R-Book 7

Installers guide to UHF

Supporting the installation of all UK DTT and satellite platforms

What's new:

- 700 MHz – the latest on the Clearance programme
- Satellite distribution
- Radio Equipment Directive

Developed in partnership with the Confederation of Aerial Industries

Trade Association for Content Delivery

Introduction

The first R-Books - publications covering the installation of digital television receiving systems - were written between 2001 and 2005. The 'R' stood for reception, although the original books also covered cabled distribution systems.

Since 2005 the television industry has undergone a technical transformation, including the migration from analogue services and the introduction of DVB-T2 transmission technology.

In parallel, demand for spectrum has increased at pace resulting in a range of new technologies and services operating at frequencies in and around those utilised by digital television, which previously has not been the case.

These developments in spectrum allocation are set to continue with the change of use of the 700 MHz band.

In order to provide guidance on how these changes could impact digital television reception, the DTG and CAI have worked in partnership to bring the R-Book up to date. As such R-Book 6 was published in 2015 with the aim to support and prepare the installation industry for future spectrum changes, including how to deal with the impact they could have on working practices.

It also contained practical advice on interference mitigation as well as advice on the latest industry guidelines.

R-Book 7 retains this valuable information but also builds upon it with the following key updates:

- 700 MHz rollout plans including timescales, frequency plans, maps of key locations, and implications for installers;
- Details of the new European regulations (the Radio Equipment Directive) being introduced in June 2017 applicable to radio reception equipment such as amplifiers, broadcast receivers, LNBs, and active antennas which will have implications for equipment manufacturers and distributors;
- A new section on satellite distribution to give an overview of new equipment required for Sky Q.

Version	Date of issue	Comments
R-Book 6	12/10/2015	Initial version
R-Book 6.1	08/02/2016	Updates referencing decisions made at WRC-15 to confirm the change of use of the 700 MHz band and to hold a review of UHF band usage at WRC 2023.
R-Book 7 Draft V1	30/01/2017	Refresh of existing content and removal of out of date content Addition of 700 MHz rollout plan Addition of Radio Equipment Directive content Addition of satellite distribution section
R-Book 7 Draft V2	22/02/2017	Second review including feedback on draft V1
R-Book 7 Draft V3	07/03/2017	Feedback included from final industry review
R-Book 7 final version	21/04/2017	Final edit
R-Book 7 V1.1	26/05/2017	Clarification added to page 25 on RED as to the definition of placing products on the market and when they need to conform to RED.

Contents

Key Guidelines

1) Aerial installation: DTT channels 49-60 (700 MHz band) are going to be cleared for use by mobile service. Aerial types need to be chosen accordingly.

Group C/D aerials will not cover any of the channels available after the 700 MHz band clearance programme, so the best strategy is to fit a group T aerial if there are currently channels in use above 48, and otherwise to fit a group K, provided these have sufficient gain. Then all available channels can be received, and some rejection of LTE signals is also achieved.

The use of group C/D aerials should be avoided as they will not cover any of the channels available after the 700 MHz band clearance. Installers replacing aerials where signals are currently transmitted in this group are recommended to advise customers about clearance and offer a wideband (group T) model.

2) LTE at 800 MHz: With more LTE networks rolling out across the UK there is a small chance of disruption to Freeview services.

Installers who believe that disruption to a DTT installation is caused by LTE 800 interference should contact at800. This is the advice even if the installer is able to rectify the issue so that all cases of interference can be followed up.

at800 contact centre: 0333 31 31 800 or 0808 13 13 800

3) Amplification that is no longer required increases the chances of LTE interference at 800 MHz.

LTE Base Station interference mitigation steps are:

- Remove any unnecessary amplifiers; and
- Where there is no filter integrated into the amplifier design, to fit a filter before the input to any remaining amplifiers or active device such as a multiswitch.

4) The need for masthead amplifiers has significantly reduced since digital switchover.

Do not use masthead amplifiers unless they are absolutely necessary.

5) If an installation does need a masthead amplifier, the following steps are recommended:

- Place it as close to the aerial as possible;
- Place it ahead of any significant losses from feeders, passive splitters, etc.;
- Install an appropriate filter before the amplifier (if a filter is not part of the amplifier design) to reduce vulnerability to interference from e.g. LTE; and
- Use an amplifier with the lowest gain consistent with adequate performance in order to minimise the risk of overload from LTE.

6) Mitigating the impact of amplifier overload.

If an amplifier is generating too much intermodulation noise due to overloading by strong signal levels, reduce the level of signal at the input, or reduce the amplifier's gain. Although this will reduce the signal level at the output, it will increase the C/N at the output.

7) Steps to reduce impulsive interference include making sure:

- The downlead uses benchmarked cable;
- The aerial has a balun (Note baluns are intrinsic to the design of log periodic aerials);
- The outlet plate and fly lead are well screened; and
- An appropriately high level of signal is being delivered to the outlet.

Persistent cases of impulsive interference should be reported to the Radio & Television Investigation Service (https://www.radioandtvhelp.co.uk/diagnostic/).

8) In the absence of adjacent channel interference e.g. from a LTE base station, ensure that DTT signal levels at outlet plates meet the criteria below in order for receivers to perform well:

Mode	Used by multiplex	Example service	Minimum level	Maximum level	Minimum C/N (MER)
DVB-T 64QAM 2/3	PSB1 PSB2	BBC1 (SD) ITV (SD)	50 dBµV	75 dBµV	23 dB
DVB-T 64QAM 3/4	COM4 COM5 COM6	ITV3 Dave 4Music	50 dBµV	75 dBµV	25 dB
DVB-T2 256QAM 2/3	PSB3	BBC1 (HD)	50 dBµV	75 dBµV	26 dB

Note: these figures are taken from CAI codes of practice COP 1 for single dwelling units and COP 2 for multi dwelling and commercial units

Section 1: Background of spectrum use

A Bright Future for DTT

Free to air digital terrestrial TV (DTT) is the most popular television platform in the UK and across much of the EU, with many homes using this as their primary source of TV.

It provides viewers with significant benefits including universal coverage and free to air services. This has become further enhanced, via an internet connection, by the availability of catch up and interactive services as well as ancillary screen, HD and PVR technology.

Ofcom has also stated that it believes DTT is likely to retain a central role in the UK over the next decade, with a full switch over to alternative technologies such as Internet Protocol TV (IPTV) not likely until post 2030[1].

The DTT industry continues to work to ensure it meets consumers' expectations up to 2030 and beyond. Despite different DTT technology adoption roadmaps across Europe, DTT remains the most popular way of watching TV in Europe, reaching over half of Europe's population.[2]

Increasing demand for spectrum

The spectrum used by DTT has been under increasing pressure for use by other sectors due to the favourable propagation characteristics of these frequencies. This has led to a need for DTT receivers to work alongside other technologies operating in both adjacent and the same frequency bands and means that future DTT installations will need to account for the potential of new technologies becoming sources of interference.

The implications for installation practices are covered in Section 2 of this guide. In addition, existing technologies such as Programme Making and Special Event (PMSE) equipment require access to share DTT spectrum, and the number of DTT multiplexes is also increasing with the introduction of Local TV services.

The list below highlights the new and existing technologies and services that utilise UHF spectrum and that are explained further in this guide:

- DTT services including local TV and interim multiplexes
- 800 MHz LTE* mobile services
- 700 MHz LTE* mobile services
- TV White Space

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[1] https://www.ofcom.org.uk/__data/assets/pdf_file/0033/79584/update-strategy-mobile-spectrum.pdf

[2] https://www.ebu.ch/news/2016/11/legal-certainty-for-digital-terrestrial-television-crucial-for-broadcasters-and-european-cultural-and-creative-industries-says-e

- Programme making and special event (PMSE) equipment

*LTE refers to Long Term Evolution which is a standard for wireless communication for mobile phones and data terminals. It is one of the technologies along with HSPA+ and WIMAX that was allowed by the ITU to be classified as 4G technology.

DTT services

The DTT platform carries a wide range of TV channels. DTT transmitters broadcast a number of signals, called multiplexes, each of which contains multiple TV channels or radio services. Currently, the following multiplexes hold licences to broadcast on the DTT platform:

- Three PSB multiplexes – BBC and D3&4 provide these multiplexes. They broadcast from all of the transmitters in the DTT network and are available to around 98.5% of households. These multiplexes carry a range of PSB services, including the BBC's channels, ITV, ITV2, 3 and 4, Channel 4 and Channel 5. Two of the multiplexes carry Standard Definition ('SD') channels only. One of the multiplexes carries the High Definition ('HD') variants of some of the PSB channels.
- Three commercial multiplexes – these are licensed to Arqiva Services Limited and SDN. They broadcast from the largest 80 transmitters achieving coverage of around 90% of households. These carry a wide range of channels including ITV 2+1, ITV 3+1 and ITV 4+1.
- Northern Ireland multiplex – one multiplex that broadcasts RTÉ and TG4 services from three transmitters and covers approximately 78% of households in Northern Ireland.
- Local Television Multiplex – this broadcasts local TV services in over 20 locations across the country with more expected in coming years. Ofcom has to date licensed 30 channels to deliver local TV services across towns and cities in the UK[3]. The general principle is that local TV is transmitted from the same mast as national services so that households do not need to re-position their aerial to receive it. However, there are exceptions so please refer to Annex A of this guide for how to find details. Local TV is transmitted on channels 21-30 and 39-60 as per the national service but typically it is transmitted at about half the height of the main aerial due to the smaller coverage area required. It is also generally transmitted at a lower power compared to the national commercial and public service broadcast multiplexes but using a more robust transmission mode to compensate.
- Geographic Interleaved spectrum multiplexes - two portions of spectrum that can be used to provide a DTT multiplex in Manchester and Cardiff. The service in Cardiff has not been launched.

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[3] http://www.localtv.org.uk/

- Interim multiplexes – In 2013 Ofcom awarded interleaved spectrum in the 600 MHz spectrum band (550 – 606 MHz) to Arqiva on an interim basis by granting a single licence for the establishment of two temporary DTT multiplexes using DVB-T2/MPEG4 technology. These multiplexes have now both launched. They carry a range of HD and SD services and cover around 76% of households.

800 MHz LTE

The increase in demand for spectrum has seen DTT frequencies in the 800 MHz band (790-862 MHz), comprising channels 61-68 auctioned to mobile operators in 2013. DTT services using channels 61-68 were moved to lower channels to accommodate this change.

700 MHz LTE

In addition, the 700 MHz band (694-790 MHz) comprising channels 49-60 is to be used for mobile broadband, meaning a further reduction in DTT spectrum of around 30%. Ofcom has set out a plan to repurpose the 700 MHz band for use as mobile broadband in the UK by Q2 2020[4]. The decision to identify the 700 MHz band for mobile use was made at the World Radio Conference in November 2015 (WRC 15) held in Geneva. These conferences are held every three to four years in order to revise international radio regulations where appropriate. Figure 1 shows the current and future layout of the UHF frequency bands IV and V along with their uses, and highlights the change following a 700 MHz clearance.

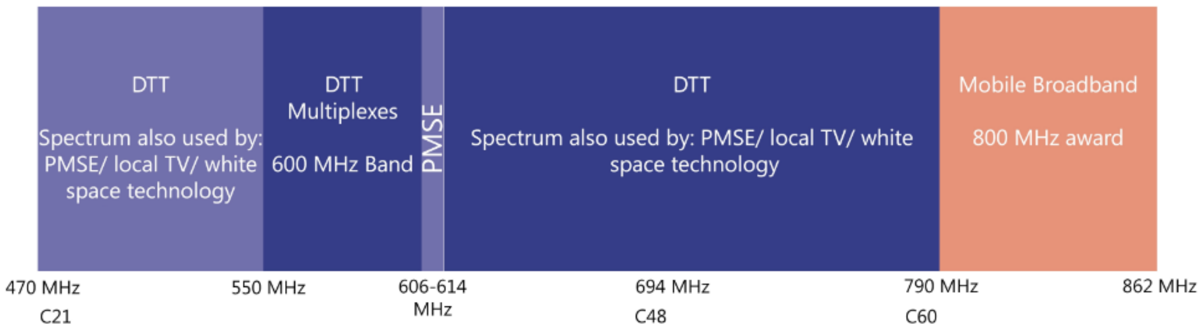


Figure 1a UHF spectrum allocations before 700 MHz clearance

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

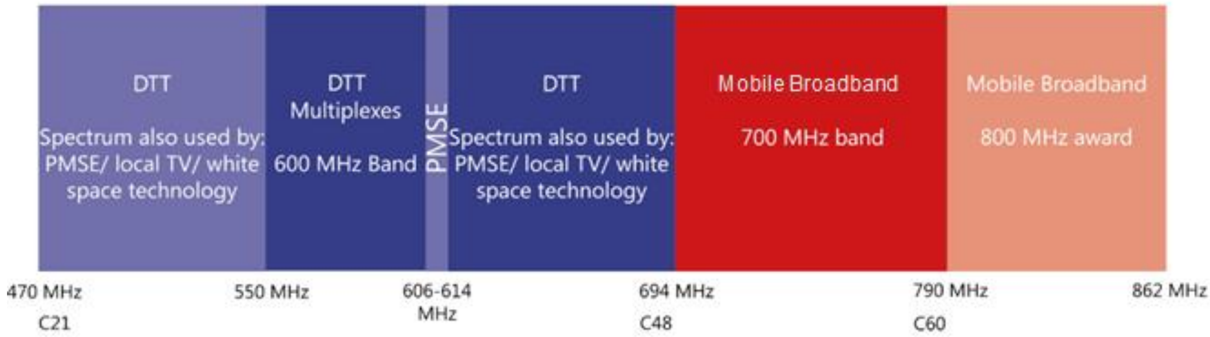


Figure 1b UHF spectrum allocations after 700 MHz clearance

TV White Space

The Ofcom framework for TV White Space (TVWS) enables DTT channels that are not in use in particular geographical areas to be used for low power applications such as internet access. Access to these unused DTT channels is governed by a series of White Space Databases[5]. The databases are used to ensure that TV White Space Devices (WSDs) only use frequencies and power levels that will have a low probability of causing interference to DTT.

Programme making and special event equipment (PMSE)

PMSE equipment such as wireless microphones, in-ear monitors and wireless cameras has access to the same frequencies that DTT uses for both transmitting and receiving. Channel 38 (606-613 MHz) is dedicated for PMSE use for wireless microphones in the UK. However PMSE equipment can also use other DTT channels on a coordinated basis similar to that used by TVWS. Due to the managed process of allocating licences to PMSE equipment, the risk of interference between PMSE and DTT is minimal.

Frequencies below channel 21

Frequencies below the current DTT spectrum allocation (<470 MHz) are used by a wide range of parties to deliver a diverse set of services. It is not considered that these services currently pose a coexistence problem for DTT, which means that they are unlikely to cause interference. However the frequency range 410 MHz to 470 MHz is currently under review by Ofcom[6].

[5] https://www.ofcom.org.uk/spectrum/spectrum-management/TV-white-space-databases
[6] https://www.ofcom.org.uk/__data/assets/pdf_file/0033/95991/Strategic-Review-of-UHF-Band-1-and-Band-2-410-to-470-MHz.pdf

Ofcom's announced policies and dates

800 MHz LTE (791 MHz/channel 61 - 862 MHz/channel 68)

Overview of 800 MHz LTE

Licences to use the 800 MHz band were awarded on the 1st March 2013 following the auction process in January 2013. As a result, frequencies that were previously occupied by DTT channels 61-68 were allocated for use by LTE.

As can be seen from Figure 2, LTE base stations operate in the frequencies immediately adjacent to DTT channel 60 whereas the LTE handsets (UE – user equipment) operate in the uplink frequencies separated from DTT by 42 MHz.

UE: User Equipment
BS: Base station
LTE base stations transmit to user equipment such as mobile phones.

Figure 2 LTE 800 frequency allocations

The advantage of this configuration is that LTE base stations, being closer in frequency to DTT channels, are the most likely sources of interference but their locations will be known and fixed. Interference caused by base stations is easier to deal with than interference caused by handsets which are likely to move location. However it is also possible for UEs to cause interference to TV receivers, typically by signals entering an inadequately screened outlet or flylead, or if the handset is close to the receiver, by signals penetrating the receiver's screening.

Due to the potential for interference to DTT services from LTE 800, the licence agreements for use of the LTE 800 spectrum required the mobile operators to set up a single consumer help scheme, which is now known as at800. There is more on at800 in Section 2 of this document: Mitigating LTE interference

Potential impact to DTT services from 800 MHz LTE

As explained above, there is a potential for interference to DTT services caused by LTE operating in close frequency proximity. The interference could appear as intermittent breaks in audio as well as blocks of errors in the video, as illustrated in Figure 3 below:

Figure 3 Example of picture failure caused by interference

The main path for the LTE signal to reach the DTT receiver is from the rooftop aerial. LTE 800 uses the frequencies previously used by broadcast television, which means that these frequencies can be picked up by aerials which operate up to channel 68. The potential for interference can be increased where households use amplifiers in their DTT installation, as these can be easily overloaded by strong LTE signals.

There are also other mechanisms for LTE interference to occur, such as ingress via poorly shielded faceplates and cabling. Installers are recommended to use benchmarked cabling to help avoid this. On occasion, interference can also be caused by direct ingress of the interfering signal through the receiver chassis itself.

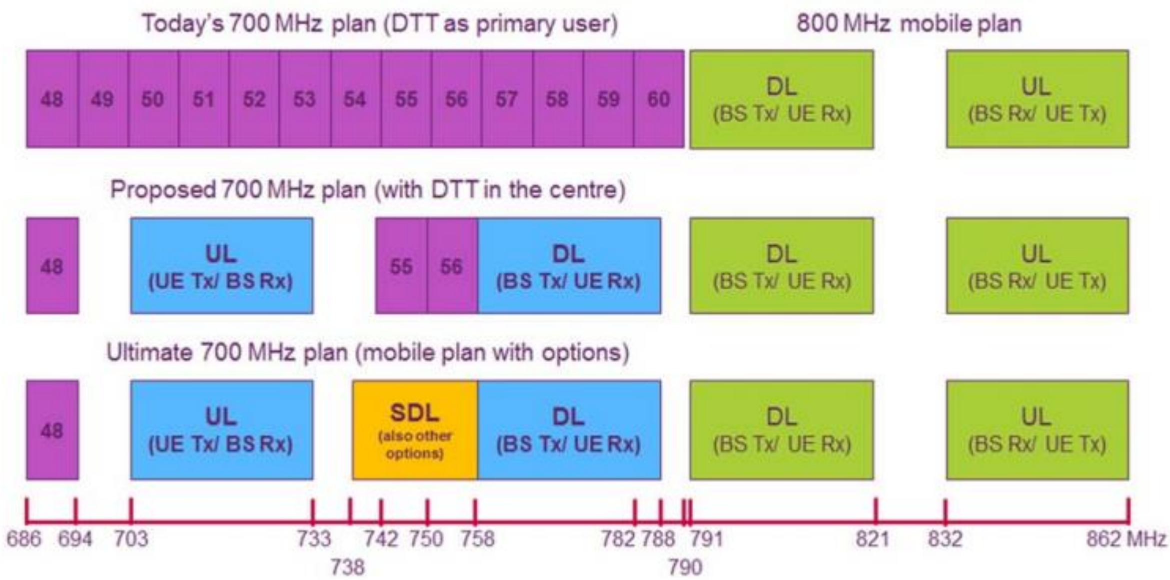
Filtering can be applied in most circumstances to resolve LTE interference issues. The filters work by reducing the level of the LTE signal whilst allowing the DTT signal to pass through with only a small reduction in level. Further information on filtering and how to mitigate the impact of amplifiers on LTE interference is given in section 2 of this document.

