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Coexistence of new services in the 700 MHz band with digital terrestrial television

Consultation

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About this document

This consultation presents our technical analysis of coexistence issues between future mobile services in the 700 MHz band and digital terrestrial television (DTT) in the adjacent band.

In November 2014, Ofcom decided that the 700 MHz spectrum band – which currently houses digital terrestrial television (DTT) and wireless microphones used for programme making and special events (PMSE) – would be repurposed for mobile data services. At that time we also presented results of our initial work on coexistence issues.

We have now completed more detailed work to investigate the nature and scale of potential interference risks. We also discuss technical aspects of some potential solutions to mitigate the risks.

Contents

Section 1

Executive summary

1.1 The 700 MHz band is currently used by digital terrestrial television (DTT), programme making and special events (PMSE) and white space devices (WSDs). In 2014 we decided to make this band available for mobile broadband. Existing services in the band are being moved to new frequencies and the band is expected to be available for mobile broadband use by 2020.

1.2 We conducted some preliminary coexistence analysis in 2014 to assess the risk of interference between new mobile services in the 700 MHz band and services in adjacent bands. A particular focus of our analysis was the potential for mobile services from handsets and base stations to interfere with reception of DTT via a rooftop aerial in the 470-694 MHz band.

1.3 That initial analysis indicated that the vast majority of households would not experience any interference due to change of use of the 700 MHz band. However, we noted that we planned to undertake further work, including field trials, to more accurately identify the nature and scale of the potential interference problem. We have now completed this further work and present details of this work and our findings in this document.

1.4 We have prioritised field work and practical measurements over theoretical modelling. For the assessment of interference from handsets, we have undertaken an in-home measurement campaign to look at real mobile handset activity in the 800 MHz band. These measurements were then processed to reflect what the measurements would have looked like if they had been taken in the 700 MHz band.

1.5 For mobile base stations, we have reviewed evidence from the ongoing programme of work to help viewers who are affected by interference from mobile services in the 800 MHz band. We have supplemented this with practical measurements of DTT equipment in the presence of 700 and 800 MHz signals.

A small number of households may be affected by interference from mobile base stations in the 700 MHz band

1.6 Our projections based on data from the current 800 MHz mitigation scheme indicate that there will be between 25,000 and 36,000 confirmed interference cases by the end of 800 MHz network roll-out. This is less than 0.2% of DTT households in the UK. We expect that the number of 700 MHz interference cases will be broadly similar.

1.7 Our measurements show that there may be a small degradation with 800 and 700 MHz base stations together compared to 800 MHz base stations alone. However, other factors will tend to reduce the interference risk relative to 800 MHz; these include greater frequency separation between mobile base stations and DTT, and improvements in DTT receiver performance which are expected to take effect over the next few years. Overall we consider that the impact of interference from 700 MHz base stations will be no greater than the impact seen in the 800 MHz band.

Our measurements indicate a minimal risk of interference from mobile handsets

1.8 The data from our handset measurement campaign shows that the vast majority of households will not experience any interference from mobile handsets.

1.9 Households with television receivers that perform poorly[1] and that are in an area of relatively high handset activity might experience a single transient picture interruption on average around once every 100 hours of viewing standard definition TV. For high definition (HD), the equivalent figure would be just one interruption in 10,000 hours of viewing.

We expect that receiver filters will be the most technically effective means to mitigate interference from handsets and base stations

1.10 Receiver filters work by allowing wanted signals (DTT) to pass through while reducing unwanted interfering signals. They are the primary mitigation technique currently used for mitigating interference to DTT reception from mobile services in the 800 MHz band.

1.11 The filters used in the 800 MHz band are designed to stop signals between 791 and 862 MHz. Following the change of use of the 700 MHz band, new filters will be needed that block signals across both the 700 and 800 MHz bands (694-862 MHz).

[1] This refers to a receiver that has below-average performance in the presence of interference. In this document, references to poor, average or good performance of receivers are references to how they perform in the presence of interference.

Section 2

Introduction

2.1 In November 2014, we published a statement (the '2014 Statement')[2] setting out our decision to re-allocate some of the frequencies currently used for delivering digital terrestrial television (DTT) and make them available for mobile data use. We refer to these frequencies between 694 MHz and 790 MHz as the 700 MHz band[3].

2.2 New mobile services in the 700 MHz band will need to coexist with DTT and other services in the band directly below (the 470-694 MHz band). This means that services in both bands will need to operate in a way that does not cause undue interference to services in the adjacent band. The risks of interference between different services in the same or adjacent bands are referred to as coexistence risks.

2.3 We undertook some preliminary technical analysis of these risks in 2014 and reported on this in our 2014 Consultation[4] and Statement. At that time the technical conditions for use of the band and the frequency plan were not finalised. These conditions are now known and we have undertaken more detailed analysis.

2.4 We present the findings of our work and discuss technical solutions for mitigating interference in Sections 3 to 5 of this document. We are not at this stage presenting proposals for how any mitigation solutions should be delivered. We plan to work closely with Government to consider the policy options for mitigating coexistence risks and will engage with stakeholders on these issues at a later date.

2.5 We note that coexistence risks specific to the use of the centre gap[5] were discussed in a separate consultation and statement[6].

2.6 Coexistence between mobile use in the 700 MHz band and PMSE use below 694 MHz was covered in our 2014 Consultation[7]. Separately, a consultation considering PMSE use of the 9 MHz guard band at 694-703 MHz and related coexistence issues was published on 20 April 2017[8].

700 MHz band plan and technical licence conditions

2.7 On 28 April 2016, the European Commission adopted a decision[9] to harmonise the technical conditions of use and band plan for the 700 MHz band.

[2] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/46923/700-mhz-statement.pdf
[3] 694-703 MHz is the guard band between DTT and mobile services.
[4] https://www.ofcom.org.uk/__data/assets/pdf_file/0025/28492/consultation-future-use-700MHz-band.pdf
[5] The frequencies in the part of the 700 MHz band between 733 MHz and 758 MHz.
[6] https://www.ofcom.org.uk/__data/assets/pdf_file/0031/92659/Maximising-the-benefits-of-700-MHz-clearance-Statement.pdf
[7] see Annex 10 of the 2014 Consultation
[8] https://www.ofcom.org.uk/__data/assets/pdf_file/0016/100942/700-mhz-guard-band-pmse.pdf
[9] Commission Implementing Decision (EU) 2016/687 of 28 April 2016 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union.

2.8 The band plan and technical conditions for the 700 MHz band were developed by CEPT[10] in response to a mandate from the Commission. CEPT issued Reports 53[11] and 60[12] on 28 November 2014 and 1 March 2016 respectively. These reports provide the basis for technical harmonisation of the 700 MHz frequency band for wireless broadband services and other uses.

2.9 One of the objectives highlighted in these reports was 'to manage the risk of interference between mobile use in the 700 MHz band and the broadcasting service below 694 MHz'.

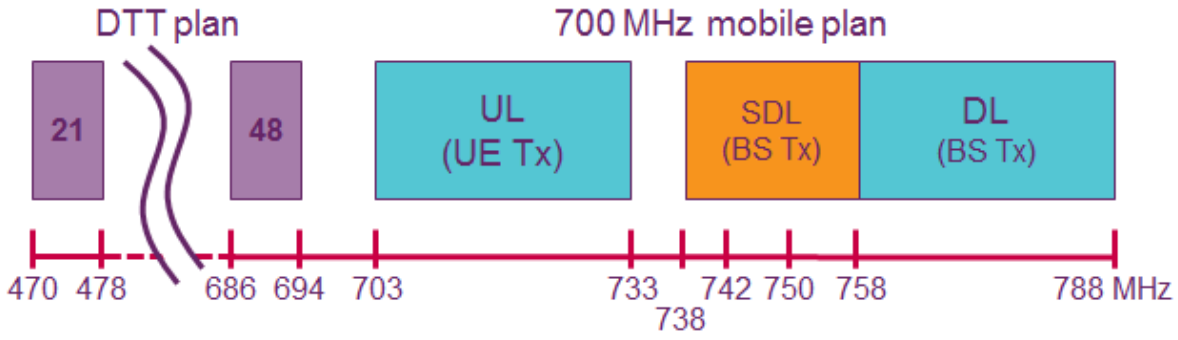
2.10 CEPT recognised that the technical conditions it proposed would not completely remove the coexistence risk and noted that the 'impact of [the remaining coexistence risks] should be determined on a case-by-case basis at national level'.

2.11 Developments in broadcast receiver standards are also expected to have a bearing on 700 MHz coexistence. Ofcom and other European regulators have worked with industry partners to set new performance objectives for DTT receiver manufacturers to make new receivers more resilient to interference from mobile services. This has been implemented in Europe in the Radio Equipment Directive (RED) 2014/EU/53[13]. The Radio Equipment Directive (RED) aims to ensure that radio equipment sold on the EU market is constructed so that it effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference. Radio equipment which conforms to harmonised standards which have been published in the Official Journal of the European Union are presumed to conform with the requirements of the RED.[14] The European Telecommunications Standards Institute (ETSI) has developed a harmonised standard which includes new performance requirements for broadcast receivers[15] We expect that new receivers sold in the UK will seek to meet performance targets which are equivalent to those specified in this standard. We discuss the impacts of this further in Section 3.

2.12 A simplified representation of the UK's 700 MHz band plan is shown in the figure below.

[10] insert definition
[11] Link to CEPT Report 53: http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP053.PDF
[12] Link to CEPT Report 60:http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP060.PDF
[13] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.
[14] Conformity of radio equipment with the RED may be achieved in other ways, as set out in the Directive.
[15] ETSI EN 303 340, *Digital Terrestrial TV Broadcast Receivers; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU, V1.1.2, 2016-09.* http://www.etsi.org/deliver/etsi_en/303300_303399/303340/01.01.02_60/en_303340v010102p.pdf. A reference to this has been published in the Official Journal. For more information, see https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/rtte_en.

Figure 2.1: 700 MHz band plan



Learning from the 800 MHz band coexistence experience

2.13 The coexistence issues in the 700 MHz band are similar in many respects to the issues dealt with for the 800 MHz band. The use of the 800 MHz band was also changed from DTT to mobile use and the cleared spectrum was the subject of an auction which took place in early 2013. All four mobile network operators (MNOs) in the UK won spectrum in the auction.

2.14 The 800 MHz licence conditions required the MNOs to work together to set up a single body to provide support to consumers affected by interference from new 4G services to DTT reception. This resulted in the creation of a new company, Digital Mobile Spectrum Limited (DMSL), which operates with the brand name at800[16]. DMSL communicates proactively with potentially affected households and provides advice and practical support as required in line with the consumer support policy agreed with the Government.

2.15 The 800 MHz coexistence scenario has provided us with valuable experience and insights which we can apply in our work on 700 MHz coexistence. In addition, DMSL has kept detailed records of its mitigation activities for the 800 MHz band and we have used this data to benchmark our estimates of the likely scale of interference in the 700 MHz band.

2.16 While there are many similarities between the 700 and 800 MHz coexistence scenarios, one key difference is that the mobile band plan for 700 MHz is reversed in relation to the 800 MHz plan. In 800 MHz, the downlink frequencies are adjacent to DTT whereas for 700 MHz, the uplink frequencies will be adjacent to DTT. We discuss the impact of this difference in section 3.

