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

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About this document

In November 2014, Ofcom announced that the 700 MHz 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. At that time we also presented results of our initial work on coexistence issues.

In May of this year, we consulted on our more detailed assessment of the nature and scale of potential interference risks between new mobile services in the 700 MHz band and DTT. We also discussed technical aspects of some potential solutions to mitigate the risks.

This update presents our conclusions on the technical assessment having taken into account stakeholder responses. We continue to consider that the technical conclusions presented in our May consultation are accurate and robust, and form a sound basis for further work on the policy options for managing coexistence risks related to the 700 MHz band.

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1. Executive Summary

1.1 Future mobile networks in the 700 MHz band will need to coexist with television services in nearby frequencies. This means that there is a risk of interference between the two services, including a risk that mobile base station and handset transmissions could interfere with television reception. We have conducted studies and a consultation to assess this risk. After analysing responses to the consultation, our conclusions are that:

i) A small number of households may be affected by interference from mobile base stations in the 700 MHz band. The impact of interference from base stations into digital terrestrial television (DTT) will be no greater, and may be considerably lower, than the impact currently seen in the 800 MHz band.[1]

ii) the vast majority of households will not experience any interference from mobile handsets.

iii) receiver filters will be the most technically effective means to mitigate interference from handsets and base stations.

1.2 In this document we present the rationale for our conclusions, including how we have taken consultation responses into account.

1.3 Our analytical work started in 2014, when we undertook a preliminary assessment of the coexistence risks which could result from the change of use of the 700 MHz band. This assessment primarily focused on the risk that handsets in the 700 MHz band could interfere with the reception of DTT services. This analysis indicated that the vast majority of households would not experience any interference.

1.4 Earlier this year we carried out more detailed analysis of the potential coexistence issues related to new mobile services in the 700 MHz band. We published the results of this analysis in our consultation, 'Coexistence of new services in the 700 MHz band with digital terrestrial television', published in May 2017.[2]

1.5 As we explained in our consultation, our technical analysis placed a priority on practical data over theoretical modelling where possible. For mobile handsets, we undertook a measurement campaign of LTE emissions at a small sample of domestic TV installations with rooftop aerials. The results of this work were presented in a technical report issued in parallel with our consultation.[3] For mobile base stations, we carried out laboratory measurements to investigate the combined impact of 700 and 800 MHz base stations on DTT reception via a rooftop aerial, and reviewed data from the 800 MHz mitigation

[1] Mobile services in the 800 MHz band launched in 2013 and also operate in frequencies near to those used by television. 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.

[2] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/101619/Coexistence-of-new-services-in-the-700-MHz-band-with-digital-terrestrial-television.pdf

[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/101655/700-MHz-Coexistence-Study-of-mobile-uplink-interference-effects-upon-DTT-reception.pdf

programme. We also carried out practical testing in relation to set-top aerials and direct signal ingress to DTT receivers and cabling.

1.6 We received nine responses to our consultation. Respondents broadly agreed that the risk of interference from base stations was unlikely to be higher than that at 800 MHz. However, some respondents thought that the interference risk from handsets could be greater in some scenarios. Some respondents were also concerned about impacts on reception of DTT via set-top aerials and the impacts on consumers more generally.

1.7 We have carefully reviewed the comments received from all respondents and respond to specific concerns within the main body of this document.

1.8 Overall, our judgment is that our technical assessment is accurate and robust, and forms a sound basis for further work on the policy options for managing coexistence risks related to the 700 MHz band.

2. Introduction

2.1 Currently, frequencies between 694 MHz and 790 MHz (the '700 MHz band') are used for digital terrestrial television (DTT) and programme making and special events (PMSE). In November 2014, we published a statement setting out our decision to re-allocate these frequencies for mobile data use (the '2014 Statement').[4] This change of use is on track to take effect in 2020.

2.2 New mobile services in the 700 MHz band will need to coexist with DTT services below 694 MHz. This coexistence scenario is similar in many respects to the one dealt with for the 800 MHz band, which started to be used for mobile services in 2013. In the 700 MHz band plan however, mobile handsets will transmit in the frequencies adjacent to DTT services.[5]

2.3 We undertook some initial coexistence analysis in 2014 to inform our decision on the change of use of the 700 MHz band, in particular with regard to the risk that new handsets in the 700 MHz band might interfere with reception of DTT. This initial analysis indicated that the vast majority of households would not experience any interference. However, we said that we would do further work to verify our initial analysis and more accurately identify the nature and scale of the coexistence risks.

700 MHz band plan and technical conditions

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

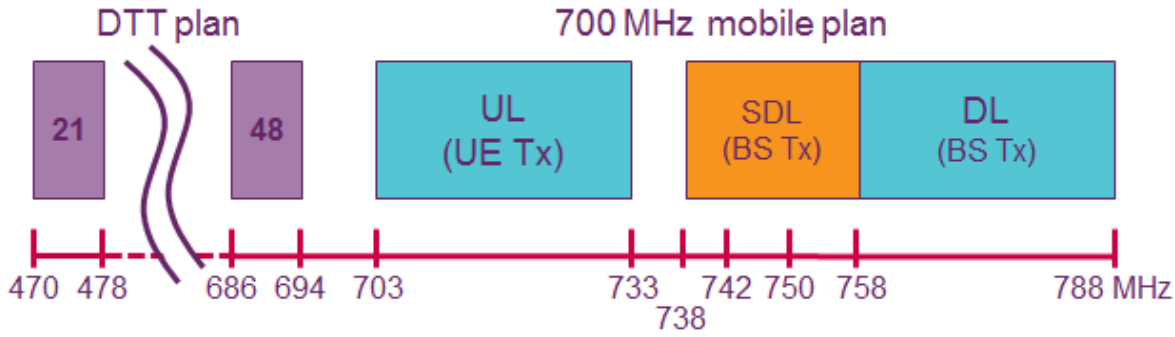
2.5 The band plan and technical conditions for the 700 MHz band were developed by CEPT in response to a mandate from the Commission. CEPT issued Reports 53 and 60 on 28 November 2014 and 1 March 2016 respectively. These reports provide the basis for technical harmonisation of the 700 MHz frequency band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

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

[4] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/46923/700-mhz-statement.pdf

[5] This is different to the 800 MHz band plan where base stations transmit in the frequencies adjacent to DTT services.