700 MHz Clearance for mobile broadband (694 MHz/channel 49 - 790 MHz/channel 60)

Overview of 700 MHz LTE

The 700 MHz band was identified as a potential candidate for mobile broadband spectrum due to the band's favourable propagation characteristics as well as the opportunity to allocate the same band to mobile services in many regions around the world. The advantage of having harmonised spectrum allocations will be a reduction in the cost of network and user equipment required to deliver mobile broadband services due to increased economies of scale. In addition, it will lead to improved consumer experience when roaming between different countries as it will be possible to use the same handset in multiple regions.

The main difference between 700 MHz and 800 MHz allocations for LTE is that at 700 MHz, LTE handsets will transmit in the frequencies closest to the DTT frequencies. In 800 MHz LTE the position is reversed with base stations transmitting on the frequencies closest to DTT. The proposed band plan, as shown in Figure 4 below, will mean there is a 9 MHz guard band between DTT channel 48 and the frequencies used by the LTE handsets. This will leave a larger separation than for 800 MHz LTE where there is a 1 MHz guard band between LTE and DTT services. The 9 MHz guard band should simplify filter design compared to the design required for a 1 MHz guard band, resulting in cheaper products.



UE = User Equipment
BS = Base station
DL = Downlink
UL = Uplink
SDL = Supplementary downlink (LTE capacity in downlink only)
LTE base stations transmit in the downlink to user equipment such as mobile phones which in turn transmit to base stations in the uplink.

Figure 4 Existing, proposed and ultimate 700 MHz frequency allocations[7]

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

Key points associated with 700 MHz clearance:

- The change of use of the 700 MHz band (channels 49-60) to make it available for mobile services was confirmed at WRC 15;
- Ofcom is currently preparing to change the use of the 700 MHz band (channels 49-60) from DTT to mobile broadband from Q2 2020;
- Clearance of 700 MHz frequencies is scheduled to begin during 2017;
- The interim multiplexes known as COM 7 and 8 will temporarily move into channels 55 and 56 from their current channels (31 to 37, excluding 36) during the clearance. This is to allow the 6 other main multiplexes currently using 700 MHz frequencies to be moved into channels 31 to 37 to clear the 700 MHz band. The intention is that the interim multiplexes are turned off by the end of Q1 2020 to make way for mobile use (LTE Supplementary Downlink/SDL) in channels 55 and 56. A list of the channels that are transmitted on the interim multiplexes is shown below;

LCN	Service	Genre	Mux	E	W	S	NI	CI
56	5USA+1	General Entertainment	COM7 HD	✓	✓	✓	✓	
57	VIVA	General Entertainment	COM7 HD	✓	✓	✓	✓	
67	CBS Reality +1	General Entertainment	COM7 HD	✓	✓	✓	✓	
71	CBS Drama	General Entertainment	COM7 HD	✓	✓	✓	✓	
77	Rishtey Europe	General Entertainment	COM7 HD	✓	✓	✓	✓	
81	TalkingPictures TV	General Entertainment	COM7 HD	✓	✓	✓	✓	
82	Vintage TV	General Entertainment	COM7 HD	✓	✓	✓	✓	
86	VIVA+1	General Entertainment	COM7 HD	✓	✓	✓	✓	
87	Keep It Country	General Entertainment	COM7 HD	✓	✓	✓	✓	
106	BBC FOUR HD	HD	COM7 HD	✓	✓	✓	✓	
107	BBC NEWS HD	HD	COM7 HD	✓	✓	✓	✓	
108	Al Jazeera Eng HD	HD	COM7 HD	✓	✓	✓	✓	
109	Channel 4+1 HD	HD	COM7 HD	✓	✓	✓	✓	
110	4seven HD	HD	COM7 HD	✓	✓	✓	✓	
113	RT HD	HD	COM7 HD	✓	✓	✓	✓	
124	CBeebies HD	Children's	COM7 HD	✓	✓	✓	✓	
245	Planet Knowledge	Streamed channels	COM7 HD	✓	✓	✓	✓	
733	Trans World Radio	Radio	COM7 HD	✓	✓	✓	✓	
55	5STAR+1	General Entertainment	COM8 HD	✓	✓	✓	✓	
63	Community	General Entertainment	COM8 HD	✓	✓	✓	✓	
91	Front Runner	General Entertainment	COM8 HD	✓	✓	✓	✓	
111	QVC + 1 HD	HD	COM8 HD	✓	✓	✓	✓	
112	QVC Beauty HD	HD	COM8 HD	✓	✓	✓	✓	

Table Key

Areas
E: England
W: Wales
S: Scotland
NI: Northern Ireland
CI: Channel Islands

Figure 5 Television services carried on the interim multiplexes[8]

- Frequency clearance events start in Q3 2017 and the interim multiplexes will be moved to channels 55 and 56 by the end of the clearance programme;
- Frequency clearance work is due to be completed by Q2 2020 – a map showing the rollout plan is shown below;
- Ofcom has outlined its intention to secure DTT spectrum below 694 MHz for use by DTT until 2030.

8 http://www.digitaluk.co.uk/channels/channel_listings - correct as of Jan 2017

Figure 6 Ofcom's 700 MHz clearance schedule[9]

9 https://www.ofcom.org.uk/__data/assets/pdf_file/0026/97361/700MHz-clearance-update-08022017.pdf

What changes are taking place during 700 MHz clearance?

The DTT transmitter network is made of up to 9 multiplexes and 1,156 TV transmitters:

- There are 80 principal transmitters carrying 3 commercial multiplexes and 3 public service broadcast (PSB) multiplexes;
- There are over 1100 smaller relay transmitters that receive the 3 PSB feeds from the main transmitters and re-transmit them on different frequencies in order to extend PSB coverage;
- There are 2 interim commercial multiplexes carried on 30 principal transmitters;
- There is 1 local TV multiplex which broadcasts local TV in over 20 locations across the country.

In order to implement the 700 MHz clearance:

- a number of the principal transmitters will require infrastructure changes;
- Some main antennas and reserve antennas will need replacing;
- To accommodate the work some temporary masts may be needed;
- A number of relay sites will need antenna replacements;
- Transmission systems at some relay sites will need retuning.

The first stage of the work is carrying out the antenna re-engineering. This is highly weather dependent and a complex operation.

The antenna works will be carried ahead of the clearance events where the transmitter systems are taken offline and retuned and combiner systems are installed and retuned.

Below are pictures of the antennas carried at a typical transmitter site and an example of the work that takes place to replace the antennas.

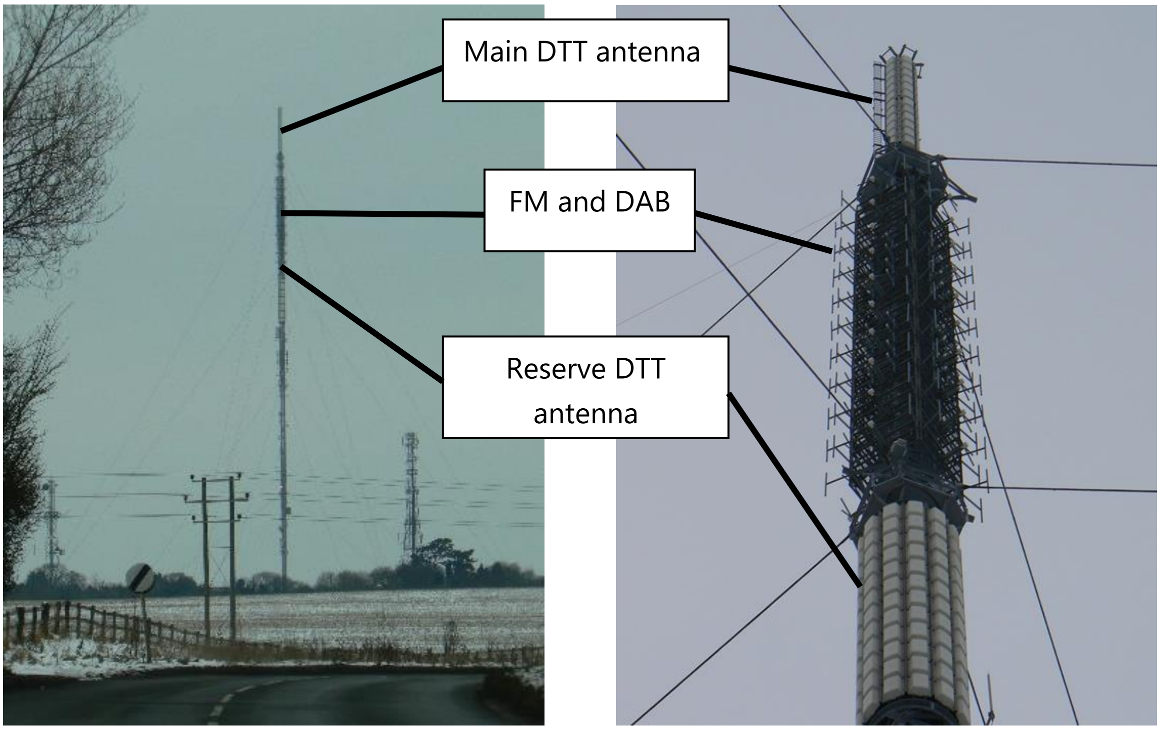


Figure 7 A helicopter being used to install an antenna[10]

[10] Photos courtesy of Ofcom

Potential impact to consumers and DTT services from 700 MHz clearance

Aerial replacements – it is estimated by Ofcom that between 100,000 and 160,000 households may need to replace their antennas due to the new use of out-of-group channels. For detailed information on areas most likely to be affected due to frequency changes please see the Aerials section of this document.

Aerial repointing – it is estimated by Ofcom that between 40,000 and 110,000 households may need to repoint their antennas to continue to receive a reliable service.

Retunes for 70% of households – 14m to 20m households will need to retune their TVs to retain their service.

90% communications – Digital UK (DUK provides support for the UK's terrestrial TV service[11]) are forecasting that around 90% of households will receive communication between 2017 and 2020 advising them of the need to retune to continue receiving all available services.

For the latest information on DTT transmitter frequencies in any particular area – the advice is to check the DUK postcode checker website[12].

Potential for 700 MHz LTE interference

As is the case with 800 MHz coexistence, base station interference to DTT services could still occur at 700 MHz. The principal mechanism for interference is likely to be overload, particularly of amplified installations. Interference caused by LTE uplink signals from handsets could be more of a problem at 700 MHz than at 800 MHz due to handsets using frequencies close to DTT channel 48. These signals can be picked up by rooftop antennas and presented at the input to the receiver. The transmitted power from handsets is much lower than from base stations, but as handsets will generally be closer to TV aerials than base stations, the potential impact to DTT services remains unclear.

It is likely that a similar solution that is being used for 800 MHz coexistence will be used for 700 MHz i.e. that fixed filters in the DTT installation will block LTE frequencies whilst allowing through DTT frequencies. With LTE services not utilising the 700 MHz band until after Q2 2020, filters are not currently widely available.

The immediate impact of the 700 MHz clearance on DTT installations will be the choice of aerial installed. With any aerial installation expected to span years and possibly tens of years, future-proofing through selecting the correct aerial will prevent issues when LTE 700 MHz comes in to service.

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[11] http://www.digitaluk.co.uk/about_digital_uk
[12] http://www.digitaluk.co.uk/coveragechecker/

Further details of the type of aerial to choose, in order to future proof installations, are given in Section 2 of this document.

TV White Space (TVWS)

Overview of TVWS

TVWS is a term used for DTT spectrum (470-790 MHz) that is unused for DTT services in a particular geographical area. Ofcom has developed a framework to allow TVWS devices to be dynamically allocated access to these frequencies through the use of a TVWS database. The devices will only be used for low power applications to avoid interference into DTT services, and will be licence exempt, although they will need to meet a minimum technical specification.

Ofcom finalised its framework authorising the commercial use of white space technology in 2015[13]. The framework is designed to allow white space devices to operate in DTT frequencies while ensuring minimal risk of causing harmful interference to DTT services.

Potential impact to DTT services from TVWS

As the Ofcom framework is designed to protect DTT services, there should be minimal impact. In addition, at the time of writing, it is not clear as to the level of commercial deployment of white space devices and whether there will be any large scale deployments. However, some commercial deployments have now started[14] in the UK and as such there may be instances where white space devices cause interference to DTT services. In these cases the Ofcom framework can mitigate the interference more or less instantly via control of the white space device's transmit power.

In practical terms, filters will not be available due to the fact the white space devices can operate in a range of frequencies and in the frequencies occupied by DTT. Using grouped aerials will not provide any advantage either, for similar reasons.

Ensuring good quality installations by using screened faceplates and benchmarked cabling will help to prevent ingress of white space device signals. However the main method of mitigation against interference will be the Ofcom framework and the databases that operate the system.

[13] https://www.ofcom.org.uk/consultations-and-statements/category-1/white-space-coexistence
[14] https://www.arranbroadband.co.uk/about-1

Spectrum below 470 MHz/channel 21

Overview of spectrum below channel 21

The frequency bands immediately below DTT channel 21 are known as UHF1 and UHF2 and cover 410-470 MHz. As mentioned earlier in this document, 410-470 MHz is used for a wide range of services including business radio, programme making and special events (PMSE), emergency services, maritime and aeronautical sectors, licence exempt and amateur radio.

While these services do not currently pose particular issues for DTT in terms of potential interference, the band 410-470 MHz is under review by Ofcom. An Ofcom call for inputs[15] on the future of the 420-470 MHz band stated that while previously Ofcom has considered rationalising and re-organising this particular band to align with European allocations, the cost benefit analysis meant that regulatory action could not be justified. In early 2017, Ofcom carried out a strategic review of spectrum below channel 21 and revised the scope to extend the frequency range from 410-470 MHz in order to make a full assessment of the band and inform their spectrum management of it for the next ten years[16].

Potential impact to DTT from services operating below channel 21

It is not currently expected that there will be major changes to the UHF1 and UHF2 bands that could cause a problem to DTT services operating above 470 MHz. However any significant increases in the risk of interference to DTT services arising from the Ofcom review will be reported in future versions of this document as they become available.

15 http://stakeholders.ofcom.org.uk/binaries/consultations/420-470-mhz/summary/420-470-mhz.pdf

16 https://www.ofcom.org.uk/__data/assets/pdf_file/0033/95991/Strategic-Review-of-UHF-Band-1-and-Band-2-410-to-470-MHz.pdf

The Radio Equipment Directive and its impact

The Radio Equipment Directive[17] (RED) is new EU legislation which replaced the Radio & Telecommunication Terminal Equipment Directive (R&TTE) from 13th June 2016 with a one year grace period for compliance. As such meeting the requirements of the RED will be compulsory from 13th June 2017 in order to CE mark equipment and sell it in the EU. The aim of directives like these is to ensure that equipment sold in the EU meets minimum technical requirements and to encourage the use of common standards.

New product requirements

RED differs from the R&TTE directive in that the new directive covers equipment designed to transmit or receive radio waves, whereas the R&TTE directive only covered devices that transmit.

This is stipulated in the RED which states:

"Equipment which intentionally emits or receives radio waves for the purpose of radio communication or radio determination makes systematic use of radio spectrum. In order to ensure an efficient use of radio spectrum so as to avoid harmful interference, all such equipment should fall within the scope of this Directive."

In addition the essential requirements for equipment are stated in article 3 of RED and 3.2 states requirements for spectrum usage:

"Radio equipment shall be so constructed that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference."

As such, the following products must now demonstrate compliance to the RED from June 13th 2017:

- **Broadcast receivers** e.g. TV receivers, DAB/DAB+/DRM/FM/AM radios;
- **Amplifiers** such as loft and masthead amplifier for distribution of TV signals;
- **Active antennas** such as indoor antenna for TV reception that contain amplifiers.
- **Satellite receivers and LNBs**

Note this list is not exhaustive and any products that intentionally emit or receive radio waves are required to demonstrate compliance to the RED.

[17] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0053&qid=1484051728942&from=en

How to demonstrate compliance to RED

In order for receiver products to demonstrate compliance to article 3.2 of the RED i.e. that they effectively use and support efficient use of radio spectrum, a number of new standards have been developed in ETSI working groups.

The following list shows which specifications apply to which products (these are freely available from the ETSI website[18]:

- EN 303 340 – Digital Terrestrial TV Broadcast Receivers
- EN 303 354 – Amplifiers and active antennas for TV broadcast reception in domestic premises
- EN 303 372-1 Satellite earth stations and systems; satellite broadcast reception equipment; Part 1: Outdoor unit
- EN 303 372-2 Satellite earth stations and systems; satellite broadcast reception equipment; Part 2: Indoor unit

Products placed on the market from June 13th 2017 must pass these standards. Equipment built according to these standards can declare conformity and be placed on the market.

The definition of placing a product on the market is in the Blue guide[19]. The Blue guide defines the rules for implementation of EU product rules and states the following:

— A product is placed on the market when it is made available for the first time on the Union market.

— Products made available on the market must comply with the applicable Union harmonisation legislation at the moment of placing on the market.

In addition, making a product available on the market is defined as follows:

— A product is made available on the market when supplied for distribution, consumption or use on the Union market in the course of a commercial activity, whether in return for payment or free of charge.

If a product is placed on the market before June 13th 2017 but is not sold until after this date, then it can continue to be sold so long as it conformed to the legislation applicable at the time it was first placed on the market. This is defined in RED FAQs[20].

