New 2002 Edition

Installing Digital Terrestrial Television

Domestic Systems

DIGITAL TV GROUP

Installing Digital Terrestrial Television – Domestic Systems

Preface

Digital Terrestrial Television (DTT) represents an exciting opportunity for both public and trade alike. New technology brings new challenges for the television and aerial installation industries and ensuring that installations are as reliable and effective as possible is of prime importance.

The re-launch of the DTT platform in late 2002 and the implementation of the CAI /DTG aerial benchmarking scheme have prompted the first major revision of this book from the Digital Television Group's Reception Task Group. It also incorporates the experience gained since the original launch of DTT in 1998 and deals with the change to a more rugged transmission mode.

It is intended to help the installer of individual Digital Terrestrial Television receiving systems and small distribution systems. Systems for MATV, large blocks of flats, and so on are covered in book three. Book Four covers the design and implementation of Integrated Reception Systems, that is the systems that carry FM radio, DAB and analogue and digital terrestrial and satellite television. It should be noted that the information in all of the DTG's publications is UK specific – it relates to the UK adoption of DVB – but can be modified to apply to other variants of DVB in other countries.

The definition of what is a domestic system is based on the CAI code of practice:

> *"A distribution system in the UK where all equipment, including aerials, is associated wholly with a single household or family unit. Only FM radio, Digital radio and/or UHF TV services are distributed at their original broadcast frequencies and in addition re-modulated channels for VCR, satellite receiver or STB outputs. There is no limit on the number of TV points or re-modulated channels".*

Doug Fisher
October 2002

Acknowledgements

This edition edited by ***Doug Fisher***

The DTG acknowledges the contribution made by the DTG Reception Group, particularly its chairman Martin Turner, together with Andy Wade and Ian Pullen We are grateful for the advice and guidance given by the Confederation of Aerial Industries in the preparation of this publication.

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Chapter 1

DTT transmission and reception

Digital Terrestrial TV is transmitted in Bands IV and V - the familiar UHF bands already used for terrestrial analogue TV. The standard 8MHz wide channels (Ch.21 - Ch.68) are used, shared with the analogue transmissions. The familiar aerial groups A, B and C/D remain relevant for DTT reception, but aerials covering group W will be required much more frequently. Again, like analogue, DTT signals use either horizontal or vertical polarisation.

Existing transmitter sites are used for DTT. The current (2002) transmitter plan includes 50 of the 51 main analogue TV transmitter sites (Fremont Point was excluded due to international co-ordination problems) and 30 of the analogue relay sites. Additional stations may be added at some future date and the spectrum planning work for further equalisation schemes, to give the same coverage for all multiplexes, is ongoing.
In the longer term, it is the Government's intention that analogue TV services should cease and part or all of the vacated spectrum then be used to provide near-universal DTT coverage.

1.1 Multiplexes

Each DTT signal occupying one UHF channel is called a multiplex. Each multiplex carries four or more TV programmes, together with electronic programme guide (EPG) information. Additionally, multiplexes can also carry radio programmes, text services, interactive programming and eventually a number of other services. Six multiplexes, listed in Table 1, are being transmitted from all 80 stations.

In channel allocation tables the multiplexes are usually referred to as 1, 2 and A-D.

Multiplex	Operator
1	**BBC**
2	**Digital 3&4 (ITV & C4)**
A	**SDN (S4C & 5)**
B	**BBC**
C	**Crown Castle**
D	**Crown Castle**

Table 1 - DTT multiplex operators

Squeezing six DTT multiplexes into an already crowded band was not an easy task for the planners. As a result, the relationship between analogue and digital channel allocations varies considerably across the different transmitter sites. In some cases (e.g. Crystal Palace) all six multiplexes are close to the analogue channels and so are within the group of channels covered by existing receiving aerials. In others (e.g. Black Hill) some multiplexes are close to the analogue channels whilst the remainder are several channels removed, and may be received poorly on existing aerials. Cases where all six multiplexes are far removed from the analogue channels are rarer, but do exist (e.g. Waltham). Note that the use of channels adjacent to analogue services is very common.

