The UK collaboration centre for innovation in digital media technology

DTG

R-Book 6

An installer's guide to the future of UHF spectrum

in partnership with the
Confederation of Aerial Industries

cai
Trade Association for
Content Delivery

supporting the installation of all
UK DTT platforms, including

Freeview youview

Includes

700MHz & 800MHz clearance
Radio Equipment Directive
Interference mitigation
TV White Space
Future of DTT
Local TV

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. This new version aims to support and prepare the installation industry for future spectrum changes, including how to deal with the impact they could have on working practices.

R-Book 6 contains practical advice on interference mitigation as well as advice on the latest industry guidelines.

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.

It is not yet known which channels will come into use as a result of 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.

2) 4G at 800 MHz: With more 4G/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 4G 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) 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/).

5) In the absence of adjacent channel interference e.g. from a 4G/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

6) The need for masthead amplifiers has significantly reduced since digital switchover.
Do not use masthead amplifiers unless they are absolutely necessary.

7) If an installation does need a masthead amp, 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. 4G/LTE; and
- Use an amplifier with the lowest gain consistent with adequate performance in order to minimise the risk of overload from LTE.

8) Mitigating the impact of amplifier overload.

If an amplifier is generating too much intermodulation noise due to overloading, 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.

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.

A report published in 2014 by Pascal Lamy for the European Commission proposes a roadmap which recommends securing access to UHF spectrum from 470-694 MHz (channels 21-48) for use by DTT until 2030[1].

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 at least 2030[2].

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, the view from DigiTAG (Digital Terrestrial TV Action Group: a European DTT industry body) is that current efforts and achievements point to a clear future for the next 20 to 30 years.[3]

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.

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[1] https://ec.europa.eu/digital-agenda/en/news/report-results-work-high-level-group-future-use-uhf-band
[2] http://stakeholders.ofcom.org.uk/binaries/consultations/700 MHz/discussion/ftv.pdf
[3] http://www.digitag.org/wp-content/uploads/2015/01/0694-Roadmap-Report web-3.pdf

The list below highlights the new and existing technologies and services that are increasing the demand for spectrum and that are explained further in this guide:

- 800 MHz 4G/LTE* mobile services
- 700 MHz 4G/LTE* mobile services
- TV White Space
- Local TV
- 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.

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 also proposed 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 from 2022 or possibly two years earlier[4]. A final decision will be 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.

[4] http://stakeholders.ofcom.org.uk/binaries/consultations/700 MHz/statement/700-mhz-statement.pdf

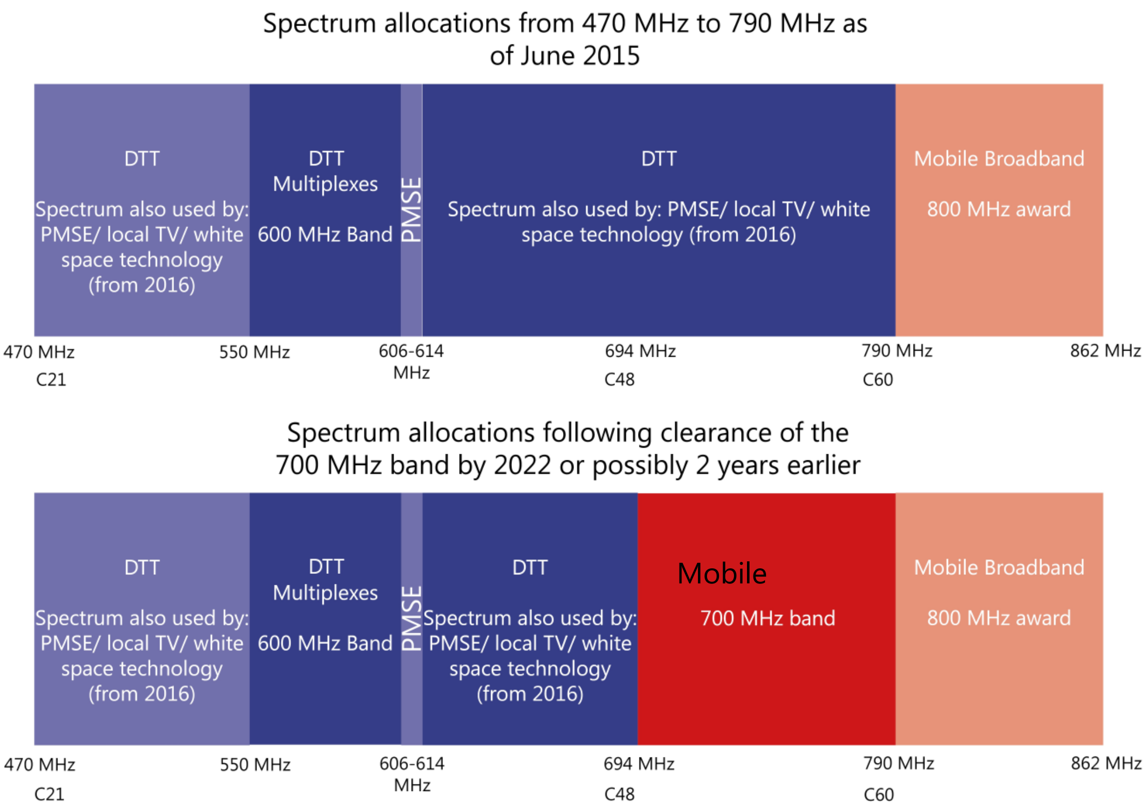

Figure 1 UHF spectrum allocations before and after 700 MHz clearance

TV White Space

Ofcom has also announced a framework for TV White Space (TVWS) where DTT channels not in use in particular geographical areas can 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.

Local TV

Ofcom has to date licensed 30 channels to deliver local TV services across towns and cities in the UK[6].

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

[5] http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/statement?utm_source=updates&utm_medium=email&utm_campaign=tvws-statement

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

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 transmitted at a lower power compared to the national commercial and public service broadcast multiplexes but using a more robust transmission mode to compensate.

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 420-470 MHz is currently under review by Ofcom, and outcomes of its analysis will be published before the end of 2015[7].

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[7] http://stakeholders.ofcom.org.uk/binaries/consultations/420-470-mhz/summary/420-470-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 there 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 a leaky 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.

The scope of at800's work includes the following support to mitigate disruption to primary receivers (but not additional receivers) where DTT is the only service at that point[8]:

- Provide information and advice to potentially affected households;
- Provide at800 accredited engineer visits and DTT receiver filters;
- Support vulnerable customers to assist with the installation of filters;
- Carry out platform changes (to a broadly equivalent cable or satellite TV service) where a filter and other remedial action does not solve the disruption problem; and
- For households requiring a platform change but which are unable to receive TV using an alternative platform, the provision of bespoke mitigation up to a limit of £10,000 per household is provided.

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 Picture failure caused by LTE 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

[8] http://stakeholders.ofcom.org.uk/binaries/consultations/award-800_MHz/statement/Annexes1-6.pdf Section A6.48

help avoid this. On occasion, interference can also be caused by direct ingress of the interfering signal through the receiver chassis itself.