Figure 2.1: 700 MHz band plan



2.7 In recent years, Ofcom and other European regulators have worked with industry partners and DTT receiver manufacturers to make new DTT receivers more resilient to interference from mobile services. New requirements on DTT receivers have been imposed for placing products on the European market through the Radio Equipment Directive (RED) 2014/EU/53[6] which entered into force on 12 June 2016 with a transitional period that ended on 12 June 2017. The RED has been implemented into UK law with effect from 26 December 2017 by way of the Radio Equipment Regulations 2017.[7]

2.8 The RED aims to ensure that radio equipment sold on the European 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[8] are presumed to conform with the requirements of the RED.[9] The European Telecommunications Standards Institute (ETSI) has developed a harmonised standard which includes new performance requirements for broadcast receivers.[10] New receivers sold in the UK are expected to meet performance targets which are equivalent to those specified in this standard.

[6] 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. The RED replaces the Directive on Radio and Telecommunications Terminal Equipment (RTTE) 1999/5/EC.
[7] https://www.gov.uk/government/publications/radio-equipment-regulations-2017. These regulations will revoke the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000.
[8] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en
[9] Conformity of radio equipment with the RED may be achieved in other ways, as set out in the Directive.
[10] 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/red_en.

The May 2017 Consultation

2.9 In May 2017 we published a consultation setting out the results of our more detailed work to assess the coexistence risks between new mobile services in the 700 MHz band and DTT (the 'May 2017 consultation').[11]

2.10 For handsets, we undertook a measurement campaign of LTE emissions at a small sample of domestic TV installations with rooftop aerials, using current 800 MHz networks as a proxy for 700 MHz. We presented the results of the measurement campaign in a technical report issued in parallel with our consultation (the May 2017 Technical Report).[12]

2.11 For base stations, we 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 roll-out. [13] We also conducted laboratory testing to look at the combined effect of 700 MHz and 800 MHz base stations on DTT reception.

2.12 We assessed a number of other potential coexistence risks including i) use of set-top aerials for reception; ii) ingress of interference direct to DTT receivers and cabling; iii) impact of DTT on mobile services; and iv) impact of mobile handsets on cable TV set-top boxes and modems.

2.13 Finally, we discussed technical solutions for mitigating coexistence risks, including the use of receiver filters and group K aerials.[14]

2.14 The provisional findings of our assessment were as follows.

- The impact of interference from 700 MHz base stations will be no greater than the impact seen in the 800 MHz band.
- The vast majority of households will not experience any interference from mobile handsets.
- Set-top aerials will be more susceptible than rooftop aerials to interference from handsets operating in the 700 MHz band. Ofcom's position continues to be that rooftop aerials are the recommended means to enjoy reliable DTT reception.
- There are unlikely to be any significant issues related to other potential coexistence risks: direct ingress to DTT receivers and cabling, interference from DTT to mobile services and interference to cable TV and modems.
- Receiver filters will be the most technically effective means to mitigate interference from handsets and base stations. Group K aerials could also help to mitigate

[11] https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television
[12] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/101655/700-MHz-Coexistence-Study-of-mobile-uplink-interference-effects-upon-DTT-reception.pdf
[13] Under the licences granted to the mobile operators for the use of the 800 MHz spectrum, they were required to work together to set up a single body to support consumers affected by interference from new 4G services to DTT reception. They created a company, Digital Mobile Spectrum Limited (DMSL), which operates with the brand name at800.
[14] Group K aerials cover DTT channels from 21 to 48, which corresponds to the channels which will remain available for DTT reception following 700 MHz clearance.

interference for households that are no longer receiving DTT in channels above channel 48.

2.15 We received nine responses to our consultation. All responses were non-confidential and are published on our website.[15]

2.16 We discuss points raised by stakeholders in their responses and present our conclusions on coexistence risks in section 3.

Legal framework

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').

2.18 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.

2.19 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.

2.20 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.

[15] https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television

2.21 The technical work which we presented in the May 2017 consultation was 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

2.22 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.

2.23 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.

2.24 We undertook an impact assessment as part of our analysis for the 2014 Consultation and 2014 Statement on the change of use of the 700 MHz band, including a preliminary assessment of coexistence risks.[16] Our May 2017 consultation and this update do not discuss policy proposals and so we have not at this stage carried out an impact assessment. However, the technical assessment presented in the May 2017 consultation and Technical Report, and the conclusions set out in this update, 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 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 EIA as part of our analysis for the 2014 Consultation on the change of use of the 700 MHz band. Following that assessment, we noted that older and disabled people could experience a greater impact from the change of use of the DTT band and that

[16] https://www.ofcom.org.uk/consultations-and-statements/category-1/700mhz

we would give particular consideration to the needs of these groups when working with Government, broadcasters and consumer groups to ensure that viewers receive appropriate information about and support with these changes.[17] A number of respondents to the May 2017 Consultation said that the coexistence risks highlighted may create particular issues for these two equality groups. We have responded to their comments in this update. Our analysis has not, though, identified any additional equality impacts to those identified in the 2014 assessment. As noted above, our May 2017 consultation and this update present our technical assessment and conclusions on the scale of potential coexistence risks and do not discuss policy proposals. We note though that different options for mitigating interference may potentially have differential impacts on some equality groups, and an EIA would need to be undertaken as part of further work considering those options.

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

3. Coexistence risks in the 700 MHz band

3.1 In this section we consider the responses we received to the May 2017 Consultation and present our conclusions on potential coexistence risks from future new services in the 700 MHz band to existing digital terrestrial television (DTT) use in the adjacent band.

Consultation responses

3.2 We received nine responses to our consultation. Most were from broadcasters or organisations with an interest in broadcasting. The responses are published on our website[18].

3.3 Respondents broadly agreed with our overall assessment of the coexistence risks and our approach to considering them. Some made comments on specific coexistence elements where they considered that the risk may be somewhat higher than we had indicated or where they thought additional evidence may be needed. We discuss these comments in more detail below and present our conclusions and next steps at the end of this section. We have categorised our discussion into the following topics:

- Risks from handsets
- Risks from base stations
- Modelling approach
- Impacts on consumers
- Other potential coexistence risks
- Technical solutions for mitigating coexistence risks

Comments on our assessment of risks from handsets

3.4 To inform our view of the risk of interference from handsets, we undertook a measurement campaign of LTE emissions at a small sample of domestic TV installations with rooftop aerials, using current 800 MHz networks as a proxy for 700 MHz. We presented the results of the measurement campaign in the May 2017 Technical Report, issued in parallel with our consultation. Our measurements showed that even households with poor performing DTT reception equipment should suffer only very rarely from interference from handsets. If 700 MHz networks were deployed and fully loaded with traffic today, viewers with poor performing equipment might see one very short picture interruption, typically less than 1 second, for every 10 hours of viewing, or 1 in 100 hours for HD viewing.