This covers examples where products have bought by a distributer or retailer prior to June 13th 2017 but then do not get sold to a consumer until after June 13th 2017. However

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[18] http://www.etsi.org/standards-search#Pre-defined Collections
[19] http://ec.europa.eu/DocsRoom/documents/18027/
[20] http://ec.europa.eu/DocsRoom/documents/22888

products that are placed on the market after June 13th 2017 must still be compliant, even if they are the same product line i.e. the legislation applies to individual products, not product lines.

New obligations for distributors

The RED introduces obligations on anyone who makes equipment available on the market. Previously under R&TTE it was only the manufacturer who was responsible for all aspects of compliance.

Under RED, the distributor must verify that equipment they place on the market has CE marking and crucially that it also has the documents to accompany this.

The definition of a distributor in RED is given as:

"The distributor means any natural or legal person in the supply chain, other than the manufacturer or the importer, who makes radio equipment available on the market."

And their requirements are:

"Before making radio equipment available on the market distributors shall verify that the radio equipment bears the CE marking, that it is accompanied by the documents required by this Directive and by the instructions and safety information in a language which can be easily understood by consumers and other end-users in the Member State in which the radio equipment is to be made available on the market, and that the manufacturer and the importer have complied with the requirements set out in Article 10(2) and (6) to (10) and Article 12(3) respectively"

As such, from 13 June 2017, it will be a legal requirement for distributors including retailers to ensure that the products they sell are compliant with the RED and, along with that, there will be strengthened market monitoring through traceability of the conformance documentation.

Section 2: Installation practices

Introduction

This section provides an overview of typical DTT and satellite distribution equipment that's available as well as examples of typical scenarios for which they may be deployed. In addition there is also an overview of technologies that could potentially cause interference to DTT and satellite services and what techniques can be employed in order to mitigate the risk as far as possible.

Cases of interference can be very difficult to solve, especially when they are intermittent. It is particularly important to have a good understanding of interference in its many forms, and also the behaviour of receivers and amplifiers, if an installer is to be successful in resolving interference problems.

Consider the case of a receiving installation that has been working well. An LTE base station is powered up nearby, and provides sufficient interference to move the operating point of the receiver into the region close to failure (the cliff edge) - see Figure 22. By itself, this interference causes no impact on the picture, but now impulsive interference from passing traffic causes decoding errors, and the familiar blocking in the picture. The cause is the arrival of the LTE base station, but the effect is that of impulsive interference from traffic. The installation engineer called to solve the problem goes looking for solutions to impulsive interference, whereas fitting a suitable filter to reduce the LTE base station interference would restore the system to satisfactory operation.

The potential sources of interference are summarised in Annex C – Summary of interference mechanisms into DTT and guidelines for mitigation.

Impulsive interference

Impulsive interference can originate from a wide range of sources, but most often from devices that generate sparks, either intentionally or otherwise. Typical sources include:

- Vehicle ignition systems, particularly motorcycles, which do not benefit from the metallic shielding that a car has;
- Light switches;
- Central heating thermostats, the suppression capacitors in these being notorious for becoming ineffective after a few years of use;
- Electric motors, particularly the type with brushes and a commutator; and
- Poorly maintained electric fences.

Impulsive interference typically has significant energy at all frequencies up to about 1 GHz, and lower TV channels are affected more than higher channels. DVB-T multiplexes are affected considerably more severely than DVB-T2.

Mitigating impulsive interference

Since impulsive interference affects all TV channels, it can be regarded as being on the same channels as the multiplexes to be received, known as co-channel interference, CCI. Therefore filtering will have little effect, if any.

Impulsive interference most commonly gets into TV systems in the following ways:

- Through the aerial. If impulsive interference is being received via the aerial, the only option is to try re-positioning the aerial so that the path from the interference source is blocked, but the path from the wanted transmitter is not.
- From the downlead. Impulsive interference can induce currents that flow in the outer conductor of the downlead. If the downlead is of poor quality, some of these currents

will leak into the interior of the cable instead of remaining on the outside. Furthermore, even if the downlead's screening is good, the currents can travel up to the aerial, and if there is no balun, can enter the downlead at this point.

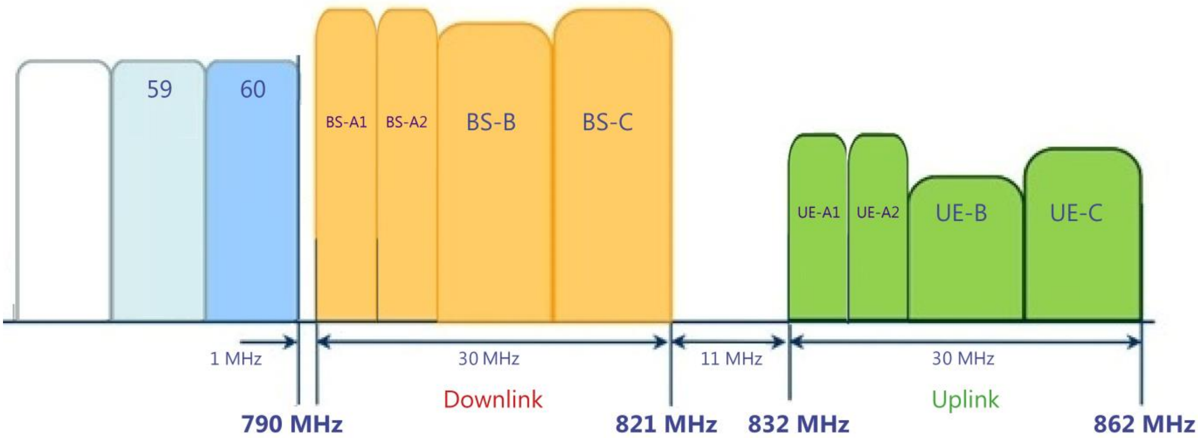
- Via the outlet plate or flylead. The quality and, in particular, the screening of outlet plates and fly leads are often extremely poor, allowing an entry point for impulsive interference. If interference is entering a reception system at this point, increasing the signal level delivered to the outlet plate will improve the signal–to-interference ratio, and may reduce actual disturbances to services.

Guideline: *In cases of impulsive interference, make sure that the downlead uses benchmarked cable, the aerial has a balun[21], the outlet plate and fly lead are well-screened, and that an appropriately high level of signal is being delivered to the outlet. Persistent cases of impulsive interference should be reported to the* Radio & Television Investigation Service (https://www.radioandtvhelp.co.uk/diagnostic/).

LTE interference

LTE is an abbreviation of Long Term Evolution, the fourth generation standard for high speed data communications for mobile phones. LTE services began in the UK in 2013, and the roll-out of base stations is expected to continue for a number of years as the operators extend their coverage areas.

LTE services can use a number of frequency bands, but the band of most interest for TV receiving systems is the 800 MHz band, because this was used until recently for TV (channels 61-68). Figure 8 shows how the frequencies are used.



UE = User Equipment
BS = Base station
LTE base stations transmit to user equipment such as mobile devices e.g. mobile phones.

[21] Note - Balanced to unbalanced conversion is intrinsic to the design of log periodic aerials.

Figure 8 LTE 800 frequency allocations

DTT broadcasting continues for the time being (see section 1) on channels up to 60. The top of channel 60 is at 790 MHz. LTE base stations (BS) transmit to user equipment (UE), such as mobile phones, in blocks A, B and C from 791-821 MHz, and UE transmits back to the base station in the corresponding blocks from 832-862 MHz.

It is possible for UE to cause interference to TV receivers, typically by entering a leaky outlet plate or flylead, or if the handset is close to the receiver, by penetrating the receiver's screening. If this happens, the householder should be advised to move the handset away from the TV receiver. Replacement of the outlet plate and the flylead with well-screened versions should also help. Indoor set-top aerials are particularly vulnerable to interference from UE, especially aerials that have amplifiers built in and it is recommended to use rooftop aerials instead where possible.

The main problem for TV systems is usually emissions from BS rather than UE. If the BS happens to be in the same direction as the TV transmitter, a rooftop aerial can pick up an extremely strong signal due to the BS being relatively close.

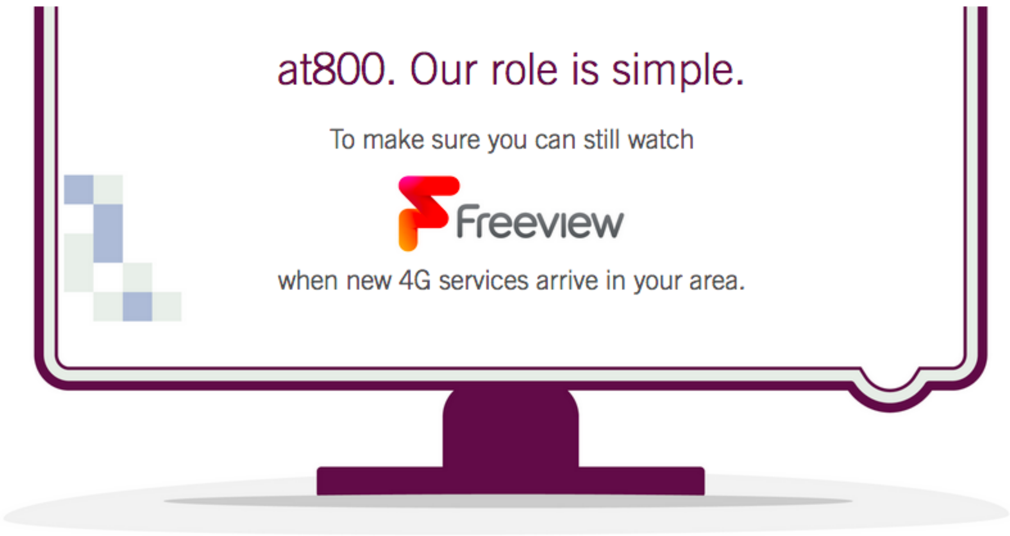
Interference can occur on any or all channels, but the channels closest to the BS frequencies are the most susceptible.

Mitigating LTE interference

at800

Following the 800 MHz LTE auctions in 2012, at800 was formed in order to provide support for households whose Freeview services could be affected by deployment of LTE at 800 MHz, and that use Freeview as their primary TV service.

at800 is funded by and represents the UK mobile operators who are launching LTE services in the UK at 800 MHz: EE, Telefonica UK (O2), Three and Vodafone.



How at800 can help

If a household is experiencing new disruption to DTT services such as loss of sound, blocky or pixelated images or loss of some or all channels, then the advice to installers is to contact at800.

It will then assess whether the disruption might be due to LTE at 800 MHz for example by checking if a new mast has been recently activated in the area.

at800 can then arrange for an at800 accredited engineer to visit the home. Alternatively, it will send a free LTE filter to the property for the householder or property manager to fit.

For installations with rooftop amplifiers, at800 can arrange for an at800-approved weatherproof filter to be installed by an at800-accredited aerial engineer.

For help or more information:

Call **0808 13 13 800**

Contact centre open 8am – 6pm Monday to Saturday. Closed Sunday and Bank Holidays. Calls are free from landlines and mobile phones.

Visit **www.at800.tv**

@at800tv www.facebook.com/at800tv

Guideline: *Installers who believe that disruption to a DTT installation is caused by LTE 800 disruption should contact at800. This is the advice even if the installer is able to rectify the issue so that cases of disruption can be tracked.*

LTE filters

The main tool for reducing interference from LTE BSs is the filter. The job of the filter is to selectively reduce the level of the interfering signal below the point where it is no longer affecting reception, while having the least possible effect on the TV multiplexes to be received. This becomes a problem when the target TV multiplexes use channels close to 790 MHz, i.e. channels 58, 59 and 60. This is because it is expensive to build a filter which transitions over a few MHz from very low loss to very high loss.

Figure 9 shows the characteristic of a typical consumer filter, and Figure 10 shows the result of passing DTT signals on channels 57-60 through this filter. Channel 58 has about 4dB of attenuation and roll-off at the top end, but in areas of reasonably good DTT signal strength this should not be a problem. On channel 59 the attenuation rapidly increases, and in many locations this would prevent reception. Channel 60 has even higher attenuation. Finally, note that all the channels above 60, including both LTE BS and UE bands, have high attenuation. Therefore this filter would be suitable for use in most areas using channel 58 and below, and would offer quite good rejection of both BS and UE bands.

Where channels 59 or 60 are in use, some compromises must be made. A more expensive filter can be used if it has a steeper slope between the passband (i.e. the channels the filter must pass) and the stopband (i.e. the channels the filter must attenuate). But if such a filter is to avoid harmful levels of attenuation on channel 60, then it may be necessary to accept less attenuation of LTE BS signals, especially in block A.

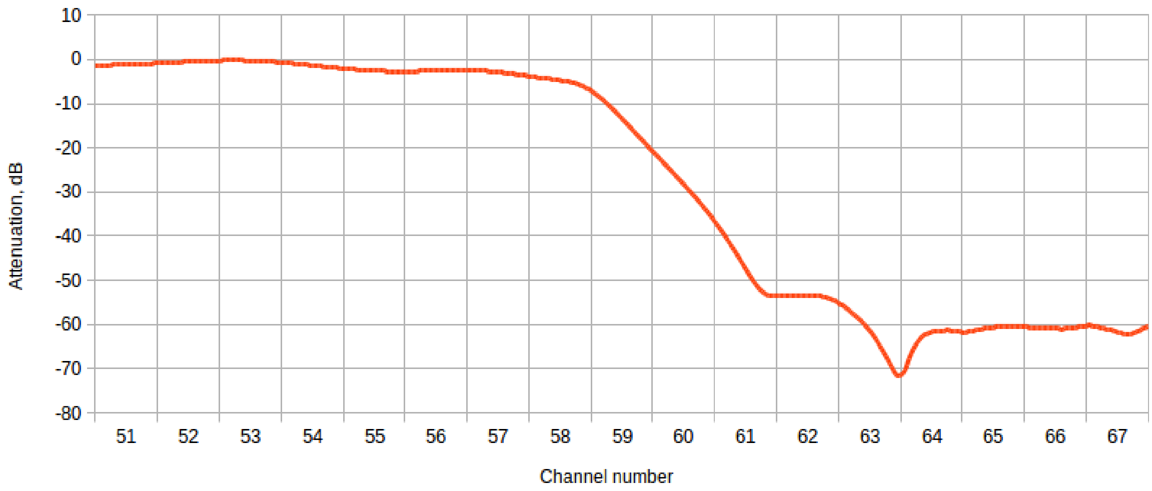


Figure 9 Characteristic of a consumer LTE filter

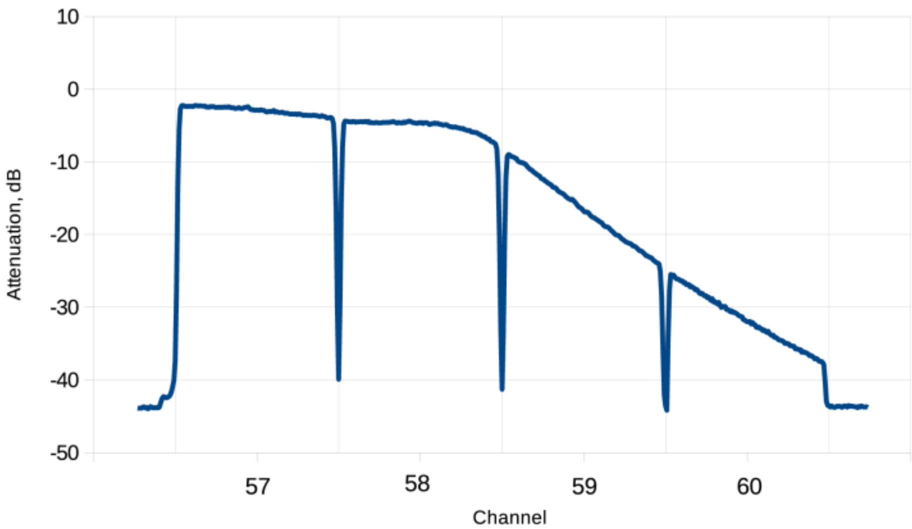


Figure 10 DTT signals after passing through a consumer LTE filter

The impact of DTT amplifiers on LTE interference

If you are using a filter, it must be installed before any active component such as an amplifier. Amplifiers generate intermodulation products, which tend to cover a wide range of channels, and will affect the DTT channels being received. (This is described in further detail in the Amplifiers section of this document.) Therefore filtering cannot be used to remove interfering intermodulation products once they have been created; filtering must be introduced before the signal reaches any amplifier to prevent significant levels of intermodulation products being generated in the first place.

Filtering is now integrated into some amplifiers, but where it is not, an external filter should be installed at the input to the amplifier to reduce vulnerability to LTE interference.

Note that launch amplifiers in communal aerial systems tend to be driven quite hard compared to other types of amplifier. They therefore tend to have the least capacity for handling LTE BS signals without generating harmful levels of intermodulation noise. This may mean that in some instances they will need a filter with higher than usual stopband attenuation.

Experience of LTE BS interference to date is that the great majority of affected systems are using some form of amplifier. Tests have also shown that an overloaded amplifier causes most degradation to the wanted signal that is closest to the interferer. In other words, it is expected that DTT multiplexes on channel 60 will be most affected.

Another point to note is that many LTE BSs are currently operating somewhat below their licensed power levels. It may be that at some point power levels are raised, giving rise to new cases of interference. In France, when a new BS is brought into use, it must operate at full power for a given period, so that all cases of interference can be found. Subsequently the power level may be reduced to the desired operating level, but the power will never exceed the initial level. The UK has not chosen to take this approach.

Guideline: *LTE BS interference mitigation steps are to remove any unnecessary amplifiers, and where there is no filter integrated into the amplifier design, to fit a filter before the input to any remaining amplifiers, or active devices such as a multiswitch.*

Receivers

We have seen how amplifiers are an important source of problems in the presence of LTE interference, but we should also give some thought to how receivers themselves behave. After all, there are still plenty of installations where an aerial is connected via a downlead directly to a TV receiver, with no amplifiers or other components involved.

There are effectively three ways in which a receiver can be prevented from decoding what would otherwise be a perfectly good DTT signal:

1. Co-channel interference (CCI). This term is often applied to unwanted DTT signals from distant transmitters using the same channel, but in the case of LTE interference we are generally referring to the intermodulation noise generated in an amplifier, or more specifically the part of the intermodulation noise spectrum that is on the same channel as the wanted DTT signal. This intermodulation noise behaves like any other noise signal, and reduces the C/N of the DTT signal. See the Amplifiers section for a description of the effects of noise;
2. Adjacent channel protection ratio (ACPR). This is a measure of how much more powerful an interferer on a nearby channel can be, compared to the wanted DTT signal, before the receiver suffers with errors on the picture. See Figure 11.