At a small number of sites, two separate channels had to be used for some of the multiplexes. This occurs at Winter Hill, The Wrekin, Sudbury, Huntshaw Cross and Dover, where the restrictions needed to minimise interference to analogue services resulted in very low power levels being radiated in certain directions. This severely limits the coverage in these directions. A second channel was therefore used to 'fill in' coverage in the affected areas, and the associated transmissions are commonly referred to as 'fillers', or sometimes 'B' transmitters

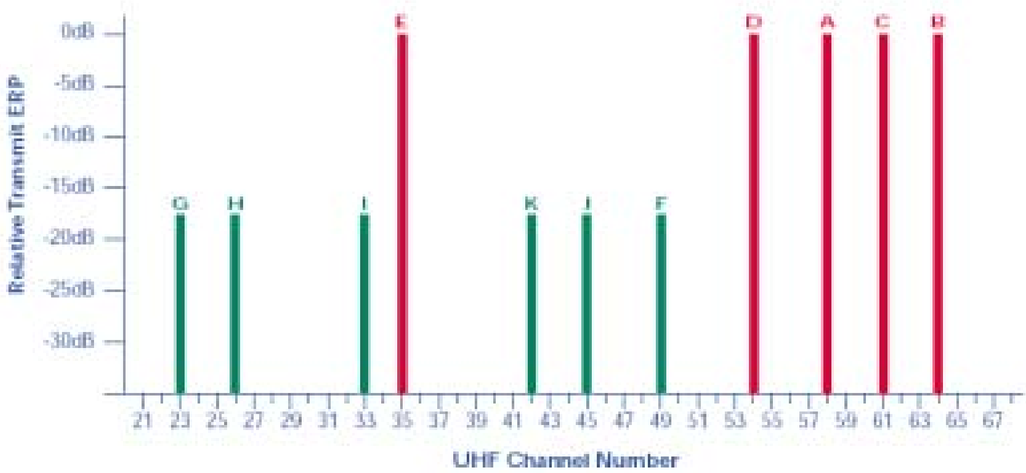


Figure 1a: Spectrum of transmissions from the Waltham transmitter.
All DTT multiplexes are transmitted with the same polarisation as the analogue services from the same site.

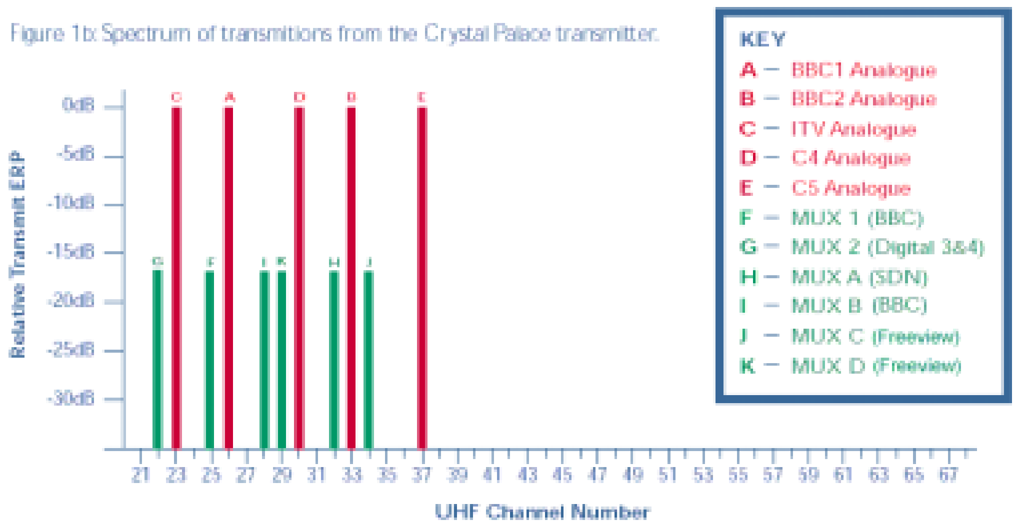


Figure 1b: Spectrum of transmissions from the Crystal Palace transmitter.
All DTT multiplexes are transmitted with the same polarisation as the analogue services from the same site.

1.2 The DTT signal

The digital signal is very different from the familiar PAL analogue signal. Some understanding of the differences will help the installer.