Legal context and analytical framework

Ofcom's specific duties and powers related to spectrum management

2.17 Ofcom's responsibilities for spectrum management are set out primarily in two Acts of Parliament which confer on Ofcom specific duties and powers in respect of spectrum (and the other sectors we regulate): the Communications Act 2003 (the '2003 Act') and the Wireless Telegraphy Act 2006 (the 'WT Act').

[16] at800.tv

2.18 Our principal duties under the 2003 Act are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum.

2.19 In carrying out our spectrum functions, we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use or further use for wireless telegraphy, (ii) the demand for use of that spectrum for wireless telegraphy and (iii) the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy. We also have a duty to have regard, in particular, to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy, (ii) the economic and other benefits that may arise from the use of wireless telegraphy, (iii) the development of innovative services and (iv) competition in the provision of electronic communications services.

2.20 The technical work which we present in this document has been undertaken with the purpose of fulfilling these duties. In particular, the assessment and, where appropriate, subsequent management of coexistence risks is an important and necessary step in ensuring that spectrum is used efficiently and that the economic and other benefits that arise from the use of the spectrum are realised.

Impact Assessment

2.21 Section 7 of the 2003 Act provides that where we are proposing to do anything for the purposes of or in connection with the carrying out of our functions, and it appears to us that the proposal is important, then we are required to carry out and publish an assessment of the likely impact of implementing the proposal, or a statement setting out our reasons for thinking that it is unnecessary to carry out such an assessment. Where we publish such an assessment, stakeholders must have an opportunity to make representations to us about the proposal to which the assessment relates.

2.22 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. 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.

2.23 We undertook an impact assessment as part of our analysis for the 2014 Consultation[17] and 2014 Statement on the change of use of the 700 MHz band, including a preliminary assessment of coexistence risks.

2.24 The technical work in this document will form an input to decisions on any actions which may be required to mitigate the identified coexistence risks, and an impact assessment, where relevant, will form part of this further work.

Equality Impact Assessment

2.25 Ofcom is required by statute to assess the potential impact of all its functions, policies, projects and practices on the following equality groups: age, disability, gender, gender reassignment, pregnancy and maternity, race, religion or belief and sexual orientation. Equality Impact Assessments (EIAs) also assist us in making sure

[17] https://www.ofcom.org.uk/__data/assets/pdf_file/0026/84176/maximising-benefits-of-700mhz-clearance.pdf

that we are meeting our principal duty of furthering the interests of citizens and consumers regardless of their background or identity.

2.26 We conducted an equality impact assessment as part of our analysis for the 2014 Consultation on the change of use of the 700 MHz band[18].

2.27 The analysis presented in this document has not identified any additional equality impacts to those identified in the 2014 assessment. Susceptibility of different households to interference depends on technical and environmental factors rather than equality groups. The choice of approach to mitigation may however potentially have differential impacts on some equality groups, and this will be considered as part of further work looking at options for mitigating interference.

[18] See paragraphs 3.15 to 3.18 of the 2014 Consultation and 3.15 to 3.18 of the 2014 Statement

Section 3

Assessment of coexistence risks from handsets and base stations in the 700 MHz band

Introduction

3.1 In 2014 we undertook an initial assessment of the risk of new mobile services in the 700 MHz band interfering with reception of DTT via a rooftop aerial.

3.2 Our provisional conclusion was that the vast majority of households would not experience any interference due to change of use of the 700 MHz band. In relation to handsets, we said that the number of households that experience noticeable interference from handsets is likely to be low. For base stations, we provisionally concluded that interference would be no greater than the interference caused by base stations in the 800 MHz band. In both cases, we said that the vast majority of problems could be solved by installing a DTT receiver filter.

3.3 We noted however that we planned to do further work to establish the potential scale and nature of coexistence issues more accurately and definitively.

3.4 We have now completed this work. Our further work supports our initial conclusion that the vast majority of households would not experience any interference due to change of use of the 700 MHz band.

3.5 In the remainder of this section we present more detail on our updated assessment of coexistence risks in the 700 MHz band. The section is structured as follows:

- Our approach to assessing coexistence risks;
- Our updated assessment of risks from handsets;
- Our updated assessment of risks from base stations;

3.6 We address other coexistence risks in Section 4, including interference from DTT to mobile.

Our approach to assessing coexistence risks

3.7 Modelling of coexistence issues in the 800 MHz band predicted that a large number of DTT households would experience a degradation in the reliability of the DTT service due to interference from mobile services. In practice a much smaller number of households have reported interference. In this document we present data on the number of reported interference cases and other key metrics from DMSL, the

organisation responsible for providing support to viewers affected by interference from mobile services in the 800 MHz band[19].

3.8 Ofcom has worked closely with stakeholders to understand the reasons for the difference between the modelling predictions and the actual reported interference. One of the key inputs to the modelling for 800 MHz was the output of the UK Planning Model (UKPM) which is used to plan DTT coverage in the UK. A joint technical review of the model was carried out by Ofcom, the BBC and Arqiva in 2015[20]. The review confirmed that the current planning assumptions used in the UKPM remain appropriate for predicting DTT coverage. However it also recommended that, when predicting the effects of DTT transmission changes and interference from other services on DTT reception, the variation in real world aerial installation gain throughout the DTT coverage area should be taken into account. DMSL has made changes to its modelling assumptions to take account of this recommendation.

3.9 In our 700 MHz technical work, we have prioritised practical data over theoretical modelling where possible. We have undertaken field work to collect realistic data on handset interference and carried out a programme of measurements to investigate the combined impact of 700 and 800 MHz base stations on DTT reception via a rooftop aerial.

3.10 We have used a number of information sources to ensure the robustness of our work, including our own measurements, information gathered by DMSL as they resolve coexistence issues in the 800 MHz band, and experience from other countries where mobile networks are being deployed in 700 MHz.

Our updated assessment of risks from handsets in the 700 MHz band

3.11 For handsets, we have undertaken a measurement campaign of LTE emissions at a small sample of domestic TV installations with rooftop aerials, using 800 MHz as a proxy for 700 MHz.

3.12 The measurement campaign involved sending signal recording equipment (loggers) to 32 volunteer households around the UK. The loggers recorded the signal strengths of the DTT and 800 MHz uplink band over a period of two weeks or more at each household.

3.13 The 800 MHz measurements were then processed to reflect what the measurements would have looked like if they had been taken in the 700 MHz band. The specific deployment characteristics in the 700 MHz band are not yet known, and the 800 MHz networks are themselves not yet mature. However we consider that it is reasonable to assume that the network topology and density in the 700 MHz band will be broadly similar to the 800 MHz band. Moreover we have extrapolated the measurement results to simulate the likely interference impacts of mature networks in the 700 MHz band.

[19] Digital Mobile Spectrum Limited (DMSL), operating with the brand name at800, is the company set up by the four mobile network operators, EE, Telefónica UK (O2), Three and Vodafone, to fulfill the responsibilities conferred on them in their 800 MHz WT Act licences.
[20] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/75032/ukpm_review_report.pdf

3.14 Some TVs or receiving equipment are better than others at rejecting interference effects. Most households will not experience picture interruptions from handset signals. Our measurements show that, if 700 MHz networks were deployed and fully loaded with traffic today, a household with a poor performing TV in an area of relatively high handset activity[21] might experience a single transient picture interruption on average around once every 10 hours of viewing standard definition (SD) TV. For high definition (HD), the equivalent figure would be just one interruption in 100 hours of viewing.

3.15 Developments in broadcast receiver standards should result in better resilience to interference from mobile services, including from handsets[22]. This should mean that, as UK households replace their old TVs with new ones, the overall potential for interference will reduce.

3.16 By 2020 when the 700 MHz band becomes available for mobile use, we expect the figures to have improved to one transient interruption in 100 hours for SD and one in 10,000 hours for HD. By 2025 we expect the figures to have further improved to one in 1,000 hours for SD and for there to be practically no interruptions to HD viewing.

3.17 Notwithstanding the fact that the majority of households will not experience any material interference from 700 MHz handsets, a combination of circumstances may make a minority subject to some interference. These circumstances could include, for example, a poor TV receiver, a poor quality aerial installation with high system gain, an antenna system pointing towards an area with high mobile use, and a weak DTT signal.

3.18 For this minority the interference will occur intermittently when mobile phone subscribers located in a small local area are transmitting. In most cases this interference could be mitigated by the use of a receiver filter - we discuss technical mitigation solutions in section 5.

3.19 Full details of the measurement procedures and results are presented in a technical report published in parallel with this document[23].

Our updated assessment of risks from base stations in the 700 MHz band

3.20 Base stations in the 700 MHz band are expected to be broadly similar to 800 MHz base stations in terms of cell size and density, emission characteristics and traffic profiles. Therefore, the current experience of coexistence at 800 MHz provides very relevant data for our assessment of the potential impact of 700 MHz base stations.

3.21 To inform our assessment of the scale of the interference risks from base stations, we have reviewed information gathered by DMSL on the number of confirmed interference cases in the 800 MHz band and used this data to estimate the likely number of interference cases by the end of 800 MHz rollout. This data provides a useful reference point for estimating the likely number of interference cases which may be expected in the 700 MHz band.

[21] in the upper quartile of the range of activity levels recorded in our handset measurement campaign, extrapolated to reflect a scenario with four mature 700 MHz networks
[22] See paragraphs 2.11 and 2.12.
[23] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/101655/700-MHz-Coexistence-Study-of-mobile-uplink-interference-effects-upon-DTT-reception.pdf

3.22 We have also investigated differences between the 700 MHz and 800 MHz scenarios which may cause the coexistence risk to be different between the bands. One of these differences tends to increase the coexistence risk while other differences tend to decrease the risk.

3.23 The key differences are highlighted in Table 3.1.

Table 3.1: Differences between 700 MHz and 800 MHz coexistence risks

Differences which may ***increase*** the coexistence risk relative to 800 MHz	Differences which may ***decrease*** the coexistence risk relative to 800 MHz
• Aggregate impact from new 700 MHz base stations, in addition to existing 800 MHz base stations as a consequence of the combined received interfering power	• Greater frequency separation between base station transmissions and DTT receivers • Improved specifications for DTT receivers

3.24 On balance, our provisional judgment is that these differences will broadly cancel each other out and the overall risk from 700 MHz base stations will not be greater than the risk from 800 MHz base stations.

3.25 This is supported by initial evidence from France where 700 MHz network rollout has already started and where, to date, a lower number of interference cases have been reported compared to 800 MHz in the same area. We will continue to monitor the situation in France over the coming months.

3.26 Taking all of this evidence together, we expect that the number of interference cases in the 700 MHz band will be similar to the number of cases in the 800 MHz band for a similar sized network rollout. Looking specifically at confirmed 800 MHz interference cases, our projections based on the 800 MHz data indicate that there will be no more than 36,000 confirmed interference cases arising from mobile services in the 700 MHz band.

3.27 In the remainder of this subsection we:

- Present an overview of the data gathered from DMSL and present our projections for the number of interference cases and other relevant metrics by the end of 800 MHz network rollout;
- Consider each of the key differential factors between 700 MHz and 800 MHz listed in table 3.1 and present the results of additional work we have done to investigate these differences;
- Review evidence from other countries where 700 MHz networks are already being deployed.

Analysis of DMSL data

3.28 The mitigation scheme currently operated by DMSL communicates proactively with households in proximity to new 4G base stations (masts) in the 800 MHz band shortly before the masts are activated. If a household experiences interference, the DTT viewer can call the DMSL helpline for assistance.