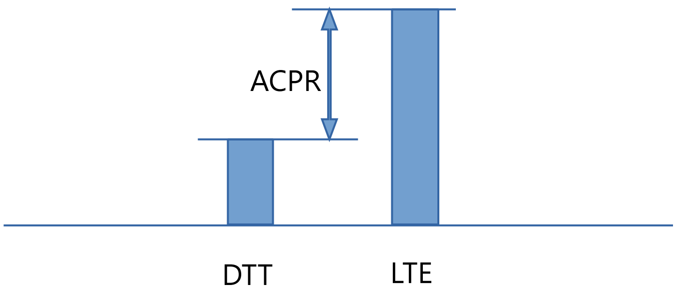


Figure 11 ACPR is the difference in level between the interferer and the victim when the victim signal just begins to fail.

ACPR differs significantly between types of receivers and with the number of channels separating the interferer (LTE) and the victim (DTT). ACPR tends to be a laboratory measurement made under controlled conditions and free from other sources of degradation, such as multipath, co-channel DTT interference, impulsive interference, etc. However, it gives a useful indication of the resilience of the receiver to strong signals on nearby channels.

3. Blocking. If a signal on a nearby channel is powerful enough, it will cause the receiver not to be able to decode a DTT signal at any level. The receiver is then said to be blocked (but this should not be confused with blocking on the picture, when the edges of blocks of pixels become visible).

For a receiver to work reliably, ALL the following conditions at the receiver input must be met:

- The wanted DTT signal must be within the operating range of the receiver, and must have a C/N significantly greater than the threshold (cliff edge) value;
- Any intermodulation noise that is co-channel with the wanted DTT signal must be sufficiently low in level as to avoid significantly degrading the C/N of the wanted DTT signal;
- Any interferer e.g. LTE or other DTT signal must not exceed the DTT receiver's ACPR; and
- Any interferer e.g. LTE or other DTT signal must not cause the DTT receiver to block.

Under laboratory conditions, receivers will normally operate satisfactorily with less than 30 dBμV of signal. However, in most domestic installations, a considerably higher level of signal is required to overcome degradation due, for example, to multipath, impulsive and other interference. Up to a point, as the signal level applied to the receiver increases, disturbance to services can decrease.

For reliable reception, the levels and C/N (or MER) of signals presented to the receiver should meet the requirements shown in Table 1.

Mode	Used by multiplex	Example service	Minimum level	Maximum level	Minimum C/N (MER)
DVB-T 64QAM 2/3	PSB1 PSB2	BBC1 (SD) ITV (SD)	50 dBμV	75 dBμV	23 dB
DVB-T 64QAM 3/4	COM4 COM5 COM6	ITV3 Dave 4Music	50 dBμV	75 dBμV	25 dB
DVB-T2 256QAM 2/3	PSB3	BBC1 (HD)	50 dBμV	75 dBμV	26 dB

Table 1 Recommended signal level ranges and C/N values for national and regional multiplexes (excludes local TV)[22]

[22] Taken from CAI codes of practice: COP 01 for multi dwelling and commercial units and COP 02 for single dwelling units.

It is important to recognise that:

- using an amplifier to raise the signal levels into the recommended ranges may make the system more vulnerable to interference;
- the minimum levels stated have been arrived at empirically, and other organisations may recommend lower levels (e.g. 45 dBμV);
- signals over 75 dBμV may cause overload, especially on older receivers; and
- operating receivers with C/N or MER values lower than recommended may cause increased occurrences of disturbances to pictures and sound.

Guideline: *In the absence of adjacent channel interference, e.g. from an LTE BS, ensuring that signals delivered to outlets meet the criteria in Table 1 should ensure that receivers perform well.*

Other services

There are two other services that can use UHF TV channels that designers and installers should be aware of:

- **TV White Space (TVWS):** TVWS services are now being deployed in the UK[23], and will be used for low power, short range data links for a variety of purposes. TVWS will be allowed to use any channel that is not already in use for DTT on a managed basis, and although extensive trials have taken place to determine the power levels that in most cases will prevent interference into TV systems, there remains the possibility of some disruption to TV reception, especially where amplifiers are in use.
- **Local modulators:** Some TV reception systems use vacant channels to carry locally modulated signals from e.g. security cameras. It is possible that nearby TVWS devices might be allocated the same channel as the local modulator, so it would be good practice to install a bandstop filter that would prevent signals on the modulator's channel from being fed into the system from the aerial.

[23] https://www.arranbroadband.co.uk/about-1

Aerials

An aerial is intended to capture TV signals from a particular transmitter, and convert them from electromagnetic waves in space to electrical signals in a coaxial cable. However, the aerial must also provide a given degree of rejection of signals coming from other directions. If this rejection is insufficient, and the interferer is a co-channel TV signal, the C/I (which in this case is much the same as C/N), may be lower than desirable. This may result in more frequent disturbances to services than if the aerial gave a high level of rejection.

Aerial groups

When the TV networks were first planned, attempts were made to keep channels in one coverage area from being spread across the available spectrum to a greater extent than necessary. Although this worked in many cases, there were some transmitters where it was necessary to spread out the channels used across much of the band, to avoid interference from and to transmitters in neighbouring coverage areas.

Aerial designers found that the broader the bandwidth of an aerial, the lower is its gain. High gain was often needed, especially towards the edge of coverage and where the path from the transmitter was blocked by terrain, vegetation or buildings. In many instances, a wideband aerial that covered all the channels from 21-68 simply did not have enough gain, and so the idea of aerial groups was developed.

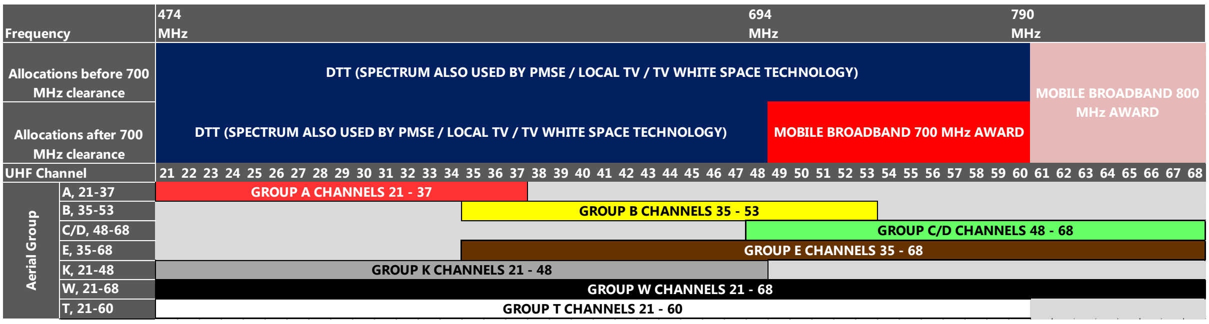


Figure 12 Aerial groups and the 700 MHz and 800 MHz bands

The aerial groups A, B, C/D, E, K, and W that have been used in the UK for many years are shown in Figure 12, together with the newly added group T.

As digital multiplexes arrived, and again as analogue channels were shut off at switchover, new channels were brought into use. Wherever possible these were kept within the same group as the previous analogue channels, to avoid consumers being unable to receive some services due to them being outside the group of channels covered by their existing aerial. However, frequency planning constraints meant that this could not always be achieved.

The plans for switchover involved clearing two groups of channels: 31-40 and 63-68. It was not known at that stage what these bands might be used for, but as it was feasible to achieve, it seemed prudent to do this to allow for future possibilities.

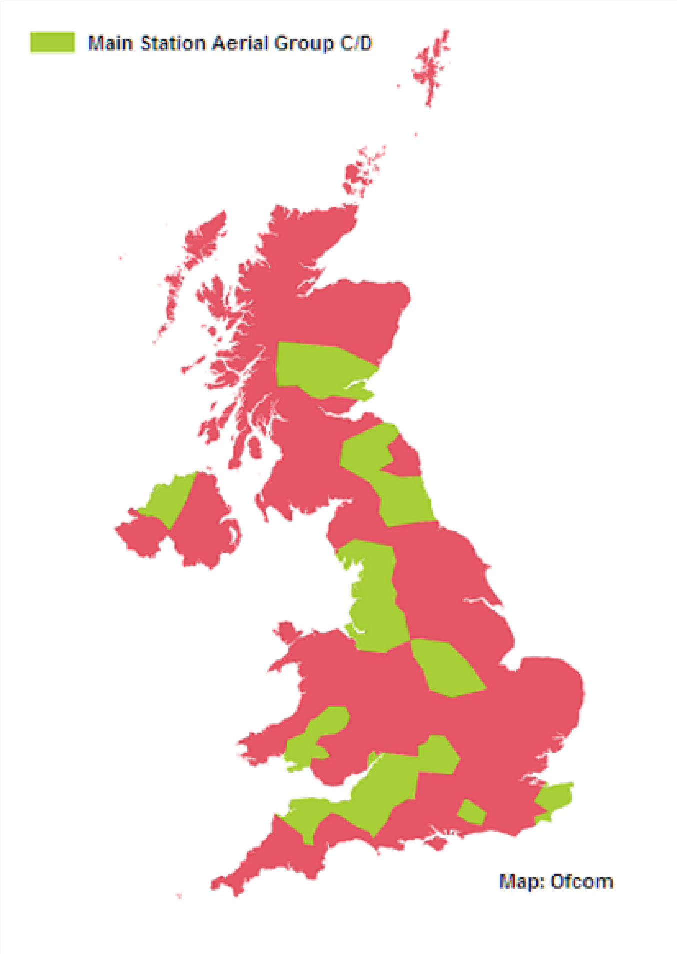
Sometime later, it was agreed across Europe to clear channels 61-68 for mobile (LTE) use, and this resulted after switchover in a second wave of frequency changes, to clear channels 61 and 62 in the UK.

Figure 15 shows the 800 MHz band (channels 61-68) in dark blue. It was recognised that TV receiving systems would need protection against LTE signals in this band, so group T was defined, covering channels 21-60. Noting that the frequency response of a Yagi aerial tends to drop quite sharply above the top of its operating frequency range, it was clear that a group T aerial could offer some much-wanted rejection of LTE signals.

The World Radio Conference in November 2015 confirmed the change of use of the 700 MHz band (channels 49-60, shown in light blue in Figure 12), and transmitters will start being cleared out of this band in 2017.

Group C/D aerials cover the 700 MHz channels as shown in green in Figure 12 so it is households in areas where these channels are used that are most likely to need aerial changes during the 700 MHz clearance. **Installers replacing aerials where signals are currently transmitted in this group are recommended to advise customers about clearance and offer a wideband (group T) model.**

The figure below shows the areas in the UK where the main transmitter station uses channels covered by group C/D aerials.



Key points:

1. Freeview viewers will need to retune as clearance takes place region by region between 2017 - 2020
2. Most Group C/D aerials should continue to provide reliable reception. However, some will need to be replaced
3. Viewers replacing their aerial are advised to opt for a wideband model

Figure 13 Main station aerial group C/D[24]

Channels 31-37 (excluding 36) are currently used for interim DTT multiplexes, but these are temporary and the plan is for these to be moved to other frequencies to make way for channels being moved out of the 700 MHz band.

All of these factors influence the choice of receiving aerial.

Guideline: *Group C/D aerials will not cover any of the channels available after the 700 MHz band clearance programme, so the best strategy is to fit a group T aerial if there are currently channels in use above 48, and otherwise to fit a group K, provided these have sufficient gain. Then all available channels can be received, and some rejection of LTE signals is also achieved.*

The use of group C/D aerials should be avoided wherever possible, as they will not cover any of the channels available after the 700 MHz band clearance. Installers replacing aerials where

[24] http://www.digitaluk.co.uk/operations/700mhz_clearance

signals are currently transmitted in this group are recommended to advise customers about clearance and offer a wideband (group T) model.

Aerial Benchmarking

This scheme lays down the minimum standards for the technical performance of UHF TV aerials based on the specific requirements for satisfactory digital terrestrial TV (DTT) reception.

Benchmarked Aerials are categorised into six standards, and the standard achieved in the certification is marked in the CAI benchmark logo found on the product packaging:

- **Standard 1:** Should provide acceptable DTT reception for homes on the edges of coverage areas.
- **Standard 2:** This is an intermediate level suitable for use across the whole of a DTT coverage area.
- **Standard 3:** This is minimum attainment level for primary service coverage areas.
- **Standard 4:** Is a standard for a specific design of aerial where tighter narrow beamwidth is needed along with wideband performance.
- **Standard F:** Is the new LTE standard for 'Fringe' aerial reception.
- **Standard S:** Is the new LTE standard for 'Standard' aerial reception.

Figure 14 CAI aerial benchmarking labels

Aerial polar pattern

An aerial's polar pattern is a diagram showing how the aerial's gain varies with direction. Ideally, aerials would accept signals only from the forward direction, and would completely reject all signals from other directions. In practice, aerials will to some extent accept signals coming from directions other than the forward direction.

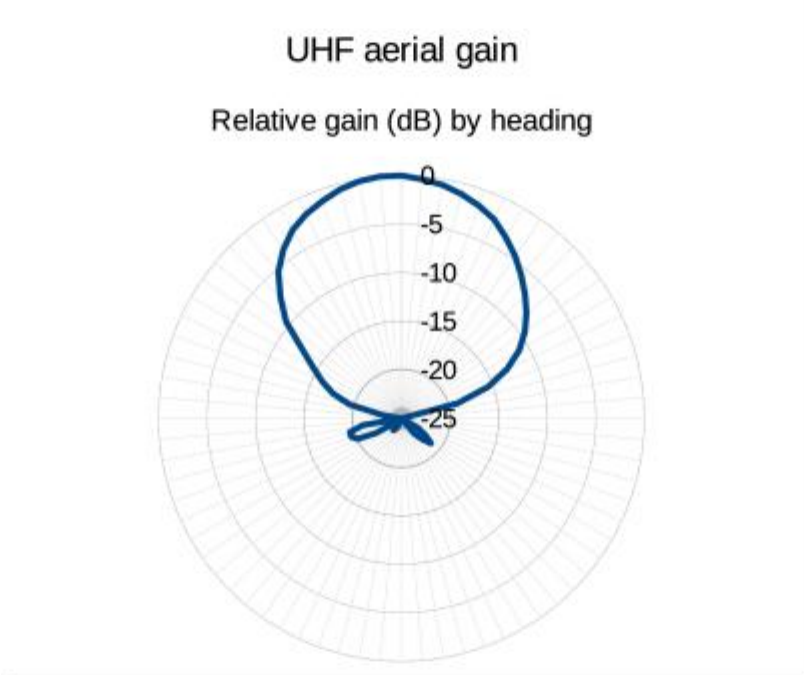


Figure 15 a polar pattern of a well-designed Yagi aerial

Figure 15 shows the polar pattern of a well-designed Yagi aerial *(data courtesy of Blake UK Ltd)*, and there are two main features to note:

- The gain either side of the forward direction (upwards in Figure 15) makes what is known as the main lobe. As the number of elements in the aerial increases, so the gain in the centre of the main lobe increases and the width of the main lobe decreases. The angular width of the main lobe, normally between the points 3dB below maximum gain, is often specified by the manufacturer. In this example, the gain falls by 3 dB from maximum at roughly 30° from the forward direction, and is said to have a 60° beamwidth.
- In this example, the gain outside the main lobe is always more than 24 dB below the forward gain.

In some locations, signal levels from transmitters in other areas can be quite strong, and if they are on the same channel as the wanted signals, can cause harmful interference. The aerial is the only means of separating co-channel signals from different directions, so attention must be paid to the polar pattern of the receiving aerial. Outside the main lobe, we want the gain to be as low as possible, so that signals from unwanted co-channel transmitters cause the minimum of interference. If the interference is coming from a direction within the main lobe of a low gain aerial, using a high gain aerial with a narrower main lobe may be necessary.

Unfortunately, some contract aerials have particularly poor patterns, with rather high gains outside the main lobe (also known as off-axis gain). These should be avoided, and CAI benchmarked aerials used wherever possible. The benchmark ensures that off-axis gain is kept low.

In recent years, a number of small log-periodic aerials have come on the market. Log periodic aerials are characterised by having a wideband response, with lower gain than a Yagi of comparable size, but particularly low off-axis gain. The main lobe tends to be fairly wide. In areas where the signal strength is high and good rejection of signals arriving outside the main lobe is required, a log periodic aerial can make an effective solution, although its frequency response in the forward direction offers little or no rejection of LTE signals.

Aerial Gain and Frequency Response

Aerial gain is a measure of how much signal the aerial produces at its terminals when correctly pointed towards a transmission of given signal strength. The frequency response is a measure of how the gain varies with frequency.

For aerials based on the Yagi, the gain increases with the number of elements the aerial has. The gain decreases with increasing bandwidth: a wideband aerial has lower gain than a narrowband aerial. The gain also rises with frequency, and then drops rapidly just above the highest channel it is intended to work on, as illustrated in Figure 16 *(data courtesy of Blake UK Ltd.)*.

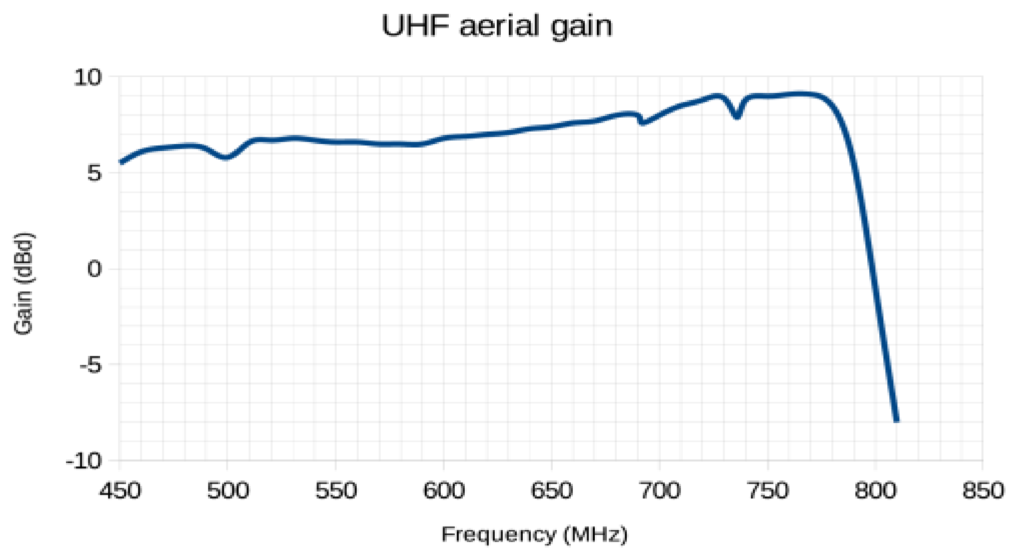


Figure 16 An example of the gain of a Yagi aerial against frequency

Aerial polarisation

Generally speaking, main transmitters radiate horizontally polarised signals, and relay transmitters radiate vertically polarised signals, although there are some exceptions to this, such as Rowridge, which radiates both horizontal and vertical components.