DTT uses a special form of modulation called COFDM (Coded Orthogonal Frequency Division Multiplex). The main advantage of COFDM, from a reception viewpoint, is to make the signal highly immune to multipath reflections. In other words, up to a point, DTT is not affected by ghosting - the COFDM signal remains perfectly receivable under conditions where an analogue signal would suffer intolerable ghosting. The other significant advantage is that it is much more tolerant of co-channel interference, particularly analogue co-channel interference. Without this attribute of COFDM, it would not have been possible to introduce national DTT services into a band that is already heavily used by analogue services. Note however that STBs and idTVs will eventually fail to decode once levels of co-channel analogue interference reach roughly the same order as those of the wanted DTT signal

The COFDM signal, as used in the UK, comprises 1,705 individually modulated carriers and is known as the 2K mode. This means that the power in a DTT signal is spread evenly across its 7.6MHz bandwidth. In contrast most of the power in an analogue TV signal is concentrated around the vision carrier. This difference has important consequences for signal level measurement, as explained later in the section on measurements.

The European specification for DTT, commonly known as DVB-T, caters for a wide range of modulation schemes, code rates etc. The main benefit of this is to allow a trade-off between capacity (i.e. number of TV programmes carried) and ruggedness of reception, to suit individual circumstances. When DTT was originally launched in the UK, it had been decided to use the 64-QAM, code rate 2/3, variant. The 64-QAM nomenclature simply refers to the fact that each carrier has 64 different states, provided by a combination of amplitude and phase modulation, which can be seen on a constellation display. Code rate 2/3 means that 2/3 of the total signal capacity is available for the services carried, with the remaining 1/3 used for error correction.

Experience has however shown that 64-QAM rate 2/3 is not sufficiently rugged, at the DTT power levels adopted in the UK. A trial of various 16-QAM modes was therefore carried out in the summer of 2002, leading to the use of 16-QAM rate 3/4 on Multiplexes 1, B, C and D from the platform re-launch in late 2002. The use of this lower order mode reduces the multiplex capacity by about 25%, but is expected to result in a significant improvement to reception reliability.

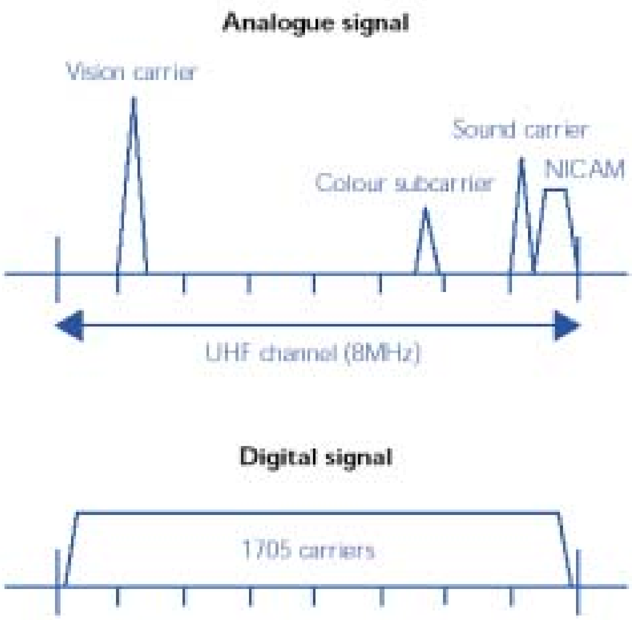


Figure 2: Analogue and COFDM channel spectra

1.3 Coverage and reception

Because of the greater efficiency of digital modulation, in theory, something in the region of 17 dB less transmitted power is needed than with analogue TV for similar coverage. This is roughly in line with the difference in the transmitted powers of the two systems. However, in practice, whereas it is often possible to operate an analogue receiver with signal levels somewhat below the minimum (albeit with poorer quality pictures), it is necessary to ensure that a digital receiver is provided with a signal somewhat higher than the minimum. This is to prevent signal level fluctuations from causing reception failure due to the digital cliff effect (see Fig. 3). Also, for many stations, it was not possible to find channels that allow an omni-directional DTT transmitting antenna to be used. Such stations therefore use directional DTT antennas, with restricted power in some directions in order to avoid causing interference to other services. For these reasons, the DTT coverage of most stations is usually less than that of analogue. To ascertain receivability at a given location reference should be made to the DTG postcode database, which is derived from coverage predictions rather than measurements, and a site survey using suitable DTT test equipment. (See chapter 2 – measurements).