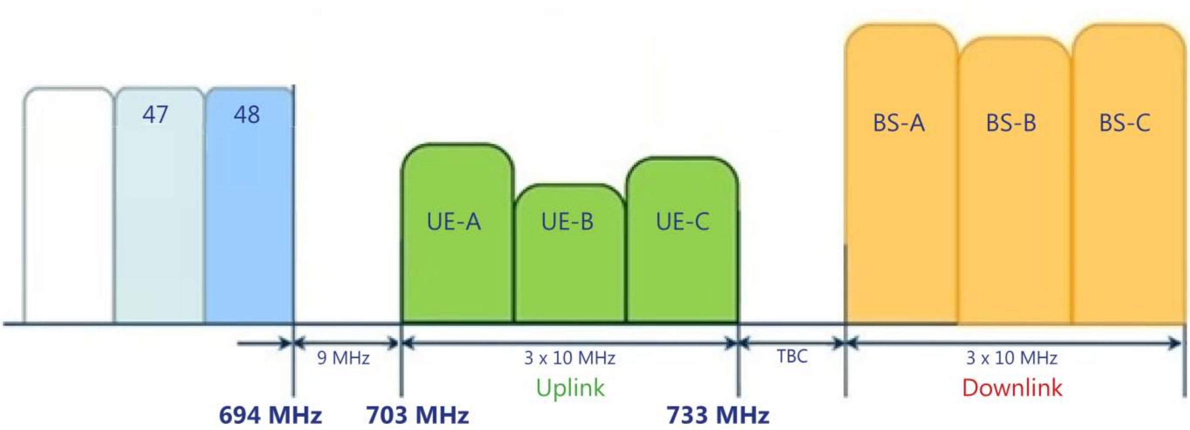
Filtering can be applied in most circumstances to resolve LTE interference issues. The filters work by reducing the level of the LTE signal whilst allowing the DTT signal to pass through with only a small reduction in level. Further information on filtering and how to mitigate the impact of amplifiers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

700 MHz LTE (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, resulting in cheaper products.



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

Figure 4 Proposed LTE 700 frequency allocations

Below are some key points associated with the 700 MHz clearance:

- Ofcom is currently preparing to change the use of the 700 MHz band (channels 49-60) from DTT to mobile broadband from 2022 or possibly up to 2 years earlier;
- Clearance of 700 MHz frequencies could begin by 2019;
- In areas where the frequencies are cleared first, Ofcom is considering the potential of an early release of the 700 MHz band. Roll out plans are currently being developed and updates from Ofcom will be included in future versions of this document as they become available;
- WRC 2015 is expected to enable the use of 700 MHz (channels 49-60) for mobile services;
- Ofcom has outlined its intention to secure DTT spectrum below 694 MHz for use by DTT until 2030.

Figure 5 gives an overview of timescales and each of the tasks involved leading up to 700 MHz clearance.

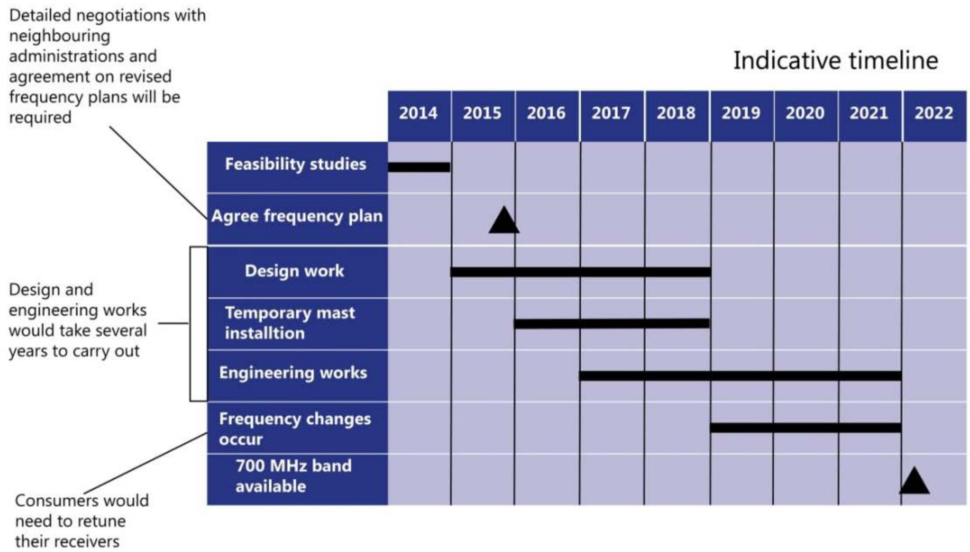


Figure 5 Ofcom's 700 MHz indicative timeline[9]

Potential impact to DTT services from 700 MHz LTE

As is the case with 800 MHz coexistence, base station interference to DTT services could still occur at 700 MHz. However due to the increased frequency separation between DTT and the LTE base stations in the 700 MHz band compared to the situation in the 800 MHz band, the principal mechanism is likely to be overload, particularly of amplified installations.

[9] Ofcom Spectrum Event 2014: http://www.ofcom.org.uk/static/spectrum-event/2014-event-day-1.pdf

Interference caused by LTE uplink signals from handsets could be more of a problem at 700 MHz than at 800 MHz due 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 going to be available in the 700 MHz band much earlier than 2022, filters are not currently being produced.

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.

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 MHz-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 is aiming to finalise its framework authorising the commercial use of white space technology by the end of 2015[10]. 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, the first commercial services could be deployed in early 2016. 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.

[10] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

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 420-470 MHz. As mentioned earlier in this document, 420-470 MHz is used for a wide range of services including business radio, 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 420-470 MHz is under review by Ofcom. A recent call for inputs[11] 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. Ofcom will be publishing outcomes of the analysis before the end of 2015, putting forward options for future management of the band if the evidence indicates that any action is needed.

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.

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

The Radio Equipment Directive and its impact

The Radio Equipment Directive (RED) is new EU legislation which replaces the Radio & Telecommunication Terminal Equipment Directive (R&TTE) from 13th June 2016. 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.

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 transmitting devices.

This means that equipment such as broadcast receivers and DTT amplifiers will now have to meet a set of European standards before it can be sold in the EU.

Work is currently underway to develop these new standards for DTT amplifiers and broadcast receivers. Equipment which falls under the new requirements may need to be compliant with them by June 2016.

As such, suppliers and installers of DTT amplifiers will need to make sure they keep up to date with the progress of when the new directive comes into force and ensure that any such equipment produced meets the new standards.

The future of DTT services

Growth in DVB-T2 receiver sales

The trend in sales of panel/flat screen TVs is towards full HD capability, that is, devices that are capable of receiving DVB-T2 transmissions rather than DVB-T only. On the other hand, sales of TVs that are SD-only i.e. which cannot receive DVB-T2 transmissions are declining.

