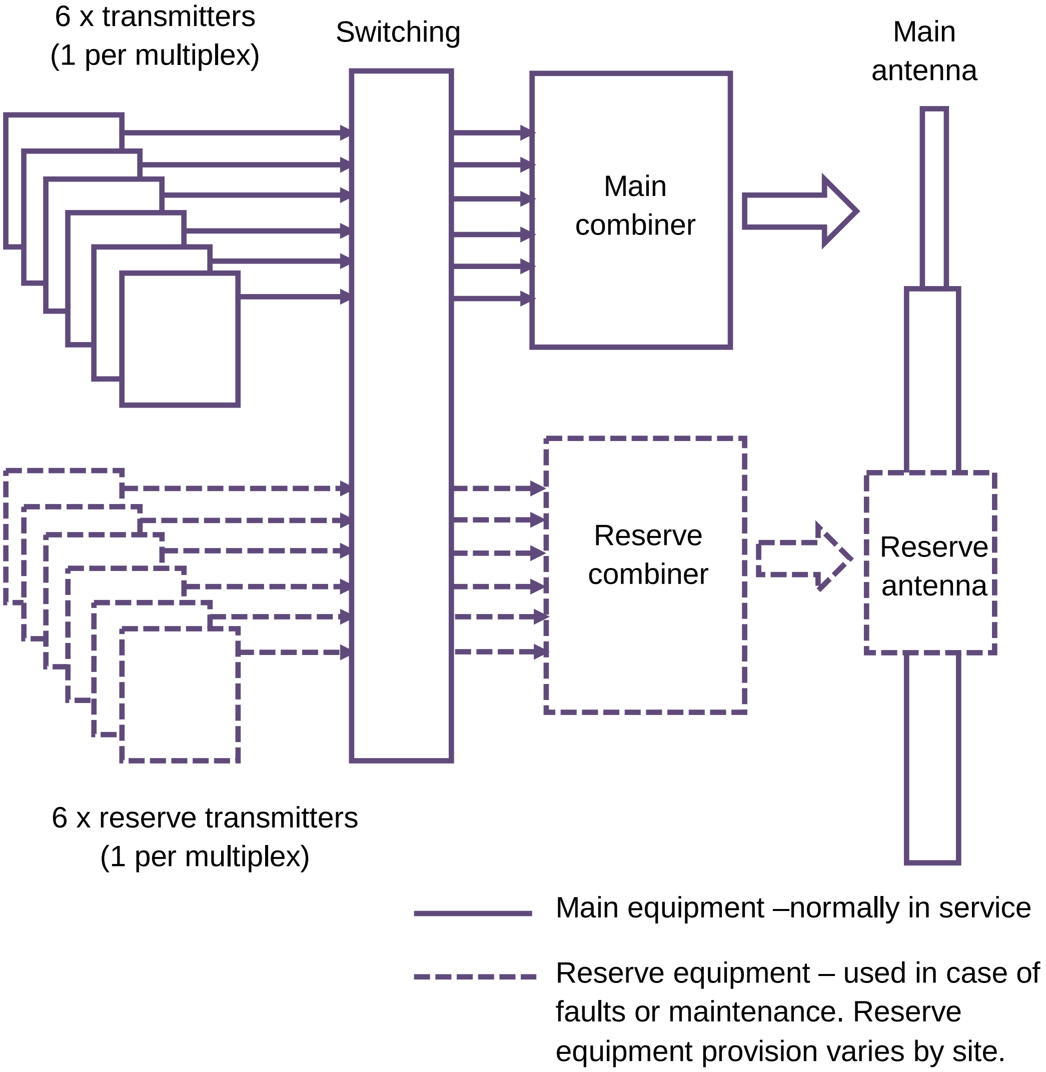
5.33 There is a great difference between the number of households served by individual transmitters in the DTT network. The largest main transmitters serve several million

[40] Any DVB-T2 upgrade would be accompanied by a move to MPEG-4.

households each, while the smallest relay transmitters serve only around 200 households. This disparity leads to differences in how the transmitters are implemented – for example the scale of the installation or the amount of reserve equipment that is provided in case of faults occurring. Each of the transmitters in the DTT network is however based upon similar building blocks.

5.34 Figure 5 provides a high level block diagram of the infrastructure that is used to broadcast DTT multiplexes. In general six transmitters, one for each of the six national multiplexes, are installed at a main transmitter site (three at a relay transmitter, one for each of the three PSB multiplexes) and these produce the radiofrequency signal that is to be broadcast to viewers' receivers. The output signals from the six transmitters are fed to a combiner unit that enables the six multiplex signals to be broadcast from the same transmitting antenna on the mast. At larger transmitters, main and reserve transmitters, combiners and antennas are provided, so that service can be maintained with minimal disruption under fault conditions.

Figure 5: Transmitter site block diagram



5.35 Many of the relevant DTT transmission infrastructure components are designed to operate over a limited set of specific frequencies and have limited versatility to change frequency. The relevant elements of the broadcast chain for the purposes of a frequency replan are:

a) transmitters;

b) combiner units; and

c) transmitting antennas.

5.36 In order to implement a change of use of the 700 MHz band, DTT network infrastructure would need to be modified or replaced to enable it to operate at the revised frequencies. Under any of the frequency plans identified above, this would include the reconfiguration or replacement of a substantial proportion of broadcast antennas (and the use of temporary masts and other infrastructure, whilst antenna reconfiguration occurs), retuning of transmitter and combiner units, and modifications at relay stations.

5.37 The outcome of the international frequency planning and coordination process would determine the extent of frequency changes which would be needed. By extension, this would also determine the scale of, timelines for and cost of infrastructure changes associated with any DTT reconfiguration.

Initial estimates indicate that DTT infrastructure changes could cost in the region of £350m-390m

5.38 In order to get a sense of the likely scale of the costs of a potential reconfiguration of the 700 MHz band, we commissioned a study from transmission company Arqiva, to provide estimates of the costs of DTT infrastructure modifications based on its experience of owning and operating the DTT infrastructure and with 800 MHz clearance and Digital Switchover.

5.39 As set out above, the scale, cost and timescales for network modifications could change to a potentially large extent if the frequency plan for DTT differed from our preferred options in a material way. We do not at this time have certainty over the frequency plan that we might be able to co-ordinate with our international neighbours. We recognise that, as noted by Digital UK in its response to our *2013 CFI*, it is important that estimates of infrastructure modification costs reflect this uncertainty. In order to do this, we asked Arqiva to provide estimates of costs for two different planning scenarios so that we have a range of possible costs upon which we can base our analysis. The two options examined are:

- a single hop minimal change scenario in which services in the 700 MHz band are moved lower in the DTT band (ch29-37) – based upon frequency plan option A above; and

- a commercial multiplex SFN scenario in which each commercial multiplex is realised as a number of regional SFNs, while PSB multiplexes operate as a MFN – based upon frequency plan option E.

5.40 As well as being dependent upon the final frequency plan, the cost to implement a replan of the DTT network would depend upon the method adopted to move transmitters to alternative frequencies.

5.41 A consequence of carrying out engineering work on the DTT network is that certain parts of the broadcast chain will be unavailable while they undergo modifications. At the larger transmitters, main and reserve equipment is available. This means that in principle, DTT services could be switched to reserve equipment while the main equipment is modified. The services could then be switched back to the main equipment and the reserve chain then modified.

5.42 While the above method would ensure that the services continue to be broadcast, the reserve equipment would however not be available during the period that modification works are carried out, thus temporarily reducing the resilience of the network. As modification work at a particular transmitter can take some weeks or months to carry out (particularly if the transmitting antennas have to be replaced), this period of reduced resilience could be prolonged.

5.43 There are a number of measures that can be taken to mitigate the risk to DTT services, such as the installation of temporary reserve equipment, or even installation of a second mast complete with duplicate antennas where the main and reserve antennas at a large transmitter need to be replaced. In practice the approach taken would depend in large part upon decisions about the degree of resilience required during the transition process. Decisions taken regarding the approach to ensuring network resilience during the transition process would have a significant impact on the timescales and costs of implementing change of use of the 700 MHz band.

5.44 Taking a precise view on network resilience during a process of change would involve reviewing the specific circumstances of each transmission site in light of the frequency plan. This could only happen in a detailed sense much later. At this stage and for the purpose of our cost-benefit analysis, we have sought to reflect a range of methods for implementing a replan of the frequencies used by the DTT platform and Arqiva based its corresponding analysis on two implementation methods for each of the two band plans considered. This took account of the experience of DSO and 800 MHz clearance, which suggests that temporary masts would not be appropriate for all transmitter sites requiring changes.

- The high scope or ‘Standard SLA solution’ estimate is based upon minimising the reduction in resilience of each transmitter to ensure minimal impact on the contractual service level agreements (SLAs) between Arqiva and the multiplex operators. This option envisages that temporary masts and antenna systems would need to be deployed at all main transmitters where any antenna works are required (21 in total).

- The reduced scope estimates are based on avoiding the use of temporary masts wherever possible, but would require agreement from broadcasters that they are prepared to accept an increased degree of risk while the engineering works are carried out and subject to consideration of associated costs. Arqiva advises that use of temporary masts is likely to be unavoidable at around 7-8 transmitters due to constraints upon how the changes could be implemented (e.g. due to availability of space on existing masts or establishing safe methods of work).

Costs

5.45 A full description of the implications for DTT infrastructure of replanning the 700 MHz band, including estimates of the costs and the timescales involved, is set out in Arqiva’s report *700 MHz High Level Estimate – Single hop & PSBMFN/COM SFN Plans* that we have published alongside this consultation.

5.46 Arqiva’s estimates of costs are summarised in Table 4 below.

Table 4: Arqiva estimates of DTT infrastructure costs in 2013 prices

	Total (£m)
Single Hop frequency plan	
High scope	410
Reduced scope	310
COM SFN frequency plan	
High scope	470
Reduced scope	360

5.47 The results illustrate that single hop frequency plan options are around £50m less expensive than those based upon SFN technology. This is primarily because the SFN option requires antenna changes at a greater number of transmitter sites and also because it includes the cost of converting the commercial multiplexes to adopt DVB-T2 which requires additional modules in the transmitter systems to be replaced.

5.48 The reduced scope options are less expensive than the high scope option due to the reduced deployment of temporary masts.

5.49 We have commissioned a review of the above estimates by an independent broadcast consultant, to benchmark the results of the Arqiva study against costs of the 800 MHz clearance and DSO projects. The review concluded that the Arqiva estimates are broadly consistent with previous projects and make reasonable assumptions given the current levels of uncertainty over the final frequency plan and the exact method to be deployed in a potential transition.

5.50 However, experience gained through previous broadcast infrastructure projects suggest that there is likely to be scope for lower costs from the actual scope of the work once we obtain greater certainty over the final frequency plan and matters such as the actual capabilities of the transmitting antennas. It is too soon to know how significant these reductions might be, but our experience leads us to believe that the final costs of modifying DTT infrastructure would likely be of the order of the reduced scope costs identified above, rather than the high scope costs. For the purpose of our central estimate, we therefore identify the Arqiva estimates for the full cost of modifying DTT infrastructure of between £310m and £360m in 2013 prices.

5.51 Arqiva also estimates the cost of reconfiguring the local TV network would be approximately £20 million in 2013 prices.

5.52 We also consider the costs of managing the infrastructure programme. We estimate these costs would be approximately £20 million. These costs are discussed in more detail in section 9.

5.53 For the purpose of our cost-benefit analysis we adjust this estimate to give a 2014 NPV of the total DTT infrastructure costs of between £350 million and £390 million. We discuss these adjustments in Section 9.

Initial estimates suggest that it would be possible to make the 700 MHz band available for use by 2022

Timescales

5.54 Arqiva has also provided indicative plans which set out the timing of the programme of infrastructure modifications. These are outlined in Figure 6. Arqiva suggests that DTT transmitters could begin to move to new frequencies from 2019 onwards, and that the programme of DTT frequency changes could be complete by the end of 2021. This implies that the 700 MHz band could be fully available by 2022.

Figure 6: Potential timeline for DTT infrastructure modifications

5.55 Once again, we believe these estimates to be broadly consistent with previous broadcast infrastructure modification projects and make reasonable assumptions given the current levels of uncertainty over the final frequency plan and the exact method to be deployed in a potential transition. However, experience gained through previous broadcast infrastructure projects would suggest that we may identify ways to reduce these timescales once we obtain greater certainty over the final frequency plan and matters such as the actual capabilities of the transmitting antennas. It is too soon to know how significant these reductions may turn out to be, although it may be possible for the spectrum to be made available sooner – possibly by up to two years.

Loss of value from existing DTT services in case of change of use

5.56 Change of use of the 700 MHz band would result in less spectrum available to the DTT platform than might otherwise be the case. Without change of use it is likely that the platform would continue to access all spectrum between 470 MHz and 790 MHz (excluding channel 38 which is reserved for PMSE), whereas, with change of use the platform would have access to the spectrum between 470 MHz and 694 MHz (again excluding channel 38). The amount of capacity on the DTT platform is one factor in determining the number of SD and HD channels that can be broadcast over it.

5.57 We expect that continued use of the 700 MHz band for DTT and interleaved use by other services (such as PMSE) would likely be the highest value alternative use of the band (after use for mobile broadband). Therefore, the opportunity cost of using the 700 MHz band for mobile broadband use is the loss in value of reduced DTT capacity and interleaved use. We discuss the loss of value to interleaved use, including PMSE and White Space Devices, in Section 7 and Section 8.

5.58 As discussed above, the DTT platform delivers significant value to consumers and citizens. However, at this stage it is very difficult to assess the effect on DTT of a reduction in potential capacity from a future 700 MHz change of use. At present, DTT has access to enough spectrum to run eight multiplexes (including the two interim multiplexes in the 600 MHz band). After a 700 MHz change of use DTT would, as before, have only enough spectrum to run six multiplexes, so the capacity on the two interim multiplexes can be seen as representing the extra capacity that could be sustained absent a change of use of the 700 MHz band. However, the demand for additional DTT capacity is uncertain at this point, particularly as only one of the two interim multiplexes has launched, and only relatively recently. Future demand for capacity may depend on the popularity of HD channels, which use more capacity than SD channels. HD variants of the main BBC, Channel 3 and Channel 4 public service broadcasting services have been available on DTT for a number of years, but to date viewing of these channels has been limited in total and in comparison with their SD variants.

5.59 Indeed, as things stand, only one of the two interim multiplexes is currently in use, delivering 5 HD channels and 1 SD channel to around 70% of the UK population. It may be the case that multiplexing efficiency improvements mean that, if the interim multiplexes need to be taken down due to change in use of the 700 MHz band, then some of these existing channels may be transferred to the remaining six UK-wide multiplexes. In other words, the value of the channels currently on the interim multiplexes may not be lost as a result of a 700 MHz change of use. Alternatively, we also recognise that the number of services available through the two interim multiplexes may increase over time. This issue is considered in further detail in the discussion document on the *Future of free to view TV*.

5.60 There are two options for providing more capacity on DTT than is available at present from the six national multiplexes. One option is to maintain the two additional interim multiplexes beyond 2022. This would entail an operating cost which we estimate at between £250 million and £290 million in 2014 NPV terms. This is based on the cost of running two commercial multiplexes[41], which we estimate is between £22 million and £26 million per year, assessed over a period of 20 years from 2022.[42]

5.61 The other option would be to upgrade the DTT platform to DVB-T2 at a cost of up to £340 million to £370 million, largely driven by the cost to households of buying new TVs or reception equipment (see below for the calculation of these costs). Each of these options would lead to a similar level of DTT capacity.[43] The two options are not

[41] We assume that without change of use the interim multiplexes would be upgraded to offer the same coverage as existing COM multiplexes.
[42] The cost of running a commercial multiplex is approximately £18 per annum. Of this cost approximately £10 million per annum is the network access service and £8 million is the managed transmission service (MTS). If a multiplex was turned off we would expect all of the MTS cost to be saved, but a proportion of the network access costs would be passed on to other multiplexes. We estimate only between 30% and 50% of the network access costs would be saved in the long run.
[43] Although both options provide a similar level of capacity in Mbps terms a full DVB-T2 upgrade would enable more channels to be offered than the current eight multiplexes because of the improvements in compression standards associated with a move to MPEG-4. This is discussed in more detail below.

mutually exclusive, and together they could deliver an even greater increase in capacity.

5.62 Given the uncertainty over future demand for DTT capacity we have considered three possible scenarios of future demand for estimating the opportunity cost:[44]

- Scenario 1: Low demand for DTT – Future demand for DTT is at or below the capacity provided by the current six national multiplexes i.e. approximately 8 HD channels and 60 SD channels. In this case there is not sufficient demand to support the two interim multiplexes beyond 2022 and these multiplexes would close with or without change of use of the 700 MHz band.

- Scenario 2: Medium to high demand for DTT – Future demand for DTT is for more than 8 HD channels (i.e. sufficient to justify continuation of the two interim multiplexes beyond 2022), ranging up to demand for as many channels as can be provided by 6 multiplexes upgraded to DVB-T2 while retaining or increasing the current number of SD channels.

- Scenario 3: Very high demand for DTT – Future demand for DTT exceeds the number of channels that can be provided by 6 multiplexes upgraded to DVB-T2. Within this scenario following change of use of the 700 MHz band the DTT platform with 6 multiplexes would be unlikely to be able to provide enough capacity even with an upgrade to DVB-T2.

5.63 In scenario 1 where there is low demand for DTT, the interim multiplexes would not continue with or without change of use of the 700 MHz band therefore both the opportunity cost and operating cost saving from 700 MHz change of use are zero.

5.64 In scenario 2 without change of use of the 700 MHz band there is enough demand to sustain the two interim multiplexes beyond 2022. If so, by definition the value of doing so would at least exceed the operating cost of between £250 million and £290 million.[45] With change of use of the 700 MHz band there would only be sufficient spectrum for 6 multiplexes instead of 8. So the cost of serving this demand would be the cost of expanding the capacity of these multiplexes such as via a DVB-T2 upgrade (i.e. the net effect is the cost of upgrading minus the operating cost saving from 6 multiplexes instead of 8).

5.65 In the final scenario, there is enough demand to justify *both* continuation of the interim multiplexes and a DVB-T2 upgrade. Even without change of use of the 700 MHz band there would be a need to expand the capacity of the multiplexes, so that all 8 multiplexes had the larger capacity available with DVB-T2. In this case the effect of 700 MHz change of use is that DTT cannot meet the level of demand with 6 multiplexes upgraded to DVB-T2 that it could (and, from a social perspective, should) meet if had the option of keeping 8 multiplexes and also upgrading to DVB-T2.[46]

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[44] We have focused here on the case in which all additional capacity is used to provide HD channels; in practice it could be used for a mix of additional SD and HD channels. We have also made the assumption that either both interim muxes or neither would remain in operation in Scenario 1.

[45] We are considering here the socially-optimal outcome, rather than a commercial decision by DTT platform operators.

[46] Although the platform may have the option to upgrade to more efficient technologies, e.g. HEVC, we do not consider that this is a feasible option in the timescales proposed for change of use of the 700 MHz band.

5.66 Our approach to estimating the DTT opportunity cost is to focus on scenario two, i.e. estimate the cost of a technology upgrade less the operating cost saving of moving from eight to six multiplexes. We have taken this approach as we consider scenarios 1 and 2 are more likely than scenario 3 and by focussing on scenario 2 rather than scenario 1 we have been cautious and allowed for higher potential opportunity costs.

5.67 This approach risks overstating the opportunity cost if the loss in value from moving to six multiplexes does not exceed the cost of upgrading, i.e. there is low demand for DTT capacity. It is less likely to understate the cost as this would only happen if there were very high demand for DTT and therefore a high value of additional DTT capacity beyond the current capacity offered on eight multiplexes.

Upgrading to DVB-T2 and MPEG-4 could mitigate the reduction in DTT capacity

5.68 As we set out above, we do not consider that DVB-T2 upgrade would be necessary to bring about change of use of the 700 MHz band for the purpose of maintaining DTT *coverage*. As such, we have not included the additional costs that a DVB-T2 upgrade would entail in our estimate of infrastructure and consumer costs described above and in Section 6. [47] However, upgrading some or all of the existing multiplexes to DVB-T2 and MPEG-4 is the most likely option that could be used to meet a demand for additional DTT *capacity* in scenario 2 in the event of a change of use of the 700 MHz band. Therefore, we use the costs of a DVB-T2 upgrade as a proxy for the opportunity cost of a change of use of the 700 MHz band.[48]

5.69 The DTT platform would have a range of options for upgrading to DVB-T2, from upgrading a single additional multiplex to DVB-T2 to upgrading all remaining multiplexes. Table 5 shows, for a number of different upgrade options, the capacity and an illustration of the number of channels that could be delivered. We assume for convenience that 20 HD channels would be carried with the remaining capacity used for SD channels. Option (a) is the case with no DVB-T2 transition following 700 MHz change of use. Option (d) is the case without 700 MHz change of use. In this case, 20 HD channels and a further 72 SD channels could be delivered. Partial transition (b) has a similar effect, while full transition (c) allows up to 116 SD channels to be offered.

[47] If a DVB-T2 transition (partial or full) is required to maintain coverage in the event of change of use then the costs associated with DVB-T2 transition would be included directly in our CBA rather than as a proxy for the opportunity cost. In this case we would need an alternative approach to estimating the opportunity cost. However, we expect any estimate would be small as any move to DVB-T2 would enable the DTT platform to deliver significantly more channels than are offered today.
[48] Ofcom has previously used a broadly analogous approach for measuring opportunity costs in setting administrative incentive pricing (AIP); see e.g. paragraph 5.67 of: http://stakeholders.ofcom.org.uk/binaries/consultations/srsp/statement/srsp-statement.pdf

Table 5: Options for upgrading the DTT platform

	(a) 6 muxes - no further DVB-T2 upgrade	(b) 6 muxes - Partial DVB-T2 upgrade	(c) 6 muxes - Full DVB-T2 upgrade	(d) 8 muxes - no further DVB-T2 upgrade
DVB-T multiplexes	5	2	0	5
DVB-T2 multiplexes	1	4	6	3
Total capacity (Mbps)	169	208	240	249
Number of channels				
SD channels	56	70	116	72
HD channels	8	20	20	20

5.70 Either a partial or full DVB-T2 upgrade can mitigate the loss in DTT capacity of moving from eight to six multiplexes. In estimating the loss in value to the DTT platform we have focussed on the cost of a full DVB-T2 transition. With change of use, DTT may or may not actually transition to DVB-T2, but the estimated costs of doing so provide a useful proxy for the loss of value to the DTT platform.

5.71 As Table 5 indicates, a partial DVB-T2 upgrade may be sufficient to meet the demand in scenario 2 and provides largely the same capacity as eight multiplexes without further upgrade. However the costs associated with a partial upgrade are uncertain as they highly depend on how many consumers would upgrade (or bring forward upgrading of) equipment in response to a DVB-T2 upgrade. They also depend on the lost consumer welfare to consumers who chose not to upgrade equipment (these consumers would receive fewer TV channels following a DVB-T2 transition). One possibility is that by 2022 most consumers who value the channels currently provided on the COM multiplexes have already purchased DVB-T2 equipment (or been provided with it as part of a subscription package[49]). In this case the loss in consumer value from mitigating the loss in capacity through a partial transition would be low. Alternatively, if by 2022 a significant proportion of customers who value the services provided on the COM multiplexes have still not purchased DVB-T2 equipment then the cost of a partial transition would be close to a full transition as most or all of these consumers would need to upgrade. Reality is likely to lie somewhere between these two extreme scenarios.

5.72 Our estimation of the costs of a full DVB-T2 transition can be split into three components; consumer receiver costs, additional[50] DTT infrastructure costs and additional consumer information costs. We discuss these in turn.

Consumer receiver costs

5.73 A full DVB-T2 transition would require consumers with DVB-T receiver equipment to replace it if they were to continue using the DTT platform.

5.74 3 Reasons (a consultancy) has provided us with a forecast of the penetration of DVB-T2 receivers and the proportion of households which use DTT as the primary feed on their primary and secondary television sets.

[49] See for example the YouView box that includes DVB-T2 technology and that service providers like BT and TalkTalk include in certain packages of services.
[50] I.e. in addition to those incurred directly for 700 MHz change of use.

5.75 We use these forecasts to predict (a) the number of households which would need to buy a DVB-T2 compatible Set Top Box (STB) which they would not otherwise have purchased (for those with a non-T2 television or standard STB)[51] and (b) the number of households who would replace their existing DVB-T Personal Video Recorder (PVR) STB with a DVB-T2 compatible version sooner than the end of its useful life as a result of a change of use of 700 MHz.

5.76 We estimate that by 2022 DVB-T2 STBs will be available for £30 (in 2014 prices) and DVB-T2 PVRs will be available for £150 (in 2014 prices). Based on this, we estimate that approximately 8 million DVB-T receivers would need to be upgraded in 2022 at a cost of around £220 million.[52] Our methodology for estimating the consumer costs is discussed in more detail in Annex 10.

Additional DTT infrastructure costs

5.77 A transition to DVB-T2 would also result in extra DTT infrastructure costs which are additional to the costs discussed above (in paragraph 6.50). This is because transmission equipment would need to be upgraded to be compatible with the DVB-T2 transition.

5.78 Arqiva has provided estimates for what these additional DVB-T2 infrastructure costs might entail. They estimate that for the Single Hop DTT band plan, the additional costs between 2019 and 2021 would be £50 million and that they would be £30 million for the COM SFN plan or between £35 million and £60 million in 2014 NPV terms.[53]

Additional consumer information costs

5.79 A transition to DVB-T2 would also result in additional consumer information costs, because consumers would need to be informed about the potential need to acquire new equipment. We estimate the additional cost of a consumer information campaign would be approximately £100 million over the 2017 to 2022 period or £85 million in 2014 NPV terms.

Total DTT opportunity costs

5.80 Based on this we estimate the total upgrade cost in 2014 NPV terms of a full DVB-T2 transition, and thus an estimate of the value of expanded capacity to the DTT platform, would be between £340 million and £370 million. Based on this upgrade cost less the operating cost saving we estimate the opportunity cost is between £80 million and £100 million.

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[51] For this, we calculate the full cost of replacement rather than the replacement cost since it is unlikely that these consumers would purchase a STB absent change of use of 700 MHz.

[52] To illustrate the consumer costs of a partial transition we have modelled a scenario where 50% of consumers with DVB-T equipment upgrade. The remaining 50% of consumers place a value on the loss of service that is uniformly distributed between zero and the cost of upgrading. This gives a consumer cost of approximately £170 million.

[53] These additional costs are higher for the Single Hop plan (the basis for our lower cost estimate) because the COM SFN plan already requires the commercial multiplexes to be upgraded to DVB-T2, so a complete DVB-T2 transition would only involve the upgrading of the remaining PSB multiplexes to DVB-T2. In contrast, under the Single Hop plan no further multiplexes would be required to upgrade to DVB-T2 so a transition to DVB-T2 would be additional to the costs in the band plan, requiring the PSB multiplexes and the three remaining DVB-T commercial multiplexes to be upgraded at further cost.

5.81 Table 6 below outlines the opportunity cost in the different demand scenarios (see paragraph 6.61).

Table 6: DTT opportunity cost in different scenarios

Scenario	DTT demand	Value of expanded capacity	Operating cost saving	Opportunity cost
1	Low	Zero	Zero	Zero
2	Medium – high	£340m-370m	£250m-290m	£80m-100m
3	Very high	Not quantified but greater than £370m	£250m-290m	Not quantified but greater than £100m

5.82 If there is low demand for DTT, the range of between £80 million and £100 million will overstate the opportunity cost. In particular, it is quite possible that the value of maintaining DTT capacity above the level that can currently be provided by the six UK-wide multiplexes could be less than the cost of DVB-T2 migration (from a commercial perspective, a consumer perspective, or both). We also may be overstating the cost by considering a full upgrade rather than a partial upgrade.

5.83 However, it is also possible in principle that using the costs of a DVB-T2 upgrade as a proxy for the opportunity cost to DTT of change of use could understate the loss of value. This could be the case if there is very high demand for DTT capacity and change of use of the 700 MHz band limits the maximum capacity. Although this situation is plausible we view it as unlikely as it would require significant growth in demand for HD services.

5.84 Our approach to estimating the opportunity cost could also understate the total cost if the additional spectrum available without change of use allowed the platform greater flexibility to manage future technological developments. For example, extra spectrum being available for use by the DTT platform could potentially facilitate partial transitions to future technologies, such as High Efficiency Video Coding[54] (HEVC), in the same way that the use of additional spectrum for the interim multiplexes has allowed the DTT platform to introduce DVB-T2 on some multiplexes without disrupting the DVB-T service on the remaining multiplexes. We also recognise that in practice there may be obstacles to DVB-T2 transition (such as the need to reach agreement among DTT operators) which would not arise if the platform simply continued to have access to the 700 MHz band and did not need a platform-wide upgrade to DVB-T2.

Alternative estimates of loss of value

5.85 A recent report by Communication Chambers for Digital UK[55] compares the marginal value of spectrum used for DTT and mobile services respectively. The report takes as its starting point a 2012 estimate by Analysys Mason for DCMS of the consumer and producer surplus from DTT services of around £64 billion (10 year NPV). Communication Chambers adjusts this to exclude some non-DTT costs of the BBC,

[54] HEVC is an advanced video encoding technique that would allow more services to be fitted into a multiplex, but would require, but would require consumers to obtain new receivers.
[55] Communications Chambers, January 2014, http://www.digitag.org/The_Value_of_DTT_in_an_era_of_increasing_demand_for_spectrum_20-1-14.pdf

and to include value created for advertisers on DTT, reaching a figure of around £80 billion.

5.86 Communication Chambers argues that below an unknown threshold level of spectrum holdings the DTT platform would have no value. It assumes this threshold level to be one-thirds of the current spectrum used by DTT (i.e. including the 600 MHz band, which allows DTT to run 8 national multiplexes). It considers this one-thirds level to be conservative on the basis that if DTT lost one third of its spectrum (i.e. leaving it with *two*-thirds of current holdings) it could provide "little more than the PSB channels (and their HD variants) on a national basis". Communication Chambers questions whether such a service would be "competitively viable".

5.87 Based on this reasoning, the report estimates the marginal value of spectrum at £0.47bn/ MHz (i.e. £80bn divided by two-thirds of 256 MHz). Assuming this marginal value is constant with the amount of spectrum lost by DTT, this would suggest that the loss of the 96 MHz in the 700 MHz band would cause a loss of value on DTT of around £45 billion.

5.88 We recognise that the Communication Chambers report primarily presents qualitative arguments, and we consider that these arguments have some validity, including the conclusion that "securing sufficient spectrum to enable DTT to continue its role as a robust competitor is essential". However, we do not consider that this method provides the base estimate of the value of the 700 MHz band to DTT.

5.89 In particular we note that this estimate is based on a reduction in the number of channels that could be offered on the DTT platform. However, as we set out above change of use of the 700 MHz band will not reduce the number of channels on the platform compared to the number available today. In addition the option for upgrading to DVB-T2 would allow the platform to avoid any reduction in channels compared to a situation without change of use of the 700 MHz band. For a number of other reasons the Communications Chambers' estimate may overstate the opportunity cost we are considering here:

- In adapting the Analysys Mason figure, Communication Chambers adjusts for the value to advertisers. This accounts for approximately 20% of the Communications Chambers' value. However, if DTT lost market share to other TV platforms this would not necessarily entail a loss of value to advertisers, who could reach viewers by advertising on those other platforms (potentially on the same channels).[56]

- Communication Chambers effectively averages the whole value of DTT over two thirds of its spectrum holdings. However, a DTT platform which only offered SD and HD PSB channels would likely deliver significant value.

- Conversely a large number of current DTT channels have a very low viewing share, suggesting that the availability of highly popular content and channels is more of a constraint on the platform than capacity.

- It is possible that viewer demand for HD will grow over time (HD variants of PSB channels also have very low viewer share at present). However if this were to lead to a need for greater DTT capacity, there remains considerable scope for

[56] We recognise that viewing tends to be more fragmented on platforms other than DTT, which can be a disadvantage to advertisers.

such a need to be addressed through either full or partial DVB-T2 transition as set out in scenario 2. This option for avoiding any loss in DTT capacity is the basis for our estimate of the opportunity cost.

5.90 In summary, we consider that using the figures presented in the Communication Chambers report to assess the DTT loss of value from the change would greatly overstate the potential impact on DTT of losing the 700 MHz band.[57]

5.91 Therefore, overall we consider that our approach to estimating the loss of value gives an appropriate estimate of the opportunity cost of the 700 MHz band to DTT.

Question 4: Do you have any comments on our analysis of the implications change of use of the 700 MHz band would have for the DTT platform?

Question 5: Do you agree with our assessment of the likely costs of upgrading DTT transmission infrastructure?

Question 6: Do you have any comments on our assessment of the timeframes within which it might be possible to complete a DTT replan?

Question 7: Do you have any comments on our assessment of the loss of value from existing DTT services in case of change of use for the 700 MHz band?

[57] We note in this regard that figures presented by Communication Chambers (marginal value of mobile spectrum of somewhere below £0.19bn/MHz) imply an upper limit on the valuation of the 700 MHz band for mobile service at £18bn, a figure which is also orders of magnitude greater than our estimates in this consultation.

Section 6

Impact on DTT viewers and resulting costs

6.1 We now consider how the changes proposed in this document would affect DTT viewers. We explain how change for viewers in this case would be much smaller in scope than in a programme like DSO, and we set out the view that:

- For most viewers the proposed replan would only involve a simple retuning of their TV or set-top box at the time of frequency changes. For up to 0.5% of households using DTT, it would also involve replacing their rooftop aerial. In addition, a small proportion of DTT viewers might be affected by interference from LTE handsets. Our technical analysis to date indicates that the majority of cases could be solved by installing a DTT receiver filter.

- Provided the process is carefully planned and well-managed, we do not believe that these changes would negatively affect viewers' perception of the DTT platform or undermine it in any material way.

- In the event that we were to proceed with change of use of the 700 MHz band, we would need to ensure that a carefully targeted information campaign was put in place to help viewers through retunes, aerial replacements and potentially receiver filter installations.

6.2 Having discussed the impact change of use of the 700 MHz band would have on viewers we move on to talk about pre-emptive actions we are taking to ensure that, in so far as possible, consumer equipment sold today is of a type which would be capable of operating following a change of use of the 700 MHz band. We set out our work to date in this area, particularly in relation to rooftop aerials.

Change of use of the 700 MHz band would mean some viewers would need to retune their televisions

6.3 As outlined in Section 5, change of use of the 700 MHz band would require some changes to be made to the frequencies over which DTT services are transmitted. Televisions and DTT STBs are tuned to pick up signals transmitted on specific frequencies. Viewers in areas where the frequencies used to transmit DTT services change as a result of the spectrum replan under consideration would therefore need to retune their televisions.

6.4 The precise number of households that needed to retune would depend upon the details of the revised DTT frequency plan that was finally agreed. Based on the early frequency planning studies referred to in Section 5, we estimate that 14-20m households would need to retune. The timing of change of use of the band would not have a material bearing on this range.

6.5 Upon purchasing their equipment, DTT consumers would have had to tune their sets in order to watch DTT channels. In addition, most viewers have already had experience of retuning.[58] Not only did all DTT viewers need to undertake two retunes as part of DSO, but a proportion of viewers also needed to retune as part of the recent 800 MHz clearance programme. Moreover, Digital UK advises viewers who contact them via the call centre or use their website that they should retune their televisions from time to time in order to ensure that they retain access to all channels in the event of changes in the line-up on DTT multiplexes.

6.6 The available evidence indicates that a very large majority of viewers feel confident retuning their televisions when they are provided with appropriate communications and support. Research conducted by Digital UK from a retune in March 2013 in the Mendip and Winter Hill transmission areas found that 81% of people thought retuning was a straightforward process and 79% said they would feel confident about retuning equipment in the future. Whilst the sample sizes for this study were small and consumers benefited from an active communications campaign when the retune took place, the results suggest that retuning is something that consumers are becoming more familiar and content with carrying out themselves. Statistics from Digital UK's consumer helpline suggest that on the day of switchover, only around 1% of households had queries regarding retuning.

6.7 Therefore, on balance, we do not consider that retuning would cause significant detriment or inconvenience for the majority of DTT viewers, when this happens with appropriate information and support. Nevertheless, we recognise that some viewers might find the retuning process challenging.

6.8 Notwithstanding our view that retunes would be unlikely to cause significant detriment to viewers, for the purposes of our CBA we have sought to ascribe a cost to the time spent conducting a retune. Digital UK estimate the retune process should only take a few minutes,[59] therefore we assume an average retune takes 5 minutes.

6.9 We estimate the total cost of consumer time lost from retuning to be between £7 million and £10 million. This is based on an estimated value of consumer leisure time of £7.76 an hour in 2022 and is explained in more detail in Section 9.[60] This estimate is likely to overstate the cost as most consumers would spend the time carrying out other tasks at the same time as the retune.

A small proportion of viewers would need to replace their aerials

6.10 In addition to giving rise to a need to retune, our analysis indicates that a change of use of the 700 MHz band would mean that a small proportion of DTT households would also need to replace their aerials.

6.11 Most aerials sold today are "wideband" aerials. This means that they are able to receive signals transmitted at any of the frequencies in the spectrum currently used by DTT. However, a many older aerials (as well as a small proportion of those aerials sold today) are only capable of receiving signals transmitted on a subset of the frequencies within the spectrum band currently used by DTT. Such aerials are called grouped aerials. As set out in Section 9, we estimate that in 2013 45% of aerials in place at consumers' premises were non-wideband or grouped aerials.

[58] Whilst the process of set up and retuning may differ, overall consumers have more experience in these tasks than they would have before DSO.
[59] http://www.digitaluk.co.uk/howtoretune/retuning_instructions.
[60] This approach is based on a previous estimate from the Department of Transport and used previously by Ofcom.