The recommended signal levels at the receiver are shown in Table 2. It may be useful for the installer to know how these have been arrived at and also to be aware of the basis of the coverage predictions used in the postcode database. In particular, it is helpful to know the assumptions that are used. The overall factor of most interest is the minimum signal level that is needed at the STB or idTV. This is derived from a number of assumptions. These include the level of interference from other stations (analogue and DTT), the receiver noise figure (7 to 8 dB depending on frequency) and the minimum C/N ratio (23 dB for 64-QAM) needed by the receiver. In the absence of any interference from other stations, these assumptions result in a minimum signal level of about 35 dBìv being needed at the STB or idTV (for 64-QAM rate 2/3) However, when interference from other stations is present, as is often the case, the predictions suggest a minimum level of between about 35 and 45 dBìv. To predict coverage, assumptions also have to be made about aerial gain (10 to 12 dB) and feeder loss (3 to 5 dB), both of which vary with frequency.

These assumptions therefore give rise to a number of points in connection with the postcode database. Firstly, if a postcode is predicted to be in coverage the actual signal level should be more than 35dBìv, but may not be as much as 45 dBìv. Secondly, these levels may not be obtained if the gain of the aerial being used is lower than the assumptions given above, or if the feeder loss is higher than the assumed figures. Finally, as most installers of DTT aerial systems will already be aware, reliable reception depends not just on being within DTT coverage, but also on overcoming the effects of man-made interference, usually impulse interference (see 1.5 below)

Another point for installers to be aware of is that some stations do not transmit the six multiplexes with equal power. In particular multiplexes C and D (and occasionally others) sometimes have lower power than the rest, typically around 3 dB but occasionally up to 8 dB. This problem is however often exacerbated by differences in the directivity of the transmissions of the various multiplexes. Where either situation applies, these multiplexes will have reduced coverage areas. There will be locations where some, but not all, digital services can be received. Reception of the lower power multiplexes is aided by careful choice of receiving aerial and good installation practice, described later in this booklet. Note that the occurrence of these problems will be reduced if future work to equalise the coverage of the multiplexes is implemented.

1.4 The digital cliff and decoding margin

Unlike analogue TV signals, which can still be viewed under weak received signal strength conditions or in the presence of interference, DTT pictures and sound will either be perfect, in the process of breaking up or non-existent! DTT reception exhibits a very rapid change from being excellent to disappearing altogether; this phenomenon is usually referred to as the digital cliff or threshold. This phenomenon may be reduced to some extent in practice, when varying levels of intermittent interference are present, in that increasing the DTT signal level will reduce the occurrence of such interference.

The excess level of the DTT signal over the minimum necessary for satisfactory reception, in the absence of impulse interference, is often referred to as the decoding margin. (See Figure 3) This is a very useful indicator of reception quality for transmission systems exhibiting the digital cliff effect. The measurement of this parameter is therefore dealt with in Chapter 2

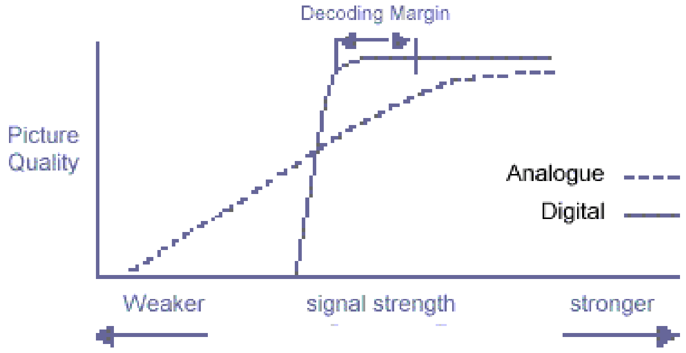


Figure 3: Picture quality v. signal strength

It is clearly important for reliable service to know that a receiver is not operating too close to the cliff edge!

1.5 Impulsive interference

Reception of DTT can be upset by impulsive interference, typically coming from domestic electrical equipment such as light switches or thermostats, or from vehicle ignition systems. The effects of impulsive interference are as if the signal has briefly gone over the digital cliff: the picture may freeze or become blocky, and the sound may mute.

Impulsive interference from domestic electrical equipment is often mainly picked up by the aerial downlead, rather than the aerial itself, due to the closer proximity of electrical wiring carrying such interference. With the existing types of aerial downleads and fly leads normally used for analogue TV reception, it is often transferred to the input of the STB or idTV through the cable outer screening. It can also be transferred through inadequately balanced aerials or unscreened components such as most older outlet plates, diplexers, or splitters. It can therefore generally be cured by replacing the downlead with CAI benchmarked cable and, where necessary, by replacing aerials with balanced types, and outlet plates, fly leads etc. with properly screened types.