3.5 We posited that developments in broadcast receiver standards as a result of the RED should further reduce the interference risk over time as UK households replace their old

[18] https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television

TVs with new ones that are more resilient to interference from mobile services, including from handsets.[19]

3.6 Most respondents that commented on the handset risk agreed that it was likely to be small. Some noted and welcomed the extensive work done by Ofcom to assess the risk of interference from handsets.

3.7 However, Digital UK noted three reasons for considering that Ofcom had understated the handset risk. They suggested that: i) improvements in TV receiver performance would not occur as quickly as assumed; ii) the worst case DTT signal level would be lower than assumed in our report; and iii) LTE traffic levels may grow to levels greater than those assumed.

3.8 We have reviewed the reasons Digital UK provided, but do not agree that we have understated the risks. There are many variables we need to take into account in making our assessment of interference risk, such as the mobile data traffic levels, DTT signal levels and receiver performance, all of which were mentioned by Digital UK. While we aimed to select values for each of these variables which are towards the lower end of the range of values in use, we refrained from using the most pessimistic view of every variable, which when aggregated, would result in unrealistic predictions.

3.9 Below, we consider each of the reasons cited by Digital UK in turn – including related comments made by other respondents – and respond to these points. Following this, we discuss other comments related to the handset interference risks.

Improvements in TV receiver performance

3.10 With regard to TV receiver performance, Digital UK suggested that recent sales trends pointed to TV replacement cycles getting longer, potentially moving to 10 years, which is longer than the 8-year replacement cycle we had assumed. It added that replaced TVs are often used as additional sets and suggested that these sets are more likely to be used to access DTT services than the main set. It also noted that the measured difference in performance between DVB-T and DVB-T2 receivers is more likely to be attributable to the benefits arising from the use of interleaving in DVB-T2 than to the receivers having an inherently better performance.

3.11 The BBC also noted that older TVs were often relocated to other parts of the house as new equipment is purchased. DTG thought that improvements in receiver performance due to the RED should not be too heavily relied upon, noting that there is currently no statutory instrument for RED in the UK.

3.12 Voice of the Listener and Viewer (VLV) pointed out that while seven to eight years may be the average replacement cycle, some people would continue to use older TVs. It said that, when changes are made to terrestrial broadcasting, the key at-risk groups are the elderly and disabled and that these are the very groups who are unlikely to change equipment

[19] See, in particular, paragraphs 3.15-3.16 and 3.51 to 3.53 of the May 2017 consultation.

that is still in working order. It added that new TV sets are a significant cost for older and less wealthy people and suggested that advice to Government should be mindful of this.

Ofcom's response

3.13 Our assumptions on replacement cycles were based on available evidence and we did not receive compelling evidence for using a different assumption[20]. We note the recent downward sales trends for TVs cited by Digital UK. However, these are over a relatively short time period and may well recover in the future as manufacturers introduce new features or reduce TV costs.

3.14 Moreover, the use of a slightly longer TV replacement cycle assumption, e.g. ten years, does not change our overall assessment that the risk of interference from mobile handsets is minimal. Changing our model by adding two years to the replacement cycle would have no impact upon the vast majority of TVs.[21]

3.15 We note Digital UK's point about the effect of interleaving in DVB-T2 on measured receiver performance. However, this does not affect the assessment in our consultation and Technical Report.

3.16 We agree that the relocation of older TVs for use as additional sets may mean that the average interruption rate for these sets could be higher relative to the main set. We also note the concerns raised by VLV regarding older and disabled people being less likely to change equipment and therefore not benefitting from the performance improvements related to new receivers. However, even discounting the benefits of new, better performing TV receivers, most viewers would still be unlikely to notice any interference. As noted in our consultation, based on today's population of TV receivers, even viewers with a below-average performing TV receiver and in an area of relatively high handset activity would on average still only experience one transient picture interruption for every ten hours of TV viewing.[22]

3.17 With regard to DTG's comments on the impact of the RED, we note that the Government will introduce regulations implementing the RED with effect from 26 December 2017.[23] Also, we note that DTG itself has recently published an update to the D-Book which, among other things, includes DTT receiver requirements which are equivalent to those prescribed in the Harmonised Standard EN 303 340[24] under the RED. Therefore, we judge it reasonable to expect that television manufacturers will make new receivers that seek to meet these revised performance targets.

[20] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/40569/mediatique.pdf
[21] The worst-performing 10% of sets would on average be 2 dB less tolerant to interference.
[22] This is based on standard definition TV viewing. The figure for high definition TV viewing is 100 hours. See paragraph 3.14 of our May Consultation.
[23] https://www.gov.uk/government/publications/radio-equipment-regulations-2017
[24] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en

DTT signal levels assumed in our report

3.18 Digital UK noted that Ofcom had assumed a worst-case DTT signal level of -65dBm in its report and pointed to real-world measurements made by Ofcom and DMSL in the Winter Hill and Selkirk areas which showed that approximately one in ten households currently use a DTT service at levels up to 7dB lower than the Ofcom worst case.

Ofcom's response

3.19 The main purpose of the -65 dBm level was to show what the impact on handset interference could be in an area with low DTT signal. Our estimates show low impact even in households with low signal level (-65 dBm) **and** poor receivers (see table 6.2 of the May 2017 technical report) **and** in an area of high handset activity. There is a very large range of differing quality of installation and signal levels among households and we understand that some viewers will be at an extreme of this range, with very poor receiver, installation and signal levels. These viewers will be more vulnerable to reception issues due to multiple causes, and not just from interference related to new mobile services. We highlighted in our Technical Report that this minority of viewers, if exposed to high levels of 700 MHz handset traffic, may experience interference, and that interference could be resolved with filters (see paragraphs 8.5-8.7 of our May 2017 Technical Report).

LTE traffic levels assumed in our report

3.20 Digital UK argued that future mobile data traffic may grow to levels greater than those assumed in our modelling. They noted that Ofcom's traffic analysis in the May 2017 Technical Report was based on assumed 700 MHz uplink traffic levels which were extrapolated by doubling measured 800 MHz data. They argued future 700 MHz traffic levels may be more than double today's traffic at 800 MHz, which they see as not yet fully mature.

Ofcom's response

3.21 It is possible to imagine that future traffic levels in the 700 MHz network could be even higher, as Digital UK argues. As explained earlier in this section, we aimed to use values for each variable in our model which are towards the lower end of the range of values in use, but not the most pessimistic value possible in every variable, which would lead to an unrealistic prediction.

3.22 In addition, our model used as a reference the busiest 800 MHz operator. We doubled their 2016 traffic levels and applied the results to all operators. In practice, we expect that some 700 MHz operators would see lower traffic levels than others.

3.23 Finally, we note that the calculated picture interruption rates in our report are based on mature 700 MHz networks. In practice, 700 MHz networks will only reach maturity after a period of some years, by which time we expect receiver performance will have improved as older receivers are replaced with new receivers that are more resilient to interference from mobile services.