6.12 Change of use of the 700 MHz band would result in a replanning of the frequencies used to transmit DTT (see Section 5). Consequently, some grouped aerials in areas affected by frequency changes may no longer be able to receive the full range of DTT services. For example, a household with a Group C/D aerial (one designed to work most efficiently between 694 and 850 MHz), might need to replace it following the proposed DTT replan. This is because all DTT multiplexes would be transmitted on frequencies below 694 MHz following the replan and some Group C/D aerials may not work sufficiently well on these lower frequencies. By contrast, we do not expect that any wideband aerials would need to be replaced as a result of the programme of change proposed in this consultation.

6.13 The precise number of aerial replacements that would be required depends on the DTT frequency plan agreed internationally. In order to get a sense of the number of aerial replacements that may be needed, we have conducted a band planning study, which is explained in more detail in Annex 8. From this study we are able to derive an estimate of the number of aerials that would potentially go out of group and therefore required replacements. We adjusted this number to reflect the following factors.

- **The number of wideband aerials expected to be used at the date of change of use.** We estimate that by 2022 at least 80% of aerials will be wideband[61].

- **Households that continue to use set top or portable aerials.** We note that set top aerial users would continue to receive the DTT signal following a change of use of 700 MHz, as they are all wideband. We estimate that between 2% and 10% of households only use a set top aerial. We also note that the DTT network is not planned and designed for TV reception by way of set top aerials.

- **A proportion of households do not use the DTT platform and will, therefore, not be affected by change of use.** Approximately 25% of households rely solely on an alternative platform[62].

6.14 On this basis, we estimate that if change of use of the band occurred in 2022, approximately 80,000 to 90,000 aerials would need to be replaced. On average, aerial replacements cost around £150. This suggests that the total cash cost of replacing aerials to accommodate a DTT replan would likely be between £9 million and £10 million (2014 NPV).

6.15 We believe that aerials would naturally be replaced at the end of their useful lives anyway, whether or not use of the 700 MHz band changed, so that consumers can continue to view DTT. For the purposes of our CBA, the relevant cost to consider is the cost of bringing forward the replacement of the affected aerials. On this basis, we estimate that change of use of the 700 MHz band would result in aerial replacement costs of between £2 million and £4 million. Section 9 provides our full methodology for assessment of aerial replacement costs.

6.16 If change of use happened before 2022, fewer households would be likely to have installed wideband aerials. We estimate that if change of use happened in 2020, it would require between 105,000 and 110,000 consumers to replace their aerials at an

[61] *Consumer aerial survey: Implementing Ofcom's UHF Strategy*, May 2014: http://stakeholders.ofcom.org.uk/consultations/700MHz/

[62] *Digital Television Update: Chart Pack for Q4 2012*, April 2013, Figure 1: http://stakeholders.ofcom.org.uk/binaries/research/tv-research/tv-data/dig-tv-updates/2012Q4.pdf

estimated cost of £3 million to £6 million. If change of use happened after 2022, the cost would fall as more households would already have wideband aerials installed.

6.17 As a result of this limited impact, the total value of time lost to households upgrading aerial equipment (to select an installer, to procure their services and to engage with them as necessary) is likely to be low, because relatively few households are affected. We estimate this cost at less than £500,000, and possibly less than £50,000, depending on the average amount of time it takes a household to arrange an aerial replacement.

A small proportion of DTT viewers might be affected by interference

6.18 Mobile use of the 700 MHz band might lead to a small proportion of DTT viewers being affected by interference. Affected viewers would experience temporary loss, or a reduction in quality, of their picture.

6.19 This is a related but different issue to the interference experienced by a small minority of DTT viewers as a result of LTE deployment in the 800 MHz band. In that case, emissions from mobile base stations are the key source of interference. In the case of 700 MHz, because the frequency band would be configured differently, mobile devices would be the predominant source of interference. Although mobile devices will of course often be much closer to DTT aerials than mobile base stations, they transmit at vastly lower power levels[63] and (for the most part) at much lower heights than DTT aerials. These two factors significantly reduce the risk of interference.

6.20 We have conducted some preliminary technical analysis to investigate the issue in this case (see Annex 10). We expect that the vast majority of households would not experience any interference at all due to change of use of the 700 MHz band. Any interference that mobile devices would cause is likely to be of a transitory nature. This is because mobile devices both move around and transmit intermittently at varying powers. Some households that may appear to face a risk of interference based on theoretical calculations may never experience interference, or experience it very infrequently (e.g. for a few seconds a year or less).

6.21 On the basis of our preliminary analysis to date, however, we believe that the number of households that are likely to experience noticeable interference is likely to be low, as discussed in Annex 10. By way of comparison, at800, the organisation responsible for managing interference from LTE deployments at 800 MHz currently estimates that at most 50,000 households will be affected by interference from LTE in that band.

6.22 Our analysis indicates that if any interference did occur, many of these problems could be solved by installing a DTT receiver filter. In the remaining cases, other measures such as improving DTT installations or replacing equipment may be required.[64]

[63] The maximum power output of a mobile handset is likely to be 16 dBm or 40mW, after accounting for body loss and antenna gain. The typical maximum power output of a mobile base station is likely to be around 60 dBm, or around 1 kW – i.e. around 25,000 times more powerful.

[64] A similar approach was taken to address interference issues following the launch of mobile services in the 800 MHz band. However in the case of the 800 MHz band, interference was caused by mobile base stations rather than mobile devices so the problem – though similar – was of a different nature.

6.23 For our CBA, we have assumed the cost of mitigating interference to be between zero and £20 million, allowing for a range of potential scenarios consistent with a cautious approach at this stage on this issue. For the reasons set out above, and discussed further in Annex 10, it appears to us likely that any actual costs will be at the low end of this range.

6.24 We are planning to undertake further work, including field trials, to identify the nature and scale of the potential interference problem more accurately, using mobile handsets that can operate at 700 MHz (in a way consistent with the latest international technical conditions) as they become available.

We do not believe these changes would undermine the DTT platform or affect viewers' perception of it

6.25 In their response to our *2013 CFI*, Digital UK and Freeview expressed concern that disruption and inconvenience caused by the process of transitioning to a new DTT frequency plan could result in material reputational damage to the DTT platform - thereby undermining the platform's competitiveness or encouraging some of its users to migrate to other platforms.

6.26 We do not believe that there is a material risk of this happening. The challenges that change of use of the 700 MHz band would pose to viewers (retunes, aerial changes, coexistence issues) have all arisen previously during DSO and 800 MHz clearance. The success of these programmes of change suggests that, provided the process is carefully planned and well-managed, change of use of the 700 MHz band should not pose significant disruption to viewers.

6.27 The analysis that we have undertaken of the potential change lends further weight to this argument.

- All that most viewers who were affected would have to do in order to continue receiving DTT is to retune their television. As discussed earlier in this chapter, there is evidence that the majority of people find retuning relatively easy.

- Only a very small proportion of DTT households (up to 0.5%) would need new rooftop aerials and we expect that the risk of interference from new mobile services is both limited and readily addressed by installing a simple filter.

Ensuring that viewers received appropriate information and support would be a key part of our approach to implementing these changes

6.28 Proceeding with the change would involve measures to ensure that viewers were aware of any actions they needed to take in order to continue to receive DTT following the spectrum replan (e.g. retune their television or purchase a new aerial). We would work with relevant stakeholders (including broadcasters and Government) to ensure that an appropriate consumer information scheme is put in place. When doing this, we would need to give particular consideration to the needs of vulnerable viewers.

6.29 Although there is some evidence of a legacy of consumer confidence following DSO (and a good deal of valuable material such as video guides to re-tuning remain accessible) our research work with vulnerable people shows that certain consumers felt that they would require assistance such as practical help, advice and clear instructions.[65]

6.30 In considering the information and support that would be appropriate for viewers, we would also expect to take into consideration the circumstances of DTT households when they may be part of lower income groups and may not tend to be early adopters or users of new mobile services. As part of these considerations, we would take into account the specific circumstances of citizens and consumers with respect to any cost to them from a change, how they might manage such costs and what the financial impact on households might be.

6.31 Based on experience from DSO and the clearance of channel 61 and 62, we have estimated that a consumer information scheme would likely cost in the region of £30 million. For the purposes of our cost-benefit analysis, we have modified this number by spreading the cost out over the five years preceding change of use of the band and discounting it at the rate of social time preference (3.5% per annum). This gives a net present value of £25 million if change of use of the band takes place in 2022.

6.32 In their responses to our *2013 CFI*, Digital UK, Channel 5 and Freeview argued that the costs of change of use of the 700 MHz band, including the costs of replacing aerials, running an information scheme and addressing coexistence issues should be funded by the mobile network operators or by Government. In this context, they argued that 'those consumers likely to feel the greatest burden of removing DTT from the 700 MHz band are also least likely to benefit from its proposed new use'. We discuss apportionment of the costs of change of use of the 700 MHz band in Section 11 of this consultation.

We will continue to promote future-proofing of consumer equipment

6.33 As discussed in the *UHF strategy statement* and our *2013 CFI*, we are committed to taking pre-emptive action now to ensure that, in so far as possible, consumer equipment sold today is of a type which would be capable of operating following a change of use of the 700 MHz band and does not lead to undue increases in consumer costs. Taking such action now will help reduce the costs that consumers would face in the event that change of use of the 700 MHz band were to take place.

6.34 There are two main strands to this pre-emptive work:

a) **Future-proofing aerials.** We have been working with industry stakeholders, in particular the Confederation of Aerial Industries (CAI), to make sure that aerial installers ensure that TV aerials made available to consumers are of a type which would be capable of operating following a change of use of the 700 MHz band, i.e. wideband aerials. Organisations such as the CAI have communicated clear guidelines on this to their members. Overall, the efforts to promote future-proofed antennas have had a positive effect, leading to a majority of new installations being future-proofed. However, our understanding is that ca. 10% of newly installed antennas may not be future-proofed and we are continuing with our efforts to address this.

[65] Kantar Media's *UHF spectrum strategy: research report*, 2014: http://stakeholders.ofcom.org.uk/consultations/700MHz/

b) **Improvements in TV receiver performance and mobile out of band emissions.** In order to reduce the risk of mobile handsets causing interference to DTT services, we believe it is important both that the resilience of TV receivers to interference from mobile services in adjacent spectrum bands be improved and that restrictions on out of band emissions from mobile handsets be tightened. As set out in Annex 6, we are actively supporting the imposition of tighter out of band emissions restrictions in the relevant international forums. We have also commissioned research which suggests that it would be feasible to improve DTT receiver performance materially without significantly increasing equipment costs.[66] We will work with industry to ensure that receivers benefit from these performance improvements.

6.35 Our consumer research[67] showed that most consumers, including those within the vulnerable category, were willing to keep up to date with technological changes. However our respondents cited uncertainty over potential future changes as a significant concern. It highlighted a level of consumer expectation that TV equipment sold from now on should be future-proofed. Respondents would expect clear information about what technologies would last and which would require updates or might be rendered redundant by any changes to DTT.

Question 8: Do you have any comments on our analysis of the implications of potential changes for DTT viewers and for the platform? Are there any effects that may be important to viewers that we should consider further?

Question 9: Do you have any comments on our consideration of consumer information and support measures and on the factors we should focus on in the next stages of work?

Question 10: Do you have views on the activities that Ofcom and other stakeholders could undertake now to help ensure that DTT equipment that consumers might buy in the coming years is as future-proof as possible?

[66] The Technology Partnership's *Study on DTT Receiver Performance*, December 2013: http://stakeholders.ofcom.org.uk/consultations/700MHz/
[67] Kantar Media's *UHF spectrum strategy: research report,* 2014: http://stakeholders.ofcom.org.uk/consultations/700MHz/

Section 7

Implications for PMSE and resulting costs

7.1 Having set out our assessment of the impact on DTT users of a change of use of the 700 MHz band we now move on to consider the impact on PMSE users. This chapter first gives an overview of the role the 700 MHz band in supporting the PMSE sector, particularly in relation to wireless audio applications. It then moves on to outline our assessment of the impact a change of use of the band would have on PMSE users and the actions we have identified to mitigate this impact. Our assessment of the impact a change of use of the band would have is described in in more detail in Annex 11.

7.2 The chapter sets out our view that:

- Loss of access to the 700 MHz band would mean some PMSE users have to replace some items of equipment earlier than they would otherwise have had to. We estimate the total cost to the PMSE industry of bringing equipment replacement forward would be between £6 million and £18 million.

- Loss of access to the 700 MHz band would materially reduce the amount of spectrum available to PMSE users. This would pose significant challenges for the PMSE community.

7.3 We are committed to working with the PMSE sector to help it meet these challenges. We have identified a range of mitigations for the impact of a change of use of the 700 MHz band on PMSE users. These include a combination of Ofcom making replacement spectrum available to PMSE users and PMSE users adopting more spectrally efficient working practices. Taken together, we believe these actions would largely mitigate the impact a change of use of the 700 MHz band would have on PMSE users. We estimate that the cost of PMSE users adopting more spectrally efficient working practices would be £10 million to £13 million.

The 700 MHz band is an important source of spectrum for wireless audio applications

7.4 The 470 to 790 MHz band is the main source of spectrum for a range of audio applications used by PMSE. The 700 MHz band comprises 30% of this. Audio PMSE applications that operate within the interleaved spectrum include:

- **wireless microphones**: low power (less than 50 mW) wireless links used to deliver high quality audio. Wireless microphones can be handheld or body worn by a performer, or can be a wireless link attached to an instrument e.g. attached to an electric guitar;

- **in ear monitors (IEMs)**: low power (10 mW) wireless links to deliver high quality stereo audio to musicians and audio engineers via a body worn receiver. Customised audio mixes can be provided to different members of a band on separate channels to support a particular requirement e.g. a singer may require a particular music mix and a drummer may require just a metronome beat;

- **audio links**: considered to be high power wireless microphones or IEMs i.e. radiated power greater than 50 mW. May also be considered to be ‘point-to-point’ links to deliver an audio signal to a remote location e.g. a broadcast studio to transmitter link (STL); and

- **talkback/intercom systems**: typically 50 mW systems used to provide an audio link between stage crew and production staff.

7.5 The use of these systems has become integral to the production of events that support the UK's important arts and culture industry. Use of spectrum for audio PMSE applications is vital within theatre, music events, film and television production, sport and news gathering. A musical stage production will often have more than 50 channels[68] for microphones, IEMs and talkback. Live concerts such as those by Bruce Springsteen or Madonna will require up to around 80 channels of audio. Festivals such as Glastonbury, the V Festival and T in the Park have very high demand for multiple artists across multiple stages (Glastonbury 2013 had 495 frequency assignments across the period of the event with a peak demand of around 100 channels being used at one time). Major TV productions such as the X Factor and Children in Need require around 100 channels to deliver audio content with a high quality of service. The reliability and flexibility of these systems has enhanced production values and allowed creative innovation.

7.6 These wireless systems also play an increasingly important role in community activities such as places of worship, education, amateur dramatics and conference facilities where use is also growing.

7.7 PMSE use of spectrum is predominantly short term and licensed for the particular time and location of an event with production companies either bringing in their own equipment or hiring equipment for the event. However, some venues often have fixed installations authorised by annual licences. Systems require careful planning to ensure that all channels operate without interference as any failure of the audio channel would have a significant impact on the event. This is particularly acute for live performances where there is no opportunity to recover the audio.

7.8 Loss of access to spectrum as a result of a change of use of the 700 MHz band would have two main impacts on some PMSE users:

a) It would require them to replace some of their equipment earlier than they otherwise would have had to; and

b) If left unmitigated, it could make it considerably more challenging for them to stage certain types of production.

7.9 We consider each of these impacts in turn.

Some PMSE users would need to bring forward the replacement of equipment

7.10 PMSE equipment that currently operates exclusively or partially in the 700 MHz band might need to be replaced in the event of a change of use of the band. In addition some equipment that currently operates below 694 MHz may also need to be replaced due to changes in the availability of interleaved spectrum.

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[68] An audio PMSE channel is typically 200 kHz wide. Narrower channels are sometimes used for talkback/intercom systems.

7.11 There are three reasons PMSE users may need to replace equipment:

a) Equipment that operates exclusively in the 700 MHz band could not be used since the band would not be available for PMSE.

b) The tuning range of some PMSE equipment extends above and below 694 MHz, i.e. lies within and immediately below the 700 MHz band. Change of use of the 700 MHz band would reduce the usable tuning range of such equipment. In cases where this resulted in a material reduction in the breadth of the equipment's usable tuning range, this might mean the equipment was no longer fit for its intended purpose.

c) Equipment that operates in the 470 to 694 MHz tuning range and is used in a fixed location could not be used if the interleaved spectrum in that location changed in a way that materially restricted use, or if it no longer covered a wide enough tuning range because interleaved spectrum, post change of use, was more dispersed.

7.12 In response to our 2013 CFI, PMSE stakeholders highlighted the cost and detrimental impact of PMSE equipment replacement that would result from a 700 MHz change of use. To investigate the potential impact we surveyed owners of PMSE equipment and used the results to estimate the total cost of replacing equipment. A full description of our methodology and results is available in Annex 12.

7.13 As part of our survey we requested information from large hiring companies, theatres and other owners of PMSE equipment. We received responses from a range of companies and individuals, together representing around 25% of all PMSE assignments in the UHF bands.

7.14 Respondents provided information on when equipment was purchased, the estimated date of replacement and the tuning range.

7.15 Using this information we have produced an estimate of the cost of replacing PMSE equipment as a result of change of use of the 700 MHz band in 2022 of between £6 million and £18 million. We have used this estimate as an input to our cost benefit analysis. This estimate is made on the basis that:

- Any equipment that is replaced between now and 2022 would be unaffected by 700 MHz change of use. Given the possibility of the band being unavailable for PMSE use from that date we expect owners of equipment to purchase new items with tuning ranges suitable for the remaining UHF spectrum (or alternative bands as they are designated).

- Equipment that operates below 694 MHz and is used in a fixed location is more likely to need replacing if it covers a smaller tuning range.

- We only consider the cost of earlier replacement, not the full cost of equipment.

7.16 Our analysis suggests that in order to address the challenges posed by change of use of the 700 MHz band, PMSE users would have to upgrade a proportion of their equipment rather than just undertaking a like-for-like replacement. When producing the above estimate, we made the following adjustments to reflect this:

- We included a 20% to 40% mark-up on all equipment. This reflects the potential need to purchase equipment that is more frequency agile and covers a wider tuning range. This mark-up represents the average cost. Some equipment will not require upgrading while other equipment will cost more to upgrade.

- We included a 25% to 50% mark-up on talk-back equipment. This reflects the potential need to replace this equipment with equipment that operates in a different frequency band. This is separate from the mark-up on equipment to cover a wider tuning range.

7.17 This cost is based on equipment needing to be replaced by 2022. However, we have explained that there is a potential for the band to be made available for mobile broadband before this date. If a change of use we to occur in 2020 we estimate the cost of replacement (including upgrade costs) would be between £11 million and £23 million.

7.18 We have not used the same mark-up for microphone equipment moving to alternative bands as we have done for talk-back equipment for the following reasons. Our assessment is that there are more significant changes required for talk-back equipment, including technology changes and potentially new duplex arrangements, than for wireless microphones which could continue to use current technology. Also the volume of sales of talk-back equipment is lower than for microphones and therefore research and development costs make up a greater proportion of the total cost for talk-back.

7.19 We also have not included any costs on incumbent users from PMSE accessing alternative bands. The candidate bands identified as potential sharing opportunities for PMSE could only support a low power licensed service. Therefore we consider any opportunity cost of PMSE use of these bands to be zero. In addition we would not impose any constraints on incumbent users of these bands or a requirement to implement any changes in how they use or access the spectrum.

7.20 We discuss the options for funding PMSE equipment replacement in Section 11.

Reductions in spectrum availability would pose significant challenges for PMSE users

7.21 Access to spectrum for PMSE within the 470 to 790 MHz band is interleaved with DTT with a requirement for PMSE operation to safeguard TV reception appropriately. This requirement determines the amount of spectrum that is considered to be *available* for PMSE use. However, there is also potential for interference from DTT into PMSE which may limit the *quality*[69] of the available spectrum in some areas. The level of DTT interference is a result of both local DTT transmissions and those from neighbouring and/or relay transmitters. It means that in some areas the amount of usable spectrum is less than that considered available. Consequently the amount and quality of interleaved spectrum available for PMSE is dependent on the configuration of the broadcast network and varies with location. This location variability is an important factor in assessing the impact loss of access to the 700 MHz band would have on PMSE.

7.22 Change of use of the 700 MHz band would constitute a significant reduction in the amount of spectrum available for audio PMSE. Firstly, there is a 30% reduction in

[69] Arqiva PMSE provides an indication of spectrum quality in the UHF spectrum look-up tool, ranging from Quality 1 (high level of DTT interference – poor quality) to Quality 4 (low level of DTT interference – high quality).

spectrum due to the loss of the band. Secondly, as spectrum availability for PMSE is dependent on the configuration of the TV broadcast network, any replan of DTT required to clear the 700 MHz band would change the amount and configuration of interleaved spectrum available to PMSE in any given location. This means that in some locations the loss of spectrum would be greater than 30%.

7.23 In order to assess the impact this reduction in spectrum availability would, if left unmitigated, have on PMSE, we took the following steps:

- We estimated how much spectrum would be available for PMSE across the country if we made the 700 MHz band available for mobile. When undertaking this assessment, we assumed the single hop frequency plan.

- We identified a sample of events with a high demand for spectrum at a variety of locations across the UK using licensing data and engagement with stakeholders.

- We sought to re-plan these events against the expected future spectrum configuration in that location. We assessed any shortfall in satisfied requirements qualitatively and graded the impact on a five point scale, ranging from minimal (no impact on the production of the event) to critical (even with action taken the event would not be viable in any recognisable form).

7.24 Our analysis indicates that:

- There is a class of very high PMSE demand events, representing around 10 to 20 sporting, theatre and live music events a year for which, even given ideal circumstances, the supply of interleaved spectrum following change of use of the 700 MHz band would not be adequate. Such an impact would require a fundamental change in the way such an event is produced. This could have a significant negative impact on the production quality and diminish audience experience.

- There is a larger set of events – representing a majority of those cases under study – for which, in order for the supply of spectrum to be adequate, significant changes to equipment and working practices would be needed. Implementing these changes would maintain the production quality of the event but there would be little opportunity for increased use of wireless audio applications absent additional spectrum.

- The availability of interleaved spectrum varies greatly by region. There is a risk that this variation could lead to certain locations becoming unattractive for hosting high PMSE demand events. This may have implications for the viability of venues in these locations.

We are committed to working with the PMSE community to help them meet these challenges

7.25 We recognise the important role the PMSE sector plays in the social and cultural life of the nation. We wish to ensure that the PMSE sector remains in a position to continue playing this role if we make the 700 MHz band available to mobile.

7.26 If we were to proceed with a change of use of the 700 MHz band, we would therefore work with the PMSE community to mitigate the impact discussed above. Our analysis indicates that a combination of the following actions would be required in order to accomplish this:

a) We would need to Identify and make available alternative spectrum sharing opportunities for audio PMSE applications. Such spectrum would need to satisfy, as far as possible, the requirements of PMSE users in terms of the quality, bandwidth, and security of access to this spectrum; *and*

b) PMSE users would need to take steps to improve the efficiency with which they use spectrum. Our survey of PMSE equipment use revealed considerable variation in the spectral efficiency achieved between deployments. This suggests that there is scope for many PMSE users to improve the efficiency of their spectrum use.

7.27 We now move on to consider each of these categories of mitigation in turn.

We have identified a range of alternative spectrum options for PMSE

7.28 In addition to continuing access to UHF interleaved spectrum our analysis suggests that alternative spectrum would be needed to fully mitigate the loss of the 700 MHz band. How much alternative spectrum would be needed depends upon the utility of the bands identified and to an extent, how far this could be complemented by the efficiency gains which improvements in equipment and working practices might deliver.

7.29 In looking to identify candidate spectrum opportunities we have applied the criteria discussed in Table 7 below.

Table 7: Criteria to identify candidate spectrum opportunities for low power audio PMSE

Criterion	Rationale
Not already allocated to mobile	Risk of interference. Audio PMSE applications typically require high quality of service which can only be provided by high quality spectrum i.e. low risk of harmful interference. On this basis sharing with mobile services is not considered viable.
Not already identified as a candidate mobile band and unlikely to be so in the medium to long term	Any spectrum identified as a candidate mobile band is at risk of reallocation at some future time. While this reallocation may be many years away we cannot provide any certainty around security of access.
The incumbent use of the candidate band is harmonised at least Europe wide	This would provide the opportunity for PMSE use to be harmonised in other territories leading to economies of scale in equipment production and distribution.
Provides a substantial block of contiguous spectrum	We consider that a fragmented spectrum supply would not be viable for PMSE users. Equipment owners and hirers would need to hold multiple items in order to access small, discrete parcels of spectrum which we do not consider as being economically viable. However, our analysis shows that moving wideband talkback/intercom systems from the 470 to 790 MHz band to alternative spectrum would provide a significant efficiency gain and free up spectrum for microphones and IEMs. Such alternative spectrum could be application specific and therefore could be isolated from the requirement to access contiguous spectrum.
Below 2GHz	The current industry consensus is that higher frequencies are inappropriate for PMSE applications due to their propagation characteristics. We are examining this assumption in our current work looking at technology evolution in the PMSE sector.

7.30 Based on the above criteria, we have identified two candidate bands that we believe have good potential for sharing with low power audio PMSE applications. We are carrying out further studies to explore the viability of these bands and we will continue to work actively over the coming months to identify effective and workable spectrum options. Any opportunity for sharing would be subject to careful consideration of the circumstances of incumbent users and detailed engagement. We have held preliminary discussions with stakeholders to outline our approach and will engage more widely once the results of our studies are completed.

- **960 to 1350 MHz**: this band is internationally allocated to the Aeronautical Service for a range of applications such as distance measuring equipment (DME) and radar. It is also used by global navigation satellite systems (GNSS) such as GPS. Sharing in this band would present some challenges but the channelling arrangements and locations of these aeronautical systems may provide significant white space that could be accessed by low power PMSE applications on a geographically interleaved basis, particularly if this use was indoors.

- **1525 to 1710 MHz**: this band is predominantly used for satellite services, including the mobile satellite service, earth exploration and space service and GNSS; initial work suggests that there is potential for sharing in some parts of this band and this may provide a helpful contribution to PMSE spectrum supply.

7.31 We have prioritised the bands above for further study as we feel they provide the best spectrum options against our criteria. Additionally we are carrying out studies into the following bands which PMSE stakeholders have highlighted as a possible future sharing opportunity. However, as these have been identified as potential future mobile bands we feel that they do not meet our objective of a long term solution for audio PMSE applications.

- **1427 to 1452 MHz**: this band has been identified as a candidate mobile band. It is also currently under study as part of Ministry of Defence's spectrum sharing plans. The band is adjacent to Radio Astronomy 'quiet band' 1400 to 1427 MHz which may limit its utility.

- **1452 to 1492 MHz**: the 1452 to 1492 MHz band is licensed in the UK following a spectrum award in 2008[70]. The band is subject to ECC Decision (13)03, "The harmonised use of the frequency band 1452 to 1492 MHz for Mobile/Fixed Communication Networks Supplemental Downlink (SDL)." We note that Germany has made the band 1452 to 1492 MHz available for wireless microphones[71] on a non-interference, non-protected basis with SDL.

- **1492 to 1518 MHz**: this band is allocated to the Fixed Service and has also been identified as a candidate mobile band. It is noted that the band is included in ERC Recommendation 70-03 (related to Short Range Devices) as a band for wireless microphone use. It is also adjacent to the band 1517 to 1525 MHz currently allocated to PMSE in the UK.

7.32 We also note that the mobile duplex gaps may provide additional spectrum resource. However, there is a risk of interference from adjacent mobile services which could limit the utility of the bands for audio PMSE applications, especially those demanding a high quality of service.

- **700 MHz centre gap and guard band**: the 700 MHz mobile band plan and technical requirements are still under study. The outcome of this work will determine the utility of the centre gap and guard band. In isolation these blocks do not offer mitigation for the more general shortfall of spectrum for PMSE but we believe that they may offer alternative spectrum for specific PMSE applications, most notably wideband talkback, which currently has a disproportionately negative effect on the spectral efficiency of some PMSE deployments.

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70 http://stakeholders.ofcom.org.uk/spectrum/spectrum-awards/awards-archive/completed-awards/award_1452/

71 http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/Areas/Telecommunications/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/DemandIdentificationProceedings/StrategicAspects.pdf

- **Centre gaps at 800 and 1800 MHz**: the European Commission is seeking to harmonise these bands, 823 to 832 MHz and 1785 to 1805 MHz for low power PMSE use. As these are isolated small blocks of spectrum and there is a risk of interference from adjacent mobile services, we do not consider these bands will offer mitigation for the more general shortfall of spectrum for PMSE.

Improvements in equipment and working practices could help offset some impact of loss of access to the 700 MHz band

7.33 We have identified a range of actions we believe the PMSE community could take to help address the reduction in spectrum availability that would result from change of use of the 700 MHz band. These include:

- using current PMSE equipment in a more spectrally efficient manner, for example by adopting best practice in both RF engineering and frequency calculation could realise significant spectrum efficiency gains for some events. However, this would not generate gains in all cases as high-value productions often already adopt best practice;

- using new, more spectrally efficient and frequency agile equipment. This could include:

  - digital PMSE technology, which, while not suitable for all applications, is now mature to the point where it could benefit some users from its greater spectral efficiency. Digital equipment could be particularly useful for indoor events with high microphone channel-counts where lower power is appropriate e.g. musical theatre;

  - taking advantage of other recent advances in PMSE technology (e.g. low-intermodulation transmission modes) to optimise frequency planning, which may result in moderate increases in spectral efficiency; and

- managing spectrum demand and planning centrally for large events, feeding into decision-making at the event design phase.

7.34 We are working with PMSE stakeholders to determine the viability and effectiveness of these actions and to determine the residual impact on PMSE after these mitigations have been considered. However, through this consultation we are seeking views from stakeholders on whether we have correctly identified actions that the PMSE industry could adopt to improve spectrum efficiency and whether there are other actions that could play a useful role.

7.35 Some of these changes are part of the long term development of the PMSE industry, e.g. adoption of digital equipment and taking advantage of advances in technology, and therefore do not have a cost specifically related to the 700 MHz band. However, some will be related to 700 MHz change of use. We have attempted to quantify the cost of a number of these changes, to the extent that they would occur in mitigation of 700 MHz change of use, including:

- employing more RF engineers and increasing the skills and best practice of current employees. We estimate between 15 and 20 new RF engineers will need to be hired and between 20 and 30 current employees will need further training. We estimate the cost of these changes in working practices would be between £10 million and £13 million over 20 years; and

- upgrading to more frequency agile equipment. As discussed above, our estimate of equipment replacement costs includes a mark-up to reflect the need for this upgrade.

7.36 We believe that these efficiency improvements are not, in isolation, sufficient to mitigate the effect of the potential loss of spectrum. Their applicability to the PMSE use cases under study was uneven and we would expect this to be the case with PMSE use in general.

We believe it should be possible to largely mitigate the impact of loss of access to the 700 MHz band

7.37 As set out above, change of use of the 700 MHz band would pose challenges to the PMSE community. We are strongly committed to helping it meet these challenges. We have identified a wide range of potential mitigations including the provision of additional spectrum and improvements in the efficiency of PMSE spectrum use. We are conducting more work to explore these options further. However, given the range of options we are looking at and our current assessment of their feasibility we are confident that the impact described in this document could be mitigated. We therefore believe that we could release the 700 MHz band for mobile, whilst ensuring that the PMSE community retains its ability to deliver its important cultural benefits.

7.38 There is clearly a residual risk to the delivery of at least some of these mitigations and their development requires significant work. Our work will involve managing this risk as part of our on-going commitment to safeguarding PMSE use in the UK. We believe that the analysis of audio PMSE undertaken as part of this consultation strengthens our ability to further the interests of PMSE users going forward.

Question 11: Do you have any comments on our assessment of the impact change of use of the 700 MHz band would have on PMSE?

Question 12: Do you have any comments on the mitigations for loss of access to the 700 MHz band including whether we have correctly identified the replacement bands suitable for further study and whether we have correctly identified actions that the PMSE industry could adopt to improve spectrum efficiency?

Section 8

Potential impact on spectrum availability for white space devices

8.1 We set out in our Annual Plan[72] that one of our priorities was to enable the use of white space devices and investigate opportunities for further appropriate sharing of bands. Ofcom has a programme of work underway to implement access to TV white spaces. The work is at present focussed on the delivery of a number of pilots. Further details of this work are available on our website.[73]

8.2 In our analysis of the impact of changing the use of the 700 MHz band we have considered the potential impact on use by White Space Devices (WSDs) as it is possible that spectrum could be used by such devices from 2015.

8.3 Given the uncertainty over the commercial deployment and take-up of WSDs, we have not sought to quantify any loss of value to that use associated with changes in white space availability. Rather, we have investigated from a technical perspective likely spectrum availability in case of change. We find that on balance WSDs would continue to have access to UHF spectrum to support the range of opportunities currently envisaged.

Change of use of the 700 MHz band would affect the amount of TV White Space available to WSDs

8.4 The changes to the DTT frequency plan discussed in this document would affect the amount of TV White Spaces available in different regions. In Annex 13 we present an assessment of this impact.

8.5 In our analysis we have quantified the white space availability that might exist after a change of use of the 700 MHz band. We did so taking account of the need to ensure a low probability of harmful interference to DTT only. This analysis suggests that, while there would be changes in availability, the overall picture is one in which significant white space availability remains.

8.6 There are two main impacts. First, the total number of channels available is reduced as a result of removing the 700 MHz band (i.e.12 channels of 8 MHz each) from the frequency ranges to which WSD have access. Second, in areas of the UK where there are higher numbers of DTT services to take account of, the white space availability increases following the changes to the 700 MHz band. This impact is greater for higher WSD powers. This analysis assumes that the approach to ensuring a low probability of harmful interference to DTT is as we have proposed in our white spaces consultation.[74] We recognise that any change in the approach to coexistence would be likely to have some effect on this analysis.

8.7 We have also considered the impact on white space availability as a consequence of a potential change of use of the 700 MHz band, taking account of the need to ensure

[72] http://www.ofcom.org.uk/files/2014/03/Annual-Plan-1415.pdf
[73] See http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/white-spaces-pilot/.
[74] *TV white spaces: approach to coexistence*¸ September 2013: http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/

a low probability of harmful interference to PMSE in addition to DTT. We cannot currently quantify the combined impact but we believe the situation is likely to vary by location such that in some areas spectrum availability may increase after the change of use while in others it may decrease.

Question 13: Do you have any comments on our assessment of the impact of the change of use of the 700 MHz band on the TVWS availability?

Section 9

Summary of costs

9.1 In Section 5 to Section 8 we have set out our assessment of the different costs that we have identified as arising from a change of use of the 700 MHz band. The purpose of this section is to bring these costs together and explain how we have adjusted the costs to ensure they are treated consistently for the purpose of our cost-benefit analysis.

9.2 In total, we estimate that costs related to 700 MHz change of use in 2022 would be between £470 million and £580 million (2014 NPV).[75] In this range we try to take into account uncertainties surrounding a number of the key factors; in particular the DTT band plan. Table 8 provides a breakdown of the costs.

Table 8: Summary of costs of change of use of the 700 MHz band in 2022

Cost category	Estimated cost
DTT infrastructure costs	• **£325m - £375m infrastructure costs** based on estimates from Arqiva • **£20m** infrastructure programme management costs
Consumer aerial costs	• 80,000 - 90,000 grouped aerials would need to be replaced • **£2m - £4m**
PMSE equipment costs	• **£6m - £18m**
Consumer information costs	• **£25m** consumer information costs • **£7m - £10m** cost of consumer time in retuning equipment
Coexistence costs	• **Between zero and £20m**
Loss of value	• **£80m - £100m**. Change of use of the 700 MHz band would reduce the spectrum that could be used for DTT. • **£10m - £13m.** The impact of PMSE having access to less spectrum could be mitigated through a number of actions. • Change of use of the 700 MHz band would be unlikely to have a material negative impact on white space availability and, on the contrary, could have some positive impact.

9.3 In this section we firstly discuss two aspects of our calculations which are relevant to a number of cost categories: we explain our proposed approach to valuing equipment which would need to be replaced as a result of the change of use, and our proposed approach to discounting for the net present value of future costs. We then set out how we have estimated each of the individual costs summarised in Table 8.

[75] The bottom of this range is the sum of the lower bound of each of the individual cost, i.e. £325m + £20m + £2m + £6m + £25m + £7m + £80m + £10m = £470m. The opposite is true of the top of the range.

In most cases we have included the cost of early replacement of equipment in our cost-benefit analysis

9.4 The majority of the costs relate to the replacement of equipment that we assume would otherwise have been replaced at the end of its asset life. For example, change of use would be likely to mean that a number of consumers would have to replace their television aerials before they would normally do so (usually when the aerial breaks).

9.5 Consumers wishing to view DTT will in any event face the full cost of replacing this equipment at some point (in the aerial example approximately £150). The effect of change of use is that consumers will incur this replacement cost earlier than they otherwise would. Therefore the relevant cost for our CBA is the cost of bringing this replacement forward.

9.6 We believe the assumption that industry and consumers will continue to replace equipment at the end of its asset life reflects the long term role of the DTT platform in delivering benefits to viewers. It is in the context of this long term role that we expect multiplex operators and consumers to continue investing in new equipment over time.

9.7 To estimate the cost of earlier replacement we compare the cash flows of replacement costs with and without change of use of the 700 MHz band. By assuming that change of use results in early replacement of an asset, we are also bringing forward all future replacements of that asset, since equipment which is replaced early will also reach the end of its asset life before it would without change of use. We therefore calculate the replacement cost of equipment to perpetuity.

9.8 For example, if as result of change of use of the 700 MHz band a consumer is forced to replace an aerial 10 years earlier than they otherwise would have (i.e. 15 years into its asset life rather than 25), we estimate the cost of earlier replacement is approximately £76. This is discussed in more detail in Annex 14.