In principle, a receiving aerial with its elements horizontal will only respond to horizontally polarised transmissions, and will completely ignore vertically polarised signals. In practice this isolation is not perfect, but there will be a large loss of signal if the aerial's polarisation is not matched to the transmission's polarisation.

Polarisation is another tool that frequency planners can use to control interference and use the spectrum efficiently. It is therefore important for a receiving aerial to meet minimum polarisation requirements.

Baluns

Most receiving aerial designs by their nature tend to produce a balanced output, where as one terminal goes up in voltage, the other terminal goes down by the same amount. Coaxial cable is naturally unbalanced, with the outer conductor staying at the same potential while the inner conductor carries the signal voltage.

A balun, which is short for *bal*anced to *un*balanced transformer, ensures that the aerial sees a balanced connection from the coax, and the coax sees an unbalanced connection from the aerial. This will help prevent interfering signals that are received on the outer of the coax from travelling up to the aerial, where without a balun the signal can get onto the inside of the coax. This is another reason to use a benchmarked aerial, as they all have baluns. An exception is log periodic aerials where baluns are intrinsic to the design.

Amplifiers

Amplifiers of various types are widely used in aerial systems to boost (increase) signal levels. However, they should be used with care as inappropriate use of amplifiers can badly degrade the quality of signals, or in extreme cases can prevent receivers from operating at all. In this section we look at amplifiers in more detail, and then go on to look at specific cases of masthead amplifiers and launch amplifiers.

All amplifiers have two main limitations that the system designer and the installer should be aware of:

- **Noise:** All amplifiers add noise to a signal. It is impossible to improve the C/N of a signal by passing it through an amplifier. After all, both the carrier and the noise components of the input signal will be amplified by the same amount, and the amplifier will also add a little noise, so the C/N will be degraded.
- **Non-linearity:** An ideal amplifier amplifies all signals by the same amount, irrespective of their amplitudes. This is represented by the straight line on the graph in Figure 17, which shows that the output signal in this case is always three times the input signal.

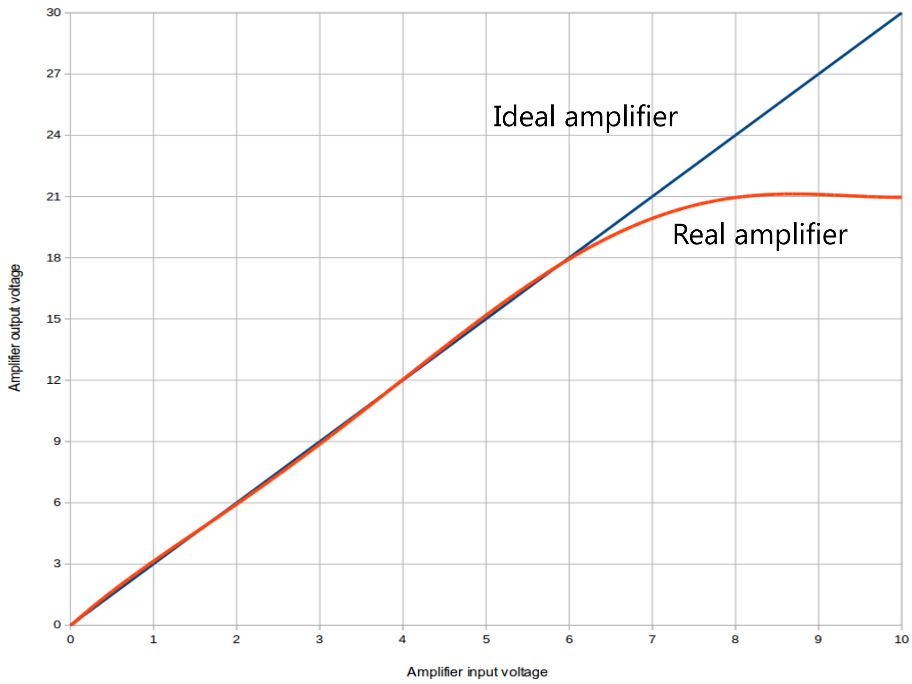
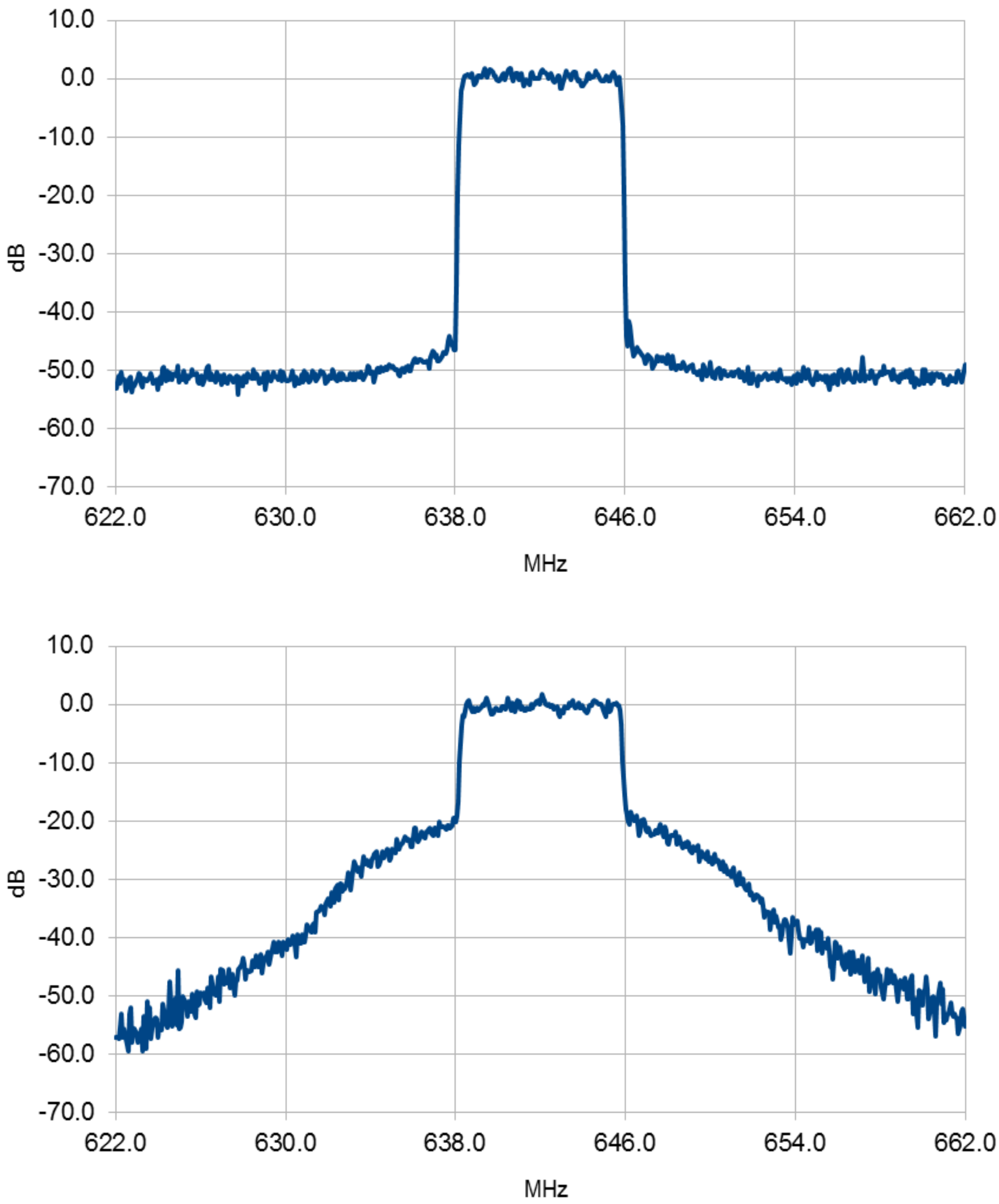


Figure 17 Amplifier input voltage versus output voltage for an ideal and a real amplifier

A real amplifier behaves reasonably like an ideal amplifier when signal levels are small, but as signal levels increase, the output does not increase as much as it should. Finally, as the input increases further still, the output does not change at all. This deviation from the ideal is usually known as non-linearity, and it has some very important characteristics.

Non-linearity has the undesirable property of generating signals that were not present at the input of the amplifier. These new unwanted signals go by the name of intermodulation products, and where the wanted signals are DTT multiplexes; the intermodulation products look and behave very much like noise.

Figure 18.a shows a single multiplex before it has passed through an amplifier. Figure 18.b shows the same multiplex after it has passed through an amplifier at a level that generates significant intermodulation noise. The multiplex now appears to be sitting on a pedestal of noise which extends either side of the channel occupied by the multiplex. As a result, the C/N of this multiplex was degraded to about 20 dB by this amplifier. This figure broadly corresponds with the ratio of the signal power to the intermodulation noise at the edge of the channel.



Figures 18.a and 18.b DTT multiplex before and after passing through an amplifier

Fortunately, the level of intermodulation noise is strongly dependent on the level of the signal in the amplifier. If the input signal is reduced by 3 dB then the intermodulation noise will be reduced by about three times as much, about 9 dB.

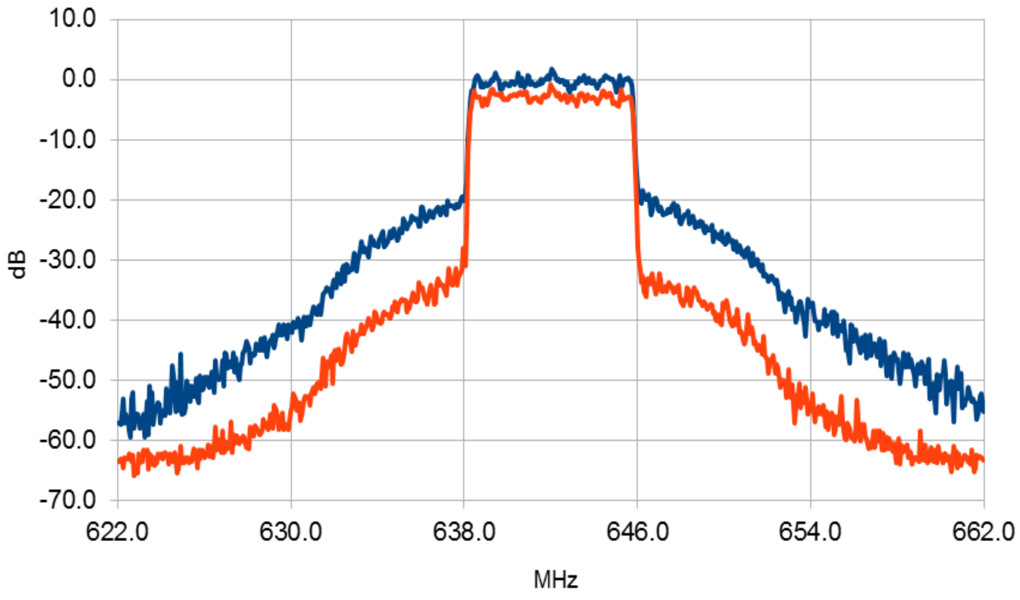


Figure 19 Reducing the signal power by 3 dB reduces the intermodulation power by approximately 9 dB

This means that reducing the input signal by 3 dB will reduce its level at the output by slightly less than 3 dB, but its C/N will increase by about 6 dB due to the much bigger fall in intermodulation noise level. In a well-designed amplifier, the intermodulation should mainly be generated in the output stage. Therefore reducing the amplifier's gain should reduce intermodulation in the same way as reducing the amplifier's input signals.

Guideline: *if an amplifier is generating too much intermodulation noise, reduce the amplifier's gain, or reduce the level of signal at the input. Although this will reduce the signal level at the output, it will increase the C/N at the output.*

Masthead amplifiers

The need for masthead amplifiers has reduced considerably since digital switchover, due to the increase in transmitter powers that could be achieved once the analogue services had been removed. Unless masthead amplifiers are needed for a specific reason, such as unusually large losses due to long cable runs, splitters, etc., they should not be used, as they will increase the vulnerability to interference (see section on interference mitigation).

Guideline: *avoid the use of masthead amplifiers unless they are absolutely necessary.*

A masthead amplifier should normally only be used to overcome a loss by having a gain just a little greater than the loss, and it should always be located ahead of the loss. For example, imagine a case where there is 10 dB of feeder loss between an aerial and a TV receiver. In Figure 20.a an amplifier with a gain of 14 dB and a noise figure of 2 dB has been installed before the lossy feeder, and in Figure 20.b, it has been installed after the feeder. Let us say that the signal at the aerial terminals has a C/N of 30 dB. What is the difference between installing the amplifier as shown in Figure 20.a compared to Figure 20.b?

The first point to note is that the signal level presented to the receiver will be the same in both cases. There is 10 dB of loss and 14 dB of gain, so there will be 4 dB of end-to-end gain irrespective of the order in which the gain and loss occur.

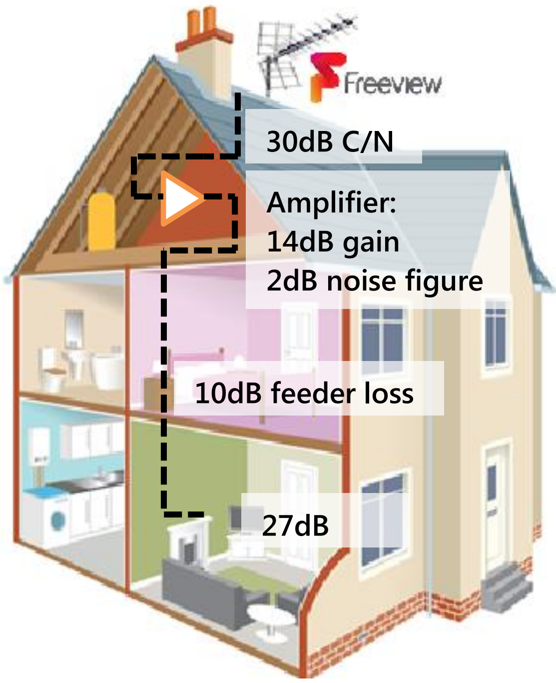


Figure 20.a the amplifier is before the loss

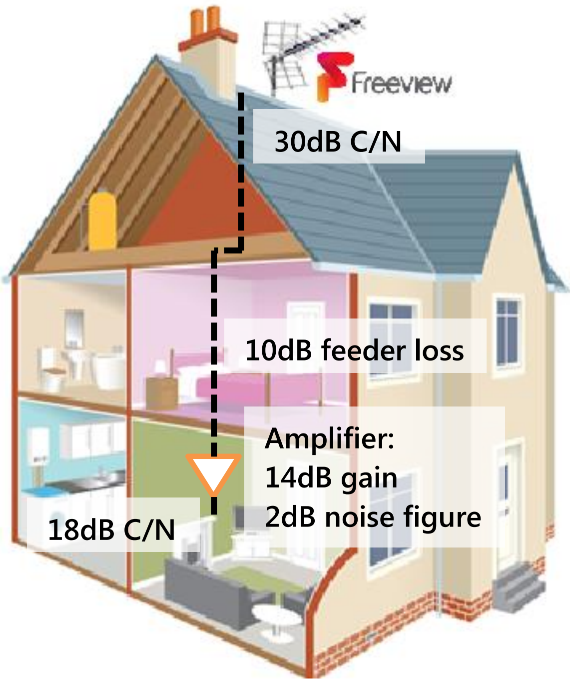


Figure 20.b the amplifier is after the loss

	C/N at the aerial	C/N at the TV receiver
Amplifier before feeder loss	30dB	27dB
Amplifier after feeder loss	30dB	18dB

Table 2 C/N for the two cases in Figures 20.a and 20.b

Table 2 shows that there is a large difference of C/N between the two cases: putting the amplifier before the feeder loss gives a C/N value of 27 dB, which for UK DTT modes represents a good quality of signal, while putting the amplifier after the feeder loss gives a C/N value of 18 dB, which is close to the point of failure. This is why we have *masthead* amplifiers!

Note that the term *feeder loss* used here should include losses from passive components such as splitters. For example, a four-way passive splitter with about 20m of type 100 cable in any one path could have a total loss of around 10 dB at UHF.

Guideline: *if an installation needs a masthead amplifier, use one with the lowest gain consistent with adequate performance in order to minimise the risk of overload from LTE, place it as close to the aerial as possible and place it ahead of any significant losses from feeders, passive splitters, etc. If one is not already integrated into the amplifier design, installing an appropriate filter before the amplifier will reduce vulnerability to interference from e.g. LTE (see* Mitigating LTE interference *section).*

Distribution amplifiers

The term "distribution amplifier" is used to include loft amplifiers, set-back amplifiers and launch amplifiers. There is no clear distinction between distribution amplifiers and masthead amplifiers; in fact masthead amplifiers with multiple outputs could be said to be distribution amplifiers. As described previously, all amplifiers introduce noise and are non-linear, and distribution amplifiers are no exception.

Launch amplifiers generally are capable of producing the highest signal power of any of these amplifier types, so we will concentrate mainly on these.

Launch amplifiers are also the most expensive type of amplifier, with the price rising in relation to the output power capability. In an IRS or a MATV system, a balance must be found between the amount of signal power that must be launched into the distribution network, the amount of intermodulation noise that can be tolerated, how hard the amplifier can be driven, and hence the size and cost of the amplifier.

In principle, the same process applies in the current all-digital environment as in the days of analogue. For the analogue world, manufacturers rated their amplifiers for two vision carriers, and a formula could be applied which gave the amount that the channel power had to be reduced, according to the number of channels in use. This power reduction is most widely known as de-rating, or sometimes as back-off.

For example, if an amplifier is rated by the manufacturer at 116 dBμV, and it is to be used with five channels, the de-rating can be calculated like this:

de-rating = 10log(N-1) dB, where N is the number of channels.
de-rating = 10log(5-1) = 6 dB

This means that the carriers can each be operated at 116 - 6 = 110 dBμV at the amplifier output, assuming they are all received at equal level.