Receivers that are labelled as HD Ready are counted as SD receivers as they do not have an in-built DVB-T2 tuner. HD services need to be provided by an external source such as a set top box (STB) with DVB-T2 built in.

Figure 6 highlights the trend of declining DVB-T-only receiver sales, with details of market share of flat screen TVs sold in the UK from May 2013 to April 2015. It can be seen that SD-only TVs have fallen from around 46% of the market share in February 2014 to around 35% in April 2015.

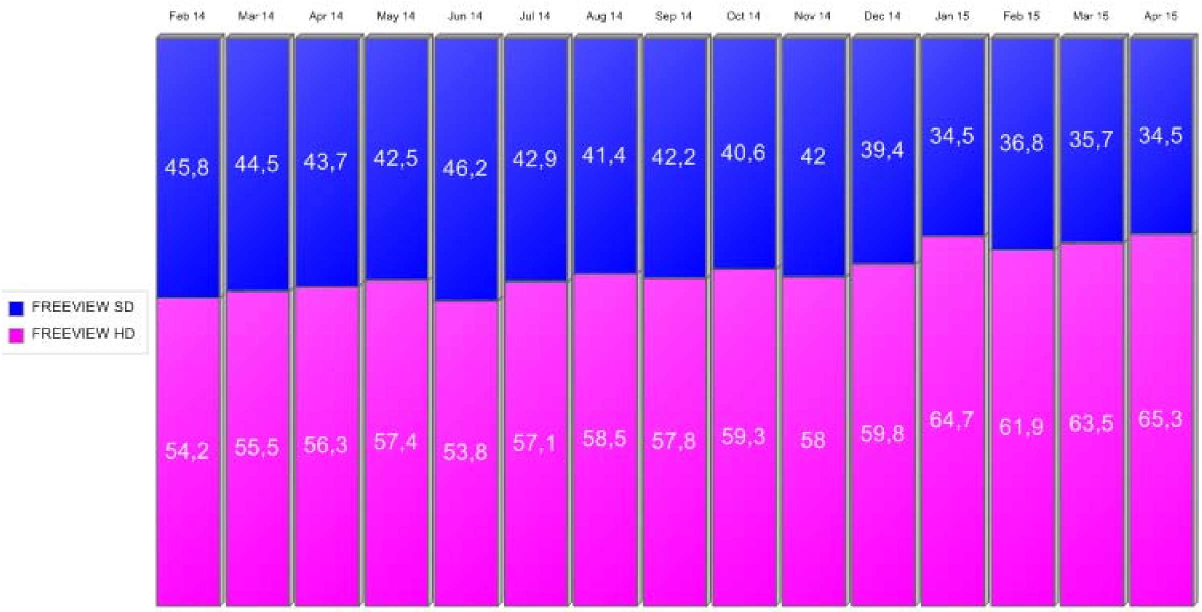


Figure 6 Market share for Great Britain of panel TV/flat screen TVs by receiver type (Source GfK)

A similar trend can be seen with STBs, with HD sales representing nearly 56% of the market share in the UK in April 2015, up from 36.5% in February 2014.

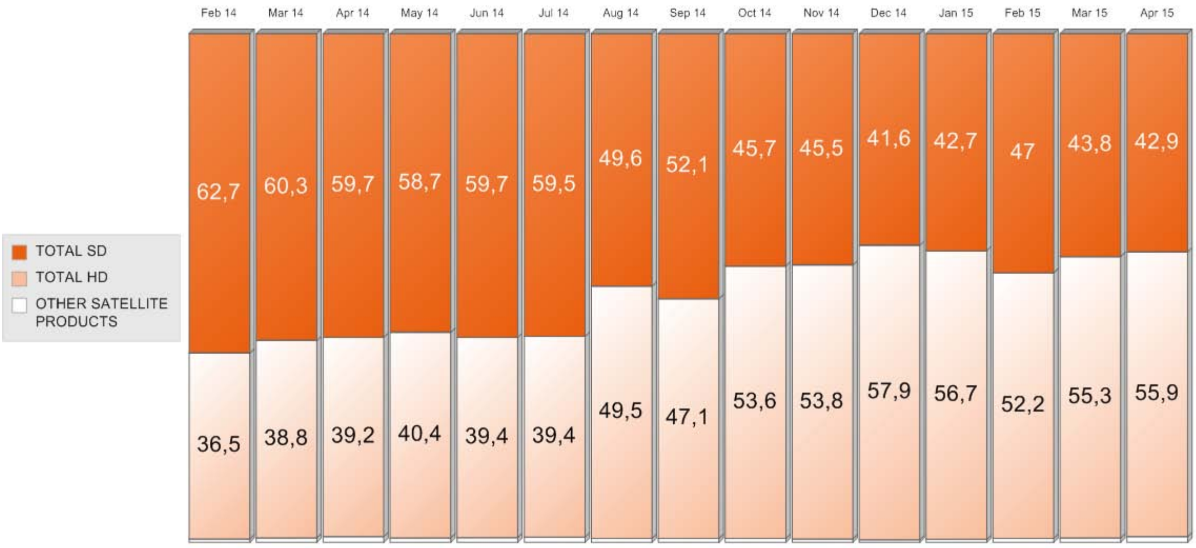


Figure 7 Market share in Great Britain for set top boxes by receiver type (Source GfK)

The cost of HD TVs and STBs is also reducing, as can be seen from the figures below. These show market share for various price-bands of receivers. As can be seen, the sub-£150 band now represents just over 50% of the market for HD STBs. This is up from around 25% for the same period in 2014. For TVs, 73.5% of all HD models are now in the sub-£500 price range compared to around 68% for the same period in 2014.