3.29 The DMSL call centre conducts a diagnostic triage process to identify the likely cause of interference. Where 4G interference is suspected, DMSL will take various actions depending on the type of household affected:

- For DTT-only households[24] receiving Freeview through a rooftop or loft aerial, DMSL will arrange for a trained aerial installer to visit the household. The installer will diagnose the cause of the reception issue and provide practical assistance to rectify the problem. This will usually involve fitting a 4G 800 MHz filter. Where necessary the installer may also take steps to improve the viewer's system, e.g. by replacing fly leads;

- For households in blocks of flats with a shared aerial system, communal-type filters are sent to the landlord and the landlord is responsible for arranging filter installation;

- For other households, e.g. those whose main TV is satellite or cable, consumer-type filters may be sent in the post for the household to self-install.

3.30 DMSL's data shows that by the end of January 2017, 54,796 installer visits had been carried out for 49,612 households, and 19,103 households were confirmed as experiencing 4G interference. Based on this data, up to 61% of households visited were experiencing reception issues unrelated to 4G.

3.31 DMSL additionally sent 5,226 communal-type filters to landlords and 68,419 consumer-type filters for self-install by viewers[25]. Since no installer visit is made in these instances, it is not known how many of these households were actually experiencing 4G interference.

3.32 The trend of interference cases is diminishing over time. This may in part be due to the densification of the mobile networks, i.e. additional base stations being activated in areas where other 800 MHz base stations are already transmitting. In these areas, some households will have already received filters and are unlikely to be affected by the new base stations.

3.33 DMSL estimate that the rollout of 800 MHz networks is about two-thirds complete. We have looked at the average number of interference cases per mast and extrapolated this data to estimate the likely number of 4G interference cases and other metrics by the end of 800 MHz rollout.

3.34 We present the estimates for the key metrics in the table below.

Table 3.2: Projected 800 MHz statistics at the end of rollout

Metric	Projected statistics*
Confirmed 4G interference cases	25,000-36,000
Installer visits	76,000-101,000

[24] Households which receive television via DTT only and who do not receive satellite and/or cable TV services.
[25] In the first few months of operation, DMSL sent large numbers of filters proactively to all households predicted to be potentially affected by interference. These figures are not included in the data presented here.

Consumer-type filters sent[26]	86,000-154,000
Communal-type filters sent	5,226-10,000

*These figures represent a linear extrapolation of the inter-decile range estimated from the 3 month average figures from July 2013 to January 2017.

Other general observations regarding the 800 MHz experience

3.35 ***It is not possible to predict which households will be affected in advance***
DMSL uses computer modelling to determine which households are at risk of interference. However there is very large variability in the quality and performance of individual receive installations which cannot be known in advance. In practice, many households predicted to be at risk, including households predicted to be at a high risk, do not report any issues with interference. Other households predicted to be at low risk, and some not predicted to be at risk at all, may experience interference. Also, a household suffering interference often may be immediately adjacent to other households experiencing an uninterrupted television service.

3.36 ***Amplifiers are a key factor in many interference cases but not in all***
Amplifiers are reported as being in use in approximately 65% of confirmed interference cases.

3.37 ***Interference is more likely in areas with high LTE signal strengths and low DTT signal strengths***
While it is difficult to model which households are most at risk of interference, it is still true that more interference cases occur in areas which receive weak DTT signals and where households are close to mobile base stations. Weak DTT signals can lead to the television operating close to its limit (the digital cliff) and being vulnerable to interference.

Key differential factors between 700 and 800 MHz

The combined effects of 700 and 800 MHz base stations

3.38 The addition of new base stations in the 700 MHz band alongside existing base stations in the 800 MHz band will have an aggregate interfering effect compared to 800 MHz base stations alone. This effect is likely to be most pronounced where 700 and 800 MHz base stations are co-located.

3.39 The interference may occur for two reasons: a simple power increase in the unwanted interfering signal power at the DTT receiver, and additional intermodulation products falling within the television band potentially causing the receive equipment to become ‘blocked’.

3.40 To investigate the scale and impact of this interference, we created a representative interference environment in the laboratory for the following installation types:

- a single dwelling without an amplifier;
- a single dwelling with a domestic amplifier (distribution);

[26] These figures do not include the proactive filters sent by DMSL during its first few months of operation.

- a single dwelling with a preamplifier (masthead);

- a multiple dwelling unit with a launch amplifier (a type of distribution amplifier often used in blocks of flats).

3.41 For each representative installation, we tested a good, average and poor performing receiver. These receivers were on sale in the UK market from about 2010 to 2014 and included popular integrated TVs and set-top boxes. For the amplifiers, we selected good and poor performing samples of unfiltered models from those available on the UK market at the time of testing and also some older models from the market before digital switchover.

3.42 We provide full details of the testing procedures and results in Annex 4.

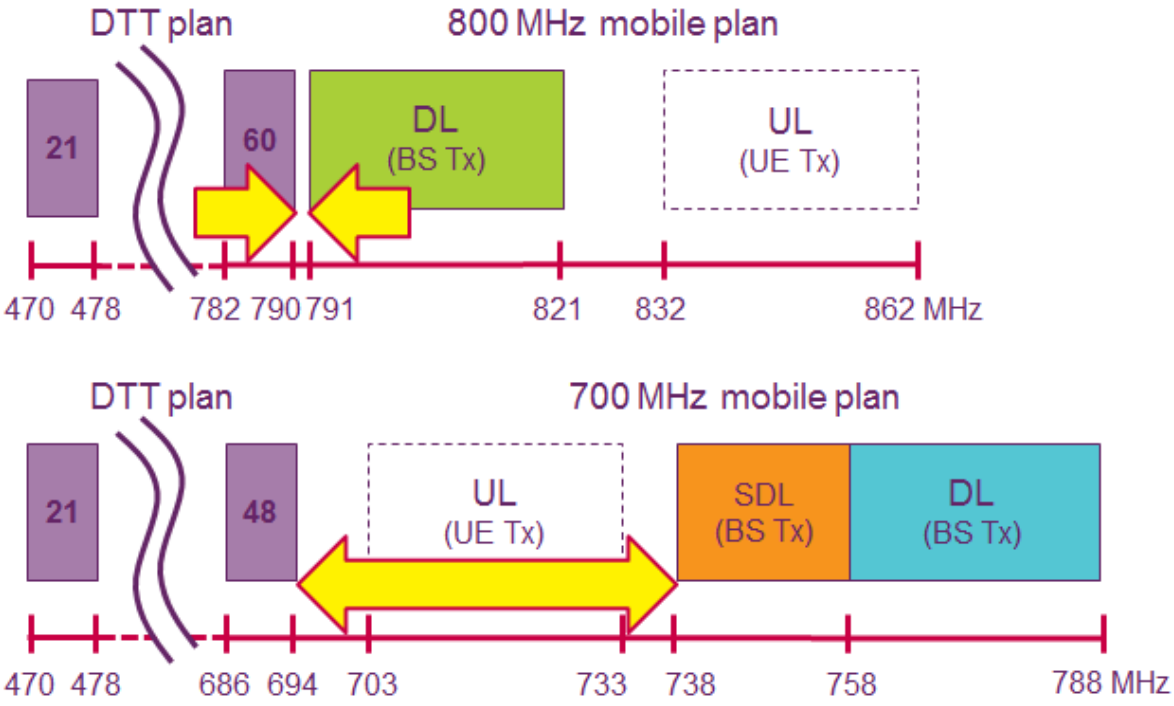
3.43 The results show that in all cases, there would be a small (1–3 dB) degradation with combined 800 and 700 MHz interference compared to 800 MHz interference alone, which is commensurate with expectations. The impact of the degradation could cause some viewers with a low signal to lose reception, whereas those with a good signal may suffer no impact. We noted a small effect between the performance on channel 23 and channel 48 with the upper channel being marginally more susceptible by up to 2 dB.

3.44 If all other conditions were the same as for 800 MHz, this would tend to result in a small increase in the potential for interference to DTT receivers compared to 800 MHz. However, as noted, other factors may tend to reduce the interference risk; we discuss these further below.

Frequency separation

3.45 In the 800 MHz band plan, the base station transmit frequencies (downlink or DL) are adjacent to the highest DTT channel 60, with a small 1 MHz guard band. This contrasts to the 700 MHz band plan where the downlink block is at the top of the band and is separated by 64 MHz from the highest DTT channel. Mobile downlink in the centre gap (one implementation being supplementary downlink (SDL)) is separated from DTT by 44 MHz.

Figure 3.1: Frequency separation in the present 800 MHz and future 700 MHz plan



3.46 The proximity of the base station downlink block to DTT in the current band plan means that the top DTT channels (channel 60 in particular) are somewhat more susceptible to interference than channels lower down the band, both in relation to adjacent channel leakage and receiver selectivity. In the 700 MHz band plan, the greater frequency separation between the downlink and DTT means that this effect no longer occurs and the new top DTT channel 48 will be less susceptible to this type of interference relative to channel 60 in the current plan.

3.47 With regard to adjacent channel leakage, the increased frequency separation in the new band plan makes it possible to consider lower out of block levels than in the 800 MHz case, thereby reducing unwanted emissions into the DTT band. CEPT report 53[27] specifies that base stations in the 700 MHz band must not generate more than -23 dBm/8 MHz into DTT channels below 694 MHz. This is a tougher restriction than for 800 MHz where the limit for high power base stations was 0 dBm/8 MHz into DTT.

3.48 With regard to receiver selectivity, the greater frequency separation means that DTT receivers should be better able to reject base station signals compared to the 800 MHz case.

3.49 In the current band plan, reception of the top DTT channels closest to the 800 MHz downlink spectrum, particularly channel 60, is more challenging and better rejection performance is needed compared to lower channels. This is consistent with our analysis of data from DMSL. While only 11% of households in the UK receive DTT services on channel 60, these households make up 18% of confirmed interference cases to the end of January 2017.

[27] http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP053.PDF

3.50 In the future band plan the greater frequency separation means that the rejection requirements will be broadly similar across the DTT band, and in all cases less challenging than for channel 60 in the current plan.

New performance targets for TV receivers

3.51 As set out in Section 2 above[28], new receivers are expected to be more resilient to interference from mobile services. The new targets agreed in Europe specify carrier-to-interference (C/I) levels which are 5-6 dB stricter than the previous non-mandatory industry specifications[29]. This improvement should benefit both 700 and 800 MHz cases as the worst performing receivers are replaced. Furthermore, where the receivers are not overloaded, the specification should ensure that receivers just meeting the specification perform 7-8 dB better in the DTT channel (48) adjacent to the 700 MHz band compared to the DTT channel (60) adjacent to the 800 MHz band[30].

3.52 The benefit of the new targets should already be starting to have an impact now as TVs from some manufacturers already meet them, and designs of other TVs are being altered to meet them.

3.53 Replacement cycles for primary TV sets are in the region of about 7-8 years[31], although industry initiatives can shorten this. This means that, whilst there is an immediate benefit which will increase year on year, the full benefits of improved receiver performance may not be fully realised until 2025, by which time we would expect almost all TVs in use to meet the new performance targets (or to perform in an equivalent way).

Comparable experience from other countries tends to support our view that interference from 700 MHz base stations is unlikely to be higher than for 800 MHz

3.54 We have been monitoring the international coexistence experience in countries where 700 MHz deployment has already started, particularly in countries where there is high DTT penetration.