Number of channels	De-rating (dB)
2	0
3	3
4	4.8
5	6

Table 3 De-rating figures for analogue TV

Analogue TV was particularly susceptible to annoying patterning on pictures arising from intermodulation, and this level of de-rating ensured that intermodulation remained sufficiently low that no patterning was visible. Operating analogue carriers above this level would risk visible patterning appearing on pictures.

In the digital world, we need a slightly different approach, for two main reasons:

- DTT is not susceptible to patterning on the picture.
- Intermodulation generated by DTT signals in a non-linear amplifier behaves like noise.

It is important to bear in mind how digital signals fail as the quality of the signal decreases. DTT has a failure threshold, sometimes called the digital cliff, below which it is impossible to decode pictures, sound or any other service carried in the multiplex, such as the programme guide. For simplicity these will be referred to collectively as pictures.

Just above this threshold is a region where pictures can be decoded, but it takes only a very small disturbance to cause errors in the picture, such as freeze-frames and blocks errors. As we move away from the threshold, increasing the quality of the signal, the likelihood of disturbances decreases until we reach a region where disturbances are so rare that we can say they do not happen. It is clear that we should avoid operating close to the threshold.

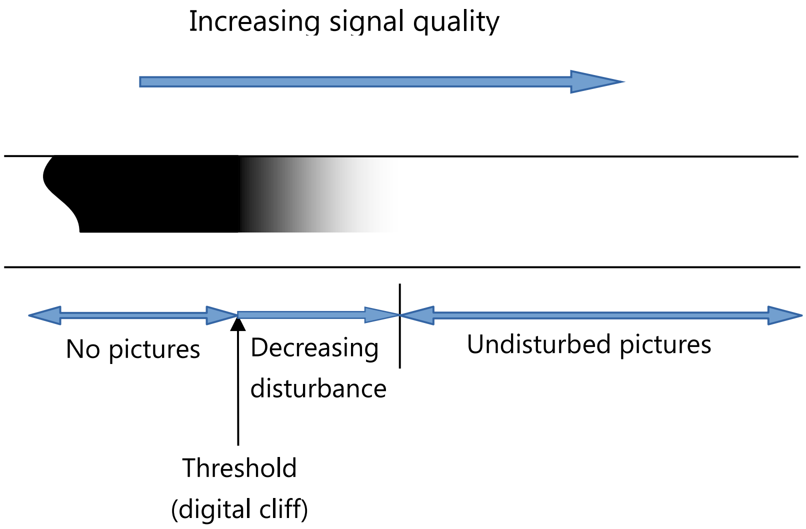


Figure 21 Illustrating the DTT threshold (digital cliff) and the operating region for undisturbed services.

The CAI's Code of Practice for MDUs makes recommendations for C/N values at both the aerial and outlet plates on a system, and these are summarised in Table 4 below.

Mux type	Minimum C/N (MER) at the aerial (dB)	Minimum C/N (MER) at the outlet (dB)
DVB-T	27	23
DVB-T2	30	26

Table 4 Minimum C/N values at aerials and outlets, recommended in the CAI's Code of Practice for MDUs

The values of C/N given in Table 4 have been determined to ensure that in normal operation the signal is well above the threshold, and clear of the zone in which disturbances are likely. This has implications for how launch amplifiers should be operated.

A DVB-T2 signal being received off the aerial at 30 dB C/N has to be delivered at no worse than 26 dB C/N, allowing a total of 4 dB of C/N degradation. Assuming we allow half of this degradation is caused by the amplifier, it can be seen that the amplifier must degrade perfect signals to no worse than 32 dB C/N.

Some tests have been carried out on a small number of amplifiers to see if it is possible to define the maximum drive level for an amplifier, given the C/N target and the manufacturer's amplifier rating. Unfortunately it was found that the results vary significantly from one amplifier model to another, so no straightforward rule has emerged. However, on the few models of amplifier tested, it seems that using the analogue de-rating formula gives a safe estimate of the usable power level, but perhaps this is not quite as cost effective as it might be. It is hoped to do more work in this area, and report the results in a future edition of this guide.

Measurements

It should be clear from discussions of signal levels and interference elsewhere in this guide that measurements of signal level and signal quality are of great importance to ensure that any terrestrial TV system, no matter how simple or complicated, works effectively. The installer should therefore be equipped with a meter that measures signal level and MER, and ideally is able to display the spectrum of TV signals as well as frequencies outside the TV band in order to assess the level of LTE interference.

Signal level

Signal level is a straightforward measurement of the strength of a signal. Meters are normally calibrated for use with digital signals occupying an 8 MHz channel, which is why an analogue-only meter is no longer of use in a digital-only environment. The unit of measurement is usually dBµV. Using dB (decibels) means that for every drop of 10 dB, the power of the signal is reduced by a factor of ten. For example, a 20 dB drop means that the power has gone down by a factor of 100, and a 30 dB drop means it has gone down by a factor of 1000. Using dB allows a wide range of signal powers to be displayed at the same time.

Recommended signal levels at outlets are given in Table 4.

Carrier to noise ratio, C/N or CNR

C/N is a measure of the ratio of the signal power in a channel to the noise power in the same channel, and is fundamental to the operation of a receiver: the C/N must be over a certain value for the receiver to work at all. C/N is normally expressed in dB.

The main problem with C/N is that it is not possible with a spectrum analyser to see the noise present in a channel without switching off the TV signal, which is not normally possible. An estimate of the noise level may be found by measuring the noise in an unoccupied nearby channel, but this cannot take account of variations in frequency response between channels, and co-channel interference (which usually behaves like noise). Modulation error ratio (MER) is a better measurement.

Modulation error ratio, MER

MER is a measurement of how much a signal deviates from the ideal. It includes transmitter distortions, co-channel interference and noise, and all of these are combined into one signal as if they were all sources of noise. By measuring the power of the signal, and then the effective power of all the degradations, the MER can be calculated. Note that if the transmitter distortions are small, MER is effectively the same as C/N.

MER is normally averaged over a period of about a second, so it is of limited use with transient interference, such as impulsive interference, because its duration is significantly shorter than the averaging period.

Bit error ratio, BER

BER is a measure of the number of errors in the received data stream. We need to be careful to understand exactly where the BER is being measured, because receivers contain mechanisms to correct errors, known as FEC (Forward Error Correction). Of course, normally pictures and sound should be delivered without any errors, a condition known as Quasi Error-Free, QEF.

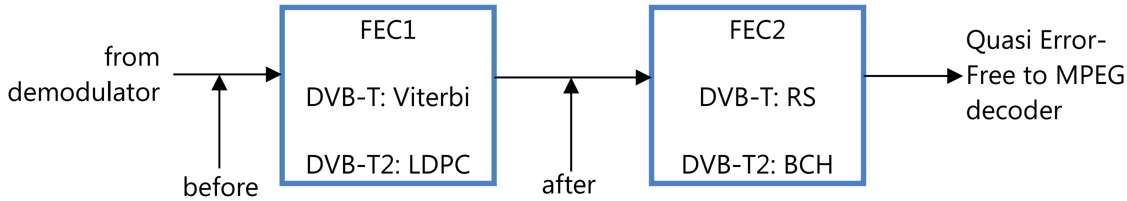


Figure 22 Receiver error correction (FEC) processes

The error correction processes in a receiver are as shown in Figure 22. The data bit-stream coming off the demodulator is fed to two successive error correction processes, FEC1 and FEC2, which under normal conditions will effectively eliminate all data errors. BER measurements are usually made before or after FEC1; after FEC2 there should be virtually no errors to measure.

In DVB-T systems, the FEC1 process is named after its inventor, Viterbi. You may hear references to BER being measured before or after Viterbi. Sometimes these are called bBER and aBER (before-BER and after-BER). The target maximum value for BER before Viterbi is 2×10^{-4}, sometimes written as 2E-4.

DVB-T2 systems use a much more powerful FEC1 process known as LDPC (Low Density Parity Check). This makes using BER measurements somewhat more difficult, as the post-LDPC BER is very low, even for quite high values of pre-LDPC BER.

Like MER measurements, BER measurements are averaged over periods of time that allow enough errors to be counted to make the measurement meaningful. For low values of BER, the time required can be several seconds. So BER measurements are also of limited use for short duration interference.

Noise margin

Noise margin is a measure of how far the MER is above the failure threshold, or digital cliff. The failure threshold varies between the various modes of both DVB-T and DVB-T2 signals (e.g. the mode used for local TV transmissions has a threshold about 10 dB lower than the other multiplexes), so this is a useful indication that the operating point is not close to failure.

Satellite reception and distribution

The reception and distribution of satellite TV signals requires quite different techniques to those used for terrestrial television. The main reasons for this are:

- Satellite signals are very weak in comparison to terrestrial. They are transmitted with lower power than terrestrial TV, and the signals have to travel over 24,000 miles from the satellite to reach us.
- Satellite signals use much higher frequencies than terrestrial. Terrestrial TV uses frequencies in the range 470 MHz to 790 MHz (soon to be reduced to 694 MHz, see earlier sections in the document on 700 MHz Clearance for mobile broadband (694 MHz/channel 49 - 790 MHz/channel 60)), whereas satellite TV signals use the frequency range from 10,700 MHz to 12,750 MHz.
- Satellite TV signals are able to use a much wider range of frequencies than terrestrial TV. Terrestrial TV currently has 320 MHz of bandwidth (soon to be reduced to 224 MHz, see earlier sections in this document on 700 MHz Clearance for mobile broadband (694 MHz/channel 49 - 790 MHz/channel 60)), whereas satellite TV has a bandwidth of 2,050 MHz – which it is able to use twice through use of horizontal and vertical polarisation, making an effective bandwidth of 4,100 MHz.

As receiver technology has developed, so too have the requirements for signal distribution. In this section we will look at legacy systems, in use in the great majority of reception systems, and also at the more recent wideband LNBs, and single cable router (SCR) systems.

Satellite reception

In common with terrestrial transmissions, satellite signals are transmitted in individual multiplexes. Each individual multiplex has its own transmitter hardware on the satellite, known as a transponder. The transponder's task is to receive signals sent up from an uplink earth station, and to re-transmit these signals back down to earth. The satellite's transmit dish aims the transponder's power at the territory required to be covered by the signal, for example the UK, or the whole of western Europe. If the transmitter power is spread over a relatively small area such as the UK, then the signal on the ground will be stronger than if it is distributed over a wider area.

Satellite signals are affected by moisture in the air in the form of cloud or rain. Heavy rainfall can cause several dB of attenuation of the signal, and in addition to this loss of signal power, there will also be an increase in the noise level in the system, both of which will degrade the signal to noise ratio in the receiver. Rainfall statistics are known, and can be used to calculate the availability, usually expressed as the percentage of a year that the signal can be received by a particular receiving installation. This will depend on many factors, including: satellite signal power, geographic location, receiving dish size, LNB noise figure, modulation and FEC (forward error correction) rate. Calculations that take account of all these factors are known as a link budget, and can be quite complex. However for most broadcast applications, it is normally sufficient to use a recommended dish size, as all the link budget calculations will have been done by the satellite operator.

Recommendations for satellite signal conditions at outlet plates

The Confederation of Aerial Industries recommends the following signal conditions should be met at outlets on a communal aerial system:

Minimum signal level:	52dBμV
Maximum signal level:	77dBμV
Minimum MER (marginal performance):	8dB
Recommended MER:	11dB

Table 5 Recommended satellite signal conditions at outlet plates

The signal conditions in Table 5 are also appropriate for satellite receiving systems in single occupier properties. The important factors are:

1. the signal levels are sufficiently high to ensure that there is negligible degradation of the C/N or MER;

2. the signal levels are not high enough to cause the receiver to overload;

3. the MER is high enough to ensure a high level of availability of the signals during all but the most severe rain fades.

Downlink frequencies

The spectrum from 10,700 MHz to 12,750 MHz can be filled with multiplexes, as illustrated in Figure 23. (Figure 23 is illustrative, and may not show the correct number of transponders, which may vary from one satellite to another. Furthermore, signal power levels may vary somewhat from one multiplex to another.) The satellite actually uses this range of frequencies twice: once with a set of signals that are horizontally polarised, and then again with another set of signals that are vertically polarised. In a single receive dish on the ground, the two sets of signals can be received simultaneously, and if the dish is aligned correctly, the two sets of signals will not interfere with each other to any significant extent.

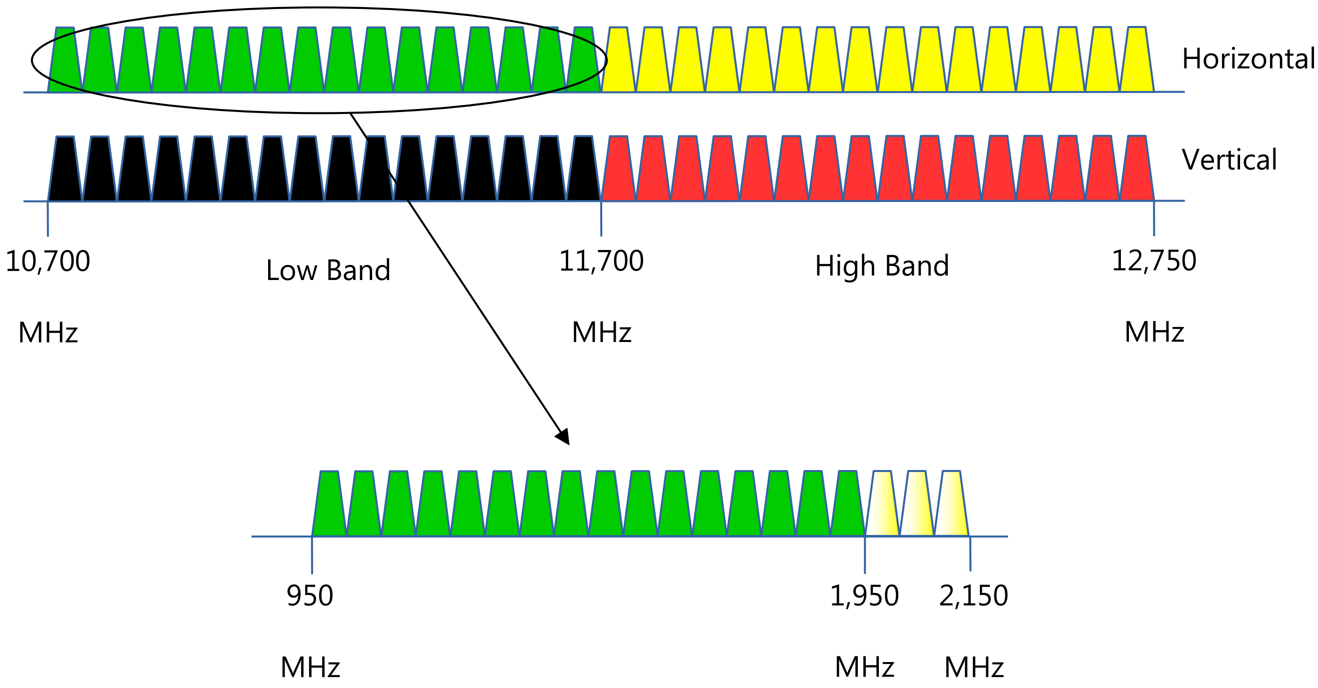


Figure 23: an LNB converts an entire band of frequencies to the satellite intermediate frequency (IF)

Why IF frequencies are used

Signals at the frequencies transmitted by the satellite would suffer a high degree of attenuation in a typical coaxial cable, and must be moved to a lower frequency range for the use of coaxial cables to become practical over useful distances. A good location in the spectrum to move them to would be just above the UHF TV band; in this way, UHF TV signals and satellite signals could be carried on the same cable with no mutual interference. However, moving the whole satellite band so that it began at 950 MHz would still leave the top of the band at 3,000 MHz, where cable attenuation is still quite high. Splitting the satellite band into two parts (sub-bands), known as Low Band (10,700 MHz to 11,700 MHz) and High Band (11,700 MHz to 12,750 MHz) has been standardised; the range of frequencies that the signals are moved to is 950 MHz to 2,150 MHz, which is known as the satellite IF (intermediated frequency) band. Splitting into Low Band and High Band results in four sets of signals (four sub-bands) that can be carried in the satellite IF: vertically polarised High Band and Low Band, and horizontally polarised High Band and Low Band.

Low Noise Block downconverters (LNBs)

The required frequency shifts and selection of vertical or horizontal polarisation take place in the LNB (Low Noise Block downconverter), which is normally located at the feed point of the receiving dish, and is integrated with the feed that gathers in the signals that have been brought to a focus by the curved reflector of the dish.

For a domestic installation where the LNB is connected directly to each satellite receiver's tuner using a single coaxial cable, there has to be a means for each tuner independently to tell the LNB which of the four possible sub-bands to supply. It would also be convenient for the receiver to supply power to the LNB using the same coaxial cable. These requirements are met using tone and voltage signalling. Each tuner supplies current to the LNB at either 13 volts or 18 volts; this powers the LNB and tells the LNB that vertical polarisation (13 volts) or horizontal polarisation (18 volts) is required. The tuner also can send a 22 kHz tone to the LNB on the same cable. If the tone is present, the LNB selects High Band, and if the tone is absent, the LNB selects Low Band.

The frequency shift that is applied to signals in the LNB is controlled by an oscillator (sometimes called a local oscillator, because it is located in the LNB). A signal coming into the LNB will be shifted to a frequency that is the difference between the incoming signal's frequency and the oscillator frequency. The choice of whether to shift the High Band or the Low Band into the satellite IF band is made by switching the oscillator frequency, normally at either 9,750 MHz or 10,600 MHz. For example, if a signal from the satellite is received on 10,750 MHz, and the oscillator is at 9,750 MHz, then the incoming signal will be found at 1,000 MHz on the LNB's output.

When there is switching in the LNB, the LNB's output cannot be used for more than one receiver. This is because two receivers sharing one feed from the LNB may need to see different sub-bands, so the tone and voltage commands from the two receivers may conflict with each other; further, there is only capacity in the satellite IF for one of the four sub-bands at a time. Note that a PVR (Personal Video Recorder) that allows recording of one programme while watching another is effectively two separate receivers as it has two independent tuners. Each tuner must be connected directly to its own output on an LNB. To enable PVRs or other arrangements of multiple receivers all to use the same dish, LNBs with multiple outputs are available: a Quad LNB has four switched outputs, and an Octo LNB has eight switched outputs.

There are two types of LNB that have four outputs, and these are known as Quad and Quattro. Quad LNBs provide four switched outputs as described above, each of which can individually be controlled by tone and voltage signalling. In contrast, Quattro LNBs provide four un-switched outputs, one for each of the four sub-bands. Normally, a Quattro LNB is used in communal systems.