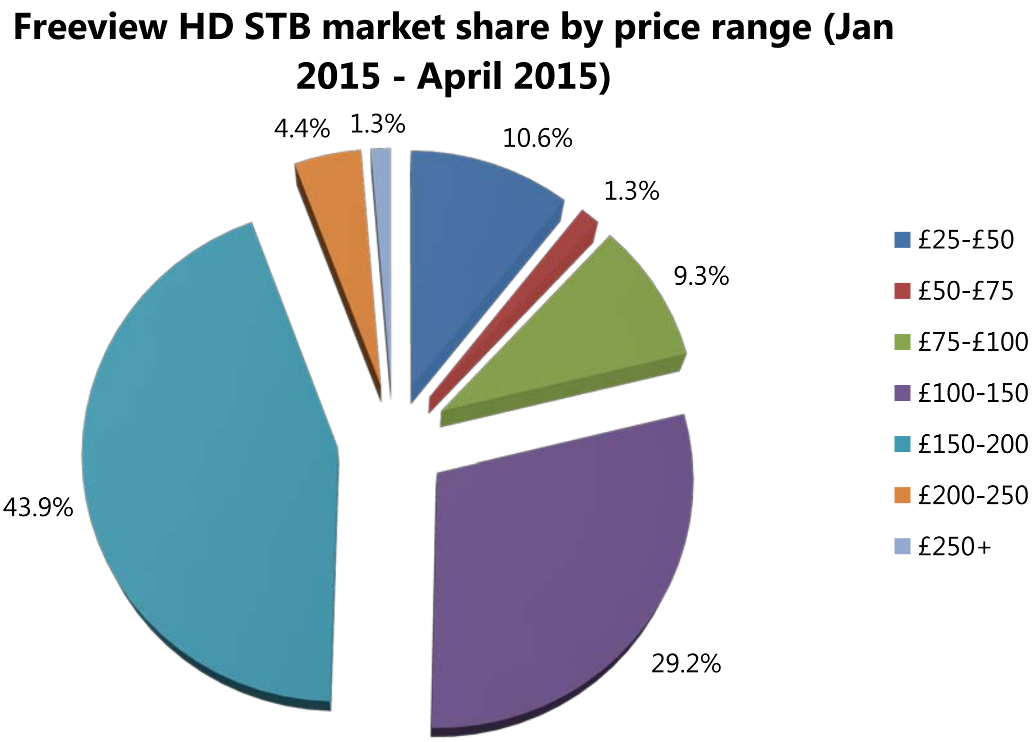


Figure 8 Market share in Great Britain of HD set top boxes by price range (Source GfK)

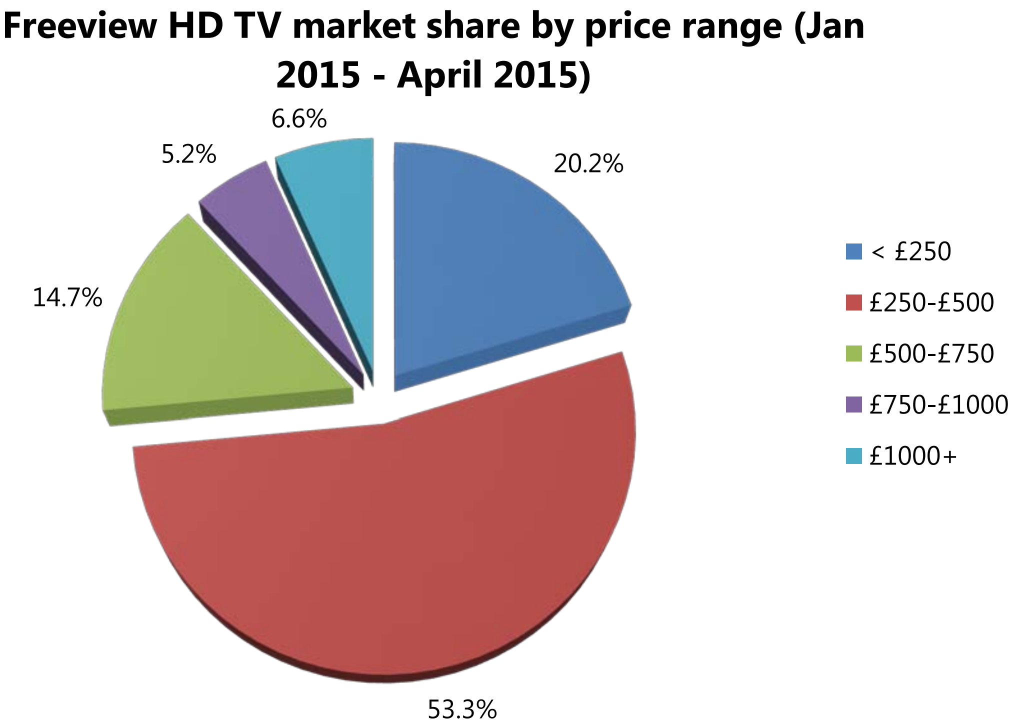


Figure 9 Market share in Great Britain of HD TVs by price range (Source GfK)

Why choose a DVB-T2 receiver?

Access to Freeview HD services

If a household has a DVB-T-only TV, it will mean that they will not have access to any of the Freeview HD services that are available, or if in Northern Ireland, the RTÉ services carried on the Northern Ireland multiplex. In order to receive these services the household will have to use an additional DVB-T2-capable STB at extra cost.

There is a wide range of content available on Freeview HD, and the number of services is increasing. In 2013, Arqiva was awarded a licence to establish interim DTT multiplexes in channels 31-37 (excluding channel 36) which covers the frequency range 550-606 MHz, known as the 600 MHz band. These multiplexes are solely using DVB-T2 technology, and provide a range of HD and SD services. Viewers without a DVB-T2 capable receiver will not be able to access these.

The latest transmission standards

DVB-T2 offers an improvement in capacity over DVB-T as highlighted in Figure 10, which shows the data rates achievable for each technology. A potential way for DTT transmissions to become more spectrally efficient would be a migration to DVB-T2 transmission only.

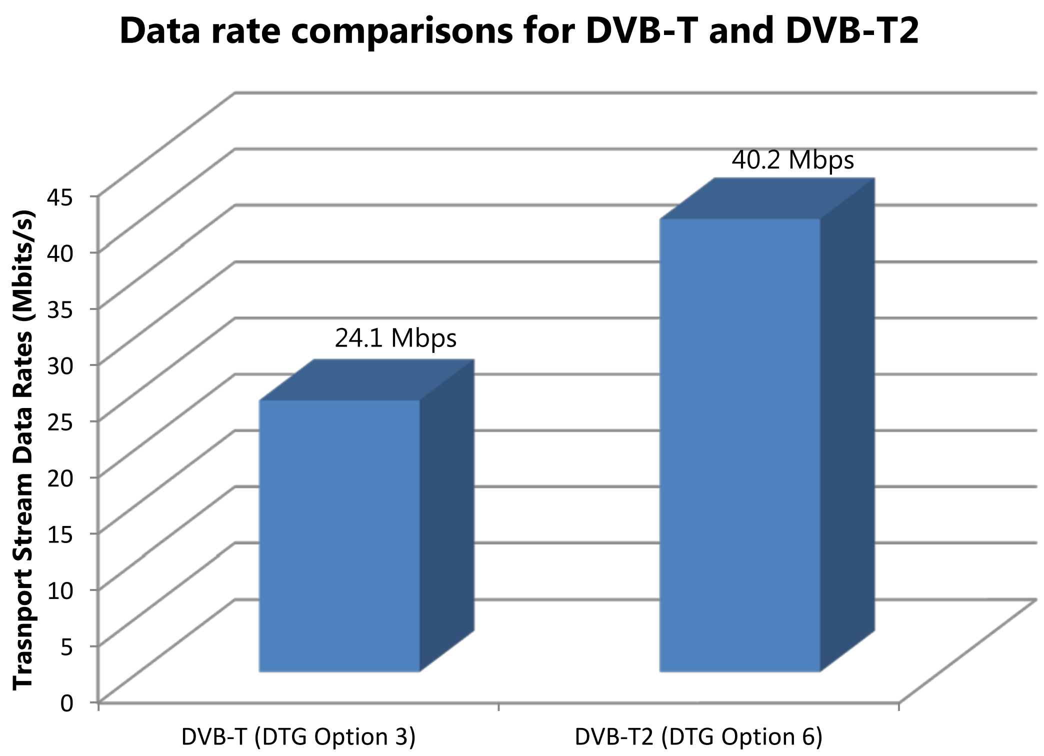


Figure 10 Data rate comparisons for DVB-T and DVB-T2 transport streams

It is recommended that households are advised to purchase DVB-T2 capable receivers if they are replacing their TV or STB as it remains the most efficient and up to date DVB transmission standard.