Other comments on the handset interference risk

3.24 The BBC broadly agreed with many of the points in our consultation but noted that channel bandwidths greater than 10 MHz would be subject to different out-of-band emission (OOBE) limits and said this could result in greater interference than envisioned in our document. It also noted that, in France, a 5 MHz block had been licensed at the bottom of the 700 MHz band and that this arrangement effectively limits interference into Channel 48 to -57 dBm/8 MHz, some 15 dB better than the CEPT value of -42 dBm/8 MHz. It suggested that this should be borne in mind as Ofcom develop the channelling arrangement for the auction process. Digital UK made a similar point and noted that Germany had specified handset out-of-block performance of -57 dBm/8 MHz.

3.25 Andrew Dumbreck Media Limited (ADML) thought that a metric giving a number of interference events per 10 or 100 hours was not particularly meaningful and said it would be more helpful to consider how many homes would have a level of disruption to viewing that would be annoying.

3.26 Digital Mobile Spectrum Limited (DMSL) noted that it had not seen evidence of interference to DTT from mobile handsets using the 800 MHz band.

Ofcom's response

3.27 We agree with the BBC's observation that a different OOBE limit of -25 dBm/8 MHz applies for channel bandwidths greater than 10 MHz. To understand the emissions levels and assess the risk that greater channel bandwidth would lead to greater interference than we predicted, we performed some laboratory measurements on out-of-band emissions from 7 handsets. We compared LTE 5, 10, 15 & 20 MHz emissions in the various block configurations. The results show that all emissions are better than the -42 dBm/8 MHz limit and are often substantially lower. In most cases the emissions were below the sensitivity of our test configuration.

3.28 From our work we observed that 5/10 MHz channel bandwidths at any position within the uplink band produced OOB emissions that were no worse than -56 dBm/8 MHz. In the case of 15/20 MHz the results were no worse than -52 dBm/8 MHz. We therefore consider that the interference risk related to channel bandwidths greater than 10 MHz is low.

3.29 Further details of these measurements are presented in annex 1.

3.30 In relation to ADML's point about the choice of interference metric, we consider that an interruption rate is an objective measure of the impact on households whereas an annoyance factor would be difficult to calculate and would necessarily involve some level of subjectivity, as viewers will have different tolerances to picture interruptions. Additionally, for the minority of viewers who might experience occasional picture disturbances, we consider that the low interruption rates indicated by our analysis imply that annoyance levels are likely to be very low in most cases.

Comments on our assessment of risks from base stations

3.31 In our May 2017 consultation we noted that the technical characteristics of base stations in the 700 MHz band are expected to be broadly similar to 800 MHz base stations. We therefore used data gathered from the 800 MHz mitigation scheme run by DMSL as the basis for our estimates of the likely scale of coexistence risks from 700 MHz base stations. We also looked at different factors between 800 MHz and 700 MHz, including the aggregate effect from both bands, to inform our assessment. We provisionally concluded that, overall, the impact of interference from 700 MHz base stations would be no greater than the impact seen in the 800 MHz band.

3.32 Most respondents that commented on this point agreed with our overall assessment.

3.33 DMSL noted that it had supplied data for some of the Ofcom report on the number of households impacted by 4G at 800 MHz and that this was to the best of its knowledge accurate at the time of writing but that it had not drawn its own conclusions from this data.

3.34 DTG did not explicitly agree or disagree but noted that the base station coexistence testing was not comprehensive. It said three receivers was not a representative sample and that further testing would clarify the assessment.

3.35 Digital UK agreed that the projected number of 800 MHz interference cases would be a reasonable estimate of the upper end of the range of new cases arising from 700 MHz transmissions. However, it also said that it could not be certain that the falling trend of interference cases at 800 MHz would continue to the end of the programme and that there was still scope for surprises.

3.36 ADML agreed that the number of homes affected by 700 MHz base station interference was likely to be in the same range as for 800 MHz but noted that our estimates for number of homes affected by 700 MHz are based on an assumption of a similar mitigation campaign as that run for 800 MHz. It suggested that the actual number of homes affected was higher than the figures we reported because not all affected homes are treated as confirmed cases, e.g. due to not qualifying for a home visit or not reporting interference.

Ofcom's response

3.37 For the base station coexistence testing, we chose three receivers from a pool of approximately 30 on sale in the UK market from about 2010 to 2014, including popular integrated TVs and set-top boxes. In addition, the full pool of receivers was tested in the presence of a fully loaded base station signal in order to inform our selection of good, average and poor performing receivers. We are therefore confident that the test results represent the likely range of performance across a reasonable sample of receivers.

3.38 While it is possible that the falling trend of 800 MHz interference cases noted in our consultation could change, 800 MHz roll-out has now been ongoing for more than 4 years and it would require a very significant surge in the number of interference cases per base station to cause the overall figure to exceed the upper limit of our estimates. Furthermore,

at the end of August 2017, there were 22,121 confirmed cases[25] of 4G interference at 800 MHz which is close to the lower decile of the model used to generate the estimates we presented in our consultation.

3.39 We agree that the base station interference case figures presented in our consultation were based on the confirmed interference case metric used for the 800 MHz mitigation programme and this does not capture households that do not qualify for a visit or who do not report interference. The basis for these figures was made clear in our consultation.

Comments on our modelling approach

3.40 We explained in our consultation that modelling of potential coexistence issues for the 800 MHz band had overestimated the number of households likely to suffer interference. Therefore, for our 700 MHz assessment we prioritised practical data over theoretical modelling where possible. This included field work to collect realistic data on handset interference, a programme of measurements to investigate the combined impact of 700 and 800 MHz base stations and information gathered from DMSL and from overseas.

3.41 Respondents that commented on our approach to modelling generally agreed that it was reasonable. Sky said it supported Ofcom's pragmatic approach and believed similar approaches should be adopted in future for analysis of spectrum use in adjacent and sharing applications. VLV noted that the evaluation work had the benefit of practical experience in addition to theoretical predictions and that this gave confidence that the planning methodology for the 700 MHz band would be sound and perhaps more accurate than was possible during the early stages of the 800 MHz planning process.

3.42 Digital UK thought that our approach was reasonable provided that the captured data and extrapolation was robust and based on a sufficiently large sample size and a broad range of scenarios to ensure that all aspects of coexistence were adequately explored. However, it said that modelling results should not be completely discounted; rather, modelling and real-world data should be used in tandem. It noted that it could not determine the robustness of all the numerical results because not all of the underlying technical data had been provided, but that it generally agreed with the conclusion drawn. However, it cautioned that the analysis was only valid if the mobile network parameters and topology remain similar to those used in the 800 MHz band. It suggested that a further coexistence analysis and consultation would be needed if the parameters for the 700 MHz band proved to be different.