3.55 In Australia, there is a mature deployment of 700 MHz in the same spectrum as the CEPT frequency plan. Other than the band edge licence condition there is no specific mitigation scheme in Australia to deal with 4G related interference and therefore no formal records on the numbers of 4G-related interference cases are available[32]. The regulator, the ACMA, has informed us that in general, digital TV reception has not been significantly affected by the rollout of 4G mobile broadband services. There have been some cases of TV masthead or distribution amplifiers being overloaded by 4G signals within close proximity (within 1 km) of a mobile base station, but they do

[28] See paragraphs 2.11 and 2.12
[29] http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP311.pdf
[30] The minimum performance required for interference from base stations between DVB-T and DVB-T2 is broadly the same (unlike the difference between performance regarding handset interference).
[31] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/40569/mediatique.pdf
[32] http://www.acma.gov.au/Citizen/TV-Radio/Television/TV-reception/whats-the-link-between-mobile-broadband-and-tv-reception

not report high numbers. No band edge interference to TV reception from mobile handset out-of-band emissions has been recorded[33].

3.56 In France, deployment of 700 MHz networks is still in the early stages, with roll-out on a regional basis as DTT is cleared from the band. At the last time of checking in April, around 600 base stations have been activated in the Paris region[34]. To date, a lower number of cases have been reported relative to the 800 MHz band and they do not report any issues with handsets. However, it is still too early to draw definitive conclusions and we will continue to engage with our counterparts in France to monitor the ongoing experience as 700 MHz deployments continue.

Question 1: Do you have any comments on our conclusions that a) the risk of interference from mobile handsets to DTT will be minimal and b) the risk of interference from mobile base stations in 700 MHz to DTT will be broadly similar to the risk for 800 MHz, with some tens of thousands of households potentially affected?

[33] In Australia, the upper DTT channels are mostly not used in dense population areas. This is largely to due to concerns about interference from handsets: the out of block emission limits in this region are more relaxed than the limits agreed in Europe.
[34] https://data.anfr.fr/explore/dataset/observatoire_2g_3g_4g/

Section 4

Other potential coexistence risks

4.1 In addition to the coexistence risk from mobile base stations and handsets to rooftop DTT reception, we have performed a broad review of other ways that interference could occur. In this section we cover the main areas identified:

1) Use of set-top aerials for reception;

2) Ingress of interference direct to DTT receivers and cabling;

3) Impact of DTT on mobile services;

4) Impact of mobile handsets on cable TV set-top boxes and modems.

Use of set-top aerials for reception

4.2 The DTT network is planned for reception using rooftop aerials, not indoor aerials, and this is reflected in our spectrum management decisions in general. In some areas, it may be possible to receive a signal using an indoor aerial, with varying reliability, but this is not a policy objective. The recommendation from the TV industry and Ofcom is to use a rooftop aerial for good reception[35].

4.3 Set-top aerials will also be more susceptible than rooftop aerials to interference from handsets operating in the 700 MHz band. To assess the risk of interference we obtained a variety of set-top aerials available from high street and online retailers, and tested them in a simulated typical domestic arrangement, with a 700 MHz mobile handset operating in the same room as the aerial.

4.4 Our tests indicated that the best performing set-top aerials in the presence of 700 MHz handset emissions are likely to be types with directional gain. Interference to these aerials can be simply mitigated by moving the handset away from the direction of maximum antenna gain.

4.5 Our tests also indicated that some aerials with built-in amplifiers may require quite significant separation from the mobile handset, which in the example tested was at least 4 metres away. We note that there is a new harmonised standard which sets out performance targets for amplified set-top aerials[36], and this should improve the situation. However these aerials will still be more susceptible to interference from handsets than rooftop aerials.

4.6 Ofcom's position continues to be that rooftop aerials are the recommended means to enjoy reliable DTT reception; viewers who rely on portable or set-top aerials will be more likely to experience reception problems and interference when watching television.

[35] https://www.freeview.co.uk/support/before-you-buy/reception-aerials-and-coverage/can-i-watch-freeview-using-a-portable-set-top-or-loft-aerial.html

[36] http://www.etsi.org/deliver/etsi_en/303300_303399/303354/01.00.02_20/en_303354v010002a.pdf. This standard has been published by ETSI and is awaiting citation in the Official Journal of the European Union in order to be harmonised. Set-top aerials which conform to a harmonised standard published in the Official Journal will be presumed to conform with the RED.

Ingress of interference direct to DTT receivers and cabling

4.7 In the ongoing 800 MHz interference mitigation programme, it has been observed that, in a small number of cases, interference has been caused by direct signal ingress from base stations to TV receivers and cabling systems with components including wall-plates, fly-leads and aerial splitters. It is not clear if the interference issues were due to the excessive attenuation of the DTT signal, or the ingress of the mobile signal due to poor screening, either of which may arise from poor quality devices.

4.8 Whilst the risk of interference from base stations is probably comparable between 700 and 800 MHz mobile sevices, the advent of 700 MHz brings a higher risk of interference from the mobile handset due to the reversed frequency arrangement.

4.9 To explore the issues, we performed some basic functional testing looking for picture break up when using a 700 MHz mobile handset generating local interference into an installation with a weak television signal in channel 48.

4.10 We tested a range of televisions and components including variants with inferior interference immunity specifications. The results indicated no issues with television receivers and most of the components under test. However, in some cases separations of less than about 50 cm between handset and cabling systems caused an issue.

4.11 We conclude that post-700 MHz clearance; no significant issues are likely to be observed that cannot be mitigated by simple physical separation or replacement of low specification components.

Impact of DTT on mobile services

4.12 New mobile services in the 700 MHz band have the potential to suffer degradation from DTT implemented below 694 MHz, especially in regions where the DTT emissions are in channel 48 and where equipment only just meets harmonised specifications (or performs in an equivalent way).

4.13 The main risks are to the base station receiver. These risks have been identified in various CEPT publications, notably in Report 53[37]. This report identified that additional isolation of up to 40 dB could be required beyond the performance specified in 3GPP TS 36.104[38] to mitigate the effects of strong DTT signals.

4.14 DTT transmissions will be filtered using systems complying with the non-critical mask[39] which provides sufficient protection in most cases. In practice, this means that the out of band performance will be the same as that experienced from the current DTT network. However, there may be isolated cases, such as where the mobile base station antenna is physically close to the DTT transmitter system, where mitigating action may need to be applied at the base station on a site-by-site basis.

4.15 Real equipment often out-performs the standard limits by a substantial margin, so we cannot at this stage be certain of the overall impact, but it is likely to be low and highly localised.

[37] http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP053.PDF
[38] http://www.etsi.org/deliver/etsi_ts/136100_136199/136104/13.06.00_60/ts_136104v130600p.pdf
[39] http://www.etsi.org/deliver/etsi_en/302200_302299/302296/02.00.02_20/en_302296v020002a.pdf

4.16 We intend to provide further information after the completion of the revised DTT frequency plan, which will allow potential mobile operators to analyse the specific conditions regarding base station equipment operating at locations close to DTT infrastructure and identify mitigating actions required.

4.17 With mitigation actions by the mobile operators at the time of deployment the consumer should suffer no degradation.

Impact of mobile handsets on cable TV set-top boxes and modems

4.18 Cable set-top boxes and modems can potentially suffer interference due to ingress when a 700 MHz mobile handset is operating nearby. In the event of any such issues, mitigation can be effected by moving the mobile handset a short distance away from the cable system equipment.

4.19 In our 2014 Statement we said that we expected the risk of interference to cable TV to be low. This conclusion was based on a series of practical tests commissioned for the 800 MHz award which looked at the main risk of interference when the mobile uplink was operating in the same channel as that in use by cable TV[40].

4.20 Since the publication of our 2014 Statement, an improved interference immunity specification has been published[41]. We expect this specification to be adopted in the UK during 2017 and it is likely that some manufacturers will develop new cable set-top boxes and modems to meet this standard, once it has been harmonised, in order to conform with the essential requirements of the Electromagnetic Compatibility Directive (2014/30/EU).[42]

4.21 Further robustness should also arise from the use of the new EuroDOCSIS 3.1 cable TV specification, which allows for wider channels to achieve faster broadband and should facilitate use in the same spectrum as mobile services. We understand that this technology will come into commercial operation over the next few years.

4.22 We are not aware of any issues that have been raised in relation to interference from handsets in 800 MHz to cable TV in the UK. Our conclusion is that interference to cable TV from 700 MHz will not be substantially different to the current situation with 800 MHz, and changes in technology and standards will further mitigate any risk.

Question 2: Do you have any comments on our analysis of coexistence risks related to set-top aerials, direct signal ingress to receivers, impact of DTT on mobile services and interference to cable TV?

[40] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/101357/2010-0792_LTE_into_CATV.pdf
[41] https://webstore.iec.ch/publication/25667
[42] Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast). As with the RED, references to standards must be published in the Official Journal of the European Union in order for them to be harmonised and provide for a presumption of conformity with the Directive.

Section 5

Technical solutions for mitigating coexistence risks

5.1 There are a number of mitigation techniques which may be used to mitigate the coexistence risks from 700 MHz base stations and handsets to DTT reception. In this section we present our initial views on the most technically effective solutions to mitigate these risks.

5.2 This consultation does not present proposals for the approach to delivering mitigation and managing consumer impacts. We intend to work closely with Government over the coming months to consider the policy options for managing the coexistence risks outlined in this document.

We expect that receiver filters will continue to be the most technically effective way to mitigate interference for the 700 MHz band

5.3 The mitigation scheme for the 800 MHz band has focused on the provision and installation of DTT receiver filters. The filters used for the 800 MHz band are passive devices which work by blocking unwanted signals in the 800 MHz band while passing wanted signals in the DTT band. They are plugged into the aerial lead between the aerial and the TV. In cases where amplifiers are used to boost DTT signals, the filters are fitted between the aerial and the amplifier.

5.4 The filters, which were specified by DMSL, have proved effective in resolving the majority of interference cases. We expect that the same approach would be effective for the 700 MHz band.

5.5 The filtering requirements for 800 MHz were much more challenging than for 700 MHz. For 800 MHz, there is only 1 MHz separation between the lowest mobile block and channel 60, requiring very sharp filtering at the edge of channel 60 in order to sufficiently attenuate mobile signals in the lowest 800 MHz block. This filtering could not be achieved with standard lumped element filters and required more expensive filter technology.

5.6 To manage this, DMSL uses two varieties of filter: channel 60 and channel 59 filters[43]. Channel 60 filters are used for areas where reception of DTT channel 60 is required, and channel 59 filters are used everywhere else. Channel 59 filters have a larger frequency separation of 9 MHz and this meant that cheaper filter technology could be used for these filters.

5.7 Both of these varieties come in either consumer or communal versions. Consumer-type filters are small filters used for the majority of households. Communal-type filters are larger, professional filters which can be used where greater attenuation is required.

5.8 For 700 MHz, there is a 9 MHz guard band between the top edge of the top DTT channel (48) at 694 MHz and the bottom edge of the lowest mobile block at 703 MHz.