Section 2: Implications for installation practices

Introduction

This section covers the technologies that could potentially cause interference to DTT 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 tables 1-4 along with mitigation techniques. Further sections then describe each of these in greater detail along with other areas of the DTT installation that need to be considered.

Summary of DTT interference mechanisms and guidelines

Interference cause	Frequencies used by technology	Nearest DTT frequencies	Interference mechanisms	Dates applicable from
Impulsive interference	470-790 MHz	All	Co-channel interference coupling into DTT aerials	N/A
			Co-channel interference coupling into downleads	
Guidelines				
1	*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*			

Table 1 Interference mechanisms and guidelines for impulsive interference

Interference cause	Frequencies used by technology	Nearest DTT frequencies	Interference mechanisms	Dates applicable from
LTE 800	791-862 MHz	786 MHz (DTT channel 60)	Blocking and unwanted out-of-block emissions both coupled into the DTT aerial	Mid 2013
Guidelines				
1	*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.*			
2	*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.*			
3	*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.*			

Table 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	2022 with possibility of being 2 years earlier
			Radiated interference from LTE handsets into faceplates, cabling, receiver chassis	
			Blocking caused by amplifier overload	
Guidelines				
1	*It is not yet known which channels will come into use as a result of 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.*			
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 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 4 Interference mechanisms and guidelines for amplifiers

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*[12]*, the outlet plate and fly lead are well-screened, and that an*

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

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 11 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.

Figure 11 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 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.

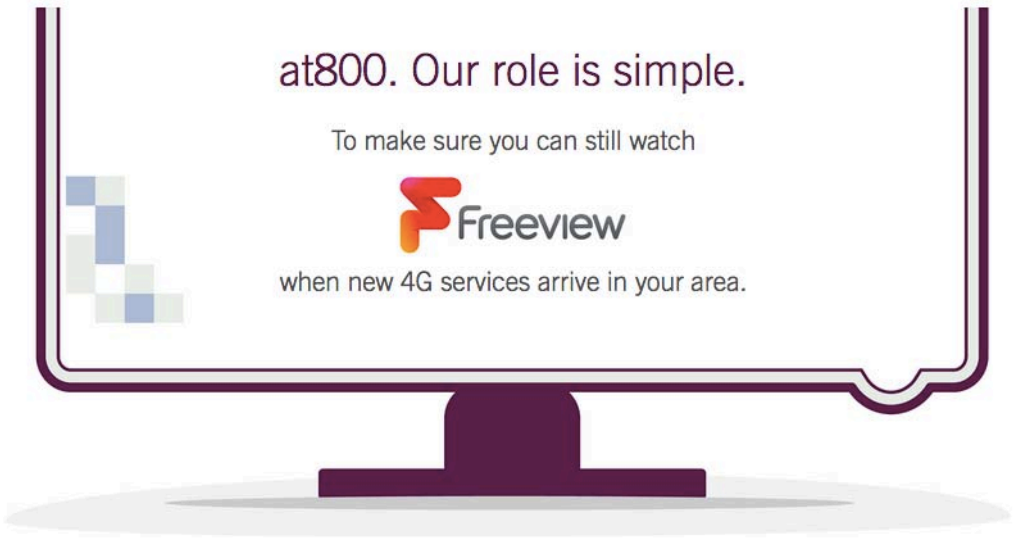
Interference can occur on any or all channels, but the channels closest to the BS frequencies are the most susceptible.

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 12 shows the characteristic of a typical consumer filter, and Figure 13 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.

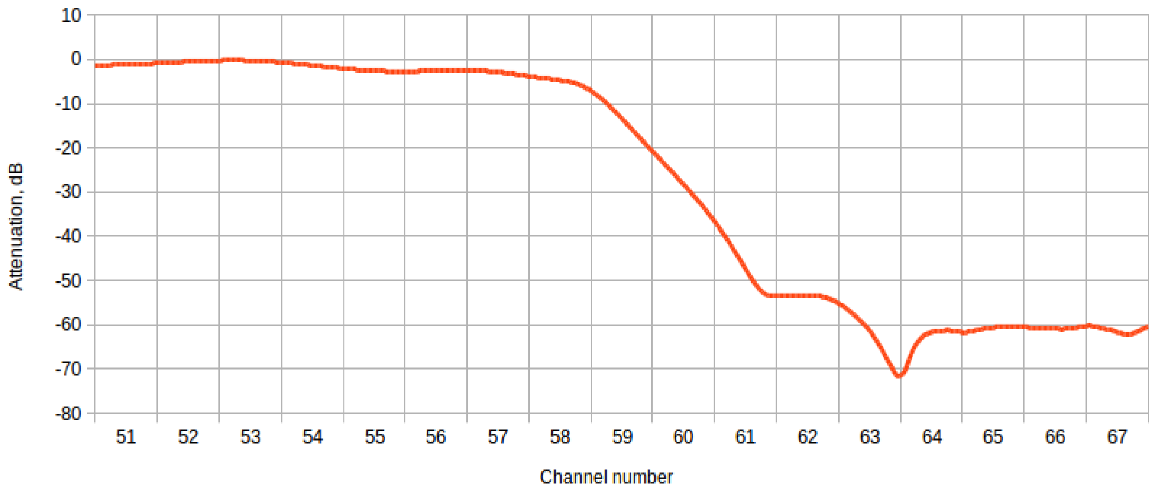


Figure 12 Characteristic of a consumer LTE filter

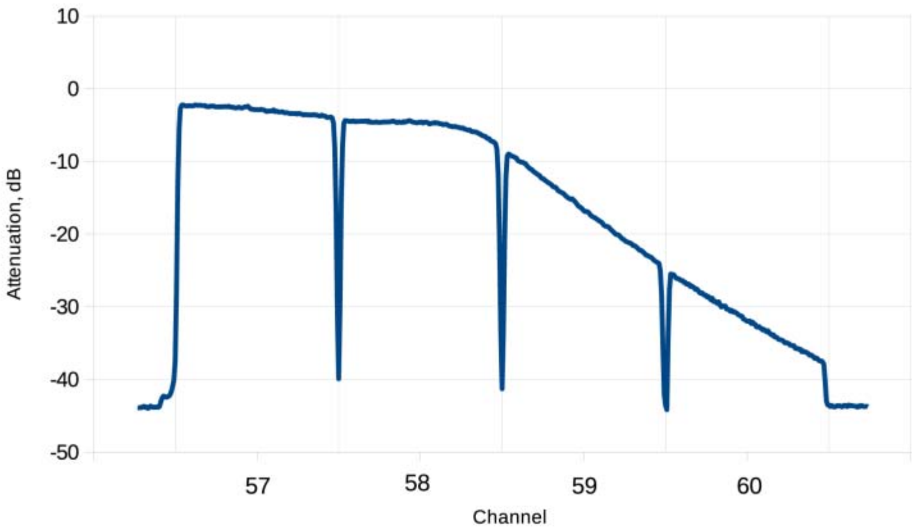


Figure 13 DTT signals after passing through a consumer LTE filter

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. When block A comes into widespread use, it is expected that the number of cases of interference into DTT on channel 60 will rise significantly.