9.9 We have estimated the cost of earlier replacement, rather than the full cost, for DTT infrastructure costs, consumer aerial costs and PMSE equipment costs.

We discount costs using the Spackman approach

9.10 Our estimated costs occur in different years. To compare these costs against the benefits on a consistent basis we need to discount both the costs and benefits back to a single year.

9.11 Spackman (2004) set out an approach for discounting where there are private costs and public benefits.[76]

9.12 In 2012, the Joint Regulatory Group (JRG), of which Ofcom is a member, considered alternative approaches to discounting for cost-benefit analysis of public policy decisions. The JRG concluded that in most cases where there are private costs but public benefits the Spackman approach is appropriate.[77]

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[76] See Spackman (2004), "*Time Discounting and of the Cost of Capital in Government*", Fiscal Studies (2004), vol. 25, no.4, pp.467-518.
[77] Joint Regulators Group, July 2012, *Discounting for CBAs involving private investment, but public benefit* http://stakeholders.ofcom.org.uk/consultations/discounting-for-cbas/statement

9.13 As set out in Section 5 we believe that citizens and consumers would benefit significantly from change of use of the 700 MHz band through lower prices, improved network performance and potentially extended coverage and new services. Therefore we feel it is appropriate to use the Spackman approach for our cost-benefit analysis since change of use of 700 MHz would result in private firms incurring some costs and consumers gaining some benefits.

9.14 The Spackman approach is a two-step method:

a) First, we convert any capital costs incurred by private firms into annual costs at the company's cost of capital (WACC). The annual cost can be calculated in a number of ways, but the approach we have used is a simple flat annuity formula. This spreads the capital costs incurred by private firms plus financing costs over a number of years, the annualisation period.

b) Second, we discounting the annualised costs, any non-capital costs and benefits back to 2014 using the rate of social time preference.

9.15 The Spackman approach only differs from discounting all costs and benefits at the social time preference rate (STPR) when capital costs are funded by private firms. Therefore, in the context of this CBA, using the Spackman approach only has an impact on the DTT infrastructure costs, PMSE replacement costs and DTT opportunity cost relative to discounting every cost at the STPR. We also use it to discount both the network cost savings and performance benefits.

9.16 Using the Spackman approach has the result of increasing both the benefits and costs of change of use relative to the case of discounting purely at the STPR.

We estimate DTT infrastructure costs would be between £325 million and £375 million

9.17 As discussed in Section 5, the cost of DTT infrastructure changes depends on the DTT band plan, which will not be finalised until after 2015. To reflect this uncertainty Arqiva estimates infrastructure costs for two possible band plans. It estimates the cost of the single hop plan is between £310 million and £410 million. The cost of the COM SFN plan is between £360 million and £470 million. Arqiva has also presented us with a cost profile which sets out what proportion of these costs it expects would be incurred in each year over the period 2014-2023. Based on our prior experience in DSO and 800 MHz clearance, we have focused on Arqiva's lower estimate for each band plan for the purposes of our cost-benefit analysis.

9.18 The above costs represent the total cost of replacing equipment. As discussed above, the appropriate cost for our cost-benefit analysis is the cost of earlier replacement. Therefore we have estimated the replacement cost using the following assumptions:

- DTT equipment having an asset life of 25 years;
- the equipment having on average been installed in 2010 as this was towards the end of DSO and 800 MHz clearance; and

- a WACC of 7.7% (pre-tax real). This comes from the Analysys Mason report for Administered Incentive Pricing.[78]

9.19 We have spread the costs over the 2014 to 2023 period using the cost profile provided by Arqiva. We assume that the costs are annualised over a 20 year period for the purpose of calculating a financing cost for the Spackman approach. We use the Spackman method to discount the costs back to 2014. This provides a NPV cost estimate of between £305 million and £355 million depending on the DTT band plan used.

9.20 The local TV network would also have to be replanned with change of use of 700 MHz since it would also lose access to some spectrum in the band. In its high level estimate, Arqiva estimates that local TV modification costs would amount to £20 million. We use the same cost profile to spread these costs out between 2014 and 2023 and discount back to 2014 using the Spackman method. This produces an NPV cost estimate of £20 million.[79]

9.21 We have also estimated the programme management costs of the DTT replanning based on experience from DSO. In DSO, programme management costs were approximately £30 million. However, in DSO all 50 of the main DTT transmitters underwent changes. In the 700 MHz infrastructure programme we estimate only between 30 and 40 of the main transmitter sites might require changes. Therefore we estimate the programme management costs would be approximately £20 million between 2014 and 2023. Spreading these costs out using the cost profile supplied by Arqiva and discounting back to 2014 using the Spackman approach produces a cost estimate of £20m.

700 MHz aerial replacement costs

9.22 As we discuss in Section 6, we expect that a relatively small number of households would have to replace their television aerials were change of use of 700 MHz to occur. This is because we expect that they would be using aerials which could not pick up signals outside of the 700 MHz band to receive their DTT signal.

9.23 Our process for assessing the costs of aerial replacement includes two parts. First, we assess the number of aerials that would need to be replaced with 700 MHz release, and then we calculate the cost associated with replacing the identified aerials.

An estimated 80,000 to 90,000 aerials would need replacing

9.24 As we discuss in Section 6, consumers with grouped aerials would be likely to need to replace them in the event of change of use of 700 MHz in order to continue to receive DTT. Based on our forecast of the future penetration of wideband aerials, the proportion of consumers which we estimate to use portable aerials and the proportion of consumers for whom DTT is the primary viewing method on either their primary or

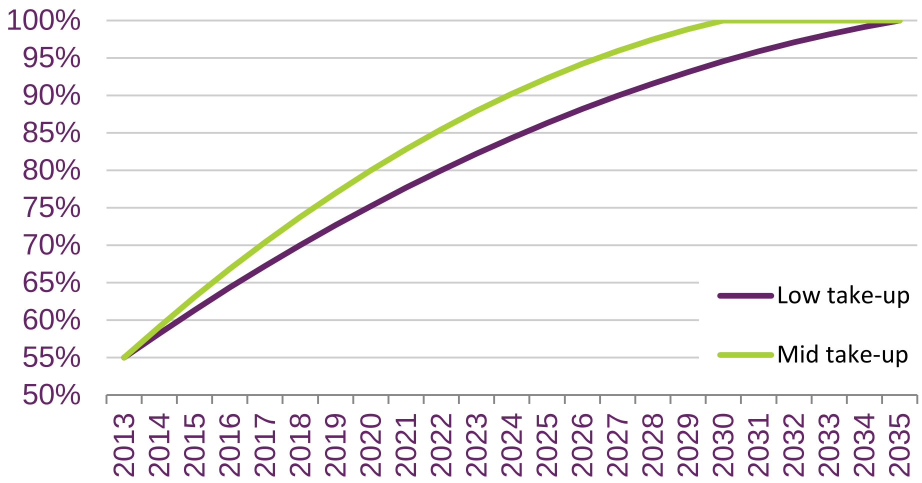
[78] See Analysys Mason and Aegis Systems, March 2013, *Opportunity cost of the spectrum used by digital terrestrial TV and digital audio broadcasting*: http://stakeholders.ofcom.org.uk/binaries/consultations/aip13/annexes/report.pdf

[79] Taking replacement costs rather than full costs tends to reduce the cost estimate. However, discounting using the Spackman methodology usually leads to a higher estimate than the undiscounted numbers. So while our numbers and Arqiva's are not directly comparable, they happen to be broadly similar.

secondary television set, we estimate that between 80,000 and 90,000 consumers would need to replace their television aerials as a result of change of use of 700 MHz.

9.25 We have made two forecasts of wideband aerial take-up over time. In our mid take-up scenario, the penetration of wideband aerials reaches 85.5% by 2022 as grouped aerials are gradually replaced by wideband aerials. In our low take-up case there is 80% penetration in 2022. In the year of 700 MHz change of use the remaining grouped aerials would potentially be affected by change of use.

Figure 7: Penetration of wideband aerials



9.26 Consumers who use portable aerials would not need to replace their aerials as portable varieties are typically wideband. Outputs from our aerial survey estimate 1% of main DTT sets and 5% of sets with DTT as a secondary input use a portable aerial to receive DTT. Other studies suggest the proportion of portable aerials may be higher.[80] Given this we have made the assumption that between 2% and 10% of households exclusively use portable aerials. This is constant throughout the modelling period.

9.27 We also factor into the analysis the proportion of households which watch television on the DTT platform since it is only these households which would lose their reception with change of use of 700 MHz. We use data from 3 Reasons (a consultancy) to estimate the proportion of households which use DTT as the primary feed on their primary television set or as the primary feed on their secondary television set. Throughout the modelling period approximately 75% of households use the DTT platform as the primary feed on either their primary or secondary television sets.

9.28 It is unlikely that all households who watch DTT only on their second or additional sets would replace their aerial with change of use. Some of these households would stop using their secondary television whilst others may switch to a non-DTT service. However, we do not have a reliable indication of the number of households that would not upgrade the aerial on their secondary television. Given this, we make the conservative assumption that all households with DTT on their second set would upgrade their aerial with release.

[80] *Annex L: Indoor aerials: contextual quantitative insights*, 2013, Kantar Media: http://stakeholders.ofcom.org.uk/consultations/700MHz/

9.29 Based on these assumptions we estimate that between 80,000 and 90,000 households would need to replace their aerials if 700 MHz change of use happens in 2022.

The cost of aerial replacement is estimated to be between £2 million and £4 million

9.30 We estimate that the cost of replacing an aerial is £150 on average (this includes the cost of an aerial and the cost of expert installation). The cost of replacing all remaining grouped aerials used to receive DTT in 2022 would be between £9 million and £10 million (2014 NPV).

9.31 However, as we discuss above, we believe that it is appropriate for our CBA to calculate the cost of earlier replacement as a result of 700 MHz change of use rather than the full cost. As discussed in Section 6, we recognise that when considering the impact on viewers as part of a programme of change, as distinct from the economic cost of change, we will take into account the specific circumstances of citizens and consumers, which differs from that of corporate organisations that manage assets.

9.32 To calculate the replacement cost, we assume the asset life of an aerial is 25 years. We also need to estimate when aerials would have been replaced without change of use. We use our forecast of wideband aerial take-up to estimate how many aerials would have been replaced in each year from 2022 to 2035.

9.33 We then multiply the replacement cost in each year by the number of aerials that would have been naturally replaced in that year, without release. This calculation is carried out across the time period up until the date when all remaining grouped aerials would naturally have been replaced, absent release. This gives us the cost of replacing the remaining wideband aerials in the year that they would have been replaced absent release.

9.34 Our final NPV of replacement costs is calculated by summing the yearly replacement cost and discounting back from the year of change of use to 2014. If change of use were to occur in 2022 the estimated aerial replacement cost would be between £2 million and £4 million.

PMSE equipment costs

9.35 We discuss the costs associated with replacing and upgrading PMSE equipment in Section 7 and Annex 12. This methodology uses the Spackman method of discounting and estimates replacement cost rather than full cost.

9.36 We estimate that the NPV cost in 2014 of bringing forward the replacement and upgrading affected PMSE equipment would be between £6 million and £18 million.

Consumer information costs

9.37 If change of use of 700 MHz were to occur, consumers would need to be informed of the potential need to retune their DTT equipment and replace their television aerials.

9.38 We have used evidence from past programmes to estimate the likely scale of the costs of providing consumers with this information.

9.39 The communication campaign associated with DSO cost approximately £127 million. In comparison, the cost associated with clearance of channel 61 and 62 was approximately £5 million.

9.40 We believe the costs associated with clearance of channel 61 and 62 are a more appropriate comparison with change of use of the 700 MHz band. A large part of the DSO campaign was informing consumers of the need to replace analogue equipment, equipment replacement is not expected to be necessary with change of use of the 700 MHz band.

9.41 As part of clearance, two DTT frequency channels were cleared. If the 700 MHz band is used for mobile then twelve DTT frequency channels would need to be cleared. Therefore we estimate the consumer information costs associated with change of use of the band are approximately six times that of the clearance of channel 61 and 62 (i.e. £30 million[81]). This is spread across 2019 to 2022 and discounted back to 2014 to give an NPV of £25 million.

Consumer retuning costs

9.42 As we discuss in Section 6, we estimate that between 14 million and 20 million households would require a retune as a result of change of use of 700 MHz.

9.43 We assume that this number of retunes would be spread across three years preceding change of use in 2022. We estimate the cost of consumer time over this period by updating the value of non-commuting leisure time provided by the Department of Transport[82] using forecasts of real GDP growth provided by the Office of Budget Responsibility. Based on this, and an average retuning time of five minutes, we calculate that the consumer time lost to retuning would result in a NPV cost of between £7 million and £10 million in 2014.

9.44 We note that this is likely to be a conservative estimate since it assumes a) that consumers spend an average of 5 minutes retuning their television; and b) that consumers will spend that 5 minutes doing nothing else other than retuning their television – in reality, we might expect many consumers to spend the time that it takes their television to retune undertaking other tasks. [83]

Coexistence costs

9.45 We set out our assessment, for the purpose of this CBA, of potential issues of coexistence between new mobile services operating above 694 MHz and existing services operating below 694 MHz in Section 6 and Annex 10.

9.46 In light of our assessment and our estimate that coexistence costs would be likely to be between zero and £20 million (2014 NPV), with a real possibility that actual costs

[81] This may be a conservative estimate since, for simplicity, we have not taken into account any economies of scale which may reduce this cost,
[82] http://www.dft.gov.uk/webtag/documents/expert/pdf/U3_5_6-Jan-2014.pdf
[83] There may also be an additional cost associated with the time lost to consumers from searching for and purchasing a new aerial. As we estimate relatively few households to be affected and that the lost time in arranging for an external party to install an aerial is likely to be relatively small, we estimate this cost to be very small. In an indicative calculation, we estimate this cost as less than £500,000 and likely to be less than £50,000 depending on the amount of time lost.

may be towards the lower end of that range. We have not applied any adjustment to these costs.

The loss of value from using the spectrum for mobile services

9.47 A change of use of 700 MHz for mobile would mean that the band could not be used for other purposes. The cost to these other users of not having access to the band is the loss of value or the opportunity cost.

9.48 The principal loss of value associated with mobile use of the 700 MHz band would be to the DTT platform since it is currently the primary user of the band. However, PMSE and WSD users also currently access the interleaved spectrum in the band and would, therefore, also incur loss of value from no longer having access to the band.

9.49 We discuss each of these in turn below.

DTT loss of value

9.50 We discuss our approach to estimating DTT opportunity cost in Section 5. We use the cost of a full DVB-T2 transition to proxy the opportunity cost. We estimate that full DVB-T2 transition would cost between £340 million and £370 million in 2014 NPV terms. We then subtract the operating cost saving of moving from eight to six multiplexes to give an opportunity cost of between £80 million and £100 million in 2014 NPV terms.

9.51 Our estimate of the cost of a full DVB-T2 transition is based on estimates of the cost of:

a) Upgrading consumer equipment

b) Upgrading DTT infrastructure

c) Informing consumers of the need to upgrade equipment

9.52 Each of these costs is affected by our choice of discounting method and how we estimate replacement costs. We discuss each of these components of the DVB-T2 cost estimate below.

9.53 As we discuss in more detail in Annex 9, a transition to DVB-T2 would mean that consumers without DVB-T2 equipment at the time of transition would incur costs of upgrading their equipment to make it compatible with the new standard. We estimate that a total of 7.9 million pieces of consumer equipment would need to be upgraded if DVB-T2 transition were to occur in 2022. We estimate that the cost of bringing forward replacement of this equipment with DVB-T2 transition in 2022 would be £220 million.

9.54 In Section 5 we set out Arqiva's estimate of the additional DTT infrastructure costs associated with a full DVB-T2 upgrade of between £30 million and £50 million. We do not consider it appropriate to count the cost of bringing forward replacement of DTT DVB-T2 infrastructure in this estimation. This is because our counterfactual does not assume that a DVB-T2 upgrade would necessarily be required in the future. Therefore, there may not be any additional future DTT infrastructure cost to allow an upgrade to DVB-T2 absent change of use of 700 MHz.

9.55 However we spread the cost estimates provided by Arqiva over the three years preceding an assumed change of use in 2022 and use the Spackman approach to discount the costs involved in financing the investment. From this, we estimate that the additional infrastructure costs involved in transitioning to DVB-T2 would be between £35 million and £60 million in 2014 NPV terms.

9.56 Our estimate of the consumer information costs associated with a full DVB-T2 transition is based on experience from DSO. We believe any DVB-T2 information campaign would be similar in scale to DSO as both changes required a large number of consumers to replace equipment. We estimate the total consumer information costs of a combined change of use of the 700 MHz band and DVB-T2 transition would be approximately £130 million.

9.57 As noted above, the estimated consumer information costs of change of use without DVB-T2 transition would be around £30 million. Hence the additional consumer information costs associated with DVB-T2 transition would be £100 million. DVB-T2 transition would account for the majority of the £130 million information costs because it would affect a larger number of households. We spread this over five years prior to change of use in 2022 and discount back to 2014 at the STPR to get a NPV of £85 million.

PMSE loss of value

9.58 In our treatment of the costs to PMSE of change of use we distinguish between transitional costs that would be incurred by firms needing to replace PMSE equipment with change of use (because the band in which it operates is no longer available for PMSE use) and the costs to PMSE users of having less spectrum to operate in (notwithstanding that we are working to identify alternative spectrum for PMSE audio applications). We discuss the transitional costs above and in Section 7. Below we set out our estimate of the costs to PMSE users of mitigating the loss of spectrum associated with change of use – the loss of value of no longer having access to the 700 MHz band.[84] A reduction in the spectrum available for PMSE would be likely to require users to use the spectrum available more efficiently. One way in which PMSE users may look to do this is by using more experienced radio frequency (RF) engineers to plan their events more efficiently. In the past experienced engineers have only been required at the largest events. Our opportunity cost calculation assumes that experienced engineers would be required at more events.

9.59 To estimate the opportunity cost to PMSE we have made the following assumptions:

a) Large hiring companies[85] would need to employ an additional RF engineer. We estimate the 10 largest hiring companies would all need to hire an additional RF engineer. We estimate the average annual salary of an RF engineer is £45,000.[86]

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[84] Our estimation of the PMSE equipment costs includes a calculation of the costs of upgrading equipment to cover a wider tuning range to help mitigate the loss of spectrum to PMSE. This cost amounts to between £6 million and £11 million of the total equipment replacement cost of £6 million to £18 million. We recognise that this cost is related to the loss of value to PMSE but have included it as part of the cost of equipment replacement since it is calculated as part of this estimation. This has no effect on the total costs, just their distribution.
[85] Hiring companies hire PMSE equipment to various events, e.g. West-end shows.
[86] Salary information is based on a survey of RF engineering jobs on Connectus, Just Engineers and Techno Jobs in December 2013.

b) Twice the present number of freelance RF engineers would be needed. There are currently between 5 and 10 freelance RF engineers in the UK. We assume the average salary of a freelance RF engineer is also £45,000.

c) Medium size hiring companies would need to train current test engineers and technicians so they are more experienced. We estimate between 20 and 30 test engineers and technicians would need additional training and as a result attract a higher salary. We estimate the additional cost of training and paying a higher skilled engineer is approximately £10,000 a year.

9.60 Summing these additional costs and discounting them back to 2014 at the STPR[87] results in an NPV of the opportunity cost to PMSE of between £10 million and £13 million.

WSD loss of value

9.61 Users of WSDs would also be affected by the reduction in availability of interleaved spectrum were there to be a change of use of the 700 MHz band. Given the uncertainty over the deployment and take-up of WSDs, we are not planning to quantify the cost of 700 MHz change of use on these users.

9.62 However, as discussed in Section 8, we have looked at the availability of white space spectrum post change of use of the 700 MHz band. Our initial analysis suggests change of use of the 700 MHz band would be unlikely to have a material negative impact on white space availability and, in certain respects, could have some positive impact. Therefore we do not expect any costs associated with changes in white space availability to have an effect on the outcome of the cost-benefit analysis.[88]

The impact of earlier or later change of use

9.63 Our assessment of the costs is based on an estimate that change of use of the 700 MHz band would conclude in 2022. If change of use were brought forward we would expect the present value of the costs to increase, conversely if change of use were delayed we would expect the present value of the costs to fall. There are two main reasons for this:

a) Deferring costs to a later date means they are lower in 2014 NPV terms as they are discounted back over more years. This affects all cost categories (a similar effect applies to benefits).

b) Over time, some households and businesses will replace equipment, and new units are less likely to be affected by 700 MHz change of use than those they replace. For example, if change of use occurs at a later date, more consumers

[87] We do not use the Spackman method for discounting the loss of value to PMSE as the costs are operating costs rather than capital costs.

[88] The analysis set out in Section 9 is based on comparing white space availability post change of use of the 700 MHz band with current availability. However, current white space availability is restricted by the low power interim multiplexes. We expect that without change of use of the 700 MHz band these multiplexes would likely be re-planned to allow for high power use in line with the existing COM multiplexes. In that case white space availability would be higher than today, but we cannot estimate exact availability without a frequency plan. Therefore comparing white space availability post change of use with availability today is likely to understate the potential opportunity cost. However, given the infancy of the white space industry, we do not think there would a significant cost associated with any potential reduction in spectrum.

will have acquired wideband aerials and so fewer aerials will be affected by change of use. This particularly affects aerial costs and PMSE equipment costs.

9.64 However, on balance we do not expect the overall costs would vary greatly between an earlier or later change of use. In particular, the most substantial cost in our analysis, DTT infrastructure costs, is not very sensitive to the year of change of use.

9.65 Because of this, our quantitative modelling of the costs of a change of use is based on a completion date of 2022, and is not designed to measure the change of use for different release dates.

Question 14: Do you agree with our use of the Spackman method for discounting both the costs and benefits of change of use?

Question 15: Do you agree with our approach of estimating the cost of early replacement or should we be considering the full cost? Do you have any comments on how we have estimated the costs of early equipment replacement?

Question 16: Do you agree with our overall assessment of the costs of change of use of the 700 MHz band?

Question 17: Do you have any comments on our assessment of the impact of earlier or later change of use of the 700 MHz band?

Section 10

Proposals

10.1 In the preceding sections, we have presented our assessment of:

- the benefits that would be associated with making the 700 MHz band available for mobile broadband;
- the costs associated with moving existing users out of the 700 MHz band; and
- the loss of value to existing uses from replacing them in that band with mobile services.

10.2 We now move on to summarise this analysis and draw provisional conclusions as to whether the benefits of the change under consideration are likely to exceed the sum of the transitional costs of change and the value the band has to existing uses. On this basis we set out our proposals for the future of the 700 MHz band.

Our analysis indicates the benefits of a change of use of the 700 MHz band would outweigh the costs

10.3 Table 9 below summarises the costs and benefits associated with making the 700 MHz band available for mobile broadband.

10.4 Our analysis suggests that the benefits of making the 700 MHz band available for mobile broadband substantially outweigh the sum of the costs of change and the loss of value to existing uses. When considering the balance of costs and benefits, it is important to note that there are a number of benefits which we have not been able to quantify but which could potentially be significant. Hence we believe there is potential for significant upside in our assessment of the benefits. Conversely we do not believe the costs are likely to exceed materially the range identified below.

Table 9: Summary of estimated costs and benefits of change (2014 NPV)

<table>
<tr><th></th><th colspan="2">Costs of change</th><th colspan="2">Benefits of change</th></tr>
<tr><td rowspan="8">Elements that we have quantified</td><td>DTT infrastructure modifications (inc. programme management costs and consumer information scheme)</td><td>£370m-420m</td><td>Reduction in costs of meeting increased demand for mobile data capacity from having to build and to operate fewer network sites</td><td>£480m-770m</td></tr>
<tr><td>Consumer aerial replacements</td><td>£2m - 4m</td><td rowspan="5">Improvement in the performance that mobile users would experience particularly deep indoors and in rural areas, also measured as the reduction in costs from having to build and to operate fewer network sites to achieve the improved performance</td><td rowspan="5">£390m - 480m</td></tr>
<tr><td>Cost of consumer time retuning TVs</td><td>£7m - 10m</td></tr>
<tr><td>Coexistence costs</td><td>£0 - 20m</td></tr>
<tr><td>PMSE equipment replacement</td><td>£6m - 18m</td></tr>
<tr><td>DTT loss of value net of operating cost savings</td><td>£80m - 100m</td></tr>
<tr><td>PMSE loss of value</td><td>£10m - 13m</td><td colspan="2">Reductions in consumer prices: a significant proportion of these network cost savings would likely be passed on to consumers</td></tr>
<tr><td colspan="2">Total: £470m - 580m with potential for reduction as better information becomes available</td><td colspan="2">Total: £900m - 1.3bn of quantified benefits</td></tr>
<tr><td rowspan="4">Elements that cannot be reliably quantified</td><td colspan="2" rowspan="3">WSD opportunity cost: current uncertainty over the deployment and take-up of WSDs does not support quantification and the change would be unlikely to have a material negative impact on white space availability</td><td colspan="2">Broader economic and social benefits from potential improvements in coverage if a 700 MHz award included a coverage obligation</td></tr>
<tr><td colspan="2">Access to new services: magnitude of benefits unclear. Could be very large, but could be zero</td></tr>
<tr><td colspan="2">Increases in capacity for delivery of emergency services communications: magnitude of benefits unclear. Could be significant</td></tr>
<tr><td colspan="2">Effect of unquantified costs: not material to total costs</td><td colspan="2">Effect of unquantified benefits: potential for significant upside over and above the quantified benefits</td></tr>
</table>

An earlier change would result in greater net benefits

10.5 The summary set out above models a scenario in which the 700 MHz band becomes available for mobile broadband in 2022. However, we have also considered the impact of earlier and later change of use of the band. In general, we expect that the earlier the change occurred, the sooner mobile operators would be able to deliver benefits such as improvements in performance. Conversely, a delay in change of use risks reducing the benefits: if mobile operators face short-term pressure to meet rising traffic, and uncertainty about how much, if any, 700 MHz spectrum they will gain access to, they may respond by building more sites, incurring network costs which could otherwise have been avoided and hence reducing the value of 700 MHz spectrum when it is subsequently released. For example the Analysys Mason model estimates that an earlier change of use in 2020 would increase the network cost saving and performance benefits by between £20 million and £70 million in the central range. On the other hand, our analysis suggests that making the 700 MHz band available to mobile broadband in 2026 as opposed to 2022 would reduce the benefits by up to £170m.

10.6 The costs of change of use will also tend to be higher (particularly in net present value terms) if a change of use occurs earlier. However, on balance we consider that any practical advantages to delaying are likely to be limited, and that changing use of the 700 MHz band at the earliest possible opportunity would be likely to deliver the optimum balance of costs and benefits. Current information indicates that it would be possible to make the 700 MHz band available for mobile use by the beginning of 2022. However, experience with previous broadcast infrastructure projects suggests that more detailed planning work might identify opportunities to expedite completion of the proposed programme of change, such that it may be possible to complete a programme up to two years earlier.

We are proposing to make the 700 MHz band available for mobile use at the earliest possible opportunity

10.7 In light of the above analysis, we propose to make the 700 MHz band available for mobile broadband at the earliest opportunity. Making a final decision on this proposal is subject to a number of further conditions. These include necessary discussions at an international level being sufficiently advanced, for example regarding technical coordination with our international neighbours, and determination of how the costs of implementing a change of use should be met.

10.8 Because our analysis indicates that an earlier change of use would generate greater net benefits, we will continue, in the period between now and our decision on the case for change, to work to preserve the option of implementing a change of use as soon as possible. This will mean that if, following our consultation, we remain of the view that a change of use of the 700 MHz is the right course of action we will still be in a position to achieve maximum benefits. However this does not prejudge the outcome of this consultation, and any decisions we take will follow careful consideration of the responses we receive.

We are considering the long term future of DTT

10.9 The approach we take to the future of the 700 MHz band is linked to debates about the long term future of the DTT platform. As discussed in Section 5, making the band available for mobile broadband would entail substantial investment in modifications to DTT transmission infrastructure. If we felt that there was a credible prospect that the amount of spectrum the DTT platform needs was likely to decrease significantly in the short to medium term, it is questionable whether this investment would be worthwhile. Rather, in such a scenario there might be a case for delaying change of use of the 700 MHz band and conducting a larger reconfiguration in a single step.

10.10 However, as set out in our discussion document on the *Future of free to view TV*, we believe that alternative delivery platforms are unlikely to provide a viable substitute to the DTT platform over the next decade. In particular we consider that IPTV platforms are more likely to act as a complement, as opposed to a substitute to broadcast TV platforms until at least 2030. In view of our assessment of the long term importance of DTT, we do not anticipate that any further changes in how much spectrum the platform needs would be likely to take place sufficiently soon to justify delaying change of use of the 700 MHz band. Nevertheless, our approach to the proposed changes for 700 MHz takes account of the principle of potential further changes.

Building in flexibility into an implementation plan

10.11 DTT transmission equipment has a long asset life (ca. 25 years). While we do not envisage any further DTT re-plans in the foreseeable future, it is inherently difficult to predict with certainty how spectrum use might evolve in the very long term. If we were to proceed with the proposed changes, we would seek to develop an implementation plan which gives multiplex operators flexibility to react quickly and efficiently to any future changes in the DTT frequency plan. For instance, we are exploring whether it would be possible and cost-effective to build additional frequency versatility into the DTT network by installing wideband antennas[89] at transmitter sites that were modified as part of the proposed 700 MHz re-plan. Doing this could enable DTT stakeholders to undertake any future network re-plans more quickly and cheaply than would otherwise have been the case and without undoing modifications introduced as a result of 700 MHz change. Our discussion document on the *Future of free to view TV* considers potential changes to the DTT platform over the longer term.

Question 18: Do you agree with our proposal that we should make the 700 MHz band available for mobile broadband?

Question 19: Do you agree with our proposal that we should seek to implement this change at the earliest possible opportunity?

[89] Wideband antennas are antennas which are capable of transmitting across the majority of, and potentially the full, range of frequencies currently used by DTT. They would not need replacement early in their useful life in case of further changes to the DTT frequency plan.

Section 11

Funding the proposed changes

11.1 As set out in the preceding chapters, change of use of the 700 MHz band would result in a range of costs. Principal among these are the following:

- cost of modifying the DTT network to allow it to operate at new frequencies;
- cost of replacing consumer aerials;
- cost of PMSE equipment replacement; and
- cost of addressing any potential coexistence issues.

11.2 We have assessed these costs, and other non-cash costs, in a way and to a degree that we consider is appropriate to inform our cost-benefit analysis based on the best available information at this stage. This assessment would need further refinement and additional information to develop actual programme cost estimates. However, we do not expect the overall cost of such a programme in 2014 NPV terms to exceed the upper bound of our cost range.

11.3 This chapter sets out an initial discussion of options for how each of these costs might be funded. Our further work is subject to discussions with Government. In particular, it is important to stress that any decisions as to whether or not public funding would be involved are a matter for Government.

11.4 Throughout our further analysis and discussions with Government, we will be mindful of our duties to citizens and consumers, in particular to vulnerable consumers and those that might find change more challenging, as set out in Section 2.

Changes to DTT transmission infrastructure

11.5 As set out in Section 5, the costs of bringing forward DTT infrastructure modification would likely be between £325 million and £375 million, with programme management costs of £20 million on top of this (2014 NPV). A consumer information campaign could cost approximately £25 million (2014 NPV).

11.6 Potential parties that might provide funding for changes to DTT transmission infrastructure are (a) DTT multiplex operators; (b) future 700 MHz licensees; and (c) Government.

Replacement of domestic DTT equipment

11.7 As set out in Section 6, we estimate that 80,000 to 90,000 households might need to replace their aerials. In total, bringing forward these aerial replacements would cost between £2 million and £4 million (2014 NPV). The full cost associated with replacing aerials is estimated to be between £9 million and £10 million (2014 NPV).

11.8 Potential parties that might provide funding for replacement of domestic DTT equipment are (a) DTT consumers; (b) DTT multiplex operators; (c) future 700 MHz licensees; and (d) Government.

Replacement of PMSE equipment

11.9 As set out in Section 7, change of use of the 700 MHz band would require some PMSE users to replace items of equipment. Bringing forward these replacements and upgrading equipment would cost between £6 million and £18 million (2014 NPV).

11.10 Potential parties that might provide funding for replacement of PMSE equipment are (a) PMSE users; (b) future 700 MHz licensees; and (c) Government.

11.11 In our discussions with Government, we will be mindful of our 2010 statement *Programme-making and special events: Future spectrum access*[90]. There, we said that PMSE users would have security of tenure in the 700 MHz band until September 2021 and that we would give them a minimum of 5 years' notice of any requirement to vacate the band.

Coexistence of new mobile services and DTT reception

11.12 Our assessment of the likely scale of the issue is not yet sufficiently mature at this stage for us to be able to provide a budgetary estimate for any remediation measures. For the reasons set out in Section 6, we would not expect the total mitigation costs to exceed £20 million (2014 NPV); rather we expect that they could be much lower.

11.13 Potential parties that might provide funding for interference mitigation measures are (a) DTT consumers; (b) DTT multiplex operators; (c) future 700 MHz licensees; and (d) Government.

11.14 Any decisions regarding public funding are a matter for Government. As we move forward, we will support the Government in its consideration of whether there might be a case for providing public funds to support the proposed programme of change.

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90 http://stakeholders.ofcom.org.uk/binaries/consultations/bandmanager09/statement/statement310810.pdf

Section 12

Next Steps

12.1 This consultation will close on 29 August 2014. Once we have considered all consultation responses, we will publish a statement setting out our decision on the proposed changes in late 2014 or early 2015. Consistent with the approach outlined in our *UHF strategy statement*, we will take a number of actions during the consultation period to ensure that we retain the option of proceeding with these changes at the earliest opportunity should our consultation process lead us to conclude that this is in the best interests of citizens and consumers. These actions include:

a) participating in international frequency planning processes (including preparation for WRC-15, discussions with neighbouring countries on DTT frequency planning options, and engaging with CEPT on the mobile band plan);

b) working with the PMSE community to develop further our understanding of alternative PMSE spectrum options and this work may develop further separately from this consultation process;

c) undertaking more detailed coexistence analysis;

d) commissioning more detailed research into options for modifying DTT infrastructure; and

e) supporting Government in its consideration of the role public funding might have in the proposed programme of change and more broadly in its consideration of future use of UHF spectrum.

12.2 If, following our consultation, we decide to make the 700 MHz band available for mobile use we will:

a) Continue with the actions outlined above at paragraph 13.1a) to 13.1e);

b) Develop plans to provide citizens and consumers with appropriate information and assistance through the transition process; and

c) Prepare and hold a spectrum auction for the 700 MHz band.

12.3 If we decide to proceed with the proposed changes, we will have to consider when to auction licences for the 700 MHz band. In particular, we would have to consider the relative merits of holding an auction near to the time of availability of the spectrum (e.g. in 2019 or 2020), following a similar approach to what we did for recent spectrum auctions, or earlier (e.g. in 2016 or 2017). We recognise that there will be less certainty among bidders about spectrum needs if we hold an early auction. However, there may be scope for mobile licensees to engage with DTT multiplex licensees in ways which could accelerate change of use and thereby increase the benefits of the change. It might also enable licensees to plan network deployment with greater certainty. We would welcome stakeholders' comments on this issue.

Question 20: If, as a result of this consultation, we decided to go ahead with the proposed changes, what factors and evidence should we take into account when *considering whether to hold an auction near to the time of availability of the spectrum or earlier?*

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made by 5pm on 29 August 2014.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/700MHz/howtorespond/ , as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response coversheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email UHFSI@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

A1.4 Responses may alternatively be posted to the address below, marked with the title of the consultation.

Jon Higham
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.7 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Jon Higham on 020 7981 3673.

Confidentiality

A1.8 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.9 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.10 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/about/accoun/disclaimer/

Next steps

A1.11 Following the end of the consultation period, Ofcom intends to publish a statement in late 2014 or early 2015.

A1.12 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/static/subscribe/select_list.htm

Ofcom's consultation processes

A1.13 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.14 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.15 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email: Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response coversheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your coversheet only, so that we don't have to edit your response.

Coversheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	☐	Name/contact details/job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this coversheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name Signed (if hard copy)

Annex 4

Consultation question

A4.1 This annex provides a list of the questions we are asking in the sections of this document.

Question 1: Do you have any comments on Analysys Mason's approach to quantifying the network cost savings and performance benefits?

Question 2: Do you have any comments on the other benefits we have identified including the likely magnitude or how they may be quantified?

Question 3: Do you agree with our assessment of the likely benefits of changing use of the 700 MHz band?

Question 4: Do you have any comments on our analysis of the implications change of use of the 700 MHz band would have for the DTT platform?

Question 5: Do you agree with our assessment of the likely costs of upgrading DTT transmission infrastructure?

Question 6: Do you have any comments on our assessment of the timeframes within which it might be possible to complete a DTT replan?

Question 7: Do you have any comments on our assessment of the loss of value from existing DTT services in case of change of use for the 700 MHz band?

Question 8: Do you have any comments on our analysis of the implications of potential changes for DTT viewers and for the platform? Are there any effects that may be important to viewers that we should consider further?

Question 9: Do you have any comments on our consideration of consumer information and support measures and on the factors we should focus on in the next stages of work?

Question 10: Do you have views on the activities that Ofcom and other stakeholders could undertake now to help ensure that DTT equipment that consumers might buy in the coming years is as future-proof as possible?

Question 11: Do you have any comments on our assessment of the impact change of use of the 700 MHz band would have on PMSE?

Question 12: Do you have any comments on the mitigations for loss of access to the 700 MHz band including whether we have correctly identified the replacement bands suitable for further study and whether we have correctly identified actions that the PMSE industry could adopt to improve spectrum efficiency?

Question 13: Do you have any comments on our assessment of the impact of the change of use of the 700 MHz band on the TVWS availability?

Question 14: Do you agree with our use of the Spackman method for discounting both the costs and benefits of change of use?