3.43 ADML thought that the comments in our consultation regarding modelling could be misconstrued to mean that predictive modelling was inaccurate and therefore not worth undertaking. It noted that the 800 MHz scheme had been underpinned by predictive modelling, and supported the use of improved predictive modelling for any 700 MHz

25 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/659420/Oversight_Board_Report__27_Sept_2017__FINAL.pdf

mitigation programme. It also suggested some aspects of the modelling that might be improved.

Ofcom's response

3.44 We agree that predictive modelling is an important tool in coexistence analysis. However, we note that in this particular coexistence scenario, some of the parameters are subject to a high degree of variability and uncertainty. DTT receiving installations contain a variety of equipment which has a wide range in terms of its quality and susceptibility to interference. This means that modelling produces a wide range of estimates for the numbers of households that are at risk of interference. Practical evidence is needed to narrow this range.

3.45 For example, we commissioned a technical study in 2014 to investigate the number of households that might be affected by handset interference and this study produced a wide range of estimates. [26] Our handset measurement campaign allowed us to refine figures from the 2014 study and provide a better indication of the approximate number of households that may be affected. This was set out in our May 2017 Technical Report.

3.46 As noted by ADML in its response, a Coexistence Technical Working Group (under the direction of the 4G TV Oversight Board) was set up for the 800 MHz mitigation programme to work on improving the interference modelling. While some improvements have been made, the high degree of uncertainty and variability in key parameters noted above means that the interference modelling still produces very high numbers of potentially affected households. Such modelling does not enable accurate identification of which households will be affected or accurate estimates of the actual number of households that will be affected.

3.47 Therefore we consider that both the analysis we have undertaken and our approach to the analysis are fit for purpose. We do not consider further analysis is necessary at this stage.

3.48 We note Digital UK's suggestion that changes to the mobile network parameters and topology for the 700 MHz band could require further analysis and consultation. We are not currently aware of any radical developments in relation to potential network parameters and topology for that band that are likely to result in the need for further analysis or consultation on coexistence risks. That said, we will remain alert to any future significant developments.

General comments regarding impacts on consumers

3.49 Some respondents commented on the importance of understanding and managing the impacts of interference on consumers.

3.50 VLV noted its primary concern that DTT viewers' interests are taken fully into account during the planning and implementation of the change of use of the band. It said that the

[26] Aegis Spectrum Engineering, Interference from LTE handsets to DTT services, a report for Ofcom, 2014. https://www.ofcom.org.uk/__data/assets/pdf_file/0025/79405/interference_from_lte_handsets_to_dtt_services.pdf

mitigation solutions in place for 800 MHz should be retained and extended for 700 MHz and that viewers should not incur the cost of resolving reception problems, including users of set-top aerials. It commented that interference could have particular impacts on vulnerable viewers. For elderly viewers, DTT is the most affordable service available and it is valued greatly as a source of social contact and entertainment. VLV called for the needs of vulnerable viewers to be given due attention.

3.51 Floating Powerhouse was concerned about how the coexistence risks would vary across different geographic areas of the UK and noted that coexistence studies should routinely include all nations of the UK. It commented that it was not clear from the consultation where the risks were felt to be greatest or what would be done to help affected consumers. Floating Powerhouse also commented that consumers pay for a licence and should be entitled to a service free from interference.

Ofcom's response

3.52 We agree that it will be important to understand and manage the impacts on consumers. We note the comments made by VLV. As discussed in our consultation, we will carry out further work to consider options for supporting consumers affected by interference from new services in the 700 MHz band, including vulnerable viewers.

3.53 We also agree that the coexistence risk will vary by geography to some extent. For example, as noted in our consultation, viewers in areas with low DTT signal strengths and high LTE signal strengths will tend to be at greater risk of interference. However, we note that evidence from the 800 MHz band mitigation programme indicates that interference can occur in any area where mobile base stations are deployed. Our analysis in the consultation was focused on identifying the overall scale of interference. Subject to decisions on mitigation policy, it may be appropriate to undertake more detailed local analysis of interference risks at a later date, as took place for the 800 MHz mitigation programme.

3.54 We note that viewers who use television receiving equipment to watch or record programmes as they are being shown on TV or live on an online TV service, and to download or watch BBC programmes on demand are required by law to hold a TV licence. As such, a TV licence confers on the viewer legal permission to install or use television receiving equipment to carry out these activities. It does not, though, guarantee that the viewer can receive signals free from interference. We note that the BBC is responsible for investigating complaints of interference to domestic radio and television and can provide advice to viewers facing reception issues[27].

Comments on other potential coexistence risks

3.55 In our May 2017 consultation we set out our provisional view on a number of other potential coexistence risks arising from the change of use of the 700 MHz band including i) Use of set-top aerials for reception; ii) ingress of interference direct to DTT receivers and

[27] https://www.radioandtvhelp.co.uk/

cabling; iii) impact of DTT on mobile services; and iv) impact of mobile handsets on cable TV set-top boxes and modems.

3.56 A number of respondents commented on the risk of interference to set-top aerials. Digital UK pointed to evidence regarding the number of main and secondary sets connected to set-top aerials and said that set-top reception remains an important way for households to access DTT services, even on their primary set. Digital UK and the BBC both noted that, for the 700 MHz band, the mobile handset would be the predominant interferer and this would be a worst-case situation for set-top DTT reception. Digital UK commented that, while it understands that Ofcom does not actively support reception using a set-top aerial, it remains firmly of the view that it is an important way for a significant minority of households to access DTT and should be given due consideration. The BBC suggested that the increased risk to set-top aerials needed to be considered in discussions about how any mitigation solutions and associated communications to the public should be delivered.

3.57 Digital UK and VLV commented that there are some households that have no option other than to use a set-top aerial and that these should be given due consideration. ADML made a similar point, noting that some households rely on set top antennas because it is difficult for them to use roof-top or loft antennas. It also said that the Switchover Help Scheme provided reception using set-top antennas for some elderly viewers. Digital UK commented that it was helpful that some better-performing indoor aerials were identified in Ofcom's tests while noting that the test detail was not provided for it to determine the degree of improvement offered by these products. VLV thought that more robust action was needed to assist these viewers.

3.58 We received only a small number of comments on the other coexistence risks, with most respondents who commented on these risks agreeing with our analysis. DMSL commented that the provisional conclusions in relation to direct signal ingress to receivers were in line with its experience from the at800 programme, with only a handful of cases of direct ingress causing interference reported. However, DTG said that the details of the direct signal ingress testing should be provided for review and should be reviewed in conjunction with representatives of the DTT and satellite installation industries.