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 14.

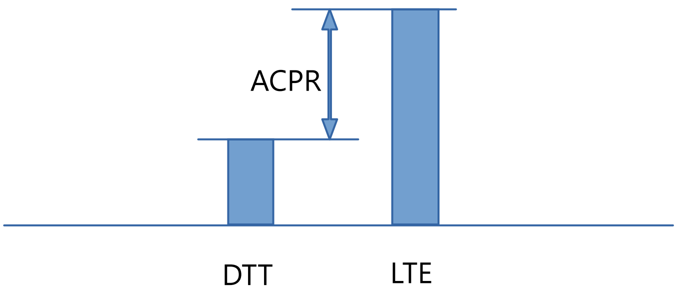


Figure 14 ACPR is the difference in level between the interferer and the victim when the victim signal just begins to fail.

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 5.

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 5 Recommended signal level ranges and C/N values for national and regional multiplexes (excludes local TV)

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 5 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 expected to start in 2016, 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.

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.

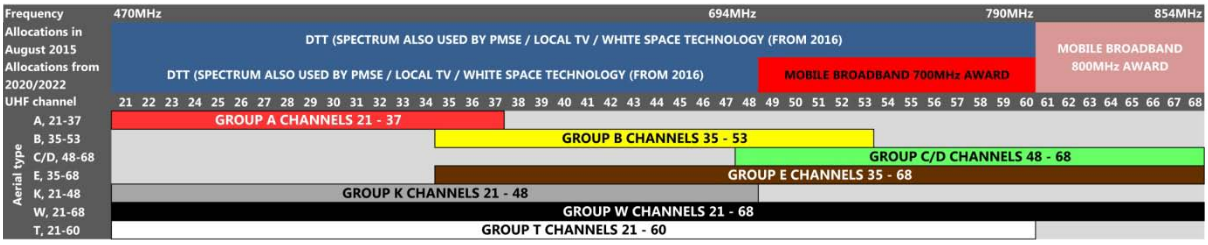


Figure 15 Aerial groups and the 700 MHz and 800 MHz bands

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 15, 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 is expected to confirm the change of use of the 700 MHz band (channels 49-60, shown in light blue in Figure 14), and we can expect transmitters to begin to be cleared out of this band in around 2019.

Channels 31-40 are currently used for interim DTT multiplexes, but these are temporary and may have to be replaced to make way for channels being moved out of the 700 MHz band.

All of these factors influence the choice of receiving aerial.

Guideline: *It is not yet known which channels will come into use as a result of 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.

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 16 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.

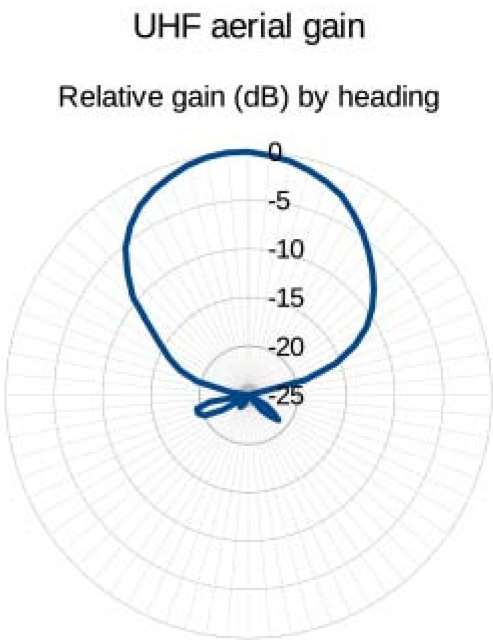


Figure 17 a polar pattern of a well-designed Yagi aerial

Figure 17 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 17) 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 18 *(data courtesy of Blake UK Ltd.)*.

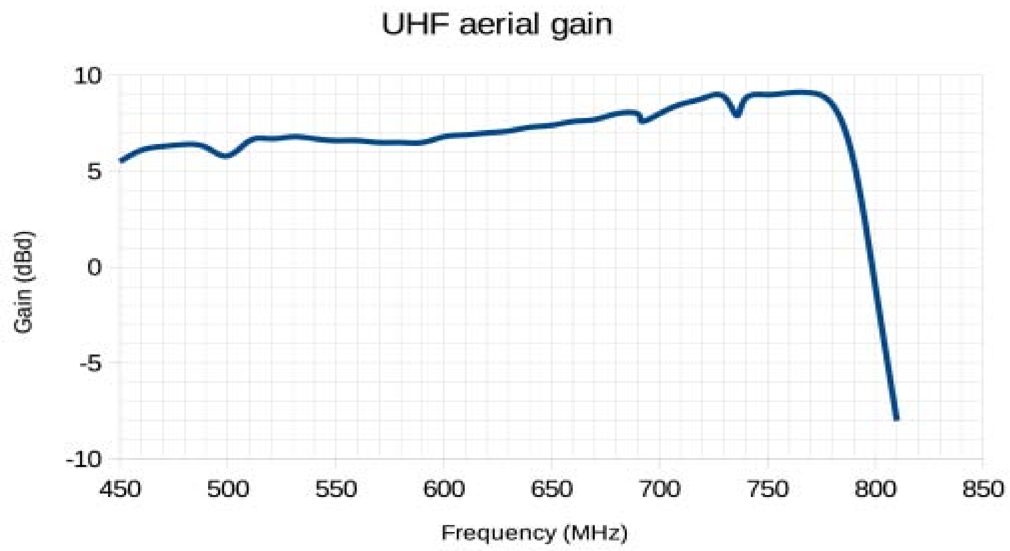


Figure 18 An example of the gain of a Yagi aerial against frequency

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 19, which shows that the output signal in this case is always three times the input signal.