Question 15: Do you agree with our approach of estimating the cost of early replacement or should we be considering the full cost? Do you have any comments on how we have estimated the costs of early equipment replacement?

Question 16: Do you agree with our overall assessment of the costs of change of use of the 700 MHz band?

Question 17: Do you have any comments on our assessment of the impact of earlier or later change of use of the 700 MHz band?

Question 18: Do you agree with our proposal that we should make the 700 MHz band available for mobile broadband?

Question 19: Do you agree with our proposal that we should seek to implement this change at the earliest possible opportunity?

Question 20: If, as a result of this consultation, we decided to go ahead with the proposed changes, what factors and evidence should we take into account when considering whether to hold an auction near to the time of availability of the spectrum or earlier?

Annex 5

Summary of responses to the April 2013 call for inputs

A5.1 In April 2013 Ofcom published a call for inputs on the *Future use of the 700 MHz band: Implementing Ofcom's UHF Strategy*.[91] We requested input from stakeholders on two specific areas:

a) The factors that are relevant for us to consider when assessing the costs and benefits associated with a potential change of use of the 700 MHz band.

b) The measures that we can and should take, ahead of any future change of use of the 700 MHz band, to reduce the disruption and costs which could result from a change of use of the band.

A5.2 We also sought comments on whether market mechanisms, such as an incentive auction, could have a role to play in determining the timing of a future release of the 700 MHz band.

A5.3 The consultation period closed in July 2013 and we received 50 responses.

A5.4 There were 26 consultation questions. In this annex we have grouped some of these questions by theme. We have also grouped the respondents according to the sectors they belong to or interests they represent.

A5.5 The respondent groupings are:

a) **TV** – Digital UK, Freeview, Digital TV Group (DTG), Channel 5 Broadcasting, Confederation of Aerial Industries;

b) **Mobile** – Everything Everywhere (EE), Vodafone UK, Qualcomm;

c) **PMSE** – Royal National Theatre, Royal Shakespeare Company, Brian Copsey, Hawthorn, Musicians' Union, Association of Professional Wireless Production Technologies (APWPT), British Entertainment Industry Radio Group (BEIRG), Raycom, University of York AV Centre, Morrison Sound;

d) **PPDR** – Metropolitan Police Service, Emergency Services Scotland, Kenyon Consulting, British Transport Police – National Policing Strategic Lead on Communications, TETRA and Critical Communications Association, The Federation of Communication Services (FCS), Motorola Solutions UK, British Association of Public Safety Communications Officials (British APCO);

e) **Other industry stakeholders** – Intellect (now techUK), Huawei, Samsung, British Sky Broadcasting Limited ('Sky'), David Hall Systems, BT; and

f) **Consumer groups, individuals and other respondents** – Voice of the Listener and Viewer, Scottish Government, Communications Consumer Panel (CCP), Jon Cole, J.P Gilliver.

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[91] http://stakeholders.ofcom.org.uk/consultations/700mhz-cfi/

A5.6 We have summarised responses under the most relevant question or alongside similar responses from other respondents.

A5.7 We have provided responses to the main points raised by stakeholders in italics, noting paragraph references for further details in the consultation.

Costs that should be taken into account in our assessment (CFI questions 1 and 2)

Question 1: Have we correctly identified and characterised the potential costs set out above, and what other costs – if any – should be taken into account in our assessment?

Question 2: What evidence, whether qualitative or quantitative, should we obtain and/or take into account in assessing each of these potential costs? Please identify any sources of specific evidence to which we should have regard.

A5.8 The majority of TV respondents broadly agreed with cost categories outlined in the CFI, however they considered that Ofcom may have underestimated some of these costs. For example, DUK and Freeview suggested that Ofcom should address the costs of aerial changes and replacing receivers for households using DTT on secondary sets.

A5.9 *Our estimations of aerial replacement costs take account of secondary sets (see paragraph 10.28 for further details).*

A5.10 *We do not consider that DVB-T2 transition is necessary to bring about change of use of the 700 MHz band (see paragraphs 6.23 to 6.31). Therefore we have not included costs of replacing receivers for households in our estimate of infrastructure and consumer costs. However, we took the costs of upgrading receivers of secondary sets into account when estimating the DTT opportunity cost (see paragraphs 6.62 to 6.65).*

A5.11 DUK suggested that when estimating the extent of aerial changes and potential infrastructure costs, Ofcom should adopt DTT frequency planning assumptions with a reasonable degree of certainty that these can be delivered in international negotiations.

A5.12 *We recognise that it is important that estimates of infrastructure modification costs reflect the uncertainty over international co-ordination. In order to do this, we asked Arqiva to provide estimates of costs for two different planning scenarios so that we have a range of possible costs upon which we can base our analysis (see paragraph 6.39).*

A5.13 TV respondents also identified a number of additional costs that should be taken into account, including:

- additional direct costs from planning and programme management;
- the impact of engineering works on other users of broadcasting masts, in particular broadcast radio transmissions;
- indirect costs of viewer disruption and platform uncertainty, which increases the risk of consumers switching to alternative platforms; and

- the impact of continued uncertainty over the future of the DTT platform, which could constrain investment in DTT and lead operators to incur further costs.

A5.14 *We have estimated programme management costs of the DTT replanning based on experience from DSO (see paragraph 10.21).*

A5.15 *We acknowledge that other users of broadcasting masts might experience periods of disruption to their services while engineering work is carried out (for example it may be necessary for radio services to operate at a reduced power temporarily while work is carried out on a mast).The contracts in place between the other mast users and Arqiva govern what level of service the third parties can expect and we understand that Arqiva put in place measures to reduce the impact on other mast users during DSO. The high level cost estimates provided by Arqiva contain a notional allowance for additional measures based upon previous experience. We do not have any evidence that other mast users suffered material additional costs during DSO and do not expect that they would do so should a replanning of the 700 MHz band go ahead.*

A5.16 *We do not believe that there is a material risk of consumers switching to alternative platforms (see paragraphs 7.25 to 7.27).*

A5.17 *We consider the long term future of the DTT platform in our discussion document on the Future of Free to View TV published on the same day as this consultation.*

A5.18 PMSE respondents did not agree with our characterisation of potential costs and benefits. They felt that the impact on those sectors reliant on PMSE would far outweigh any benefits to citizens and consumers.

- The APWPT considered that to get a full sense of the socio-economic value of PMSE, a proportion of the revenues made by productions and related industries need to be taken into account.

- PMSE respondents highlighted the cost of PMSE equipment replacement, with many observing that they had only recently upgraded equipment as a result of the clearance of the 800 MHz band and channel 69.

- One respondent noted the cost in labour of reengineering and installation work, particularly where equipment is in permanent use at a show or studio.

- Respondents also commented on the costs to DTT consumers of replacing equipment, soon after DSO, without any marked benefit, as well as the potential cost to consumers as a result of an increase to the cost of creating content from reduced PMSE spectrum availability.

A5.19 Among consumer groups, individuals and other respondents, The Voice of the Listener and Viewer and the Scottish Government believed that we have correctly identified cost categories. Like some TV and PMSE respondents above, the CCP noted that consumers and PMSE users would be required to experience considerable disruption only a couple of years after they were required to adjust their equipment or retune their apparatus.

A5.20 *We estimate the cost of replacing PMSE equipment with input from industry e.g. through our survey and we sought to reflect all relevant costs in our estimates (see paragraphs 8.15 to 8.16). Mitigating the impact on PMSE is a core part of our implementation strategy (see paragraphs 8.25 to 8.38).*

A5.21 *The changes proposed in this consultation would not require consumers to change the TVs or set-top boxes they currently use to enjoy DTT services. For most viewers the replan would only involve a simple retuning of their TV at the time of frequency changes. Section 6 provides information on costs to DTT consumers. The timing of changes for consumers and PMSE users would likely be from around 2019 or later.*

A5.22 Of the mobile respondents, Vodafone considered that outline costs have been correctly identified. It added that if temporary use of the 600 MHz band delayed the timing of a 700 MHz change of use, there would be a cost arising from the delay in mobile use.

A5.23 *The basis on which we made interim use of the 600 MHz band available was to support our long-term strategy for the UHF band (see paragraph 6.7, f).*

A5.24 EE considered that there were two offsetting benefits of potential DVB-T2 costs:

a) Upgrading to DVB-T2/MPEG4 equipment would mean consumers could receive HD channels. Although there may be a tail of consumers for whom the benefits would not outweigh the costs (estimated to be 20%), the countervailing benefit should be considered at an aggregate level.

b) If all multiplexes can be upgraded then there is the potential for additional DTT capacity.

A5.25 *As we noted above, we do not consider that DVB-T2 transition is necessary to bring about change of use of the 700 MHz band (see paragraphs 6.23 to 6.31).*

A5.26 A number of PPDR respondents argued that the long term costs to the UK of not having spectrum for PPDR in the 700 MHz band are large, and should be taken into account. Given that 700 MHz is already in use for PPDR elsewhere in the world and is expected to be in widespread use by the target release date, harmonisation could allow for economies of scale for handsets. It is unlikely that the same scale opportunities will exist for public services located in other bands, and choosing any other band could restrict the choice of and materially increase the cost of the specialised and high cost handsets in use by PPDR users and thus impose additional cost on UK PPDR agencies.

A5.27 *Decisions on whether and how the 700 MHz band might play a part in the delivery of PPDR communications are a matter for Government (see paragraphs 5.79 to 5.81).*

A5.28 Other industry stakeholders generally agreed with the costs identified. Sky and BT called for the inclusion of the opportunity cost to WSDs. David Hall Systems considered that there may be potential costs arising from any changes made to other frequency bands as a result of 700 MHz change of use. Intellect considered that the following should also be taken into account when considering costs:

- the cost of planning and programme management;
- secondary TV sets;
- additional costs associated with higher receiver immunity targets; and
- potential additional costs to improve out of band emissions of mobile handsets.

A5.29 *We have considered the impact of a change of use of the 700 MHz band on overall TVWS availability (see Section 8 and Annex 13 and paragraphs 10.65 and 10.66).*

A5.30 *As set out above, see paragraph 10.21 for programme management costs and paragraphs 10.28 and 6.62 to 6.65 on the use of secondary sets in the assessment of costs.*

A5.31 *We have been actively supporting the imposition of tighter mobile out of band emissions restrictions in the relevant international fora and this has resulted in lower values in CEPT's proposals than in APT (see Annex 6). We have also commissioned research which suggests that it would be feasible to improve materially DTT receiver performance without significantly increasing equipment costs*[92]*. For the purposes of our CBA, we have estimated the costs of any potential interference to DTT as being between £0 and £20m (see paragraphs 7.18 to 7.24 and 7.34).*

Benefits that should be taken into account and the likely future demand for additional spectrum for mobile data services (questions 3, 4 and 5)

Question 3: Have we correctly identified and characterised the potential benefits set out above, and what other benefits – if any – should be taken into account in our assessment?

Question 4: What evidence, whether qualitative or quantitative, should we obtain and/or take into account in assessing each of these potential benefits? Please identify any sources of specific evidence to which we should have regard.

Question 5: In particular, what is your view of the likely future demand for additional sub-1 GHz spectrum for the provision of mobile data services, and what evidence supports this view?

A5.32 The majority of TV respondents considered that Ofcom had broadly identified the relevant categories of potential benefits, but that these benefits are inherently uncertain and difficult to quantify. While TV respondents acknowledged increased demand for mobile data, they considered that the magnitude of this future demand is uncertain and therefore the need for the 700 MHz band has yet to be proven. In quantifying benefits, Ofcom should be careful to make sure they are evaluated in the light of alternative methods of meeting demand, e.g. small cells, Wi-Fi offloading, upgrading existing technologies to more efficient technologies, and alternate bands of spectrum. The benefits attributed to using 700 MHz should be the marginal benefits after other methods of meeting demand have been exhausted. The Confederation of Aerial Industries, alongside some PMSE respondents, suggested creating a model of a rationalised spectrum efficient network to obtain information on spectrum needs over and above current allocations – they considered that it may be that no extra is required.

A5.33 *Our estimate of the benefits of mobile use takes account of other methods of meeting a given level of traffic, including release of other spectrum bands, improvements in spectral efficiency and increases in Wi-Fi offloading (see paragraphs 5.18 to 5.29 and report from Analysys Mason).*

[92] The Technology Partnership's *Study on DTT Receiver Performance*, December 2013: http://stakeholders.ofcom.org.uk/consultations/700MHz/

A5.34 DUK considered that whilst 700 MHz change of use may in theory lead to cheaper prices to consumers, mobile operators may choose to deploy the cost savings in other ways. In addition, DUK considered that adding the 700 MHz band to a handset would add cost and complexity, regardless of international harmonisation.

A5.35 *Given the competitiveness of the UK mobile market we believe there would be significant benefits for consumers in the form of lower mobile tariffs (see paragraphs 5.49 to 5.64).*

A5.36 *700 MHz handsets supporting the APT band plan are expected to become available in the near future and other regions have adopted this band plan (see Annex 6). Given the potential for economies of scale and international harmonisation we think that it is likely such handsets would be available in the EU at little or no additional cost.*

A5.37 DTG noted that the benefits outlined are entirely related to mobile with no mention that change of use may also be an opportunity for DTT as a DVB-T2 transition would increase the potential range of HD services despite the reduction in capacity. This would both offer increased benefits to consumers and promote the longevity of free to view DTT.

A5.38 *As set out above, we do not consider that DVB-T2 transition is necessary to bring about change of use of the 700 MHz band (see paragraphs 6.23 to 6.31).*

A5.39 Vodafone considered that benefit categories have generally been correctly identified, but that the following should be taken into account:

- the potential for the 700 MHz band to become a 'first-tier' LTE band across Europe, thereby increasing the UK penetration of 700 MHz compatible mobile devices and in turn the proportion of mobile traffic that could be carried by the 700 MHz band;
- the benefits to consumers and mobile network operators (MNOs) of making 700 MHz available for mobile use before cell-splitting becomes necessary; and
- that a 700 MHz change of use would potentially bring the 600 MHz band into core DTT use. Whereas the counterfactual would only involve supplementary, incremental and potentially marginal DTT use, the former is a more effective use of spectrum.

A5.40 *We recognise the global harmonisation of the 700 MHz band is one of the key drivers of value and have taken this into account when considering the take-up of 700 MHz compatible devices. We have also considered whether this harmonisation would support the development of new services or technologies.*

A5.41 *Making 700 MHz available for mobile use before building more network sites becomes necessary is a key part of our assessment of the benefits of using the 700 MHz band for mobile services. In addition we have examined whether bringing forward change of use would result in significant additional benefits (see section 4).*

A5.42 *We have considered the value of both the 600 MHz band and 700 MHz band when assessing the opportunity cost of the 700 MHz band to DTT (see section 5).*

A5.43 EE considered that if the 700 MHz band were allocated to those mobile operators who already have significant sub-1 GHz holdings, there may not be significant incremental coverage benefits.

A5.44 *The importance of sub-1 GHz spectrum is reflected in our network cost saving and performance improvement modelling. Beyond what is captured in the modelling, release of the 700 MHz band could be combined with other incentives to further extend mobile coverage to more remote areas including roads and railway lines (see paragraphs 5.30 to 5.48).*

A5.45 PMSE respondents commented that there is further demand for, and therefore benefit of, sub-1 GHz spectrum use by all current occupiers. While respondents noted that mobile broadband may bring some benefits to consumers in the future, this should not be at cost to any other existing industries. PMSE respondents, like TV respondents, questioned the need for additional spectrum for mobile services. Respondents called for Ofcom to carry out work on re-farming and improving efficiency of spectrum used for mobile as an alternative to further clearances.

A5.46 *As stated above, the estimate of benefits takes account of other methods of meeting a given level of traffic including release of other spectrum bands, improvements in spectral efficiency and increases in Wi-Fi offloading (see paragraphs 5.18 to 5.29).*

A5.47 PPDR respondents and Intellect considered that numerous benefits would accrue from 2x10 MHz of reserved spectrum for emergency service use in the 700 MHz band.

A5.48 Mobile respondents also commented on PPDR use of the spectrum:

- EE suggested that if spectrum was reserved for PPDR in the 700 MHz band, this would be on the basis that it was more valuable than mobile use therefore could not be considered to reduce the benefits of making 700 MHz available to mobile.

- Vodafone considered that public safety applications could be accommodated with no impact on mobile broadband usage and minimal impact on DTT.

A5.49 *As set out above, decisions on the delivery of PPDR communications are a matter for Government (see paragraphs 5.79 to 5.81).*

A5.50 Kenyon Consulting considered that there will be further demand for mobile broadband spectrum in all topographies. It suggested that we adopt a more forward-looking strategy for migrating from wide-area broadcast infrastructure to localised mobile broadband infrastructure.

A5.51 *Our view is that it is not credible to propose a complete change from a traditional broadcast infrastructure to a more localised (low power / low tower) arrangement within the timescales within which we envisage a change of use of the 700 MHz band occurring. We have however considered the option of adopting a low power / low tower architecture along with other approaches that might facilitate the release of additional spectrum in the future and we describe these options in more detail in Annex 8.*

A5.52 The Scottish Government considered that potential benefits were well identified and characterised.

A5.53 The Voice of the Listener and Viewer noted the value to consumers from mobile data, but considered that it may be some years before demand for the 700 MHz becomes sufficiently apparent to require action.

A5.54 *The analysis we have presented in this consultation indicates that changing use of the 700 MHz band at the earliest possible opportunity would deliver greater net benefits (see paragraphs 11.5 and 11.6).*

A5.55 The CCP noted the benefits that allocation of 700 MHz to mobile services would bring but, alongside an individual respondent, urged careful consideration of the impact this could have on DTT consumers and vulnerable consumers in particular. The CCP welcomed further detail on the benefit of using the 700 MHz band for mobile, rather than the 600 MHz band as it did not consider the importance of harmonisation to economies of scale as a sufficient explanation.

A5.56 *Ensuring that viewers receive appropriate information and support would be a key part of our approach to implementing these changes (see paragraphs 7.28 to 7.32).*

A5.57 Intellect, Samsung and Huawei all considered that there is additional demand for sub-1 GHz spectrum for mobile broadband use. Sky noted that while the growth of mobile data traffic is likely, at least half of this increase in demand can be expected to be served by offloading mobile data on fixed networks.

A5.58 *Mobile operators have a range of options for increasing mobile data capacity and coverage including: acquiring more spectrum, using more efficient technologies; deploying more mobile sites; and encouraging greater use of Wi-Fi and femtocell data offloading. All of these techniques will be important for meeting future demand growth (see paragraphs 5.4 to 5.9).*

A5.59 BT considered that the 700 MHz spectrum will have sufficiently high value for mobile use only when devices are widely available in the European market. This may be after other large countries, that are less dependent on DTT, roll-out 700 MHz networks.

A5.60 *We recognise that the value of the 700 MHz band will depend on the take-up of compatible devices and Analysys Mason has taken this into account in its modelling. Given momentum behind the band is growing, with a number of APT countries having already auctioned the spectrum and a number of European countries planning to hold auctions before 2020, we believe it is reasonable to assume devices will start to become available from 2016.*

The weighting of costs and benefits (question 6)

Question 6: Should we place different weights on some costs and benefits than on others, for example depending on whether costs would be borne by consumers, DTT operators, or mobile operators?

A5.61 DUK stated that the CBA should be a neutral assessment of costs and benefits associated with clearance. However other TV respondents considered that policy decisions informed by the CBA should be weighted to reflect the fact that there is an imbalance between those affected by costs and the likely beneficiaries. In particular, they observed that viewers would not gain any benefit from clearance, but may be faced with costly disruption. DUK noted that those consumers who would benefit from future mobile services are likely to differ from those who would most acutely be affected by any disruption to DTT, e.g. older viewers may not be early adopters of new mobile services but are more likely to be users of DTT.

A5.62 Vodafone considered that it may be appropriate for Ofcom to give more weight to some factors than others. However, that this should be done separately to any quantitative CBA, so that the economic impact of any such decision is transparent.

A5.63 A number of PMSE respondents were in favour of weighting the costs and benefits.

- One respondent noted that consumers would be paying for the re-engineering of the DTT network and the cost of modifying their own domestic installations with no significant gain in service or TV programming, and PMSE would face significant costs to re-engineer their systems without any additional gain.

- The Royal National Theatre stated that Ofcom should ensure that there is no cost to consumers or to any existing users of the spectrum, and that those bidding on the spectrum should absorb the cost of modification or replacement of equipment, which cannot be borne by PMSE users.

- BEIRG commented that incumbent users who have no alternative spectrum to move to in order to meet demand should be favoured ahead of new mobile services where alternative spectrum management and re-farming can ensure adequate spectrum access for these services.

A5.64 British APCO believed there should be a greater weight placed on the benefits to public safety. The Met Police noted that it is not possible to assign ‘business case’ type values to emergency services.

A5.65 BT considered that consumers should have some additional weighting in the process to reflect their expectations that equipment purchased will remain usable for many years.

A5.66 Huawei considered it could be beneficial if different weights were given to some costs and benefits. For example, it is anticipated that future mobile network and handset costs will reduce, reducing the cost of accessing mobile services for consumers. However costs borne by consumers should be given a different weight.

A5.67 Intellect noted that its member companies with an interest in DTT pointed out that the financial beneficiaries of a 700 MHz change of use are not the same as those incurring costs of facilitating any transition and so suggested that Ofcom should carefully consider the necessary incentivisation. Conversely, members with mobile interests highlighted that since mobile penetration is very high, the majority of consumers facing costs due to DTT migration would also be beneficiaries of improved broadband efficiency. Intellect stated that the desired outcome would be one that results in the availability of adequate and appropriate spectrum above and below 1 GHz for mobile services while ensuring sufficient spectrum for DTT services.

A5.68 The Voice of the Listener and Viewer and the CCP argued that the beneficiaries of change of use should bear the costs of any change.

A5.69 *Section 11 sets out an initial discussion of options for how each of these costs might be funded. We plan to develop our analysis of these issues in light of responses to this consultation.*

Other comments on costs and benefits (question 7)

Question 7: Do you have any other comments on the work we are currently undertaking on potential costs and benefits?

A5.70 DUK viewed that the CBA needs to take into account the potential loss of consumer and citizen benefit that would arise were the DTT platform to be weakened as a result of any 700 MHz clearance process. In addition to the loss of DTT services, this would include the loss of wider competition and innovation benefits.

A5.71 *We consider that the proposed change would safeguard the benefits associated with DTT (see paragraphs 6.11, 6.13 and 6.23 to 6.31).*

A5.72 A number of PMSE stakeholders raised concerns about potential interference from any new mobile services that could affect PMSE users operating in the 600 MHz band.

- BEIRG stated that Ofcom must continue to study the potential for interference and likely cost impacts before making any decisions on the future of 700 MHz. It also stated that it is imperative that Ofcom ensure that appropriate guard bands are provided within part of any new service allocations, and that these guard bands do not further encroach on PMSE spectrum.

- The APWPT stated that Ofcom should adopt and monitor the most stringent emissions mask in order to mitigate the threat to PMSE from LTE out of band emissions.

A5.73 Qualcomm and Huawei expressed that Ofcom should aim for alignment with the 3GPP band 28 plan, both in terms of frequency and out of band emission limits, to maximise the benefits of harmonisation.

A5.74 *Annex 6 sets out the current status of harmonisation discussions in CEPT and Annex 10 provides our assessment of the risk of mobile interference to PMSE.*

A5.75 Vodafone considered that given the level of uncertainty about level of mobile broadband demand, some form of breakeven analysis may be the best way to conduct a CBA. For example by considering what level of future mobile demand would give a neutral outcome of costs and benefits between DTT and mobile use for 700 MHz, and then evaluate the probability, risks and opportunities of a level of demand that is higher than this breakeven point.

A5.76 *We recognise there is significant uncertainty over future demand for mobile broadband services. We also note that there is considerable uncertainty over a number of other factors including spectral efficiency, traffic distribution and site sharing. Therefore rather than considering a breakeven analysis as suggested by Vodafone we have presented a range for both the estimated benefits and costs.*

A5.77 Samsung and Intellect considered that Ofcom's key objective should be to achieve a harmonised European market at an early stage. Therefore they urged Ofcom to seek a common understanding on the release of the 700 MHz and encourage other European countries to set an informed perspective on the UHF band and the future of DTT.

A5.78 *Consistent with our UHF strategy statement, we are actively engaged in UK, European and international discussions to identify harmonised conditions for the band (see paragraphs 3.13 to 3.17 and Annex 6).*

The timing of a potential change of use, and the impact this would have on costs and benefits (questions 8 to 13)

Question 8: Have we correctly identified the costs and benefits that could vary depending on the timing of release, and the impact of those factors? Are there other costs and benefits which would vary depending on the timing of release of the 700 MHz band which we should take into account?

Question 9: How quickly could the 700 MHz band be released? What would be the impact on DTT infrastructure costs of releasing at the earliest possible time compared to a later time? What would be the factors which affect these costs?

Question 10: How, and to what extent, are the costs for existing (PMSE) and potential (WSD) interleaved users of the 700 MHz band likely to vary depending on the timing of release? What would be the factors which affect these costs?

Question 11: Should we consider any other cost-related arguments / evidence in favour of an earlier or later release date?

Question 12: What would be the impact on mobile broadband delivery and competition of releasing the 700 MHz band later rather than sooner?

Question 13: Should we consider any other benefit-related arguments / evidence in favour of an earlier or later release date?

A5.79 TV respondents considered that timing would be dependent upon the speed with which the necessary technical changes can be made to the DTT network; and the resulting impact on consumers. Respondents also considered that significant further work is required to assess the outcome and timescales of the various DTT band planning scenarios.

A5.80 *The DTT Frequency Planning Group (DFPG)*[93] *has put together a range of options for potential DTT band plans (see paragraphs 6.19 to 6.22 and Annex 8) which would also determine the scale of, associated timelines for and cost of infrastructure changes (see paragraphs 6.32 to 6.54).*

A5.81 The CAI commented that a later release would be beneficial to industry and consumers in order to ensure that the interference issues are fully understood and costed.

A5.82 *We have carried out an initial assessment and we plan to undertake detailed further work to refine that assessment and to identify the nature and scale of the potential interference more accurately (see paragraph 7.25).*

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[93] The DFPG is chaired by Ofcom and has replaced the Joint Frequency Planning Project (JPP). DFPG comprises representatives from each of the DTT multiplex licensees, the BBC and transmission company Arqiva.

A5.83 Freeview and DUK suggested that more work needs to be carried out to make credible predictions about aerial replacement timing and evaluate the precise numbers of people who may be affected.

A5.84 *We estimate that if change of use of the band occurred in 2022, approximately 80,000 to 90,000 aerials would need to be replaced (see paragraphs 7.10 to 7.17).*

A5.85 Some mobile, TV and other industry stakeholders considered that any 700 MHz change of use in the UK would depend on the international context. Intellect and Samsung highlighted the importance of timing being synchronised with other European countries.

A5.86 *To implement a change of use of the 700 MHz band we would need a range of international agreements both in relation to replanning the spectrum that would remain in use for DTT and to mobile deployment in the band (see paragraphs 3.13 to 3.17, 6.14 to 6.18, and Annex 6).*

A5.87 The DTG suggested that timing should be conditional on mobile broadband reaching a certain capacity before moving DTT. Similarly the CAI, The Voice of the Listener and Viewer and an individual respondent considered that change of use should be delayed until a clear picture of actual demand and the real capacity for the 800 MHz band is known. The Voice of the Listener and Viewer stated that if it is clear that mobile broadband demand is not being met by 800 MHz then an unsatisfied need for more spectrum would impede mobile broadband services as well as constrain competition.

A5.88 The CAI and an individual respondent commented that early release would encourage mobile operators to design less spectrum efficient systems.

A5.89 *As set out in paragraphs 5.4 to 5.7, we expect mobile data demand to continue to grow significantly. Given the long lead time for a change of use of the 700 MHz band, decisions have to be taken in advance of this demand.*

A5.90 Vodafone considered that potential costs to WSDs would be reduced by early change of use because it would reduce the (albeit small) possibility of usage by WSDs having grown to the point where it could not be supported by the reduced amount of white space after the release.

A5.91 *We have assessed the impact of the change on the availability of white spaces (see Section 8 and paragraphs 10.65 and 10.66).*

A5.92 Qualcomm considered that PMSE users in the UHF band would benefit from an early decision on the transition plan in order to have visibility of future spectrum availability and adapt their technology accordingly.

A5.93 BEIRG reiterated that it does not accept that there is a need for 700 MHz to be cleared of existing incumbents. However, PMSE respondents in general were of the view that release as early as 2018 should not be considered. These respondents argued that a change to spectrum allocation with short notice would cause major upheaval for PMSE, wider broadcast industries, and citizens and consumers. In particular, a change would require members of the PMSE sector to replace their equipment, and to do so with insufficient lead time. A number of stakeholders reiterated that PMSE users have already been required to purchase new equipment by the channel 69 clearance, and that the industry typically gets between 15 and 20 years of use out of professional equipment. These stakeholders argued that to expect the industry to replace equipment so soon is financially unviable. DUK echoed these points stating that the earlier the clearance the more acute the detrimental impact on PMSE users.

A5.94 *We view mitigating the impact on PMSE as a core part of an implementation strategy (see paragraphs 8.25 to 8.38).*

A5.95 PPDR respondents considered that early release may not benefit the emergency services as devices and functionality may not be available; equipment is expected to be available between 2018 and 2020. Conversely, late release would delay mission critical broadband for the emergency services.

A5.96 Vodafone considered that the benefits of public safety application use of 700 MHz should be factored into the analysis of an earlier or later release date.

A5.97 *As set out above, decisions on the delivery of PPDR communications are a matter for Government (see paragraphs 5.79 to 5.81).*

A5.98 The Scottish Government considered that Ofcom has correctly identified the costs and benefits that could vary depending on when release occurs. If results of the CBA are favourable, they would welcome the release happening earlier rather than later as this has the potential to improve mobile broadband services in Scotland, both in terms of population coverage and quality of service.

A5.99 Intellect and Samsung commented that given the common replacement cycle for integrated digital televisions (IDTVs) of 7 years and a much longer cycle for aerial installations, it is important that an appropriate timescale is set for transition which provides a suitable timeframe for TV manufacturers to offer suitable products. The transition timescales should also be compatible with other related initiatives such as the deployment of LTE800, white space devices (WSD) and the 600 MHz DTT deployment.

A5.100 Huawei advocated a 2018 start date as releasing the 700 MHz band later rather than sooner will compound the data traffic pressures that are expected to have built up by then.

A5.101 *The analysis we have presented in this consultation indicates that the earlier change occurs, the greater the net benefits are likely to be. Therefore we propose 700 MHz change of use at the earliest opportunity, subject to a number of further factors being satisfied and/or resolved (see paragraphs 11.5 and 11.8).*

The use of incentive and overlay auctions (questions 14 to 19)

Question 14: Is the range of potential dates for release likely to be wide enough to merit consideration of an incentive auction approach?

Question 15: If so, what are the challenges to designing an effective incentive auction in this case, and how might these challenges be addressed?

Question 16: If we followed an incentive auction approach, how should we take account of wider costs and benefits – i.e. those not felt by participants in the auction?

Question 17: Do you have any views at this stage as to the parameters of an incentive auction, such as the default date and payment mechanism?

Question 18: Is there a version of the overlay auction approach which could be suitable for 700 MHz release?

Question 19: What are the benefits and risks of conducting an overlay auction in this case?

A5.102 No stakeholder group responded in favour of an incentive or overlay auction:

- Mobile, PPDR respondents and Huawei considered that auctions would not be an effective means of determining timing of release because bidders would not be able to reliably determine the value of the spectrum.

- Mobile and TV respondents, Intellect and Samsung noted that due to the number of stakeholders involved, a universally co-ordinated clearance and change of use would be required. As a result, respondents considered that neither an incentive or overlay auction would be viable options for determining timing of a 700 MHz change of use.

- Most PMSE respondents did not comment on market mechanisms. BEIRG reiterated that it does not accept that 700 MHz has to be cleared at all.

A5.103 *We do not consider that the use of an incentive auction would be the right option should we proceed with a change of use of the 700 MHz band.*

The potential impact of a 700 MHz change of use on DTT consumers (questions 20 and 21)

Question 20: Have we correctly identified and characterised the potential impact of 700 MHz release on consumers accessing DTT? What other impact – if any – should be taken into account in order to identify pre-emptive measures to reduce this impact?

Question 21: Do you have any comments on the pre-emptive measures relevant to DTT identified above? Are there other pre-emptive measures we should be considering?

A5.104 DUK, Freeview and Channel 5 agreed with the three areas that Ofcom identified in the CFI as likely to affect DTT viewers (change of aerial, interference from new mobile services and possible platform upgrade). DUK and Freeview also noted that a large proportion of households would be expected to carry out a retune of their DTT equipment, and that a proportion of these viewers would need some assistance in managing that process successfully.

A5.105 *We recognise that a small proportion of viewers might find the retuning process challenging. It would be important to ensure that these viewers received adequate information and support (see paragraphs 7.3 to 7.9).*

A5.106 The Confederation of Aerial Industries and an individual respondent raised a number of additional impacts that needed to be taken into account when identifying pre-emptive measures. This includes the impact on viewers using aerial amplifiers or communal aerial systems, and on cable users. They suggested that Ofcom should fund realistic testing of interference.

A5.107 *We are planning to undertake further work to establish more accurately and definitively both the potential scale and nature of coexistence issues. This will likely involve field trials once a DTT band plan has been established and once the equipment for testing becomes available (see Annex 10).*

A5.108 DUK and Freeview supported the proposed pre-emptive measures outlined in the CFI. In particular, these respondents emphasised the importance of ensuring that channel 48 is fully protected from adjacent band services to reduce the risk of coexistence issues. The Confederation of Aerial Industries and an individual respondent stated that a clear requirement for better out of band energy performance must be made a condition of entering any 700 MHz auction. In addition, Intellect and Samsung considered that Ofcom should work with the consumer equipment industry to define stable and long term targets for immunity requirements in Europe.

A5.109 *As set out above, we are actively supporting the imposition of tighter out of band emissions restrictions in the relevant international fora. We have also commissioned research which suggests that it would be feasible to materially improve DTT receiver performance without significantly increasing equipment costs (see paragraph 7.34).*

A5.110 One respondent commented that users who have to change aerials to maintain DTT should be given information on Freesat as an alternative.

A5.111 Vodafone considered that we have correctly identified the key aspects of the impact on consumers and that we are considering the right pre-emptive measures. In addition, Vodafone suggests other measures could be taken during replanning of DTT before release, e.g. upper channels (particularly channel 48) could be assigned to transmitters in less populated areas, or to programme channels that are predicted to have lower viewing figures. They also noted that Ofcom may have over-estimated the impact of interference for the 800 MHz band, and Ofcom should learn from this for its future impact assessment of the 700 MHz band.

A5.112 *As set out above, for information on DTT band planning see paragraphs 6.19 to 6.22 and Annex 8.*

A5.113 The Scottish Government considered that the potential impact of 700 MHz release on consumers accessing DTT has been correctly identified and characterised. The Voice of the Listener and Viewer and the CCP agreed with the identified impacts on new aerials and receivers, and welcomed the acknowledgement that vulnerable consumers will need particular consideration and information during any transition. The Voice of the Listener and Viewer stated that implementation timescales need to be sufficiently long that consumers have adequate time to respond to the changes. The CCP encouraged Ofcom to make early contact with equipment manufacturers to ensure that sufficient and correct equipment is in place in advance of any change of use.

A5.114 *We are committed to taking pre-emptive action now to ensure that, in so far as possible, consumer equipment sold today is of a type which would be capable of operating following a change of use of the 700 MHz band (see paragraphs 7.33 to 7.34).*

A5.115 BEIRG was of the view that there was a material risk that the DTT platform would have insufficient spectrum to continue to deliver important benefits if it is cleared from the 700 MHz band. The Royal National Theatre considered that consumers would be disappointed by the content they receive if there is insufficient spectrum available for PMSE equipment to support DTT programming.

A5.116 BEIRG also considered that DTT consumers would be negatively affected by a 700 MHz change of use through platform changes, or a potential reduction or loss of HD, other services, or coverage.

A5.117 The FCS and some Intellect members were of the view that we should ensure that there is enough spectrum for all of the DTT services with the same coverage as they have today.

A5.118 *As noted above, our proposals safeguard the benefits associated with DTT (see paragraphs 6.11 to 6.13 and 6.23 to 6.31) and PMSE. We have identified a range of mitigations for the impact change of use of the 700 MHz band would have on PMSE users (see paragraphs 8.25 to 8.38).*

Measures to support consumer adoption of DVB-T2, and the wider technological evolution of the DTT platform (questions 22 and 23)

Question 22: Have we identified the correct measures to support consumer adoption of DVB-T2?

Question 23: What regard, if any, should we have to wider technical evolution of the DTT platform, such as HEVC?

A5.119 DUK stated that DTT broadcasters are supportive of the long term adoption of DVB-T2/MPEG4 more widely on the platform. They were of the view that none of the planning scenarios being considered at that time by the Joint Frequency Planning Project (now the DTT Frequency Planning Group) would maintain the same DTT coverage as today without a migration of Freeview to DVB-T2. Channel 5 considered that if all existing services could not fit into new frequencies, a publicly-supported transition to DVB-T2 will be necessary. Channel 5 stated strong opposition to a partial DVB-T2 transition if this meant some viewers dependent on DVB-T were denied the full range of DTT services to which they had been used.

A5.120 DUK and Freeview commented that appropriate measures to support consumer and industry messaging will be helpful. Freeview noted that there is considerable consumer confusion regarding logos in the market and this may be a barrier to take-up of the latest equipment. Both Freeview and DUK suggested that, given the relatively small size of the UK market, discussions with consumer equipment manufacturers should take place on a pan-European level. DUK believe Ofcom could help provide more certainty for the supply chain and consumers about the adoption of more advanced technical standards.

A5.121 The Confederation of Aerial industries and an individual respondent noted that the public are under financial pressure, and considered that in most cases a new format would not give any great improvement in viewing experience. They commented that he mobile operators or auction profits should fund or subsidise new consumer equipment.