Ofcom's response

3.59 As noted in our consultation, our advice to consumers will continue to be that rooftop aerials are the recommended means to enjoy reliable DTT reception and that viewers who rely on portable or set-top aerials will be more likely to experience reception problems and interference when watching television. This is consistent with advice from the Radio and Television Investigation Service, which is managed by the BBC.[28] For this reason we have not included them in our coexistence impact estimates.

3.60 Ofcom is not the UK body responsible for considering signal ingress. However, we performed simple, functional testing which confirmed that no significant issues are likely to

[28] https://www.radioandtvhelp.co.uk/interference/rtis_tv/portable_tv

arise as a consequence of the change of use of the 700 MHz band. We can confirm that we intend to publish further details of this testing on our website in the near future.

Comments on technical solutions for mitigating coexistence risks

3.61 In our May 2017 consultation we said that we expect receiver filters to continue to be the most technically effective way to mitigate interference for the 700 MHz band, and presented our proposed attenuation requirements for 700 MHz filters. We noted that it may be possible to start using 700 MHz filters in advance of the end date for clearance of the 700 MHz band in 2020, and said we would start work to explore the potential for this.

3.62 We also said that the use of group K aerials would help to mitigate 700 MHz coexistence issues and that it may be possible to start using group K aerials in advance of 2020 for households which are no longer receiving DTT in channels above channel 48.

3.63 Most respondents agreed that receiver filters would be an effective mitigation method. However, broadcast respondents noted concerns that use of 700 MHz filters could impact reception of the interim multiplexes in DTT channels 55 and 56.

3.64 Arqiva's response focused on this issue. It said the interim multiplexes are strategically important to the DTT platform and that it is important to balance any mitigation scheme with ensuring that the services they deliver remain available to as many viewers as possible for as long as possible. Digital UK suggested that, while the interim multiplexes remain, the universal deployment of 700 MHz low pass filters could not take place and any mitigation programme would need to be carefully managed to avoid consumers losing access to these multiplexes. DMSL suggested an additional filter could be specified that blocked frequencies above 758 MHz. This would mitigate against interference from new 700 MHz base stations while not blocking reception of the interim multiplexes.

3.65 Arqiva and Digital UK said that experience at 800 MHz had shown that improvements to the DTT receiving system were an effective way to mitigate interference and that this approach would also have the benefit of not compromising reception of the interim multiplexes. Digital UK added that it understood that DMSL had resolved the vast majority of 800 MHz related interference cases through improvements to the receiving system, rather than by the addition of a filter. Digital UK considered this helpful because it reduced the likelihood that these households would need replacement filters.

3.66 DMSL said that its experience suggested that filters offer protection against unwanted signals, but that visible interference was often indicative of aerial systems not providing adequate DTT signal strength and/or quality. Additional basic aerial system work was often needed to ensure continued reliable reception of DTT.

3.67 Digital UK thought that handset out-of-block emissions were potentially the dominant interference mechanism in relation to set-top reception. It commented that filters would do nothing to remove these emissions. The BBC said that the -42 dBm/8 MHz limit meant that there was a fundamental limit to the reduction of overall interference (of 3 dB) possible as a result of improving DTT receiver ACS, either by an external filter or by

improved receiver performance. [29] It said that it was therefore difficult to understand how the introduction of new receiver designs would result in a reduction in picture interruption rates.

3.68 Digital UK also suggested that any 700 MHz interference mitigation programme would need to avoid the possibility of households inadvertently cascading 700 MHz and 800 MHz filters.

3.69 With regard to group K aerials, most respondents that commented on this point agreed that these aerials could in theory be beneficial for households no longer receiving DTT channels above channel 48. However, they thought this would be difficult to implement in practice.

3.70 Arqiva, the BBC, DMSL, Digital UK and DTG all noted that group K aerials would have the potential to affect the reception of interim multiplexes. The BBC said it saw limited benefits and the possibility of greater viewer confusion from the widespread promotion of group K aerials at an early stage in the 700 MHz clearance process. Digital UK thought that installers may not wish to carry stock of more than one aerial group or concern themselves with details of which multiplexes are available from any particular transmitter. It suggested that the practical guidance should therefore be to continue to promote the use of group T antennas as being a universal solution until such time as the interim multiplexes cease to operate.

Ofcom's response

3.71 Where the interim multiplexes operate in the centre gap, our position on the issue of interference remains as set out in our October 2016 Statement.[30] That is, that use would be subject to Arqiva:

- being able to demonstrate that the interim multiplexes can operate in the centre gap without causing interference to mobile services in the paired spectrum; and
- satisfying us that it will take appropriate steps (at its own cost) to manage the impact of interference from mobile services in the paired spectrum into the interim multiplexes.

3.72 Therefore, we would not expect other users of the band to be required to manage the risk of interference from or to the interim multiplexes, or to bear additional cost related to managing this risk.

3.73 This would mean that Arqiva would be responsible for covering the costs of any mitigation measures that are specific to dealing with this risk (i.e. which are additional to any measures which may already be put in place to mitigate interference to the main TV multiplexes). This would include for example the use of filters like the ones suggested by

[29] Adjacent channel selectivity
[30] https://www.ofcom.org.uk/consultations-and-statements/category-1/maximising-benefits-700mhz-clearance

DMSL in its response, which would be specifically designed to allow continued reception of the interim multiplexes.[31]

3.74 We note the suggestion from Arqiva and Digital UK that improvements to DTT receiving systems would be an alternative approach that would avoid the need for a filter. However, DMSL's response indicates that both filters and improvements to DTT receiving systems are useful, and we understand that DMSL continues to install filters in the majority of, if not all, cases where mobile interference is diagnosed. It is therefore unclear that improvements to DTT reception systems alone would be sufficient to resolve all cases of interference. It would also be questionable whether reception problems which can be resolved without the use of filters are in fact attributable to interference from mobile services.

3.75 Nevertheless, we consider this information helpful confirmation that our estimates of the likely scale of interference from 700 MHz mobile services are likely to be upper estimates, and improvements to aerial installations already undertaken by DMSL may make many households less vulnerable to interference from 700 MHz mobile services.

3.76 In addition, we note that evidence from the ongoing roll-out of mobile services in the 700 MHz band in France continues to show a much lower number of interference cases, relative to the number of base stations deployed, than that seen for the 800 MHz band.

3.77 We consider that, in practice, the effectiveness of filters will not be limited by handset OOB emissions. As discussed earlier in this section, our measurements show that real emissions are significantly lower than the regulatory limit and therefore filters should be effective in mitigating interference.