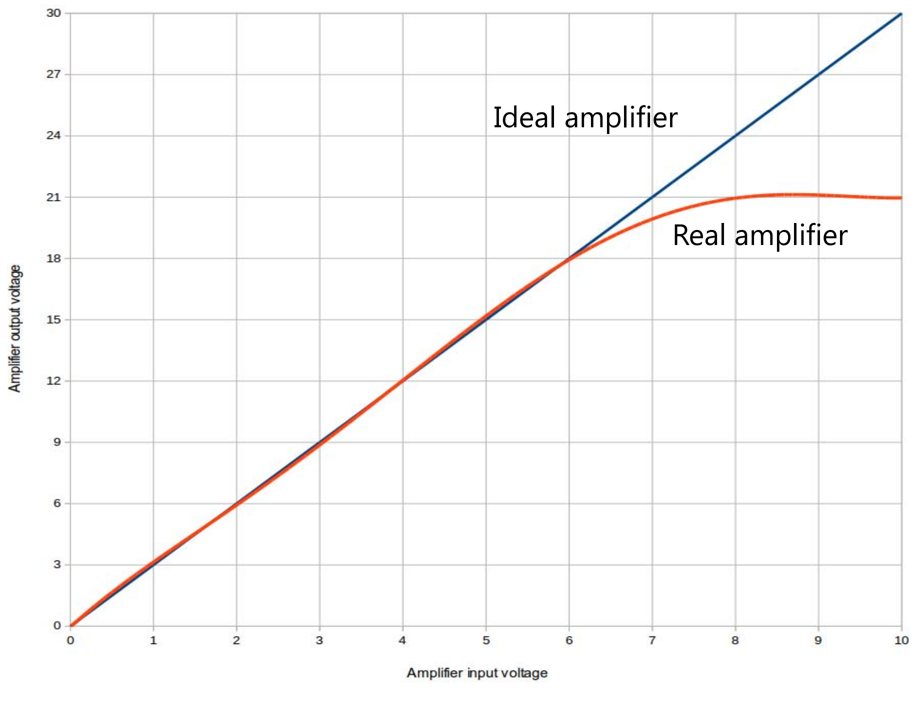
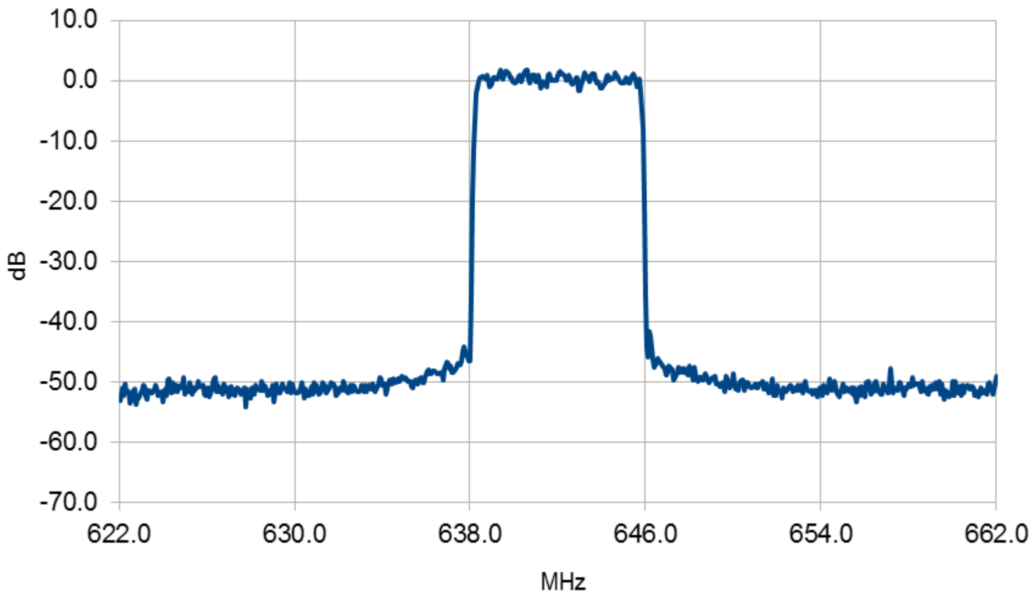


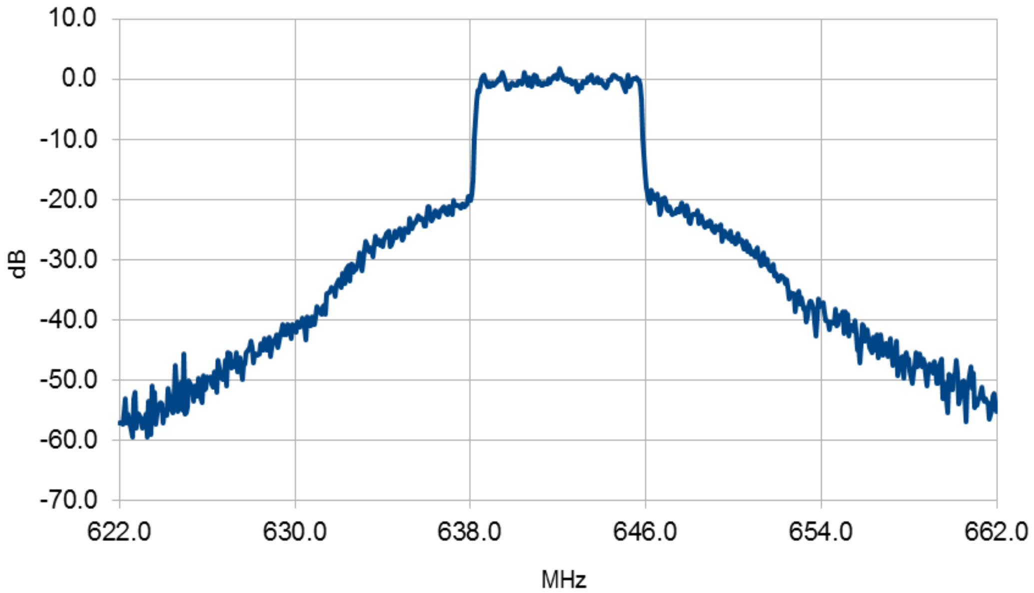
Figure 19 Amplifier input voltage versus output voltage for an ideal and a real amplifier

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 20.a shows a single multiplex before it has passed through an amplifier. Figure 20.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 20.a and 20.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.