Communal systems

While an Octo LNB might appear to make a simple and inexpensive way of getting satellite signals to up to four flats, with two cables per flat, most systems are also required to carry terrestrial TV signals, and often FM and DAB radio. This is best achieved with a combination of a Quattro LNB and a multiswitch in a configuration known as an IRS (Integrated Reception System).

A multiswitch connects to all four satellite sub-bands simultaneously, each one on a separate cable. It also connects to terrestrial TV and radio signals; often these have to be combined externally onto one cable. The number of outputs on a switch varies from one model to another, typically from four to thirty-two. Each output carries the full set of terrestrial signals, together with one of the four satellite sub-bands, depending on the tone and voltage signalling that it is sent by the satellite receiver. As far as any satellite receiver is concerned, a multiswitch behaves in the same way as an LNB.

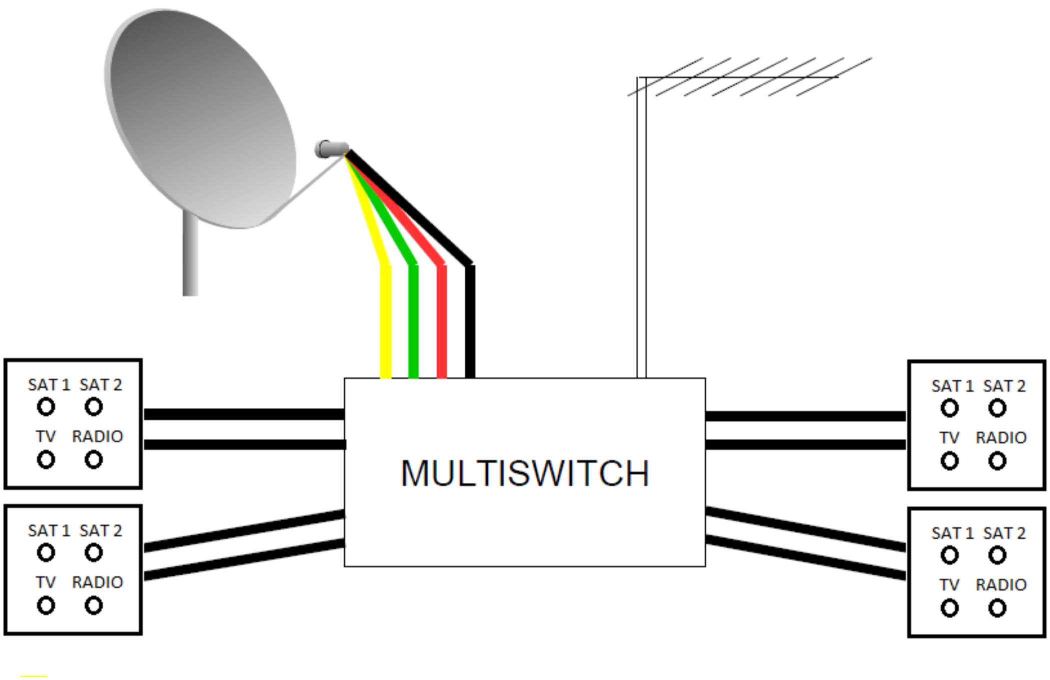


Figure 24: An example of a multiswitch being used in an IRS to feed four flats

The type of IRS shown in Figure 24 is known as a 5-wire IRS, because it has four cables from a satellite dish and a further one carrying terrestrial signals (UHF TV, FM, DAB, for example). It is quite common for systems to be built that carry the signals from more than one satellite network (e.g. Astra, Hot Bird). An IRS providing access to two satellite networks would be known as a 9-wire system, as it would have two sets of four satellite signal cables together with the terrestrial signal cable.

It is important that the four satellite signal inputs on the multiswitch are connected to the correct set of satellite signals or the receiver will not see the signals that it is expecting. To help avoid confusion, the cables carrying these signals should be colour coded as follows:

Cable colour	Signals
Yellow	Horizontal High Band (HH)
Green	Horizontal Low Band (HL)
Red	Vertical High Band (VH)
Black	Vertical Low Band (VL)
White	VHF + UHF

Table 6 Colour coding for multiswitch input cables

It is common to install two cables (often referred to as "drop cables") from the multiswitch to each flat, so that a PVR can be used. When two cables are used, the outlet plate in the flat should have four sockets (a quad plate): two for satellite, one for terrestrial TV, and one for radio (FM and DAB). The four sockets and two drop cables are connected via a triplexer behind the face plate, which filters the signals so that each type of signal appears only on the appropriate socket.

Single cable router, SCR

While the use of two cables per flat has been widely adopted, this is not able to satisfy the requirements of residents wanting to operate more than a single PVR, for example to have an additional receiver in another room. SCR addresses this problem by allowing multiple satellite receivers to operate on a single cable.

In the conventional IRS (sometimes referred to as "legacy IRS") described above, the LNB converts each of the four satellite sub-bands to the satellite IF, and the multiswitch routes the whole of the appropriate sub-band to the satellite receiver's tuner(s), responding to the tone and voltage signalling received by the multiswitch. With SCR, each tuner is allocated a unique channel on its cable, and the multiswitch routes the single desired multiplex into that channel. The channels used by receivers are known as user bands.

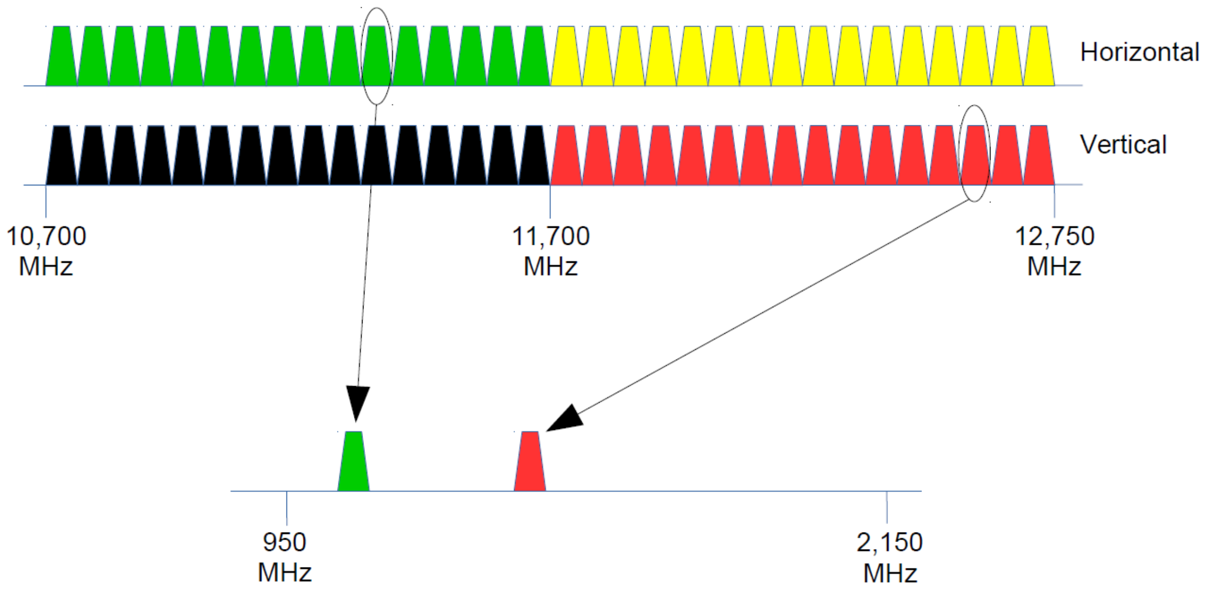


Figure 25: SCR operation with two receivers using two user bands on the same cable

SCR vs. dSCR

There have been two generations of SCR devices. First generation devices used analogue techniques, including typically SAW filtering, to separate the user bands. These devices are limited to a maximum of eight user bands per cable, and in practice normally only use up to four. Second generation devices use digital filtering techniques internally, and enable up to thirty-two user bands to be provided, but in practice this is normally limited to sixteen. Second generation devices are distinguished from first generation devices by the prefix d (dSCR), where the d indicates that digital techniques are used in the signal processing. Note that this has nothing to do with the satellite signals being digital; both SCR and dSCR should be capable of handling any signal format, analogue or digital.

First generation devices conform to BS EN 50494:2007, "Satellite signal distribution over a single coaxial cable in single dwelling installations" (which has extensions for use in MDUs), and second generation devices conform to BS EN 50607:2015, "Satellite signal distribution over a single coaxial cable. Second generation." EN 50607 is quite similar to EN 50494, the main differences being the introduction of a number of extensions, for example to allow a greater number of user bands. In fact, EN 50607 systems are backwards compatible with EN 50494 receivers. However, while Sky's proprietary dSCR system is similar to EN 50607, it differs in a number of ways, so that Sky receivers will only operate with distribution systems where the multiswitches are able to implement Sky's specific system.

An SCR multiswitch is significantly more complex than a conventional multiswitch, and needs to be able to exchange information with the receivers about the user bands that will be used, the multiplex that is required, and so on. The data exchange uses DiSEqC™, an openly available standard created by Eutelsat. DiSEqC™ is effectively an extension of the tone and voltage signalling described in the LNB section of this report above. The 22 kHz tone is pulsed on and off in two different ways to represent the 1s and 0s of a binary message. This is a relatively slow data transmission method; a 5-byte message takes about 67 milliseconds to send. This is why the number of bytes in a message is kept to a minimum.

The Sky Q receiver

The Sky Q receiver range has multiple tuners inside the box, and is able to operate with a full range of services using either one dSCR-fed cable or two wideband signal cables. The main receiver is connected to the incoming feed from the dish or communal system, and is intended to act as a hub or gateway. Secondary receivers in the same home are fed via Wi-Fi or Ethernet from the main receiver and do not use any direct satellite feeds

The main receiver can operate in either of two modes:

- Wideband mode (sometimes called full band capture), where the LNB provides signals on two cables;
- dSCR mode (shown on the receiver’s set-up page as SCR), normally for communal systems, where the signal format must be in Sky's variant of the dSCR mode on a single cable.

Wideband mode

As discussed above, a conventional satellite receiving system will produce four sub-bands, all of which use the frequency range 950 MHz to 2150 MHz. In a system using a wideband LNB, there are only two cables, each carrying a new wider satellite IF range: 290 MHz to 2340 MHz. The whole vertically polarised signal band is converted down to this new IF range and carried on one cable, while the whole of the horizontally polarised signal band is converted down and carried on the other cable - see Figure 26. The LNB's conversion oscillator frequency is 10.41 GHz.

In a wideband system, all signals from one satellite location are present on the two cables, and no switching of signals on the cables is required. The receiver feeds these signals internally to all the tuners, which can operate independently and access any required multiplex on the satellite platform.

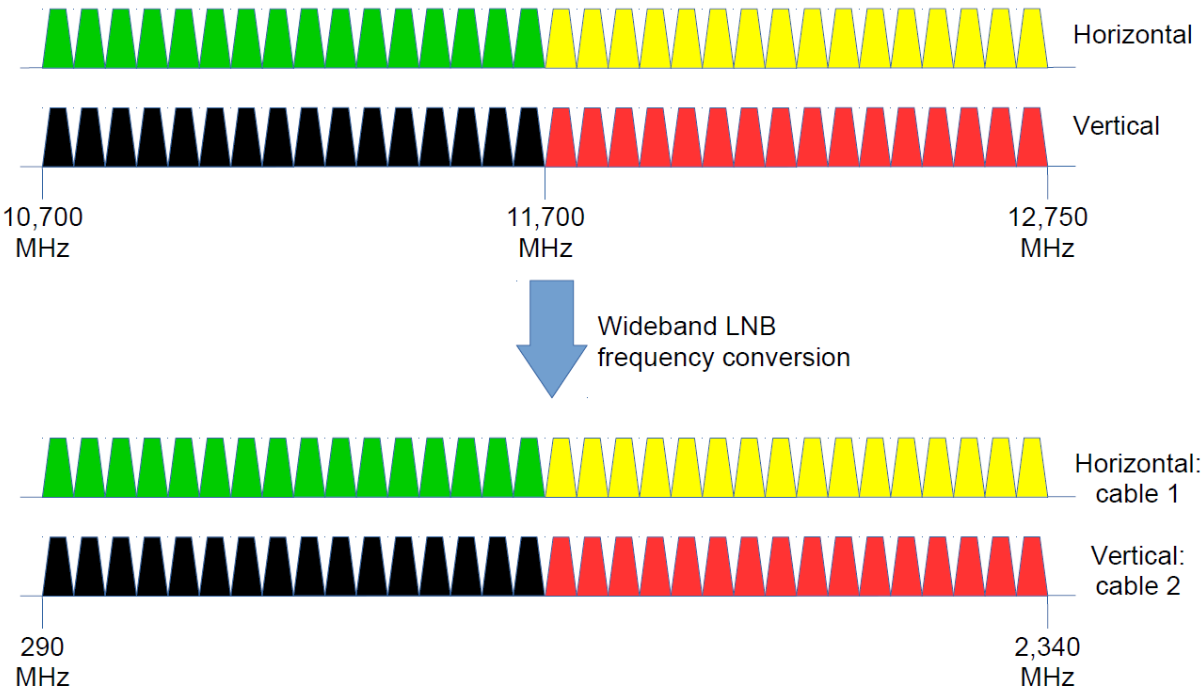


Figure 26: a wideband LNB converts the whole of each polarisation to a new, wider IF range

Wideband systems are normally intended for use in individual households equipped with their own dish, but some equipment is now available that allows the use of wideband LNBs in communal systems. In these systems, the cable colouring convention shown in the next table should be used:

Signals	Cable colour
Vertical polarisation, satellite 1	Black
Horizontal polarisation, satellite 1	Green
Vertical polarisation, satellite 2	Red
Horizontal polarisation, satellite 2	Yellow
Terrestrial	White

Table 7 Cable colour coding for multiswitches with wideband inputs

When using wideband systems it is no longer possible to carry terrestrial TV signals on the same cable as satellite, because wideband systems use frequencies down to 290 MHz. Furthermore, wideband systems cannot use outlet plates that contain diplexers or triplexers, as the satellite sockets are filtered to prevent passing signals below 950 MHz.

dSCR mode

Connecting a Sky Q receiver to a communal system requires that the system is able to provide signals that are compliant with Sky's variant of dSCR. Sky Q receivers will not operate either with the Sky's variant of SCR or conventional (legacy) systems.

Up to sixteen user bands can be operated on a single cable, each providing independent access to any of the multiplexes on the platform. In the Sky system, the user bands are at predetermined frequencies, as shown in the table.

User Band	Centre frequency
UB3	1680 MHz
UB9	1280 MHz
UB11	1380 MHz
UB14	1480 MHz
UB15	980 MHz
UB16	1030 MHz
UB17	1080 MHz
UB18	1130 MHz
UB19	1530 MHz
UB20	1580 MHz
UB21	1630 MHz
UB22	1730 MHz
UB23	1780 MHz
UB24	1830 MHz
UB25	1880 MHz
UB26	1930 MHz

Table 8 User bands and their frequencies for the Sky Q system

Note that UB3, UB9, UB11 and UB14 are not normally used by Sky Q receivers as these channels are close to those used by legacy (SCR) PVRs.

Smart splitters

Sometimes it is convenient to run more than one satellite receiver from a single dSCR feed. Two Sky Q receivers should not share the same dSCR feed, since a single receiver may use most of the available channels. However, a single dSCR feed can be used for one Sky Q receiver and an SCR-equipped PVR or set top box. However a dSCR/SCR feed cannot be mixed with a legacy system that uses tone and voltage switching to select frequency band and polarisation.

Any receivers on the same cable may initiate communications with the dSCR multiswitch. Receivers have no awareness of what any other receiver is about to do, so there is a small probability that two receivers will each try to send a DiSEqC™ message at the same time.

The resulting collision will cause both messages to fail to be received correctly by the multiswitch.

Both EN 50494 and EN 50607 describe methods of detecting failures due to collisions, and a means of recovering from such a failure. Unfortunately older satellite receivers may not fully support these standards, so an external device known as a smart splitter may be used. A smart splitter is an active device that intercepts DiSEqC™ messages from receivers, and if two arrive together, it adjusts the relative timing of the messages so that they no longer collide, as illustrated in Figure 27.

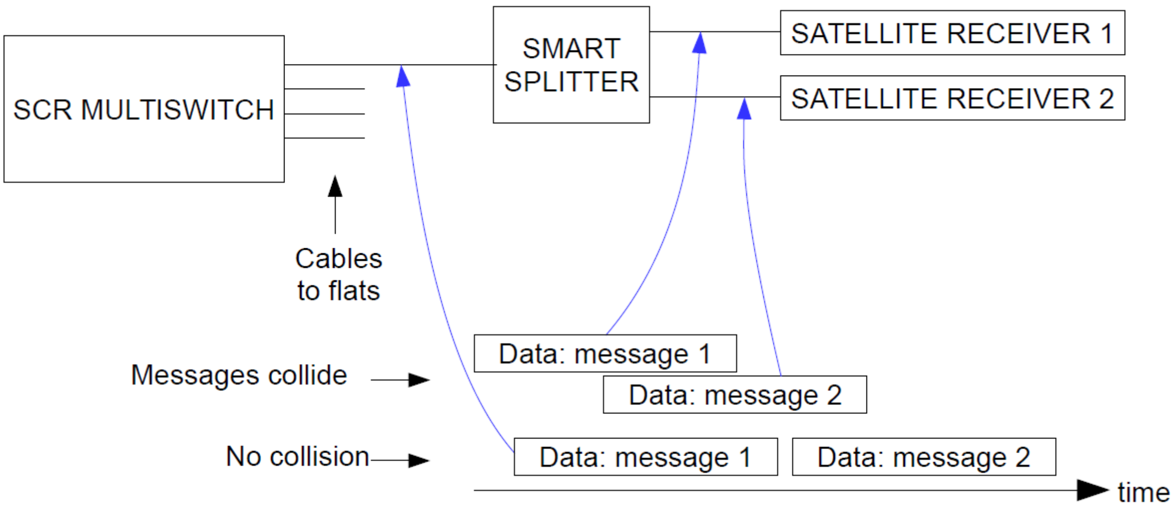


Figure 27 Use of a Smart Splitter to avoid DiSEqC™ collisions between messages from receivers to the multiswitch

Interference into satellite systems

Since mobile phone handsets and base stations operate in frequencies that are within the standard satellite IF range and mobile phone handsets are likely to be operated from time to time in fairly close proximity to receiving equipment and cabling, it is important that appropriate quality materials and workmanship are used. Cables qualified under the CAI cable benchmarking scheme should be used, as these will provide a specified minimum level of screening. Only crimped or self-install F connectors should be used, fitted to the cable in accordance with the manufacturer's specifications, and tightened onto the F socket to the required torque (i.e. not left finger tight).