3.78 Furthermore, our May 2017 Technical Report shows that the interference signal received at the rooftop is much lower than the worst case for the vast majority of the time. For example, figure 6.2 in our Technical Report shows that, for 99.999 % of the time, there is an effective 20 dB reduction in interference levels from the peak, and this would apply to adjacent channel leakage, meaning levels better than -76 dBm/8 MHz.

3.79 With regard to group K aerials, we note the concerns raised. As discussed above, the potential impact on reception of interim multiplexes will need to be managed by Arqiva. However, we agree that it will be important to avoid the risk of viewer confusion. We noted in our consultation that the use of group K aerials would not be appropriate where channels above channel 48 are in use.

3.80 We do not have any plans to actively promote the use of group K aerials at this time. We will keep this under review and engage with relevant stakeholders at a later date as appropriate. However, we do think it would be appropriate for industry to get ready for the use of group K aerials in the future (including benchmarking such aerials). These aerials have higher gain than group T aerials of the same size and they do have future benefits in terms of interference mitigation.

[31] We also note that these filters would not help in reducing any interference from future supplementary downlink use and this could result in such filters needing to be replaced at a later date.

Summary of conclusions and next steps

3.81 We have carefully considered the information and evidence provided in consultation responses. Overall, they do not alter our (provisional) assessment set out in our May 2017 consultation, and we draw the high-level conclusions that:

- the impact of interference from 700 MHz base stations will be no greater than the impact seen in the 800 MHz band;
- there will be a minimal risk of interference from mobile handsets; and
- receiver filters will be the most technically effective means to mitigate interference from handsets and base stations.

3.82 We also note that there are reasons to consider that the risk of interference from mobile base stations may be considerably lower than that seen for the 800 MHz band. Some respondents suggested that the majority of 800 MHz interference cases were resolved through improvements to the receiving system and that this could reduce the likelihood that these households would need 700 MHz filters. Also, evidence from the ongoing 700 MHz roll-out in France continues to show a much lower number of interference cases than that seen for the 800 MHz band. We will continue to monitor these figures as the 700 MHz roll-out in France continues.

3.83 As noted in our consultation, the conclusions on coexistence risks presented in this document will feed into further work to consider the policy options for managing the coexistence risks, and we expect to consult on this work next year.

A1. Out-of-band handset measurements

Laboratory work to understand real handset emissions

A1.1 To understand typical out-of-band (OOB) emissions from handsets that could leak into the spectrum used for DTT, Ofcom conducted a series of laboratory measurements using a representative sample of consumer handsets supporting the 700 MHz band (LTE band 28).

A1.2 The purpose of the tests was to measure the contribution of the handsets into DTT channel 48 (686 - 694 MHz) considering emissions from LTE 5, 10, 15 and 20 MHz channel bandwidths occupying various frequency blocks.

A1.3 We selected a sample of six popular handsets available on the UK market in 2017, and one that was available on the APT market from 2014 (representing a roaming mobile engineered to a less demanding standard that pre-dates the -42 dBm/8 MHz agreement in CEPT[32]).

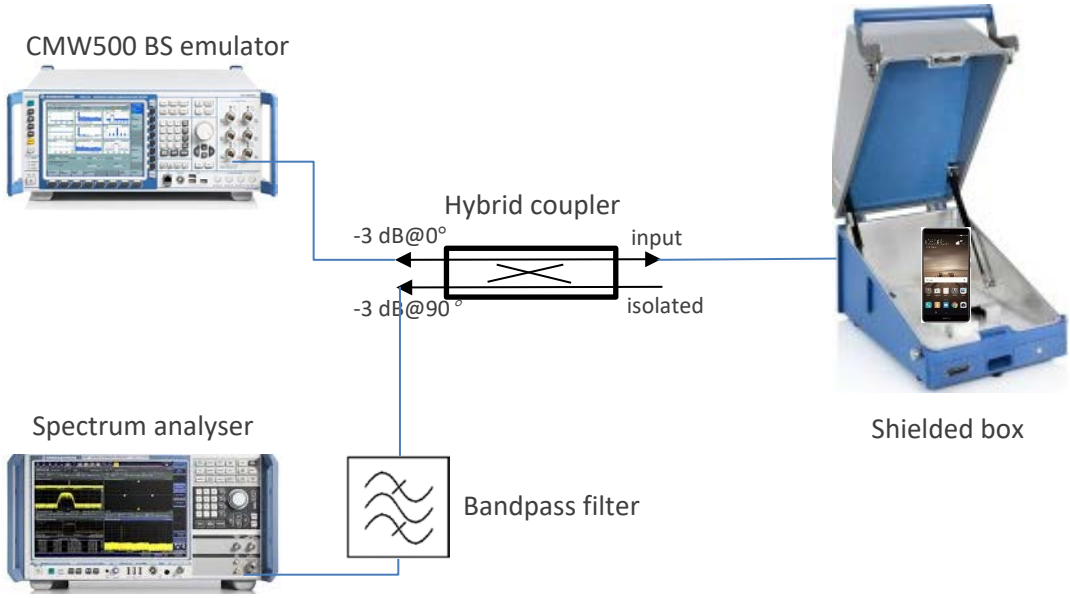
Measurement arrangement to capture low-level leakage

A1.4 The test setup consisted of a base station emulator connected to a test mobile via an antenna coupler in a shielded box. The emulator was configured to cause the mobile to emit the highest power signal for various LTE configurations, which was then observed on a spectrum analyser.

A1.5 To facilitate low-levels of OOB leakage to be observed, the mobile signal was filtered to attenuate the LTE signals above 694 MHz, thus allowing the noise floor of the instrument to be reduced and reveal underlying emissions.

[32] CEPT Report 53 approved on 28 November 2014 by the ECC.
http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP053.PDF

Figure 1: Handset test setup



A1.6 To account for varying amplitude and bandwidth effects, the tests were carried out for two modulation schemes for full and partial resource block (RB) configurations. Partial RB allocations are specified in the 3GPP standard for handset conformance testing.[33] The standard also identifies where to stack partial RB allocation, i.e., to the low and high band edge respectively.

A1.7 The LTE configurations used for testing each handset are as shown in Table 1.