A5.122 The DTG considered that sale of DVB-T should be phased out at the earliest opportunity to minimise the legacy cost of migration to DVB-T2. In addition, a coherent and consistent consumer proposition relating to an obvious and attractive benefit would undoubtedly drive technological change.

A5.123 The Voice of the Listener and Viewer commented that increasing the range of HD channels on offer would be an important incentive to drive DVB-T2 take-up. They also stated that more advanced coding technologies such as HEVC may have an important role to play in the future of the DTT platform.

A5.124 In the event that a migration to DVB-T2 is required, both DUK and Freeview noted the challenge involved in driving take-up of DVB-T2 equipment, especially for second sets where HD is less of a driver due to smaller screen sizes. They stated that any future move toward HEVC would require sufficient spectrum to be made available for DTT to facilitate MPEG2 or MPEG4/HEVC simulcasting.

A5.125 Channel 5 commented that if a move to DVB-T2 is required, the extent of viewer support will be considerable, and the beneficiaries of spectrum release, or Government, should pay to compensate DTT viewers.

A5.126 Vodafone was of the view that Ofcom should consider discussing with Government mandating that new receivers sold must support DVB-T2.

A5.127 Intellect and the FCS considered that if there is a 700 MHz change of use, the entire DTT platform should migrate to DVB-T2 at the same time in order to minimise consumer disruption of two transitions and make the most efficient use of the available spectrum. Intellect considered that DTT propositions with additional value would be necessary to counterbalance the negative impact of new technology migrations.

A5.128 Intellect considered that the transition to HEVC should only be implemented when at least one of the two following milestones is achieved:

i) the introduction and transition to UHD services; and

ii) the integration of HEVC in DTT receivers is systematic and a high number of households are sufficiently equipped.

A5.129 Samsung considered that current conditions indicate that HEVC should not be associated with the release of the 700 MHz change of use. However introduction of HEVC could be part of a long term roadmap for creating additional value for consumers.

A5.130 *As set out above, we do not consider that DVB-T2 transition would be necessary to bring about change of use of the 700 MHz band (see paragraphs 6.23 to 6.31).*

The potential impact of a 700 MHz change of use on PMSE users (questions 24, 25 and 26)

Question 24: Have we correctly identified and characterised the potential impact of 700 MHz release on PMSE users? What other impact – if any – should be taken into account in order to identify pre-emptive measures to mitigate this impact?

Question 25: Do you have any comments on the pre-emptive measures identified above? Are there other pre-emptive measures we should be considering?

Question 26: Do you have suggestions for how we can assess the impact on PMSE users and equipment if 700 MHz is no longer available for PMSE use?

A5.131 Channel 5 responded to stress the importance of making sure PMSE has adequate access to spectrum. DUK felt that Ofcom has understated the impact 700 MHz change of use would have on those who operate in the 470-694 MHz band. DUK noted that while PMSE is under particular pressure, Ofcom must ensure that impact on other users such as local TV and white spaces are also considered. They were also of the view that if Ofcom are seeking to warn PMSE users to avoid buying equipment in the 700 MHz band because of the potential clearance of broadcasting from the band, it needs to clearly advise users which frequencies they should be buying equipment in instead.

A5.132 Vodafone raised a number of points in relation to PMSE, including:

- consideration should be given to using the PMSE licence fee structure to encourage use of more spectrally efficient digital technologies and migration to new frequency bands;
- the importance of distinguishing between equipment replacement costs resulting from a change of frequency for PMSE and the wider costs from a loss of spectrum; and
- Ofcom should consider a broader strategy for PMSE over a period of a decade. It commented that the 2025 to 2090 MHz band should be considered for PMSE use.

A5.133 PMSE respondents reiterated that many PMSE operators have reinvested in equipment after channel 69. The Royal National Theatre also noted that some equipment outside of the 700 MHz band would need to be modified as part of the band plan change. PMSE respondents considered that the level of disruption, and the reduction in quantity of spectrum, will have a severe impact on the PMSE sector and consequently the wider entertainment industry.

A5.134 PMSE respondents considered that if PMSE users were to be cleared from the band, a formal compensation scheme would be essential. In addition they called alternative frequency band allocations dedicated to PMSE for use in the longer term. A number of stakeholders made suggestions for spectrum that could be used for PMSE, including the 700 MHz band; the 1.4 GHz L-band (1492 to 1525 MHz); and spectrum between 1.2 to 1.6GHz. David Hall Systems considered that there should be a greater emphasis on PMSE operating in fragmented spectrum in future.

A5.135 *As set out above:*

- *mitigating the impact on PMSE, including identifying alternative spectrum, is a core part of an implementation strategy (see paragraphs 8.25 to 8.38);*
- *for PMSE equipment costs see paragraphs 8.10 to 8.20;*
- *technical analysis indicates that, overall, changing the use of 700 MHz would not have an adverse impact on overall white space availability (see Section 8 and Annex 13); and*
- *our proposals are designed to safeguard the benefits associated with the DTT platform, including local TV services (see paragraphs 6.11 to 6.13).*

A5.136 A number of PMSE respondents suggested that Ofcom needs to clarify in greater detail what it means by the pre-emptive measures identified to support industry efforts to improve PMSE equipment. The APWPT note the importance of PMSE devices being free of latency, and question the relevance of digital microphones as a solution.

A5.137 *There is a range of actions we believe the PMSE community could take to address the reduction in spectrum availability that would result from change of use of the 700 MHz band. We have been working with stakeholders to determine the viability and effectiveness of these actions and to determine the residual impact on PMSE after these mitigations have been considered (see paragraphs 8.33 to 8.36).*

A5.138 *As set out in paragraph 3.11, ensuring that the PMSE sector has access to an appropriate amount of spectrum in the future is a high priority for Ofcom.*

Annex 6

International engagement on development of a mobile band plan

A6.1 This annex provides a summary of the current stage of international harmonisation work to identify technical conditions (band plan and out-of-band emissions) for mobile use of the 700 MHz band. This informs many aspects of our CBA, including:

- on the benefit side, the amount of spectrum available for paired mobile use and the availability and cost of handsets that could use 700 MHz; and
- on the cost side, availability of channel 48 (686-694 MHz) for DTT and PMSE, and coexistence between DTT and mobile use.

A6.2 In the following pages we set out:

a) a summary of the scope and timelines for the on-going discussions at the International Telecommunication Union (ITU) and the European Conference of Postal and Telecommunication Administrations (CEPT);

b) an explanation of the main options for the band plan and out-of-band emission limits, setting out the consensus in CEPT in support of a 2x30 MHz band plan and harmonisation of 3GPP band 28 conditions in CEPT and Asia-Pacific; and

c) an overview of the next steps in these international discussions.

ITU and CEPT working groups tasked with identifying technical conditions for mobile use at 700 MHz

A6.3 Ofcom has been actively participating in international discussions in the ITU and CEPT to develop a band plan and associated technical conditions for mobile use of the 700 MHz band.

A6.4 The World Radiocommunication Conference 2012 (WRC-12) initiated this work following its decision to add a mobile allocation in the 694 to 790 MHz band in ITU Region 1 (Europe, the Middle East and Africa) immediately after WRC-15, with the proviso that WRC-15 will specify any technical and regulatory conditions applicable to the allocation. WRC-12 required studies on channelling arrangements (i.e. a band plan) for mobile broadband and on compatibility with DTT in adjacent spectrum below 694 MHz in order to develop these conditions.

A6.5 In addition, the European Commission issued a mandate to CEPT to develop harmonised technical conditions for mobile use of the 700 MHz band.[94] The Commission set a deadline of July 2014 for a draft final report from CEPT for consultation and it requires CEPT to deliver the final report in November 2014. The Commission has also requested CEPT to develop a further report after WRC-15 to review the previous results in the light of WRC-15 decisions on the 700 MHz band.

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[94] https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/Mandate_CEPT_700_MHz%20.doc.pdf

A6.6 Part of the scope of work on the band plan and adjacent band compatibility is to identify conditions that would maximise harmonisation beyond Europe. In particular, CEPT has been considering whether it would be possible to align with the band plan and associated conditions developed for the Asia-Pacific region (known as 3GPP band 28) and subsequently adopted in Latin America. There is a separate band plan in the United States which does not present a potential harmonisation option for Europe because of its fragmented nature.

A6.7 For Europe to benefit from an alignment with 3GPP band 28, it would be necessary to create an environment where common terminals could be used across the Asia-Pacific, Latin America and Europe/Middle East/Africa regions. For this to work, the technical conditions in Europe, including both the band plan and mobile terminal out-of-band emission limits, would need to be compatible with the 3GPP band 28 specification. We explain below the actions CEPT is taking to secure this.

ITU-R work on channelling arrangements

A6.8 ITU-R Working Party 5D (WP 5D) was assigned the task of studying channelling arrangements for mobile broadband in 694 to 790 MHz in Europe, the Middle East and Africa under the scope of agenda item 1.2 of the World Radiocommunication Conference 2015 (WRC-15), taking into account:

a) potential harmonisation with arrangements as many countries as possible across all Regions;

b) coexistence with existing channelling arrangements in the 800 MHz band; and

c) technical requirements to manage compatibility with DTT broadcasting below 694 MHz.

A6.9 Since WP 5D is not responsible for carrying out the compatibility studies, it has had to rely on information provided by other bodies. In practice, A6.8c) above only relates to the frequency separation between the boundary of the mobile allocation at 694 MHz and the lower edge of the mobile IMT band plan. ITU-R Joint Task Group 4-5-6-7 has provided information on its coexistence studies and its most recent liaison with WP 5D indicated that its studies on adjacent band compatibility at the 694 MHz boundary have been based on a frequency separation of 9 MHz above that boundary so that the mobile channelling arrangement starts at 703 MHz.

A6.10 WP 5D has been developing a working document to compile relevant information and proposals on channelling arrangements. Its latest version, produced before JTG 4-5-6-7 provided the information on frequency separation, showed the following options under consideration.

Table 10: Channelling arrangements under consideration in ITU-R WP 5D

	Mobile station transmitter	Base station transmitter
Option 1	696 to 736 MHz	751 to 791 MHz
Option 2	703 to 733 MHz	758 to 788 MHz
Option 3	703 to 743 MHz	751 to 791 MHz

A6.11 The meeting of WP 5D on 18-25 June 2014 will need to inform JTG 4-5-6-7 of its work on the band plan so that the final meeting of the JTG in July 2014 can incorporate the relevant text into the draft Conference Preparatory Meeting Report. If WP 5D has concluded then this will be a straightforward matter, otherwise WP 5D will need to describe the current status and the way forward. We expect that the option 1 in Table 10 above is unlikely to be part of further work, as it uses the frequencies 696 to 703 MHz and, as discussed below, CEPT will be consulting in the summer on its consensual preference for the second option.

A6.12 WP 5D will ultimately incorporate the 700 MHz band plan for Europe, the Middle East and Africa in a revision of Recommendation ITU-R M.1036-4[95] which contains the global and regional channelling arrangements for all the IMT bands currently in use.

CEPT work on channelling arrangements

A6.13 The work under the Commission mandate to CEPT is taking place in Electronic Communications Committee Project Team 1 (ECC PT1) in conjunction with the lead CEPT group on WRC-15 agenda item 1.2 (CEPT Conference Preparatory Group Project Team D - CPG PTD), through a series of common meetings. The Commission mandate requires CEPT to develop a preferred channelling arrangement and to identify least restrictive technical conditions (i.e. a block edge mask) for wireless broadband use in the 694-790 MHz frequency band for the provision of electronic communications services, as well as PPDR[96] services that can make use of such technical conditions. A separate task, scheduled after WRC-15, asks CEPT to consider the WRC outcome and to assess if there is any need to refine these technical conditions. We will also review any material development in due course.

A6.14 CEPT examined options for band plans and initially focussed its considerations on two main options:

- a 2x30 MHz arrangement, aligned with the lower part of the Asia-Pacific band plan (3GPP band 28). The benefit of this arrangement is that mobile terminals would be able to use the new European band if they supported 3GPP band 28; and
- a possible 2x40 MHz arrangement as a Europe-only option.

A6.15 In addition, CEPT considered options for the use of the remaining spectrum in the 700 MHz gap. A 2x30 MHz band plan would include a 25 MHz centre gap, which could be harmonised for supplemental downlink for mobile broadband or used on a national basis for programme making and special events (PMSE) or Public Protection and Disaster Relief (PPDR) applications.

Strong momentum in CEPT behind a 2x30 MHz band plan and harmonisation with Asia-Pacific, EMEA and Latin America

A6.16 The main consideration in CEPT was whether to harmonise technical conditions with 3GPP band 28 or to develop a Europe-only arrangement, which would lead to

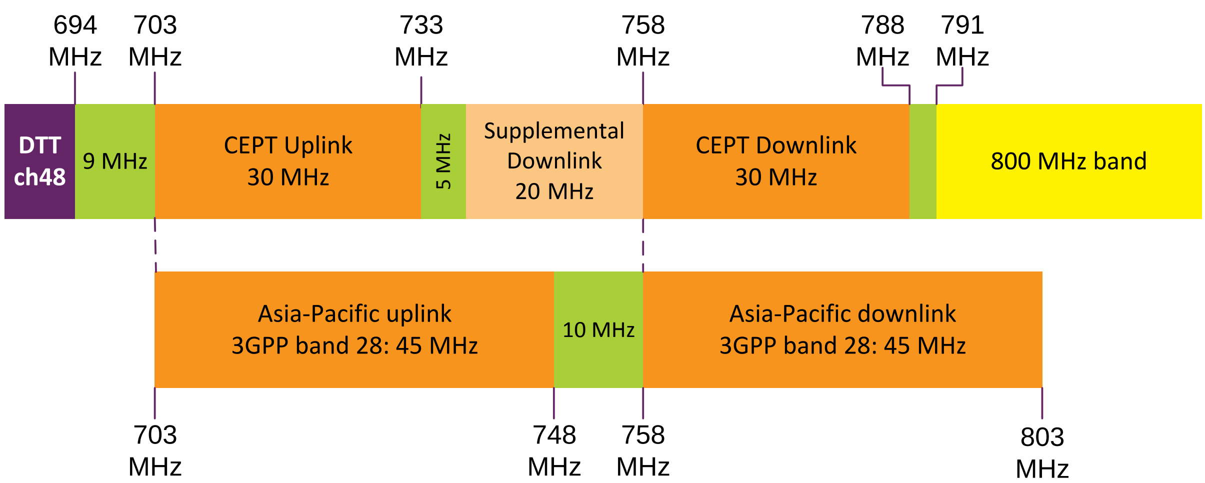
[95] http://www.itu.int/rec/R-REC-M.1036/en
[96] PPDR: Public Protection and Disaster Relief, in this case broadband communications for the emergency services

a new band specification in 3GPP. The band 28 specification has already been adopted in the Asia-Pacific region and parts of South America. Harmonisation between CEPT and these world regions requires both a CEPT band plan that is compatible (i.e. that has the same duplex spacing and uses a sub-part of the band 28 frequencies) and identical out-of-band emission limits.

A6.17 Discussions with African and Middle Eastern countries had already indicated that the rest of ITU Region 1 had a preference for harmonisation with the Asia-Pacific band plan. Therefore, if CEPT went its own way, the band plan would in all probability be a Europe-only arrangement with no prospect of wider adoption.

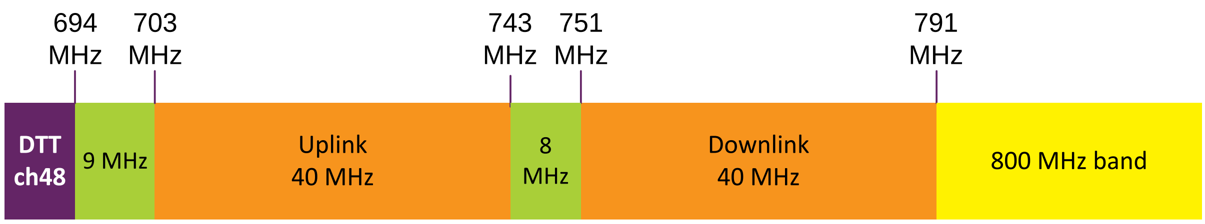
A6.18 Because part of 3GPP band 28 overlaps with the 800 MHz band (3GPP band 20), it is not possible to utilise the full 2x45 MHz of band 28 in CEPT. Only its lower 2x30 MHz could be implemented as paired spectrum in Europe. The Asia-Pacific band plan therefore offers less paired spectrum than other possible alternatives but it brings the prospect of a common sub-1 GHz band plan across a significant part of the globe. Terminals could therefore be built for the Asia-Pacific market and Europe would get the benefits of this. The 25 MHz centre gap could also be harmonised for supplemental downlink in Europe or could be available for other national applications, such as PMSE or PPDR. The alignment of the 2x30 MHz option and the Asia-Pacific band plan is illustrated in Figure 8.

Figure 8: 2x30 MHz band plan option based on utilising part of 3GPP band 28



A6.19 The alternative proposal for a Europe-only band plan would sacrifice the economies of scale that derive from harmonisation with other regions but could provide a greater amount of paired mobile broadband spectrum. This band plan is illustrated in Figure 9.

Figure 9: 2x40 MHz band plan option



A6.20 Based on consideration of the benefits of harmonisation and the total quantity of spectrum that could be made available, whether as paired or unpaired (e.g. for SDL), CEPT provisionally concluded in May that:

a) it would move forward with the 2x30 MHz band plan and with a lower out-of-band emission limit (-42 dBm/8 MHz below 694 MHz) than in the current 3GPP specification for band 28; and

b) It would seek to ensure that technical conditions in the 3GPP band 28 specification would change to reflect CEPT's preferred value for out-of-band emissions.

A6.21 This reflected a broad consensus in CEPT amongst administrations and strong support from industry stakeholders such as global handset and chipset manufacturers. CEPT has been liaising with 3GPP to set out its request for an update of the band 28 specification, to incorporate the out-of-band emissions agreed in CEPT PTD. CEPT will continue to liaise with 3GPP over the coming months to help them consider this request and to monitor progress in this consideration.

A6.22 We expect this process to lead to an update of the 3GPP band 28 specification in the coming months, probably shortly after CEPT's finalisation of its report. We have therefore based our analysis in this consultation on CEPT preferred harmonisation conditions, with 2x30 MHz available for paired mobile use, up to 25 MHz available for unpaired use and tighter out of band limits that are common across Asia-Pacific, EMEA and Latin America.[97]

Next steps

A6.23 CEPT has developed a draft report for the European Commission outlining the band plan and technical conditions for mobile use of 700 MHz. The draft report will be delivered to the ECC meeting which takes place during 24-27 June 2014 and will be published for public consultation at the same time as being sent to the Commission. The ECC PT1 meeting at the start of September 2014 will consider any comments made during the consultation period and develop a final version of the report for approval at the 25-28 November 2014 ECC meeting. That meeting will adopt the final version of the CEPT report and send it to the Commission.

A6.24 In ITU-R, the band plan for 700 MHz will be incorporated into a new draft version of Recommendation ITU-R M.1036-4, which provides channelling arrangements for all IMT frequency bands. Since the mobile allocation in ITU Region 1 has to be finalised at WRC-15, the approval of the update to ITU-R M.1036 is likely to occur at the Radiocommunication Assembly in October 2015.

[97] It seems relatively unlikely that 3GPP would decide against updating its band 28 specification. However, if it took this view, we would expect CEPT to revisit the basis on which to harmonise use of the band. This would not change our overall assessment of the issues of coexistence between mobile use and DTT for the purpose of the CBA. However, it would inform our further work and plans for field trials. It would also not affect our assessment of quantified benefits, but could reduce the effect of those unquantified benefits that relate to widespread international harmonisation.

Annex 7

Background on the DTT platform

A7.1 This annex provides an overview of how the DTT platform is structured and licensed in the UK. It is intended to provide further context for our proposals and more specifically those aspects that relate to DTT.

DTT comprises a wide range of different organisations

A7.2 DTT in the UK operates on a horizontal model; it is not co-ordinated and managed by a single organisation. Instead it comprises a wide range of different organisations, each of which participates in one of more parts of the value chain.

A7.3 Operators in this value chain include, among others:

- **multiplex**[98] **operators** (see Table 11 below) are authorised users of the spectrum used to transmit the DTT services to viewers' aerials;
- **channel providers** have to secure carriage on a multiplex to reach and provide content viewers' television sets;
- **a transmission company** owns and operates the transmission network under contract to the multiplex operators;
- **consumer equipment manufacturers** design and manufacture digital receiving equipment;
- **retailers** market and sell digital receiving equipment to consumers.

A variety of services are offered on DTT

A7.4 Over 50 channels, both SD and HD, and a range of radio stations currently operate on DTT.

A7.5 Freeview is the most familiar brand name for the DTT platform. Freeview was established in 2002. It does not itself provide any programming but is a marketing organisation managed by DTV Services Ltd, a company owned and run by its five shareholders – BBC, BSkyB, Channel 4, ITV and Arqiva.

A7.6 Following the launch of Freeview there has been a proliferation of platforms using DTT technology. YouView, BT TV and TalkTalkTV all use DTT technology to deliver a subset of their channels, providing additional services through a broadband connection[99].

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[98] A multiplex is a transmission consisting of multiple streams of information conveyed at the same time in the form of a single, complex signal. The separate streams are then recovered individually at the receiving end.
[99] For further information on DTT services, please see *Future of free to view TV:* http://stakeholders.ofcom.org.uk/consultations/700MHz/ftv/

The services that viewers receive vary across the UK

A7.7 The DTT network comprises 80 principal transmitters that provide coverage to the large majority of UK households. The main transmitters are supplemented by over 1,000 smaller relay transmitters that fill in coverage deficiencies caused by the topography (hills, valleys etc.) preventing reception from the main transmitters.

A7.8 Most reception of DTT services is by fixed receivers, the majority of which are connected to rooftop or loft aerials that point at one specific transmitter. The services that the viewer receives are determined by which multiplexes the transmitter carries.

A7.9 As illustrated in Table 11, there are currently six UK-wide multiplexes in full operation. Three of these carry content from the public service broadcasters (the PSB multiplexes) while three carry purely commercial programming (the commercial multiplexes). In addition, three further multiplexes are in the process of being rolled out: two commercial multiplexes licensed to use spectrum in the 600 MHz band on an interim basis[100] and a local TV multiplex. The local TV multiplex and one of the 600 MHz multiplexes have commenced operation in some areas, while the second 600 MHz multiplex is currently unoccupied.

A7.10 Each transmitter broadcasts at least three multiplexes, although some broadcast more:

- all sites carry the three PSB multiplexes covering 98.5% of UK households;
- the 80 largest transmitters carry a further three commercial multiplexes covering around 90% of UK households;
- the interim multiplexes operating in the 600 MHz band are currently being rolled out to up to 30 of the largest transmitters across the UK and will provide coverage to 70% of UK households; and
- the local TV multiplex is expected to broadcast from 40-60 transmitter sites to provide coverage to up to 50% of households. Ofcom is currently in the process of awarding licences for local TV services.

A7.11 In addition there are two regional multiplexes (with an option for a third):

- a Northern Ireland multiplex is broadcast from three main sites covering approximately 78% of households in Northern Ireland;
- a multiplex using geographically interleaved spectrum provides services in Manchester; and
- there is allocation for a multiplex in Cardiff, although it is not currently in use.

[100] Following digital switchover Ofcom awarded the 600 MHz band (550 to 606 MHz) to Arqiva on an interim basis for the establishment of temporary DVB-T2/MPEG4 multiplexes. The licence runs until 2026, with a minimum duration to 31 December 2018, subject to revocation on 24 months' notice following any decision on a change of use of the 700 MHz band.

Table 11: Multiplex operators

Multiplex	Operator	Notes
PSB1 / BBC A	BBC	
PSB2 / D34	Digital 3 and 4	Joint venture between ITV (acting on behalf of the regional Channel 3 licensees) and Channel 4
PSB3 / BBC B	BBC	DVB-T2/MPEG4 multiplex carrying HD channels
COM4 / SDN	SDN	Wholly owned subsidiary of ITV
COM5 / Arqiva A	Arqiva	
COM6 / Arqiva B	Arqiva	
COM7	Arqiva	DVB-T2/MPEG4 multiplex carrying HD channels operating in the 600 MHz band on an interim basis
COM8	Arqiva	DVB-T2/MPEG4 multiplex intended to carry HD channels operating in the 600 MHz band on an interim basis
Local / LTVMux	Comux	
RNI_1 / NIMux	Multiplex Broadcasting Services N.I.	• Joint venture between RTÉ and TG4 • DVB-T2/MPEG4 multiplex carrying SD channels
GIMux	Canis Media (Manchester) Cube Interactive (Cardiff)	Cardiff allocation not currently in use

Ofcom licenses multiplexes

A7.12 Each of the multiplex operators holds a Wireless Telegraphy Act licence issued by Ofcom, which authorises its use of particular spectrum. All multiplexes, except BBC A, also hold a multiplex service licence awarded under the Broadcasting Act 1996. The BBC A multiplex was granted directly to the BBC under its Charter and associated Framework Agreement with DCMS and therefore does not require a Broadcasting Act licence.

There needs to be effective technical coordination between multiplexes

DTG and the D-Book

A7.13 As discussed above, DTT in the UK operates on a horizontal model. There are several independent multiplex operators (rather than a single platform operator) and multiple consumer equipment manufacturers which supply a diverse range of domestic receiver equipment. In order to ensure platform stability there needs to be effective interoperability between the multiplexes and receivers.

A7.14 The multiplex licences place a number of conditions upon the licensees (which the BBC also adheres to in the case of the BBC A multiplex) which seek to ensure interoperability, for example, by limiting the permissible basic transmission modes[101]. However, many detailed aspects of implementation lie outside of the scope of the multiplex licences.

A7.15 Since the launch of DTT services, The Digital Television Group (DTG) (an industry body whose membership includes multiplex operators and receiver manufacturers) has sought to address this through its *UK Digital Terrestrial Television: Requirements for Interoperability*[102] (known as the 'D-Book'). The D-Book contains detailed implementation standards for DTT transmission and reception in the UK. Manufacturers wishing to use the Freeview logo must ensure their receivers comply with relevant parts of the D-Book.

A7.16 Detailed specifications for technical developments on the DTT platform are agreed within the DTG and subsequently incorporated into the D-Book. Membership of the DTG allows direct participation in the development of technical specifications as well as access to the D-Book.

Digital UK

A7.17 To a large extent the existing DTT multiplexes are operated as independent entities. However in order to ensure full interoperability and provide some platform-wide services, there needs to be a certain amount of on-going technical coordination. Two significant areas where on-going co-operation between multiplexes takes place are in providing electronic programme guide (EPG) data, and in the assignment of logical channel numbers (LCNs).

A7.18 Each multiplex contains programme schedule data which is used by receivers to form and display an EPG, as well as help home recording services function. In order to display an EPG containing schedules for all DTT services (and not just for the multiplex the receiver is currently tuned to), schedule data is 'cross carried' by all multiplexes. This means each multiplex contains information on the schedule of services carried on all other multiplexes.

A7.19 Technical infrastructure is in place to implement cross-carriage. This infrastructure provides a central point for the collation and subsequent distribution of this central service information (CSI) to individual groups of transmitter sites. Data is contributed by each multiplex operator to this central point. It is then collated and made available for distribution to the transmitters.

A7.20 DTT programme services are also assigned unique LCNs. LCNs allow viewers to select programme services at a consistent location in their EPGs or via their remote control (e.g. ITV2 is allocated LCN 6, or button '6' on a remote control). Central allocation of LCNs is required in order to prevent LCN conflicts and possible subsequent errors in receiver behaviour.

A7.21 LCN allocation, as well as overall management of the CSI infrastructure, is carried out by Digital UK, a company jointly owned by the BBC, ITV, Channel 4 and Arqiva.

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[101] Licensees are required to comply with the *Television Technical Performance Code:* http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/tech-guidance/tv_tech_platform_code.pdf and the *Reference Parameters*: http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/tech-guidance/dttt_uk.pdf

[102] http://www.dtg.org.uk/work/dbook.html

Annex 8

DTT band planning options

A8.1 In Section 5, we discuss the changes to the DTT frequency plan that would be necessary if we decided to make the 700 MHz band available for mobile broadband use.

A8.2 This annex describes the frequency planning options we have developed with the DTT Frequency Planning Group[103] (DFPG). It sets out the implications in more detail and assesses the options that we have identified as having the potential to best serve the interests of UK citizens and consumers.

DTT is currently a multi-frequency broadcast network

A8.3 The DTT multiplexes broadcast from a network of over 1,100 transmitters and the frequencies the multiplexes use at each location have been carefully planned to ensure that coverage targets are met. Adjacent transmitters operate on different frequencies to avoid interference occurring in the areas where signals overlap. This configuration is known as a multi-frequency network (‘MFN’), as a DTT multiplex will be broadcast on different frequencies across the country. Each transmission frequency is used many times in different parts of the country. Each transmitter in a MFN can carry different programming within the multiplex which provides the ability to broadcast national and regional programming in different parts of the country.

A8.4 An alternative approach to the MFN is a single frequency network (SFN) where several transmitters operate on the same frequency which potentially reduces the amount of spectrum required. The signal from each transmitter needs to be accurately synchronised in a SFN to ensure that interference does not occur. Operating as part of a SFN potentially also comes at a cost as the amount of programme services that can be carried in a SFN multiplex is lower than in a MFN multiplex. This is because there is a greater overhead in a SFN multiplex that reduces the proportion of the capacity that can be occupied by programme services. The cost to establish and maintain a SFN is also greater than for a MFN due to the requirement to synchronise the transmissions.

We would need to co-ordinate a new DTT frequency plan with our international neighbours

A8.5 A key consideration when developing a frequency plan is to ensure that UK DTT services do not suffer undue interference from transmitters in other European countries, and that they do not cause undue levels of interference to services in other countries.

A8.6 International frequency coordination agreements determine the levels of incoming interference that we can expect to suffer and the amount of outgoing interference we can export. Any frequency plan for the UK’s transmitters needs to exist within

[103] The DFPG is chaired by Ofcom and has replaced the Joint Frequency Planning Project (JPP). DFPG comprises representatives from each of the DTT multiplex licensees, the BBC and transmission company Arqiva.

these internationally agreed rights which we can only change through a process of negotiation with neighbouring countries.

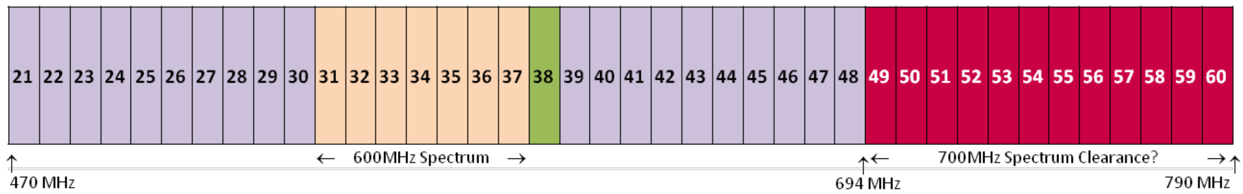
A8.7 Any reorganisation of the frequencies used by DTT would require renegotiation of the UK's international frequency use rights.

A8.8 In the light of our proposals, we have worked with the DFPG to develop a number of options for DTT frequency plans that could be put in place following a change of use of the 700 MHz band. This analysis will inform any frequency planning negotiations we have with neighbouring countries and is a key input into our assessment of the implications a change of use of the band would have for the DTT platform.

A8.9 The DFPG planners have carried out studies of DTT band plan options assuming:

- The 700 MHz band from 694 to 790 MHz (channels 49 to 60) ceases to be used by DTT throughout Europe;
- the range from 470 to 694 MHz (channels 21 to 48) remains in use for DTT, as per Figure 10;
- PMSE and radio astronomy in Europe continue to occupy 606 to 614 MHz (channel 38) on an exclusive basis;
- Six DTT UK-wide multiplexes are required after any reorganisation. Thus the interim HD multiplexes in the 600 MHz band from 550 to 606 MHz (channels 31 to 37) are switched off in time; and
- DTT coverage requirements are the same as today (i.e. PSB multiplex coverage of 98.5%, commercial multiplex coverage around 90% and other multiplexes achieving a similar level of coverage as at present.

Figure 10: DTT UHF channels



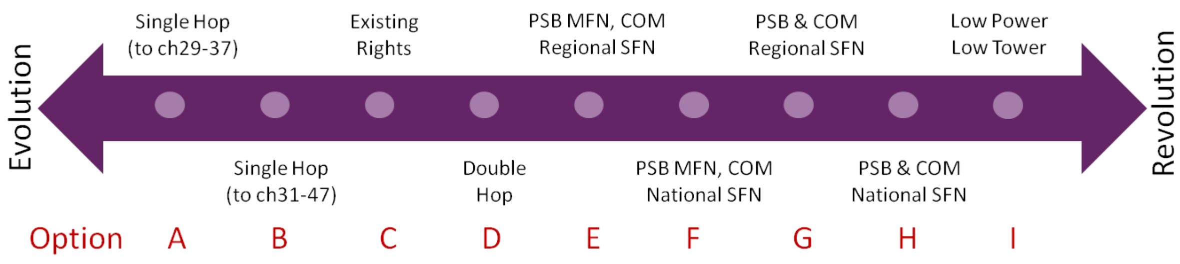
A8.10 As we do not have any indication of the position neighbouring countries are likely to take in negotiating revised coordination agreements, the DFPG planners considered four scenarios for European interference: ranging from optimistic (i.e. the plans of our neighbours are broadly compatible with ours) to very pessimistic (where other countries' plans do not align well with ours).

A8.11 For these initial studies, the DTT planners only considered the 80 primary DTT transmission stations which carry the main six DTT multiplexes, and cover up to 95% of UK households. These 80 stations broadcast at the highest powers (up to 200kW), and are responsible for most of the major interactions between DTT stations within and outside the UK.

The DFPG developed a series of options ranging from evolutionary to revolutionary in nature

A8.12 The scenarios considered by the DFPG range from evolutionary (moderate changes to the current DTT band plan) to revolutionary (entirely new DTT band plans) as shown in Figure 11 below.

Figure 11: DTT band plan options

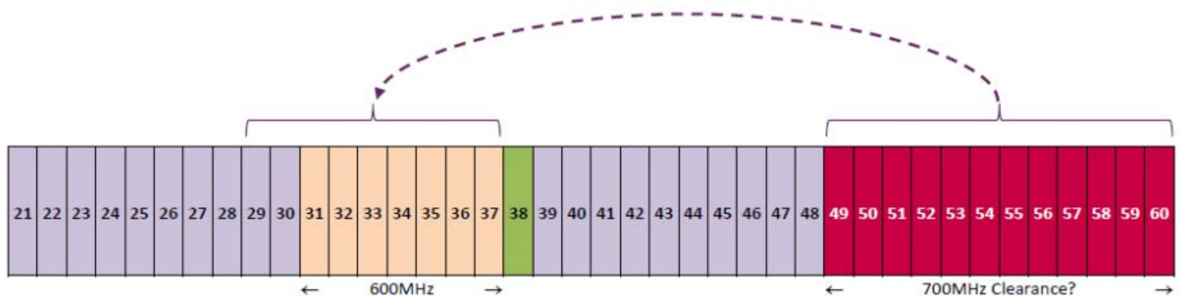


DTT band plan options

A8.13 The principal DTT band plan options DFPG investigated are:

A. Single Hop (to channels 29-37) – in general, DTT multiplexes currently using channels 21 to 48 retain their existing channels. DTT multiplexes currently using channels 49 to 60 hop down to channels 29 to 37, as shown in Figure 12. This big jump down in frequency means that some UK households could need to replace their TV aerials.

Figure 12: Single Hop to channels 29-37

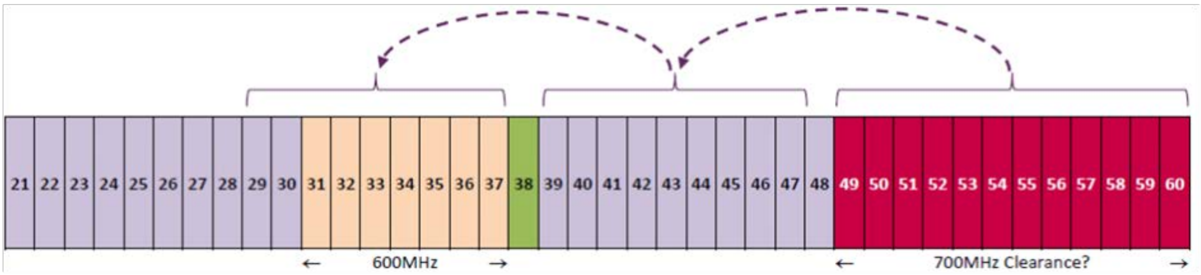


B. Single Hop (to channels 31-47) – in general, DTT multiplexes currently using channels 21 to 48 retain their existing channels. DTT multiplexes currently using channels 49 to 60 hop down to channels 31 to 47. This option reduces the number of households who may need to replace their TV aerials compared to the previous scenario, but requires more changes to the DTT transmission infrastructure.

C. Existing Rights –the three PSB multiplexes are re-planned using existing GE-06 spectrum coordination rights in channels 21 to 48, but excluding channels 31 to 37. The three commercial multiplexes are re-planned using existing spectrum coordination rights in channels 31 to 37 and any remaining spectrum. Although this plan uses the lowest number of new channels compared to the other options, the commercial multiplexes have very few channels available to them in this scenario, and commercial coverage would be several per cent below current levels.

D. Double Hop - DTT multiplexes currently using channels 49 to 60 hop down to channels 39 to 47, whilst DTT multiplexes currently using channels 39 to 47 hop down to channels 29 to 37, as shown in Figure 13. In general, DTT multiplexes currently using channels 21 to 30 retain existing channels. The planners were unable to sustain this scenario and found that there is insufficient spectrum in some areas for a double hop to work, resulting in some transmitters losing multiplexes, and thus not meeting both PSB and commercial coverage targets.