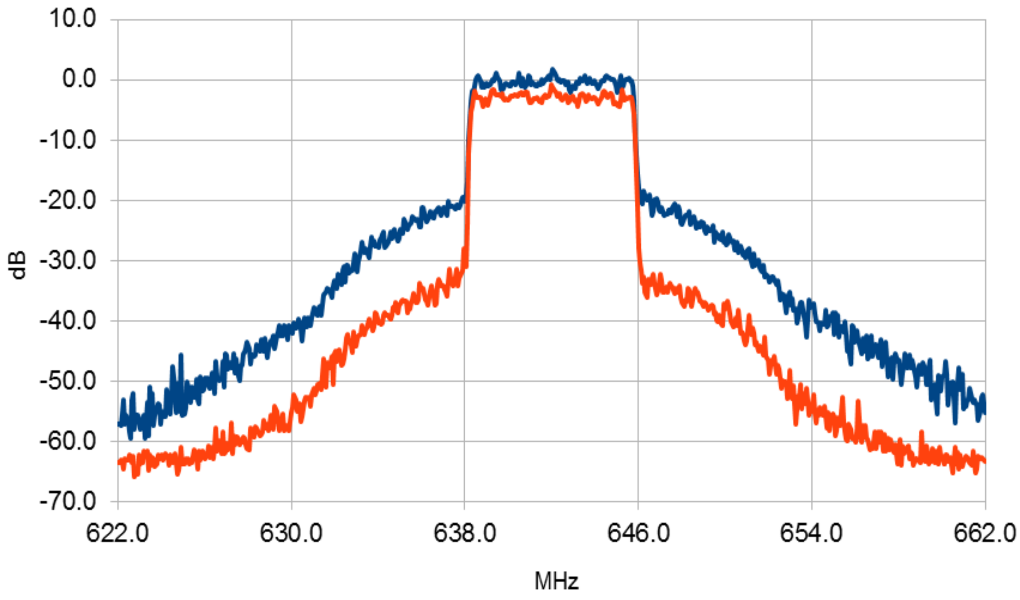


Figure 21 Reducing the signal power by 3 dB reduces the intermodulation power by approximately 9 dB

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 22.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 22.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 22.a compared to Figure 22.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.

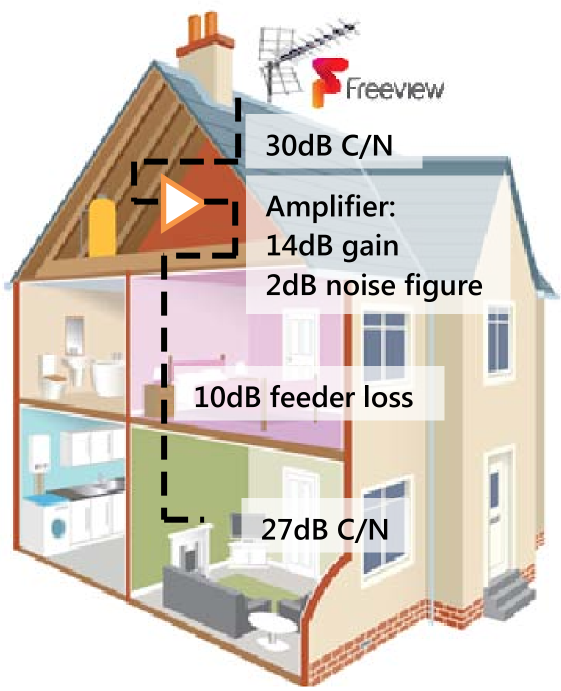


Figure 22.a the amplifier is before the loss

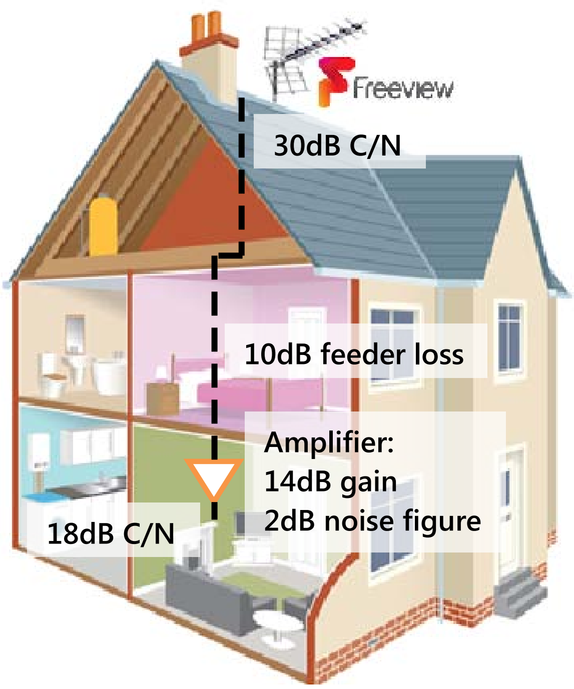


Figure 22.b the amplifier is after the loss

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

Table 6 C/N for the two cases in Figures 22.a and 22.b

Table 6 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/4G (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 7 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.

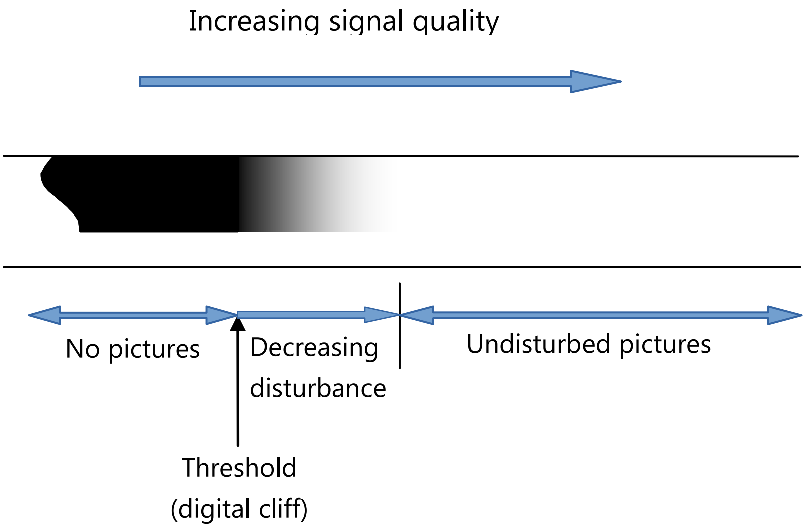


Figure 23 Illustrating the DTT threshold (digital cliff) and the operating region for undisturbed services.

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 8 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 8 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 8 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 8.

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.

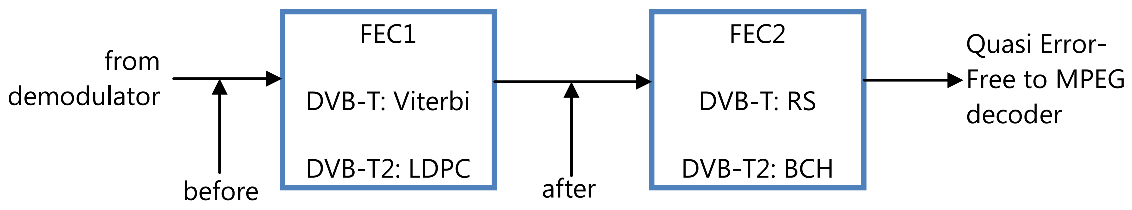


Figure 24 Receiver error correction (FEC) processes

The error correction processes in a receiver are as shown in Figure 24. 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.

Ultra Wideband LNBs

Ultra wideband LNBs are expected to start being used in satellite receiving installations in the near future. Unlike conventional LNBs, which use the frequency range 950-2150 MHz, ultra wideband LNBs use the range 290-2350 MHz. In other words, they carry satellite signals on the same frequencies as UHF terrestrial TV signals. Installers should therefore be aware that systems using ultra wideband LNBs cannot use the same cables to carry UHF terrestrial TV signals.

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.
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.
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.
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.
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.
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

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