Table 1: LTE modulation and resource block configurations

Centre frequency MHz	Channel bandwidth MHz	Uplink modulation scheme	Uplink resource blocks	Comments
705.5	5	QPSK, 16QAM	25 (full), 8 (partial)	F_{offset} = 15.5 MHz, partial RB stack low
708	10	QPSK, 16QAM	50 (full), 12 (partial)	F_{offset} = 18 MHz, partial RB stack low
710.5	15	QPSK, 16QAM	75 (full), 16 (partial)	F_{offset} = 20.5 MHz, partial RB stack low
713	20	QPSK, 16QAM	100 (full), 18 (partial)	F_{offset} = 23 MHz, partial RB stack low

[33] ETSI TS 136 521-1, v14.4.0, 2017-11, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE); conformance specification; Radio transmission and reception; Part 1: Conformance testing. http://www.etsi.org/deliver/etsi_ts/136500_136599/13652101/14.04.00_60/ts_13652101v140400p.pdf

725.5	15	QPSK, 16QAM	75 (full), 16 (partial)	F_{offset} = 35.5 MHz, partial RB stack low
723	20	QPSK, 16QAM	100 (full), 18 (partial)	F_{offset} = 33 MHz, partial RB stack low
n.b. F_{offset} denotes the offset between centre frequencies of LTE and DTT channel 48.				

Results organised by emission width and proximity to channel 48

A1.8 Table 2 shows the highest OOB power measured in channel 48 for each handset with different bandwidth arrangements. The (low) bandwidth columns give figures for blocks situated at the lower end of the uplink band (i.e. nearer to channel 48) creating an edge-to-edge DTT channel 48 – LTE uplink separation of 9 MHz. The (high) bandwidth columns give figures for blocks situated at the top end of the uplink band. The results in Table 2 show that, across the 7 handsets, the maximum emission into channel 48 for 5, 10, 15 and 20 MHz bandwidths at the lower end of the uplink band are -57, -56, -53 and -52 dBm respectively. In the case of 15 and 20 MHz bandwidths at the top end of the uplink band, the maximum emissions into channel 48 are -69 and -62 dBm respectively.

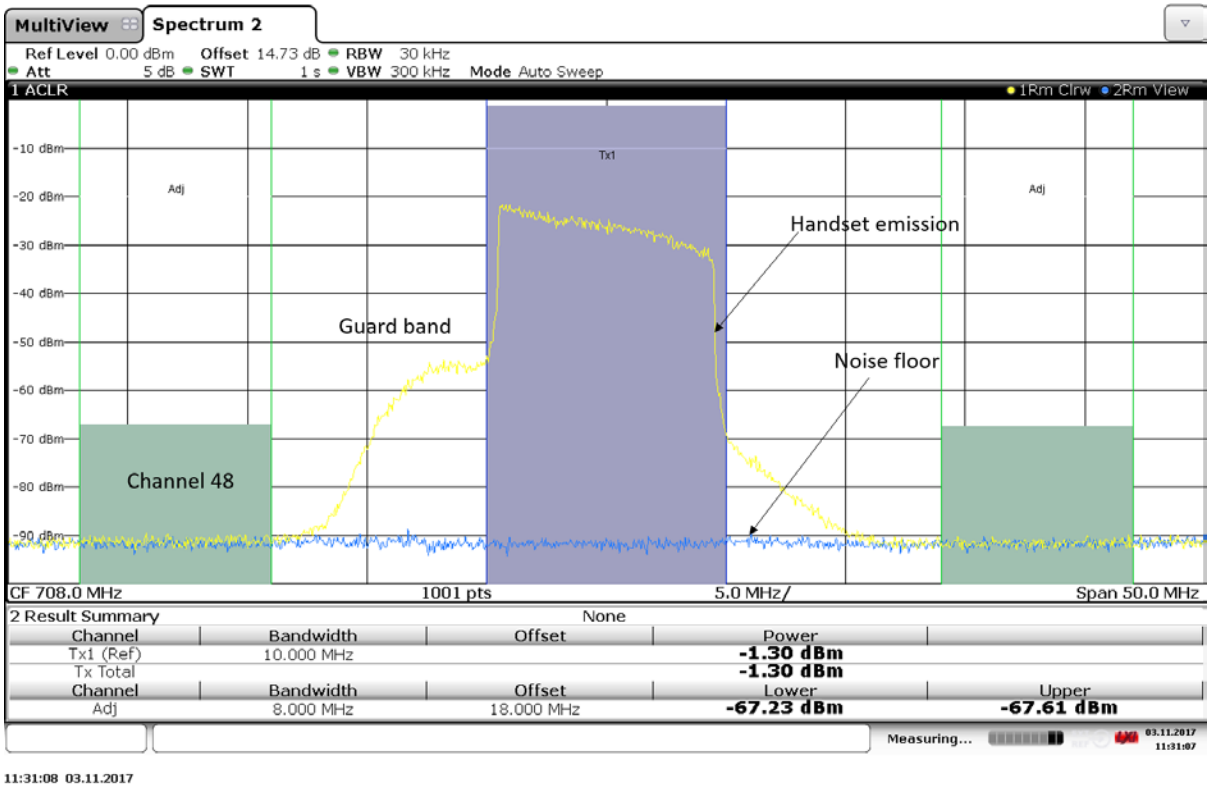
A1.9 In the vast majority of cases, the emissions measured in channel 48 were below the sensitivity of the test setup, so the figures presented are higher than actual levels. Emissions to channels below channel 48 were substantially lower than for channel 48 and mostly invisible with respect to the measurement noise floor.

Table 2: OOB Emissions into channel 48

	OOB power in channel 48 dBm/8 MHz					
User Equipment	**5 MHz (low)**	**10 MHz (low)**	**15 MHz (low)**	**20 MHz (low)**	**15 MHz (high)**	**20 MHz (high)**
handset 1	-57	-56	-53	-52	-71	-62
handset 2	-62	-62	-59	-55	-71	-64
handset 3	-62	-61	-59	-52	-74	-66
handset 4	-63	-63	-62	-62	-72	-71
handset 5	-62	-61	-62	-61	-75	-70
handset 6	-61	-61	-60	-59	-70	-65
handset 7	-64	-64	-64	-64	-69	-69
Maximum	-57	-56	-53	-52	-69	-62
Median	-62	-61	-60	-59	-71	-66

A1.10 Figure 2 illustrates a spectrum response plot for a handset configured to transmit within a 10 MHz bandwidth at the lower end of the uplink band (i.e. with 9 MHz separation from DTT channel 48). In Figure 2, the spectrum analyser measures the net power in channel 48 as -67 dBm/8 MHz.

Figure 2: Example measurement of OOB emission.



Summary of measurement results

A1.11 Our results show that the worst mobile handset on test operating at a 5/10 MHz channel bandwidth produced a maximum OOB emission level of -56 dBm/8 MHz in channel 48. This level is substantially lower than the maximum level agreed in CEPT.

A1.12 Considering larger bandwidths of 15/20 MHz at any position within the uplink band, the OOB emissions were no worse than -52 dBm/8 MHz, which is still 10 dB better than the CEPT limit.