Figure 13: Double Hop



E. PSB MFN, COM regional SFN – the PSB multiplexes are planned as a multi-frequency network (MFN). The commercial multiplexes are planned as a regional single frequency network (SFN), which requires the use of the advanced transmission standard DVB-T2. This scenario attempts to minimise the number of household aerials replacements. However, any households that do not have DVB-T2 receivers would have to replace their equipment if they wish to continue receiving the commercial multiplexes.

F. PSB MFN, COM national SFN – the three commercial multiplexes are planned as national SFNs using channels 22, 25 and 28 with a few exceptions. This approach requires the use of DVB-T2 and also a greater need for domestic aerial replacements so has a large consumer equipment impact. The three PSB multiplexes are planned as a MFN using the remaining spectrum.

G. PSB & COM regional SFN – in general, the PSB and commercial multiplexes are planned as regional SFNs using two channels per multiplex per region (though only one channel per commercial multiplex is used in a few regions). DVB-T2 is required for all multiplexes so there is a potentially a large consumer equipment impact. However, this option does minimise aerial replacements.

H. PSB & COM national SFN – the PSB and commercial multiplexes are planned as national SFNs using one channel per multiplex. DVB-T2 is required for all multiplexes so again there is a potentially large consumer equipment impact. This option requires the whole of Europe also to use national SFNs, which from our initial discussions with other countries seems unlikely at present. The PSB multiplexes would also be unable to carry regional programming.

l. Low power/Low tower – broadcast services are transmitted from a network that comprises a larger number of smaller transmitters than a traditional broadcast network. The broadcast services could either be carried as traffic within mobile operators' networks or as separate broadcast signals.

A8.14 Table 12 below compares the various spectrum planning options against our objectives (as set out in Section 5) for seeking to ensure that DTT has sufficient spectrum to continue to deliver the benefits it does now as well as other considerations such as cost each option would impose upon consumers.

Table 12: Comparison of spectrum planning options

	Option A Single Hop (to ch29-37)	**Option B** Single Hop (to ch31-47)	**Option C** Existing Rights	**Option D** Double Hop	**Option E** PSB MFN, COM regional SFN	**Option F** PSB & COM regional SFN	**Option G** PSB MFN, COM national SFN	**Option H** PSB & COM national SFN	**Option I** Low power low tower
Ability to support six UK-wide multiplexes	✓	✓	✓	✗	✓	✓	✓	✓	✓
Meets PSB multiplex coverage target (98.5% UK households	✓	✓	✓	✗	✓	✓	✗	✓	✓
Meets commercial multiplex coverage target (c.~90% UK households)	✓	✓	✗	✗	✓	✓	✓	✓	✓
Ability to support nations and regions programming	✓	✓	✓	✗	✓	✓	✓	✗	✓
Cost of consumer equipment changes	Low	Low	Low	Low	Medium	High	High	High	High
Cost of DTT infrastructure changes	Low	Low	Medium	High	Medium	High	High	High	Very high

If we re-plan DTT, we will seek to coordinate a plan based on 'minimal change' to the DTT network

A8.15 As we set out Section 5, we are seeking to deliver a band plan that would ensure the DTT platform can continue to deliver coverage and number of multiplexes broadly similar to today and that the PSB channels can continue to deliver regionalised programming, should a change of use of the 700 MHz band take place. Based on our analysis, Six of the band plan options - A, B, E, F, G and I - could meet these three objectives.

A8.16 Option D does not meet our objective for maintaining multiplex coverage. Option H does not permit regional programming to be carried on the PSB multiplexes (as multiplexes operating as part of a UK-wide SFN have to carry identical programme content from all transmitters).

A8.17 Although option I could meet coverage targets, it is the most difficult option to assess as there is some uncertainty over the technical arrangement it might adopt. We provided further commentary on this option below in paragraphs A8.21 to A8.27 below.

A8.18 Four of the six candidate options – E, F, G and I – involve transmitters working as part of a SFN (or possibly a completely different technology in the case of option I). We consider that the use of SFNs in the DTT band plan is sub-optimal for a number of reasons:

- *Impact on consumers' receivers*: Adopting an SFN would require that some or all of the multiplexes switch from using DVB-T technology (compatible with all DTT receivers) to newer DVB-T2 technology (which is only receivable on certain equipment e.g. Freeview HD) to achieve the coverage required. We project that 7.9 million DTT receivers would still not be DVB-T2 capable in 2022. In the event of a switch to DVB-T2 these consumers would have to either purchase new equipment or lose services carried on the affected multiplexes. Thus to minimise impact on these consumers, we propose to favour the spectrum planning options that do not require a transition to DVB-T2.

- *Multiplex capacity:* SFNs require a greater proportion of the multiplex signal to be allocated to either error correction or guard interval to ensure that transmitters do not interfere with each other. This leaves less space for programme services. This represents an opportunity cost of around three standard definition programme services or one high definition service per affected multiplex.

- *Infrastructure cost*: the estimated infrastructure cost of the two MFN options A and B is around £50 million less than the SFN options[104]. The SFN options are more expensive because they involve more frequency changes than the MFN options and also require adoption of DVB-T2. The cost of adopting option I would be considerably more as discussed below.

A8.19 On the basis of this analysis we believe one of the two single hop band plans (A and B) would be the best option for the UK because they would keep changes to DTT infrastructure to a minimum, have the smallest impact on DTT viewers, and they are the options on which we are most likely to be able to achieve agreement

[104] Based upon studies commissioned from Arqiva.

with neighbouring countries (as they should require fewer changes to their plans and infrastructure than more radical options).

A8.20 We will use the two single hop band plans as a starting point in discussions with our international neighbours.

We do not consider that a move to a low power / low tower network infrastructure is a credible prospect at this time

A8.21 The most radical frequency planning option we looked at is a scenario of DTT distribution over a "low power / low tower" network. We now describe in more detail what this option would entail and why we do not believe it is a credible option within the timeframes in which change of use of the 700 MHz band might take place.

A8.22 As noted above, the current DTT transmitter network consists of over 1,100 transmission sites - 50 large transmitter sites that each serve large geographical areas, and a further 1,106 smaller relay transmitter sites which are relatively sparsely distributed throughout the UK.

A8.23 In contrast, cellular mobile phone networks are much denser - with each network often using more than 10,000 sites. However, mobile networks almost exclusively use 'lower powers and lower towers', due, in part, to the need to keep cell sizes relatively small to re-use frequencies and provide sufficient capacity for the data and voice services carried over mobile networks.

A8.24 In theory it should be possible to deliver broadcast television services using a low power / low tower arrangement instead of the current high power network. One advantage of doing so could be that the television services of neighbouring countries could in principle co-exist in a reduced amount of spectrum, as the amount of interference exported from one country into another would be less than for a high power network. This approach would however only deliver spectrum efficiency benefits if all our neighbouring countries also moved to low power / low tower broadcast networks.

A8.25 Another advantage of the low power / low tower approach is that it allows an increased flexibility in planning coverage. This would mean that broadcasters could more closely align regional and local services with social or political boundaries. Also, only one form of network infrastructure would need to be deployed. In such a scenario base stations might broadcast conventional 'linear' television, alongside the voice and data services that they already provide.

A8.26 There are two models for how this might work :

a) Mobile operators could carry the broadcast content through their mobile networks using a technology standard developed to facilitate delivery of both broadcast and multicast services such as Multimedia Broadcast Multicast Services (MBMS). This would permit broadcasters to relinquish the spectrum they currently use, but would place a very significant burden upon the mobile networks and would require MNOs to upgrade their network infrastructure and use additional spectrum to provide more capacity for the video service traffic.

b) Base stations could broadcast television services alongside the mobile services using conventional broadcasting signal standards such as DVB-T2. In this case sharing would be limited to some of the physical infrastructure such as the mobile towers masts

A8.27 The DFPG planners have carried out initial studies of a hypothetical low / power low tower network loosely based upon existing base station locations using both eMBMS (the LTE version of MBMS) and DVB-T2. We set out below a summary of the results of the modelling and our wider conclusions on the implications of adopting a low power/low tower network architecture.

eMBMS would not meet coverage targets except at very high cost and would have a large impact on consumers

A8.28 The planners' study suggests that coverage of the television services would fall short of the targets set out in our objectives (due mainly to the lack of mobile sites in rural areas and the short guard interval provided by eMBMS). This could possibly be addressed by building more sites, although building a denser network than the current mobile networks would come at a significant cost. An additional benefit for consumers (particularly in rural areas) could be that that coverage of the mobile networks would improve. Further description of the cost involved in moving to a low power / low tower architecture is set out below.

A8.29 Every household making use of DTT would need to buy new receiver equipment, which would represent a cost to consumers running into several hundred million pounds.

DVB-T2 could deliver coverage through a low power / low tower network, but at significant cost to broadcasters and to consumers

A8.30 The planners carried out a further study using DVB-T2 instead of eMBMS. This analysis indicated that the predicted coverage from the hypothetical low power / low tower network could in theory match that of the current DTT network, but with a small drop in capacity for programme services (compared with the traditional broadcast network). Although coverage targets could be met, the study indicated that around 20% of domestic aerials pointing at existing high power transmitter sites would need to be re-directed towards the low power transmission sites which would represent a significant consumer cost.

A8.31 Adoption of DVB-T2 is a pre-requisite for a low power / low tower network to operate as it would require many transmitters to operate as part of a SFN. Although a smaller number of consumers would have to purchase new equipment than would be the case for the eMBMS option, we expect that around 7.9m pieces of receiver equipment would still not be compatible with DVB-T2 if the transition were to occur in 2022. As set out in Section 9 and Annex 9 of this document, we have estimated that the associated cost to consumers of equipment replacement in 2022 would be £220m.

Adopting a low power / low tower architecture would involve a major transition

A8.32 There are also other significant challenges to be considered for the adoption of a low power / low tower architecture. These include the viability and availability of mobile sites for additional broadcast infrastructure; the availability and capacity of fibre distribution links to multiple mobile sites for up to about 240 Mbit/s; and how a transition from the current high power network would be effected.

A8.33 Moving to a low power / low tower architecture would involve switching off many of the principal DTT transmitters that serve around 90% of the population and possibly also some or all of the 1,100 smaller relay transmitters and moving to using a denser network of lower power transmitters. The actual number of low power transmission sites needed depends upon the assumed technical characteristics over which there is at present considerable uncertainty.

A8.34 The DFPG planners have estimated that if a variant of DVB-T2 is used to deliver the broadcast services, around 3,000 – 3,500 transmission sites would be needed to deliver coverage similar to the current 1,156 broadcast transmitter sites. It is difficult to be precise about how much such a network would cost as the technical characteristics are at this stage uncertain.

A8.35 If we assume that the cost to establish a low power / low tower DTT transmitter is similar to that for a mobile broadband site, it might cost somewhere in the region of £350m to establish a single multiplex at 3,500 sites. We would expect savings through infrastructure sharing to be possible, but the total cost for six multiplexes to move to a low power / low tower architecture would nevertheless be considerably more than £350m. If instead eMBMS is proposed, the number of transmission sites required (and therefore the cost) would be greater.

Achieving benefits through a low power / low tower architecture would involve international agreement

A8.36 Perhaps most significantly, a transition to low power / low tower architecture would require neighbouring countries to adopt and coordinate the change. Our early discussions with other administrations suggest that there is at present no great appetite in Europe for a radical replanning of the frequencies or networks used by DTT such as would be required to adopt low power / low tower architecture in the UK.

A8.37 In view of the significant coordination and cost issues, as well as uncertainty over the model under which broadcast services would be delivered, we think that it is unrealistic to expect that a transition from a high power broadcast network to a low power / low tower architecture could take place within the short to medium term. We therefore believe that it will only be realistically possible to make the 700 MHz band available in the earliest timescales (whilst seeking to maintain the benefits that the DTT platform delivers) through adoption of one of the planning options based upon a traditional broadcasting network.

Annex 9

DVB-T2 consumer equipment costs

A9.1 As we discuss in Section 5, we do not consider that a DVB-T2 upgrade would be necessary in order to accommodate a change of use of the 700 MHz band. However, for reasons set out in paragraphs 6.68 to 6.84, we use the cost of a full DVB-T2 upgrade as a proxy for estimating the opportunity cost to DTT of no longer having access to the 700 MHz band.

A9.2 In Section 5 we briefly discuss that a constituent part of the calculation of the opportunity cost to DTT is the costs that some consumers would bear in the instance of a DVB-T2 transition. This cost arises as a full DVB-T2 transition would result in consumers with DVB-T equipment losing access to all of their DTT channels. Therefore, in order to continue to receive DTT, these consumers would have to replace their equipment so that it was compatible with DVB-T2.

A9.3 This annex sets out our methodology and results for estimating the consumer cost of upgrading existing equipment to DVB-T2. We consider the number of pieces of equipment that would need to be replaced and then estimate the cost of replacing that equipment.

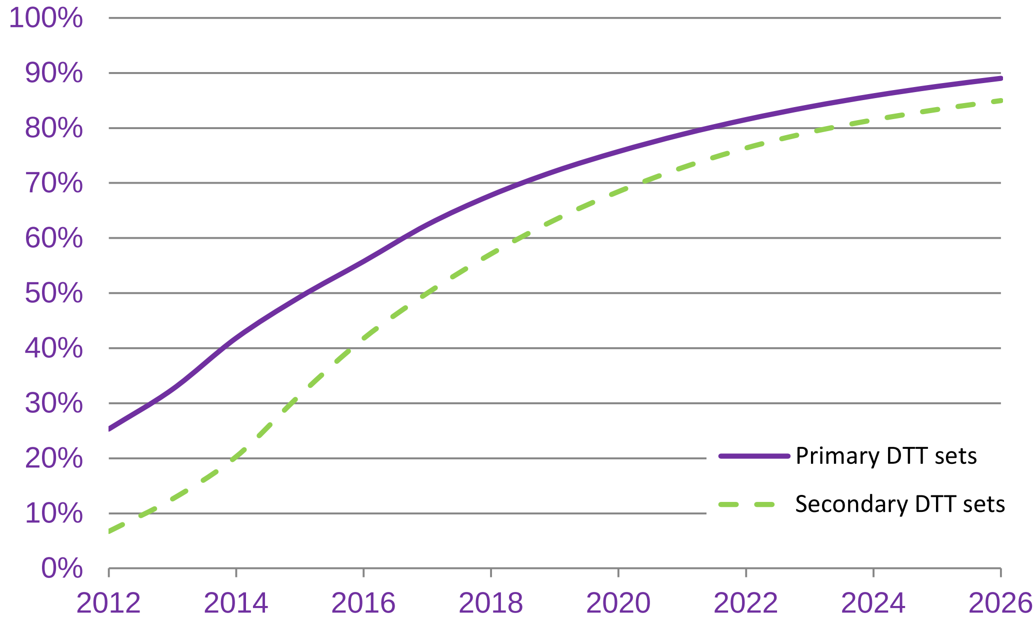
A9.4 We estimate that if DVB-T2 transition was to occur in 2022, approximately 7.9 million pieces of equipment would need to be replaced so that they were compatible with DVB-T2, at an estimated cost of £220 million.

DVB-T2 penetration is expected to grow over time

A9.5 We use industry forecasts from 3 Reasons (a consultancy) to estimate the number of television sets that use DTT as a primary feed.[105] These forecasts are split into primary and secondary sets. 3 Reasons has also provided forecasts on the penetration of DVB-T2 equipment over time. These forecasts are shown in Figure 14, below.

[105] These are televisions on which DTT is the platform that is primarily viewed.

Figure 14: Forecasted penetration of DVB-T2 equipment (source: 3 Reasons)



A9.6 Although there is significant uncertainty over take up of DVB-T2 equipment we consider the 3 Reasons forecast a reasonable estimate of future penetration. 3 Reason's projections estimate that, in 2022:

- 12.4 million households will have DTT on their primary television sets and 23.7 million will have DTT on their secondary sets;
- 18% of primary sets and 24% of secondary sets will not be compatible with DVB-T2; and
- this implies that 2.3 million primary television sets and 5.6 million secondary sets would lose their DTT reception in the event of a full DVB-T2 transition.

A9.7 To establish an upper bound on the potential costs, we assume all equipment on both primary and secondary sets will be replaced. This is likely to be a conservative assumption since some consumers may not place a particularly high value on receiving DTT on their secondary sets and therefore may not replace that equipment (instead, they may use the secondary sets mainly for streaming content or viewing DVDs).[106]

A9.8 Given these forecasts, we estimate that approximately 7.9 million pieces of equipment would need to be replaced were transition to occur in 2022. If transition happened in 2020, we estimate that this figure would be 10.2 million.

[106] For any consumers that decided not to replace their equipment there would still be a loss in consumer value but this would be less than the replacement cost.

We estimate that the cost of replacing DVB-T equipment in 2022 would be approximately £220 million

A9.9 Consumers can receive DTT directly through a television, through a set-top box (STB) connected to their television or through a PVR STB (personal video recorder STB) connected to their television.

A9.10 In the event of DVB-T2 transition, consumers who receive DTT with DVB-T equipment, whether directly or via a STB, will have the following options:

- purchase a new DVB-T2 STB (either a standard STB or a PVR STB);
- replace their televisions earlier than planned (to a set compatible with DVB-T2); or
- stop receiving DTT.

A9.11 In estimating the cost to consumers of replacing equipment, we expect consumers to be rational and choose the least cost option. Therefore, we expect consumers which were about to replace their DVB-T television to replace equipment earlier than planned. For consumers who were not planning to replace their television for a number of years we would expect them to choose the cheaper option of purchasing a new STB which would allow them to receive DVB-T2 broadcasts on their existing television.

A9.12 Based on desk research, we have assumed that the cost of a standard DVB-T2 STB is £30[107] and the cost of a DVB-T2 PVR STB is £150. We have assumed that these costs will stay constant in real terms over the modelling period.

A9.13 For consumers with a DVB-T television or non-PVR STB we assume that they buy a new STB, which would not have been purchased absent a DVB-T2 upgrade. In this case, as consumers would not otherwise have purchased it, the cost to the consumer is the full cost of purchasing the STB (£30) rather than the cost of early replacement. In some cases, this assumption may overstate the true cost (i.e. for some viewers, the cost of bringing forward television replacement will be less than the full cost of a new STB).

A9.14 Consumers with a DVB-T PVR STB would not continue to receive PVR functionality if they purchased a standard DVB-T2 STB or television. Therefore they need to purchase a new DVB-T2 PVR STB which would have been purchased at a later date without a DVB-T2 upgrade. For these consumers, we consider the cost of earlier equipment replacement based on when they would have naturally replaced this equipment.[108]

A9.15 We do not have a breakdown of DVB-T and DVB-T2 equipment, distinguishing between standard STBs and PVR STBs. Therefore, we assume that the proportion of DVB-T equipment that are PVRs is the same as the proportion of total equipment

[107] At present only a limited number of STBs are available at this price. However in the event of a DVB-T2 transition we would expect a large number of competing STBs to be launched at or below this price. This is similar to our experience with DSO where a large number of DVB-T receivers where available for less than £30.
[108] See Annex 14 for a full description of this methodology.

that are PVRs.[109] Therefore, we estimate 6.25 million STBs will be purchased and 1.6 million PVRs will be purchased early.

A9.16 To estimate the replacement cost of PVR equipment we assume the asset life of PVR equipment is 10 years and discount it back to 2014 using the STPR (3.5%).

A9.17 A key input into the replacement cost estimate for PVR equipment is the year that PVR equipment would have been replaced absent DVB-T2 transition. We assume that all PVRs would be replaced with DVB-T2 equipment by 2030; we consider this to be a reasonable assumption given our assumed 10 year asset life. We assume the replacement of these PVRs is spread evenly over the years between change of use and 2030.[110]

A9.18 We calculate the total cost of DVB-T2 replacement as the sum of the cost of a new STB for all DVB-T direct feed televisions and standard STBs plus the early replacement cost of all DVB-T PVRs.

A9.19 The total cost of the replacement of legacy equipment with DVB-T2 transition in 2022 is £220 million.

A9.20 The later DVB-T2 transition occurs, the lower the cost of upgrading consumer equipment will be. This is because more consumers would have naturally replaced their equipment to DVB-T2 by this point. If change of use happened in 2020 we estimate consumer equipment costs would be approximately £340 million.

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[109] This is likely to overestimate the volume of PVR equipment that needs replacing as PVR equipment is more likely to be compatible with DVB-T2. This would subsequently underestimate the volume of direct feed TVs and standard STBs that would need to be replaced. However, as bringing forward replacement of a PVR is, on average, more expensive than purchasing a STB, this is likely to lead to an underestimate of DVB-T2 equipment costs.

[110] This is a simplifying assumption and in reality we would expect more PVRs to be replaced nearer the date of change of use.

Annex 10

Assessment of potential interference from new mobile services

Summary

A10.1 New mobile services in the 700 MHz band have the potential to cause interference into neighbouring services operating in frequencies at 694 MHz and below. Because of the planned configuration of the 700 MHz band, the most likely cause of any interference would be from mobile devices into rooftop DTT aerials. However, for the reasons set out in this annex we believe that the extent of any such interference is likely to be limited and in most cases addressed relatively straightforwardly.

A10.2 Specifically, our work to date suggests that:

- only a small proportion of households would be likely to suffer interference;
- in many of those cases, the interference would be transitory if noticeable at all – amounting potentially to just a few seconds of picture degradation per year;
- for those households suffering noticeable and more frequent interference, a cheap, easy-to-fit filter would resolve the problem in most cases. Only a very few would require improvements or changes to DTT installations;
- as a result, we estimate that the costs of addressing any coexistence issues with DTT would lie in a range from £0 to £20m, and most likely would be much closer to the bottom end of this range.

A10.3 We plan to undertake further work – including field trials – to establish more accurately and definitively both the potential scale and nature of coexistence issues.

A10.4 For the reasons set out below, we have not included any cost element in relation to the mitigation of potential interference to cable TV services or to PMSE. For white space devices, the question is somewhat different: WSDs operate on the principle that there is a low probability of them causing harmful interference to other services. Hence the relevant question is the extent to which change of use of the 700 MHz band would affect the amount of available spectrum. We address that question in Section 8.

Introduction

A10.5 This annex assesses the potential interference that LTE services in the 700 MHz band could cause to DTT and PMSE services operating in spectrum below 694 MHz as well as to cable TV services using the 700 MHz band.

A10.6 As discussed below, there are a number of uncertainties about some of the key variables which will determine the extent of any interference. Technical standardisation of mobile use of the 700 MHz band is on-going in Europe and equipment currently available in Asia-Pacific may not reflect the conditions CEPT is proposing to 3GPP[111]. As a result, we have not yet been able to conduct real world measurements or trials.

A10.7 We have undertaken high level, indicative modelling of the potential impact of LTE transmissions in the 700 MHz band on the DTT service in the adjacent band[112]. This modelling gives us insight into the upper bound of these impacts sufficient to form a view as to whether they are likely to have a material impact on our proposal to change use of the 700 MHz band.

The 700 MHz band plan and the main coexistence risk

A10.8 The current European proposal for the 700 MHz band plan being developed by CEPT[113] situates the downlink frequencies (i.e. those in which mobile base stations would transmit) at the top of the allocation and the uplink frequencies (those in which mobile devices would transmit) at the bottom, adjacent to the DTT receivers and other users such as PMSE using UHF channel 48 and below (see Annex 6). It also proposes a guard band of 9 MHz.

A10.9 In line with the views held within CEPT, we expect that any coexistence issues in the 700 MHz band would arise mainly from interference caused by transmissions from mobile devices. This interference is likely to be transitory in nature as both the mobile devices' transmit powers and locations relative to DTT receivers will vary. This contrasts with the situation in the 800 MHz band, where the lower end of the band (i.e. that closest to DTT) is used for downlink. Coexistence issues, to the extent that they occur at 800 MHz, are primarily caused by base station transmissions resulting in relatively steady interference.

Parameters for theoretical modelling of mobile interference to DTT

A10.10 Mobile device transmissions vary in response to factors such as position in the serving mobile network cell, intra-network interference and the services the device is accessing. Capturing these effects in a theoretical model is challenging. For there to be disruption to a DTT viewer, a number of factors need to come together – for example, the mobile device needs to be in a particularly unfavourable (outdoor) location relative to a TV aerial, it needs to be operating at relatively high power, it (obviously) needs to be using the 700 MHz band rather than an alternative frequency, and the DTT signal needs to be weak. In addition, some types of DTT receiver may be particularly susceptible to interference.

A10.11 Hence, in many cases where a household is theoretically susceptible to interference, there may be few or no instances where mobile devices are in a position, and operating at sufficient power, to cause such interference. Equally, other households may be in locations (for example close to a bus-stop) where the likelihood of mobile devices being in a position to cause more sustained interference is much higher.

[111] CPG-PTD(14)175 Annex 4 Rev 1

[112] Conducted by our consultants Aegis Spectrum Engineering Services *Interference from LTE handsets to DTT services*, 2014: http://stakeholders.ofcom.org.uk/consultations/700MHz/

[113] See Annex 9 of ECC PT1(14)077 draft CEPT-Report 700 MHz for further details.

A10.12 Our analysis suggests that the majority of households would not experience any interference at all from a change of use of the 700 MHz band. Of those households that might be in a position to experience interference, we would expect a range of effects. In many cases, viewers might experience a fleeting image break-up once or twice a year. In more seriously affected households, viewers might suffer from image break-up intermittently for a few seconds during an evening of TV viewing. In the very worst cases, viewers might suffer regular and sustained interference.

A10.13 Key factors that affect the scale of coexistence and the assumptions made in the modelling are described in Table 13 below. We examine some of these factors in more detail in the each of the following sections.

Table 13: Key factors that affect the scale of coexistence and related modelling assumptions

Factor	Modelling Assumptions
DTT transmission signal level at the receiver	Ofcom and the Joint Planning Project have developed a number of options for DTT services following a potential release of the 700 MHz band. The UK Planning Model (UKPM) produces a file giving, for each 100m pixel, a prediction of the median wanted and unwanted DTT fields in each pixel, together with their location variability. In its report, Aegis provides further details of the option it has used for its analysis.
DTT receiver adjacent channel selectivity (ACS)	Aegis has used ACS values taken from those used in ITU[114] studies in JTG 4-5-6-7 for a DVB-T2 signal interfered with by an LTE signal. This indicates that the interference potential varies with the LTE data rate. To avoid underestimating this effect and for simplicity, we have used values for data rate that maximise the potential for interference in our modelling (i.e. 1 Mb/s). The paper gives ACS values (derived from measured protection ratios) for the 50th and 90th percentile of the measured receivers. We used both of these figures in the analysis in this annex.
Band plan duplex arrangement	The mobile device transmit band is adjacent to the DTT reception band.

[114] ITU document 4-5-6-7/493 Table 5/Appendix 6/Annex 2

Guard band	Aegis uses a figure of 9 MHz (consistent with what CEPT has proposed).
Mobile device transmission power and out of band (OOB) emissions derived from it	In a mobile network, mobile device transmit powers vary. The maximum power allowed is +23dBm. However, the available evidence indicates that it is rare for a mobile device to transmit at this level and that +9dBm represents the 90th percentile power in an urban area. Aegis uses both figures in its modelling and takes a 7dB reduction for body loss and antenna gain into account.
Mobile device adjacent channel leakage ratios (ACLR) / OOB emission limits	The CEPT proposal of -42dBm was used.
Mobile device signal level incidental to a victim DTT aerial	In order to assess the susceptibility of any household to interference from a mobile device, the modelling assumes a worst case geometry between the mobile device and victim DTT aerial such that the combination of the DTT aerial gain pattern and free space path loss between the aerial and the mobile device would maximise the potential for interference. This worst case geometry is described in the attached Aegis report[115] and is also used in CEPT document CPG-15 PTD (13)122.

Potential interference scenarios

A10.14 We have considered four potential interference scenarios:

- Emissions from base stations to DTT receivers via rooftop aerials;
- Emissions from mobile devices located outdoors to DTT receivers via rooftop aerials;
- Emissions from mobile devices located indoors to DTT receivers via rooftop aerials; and
- Emissions from mobile devices located indoors to DTT receivers via set top aerials.

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[115] "Interference from LTE handsets to DTT services" – Aegis Spectrum Engineering 2523/SPP/R/4/3.

A10.15 We examine each scenario in turn.

Emissions from base stations to DTT receivers via rooftop aerials

A10.16 Our previous work on 800 MHz base station interference to DTT reception suggested that some coexistence issues could arise in the particular circumstances of 800 MHz LTE deployment. Experience to date suggests that the actual level of interference is extremely limited. The total number of confirmed cases of interference at the end of March 2014 was just over 1,500[116]. If the current level of interference cases per mast continues, the likely total number of cases may be only 20,000. In any case, DMSL, the organisation responsible for mitigating interference estimates that no more than 50,000 households will suffer 800 MHz interference in total.

A10.17 There is a risk that base stations operating in the 700 MHz band might also cause interference to DTT receivers. However, we believe the likelihood and effects of this risk are relatively small: the wider frequency separation between the 700 MHz downlink and DTT means that interference is most likely to be lower than at 800 MHz.

Emissions from mobile devices located outdoors to DTT receivers via rooftop aerials

A10.18 The most likely cause of interference to DTT viewers is from mobile devices located outdoors into DTT receivers via rooftop aerials. Aegis has carried out indicative theoretical analysis of the potential effects.

A10.19 The objective of the Aegis modelling is to identify the number of households that might be at risk of interference some of the time – that is, households with relatively poor DTT receivers in locations where the DTT signal is weak. It then assessed whether the potential interference to these households could be mitigated by installing a filter.

A10.20 In interpreting Aegis's results, we are particularly conscious of the circumstances that have to combine for a DTT viewer to suffer from interference. In this regard, some of Aegis's calculations make simultaneously "worst case" assumptions for many key variables. The probability of all of these assumptions being correct at a large number of households is extremely small.

A10.21 Three factors relating to the assumptions about mobile devices are of particular importance when considering the likelihood of the model results: location, power levels and out of band emissions.

A10.22 First, for there to be interference a mobile device needs to be in a particularly unfavourable location relative to a TV aerial. Specifically the device needs to be:

- located a particular distance from the TV aerial. The probability of interference is greatest when the mobile device is around 20m from a 10m-high TV aerial; and

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[116] See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/312928/Oversight_Board_Report__April__FINAL.pdf

- located (very broadly) between the TV aerial and the relevant DTT transmitter (so that the TV aerial will receive the full impact of the mobile signal).

A10.23 Their mobility means that mobile devices may be in such adverse locations some of the time which means that some viewers may experience interference from time to time. However, there will be many households for which the probability of a mobile device being in such a location is low or even zero – so some potentially affected households may never experience interference. All of the Aegis results need to be interpreted with this in mind.

A10.24 Second, the mobile device needs to be operating at a reasonably high power level and doing so in the 700 MHz band. Aegis's modelling assumes that devices can transmit up to a maximum power level of 23 dBm. However, such transmit powers are most likely in indoor locations and near the edge of cells in rural or semi-rural areas. The former case is irrelevant to the question of interference from devices that are outdoors. The latter case is only likely to be relevant to the DTT reception of a small number of households. Moreover, where operators plan their networks for indoor reception at premises (as is the case with the 4G coverage obligation), those premises will need to be reasonably far from the (outdoor) cell edge – if they were close to the true cell edge, they would not receive an indoor signal. This will further reduce the likelihood of a mobile device operating at full power in a rural area near a DTT household.

A10.25 Aegis has modelled a case in which *all* handsets transmit at maximum power (23 dBm) in the 700 MHz band. However, because such power levels will only rarely occur in the majority of locations, we consider that this scenario is of little relevance to our assessment. We place far greater weight on Aegis's alternative case in which all handsets operate at 9 dBm. This figure is based on available evidence[117] which suggests that 90% of the time a mobile device operates at or below this level.

A10.26 Third, Aegis assumes all devices operate at the proposed regulatory limit for OOB emissions. In reality it is likely that mobile devices will be designed to operate within an implementation margin relative to the regulatory limit and thus have a more benign impact on DTT receivers. Again, this suggests that the Aegis results may overstate the risk of interference – particularly with regard to the number of households where interference could not be resolved with a filter[118].

A10.27 In addition to these considerations, we know from previous work that combining UKPM data with this form of simple coexistence modelling tends to overestimate the vulnerability of households to interference. We would also expect more selective DTT receivers and amplifiers to form a greater proportion than they do today of the installed base by the time the 700 MHz band could be cleared for mobile services. These factors are likely to reduce any effects from mobile use of 700 MHz on DTT reception. There is therefore a further risk that the modelling could overstate the higher end numbers of households affected by interference.

[117] ITU document 5-6/81-E "Additional System Characteristics of an operational IMT network deployed in Australia in the 800 MHz band".
[118] On the other hand, notwithstanding the current developments, there is some residual risk that the CEPT could select an OOB emission limit that is higher than the -42dBm[118] used in the modelling.

Modelling Results

A10.28 Table 14 below is derived from the Aegis report and shows the key results. We have scaled the results by 75% to exclude households that do not use DTT either on primary or secondary sets[119].

Table 14: Results of coexistence modelling – mobile terminal power of 2 dBm[1]

	Modelling results based on the out-of-band emission limit of −42dBm/(8 MHz)	
	50th percentile of DTT Receiver ACS	90th percentile of DTT receiver ACS
TV receiver without external filter	*3k*	*55k*
TV receiver with external filter	*2k*	*2k*

[1] Terminal power not exceeded by 90% of samples in an outdoor urban environment: +9dBm, with reduction of −4dB body loss and −3dB antenna gain = 2 dBm.

A10.29 The table shows the number of households potentially at risk of interference based on two alternative assumptions about DTT receiver performance:

- In the first case, Aegis assumed that all DTT receivers were at the 50th percentile with regard to their adjacent channel selectivity. On its own, we would expect this to lead to an underestimate of the number of affected households (although the other factors discussed above might nonetheless reduce the number of affected households below the figures shown in the table).

- In the second case, Aegis assumed that all receivers performed as poorly as receivers at the 90th percentile (i.e. the receivers had a low ACS). For this to be the case, it would have to particularly likely that households in areas with weak DTT signals also happened to have poorly performing DTT receivers. We consider this an unlikely correlation which means that the 90th percentile numbers are likely to overstate the likely effect.

A10.30 The modelling also suggests that, in many cases (all but around 2,000) the coexistence issue could be fixed by use of a simple filter.

A10.31 In the case of LTE at 800 MHz, DTT consumers also fit filters to manage interference. At some households, the filter can be fitted directly to the wall plate of a consumer's DTT installation – a procedure that is simple and low-cost. However, for other households, fitting filters is more costly and complicated because the consumer has an amplified system. Here the filter needs to be fitted on the aerial-side of the amplifier and some amplifiers are located on rooftops.

[119] http://stakeholders.ofcom.org.uk/binaries/research/tv-research/tv-data/dig-tv-updates/2012Q4.pdf

A10.32 In the case of 700 MHz, we think that interference to amplified systems is unlikely because amplifier overload typically results from interfering equipment operating at relatively high powers (which is not likely to be the case with mobile devices). Hence filter installation to mitigate 700 MHz interference should be straightforward.

A10.33 Specifically, most of the early results from our WSD field trials – with devices operating at 36 dBm – show little evidence of interference to amplified systems. These trials are of particular relevance to the potential coexistence effects at 700 MHz as they involve equipment transmitting in reasonably close proximity to DTT aerials at relatively low powers (albeit greater powers than mobile devices). They suggest that interference from mobile devices operating at a maximum EIRP of 23 dBm to amplified DTT aerials would also be very limited.

A10.34 Nonetheless, we recognise that in a number of instances, a filter may not be sufficient. In these cases other measures, such as improving existing domestic DTT installations or replacing some of the equipment, might be required as has been the case for 800 MHz.

A10.35 As explained above, Aegis also modelled the effect of all mobile devices transmitting at full power (23 dBm). These showed that as many as 600,000 households could – in principle – be affected. However, we attach little weight to this result for the reasons set out in paragraphs A.1.24 to A.1.25. We believe mobile devices will only transmit at 23 dBm in a number of cases and that those cases are unlikely to be relevant to interference from outdoor mobile devices to TV aerials.

Emissions from mobile devices located indoors to DTT receivers via rooftop aerials

A10.36 In this scenario, we are examining whether mobile devices located inside a household is likely to cause interference to its rooftop aerial. Our consultants have performed a limited set of field trials[120] that show this is unlikely to be a material issue.

A10.37 Thus, we do not believe that this potential interference scenario will be a significant factor relative to other scenarios in scaling the coexistence issue. Therefore we do not believe that it is material to the costs.

Emissions from mobile devices to DTT receivers via set top aerials

A10.38 We have also considered coexistence issues resulting from mobile device emissions to DTT receivers via set top aerials. A report prepared for Ofcom indicates that 8% of all UK homes use set top aerials as a means of TV reception (10% for DTT households) on at least one TV set and that this figure falls to 2% for main TV sets[121]. A proportion of these households may be liable to interference from mobile devices operating in the 700 MHz band.

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[120] " Measurement of coupling loss between mobile handsets and DTT receive antennas at 700 MHz" Aegis Spectrum Engineering Services

[121] UHF Spectrum Strategy Research Report (Kantar Media) published alongside this document, at p. 65. This research is based on a sample universe of all UK households, comprising adults aged 16+ personally or jointly responsible for making decisions about TV equipment purchases, and was conducted amongst 1,643 respondents, thus providing a robust nationally representative sample. We are aware of an earlier document from Digital UK (Technical Note, *Domestic Receiving Systems: Set-*

A10.39 It is difficult to predict reliably the scope (i.e. the separation distance at which interference may typically occur) and scale (i.e. proportion of set top aerials that may be liable to interference) of potential coexistence issued caused by mobile devices operating in the 700 MHz band, because the estimates are very sensitive to the technical input assumptions and modelling approach.

A10.40 In any event, we attach very little weight to any potential coexistence issues caused to set top aerials in our analysis because the DTT network is not planned and designed for TV reception by way of set top aerials. Ofcom and other organisations (*e.g.* BBC RTIS, CAI, Freeview and at800) advise consumers that set top aerials are much less effective. Consistent with this advice, consumers tend to adjust their expectations from this means of reception that is less reliable than that by way of rooftop aerials, because it is more prone to interference from a range of sources.