43 https://at800.tv/industry-trade/approved-filters/

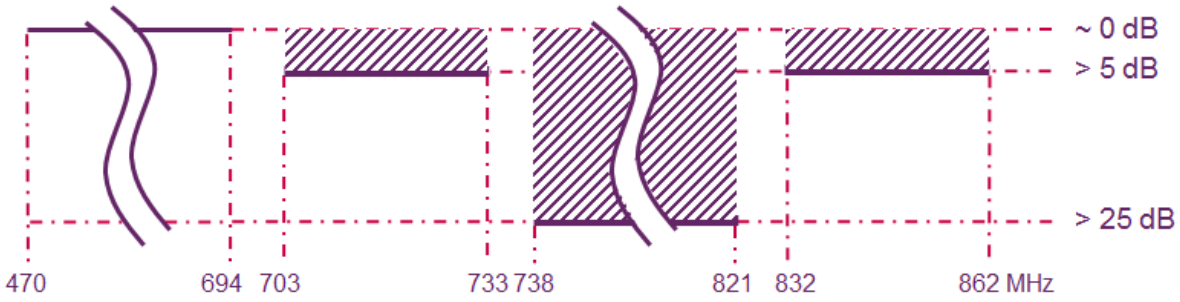
5.9 For the uplink part of the 700 MHz band between 703 and 733 MHz, we believe that filtering which provides attenuation of >5dB would be sufficient to mitigate any interference from handsets.

5.10 For the downlink part of the band between 758 and 788 MHz, we believe that filtering which provides attenuation of >25dB would be sufficient to mitigate any interference from base stations.

5.11 It is desirable to have a filter specification that provides attenuation across the entirety of the 700 and 800 MHz bands. This could be achieved by cascading band-specific filters but this would worsen insertion loss and would overcomplicate the practical design for consumers.

5.12 The diagram below shows the minimum attenuation requirements we would propose across the 700 and 800 MHz bands.

Figure 5.1: Attenuation requirements for 700 MHz filters



5.13 There are a number of low cost products already available in Europe that exceed this attenuation requirement, often by considerable margins.

5.14 New 700 MHz filters would need to be used following the clearance of the 700 MHz band in 2020. It may however be possible to start using 700 MHz filters in advance of this date for households which are currently receiving DTT services on channels below 694 MHz. We will work with Government and stakeholders over the coming months to explore the potential for early use of 700 MHz filters instead of 800 MHz filters where appropriate, to future-proof households against any future interference issues.

The use of group K aerials would help to mitigate 700 MHz coexistence issues

5.15 The rooftop aerial used to receive DTT can play a significant role in helping to mitigate interference because, chosen judiciously, it can increase the DTT signal and attenuate the mobile downlink, thus leading to a lower probability of interference.

5.16 In recent years installers have been encouraged to use wideband aerials because they cover the whole of the frequency band currently used for DTT (UHF channels 21 to 60, 470-790 MHz), insuring against frequency changes.

5.17 After 700 MHz clearance, which is planned to complete in 2020, the majority of DTT services will operate within UHF channels 21 to 48 (470-694 MHz). Some temporary DTT services, known as ‘interim multiplexes’, may continue to operate in the 700 MHz band for a period of time beyond 2020 (in UHF channels 55 and 56, 742-758

MHz). We discussed this in our 17 October 2016 Statement, 'Maximising the benefits of 700 MHz clearance'.[44]

5.18 Wideband aerials will continue to be needed by households receiving DTT in channels in the 700 MHz band (above UHF channel 48) until the end of the clearance process in 2020, and potentially somewhat longer for households receiving the interim multiplexes.

5.19 For households which are no longer receiving DTT services in the 700 MHz band, we recommend that households that need to replace their aerials use group K aerials.

5.20 Group K aerials cover channels from 21 to 48, and our technical analysis of coexistence issues suggests this aerial type may provide additional benefits compared to wideband aerials in two respects. First, they often provide additional gain relative to wideband aerials, and second, they offer some attenuation to both 700 and 800 MHz mobile bands. This means that households with these aerials would receive some additional protection against interference from the 700 MHz band and above.

5.21 As with filters, it may be possible to start using group K aerials in advance of 2020 for households which are not receiving DTT in channels above channel 48.

Question 3: Do you agree with our conclusions that DTT receiver filters will be the most effective mitigation technique for the 700 MHz band and that group K aerials will also help to mitigate against 700 MHz coexistence issues?

[44] https://www.ofcom.org.uk/__data/assets/pdf_file/0031/92659/Maximising-the-benefits-of-700-MHz-clearance-Statement.pdf

Section 6

Next steps

6.1 This consultation will close on 14 July 2017. Once we have carefully reviewed all consultation responses, we will consider whether any further information or analysis is needed.

6.2 In parallel, and taking into account the outcomes of this consultation, we plan to work closely with Government to consider the policy options for managing the coexistence risks outlined in this document and engage with stakeholders on these issues at a later date.

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom would like to receive views and comments on the issues raised in this document, **by 5pm on 14 July 2017** .

A1.2 We strongly prefer to receive responses via the online form at https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television/. We also provide a cover sheet (https://www.ofcom.org.uk/consultations-and-statements/consultation-response-coversheet) for responses sent by email or post; please fill this in, as it helps us to maintain your confidentiality, and speeds up our work You do not need to do this if you respond using the online form.

A1.3 If your response is a large file, or has supporting charts, tables or other data, please email it to UHFSI@ofcom.org.uk, as an attachment in Microsoft Word format, together with the cover sheet (https://www.ofcom.org.uk/consultations-and-statements/consultation-response-coversheet).

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

Reuben Braddock
Spectrum Group
Ofcom
Riverside House
2A Southwark Bridge Road
London SE1 9HA

A1.5 If you would like to submit your response in an alternative format (e.g.a video or audio file), please contact Reuben Braddock on 020 7981 3108, or email UHFSI@ofcom.org.uk.

A1.6 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.

A1.7 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.

A1.8 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at Annex X. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

A1.9 If you want to discuss the issues and questions raised in this consultation, please contact Reuben Braddock on 020 7981 3108, or by email to UHFSI@ofcom.org.uk.

Confidentiality

A1.10 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish all responses on our website, www.ofcom.org.uk, as soon as we receive them.

A1.11 If you think your response should be kept confidential, please specify which part(s) this applies to, and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.

A1.12 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.13 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further at https://www.ofcom.org.uk/about-ofcom/website/terms-of-use.

Next steps

A1.14 Following this consultation period, Ofcom plans to publish a statement in Q4 2017, subjectto responses.

A1.15 If you wish, you can register to receive mail updates alerting you to new Ofcom publications; for more details please see https://www.ofcom.org.uk/about-ofcom/latest/email-updates

Ofcom's consultation processes

A1.16 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in Annex 2.

A1.17 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.

If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact Steve Gettings, Ofcom's consultation champion:

Steve Gettings
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA
Email: steve.gettings@ofcom.org.uk

Annex 2

Ofcom's consultation principles

Ofcom has seven principles that it follows for every public written consultation:

Before the consultation

A2.1 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. 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

A2.2 We will be clear about whom we are consulting, why, on what questions and for how long.

A2.3 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 for people to give us a written response. If the consultation is complicated, we may provide a short Plain English / Cymraeg Clir guide, to help smaller organisations or individuals who would not otherwise be able to spare the time to share their views.

A2.4 We will consult for up to ten weeks, depending on the potential impact of our proposals.

A2.5 A person within Ofcom will be in charge of making sure we follow our own guidelines and aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.

A2.6 If we are not able to follow any of these seven principles, we will explain why.

After the consultation

A2.7 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish all the responses on our website as soon as we receive them. After the consultation we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

Cover sheet 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 ☐

Whole response ☐

Part of the response ☐

Name/contact details/job title ☐

Organisation ☐

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 cover sheet 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 3

Consultation questions

Question 1: Do you agree with our conclusions that a) the risk of interference from mobile handsets to DTT will be minimal and b) the risk of interference from mobile base stations in 700 MHz to DTT will be broadly similar to the risk for 800 MHz, with some tens of thousands of hosueholds potentially affected?

Question 2: Do you have any comments on our analysis of coexistence risks related to set-top aerials, direct signal ingress to receivers, impact of DTT on mobile services and interference to cable TV?

Question 3: Do you agree with our conclusions that DTT receiver filters will be the most effective mitigation technique for the 700 MHz band and that group K aerials will also help to mitigate against 700 MHz coexistence issues?

Annex 4

DTT reception performance in the presence of 700 and 800 MHz base station signals

Introduction

A4.1 In Section 3 we present a summary of our assessment of the coexistence risk from 700 MHz base stations into DTT receivers via a rooftop aerial. In this annex we provide more details of the laboratory measurements that we undertook to investigate the combined impact of 700 and 800 MHz base stations into DTT receiving equipment. We first summarise the methodology and then discuss our results and conclusions.

A4.2 New base stations in the 700 MHz band alongside existing base stations in the 800 MHz band will have an aggregate interfering effect compared to 800 MHz base stations alone. This effect is likely to be most pronounced where 700 and 800 MHz base stations are co-located.

A4.3 The interference may occur for two reasons: a simple power increase in the unwanted interfering signal power at the DTT receiver, and additional intermodulation products falling within the television band potentially causing the receive equipment to become ‘blocked’.

High-level approach

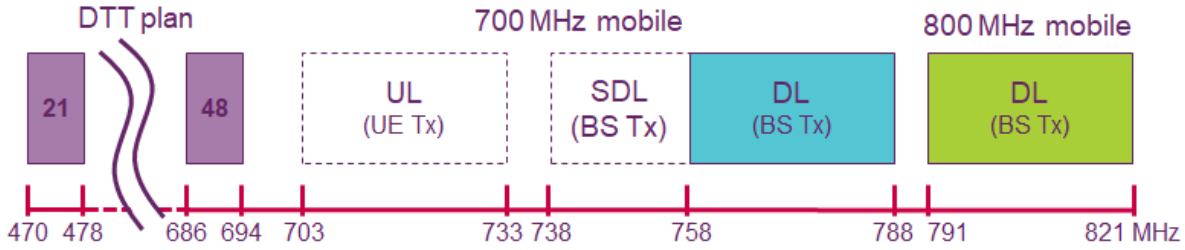
A4.4 To investigate the scale and impact of this interference, we created a representative interference environment in the laboratory, with 700 and 800 MHz base station signals and DTT transmissions operating in the presence of representative DTT receiver installations.

A4.5 For the mobile signals, we simulated realistic LTE signal profiles of equal amplitude in the 800 MHz and 700 MHz downlink bands, as might be expected where multiple services are offered from one or more operators from a single base station location.

A4.6 We tested two scenarios:

- LTE 800 MHz base stations only (30 MHz downlink);
- LTE 800 and 700 MHz base stations together (2 x 30 MHz downlink).

Figure A4.1: Mobile downlink and DTT frequency arrangement



A4.7 We did not test the impact of SDL spectrum (3GPP Band 67) with 800 MHz, but we would expect the results to be similar, as whilst the combined frequency span of both 700 MHz SDL and 800 MHz together would be wider, the net maximum total power within the entire SDL block would be slightly lower than the 700 MHz case tested.

A4.8 We were interested to know if multiplexes near the bottom part of the DTT band would be less susceptible to interference due to the greater frequency separation from a LTE signal. For this reason, we created two DTT transmission configurations – one designed to test reception of a multiplex at channel 22 (at the bottom of the DTT plan and farther away from the 700 MHz band), and one at channel 48 (at the top of the DTT plan and nearer to the 700 MHz band).

A4.9 In each case the configuration also included five additional uncorrelated channels, transmitting at the same power as the channel being tested. This is to simulate a typical scenario, where six multiplexes are being transmitted, using six channels[45]. We used DVB-T as it is less robust than DVB-T2, thereby representing a worst case, modulated at 64 QAM 2/3 rate.