Further information about recommended installation practices and interference mitigation can be found in the CAI's Codes of Practice.

Optical Fibres

In recent years, the use of optical fibres for carriage of TV signals has become commercially viable, mainly due to the availability of inexpensive laser devices that have a sufficiently large modulation bandwidth to be able to carry a full set of terrestrial and satellite TV signals.

The major advantage of optical fibre is its very low loss compared to cable. Fibres can offer a loss as low as 0.2 dB per kilometre. In contrast loss for type 100 coaxial copper cables at the top end of the standard satellite IF band is 30 dB per 100 metres. Fibre optic systems are clearly most suited to systems with signal runs in excess of about 100 metres.

Optical fibres offer these additional advantages:

- The loss of a fibre is independent of the signal frequency, so unlike with copper coaxial cable, equalisation is not required;
- The diameter of a sleeved single fibre is typically less than half that of a copper coaxial cable;
- The fibre can provide electrical isolation between the two ends, eliminating problems arising from unequal earth potentials.

However, there are disadvantages too:

- Making joints and fitting connectors requires relatively expensive equipment;
- There is a need for scrupulous cleanliness when making connections. The tiniest amounts of dirt in a connector can cause a big increase in loss;
- A sharp bend in a fibre can cause increased loss.

A fibre distribution system is typically structured as shown in Figure 28. At the headend, the terrestrial and satellite signals are combined and modulated onto the laser, typically in the RF to optical converter. There is normally a need for some processing of terrestrial signals to control signal levels, and also to ensure that only the desired multiplexes are admitted, and that all interference, especially from 800 MHz mobiles and base stations, and potentially TV White Space devices, is excluded.

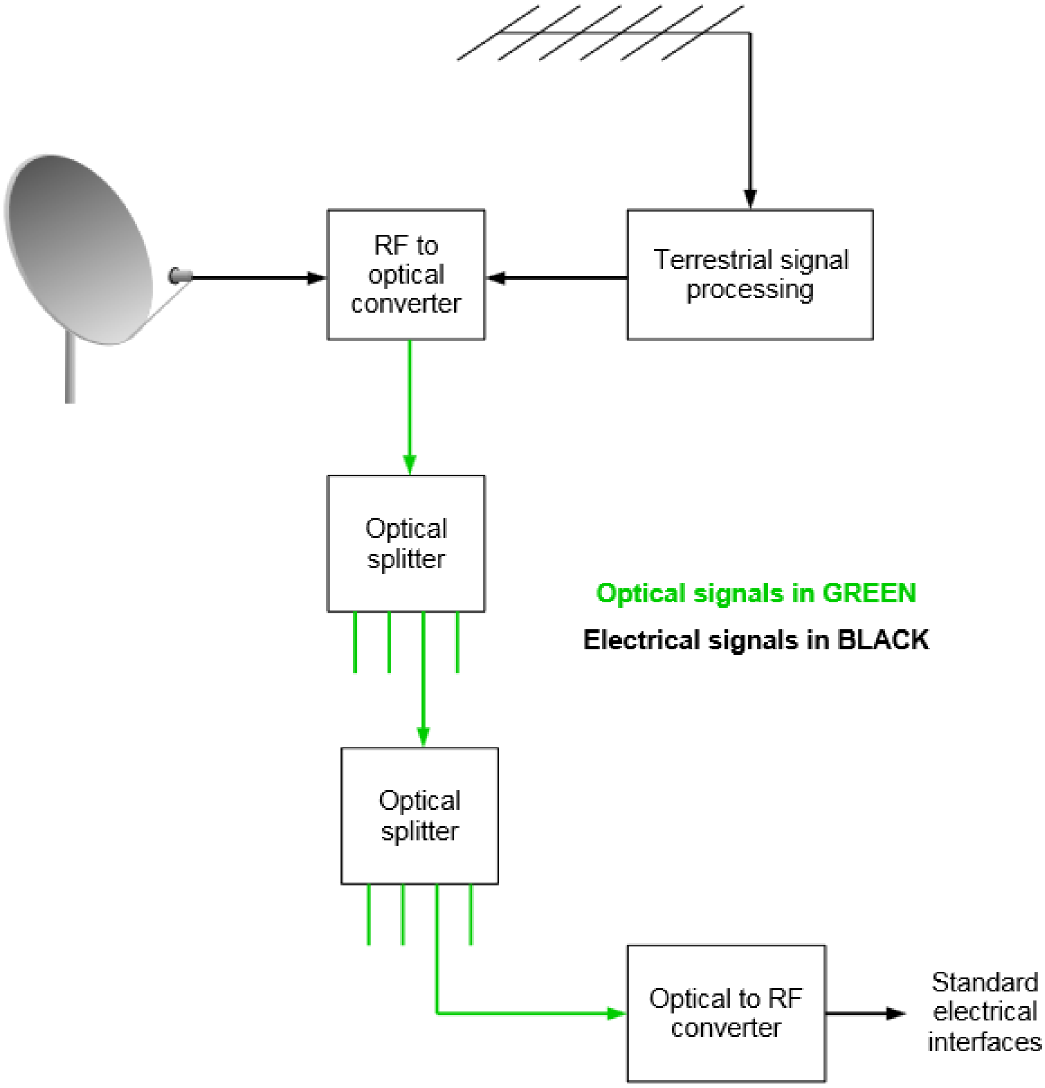


Figure 28 the structure of a typical fibre optic distribution system

The distribution network comprises an arrangement of fibres and optical splitters, not dissimilar to coaxial cable distribution networks found in many MATV systems. Each optical splitter introduces some power loss; for example, a 4-way splitter would introduce about 7 dB loss. The manufacturer will specify the maximum permissible loss across the distribution network, and this will limit the number of homes that can be fed from a single source without optical amplification.

When the fibre enters the home, it terminates on an optical to RF converter. These converters are available with a number of different output configurations, such as Quad, Quattro, SCR and dSCR. Once the signals are back in the electrical domain, they can be used with other IRS equipment; for example, a Quattro optical to RF converter can be used with a multiswitch, and a dSCR optical to RF converter can be used with a Sky Q receiver.

Optical to RF converters are typically powered either by a receiver or by an external power supply.

About the DTG

The DTG is the UK collaboration centre for innovation in digital media technology, underpinning the free-to-air platforms Freeview, Freesat and YouView and supporting the development of Sky, Virgin Media, BT, TalkTalk, Connect TV and VuTV.

It has been central to the distribution of TV in the UK for nearly two decades and is currently embracing the convergence of content and networks across industries to focus on the efficient delivery of video to all screens - mobile, tablet and TV, in all formats - standard, high and 4k definitions and beyond.

The DTG is currently supporting the next generation of digital TV and related technologies though its work in the following areas: the delivery of video to mobile devices; television on tablets; spectrum coexistence management; TV white space; home networking; accessibility, and the UK UHD Forum.

About the CAI

The CAI is the recognised body for the aerial and satellite industry. The CAI is committed to raising Standards within the industry and the criteria for membership are extremely high.

CAI Members only employ qualified personnel whose work is monitored by an Inspector. If a CAI Member is undergoing inspection, it may be that the CAI Inspector will wish to accompany them to view their installing capabilities. This would be at no extra charge to the customer. It is however, within the rights of the customer to refuse the installation to be inspected.

All CAI Members guarantee their installations for a minimum of 12 months. In addition to this, the CAI undertakes to back-up this guarantee with its own 12-month guarantee, for domestic installations only.

This means that should a CAI Member fail to honour their 12-month guarantee on a domestic installation, the consumer can seek redress via the CAI. Provided that the problems are within the realms of the original guarantee, the CAI will arrange to have the work corrected - at no extra cost to the consumer.

All Members are required to work to the exacting standards laid down in the CAI's Codes of Practice.

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Definitions and abbreviations

ACPR: Adjacent Channel Protection Ratio	This is a measure of how much more powerful an interferer on a nearby channel can be, compared to the wanted DTT signal, before the receiver suffers with errors on the picture.
BER: Bit Error Ratio	BER is a measure of the number of errors in the received data stream.
BS: Base Station	BS is used to define the equipment and towers in mobile networks e.g. 4G/LTE which transmit and receive to and from mobile handset equipment (user equipment – see UE).
CCI: Co-channel Interference	This term is often applied to unwanted DTT signals from distant transmitters using the same channel as the wanted DTT signal, but in the case of LTE interference we generally are referring to the intermodulation noise generated in an amplifier, or more specifically the part of the intermodulation noise spectrum that is on the same channel as the wanted DTT signal.
C/N or CNR: Carrier to Noise Ratio	C/N is a measure of the ratio of the signal power in a channel to the noise power in the same channel, and is fundamental to the operation of a receiver: the C/N must be over a certain value for the receiver to work at all. C/N is normally expressed in dB.
Coexistence	This term is used to define the ability of different technologies to operate simultaneously without causing harmful interference to one another.
dSCR	Digital Single Cable Router - mechanism for allowing multiple satellite receivers to operate on a single cable. dSCRs use digital signal processing techniques in comparison to SCRs which use analogue signal processing.
DTT: Digital Terrestrial TV	Digital TV broadcast entirely over land based circuits i.e. not satellite or cable.
DVB-T: Digital Video Broadcasting – Terrestrial	DVB-T is a standard for the broadcast transmission of digital terrestrial TV which was first published by the European consortium DVB in 1997 and first broadcast in the UK in 1998.
DVB-T2: Digital Video Broadcasting – Terrestrial Second Generation	DVB-T2 is an extension to the DVB-T standard which offers improvements to over DVB-T such as increased capacity and robustness to impulsive interference. DVB-T2 is used to transmit HD services in the UK.
GTU: Gateway termination unit	Fibre GTUs convert optical power to RF power.
HDTV: High Definition TV	High definition TV is broadcast using DVB-T2 transmission technology in the UK and provides a higher resolution than standard definition.
Impulsive interference	Impulsive interference can originate from a wide range of sources, but most often from devices that generate sparks, either intentionally or otherwise.
IPTV: Internet Protocol TV	A system in which television services are delivered using the internet. This could be via a set top box connected to a TV which links to Wi-Fi, smart TVs with an Ethernet or Wi-Fi connection or using apps on smart phones and tablets.
IRS: Integrated reception system	IRS are cabled distribution systems designed to deliver FM radio signals in Band II, Digital Audio Broadcasting (DAB) in Band III, analogue and Digital Terrestrial Television (DTT) signals in Bands IV and V, and Digital Satellite Television (DST).
LNB: Low Noise Block Downconverter	An LNB receives microwave signals from a satellite dish and converts them to lower frequencies in order to send the signal to a set top box.
Local TV	Ofcom have to date have licensed 30 channels to deliver local TV services across towns and cities in the UK. Local TV is transmitted on channels 21 to 30 and 39 to 60 as per the national service but typically it is transmitted at about half the height of the main aerial due to the smaller coverage area required.
LTE: Long Term Evolution	LTE refers to Long Term Evolution which is a standard for wireless communication for mobile phones and data terminals. It is one of the technologies along with HSPA+ and WIMAX that was allowed by the ITU to be classifed as 4G technology. LTE 800 operates in the old DTT channels 61 to 68 (791 MHz to 862 MHz). LTE 700 will operate in the DTT channels 49 to 60 (694 MHz to 790 MHz). LTE 700 is expected to be in use by no later than 2022 in the UK.
MATV: Master Antenna TV	Supplies signals from a single aerial system to a number of receivers and are principally used to distribute terrestrial TV and radio received off-air.
MER: Modulation Error Ratio	MER is a measurement of how much a signal deviates from the ideal.
PMSE: Programme Making and Special Events	PMSE is a term used to denote equipment that is used to support broadcasting, news gathering, theatrical productions and special events, such as culture events, concerts, sport events, conferences and trade fairs. Examples of such equipment are wireless microphones and in-ear monitors.
PPDR: Public Protection and Disaster Recovery	PPDR services are provided by a service or agency, recognised as such by the national administrations, that provides immediate and rapid assistance in situations where there is a direct risk to life or limb, individual or public health or safety, to private or public property, or the environment but not necessarily limited to these situations (Source: Commission Recommendation C(2003)2657)).
PVR: Personal Video Recorder	An interactive TV recording device.
RED: Radio Equipment Directive	RED replaced the Radio & Telecommunication Terminal Equipment Directive from June 2014. The aim of both directives is to ensure that products sold in the EU meet minimum technical requirements and to encourage harmonisation of spectrum use. The RED introduced new requirements which meant that broadcast receivers will have to meet requirements for efficient and effective use of spectrum.
SCR	Single Cable Router - mechanism for allowing multiple satellite receivers to operate on a single cable - see also dSCR
SDTV: Standard Definition TV	SDTV is television system that uses a resolution that is not considered to be high definition.
TVWS: TV White Space	TVWS is a term used for DTT spectrum (470 MHz to 790 MHz) that is unused for DTT services in a particular geographical area. Ofcom have developed a framework to allow TVWS devices to be dynamically allocated access to the unused frequencies through the use of the TVWS database. The devices will be used for low power applications so as to avoid interference with DTT services and will be licence exempt in terms of use of the frequencies although they will need to meet a minimum technical specification.
UE: User Equipment	UE is used to define the mobile handsets or other mobile equipment which can transmit and receive to and from mobile phone networks such as 4G/LTE.

Annex A – DTT multiplex and service information

For more information on DTT multiplexes, channel line-up and updates, industry news and to check DTT coverage in a particular area, please use the link below to the Digital UK industry support webpage:

http://www.digitaluk.co.uk/industry

Annex B – UK DTT frequencies*

* From Q2 2020 channels 49 to 60 will no longer be in use for DTT – see 700 MHz Clearance for mobile broadband (694 MHz/channel 49 - 790 MHz/channel 60) section of this report for details.

DTT Channel	Centre frequency (MHz)
21	474
22	482
23	490
24	498
25	506
26	514
27	522
28	530
29	538
30	546
31	554
32	562
33	570
34	578
35	586
36	594
37	602
38	610
39	618
40	626
41	634
42	642
43	650
44	658
45	666
46	674
47	682
48	690
49	698
50	706
51	714
52	722
53	730
54	738
55	746
56	754
57	762
58	770
59	778
60	786

Annex C – Summary of interference mechanisms into DTT and guidelines for mitigation

<table>
<tr><th>Interference cause</th><th>Frequencies used by technology</th><th>Nearest DTT frequencies</th><th>Interference mechanisms</th><th>Dates applicable from</th></tr>
<tr><td rowspan="2">Impulsive interference</td><td rowspan="2">470-790 MHz</td><td rowspan="2">All</td><td>Co-channel interference coupling into DTT aerials</td><td rowspan="2">N/A</td></tr>
<tr><td>Co-channel interference coupling into downleads</td></tr>
<tr><th colspan="5">Guidelines</th></tr>
<tr><td>1</td><td colspan="4">In cases of impulsive interference, make sure that the download uses benchmarked cable, the aerial has a balun*, the outlet plate and fly lead are well screened, and that an appropriate level of DTT signal is delivered to the outlet as shown in Table 5. Persistent cases of impulsive interference should be reported to the Radio & Television Investigation Service (https://www.radioandtvhelp.co.uk/diagnostic/) for investigation.
*Note balanced to unbalanced conversion is intrinsic to the design of log periodic aerials</td></tr>
</table>

Table C.1 Interference mechanisms and guidelines for impulsive interference

<table>
<tr><th>Interference cause</th><th>Frequencies used by technology</th><th>Nearest DTT frequencies</th><th>Interference mechanisms</th><th>Dates applicable from</th></tr>
<tr><td>LTE 800</td><td>791-862 MHz</td><td>786 MHz (DTT channel 60)</td><td>Blocking and unwanted out-of-block emissions both coupled into the DTT aerial</td><td>Mid 2013</td></tr>
<tr><th colspan="5">Guidelines</th></tr>
<tr><td>1</td><td colspan="4">Installers who believe that disruption to a DTT installation is caused by LTE 800 interference should contact at800. This is the advice even if the installer is able to rectify the issue so that cases of interference can be tracked.</td></tr>
<tr><td>2</td><td colspan="4">LTE BS interference mitigation steps are to remove any unnecessary amplifiers, and where there is no filter integrated into the amplifier design, to fit a filter before the input to any remaining amplifiers or active device such as a multiswitch.</td></tr>
<tr><td>3</td><td colspan="4">In the absence of adjacent channel interference, e.g. from an LTE BS, ensuring that DTT signals delivered to outlets meet the criteria in Table 5 should ensure receivers perform well.</td></tr>
</table>

Table C.2 Interference mechanisms and guidelines for LTE 800

Interference cause	Frequencies used by technology	Nearest DTT frequencies	Interference mechanisms	Dates applicable from
LTE 700	694-790 MHz	690 MHz (DTT channel 48)	Adjacent channel interference from LTE handsets coupling into DTT aerials	Q2 2020
			Radiated interference from LTE handsets into faceplates, cabling, receiver chassis	
			Blocking caused by amplifier overload	
Guidelines				
1	*Viewers replacing their aerial are advised to fit a group T aerial if there are currently channels in use above 48, and otherwise to fit a group K, provided these have sufficient gain.*			
2	*The use of group C/D aerials should be avoided wherever possible, as they will not cover any of the channels available after the 700 MHz band clearance.*			

Table C.3 Interference mechanisms and guidelines for LTE 700

Interference cause	Frequencies used by technology	Nearest DTT frequencies	Interference mechanisms	Dates applicable from
Amplifiers	470-790 MHz	All	Intermodulation noise	N/A
			Overload caused by strong adjacent signals such as LTE	
Guidelines				
1	*If an amplifier is generating too much intermodulation noise due to overload, reduce the amplifier's gain or reduce the level of signal at the input. Although this will reduce the signal level at the output, it will increase the C/N at the output.*			
2	*Avoid the use of masthead amplifiers unless they are absolutely necessary*			
3	*If an installation needs a masthead amplifier, use one with the lowest gain consistent with adequate performance in order to minimise the risk of overload from LTE, place it as close to the aerial as possible and place it ahead of any significant losses from feeders, passive splitters, etc. If one is not already integrated into the amplifier design, installing an appropriate filter before the amplifier will reduce vulnerability to interference from e.g. LTE/4G (see section on interference mitigation).*			

Table C.4 Interference mechanisms and guidelines for amplifiers