A10.41 Accordingly, we have not attributed any costs to interference caused by mobile devices to DTT receivers via set top aerials for the purposes of our CBA.

A10.42 Finally, for those viewers who use set top aerials and might experience interference to DTT reception, the following options are available:

- Not using the interfering mobile device at home whilst watching DTT, or moving the device away from the set top aerial to a distance where it does not cause interference. However, we recognise that this may not be effective in all cases: where the DTT reception on the set top aerial is already marginal, the required separation distance may be substantial, and in some cases, mobile devices could potentially cause interference to weak DTT reception using set top aerials in neighbouring houses.

- For set top aerials with built-in amplifiers with gain control, turning down the gain control (provided the gain is not turned so low that it prevents DTT reception).

- For set top aerials with built-in amplifiers with no gain control, replacing them with a passive set top aerial (provided it has sufficient gain to deliver adequate DTT reception).

- For passive set top aerials, fitting a 700 MHz filter on their output may reduce the scale of experienced interference, though it is unlikely to eliminate it fully in every situation.

A10.43 Furthermore:

- Installing a new wall socket feed from an existing rooftop aerial, or installing a rooftop aerial where one is not in place, would remove the need to use a set top aerial altogether and, therefore, provide more reliable TV reception.

- Where reception through a set top aerial cannot be restored, a platform change (*e.g.* to satellite TV) may provide a solution. We note, however, that feeding multiple rooms with satellite TV reception can be difficult.

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top and Loft Aerial Usage, 26 April 2012), which includes higher figures for set-top aerial use. However, we note that the differences in methodology mean that the figures Kantar prepared provide a better, more recent basis for our assessment.

A10.44 Some of these options may be less practical than others for large purpose built flats, though many of these purpose built flats have an Integrated Reception System (IRS) installed already. Nevertheless, extending the outlet of an IRS to other rooms may not be straightforward and specific solutions may need to be tailored to individual circumstances.

Provisional conclusion on costs for managing coexistence to DTT

A10.45 To reach a view of the potential costs, we have taken account of our assessment of the scale of potential coexistence issues to DTT. We have also assumed that a filter costs up to approximately £20 (including parts and potential other costs e.g. delivery directly to a household) and that other service restoration measures (such as improving existing domestic DTT installations or replacing some of the equipment) could cost up to approximately £200 per household. Based on these assumptions, and even if it were deemed necessary to implement a centrally coordinated remediation scheme with reasonably high overheads, we consider that £20m would likely be more than sufficient to address any coexistence issues. For the purposes of our CBA, we have therefore factored in a cost of between £0 and £20m for addressing coexistence issues to DTT.

A10.46 Some illustrative calculations demonstrate why we believe this range of costs is reasonable. The figures above suggest that the number of households that are at risk of interference from mobile devices is of the order of 50,000. Of these potentially affected households, our modelling indicates that all but 2,000 could be mitigated by the installation of a simple filter and the remaining 2,000 households might need improvements to their DTT installations. This would lead to a cost for viewer mitigations of approximately £1.4m – assuming that all of the affected households suffered interference that required mitigation. There is potential for a few additional cases of interference from mobile base stations, but as explained above, we anticipate that this will be limited.

A10.47 We recognise that there is significant uncertainty in these estimates. However, as explained above, our expectation is that the actual level of mitigation that is eventually required will be relatively small. We have cautiously allowed for mitigation costs of up to £20m (including provision of information to consumers) although we anticipate that the actual figure is likely to be lower.

Cable TV

A10.48 We have also considered the potential for interference between mobile services operating in the 700 MHz band and cable TV networks operated in the UK (by Virgin Media) and consumer equipment.

A10.49 A similar issue arose in the context of 800 MHz clearance (again, related to potential interference between LTE and cable TV networks). Our technical investigations of that issue showed that it was not likely to be a material problem. We are, however, separately investigating the potential for interference arising from mobile services operating in the 700 MHz band.

A10.50 Given our previous analysis in the context of 800 MHz, we think the likelihood of this being a material problem is low. In the case of consumer equipment, the natural replacement cycle is such that, to the extent that any equipment might be liable to interference (e.g. because of screening issues), the majority of such equipment will have been replaced prior to any clearance on the timescales envisaged under our proposals.

A10.51 In the course of our investigations we will consider further the potential for costs to arise. As we do not presently consider that this will result in material coexistence concerns, we have not reflected any associated costs in our CBA.

PMSE

A10.52 As with the case of potential interference to DTT, it is probable that the primary cause of any interference to PMSE would be from mobile devices as there is a large frequency separation between the frequencies that PMSE use and those that mobile base station would transmit at.

A10.53 An IRT report to CEPT group FM51[122] on using the LTE band duplex gaps for PMSE has tested a mobile device radiating at full power with a PMSE receiver that is using low wanted receiver signal power to mimic a faded radio channel for a PMSE radio link. Its conclusions show that there is minimal risk that a mobile device operating in the vicinity of a PMSE receiver would cause interference to that PMSE receiver when there is a frequency separation of 9 MHz (i.e. the likely guard band between PMSE and mobile use at 700 MHz).

A10.54 The evidence we have indicates that there is not a material issue with PMSE coexistence in channel 48 and below. Therefore, we have not assigned any costs in this CBA. We are planning to improve our understanding of this issue in the broader context of our review of spectrum access for PMSE.

[122] The FM 51 report is FM51(14)116_Annex_IRT Measurements Duplex Gap use for PMSE.

Annex 11

Impact of a change of use of the 700 MHz band on PMSE

A11.1 In Section 7 we outline our assessment of the impact that a change of use of the 700 MHz band would have on the PMSE sector. In this annex we provide further details of our assessment of the scale of this impact. Critically, this assessment assumes that there are *no* mitigating actions because its objective is to consider the impact of change of use in this hypothetical case. We first summarise the methodology and then discuss our results and conclusions.

A11.2 We are committed to safeguarding the important cultural benefits which PMSE provides. If we went ahead with change of use of the 700 MHz band, we would therefore work with the PMSE community to mitigate the impacts described in this annex as part of our overall strategy for the future of the sector. In Section 7 we set out current thinking on how we would look to achieve this.

Methodology

We estimated how much spectrum there would be available for PMSE following a change of use of the 700 MHz band

A11.3 Change of use of the 700 MHz band would affect spectrum availability in two ways:

i) the direct loss of the 700 MHz band itself; and

ii) the consequential loss of available spectrum as a result of a replanned DTT network in the frequencies from 470 to 694 MHz.

A11.4 We commissioned Arqiva PMSE (formally JFMG) to assess how much usable PMSE spectrum there would be across the country if we made the 700 MHz band available for mobile and implemented the single hop DTT frequency plan (see Annex 8 for more detail). The single hop frequency plan included frequency assignments for both main and relay DTT stations. This provided a UK wide indicative post 700 MHz DTT plan against which we could assess the impact from the consequential loss of spectrum. We have not replicated this analysis for any of the other DTT frequency plans discussed in Annex 8. This is because at a high level, the amount of spectrum available for PMSE is broadly the same for each of the frequency planning options with different locations being affected to a greater or lesser extent (with the exception of more radical changes to the DTT network such as national SFNs which we consider unlikely to be appropriate given the analysis set out in this document).

A11.5 When assessing the availability of spectrum, Arqiva PMSE applied the same process it currently uses to provide information on spectrum availability based on today's DTT broadcasting network. It assessed spectrum quality using the Spectrum Quality Indicator ('SQI') model described below. This means we can make a direct comparison between the current situation and the situation that would exist if we were to proceed with the proposed changes. Figure 15 provides further background information on Arqiva PMSE's approach to making PMSE assignments.

Figure 15: Overview of Arqiva PMSE's approach to making PMSE assignments

The geographical variability of available spectrum is a very important consideration in assessing the impact of spectrum changes on PMSE. When making assignments Arqiva PMSE apply a range of protection criteria to protect DTT reception. For microphones and IEMs these protection criteria result in the whole 470-790 MHz band being available for indoor PMSE use and outdoor use being limited to protect DTT. In addition, and far more significant to the utility of the spectrum for PMSE, interference from DTT may make spectrum shown as available (based on protection criteria) unusable for audio PMSE applications demanding a high quality of service.

To provide PMSE users with an indication of 'spectrum quality' Arqiva PMSE developed the Spectrum Quality Indicator. The SQI is a four point scale indicating spectrum quality based on the level of interference from DTT at that location:

SQI 1. The channel is used for TV broadcast reception at this location. Expected signal levels for TV are high representing a nearby high power broadcast station. Use of typical wireless microphone or personal monitor systems is not generally recommended unless extreme care in deployment is taken to minimise the risk of interference from TV signals.

SQI 2. The channel is used for TV broadcast reception at this location. Expected signal levels for TV are moderate representing main coverage area. Use of typical wireless microphone or personal monitor systems within a building having substantial construction to reduce penetration of TV signals may be successful.

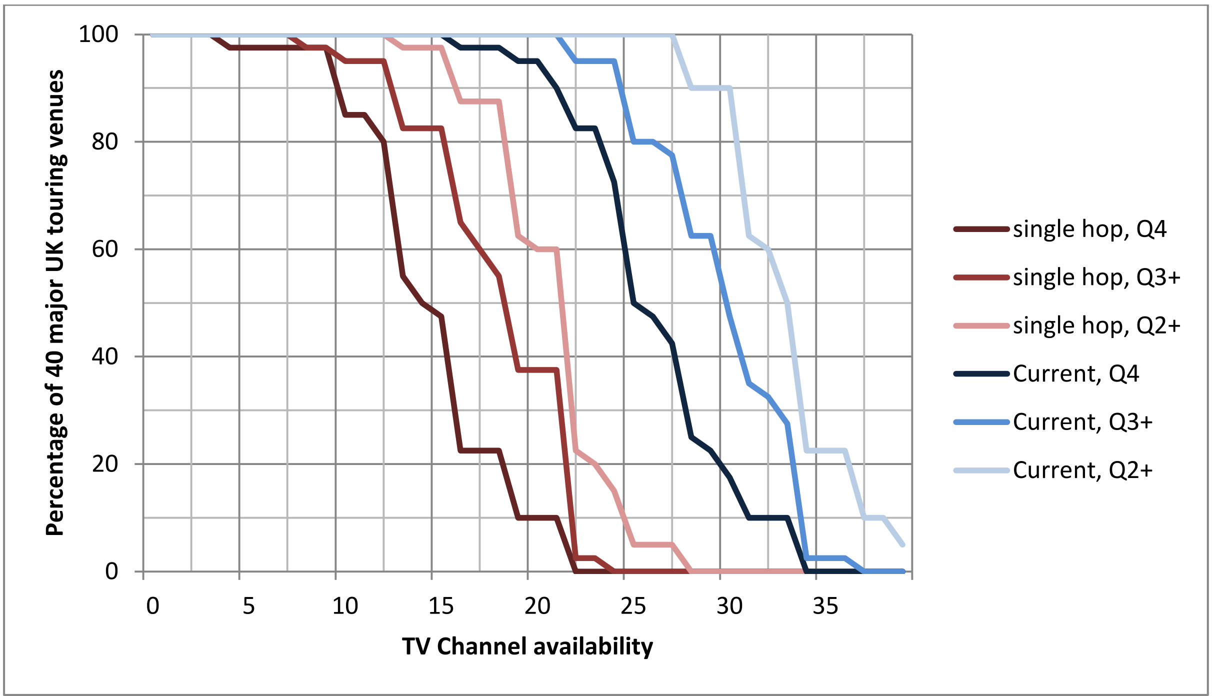
SQI 3. The channel is used for TV broadcast reception at this location. Expected signal levels for TV are low representing edge-of-service area. Use of typical wireless microphone or personal monitor systems within a building of predominately brick, block, stone or metal construction is unlikely to be affected.

SQI 4. The channel is not used for TV broadcast reception at this location. Background signal levels for TV would not normally be expected to cause interference to operation of typical wireless microphone of personal monitor systems.

A11.6 The single hop plan does not include any allocations for Local TV and we therefore have not factored this into our analysis. However, we note that any allocation for Local TV in any given location would further reduce spectrum availability for PMSE in that location i.e. another 8 MHz TV channel would potentially not be available. The increased impact to PMSE would be constrained within the Local TV coverage area and we consider it would only be a marginal additional effect compared to the impact of a change of use of the 700 MHz band. We would seek to address the effect through the mitigating actions described in Section 7.

A11.7 Figure 16 below compares the location variability of available channels for different quality of spectrum at 40 major UK touring venues between current spectrum availability and under the single hop plan.

Figure 16: Availability of spectrum by quality at a sample of 40 major UK touring venues



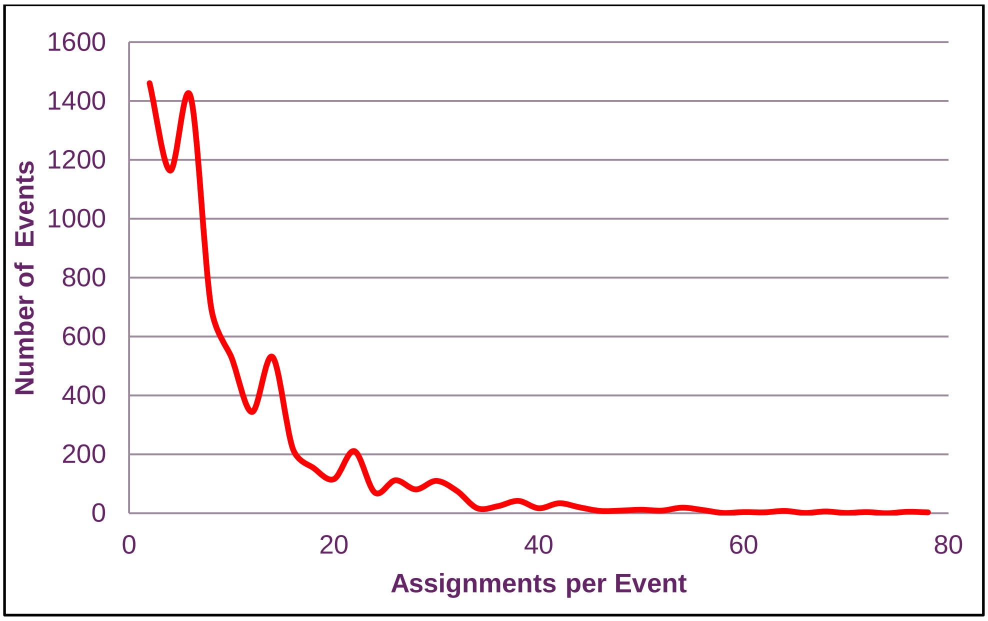
We then assessed how this change in PMSE spectrum availability would affect a sample of peak demand events

A11.8 We then considered what effect this change in PMSE spectrum availability would have on a sample of events which we identified using the PMSE licensing database and engagement with PMSE stakeholders. This sample consists of peak spectrum demand events, such as festivals, rock concerts or large TV productions and events identified as having particular challenges such as touring theatre. Due to the geographical variability of available spectrum we considered peak demand events at a variety of locations across the UK.

A11.9 Peak demand events make up only a small proportion of PMSE use, but they are challenging to accommodate. 93 per cent of all sets[123] of assignments in the data covering 1 January 2012 to 31 March 2013 have 24 or fewer assignments which could be accommodated in 20-24 MHz of spectrum. The remaining 7%, including many high-profile events, make up the peak demand events that would start to be affected by a change of use of the 700 MHz band (approximately 1000 events per year across various sectors such as concerts, musical theatre, broadcasting etc.). Figure 17 illustrates the distribution of assignments against events.

[123] We use sets of assignments with the same licensee, start date and venue as a proxy for individual events.

Figure 17: Events by number of assignments



A11.10 In order to assess the impact that a change of use of the 700 MHz band would have on these peak demand events, we first sought to develop an understanding of spectrum requirements of each event and how organisers satisfied them. In order to do this we:

a) contacted the stakeholders responsible for each event to determine, as far as possible, the breakdown of assignments for each application (microphones, IEMs and talkback) and the model and type of equipment used. Where we were unable to get this information we made assumptions based on careful analysis of channel use patterns and licence data.

b) examined each event against the information obtained from the licensing database, information from stakeholders and the configuration and quality of spectrum at the time of the event. This was an important step to determine the minimum spectrum quality level the event organiser was able to utilise in satisfying the production demands i.e. use of 'grey space' rather than white space.

A11.11 Having done this, we sought to replan the events against the future spectrum availability and quality in that location (based on the single hop DTT frequency plan). Where there were shortfalls in spectrum availability we considered illustrative changes in equipment type and working practices in order to satisfy the demand e.g. using a microphone with a wider tuning range than that used by the event to allow other frequencies to be utilised. From this, we qualitatively assessed the impact this would have. We graded this assessment on a five point scale:

Table 15: Classification of impact of a potential loss of the 700 MHz band

Classification	Impact on Equipment Selection	Impact on Working Practice	Assignment Count
Minimal	None	None	Satisfied
Slight	The same equipment could be used, albeit in different frequency ranges	Some minor changes needed	Satisfied
Substantial	High specification equipment needed if not already in use	Substantial changes needed	Satisfied
Severe	High specification equipment needed if not already in use	Substantial changes needed	Some assignments lost (production quality reduced)
Critical	High specification equipment needed if not already in use	Substantial changes needed	Significant loss of assignments; the event would no longer be viable in any recognisable form.

Results

Many of the peak demand events we looked at suffered a severe or substantial impact

A11.12 Table 16 below summarises how a change of use of the 700 MHz band would affect the events we considered. The majority were at least substantially impacted by a change of use of the 700 MHz band; there was a sizable minority where the impact would be severe.

Table 16: Summary of case studies

Event	Sector	Assignments	Impact
V Festivals	Live music	85 (peak case)	Substantial
T in the Park	Live music	242*	Substantial
NFL International Series, Wembley Stadium (Rams vs. Patriots)	Sport	123	Severe
Michael Jackson Immortal Tour	Live music	76	Slight
Glastonbury Festival	Live music	495*	Severe
Madonna, Murrayfield Stadium	Live music	54	Minimal
Cisco Conference, London Excel Centre	Corporate Event	133	Slight
Bruce Springsteen - Sunderland	Live music	78	Substantial
Bruce Springsteen - Manchester	Live music	78	Severe
X Factor/Britain's Got Talent - Fountains TV	Broadcast	106	Substantial
X Factor - Manchester Gmex	Broadcast	94	Substantial
Summertime Ball	Live music	179*	Severe
West End Theatre	Theatre	3038*	Substantial
War Horse, UK Tour	Theatre	61	Severe †
The Lion King, UK Tour	Theatre	61	Slight †
Priscilla, Queen of the Desert, UK Tour	Theatre	33	Slight
BBC Children in Need	Broadcast	94 + 58 proximate**	Severe
Comic Relief	Broadcast	79 + 18 proximate**	Slight

* *In these cases, the use of assignments is not fully co-located and coincident e.g. used on different stages at different times*
** *The "proximate" assignments are those used on other productions in the same building/location*
†*The difference in impact for these similar events is due to the increased use of talkback communication systems in War Horse. These duplex communication systems significantly reduce available spectrum for microphones.*

We considered how representative peak demand events are

A11.13 In order to establish how representative peak demand events are of the broader population of PMSE events we examined the distribution of the number of PMSE events against the event size in terms of number of spectrum assignments for use cases separated by sectors and duration (greater than 30 days and equal to or less than 30 days).

A11.14 For events with assignments of less than 30 days duration the analysis shows:

- Except for theatre all sectors broadly follow the same distribution of exponential drop-off with increasing duration and size.

- For live music the drop-off by duration is greater than average – events are more concentrated in 2 days or less. We would expect the greatest population of events impacted by the loss of 700 MHz to be in this sector.

- For theatre the modal value for assignment size is eight and for weekly assignments it is 12. There are also local maxima around the 12 to14 day mark and 20 and 28 day marks. These isolated maxima correspond to large touring musicals that play at a venue for a longer period of time.

A11.15 The heat maps below provide examples of the analysis of theatre productions and live music events less than 30 days duration. For theatres there is a clear association between numbers of events and duration corresponding to one, two and three weeks. For live music there is a clear drop-off in number of events with increasing duration which reflects the nature of this sector, i.e. playing one or two nights at a venue before moving on.

Figure 18: Heat maps of assignments and number of events for theatre and live music of less than 30 days duration

Theatre

Duration (days)

Assignments in Set	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
0																
4		57	11	45	2	1	3	12			3		1	1	4	5
8		59	15	71	36	3		6	3	4	2	1		3	1	3
12		27	2	118	5	3	2	2	2		3					1
16		20	10	66	6	1	6	2	1		1				1	1
20		3	1	27	1		1	2				1				
24		3	4	6		4	33	3			5	1			1	
28		1		25			4	6	1		1					
32				6							7	3			6	1
36				6		1	9	12	3	1	5					
40				2			11	2			1					
44				16	2											
48		1														
52						1				3					1	1
56																
60																
>60		3						1								

Live Music

	Duration (days)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	0																
Assignments	4		1051	66	29	9	5	4	7		1	2					
in Set	8		716	66	21	4	4	1	3	3	4						1
	12		363	23	3	2	4	1	2	1							
	16		331	23	17			1				1	1				
	20		157	25	12	3			1							1	
	24		114	15	16		1									1	
	28		79	7	5												
	32		72	12	2		1			1							
	36		16	10	2	1											
	40		12	1													
	44		17	1													
	48		14	5	1												
	52		3	3													
	56		15	2	1	1											
	60		6	1	1												
	>60		23	6	2	1		1	1							1	

A11.16 For events with assignments of greater than 30 days the analysis shows:

- In terms of the size of spectrum assignments per event, each sector again follows a broadly similar exponential drop-off with size.
- Peaks at 44, 52, and 81+ assignments for theatre correspond to West End shows and major venues (e.g. The National Theatre and the Barbican).
- There is a sub-set of 12 large, fixed, PMSE installations at broadcasting venues that would be impacted in the same way as the broadcast peak demand case studies, assuming number of assignments corresponds to use. At the upper end of this sub-set are numbers of assignments that couldn't be simultaneous and co-located with current spectrum supply, so we believe that our identified peak demand cases provides a good representation of this sector.

Conclusions

A11.17 Across the case studies our analysis shows that without further mitigating steps:

- For a small subset of very large events with a high count of simultaneous (or near-simultaneous) co-located assignments, even under ideal conditions, the supply of spectrum would not be adequate. This could be the case for up to 10-20 large sporting events, broadcast productions and live music events a year e.g. our results for the NFL International Series game at Wembley and the War Horse tour suggest that other events of these types would be affected similarly. The practical implication of this would be that producers would have to fundamentally change the way in which they stage these events. This could have an adverse impact on audience experience.

- As we discuss above, spectrum availability varies from region to region. Although we did not classify any of the impacts identified in our case studies as critical, there is a risk that in some areas spectrum supply might be sufficiently low that some events might fall into the critical category. This impact would be especially acute in the case of touring shows which would need to tailor the production to meet the minimum spectrum availability of a tour or carry enough equipment and resource to allow the audio set to be reconfigured for each location.

- For both long term and short term events the data demonstrate that the peak demand cases under study are at the upper end of a continuous distribution rather than exceptional events of a different nature to the broader population of similar events. They are, therefore, representative of the broader range of peak demand events and it follows that there will be some significant, albeit lesser, impact to the broader population of these events.

Annex 12

PMSE equipment survey

A12.1 In Section 7 we set out the potential impact of a change of use of the 700 MHz band on the PMSE industry. One of the impacts we identified was the likely need to replace and upgrade some PMSE equipment.

A12.2 To inform our assessment and to understand the potential impact on PMSE equipment we undertook a survey of equipment owners. In this annex we set out the methodology and findings of our survey and explain how we have used that survey to estimate the costs of upgrading and replacing equipment.

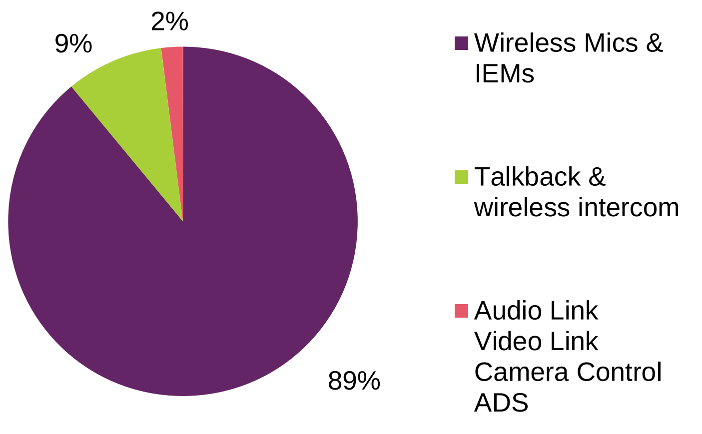
A12.3 We estimate the NPV of the total cost associated with replacing and upgrading PMSE equipment in 2022 is between £6 million and £18 million.

The majority of PMSE assignments in UHF bands IV and V are wireless microphones and in-ear-monitors

A12.4 Analysis of Arqiva PMSE (formerly JFMG) licensing data[124] reveals that, within bands IV and V (470-862 MHz), the large majority of PMSE assignments in the DTT interleaved spectrum are wireless microphones and in-ear-monitors, with some use of talkback devices and wireless intercom devices. Assignments for these four types of equipment amount to 98% of all PMSE assignments in this part of the spectrum.

A12.5 Figure 19, below, shows the average proportion of UK assignments in Bands IV and V for each type of PMSE equipment since 8 September 1999.[125]

Figure 19: PMSE assignments in Band IV/V



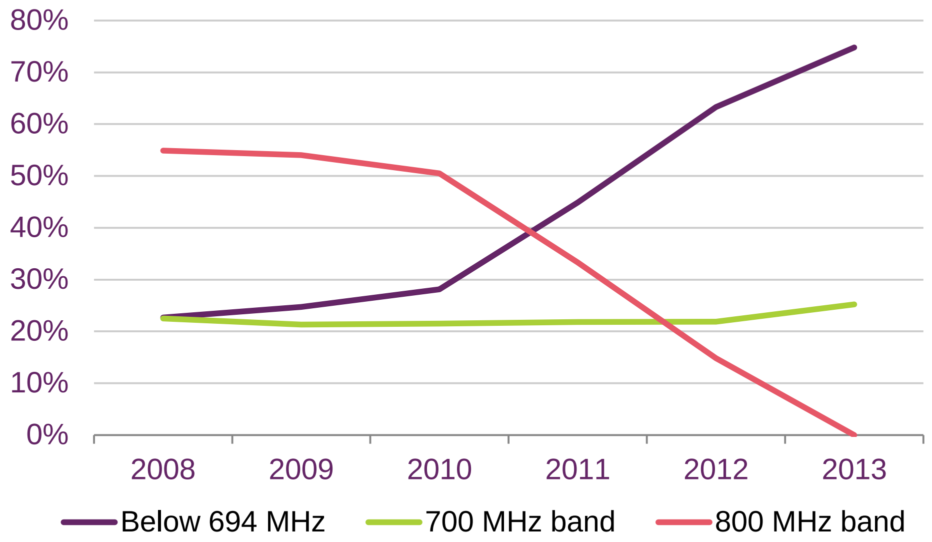
[124] Access to the spectrum is licensed on Ofcom's behalf by Arqiva PMSE (www.pmse.co.uk), which manages and coordinates spectrum use in order to avoid interference to DTT and between other PMSE users.

[125] A PMSE assignment is a single allocation of spectrum. This could be a specific frequency, location, time or more general such as a band (known as a block booking – usually in 8 MHz TV channel blocks), or could cover a region/area.

A12.6 Between 2008 and 2012, Digital Switchover (DSO) converted the UK DTT network from analogue to digital transmission including clearing the 800 MHz band (790-862 MHz) of DTT and PMSE use. As a result of this clearance, any PMSE equipment or assignments in the 800 MHz band had to move to lower frequencies.

A12.7 Figure 20, below, shows the proportion of PMSE assignments in the geographic interleaved spectrum in the 700 MHz band (694-790 MHz), the 800 MHz band (790-862 MHz), and below 694 MHz (channel 49), for the whole of the UK between 2008 and 2013.

Figure 20: Distribution of PMSE assignments within the band 470-862 MHz



A12.8 The total number of PMSE assignments has almost doubled since 2008; from approximately 44,000 to 77,000. However, Figure 20 shows that migration from the 800 MHz band was almost entirely to below 694 MHz. As a result, the proportion of assignments in the 700 MHz band has remained at around 20 – 25% since 2008 (with a small increase in 2013), but the number of assignments in the band has almost doubled.

A12.9 While Arqiva PMSE data provides information on the number of assignments made across the industry we do not have a central source of information on the equipment currently in use – particularly how many devices are in use and what frequencies they use. For example a device could be used on multiple occasions under separate assignments recorded in our licensing database. One of the aims of our survey was to bridge this information gap.

A12.10 The tuning range of equipment (the frequencies over which the equipment is capable of operating) will determine how likely it is that equipment would be affected by change of use of the 700 MHz band. For the purposes of this survey we have taken a conservative approach and assumed that equipment will not have access to the 700 MHz duplex gap or guard band.

A12.11 If the 700 MHz band were to be used for mobile services, equipment that is tuned solely to frequencies between 694 MHz and 790 MHz would become redundant, unless it were capable of being retuned. However, most PMSE equipment cannot be retuned to operate in different frequencies.

A12.12 Equipment which is capable of tuning only to frequencies below 694 MHz (channel 49) might also be affected if it is always or sometimes used in fixed locations that are affected by the replan of DTT frequencies. This will change the amount and configuration of interleaved spectrum (between 470-694 MHz) available for PMSE in certain locations. This may mean that users' equipment loses some, or all, of its utility as a result of the reconfiguration of interleaved spectrum and could result in PMSE users needing to replace equipment, possibly to equipment that covers a wider tuning range.

A12.13 Some equipment tunes to frequencies both above and below 694 MHz. Change of use of the 700 MHz band would reduce the effective tuning range of this equipment, both by loss of access to this band and a possible change in the amount and configuration of interleaved spectrum below 694 MHz. The extent to which a potential clearance of the 700 MHz band might affect this equipment will vary, depending particularly on the specific tuning range of equipment. If a piece of equipment tunes predominately to frequencies below 694 MHz, it is less likely to be affected (particularly if it is capable of tuning to a wide range of frequencies between 470-694 MHz).

A12.14 We received survey responses from companies responsible for approximately 25% of all PMSE assignments in the UHF bands We sent owners a questionnaire to provide information on their equipment including how much of each equipment model they currently hold, when it was purchased and when they expect to replace it.

A12.15 Our objective was to contact companies which together accounted for as much equipment currently in use as possible. We therefore contacted: companies who made the largest claims under the channel 69 funding scheme[126]; companies recommended to us by stakeholders; and companies or individuals with assignments in the 700 MHz band. All data was collected between May 2013 and October 2013.

A12.16 The disparate nature of the PMSE community means it is not feasible to obtain a reliably random sample of equipment. We recognise our approach is not systematic and we did not receive responses from all companies or individuals we contacted. Therefore there is some risk of bias, e.g. those owners of equipment which risks being affected might have been more likely to respond to our survey. However given the large number of response we received we believe our sample is representative of the PMSE industry.

Amount of equipment surveyed

A12.17 Overall we received responses from companies who together held 6,906 individual items of equipment.

A12.18 We asked for information about the tuning range of equipment. We can therefore separate this equipment according to the frequencies in which it operates, namely: only in the 700 MHz band; only below 694 MHz; or capable of tuning to frequencies both above and below 694 MHz. The 6,906 items of equipment can be separated into these three categories as follows:

[126] *Funding for moving programme-making and special events from channel 69,* August 2010: http://stakeholders.ofcom.org.uk/binaries/consultations/pmse_funding/statement/statement.pdf

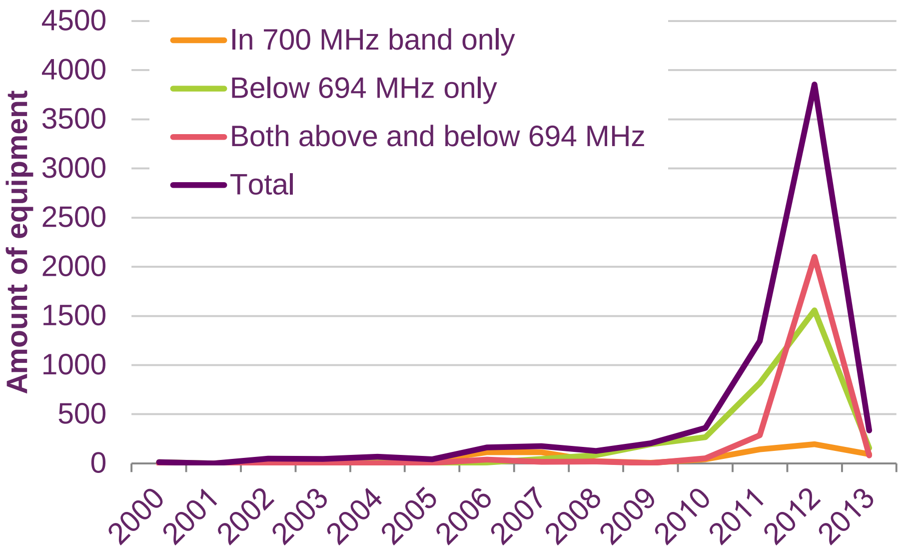
- 700 MHz only: 823 items;
- below 694 MHz only: 3,457 items; and
- both above and below 694 MHz: 2,626 items.[127]

Year of equipment purchase

A12.19 We asked for information on the year in which each item of equipment was purchased, with the aim of estimating how much of this equipment would still be in use at the date of a potential 700 MHz change of use.

A12.20 Results are shown in Figure 21 below:[128]

Figure 21: Amount of equipment purchased by year[129]



A12.21 Figure 21 indicates that most equipment in use has been purchased since 2010. This is likely to have been largely driven by clearance of the 800 MHz band. Importantly, purchases of 700 MHz-only equipment accounted for a relatively small proportion of this apparent spike in demand. 700 MHz-only equipment was about 10% of sales from 2010-2013, compared to about 40% from 2000-2009 (although the sample size in these earlier years is much smaller).

A12.22 The figure for the amount of equipment purchased in 2013 is significantly lower as this survey was conducted part way through 2013 so it does not reflect a full year, and also because channel 69 clearance was largely completed by then.

Asset life of equipment

A12.23 The survey also asked owners to provide an estimate of when they might naturally replace their equipment. Whilst many owners were unable to answer this question,

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[127] For example, this equipment might have a tuning range covering 606 MHz to 790 MHz.
[128] Not all respondents provided information on the purchase date. This equipment is not reported in Figure 21. For estimating the impact of change of use of the 700 MHz band we assume equipment was purchased in 2012 when purchase date information is unavailable.
[129] Survey conducted part way through 2013.

estimates about when equipment might need to be replaced were provided for 28% of all equipment surveyed. From these we can estimate the asset life of equipment, by comparing the year of purchase with the expected year of replacement. For instance, if an owner bought equipment in 2005 and anticipates replacing it in 2020, the equipment has an expected asset life of 15 years.

A12.24 Our survey indicates an average asset life of 10 years. The channel 69 clearance funding scheme assumed that the asset lives of PMSE equipment was 15 years.[130] We have considered a range of 10 years to 15 years in our analysis.

Value of equipment

A12.25 We asked owners of equipment to provide information on the types and models of the equipment that they own. We then estimated the value of equipment with different tuning ranges using this information and additional desk research.

A12.26 Table 17 below shows the results for wireless microphones and in-ear monitors.[131] The final column shows the average additional cost for equipment with a larger tuning range. For example, on average wireless microphones with a tuning range of between 100 MHz and 200 MHz cost 59% more than wireless microphones with a tuning range of between 50 MHz and 100 MHz. There is no evidence of a further price premium above 200 MHz (we recorded a slight reduction (2%) but this can be attributed to ‘noise’ in the data).

Table 17: Average equipment price by tuning range

Tuning Range (MHz)	Average equipment price (£)	Mark-up on equipment with next smallest tuning range
Wireless Microphones:		
0 - 50	1,549	NA
50 - 100	1,722	11%
100 – 200	2,744	59%
200 +	2,697	-2%
In-ear monitors (IEMs):		
0 – 50	675	NA
50 - 100	1,233	83%
100+	1,602	30%

A12.27 We estimate the total cost of replacing PMSE equipment is between £6 million and £18 million In the event of a clearance of the 700 MHz band, not all PMSE equipment would be affected. Our methodology for estimating the cost of equipment replacement is:

130 This assumption was based on a survey of manufacturers and responses to the funding consultation. Manufacturers noted that equipment generally had an asset life of between 10 years and 20 years. PMSE users who responded to the consultation estimated an average asset life of 16.8 years.

131 We have not provided a breakdown for talkback equipment as our sample size was much smaller.

a) Estimate the amount of PMSE equipment in use today, then estimate how much of it will still be in use in 2022 and is likely to need replacing or upgrading as a result of change of use of the 700 MHz band. We assume that the total stock of PMSE equipment stays broadly constant but that any equipment purchased from 2014 will operate below 694 MHz.

b) Estimate the cost of earlier replacement of this affected equipment. This is based on the cost of the equipment and how much earlier than the natural replacement date the equipment would have to be replaced as a result of change of use of the 700 MHz band.

c) Finally, estimate the additional costs associated with upgrading some equipment to reflect the reduction in interleaved spectrum. This upgrade cost is applied to all affected equipment replaced from 2014.

A12.28 We have assumed that the more flexible equipment is (i.e. the greater number of frequencies between 470 to 694 MHz that the equipment is capable of tuning to), the less susceptible the equipment will be to changes in the spectrum available for PMSE use.

Amount of equipment replaced

A12.29 To assess the total amount of equipment affected, we extrapolated from our survey sample to the wider PMSE industry, based on the number of PMSE assignments held by respondents to our survey.