A4.10 For the DTT reception installation, we created four representative installation types:

i) Type 1 - a single dwelling without an amplifier (baseline case);

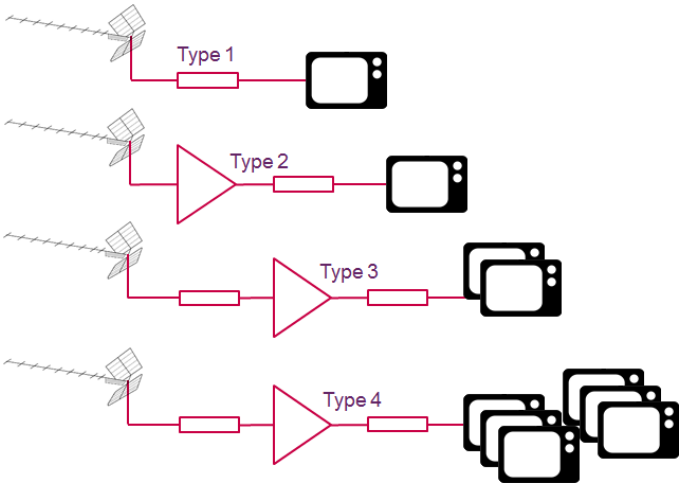
ii) Type 2 - a single dwelling with a domestic amplifier (a type of indoor amplifier used to boost signals and distribute to multiple receivers);

iii) Type 3 - a single dwelling with a preamplifier[46] (a type of low noise amplifier used to overcome weak signals at fringe of coverage);

iv) Type 4 - a multiple dwelling unit with a launch amplifier (a type of distribution amplifier often used in blocks of flats).

[45] The number of multiplexes available varies from place to place, from three to nine.
[46] A preamplifier is also known as a masthead amplifier because it is normally installed near the TV aerial.

Figure A4.2: DTT installation configuration types



A4.11 In each scenario we simulated the effects of various installation gains in the range -27 to 14 dB using a variable attenuator to adjust the overall gain and account for cable losses. This produced realistic receiver levels with DTT signal amplitudes from -42 to -62 dBm that CAI installers target[47].

A4.12 To perform the tests we fixed the DTT level and then increased the aggregate LTE power level gradually until reaching the failure point at the receiver where artefacts started to become visible on screen (as per the D-Book procedure[48]). The maximum power level we generated was -6 dBm at the receiver, so in some cases we were not able to generate sufficient power to cause interference.

A4.13 Further details of the test set-up and parameters are presented at the end of this annex.

Reception equipment selection

A4.14 For each representative installation, we tested a good, average and poor performing receiver. These receivers were on sale in the UK market from about 2010 to 2014 and included popular integrated TVs and set-top boxes.

A4.15 For the amplifiers, we selected good and poor performing samples of unfiltered models from those available on the UK market at the time of testing and also some older models from the market before the introduction of digital TV which are likely to still be present in some DTT installations.

A4.16 The DTT receivers selected for testing are shown in Table A4.1. Figure A4.3 presents their performance measured in the presence of a fully loaded BS signal with a guard band of 9 MHz. Based on these measurements, Rx14, Rx26 and Rx16 were selected for testing each installation type.

A4.17 Similarly, good and poor performing amplifiers were selected based on measured performance of 1 dB compression and 3rd order intercept points. The selected

[47] Code of practice, installation of terrestrial and satellite TV reception systems (MDU & commercial), CAI COP 01 revised July 2014.
[48] D-Book 9, digital terrestrial television requirements for interoperability

amplifiers are shown in Table A4.2. Further detail regarding amplifier selection can be found in paragraphs A4.28 and A4.29.

Table A4.1: DTT receivers selected for testing

ID	Comment
Rx14	DTV, good performance
Rx26	STB, medium performance
Rx16	STB, poor performance

Figure A4.3: Previous results from measuring the protection ratios of candidate receivers. Wanted level vs interfering level using BS fully-loaded waveform, DVB-T 64 QAM and 9 MHz guard band between LTE and DTT

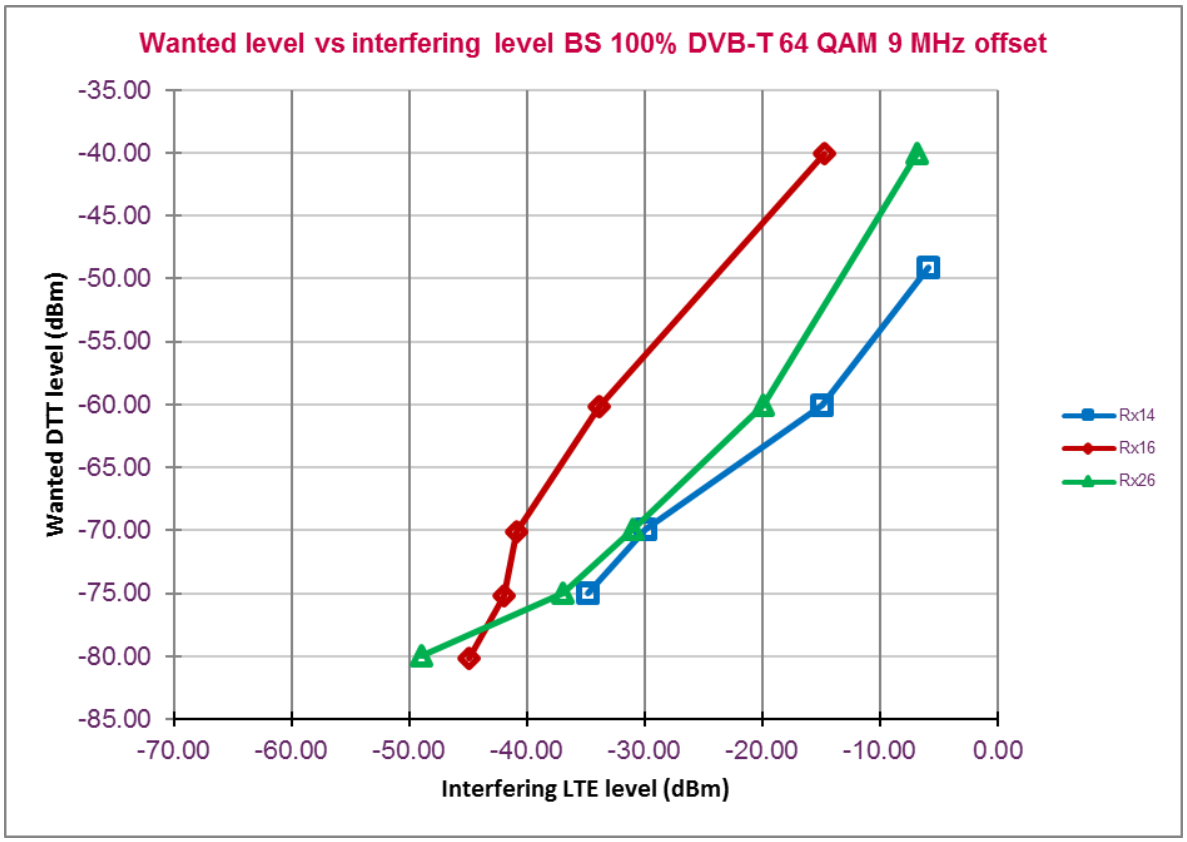


Table A4.2: Amplifiers selected for testing

ID	Installation type	Comment
Amp11	Type 2	Domestic, max gain setting, good performance
Amp12	Type 2	Domestic, min gain setting, poor performance
Amp2	Type 3	Preamplifier, good performance
Amp3	Type 3	Preamplifier, poor performance
Amp17	Type 4	Launch, poor performance

Test results and observations

A4.18 The following six figures A4.4 to A4.9 show the C/I ratios for each amplifier/installation type. C/I is defined here as the wanted DTT signal level relative to LTE adjacent channel interference (ACI) level. The ACI level is measured at onset of picture failure or pixelation.

A4.19 In each case the graphs show all of the television receivers and DTT channel configurations. Some of the higher wanted DTT amplitude points are not plotted for one of three reasons: either we could not generate a high enough unwanted signal to cause failure, or the amplifiers distorted the wanted signal causing picture loss without any unwanted LTE signal present.