A12.30 Among respondents to our survey, those who owned the 823 pieces of equipment which used the 700 MHz band had between them 5,725 assignments in the 700 MHz band in 2012, representing 26.7 per cent of all such assignments. On the assumption that our results represent 26.7 per cent of all equipment in the 700 MHz band we estimate there are around 3,000 items of PMSE equipment operating in the 700 MHz band today.[132]

A12.31 Table 18 below shows the percentage of assignments for our different equipment categories and our estimates of the total amount of equipment based on the number of assignments in 2012. In total, we estimate there are approximately 27,000 pieces of PMSE equipment in use in UHF bands IV and V today.

[132] There is some risk this underestimates the total amount of equipment e.g. the owners who responded may have more assignments per piece of equipment than average. However, there is no particular reason to expect this, particularly given the range of responses we received, covering a large number of total PMSE assignments.

Table 18: Extrapolating survey results

Equipment covering	Equipment in survey response	Percentage of total assignment in frequency range	Estimated total amount of equipment
700 MHz only	823	26.7%	3,080
Below 694 MHz only	3,457	25.1%	13,770
Both above and below 694 MHz	2,626	25.5%	10,300
Total	**6,906**		**27,150**

A12.32 Equipment could be affected by change of use of the 700 MHz band in two ways:

a) Some equipment may need to be replaced earlier than originally planned. This will be the case if the equipment would not otherwise be replaced until after change of use; and,

b) Some equipment may need to be upgraded at additional cost. This could apply to equipment that is replaced before change of use of the band, i.e. in the next eight years, and equipment that would not have been replaced until after change of use. For modelling simplicity we assume that all equipment that is replaced early also needs to be upgraded, but not all equipment that needs to be upgraded is replaced early (i.e. some equipment reaches the end of its asset life before 700 MHz change of use and is upgraded at that point).

A12.33 We expect that any equipment replaced from 2014 would not need to be replaced again. However, this equipment might still need to be upgraded to reflect the reduction in availability of interleaved spectrum. We assume that any upgrade takes place when the equipment is replaced to avoid replacing twice.

A12.34 Whether equipment needs to be replaced or upgraded depends on the tuning range of the equipment:[133]

a) We expect that all equipment that tunes to frequencies only in the 700 MHz band will need to be upgraded and replaced.

b) We expect that only a proportion of equipment that operates in frequencies below 694 MHz will be upgraded and replaced. We assume that the greater the number of channels between 470-694 MHz that equipment is capable of tuning to, the less likely an item of equipment is to be affected if the 700 MHz band is cleared.

A12.35 To reflect this second point we have made estimates based on the assumption that the probability of a piece of equipment not being affected is equal to the percentage of the frequencies between 470-694 MHz which are in the unit's tuning range. For example, if an item of equipment has a tuning range that covers 25 per cent of the frequencies between 470-694 MHz, we are assuming that this item has a 25 per cent chance of not being affected. In other words, we would be estimating that one in four items of equipment with this tuning range would not be affected. This is a simplifying assumption for the purposes of modelling that aims to capture the average impact on PMSE equipment.

[133] We assume that all talk-back equipment is affected regardless of the tuning range.

A12.36 Using this approach we estimate that approximately 70% of all PMSE equipment (i.e. 19,000 pieces of equipment) may need to be upgraded.

A12.37 Table 19 below shows the estimated number of items of PMSE equipment affected as a result of change of use of the 700 MHz band in 2022.The low cost estimate is based on an asset life of 10 years while the high cost estimate is based on an asset life of 15 years.

Table 19: Amount of equipment affected by 700 MHz change of use in 2022 for different equipment asset lives

	Low cost	High cost
Total equipment	27,200	27,200
Equipment not affected by change of use	7,800	7,800
Equipment that needs to be upgraded	19,400	19,400
Of which also needs to be replaced early	1,500	12,700

A12.38 In our high cost estimate more equipment needs to be replaced early because we assume a longer asset life of 15 years.

Replacement costs

A12.39 The cost of replacing PMSE equipment as a result of change of use of the 700 MHz band includes the cost of earlier replacement of some equipment plus the cost of upgrading some equipment. We can distinguish between:

- Equipment which does not need to be replaced early or upgraded – i.e. which could operate effectively following change of use. There is no cost associated with change of use.

- Equipment which needs to be upgraded, but which would in any case be replaced before change of use and can be upgraded at this point. In this case there is an upgrade cost.

- Equipment which needs to be upgraded, and which would otherwise not be replaced until after change of use. In this case there is an early replacement and upgrade cost.

A12.40 The cost of earlier replacement is the cost of bringing equipment replacement forward to a date earlier than originally planned. This is estimated using the same methodology as used elsewhere in this consultation and explained in more detail in Annex 14. The average cost of early replacement is between £400 and £540 per piece of equipment.[134]

A12.41 The cost of upgrading equipment reflects the possible need to purchase different equipment as a result of a reduction in the amount of interleaved spectrum post change of use of the 700 MHz band. The impact of a reduction in spectrum is discussed in more detail in Section 7 and Annex 11. In this equipment survey we focus on two mitigating actions relating to equipment replacement:

[134] To estimate the cost of early replacement we use a discount rate of 5% as set out in *Funding for moving programme-making and special events from channel 69*, August 2010: http://stakeholders.ofcom.org.uk/consultations/pmse_funding/statement/

- Upgrading equipment to cover a larger tuning range. Based on the results of Table 19 we estimate the average cost of upgrading equipment is a mark-up on the current cost of between 20% (low cost estimate) and 40% (high cost estimate). This is an average mark-up applied to all equipment that needs upgrading in our modelling; in reality some equipment will not require upgrading, other equipment will cost more than this to upgrade. This mark-up is applied to all affected equipment (excluding talk-back equipment).

- Replacing talk-back equipment to operate in a different frequency band. We estimate the cost of upgrading talk-back equipment is a mark-up of between 25% (low cost estimate) and 50% (high cost estimate); this is an average mark-up applied to all talk-back equipment.[135]

A12.42 As explained in Section 7 we do not consider any additional costs for microphone equipment moving to alternative bands as we have done for talk-back equipment. Our assessment is that there are more significant changes required for talk-back equipment.

A12.43 Based on these assumptions we estimate the total cost of replacing PMSE equipment as a result of change of use in the 700 MHz band in 2022 is between £6 million and £18 million. Table 20 below shows the cost estimate split by the cost of earlier replacement and the cost of upgrading equipment.

Table 20: Estimated replacement cost for change of use of the 700 MHz band in 2022

	Low estimate	High estimate
Cost of earlier replacement	£0.6 million	£6.8 million
Cost of upgrading equipment to cover a wider tuning range	£5.0 million	£9.8 million
Cost of upgrading talk-back equipment	£0.8 million	£1.5 million
Total cost	**£6 million**	**£18 million**

A12.44 This represents the cost of replacement if a change of use were to finish in 2022. If the band were to be used for mobile services before 2022 the cost of earlier replacement would go up. For example, we estimate that the total cost of replacement were a change of use to finish in 2020 would be between £12 million and £24 million. If change of use were to be delayed beyond 2022 our estimate of the cost will fall.

[135] Estimating the cost of replacing talk-back equipment to operate in alternative bands is more uncertain as it will depend on the band chosen and whether a similar decision is reached across Europe. However, some talkback equipment that operates in other spectrum bands is already available for a small premium. If talkback equipment as a whole moves to an alternative band this premium could fall to close to zero. Therefore our estimate of the mark-up is likely to overstate the total cost.

Annex 13

Potential impact of a 700 MHz change of use on spectrum availability for white space devices

A13.1 As set out in Section 8, we have investigated from a technical perspective the likely availability of spectrum for white space devices (WSDs) in the case of a change of use of the 700 MHz band. Overall, our analysis indicates that WSDs would have access to spectrum in the TV bands such that they could continue to operate if we were to proceed with these changes.

A13.2 Our analysis indicates that in some areas of the country availability of TV white spaces (TVWS) would fall as a result of a change of use of the 700 MHz band. However, in other areas our analysis indicates that the availability of TVWS would increase following a change of use of the 700 MHz band. The results of our analysis are explained further in this annex.

We do not expect a change of use of the 700 MHz band would have a material negative impact on overall TVWS availability

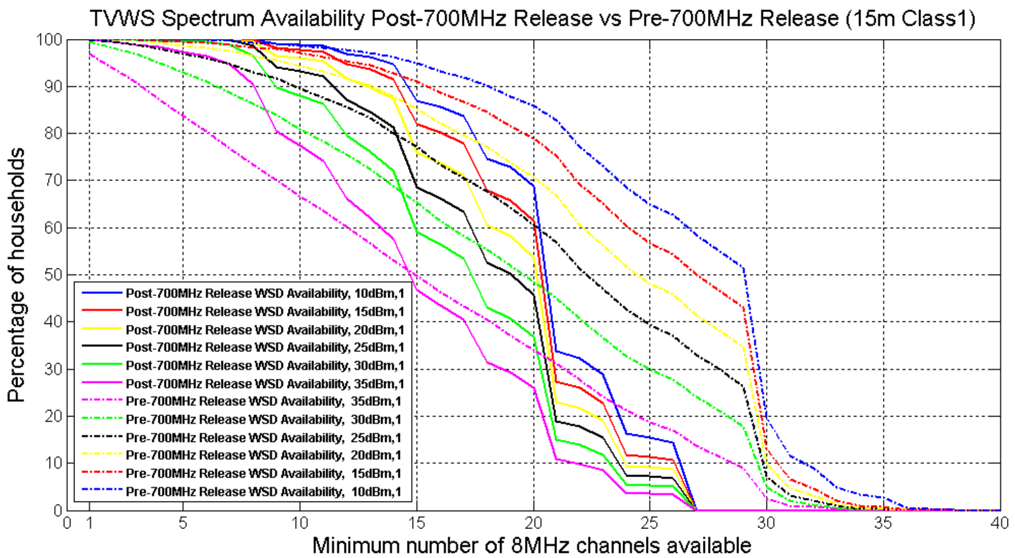
A13.3 We expect that replanning DTT services to facilitate a change of use of the 700 MHz band would have an impact on the availability of interleaved spectrum for use by WSDs. We have not included an amount to represent a cost/benefit for this change in availability in our CBA because the value of WSDs in the future is uncertain. Nevertheless, we consider that it is important to assess the potential impact on the availability of interleaved spectrum for use by WSDs to give an indication of the future prospects for spectrum availability in the case of a change of use of the 700 MHz band.

A13.4 The availability of interleaved spectrum for use by WSDs would depend on the final DTT plan. For the purposes of this analysis, we selected the single hop DTT band plan (see Section 5 and Annex 8) as we consider this band plan to be representative of that which might finally be adopted. The spectrum availability for WSDs was calculated both for the current on-air DTT plan and for the single hop plan. The results are compared in Figure 22 (below) for a range of different classes of White Space Devices at different heights above ground level.

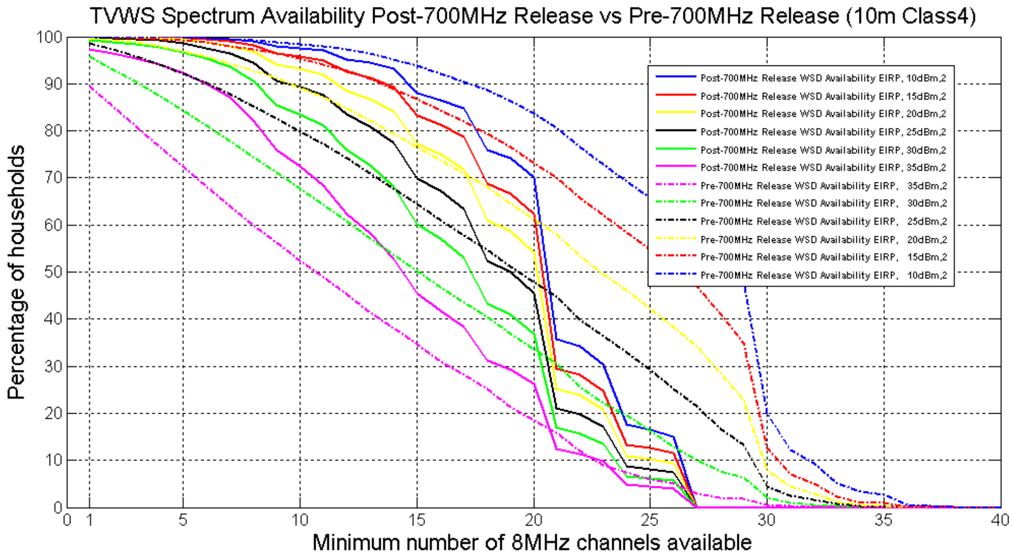
A13.5 Consistent with the work of the Digital Frequency Planning Group (DFPG) to date, the calculations for the single hop DTT plan post a 700 MHz change focused on the main DTT transmitters. Therefore, they did not include detailed consideration of infrastructure operating at relatively lower powers such as relay transmitters or Local TV services. Whilst we are in the early stages of negotiations with neighbouring countries on the overall requirements for DTT following a potential change, we considered that it would be premature to include now details of frequencies relating to lower power infrastructure, such as that for interleaved Local TV services, until the degree of development of these international discussions supports specific frequency options for infrastructure operating at relatively lower powers. It should be noted that the calculation for the current on-air DTT plan did include low power Local TV services and the 600 MHz multiplexes. Introducing Local TV services to the single hop plan would be expected to reduce the overall availability of spectrum for White Space Devices, but in our view not significantly (even though Local TV services would be lower in power than the main DTT multiplexes, they would use a more robust transmission mode which would be expected to produce a similar overall interference management requirement to the main DTT multiplexes). Therefore, although the calculations of TVWS spectrum availability did not take account of Local TV services post a 700 MHz change, we would not expect their addition to have a material effect on overall TVWS availability.

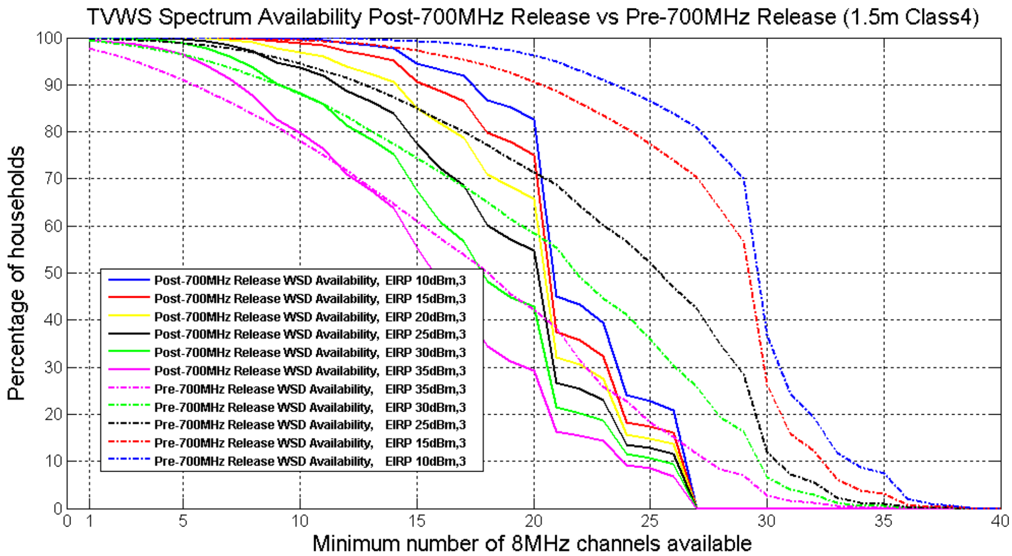
A13.6 Figure 22 (below) shows the assessment of TVWS spectrum availability for different heights and classes of WSD for the single hop DTT plan[136]. There are four graphs, one for each reference scenario (where the scenario relates to the height of the WSD and the class of the device – there are five different classes specified depending on the out-of-band performance of the device). In each graph, there are two sets of curves, one for the current (pre-release) DTT plan and the other for the single hop (post release) plan. Each set of curves consists of five different curves of availability for five different WSD power levels. The availability of UHF Channels can be read directly from the curves. So for example, in the first graph (15m, class 1), the availability of spectrum for a WSD power of 35 dBm in the current situation (pre-release plan) is 15 UHF Channels for 50% of households in the UK.

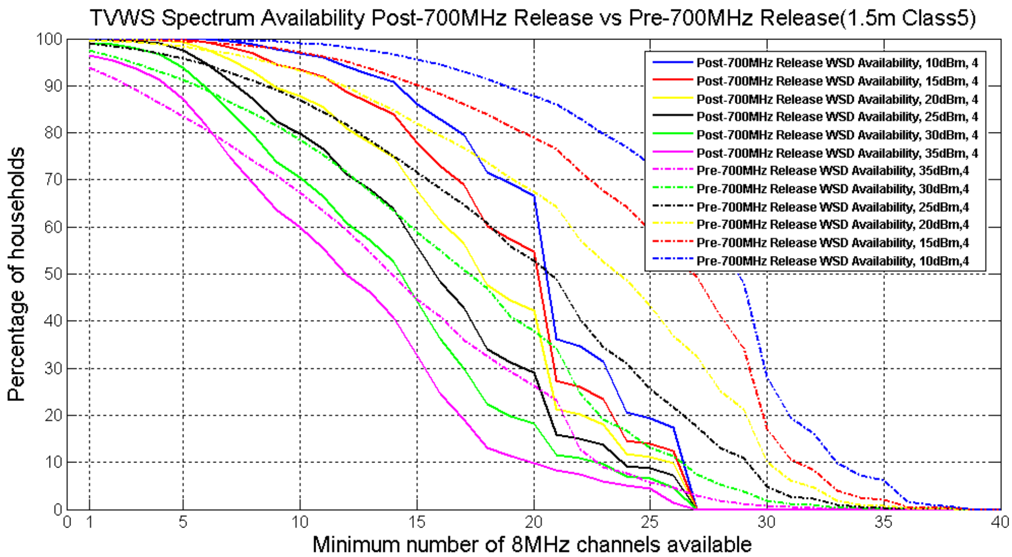
Figure 22: Assessment of TVWS spectrum availability for different heights and classes of WSD for the single hop DTT plan



[136] The availability curves have been recalculated since *TV white spaces: approach to coexistence* consultation because of changes in the software model: http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/


TVWS Spectrum Availability Post-700MHz Release vs Pre-700MHz Release (10m Class4)
Percentage of households
Minimum number of 8MHz channels available


TVWS Spectrum Availability Post-700MHz Release vs Pre-700MHz Release (1.5m Class4)
Percentage of households
Minimum number of 8MHz channels available
Post-700MHz Release WSD Availability, EIRP 10dBm,3
Post-700MHz Release WSD Availability, EIRP 15dBm,3
Post-700MHz Release WSD Availability, EIRP 20dBm,3
Post-700MHz Release WSD Availability, EIRP 25dBm,3
Post-700MHz Release WSD Availability, EIRP 30dBm,3
Post-700MHz Release WSD Availability, EIRP 35dBm,3
Pre-700MHz Release WSD Availability, EIRP 35dBm,3
Pre-700MHz Release WSD Availability, EIRP 30dBm,3
Pre-700MHz Release WSD Availability, EIRP 25dBm,3
Pre-700MHz Release WSD Availability, EIRP 15dBm,3
Pre-700MHz Release WSD Availability, EIRP 10dBm,3


TVWS Spectrum Availability Post-700MHz Release vs Pre-700MHz Release(1.5m Class5)
Percentage of households
Minimum number of 8MHz channels available
Post-700MHz Release WSD Availability, 10dBm, 4
Post-700MHz Release WSD Availability, 15dBm, 4
Post-700MHz Release WSD Availability, 20dBm, 4
Post-700MHz Release WSD Availability, 25dBm, 4
Post-700MHz Release WSD Availability, 30dBm, 4
Post-700MHz Release WSD Availability, 35dBm, 4
Pre-700MHz Release WSD Availability, 35dBm,4
Pre-700MHz Release WSD Availability, 30dBm,4
Pre-700MHz Release WSD Availability, 25dBm,4
Pre-700MHz Release WSD Availability, 20dBm,4
Pre-700MHz Release WSD Availability, 15dBm,4
Pre-700MHz Release WSD Availability, 10dBm,4

A13.7 The charts in Figure 22 indicate that the maximum number of channels available for WSDs in areas of the country where the DTT interference management requirements are low reduces with a change of use of the 700 MHz band (the reduction arises from the removal of the 12 UHF channels in the 700 MHz band). The maximum number of channels available to White Space Devices after DTT replanning is 26 (Channels 21 to 48, minus channel 38 (PMSE) and 48 (guard band)). The reduction is apparent when comparing the TVWS spectrum availabilities for the “pre” and “post” scenarios to the right hand side of the graphs (i.e. for the lower percentages of households where the numbers of 8 MHz channels available are higher).

A13.8 However, in areas of the UK where there are more DTT services to account for (and overall TVWS availability is lower) to the left of the graphs, replanning DTT services from the 700 MHz band actually increases the TVWS availability, and the increase becomes even more significant as the power of the White Space Device increases. We believe that this increase in availability arises because the need to manage the risk of interference with the low power interim 600 MHz multiplexes is removed in the 700 MHz change of use scenario, and the 600 MHz multiplexes have a disproportionate overall effect on TVWS spectrum availability because of their low relative powers. Generally, the TVWS spectrum availability post a 700 MHz band change of use would offer about 96% of the UK population at least one UHF channel, even for the scenario where the White Space Device is 1.5m above ground and is in the worst class for out-of-band interference (the 1.5m class 5 scenario).

A13.9 We are planning to undertake further work to develop these initial findings. However, these initial findings are encouraging both for the potential 700 MHz change of use and for the future availability of spectrum for White Space Devices, because the level of TVWS availability is most important in highly populated areas of the UK (where there are typically more DTT services to coexist with). Note however that these conclusions might alter in the future if the TVWS coexistence parameters were to be adjusted in light of forthcoming coexistence tests.

A13.10 Our findings are in contrast to early analysis undertaken at the time of the UHF Strategy Statement[137] which suggested that TVWS availability would fall significantly at the time of a potential 700 MHz change of use. However that previous analysis was based heavily on the use of SFNs for the DTT plan in case of change and DFPG has done further work since then to optimise options in relation to potential DTT band plans. We believe that these refinements to the DTT planning approach are responsible for the improved availability of frequencies for White Space Devices. However we would emphasise that these conclusions are only preliminary as there is, as yet, no internationally band plan and further changes to the DTT plan would potentially have an impact on the availability of spectrum for WSDs.

A13.11 It should also be noted that our assessment is based solely on compatibility of White Space Devices with DTT. In areas of high PMSE activity, such as in London, the need to manage the risk of interference to PMSE may have a greater effect on TVWS availability in a case of 700 MHz release because there would be fewer UHF channels overall to share between services. However, this could be offset because

[137] *Securing long term benefits from scarce low frequency spectrum,* November 2012, paragraph 5.35

the 600 MHz multiplexes will have been switched off. We will continue to investigate the combined effects of a change of use of the 700 MHz band and the need to manage risks of interference to PMSE on TVWS availability, but at this stage we do not believe that the combined effects would have a material negative effect on overall availability.

Annex 14

Cost of early equipment replacement

A14.1 In this annex we set out the methodology that we have adopted in our analysis in relation to the cost of early equipment replacement.

A14.2 The majority of the costs that we have sought to estimate in our cost-benefit analysis relate to the replacement of equipment that would otherwise have been replaced at the end of its asset life. For example, a change of use would be likely to result in the replacement of a number of transmitters in the DTT network. We would, however, expect these transmitters to be replaced in any event at the end of their asset life.

A14.3 Early replacement of equipment also brings forward subsequent replacements. For example, suppose a transmitter is due to be replaced in 2035, then 2060, and then 2085. Replacing it in 2022 would bring the subsequent replacements forward to 2047, 2072 etc. We have, therefore made an adjustment based on comparing the series of replacement costs with and without a 700 MHz change of use to perpetuity, assuming equipment is continually replaced at the end of its asset life.

A14.4 Table 21 below shows an example cash flow comparison with and without 700 MHz change of use. In the example, it is assumed that change of use occurs in 2022, replacement would otherwise have occurred in 2035 without change of use and the equipment has a 25 year asset life. The cash flows are only shown to 2085 for illustration; however we assume that replacement continues beyond this to perpetuity.

Table 21: Example cash flows with and without 700 MHz release

	2022	2035	2047	2060	2072	2085
With 700 MHz change of use	Cost incurred		Cost incurred		Cost incurred	
Without 700 MHz change of use		Cost incurred		Cost incurred		Cost incurred

A14.5 The difference between these two cash flows is the cost of bringing forward equipment replacement. This gives the following cost of early replacement which is based on a geometric series to perpetuity:

$$Cost\ of\ early\ replacement = \frac{Total\ Cost\ x\ \left(1 - \frac{1}{(1+r)^n}\right)}{1 - \frac{1}{(1+r)^a}}$$

A14.6 Where r is the discount rate. r is either based on the relevant Weighted Average Cost of Capital (WACC) or Social Time Preference Rate (STPR) depending on who bears the cost: if the cost is borne by society, we use the STPR; if the cost is borne by private firms, we use the appropriate WACC. *n* is the difference between the year of natural replacement and year of 700 MHz change of use and *a* is the asset life of the equipment. The total cost is the cost of purchasing the equipment as new. Where we do not have the relevant information on these parameters, we make a reasonable assumption based on available information and knowledge of the industry.

A14.7 Table 22 below gives an example of the replacement cost calculation for three different pieces of equipment with different asset lives and discount rates.

Table 22: Example cost of early replacement calculation

	Example 1 – Consumer aerials	**Example 2 – PMSE equipment**	**Example 3 – DTT infrastructure**
Cost of equipment	£150	£1,000	£50,000
Year of 700 MHz change of use	2022	2022	2022
Year of natural replacement	2023	2031	2034
n	1	9	12
Asset life (a)	25 years	12 years	25 years
Discount rate	3.5%	5%	7.7%
Cost of early replacement	£9	£802	£34,940

A14.8 Example 1 considers the early replacement of an aerial which was purchased in 1998 and is due to be replaced one year after change of use. We use the STPR in this calculation as the cost is borne by consumers. Since change of use only brings the replacement of this aerial forward by one year, the equipment to be replaced is almost fully depreciated, and the cost of early replacement is relatively small (only 6% of the full equipment cost).

A14.9 By contrast, Example 2 (which shows the early replacement of a piece of PMSE equipment) illustrates how the cost of early replacement increases as replacement is brought forward over a greater number of years where the asset has not served much of its expected useful life. The PMSE equipment in this example would naturally have been replaced in 2031. Instead, it is replaced in 2022. The cost of bringing forward replacement of this piece of equipment is £802 (80% of the full equipment cost). We use a discount rate of 5% in this example as the cost falls on private PMSE firms and this is our estimated PMSE WACC.

A14.10 Example 3 shows the cost of bringing forward replacement of a piece of DTT infrastructure equipment which is halfway through its asset life. The discount rate used here is the DTT WACC which we estimate at 7.7%. The £50,000 piece of DTT equipment in this example was purchased in 2009 and was due to be replaced in 2034. The cost of early replacement of the equipment with change of use, halfway through its asset life, is £34,940 (70% of the total cost of replacing the equipment).

Annex 15

Figures and table references

Annex 16

Reports used in this cost-benefit analysis

A16.1 To develop our proposals, we also used analysis from a number of reports, most of them prepared by independent consultants. The reports are as follows:

- *Assessment of the benefit of a change of use in the 700 MHz band to mobile*, May 2014, Analysys Mason
- *Consumer aerial survey: Implementing Ofcom's UHF Strategy*, May 2014, Ofcom
- *Terminal capabilities in the 700 MHz band*, October 2013, Real Wireless
- *Study on DTT receiver performance*, Dec 2013, The Technology Partnership
- *700 MHz High Level Estimate: Single Hop & PSB MFN/COM SFN Plans*, May 2014, Arqiva
- *Measurement of coupling loss between mobile handsets and DTT receive antennas at 700 MHz*, May 2014, Aegis Systems
- *Interference from LTE handsets to DTT services*, May 2014, Aegis Systems
- *UHF spectrum strategy: Research report*, 2014, Kantar Media
- *Annex K: Outdoor aerials contextual quantitative insights* & *Annex L: Indoor aerials contextual quantitative insights*, 2013, Kantar Media

A16.2 These reports are available at http://stakeholders.ofcom.org.uk/consultations/700MHz/.

Annex 17

Glossary of terms

3GPP	The 3rd Generation Partnership Project - Collaboration between groups of telecommunications associations, to make a globally applicable third-generation (3G) mobile phone system specification within the scope of the International Mobile Telecommunications-2000 project of the International Telecommunication Union (ITU).
4G	Fourth generation mobile phone standards and technology
ACLR	The Adjacent Channel leakage ratio (ACLR) of a radio transmitter is the ratio of in band transmitted power to out-of-band power in the adjacent channel (or for a specified frequency offset).
ACS	Adjacent channel selectivity. A measure of how susceptible a receiver is to unwanted signals in adjacent spectrum.
APT	Asia-Pacific Telecommunity
ARPU	Average revenue per user - A measurement used by pay-television or mobile companies to indicate the average monthly revenue earned from a subscriber.
CAI	Confederation of Aerial Industries. A trade association representing aerial installers and manufacturers in the UK.
CBA	Cost-benefit analysis
CCP	The Ofcom Communications Consumer Panel is the independent research and policy advisory body on consumer interests in telecommunications, broadcasting and spectrum markets (with the exception of content issues).
CEPT	The European Conference of Postal and Telecommunications Administrations
CFI	Implementing Ofcom's UHF strategy consultation 'Future use of the 700MHz' call for inputs published April 2013
COM	Commercial multiplex. Three of the six UK-wide DTT multiplexes that do not carry any of the public service broadcaster channels.
Communications Act	The Communications Act 2003, which came into force in July 2003.
CPG PTD	CEPT Conference Preparatory Group Project Team D
CSI	Central service information. A means for collating the Electronic Programme Guide information for all of the UK's DTT multiplexes so that receivers are able to display listings information for all DTT services regardless of which service the viewer is watching.
dB	Decibel. A notation for dealing with ratios that vary over several orders of magnitude by using logarithms.
dBm	The power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).
DCMS	Department for Culture Media & Sport

DFGP	DTT Frequency Planning Group. The DFPG carries out frequency planning work, is chaired by Ofcom and comprises representatives from each of the DTT multiplex licensees, the BBC and transmission company Arqiva.
DME	Distance measuring equipment is a transponder-based radio navigation technology that measures slant range distance by timing the propagation delay of VHF or UHF radio signals.
DMSL	Digital Mobile Spectrum Limited
DSO	Digital switchover. The process of switching over from analogue television or radio broadcasting systems to digital. Television DSO completed in 2012.
DTG	The Digital Television Group -The DTG is an industry association for digital television in the UK. The DTG publishes and maintains the technical specifications for the UK's Freeview and Freeview HD platforms (the 'D-Book'), and operates a digital television receiver test centre.
DTT	Digital Terrestrial Television - Broadcasting delivered by digital means. In the UK and Europe, DTT transmissions use the DVB-T and DVB-T2 technical standards.
DVB-T	Digital video broadcasting – Terrestrial. A standard for terrestrial transmission of digital television developed by the DVB consortium
DVB-T2	Digital video broadcasting – Terrestrial 2. The latest digital terrestrial transmission technology developed by DVB.
eMBMS	Evolved Multimedia Broadcast Multicast Service is the multicast standard for Long Term Evolution (LTE) that allows multimedia content to be sent once and received by many end users.
EPG	Electronic Programme Guide. A programme schedule, typically broadcast alongside digital television or radio services, to provide access to and information on the content and scheduling of current and future programmes.
ERC	The European Research Council (the independent body that funds investigator driven frontier research in the European Union(EU)
ES	Emergency services
ETSI TETRA	(Terrestrial trunked radio) standard
EU	European Union
GHz	Gigahertz. 1,000,000,000 (or 10^9) oscillations per second
GI	Geographic Interleaved spectrum. Spectrum that is unused in a particular area by transmitters in a multi-frequency network.
GNSS	Global navigation satellite systems
GPS	The Global Positioning System is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites
HD	High Definition - A television or other video service with at least 720 lines of vertical resolution. This higher resolution picture raster can provide enhanced quality and more detailed pictures, particularly on

	larger displays
HEVC	High Efficiency Video Coding - A video compression system which offers further efficiency improvements over MPEG-4.
IEMs	In–ear-Monitors are devices used by musicians, audio engineers and audiophiles to listen to music or to hear a custom crafted mix of vocals and stage instrumentation for live performance or recording studio mixing. They are often custom fitted for an individual's ears to provide comfort and a high level of noise reduction from ambient surroundings.
IoT	Refers to uniquely identifiable objects and their virtual representations in an Internet-like structure.
IPTV	Internet protocol television. The term used for television and/or video signals that are delivered to subscribers or viewers using internet protocol (IP), the technology that is also used to access the internet. Typically used in the context of streamed linear and on-demand content, but also sometimes for downloaded video clips
IRS	Integrated Reception System provides broadcast signals from multiple sources (typically terrestrial television, FM radio, DAB digital radio and satellite TV) to multiple outlets, via a single aerial cluster and signal booster-distributor.
ITU	International Telecommunications Union - Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland.
ITU-R	International Telecommunications Union Radiocommunication Sector
JRG	Joint Regulatory Group brings together the UK's economic and competition regulators, meeting four times a year at senior level to discuss issues of mutual interest, exchange experiences and good practice and report on recent developments in their own particular sector
LCN's	Logical Channel Number. The number assigned to an individual DTT channel on electronic programme guides (EPGs).
LTE	Long Term Evolution. Part of the development of 4G mobile systems that started with 2G and 3G networks. Aims to achieve an upgraded version of 3G services having up to 100 Mbps downlink speeds and 50 Mbps uplink speeds.
M2M	Machine to machine refers to technologies that allow both wireless and wired systems to communicate with other devices of the same type M2M is a broad term as it does not pinpoint specific wireless or wired networking
MBMS	Multimedia Broadcast Multicast Services refers a point to multi point interface specification in the 3GPP standards for efficient delivery of broadcast services e.g. TV, radio, data
MCL	Minimum coupling loss refers to the minimum distance loss including antenna gains between transmitter output and receiver input.
MCS	Minimal change scenario
MFN	Multi-frequency network -A network of transmitter sites in which each transmitter uses a different frequency from its neighbours.

MHz	Megahertz. A unit of frequency of one million cycles per second.
MNO	Mobile network operator
MPEG	Moving Picture Experts Group. A set of international standards for compression and transmission of digital audio-visual content. Most digital television services in the UK use MPEG2, but MPEG4 offers greater efficiency and is likely to be used for new services including TV over DSL and high-definition TV.
MTS	Managed transmission service
Multiplex	In digital TV broadcasting, a single signal which contains, when decoded, multiple discrete streams of digital information (including video and audio streams). Individual components of the multiplex are decoded at the receiver in order to present the desired TV service to the viewer.
mW	Milliwatt
NFL	National Football League
NPV	Net present value
OOB	Out of band activity outside of a defined telecommunications frequency band, or, metaphorically, outside some other kind of activity.
PMSE	Programme-making and special events. A class of radio application that support a wide range of activities in entertainment, broadcasting, news gathering and community events.
PPDR	Public Protection and Disaster Relief. Includes emergency services such as the fire brigade and police.
PSB	Public service broadcasting or public service broadcaster. The Communications Act in the UK defines the PSBs as including the BBC, ITV1 (including GMTV1), Channel 4, Five and S4C
PSSR	Public sector spectrum release
PVR	Personal video recorder (also known as digital video recorder' and 'digital television recorder). A digital TV set-top box including a hard disk drive which allows the user to record, pause and rewind live TV.
PVR STB	Personal video recorder set-top box connected to their television
QoS	Quality of service is the overall performance of a telephony or computer network, particularly the performance seen by the users of the network. To quantitatively measure quality of service
RF	Radio frequency
RSGP	Radio Spectrum Policy Group - High-level advisory group that assists the European Commission in the development of radio spectrum policy.
RSPP	The Radio Spectrum Policy Programme defines the roadmap for how Europe can translate political priorities into strategic policy objectives for radio spectrum use.
RTÉ	Raidió Teilifís Éireann. Ireland's national public-service media organisation.
SD	Standard Definition -The lower, and currently most common, of the picture resolutions used for television broadcasting. Standard definition TV services in the UK and Europe have a vertical resolution of 576

(interlaced) lines.

SDL	Supplemental down link
SFN	Single Frequency Network. A transmission network where all transmitters operate on the same frequency.
SLAs	Service level agreements
SQL	Spectrum quality indicator
SRD	Short range device is a general term, applied to various radio devices designed to operate usually on a license exempt basis, over short range and at low power levels. This includes devices such as alarms, telemetry and telecommand devices, radio microphones, radio local area networks and anti-theft devices with maximum powers of up to 500 mW at VHF/UHF, as well as certain microwave/Doppler devices with maximum powers of up to 10 W
STB	Set-top box is an information appliance device that generally contains a TV-tuner input and displays output connects to a television set and an external source of signal, turning the source signal into content in a form that can then be displayed on the television screen or other display device. They are used in cable television, satellite television, and over-the-air television systems, as well as other uses.
STL	Studio to transmitter link
STPR	Social time preference rate
TG4	A public service broadcaster for Irish-language speakers.
UE	User equipment
UHF	Ultra High Frequency. The part of the spectrum between 300 MHz and 1 GHz.
UKPM	United Kingdom Planning Model. A set of propagation and coverage prediction algorithms used by the JPP to plan UK DTT services.
WACC	Weighted average cost of capital
Wi-Fi	Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards. Such systems typically use one or more access points connected to wired Ethernet networks which communicate with wireless network adapters in end devices such as PCs. It was originally developed to allow wireless extension of private LANs but is now also used as a general public access technology via access points known as "hotspots".
WRC	World Radiocommunication Conference. The WRC reviews and revises the Radio Regulations, They are held every two to three years.
WSDs	White space devices, which make use of transmission frequencies that are nominally allocated to other services but which are unused in the vicinity of the device.