Figure A4.4: C/I ratios for installation with no amplifer

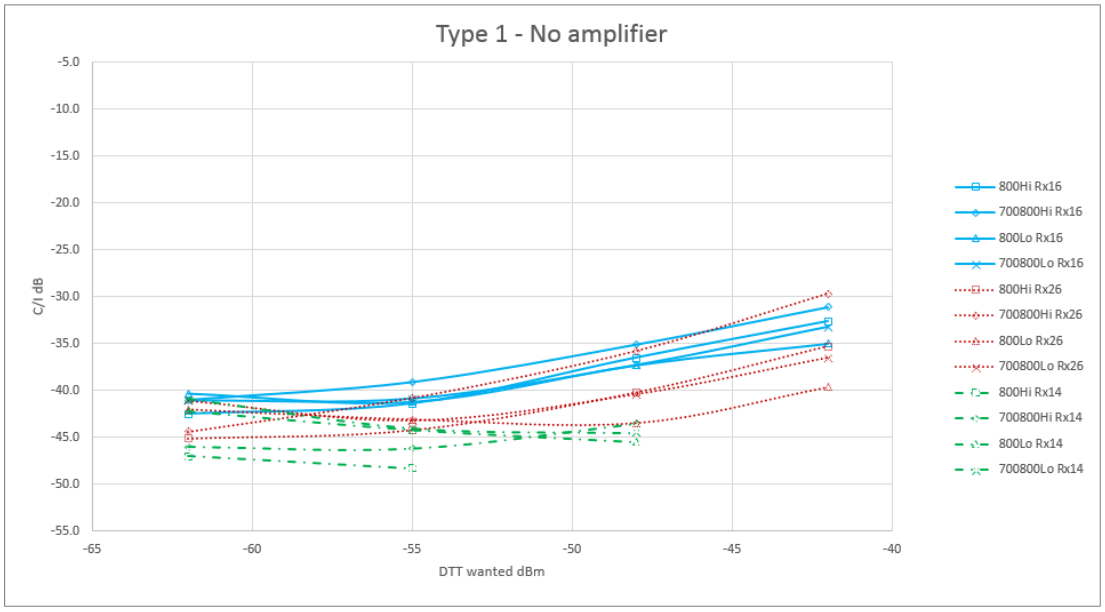


Figure A4.5: C/I ratios for installation with a poor pre-amplifier

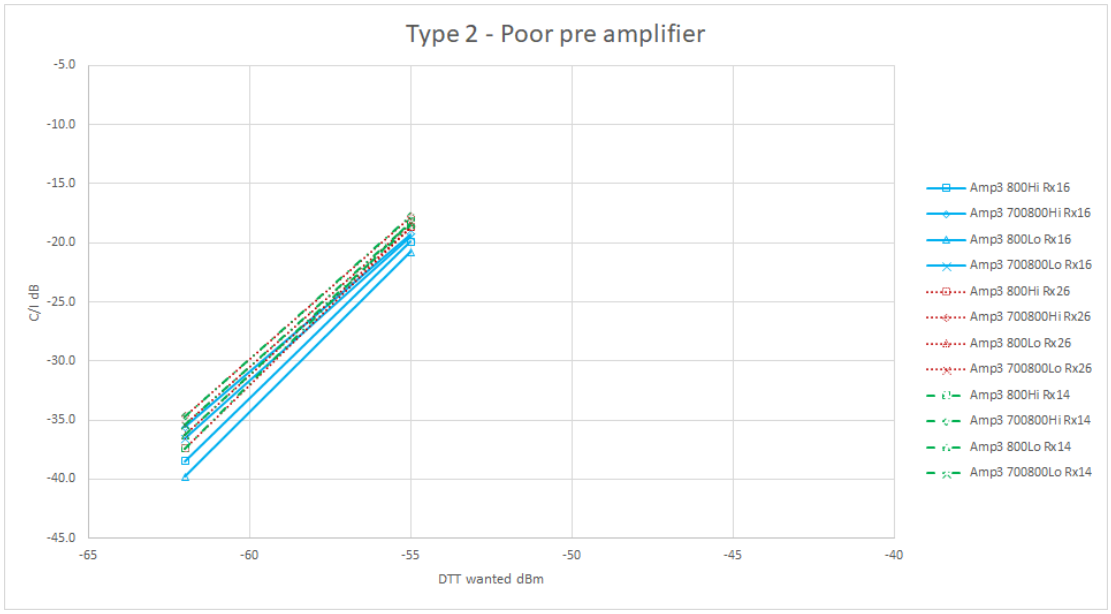


Figure A4.6: C/I ratios for installation with a good pre-amplifier

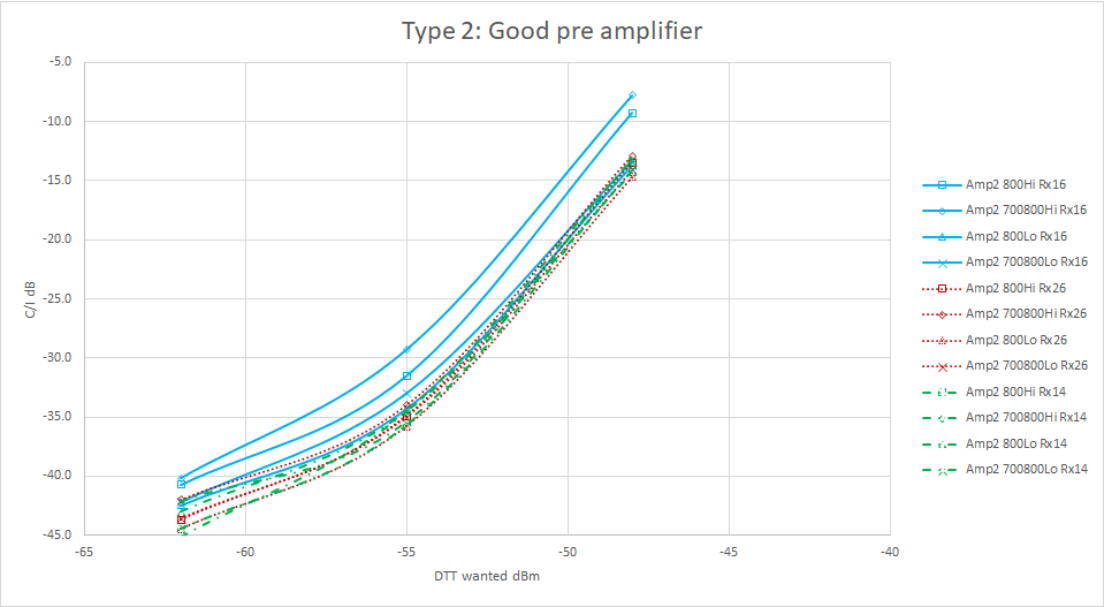


Figure A4.7: C/I ratios for installation with a poor domestic amplifier

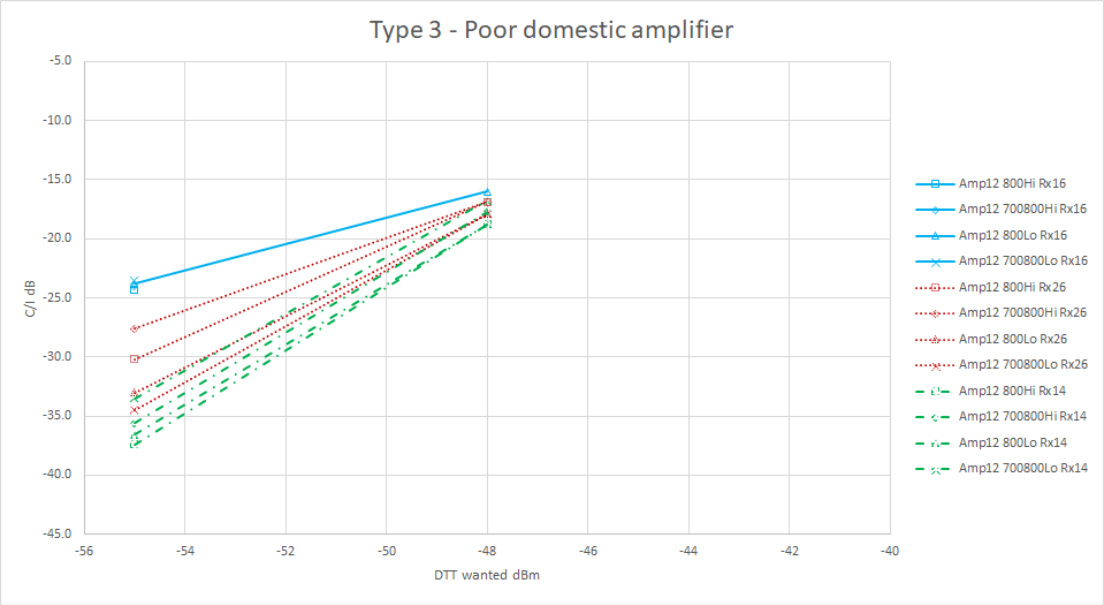


Figure A4.8: C/I ratios for installation with a good domestic amplifier

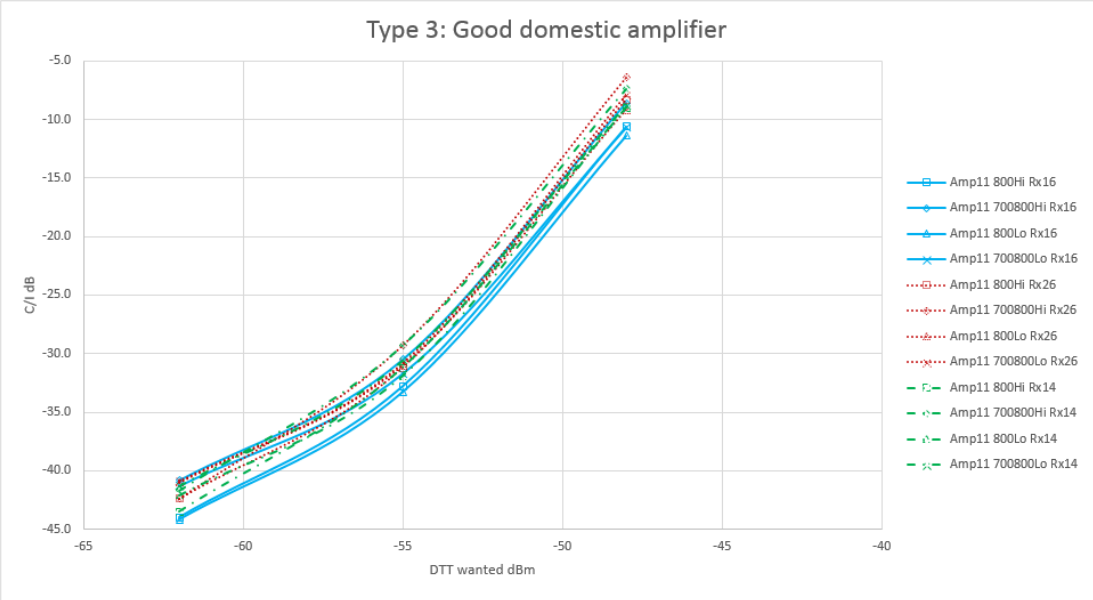
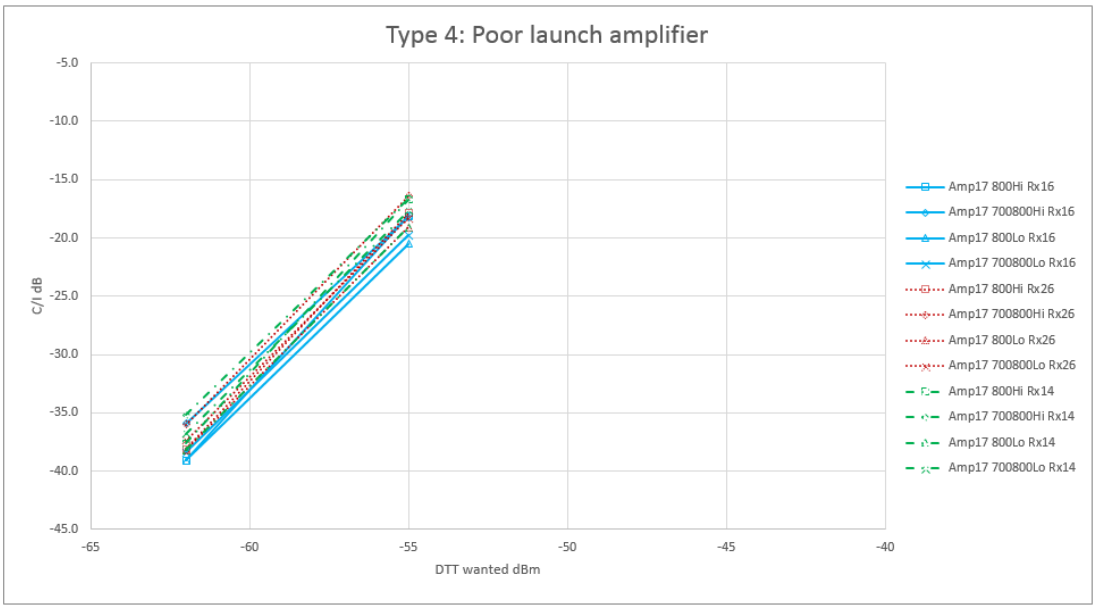


Figure A4.9: C/I ratios for installation with a poor launch amplifier



High-level observations

A4.20 The baseline measurements with no amplifier show that the C/I ratios degrade by a few dBs when the 700 MHz layer is added on top of the 800 MHz layer for high DTT channels. However, the additional impact of the 700 MHz layer is minimal in the lower DTT channels.

A4.21 Whilst the installation gains will be different, comparison of baseline and amplifier tests clearly shows that the DTT system falls into non-linearity earlier with any type of amplifier installation (the slope of curves with amplifiers increase with a higher wanted DTT signal). Above a wanted signal level of -62 dBm the overall C/I performance degrades significantly.

Conclusions

A4.22 Our measurements show that amplifiers and TV receivers are slightly more susceptible (typically 1 to 3 dB in most cases) to combined 800 and 700 MHz interference than to 800 MHz interference alone. In addition, we note a small effect between the performance on channel 22 and channel 48 with the upper channel being marginally more susceptible, typically by up to 2 dB.

Additional information on test set-up, parameters and amplifier selection

Test set-up

A4.23 The following steps were performed in undertaking the measurements:

i) load DTT signals as per DTT channel arrangement;

ii) adjust the step attenuator(s) based on preset cable loss to change the installation gain to simulate loss elements in the installation (such as feeder cables);

iii) adjust the wanted DTT signal to the target level;

iv) ensure the level of each unwanted DTT signal equals the wanted;

v) load required LTE signals;

vi) adjust the level of LTE signals in steps of 1 dB until picture failure;

vii) back off the level of LTE signal by 1 dB and watch the screen for 20 seconds;

viii) take the reading of LTE signals if no picture failure observed, otherwise repeat steps v to vii.

Test parameters

A4.24 The technical parameters and assumptions used in the testing are listed in Tables A4.3 and A4.4.

Table A4.3: LTE parameters used in testing

Parameter	Value/assumption	Notes/reference
Total bandwidth	800 MHz only: 30 MHz (5 MHz/5 MHz/10 MHz/10 MHz) 800 plus 700 MHz: 63 MHz (3 MHz guard band between 800 and 700 MHz bands) 700 MHz only: 30 MHz (5 MHz/5 MHz/10 MHz/10 MHz)	Based on 800 MHz award and CEPT 700 MHz frequency plan
Traffic profile	100 % loaded	Worst case scenario
In-band power	Each carrier with equal power spectral density, total power level varying depending on the DTT failure point	Working assumption/test method
Out of band emissions	Compliant with 3GPP	Simulated LTE signals from R&S signal generator

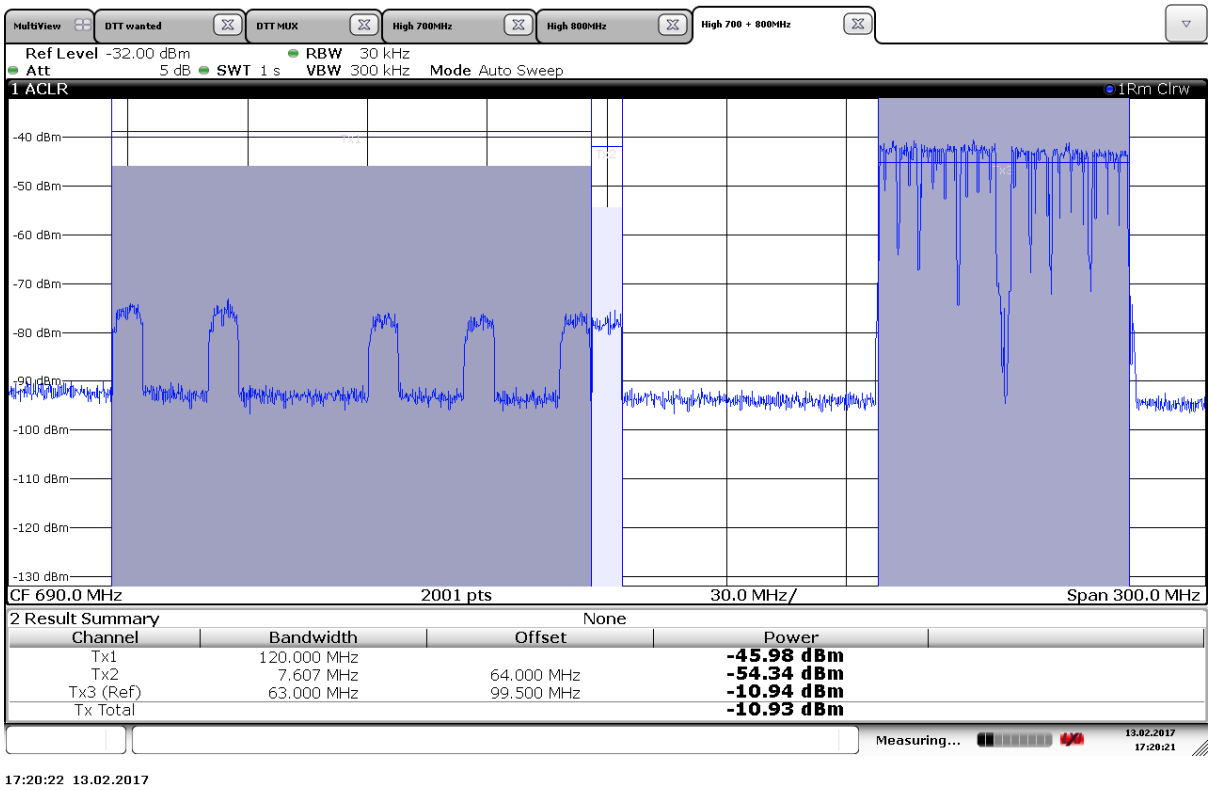
Table A4.4: DTT parameters used in testing

Parameter	Value/assumption	Notes/reference
Channel bandwidth	8 MHz	Ofcom Broadcasting Code[49]
Channel arrangements	High: ch33, ch36, ch41, ch44, ch47, ch48 (wanted mux) Low: ch22 (wanted mux), ch23, ch25, ch26, ch28, ch30	post-700 6CORE frequency plan, equal power level suggested by stakeholders
Mode	DVB-T, 64QAM, code rate 2/3, DFT 8K, Guard interval 1/32	Ofcom Broadcasting Code[7]
Levels at receiver	-62 dBm, -55 dBm, -48 dBm, -42 dBm	Within the range of CAI recommended levels[50]
Aerial gain	Good/decent coverage: 9.15 dBi poor coverage: 13.15 dBi	CAI benchmarking figures[51] for group K (ch37 – ch48) aerials
Pre-amplifier cable loss	4 dB/30 metres	CAI figures[8] plus real-world experience
Amplifier gain	Variable	Measured

A4.25 The LTE BS signals were generated using the built-in LTE module of an R&S SMB100A signal generator. The DTT wanted signal was generated by an R&S SFC modulator. The original signal used to generate the DTT unwanted was recorded over the air from Sandy Heath transmitter. To produce unwanted DTT signals, it was then re-sampled and replicated using an R&S SMU200A signal generator to form five uncorrelated signals. Two distinct DTT channel arrangements are considered to verify the dependency of the interference on frequency offset. An example of the spectrum arrangement in testing is shown in Figure A4.10.

[49] https://www.ofcom.org.uk/tv-radio-and-on-demand/broadcast-codes/broadcast-code
[50] Code of practice, installation of terrestrial and satellite TV reception systems (MDU & commercial), CAI COP 01 revised July 2014.
[51] https://www.cai.org.uk/downloadables/finish/37-aerial-benchmarking/519-aerial-benchmarking-cai-dtg-rev-1-iss-15-22-01-2014

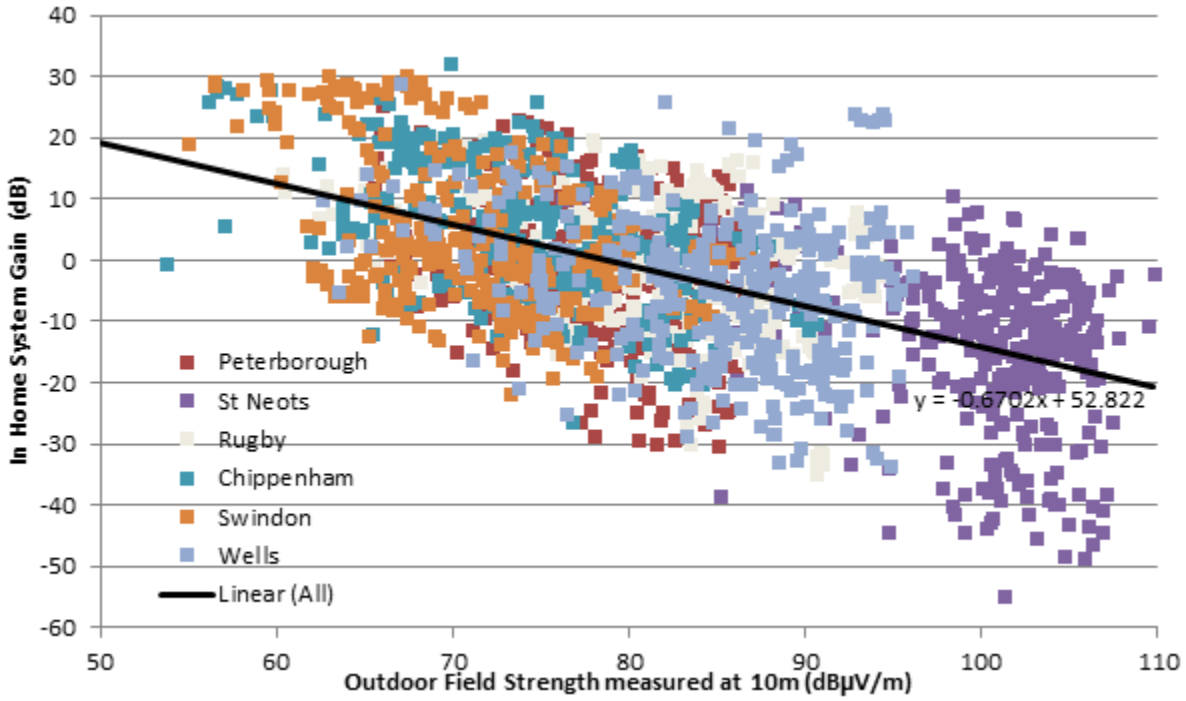
Figure A4.10: a screenshot taken in testing, showing a high DTT arrangement with LTE800 plus 700 MHz signals



A4.26 Figure A4.11 shows a linear fit to 2,000 in-home gain measurements in 6 locations, made as part of the review of the UKPM[52]. Based on the correlation between DTT system gain and outdoor field strength, we estimated the pre-amp signal level given measured amplifier gains and desirable signal levels at the receiver. Subject to installation type, aerial gains and cable losses are derived from CAI benchmarking figures.

[52] Ofcom, BBC, Arqiva and Plum Consulting, *Review of UKPM performance & domestic DTT receiver installations: implications for DTT coverage planning and interference modelling*, December 2015. https://www.ofcom.org.uk/__data/assets/pdf_file/0017/75032/ukpm_review_report.pdf

Figure A4.11: In-home system gain with linear fit



Selection of amplifiers for testing

A4.27 In consultation with Mandercom Ltd, we acquired a mixed pool of 23 amplifiers, all of which were manufactured in the era before digital switchover between 2006 and 2012. For each amplifier, we measured the output gain, 1 dB compression and 3rd order intercept points. Based on these measurements (primarily on third order intercept), we chose five amplifiers for use in our testing to give a good spread of performance.

A4.28 The test results are summarised in Table A4.5.

Table A4.5: Summary of amplifier test results

ID	Gain measured at 690 MHz (dB)	1dB compression point (dBm)	Third Order Input Intercept Point (dBm)	Type	Performance
Am1	15.1	6	19.2	Preamplifier	
Am2	13.0	**6**	**18**	**Preamplifier**	**Good**
Am3	25.7	**-8**	**17.2**	**Preamplifier**	**Poor**
Am4	14.3	0	13.9	Preamplifier	
Am5	16.7	-3	9.2	Preamplifier	
Am6	4.2	-3	9.6	Preamplifier	
Am7	25.5	-8	12.7	Preamplifier	
Am8	34.0	-13	not measured	Preamplifier	
Am9	10.4	6	13.8	Domestic	
Am10	12.9	-12	-1.3	Domestic	
Am11	21.8	**-4**	**15.8**	**Domestic**	**Good**

Am12	11.6	**-20**	**-11.4**	**Domestic**	**Poor**
Am13	13.4	**-2**	**11**	**Domestic**	
Am14	7.5	**-12**	**-10.8**	**Domestic**	
Am15	30.3	-3	3.7	Launch	
Am16	34.2	-2	20.8	Launch	
Am17	45.7	**-17**	**20.9**	**Launch**	**Poor**
Am18	42.1	-8	20.2	Launch	
Am19	34.2	-13	20.9	Launch	
Am20	19.3	-5	20.9	Launch	
Am21	36.7	-4	21.5	Launch	
Am22	15.9	19	22	Launch	
Am23	12.8	-2	7.7	Launch	