When vehicle ignition is the cause of the interference, then tilting the aerial slightly upwards or repositioning it so that some part of the building comes between the aerial and the road (without of course blocking the view to the transmitter) will sometimes improve reception.

Chapter 2

Signal measurements for DTT

There are a number of parameters that can be measured when installing DTT in the home. Probably the most fundamental of these, in terms of a single indication of reception quality, is decoding margin, This is the excess level of the signal, above that needed for satisfactory decoding, as previously mentioned in Chapter 1. It is not however a parameter that can easily be measured directly in all circumstances, and so it is effectively deduced from other measurements, as explained below:

2.1 Signal Level

The first and easiest parameter to check is signal level (also referred to as amplitude or signal strength). In many cases this gives a good indication of the available decoding margin, or the extent of any shortfall.

The level of a DTT signal is measured in the usual units of dBµV, but the values that will be encountered are much lower than for analogue signals (see Table 2, Recommended signal levels) and the relative levels will vary from one transmitter to another.

It is helpful to understand that the level of a DTT signal represents the total power of all the carriers in the COFDM signal and not the level of each individual COFDM carrier.

	Max signal level	Min signal level
Analogue TV	80dBµV	60dBµV
DTT	70dBµV	45dBµV (see notes)

Table 2: Recommended signal levels

(1) The 45 dBµV figure applies where the STB or idTV is the first item in the RF distribution chain. (This is the normal arrangement and is strongly recommended) A 5dB higher level is necessary to take into account the typical low gains and high noise figures for any satellite receiver or VCR (either operating or in standby mode) used ahead of the STB or idTV.

(2) The recommended signal levels in Table 2 are measured at the outlet plate except where a satellite receiver or VCR is used ahead of the STB or idTV, in which case they are measured at the input to the STB or idTV. They assume a minimum C/N (carrier-to-noise ratio) requirement, including a satisfactory margin, of 26dB for 64-QAM rate 2/3 and 22 dB for 16-QAM rate 3/4.

(3) These levels are recommendations and should be used only as a guide. Individual installations may need more or less signal level in order to achieve an acceptable decoding margin, depending on the particular system configuration.

For satisfactory reception of digital signals, it is important that ALL of the signals applied to the receiver, both analogue and digital, are within the ranges shown in Table 2. Digital signals are generally in the region of 17dB lower in power than analogue, and in some cases significantly lower still. Particular care is needed when ensuring adequate levels of digital signal, that the analogue signals are not too great, causing overload in the receiver. (Although the distortion on the analogue signals may not be very noticeable, the DTT signals could suffer from such high levels of intermodulation products that they can no longer be decoded.) Similarly, in existing installations where the analogue signals are delivered at around 60dBìv, digital signals may only be in the region of 40 to 45 dBìv and therefore give unreliable service.

These maximum and minimum levels define a so-called window of operation for the receiver. Note that as the difference in power level between the weakest digital signal and the strongest analogue signal increases, the size of the window decreases.

2.2 Carrier-to-noise ratio (C/N)

This is the ratio between the level of the signal (somewhat misleadingly called the carrier) and the level of noise reaching the demodulator in the receiver. It is expressed simply in dB (not dBµV) as it is the ratio of two levels. DTT receivers require a certain minimum value of C/N in order to decode a signal correctly. This value, when an allowance has been made for a small decoding margin, should be at least 26dB for 64-QAM rate 2/3 or 22 dB for 16-QAM rate 3/4 depending mainly on the severity of the multipath environment through which the signal has propagated and levels of co-channel and adjacent channel interference. Other factors also affect the required C/N, such as the quality of the receiver itself and intermodulation in any aerial or distribution amplifiers in the receiving system.

For a straightforward system with a receiver fed directly from an aerial (without amplifiers), measurement of an adequate signal level will automatically guarantee an adequate C/N, assuming that the receiver itself does not have an unduly high noise figure and that the level of any co-channel interference is insignificant. The use of amplifiers between aerial and receiver complicates matters, because although the signal level is boosted to overcome downlead loss and receiver noise, the amplifier itself adds noise and distortion. Delivery of an apparently adequate signal level will not necessarily guarantee sufficient C/N to decode the signal.

Carrier-to-noise ratio is also important in analogue receiving systems, but has tended to receive insufficient attention from installers. Many existing analogue systems would have benefited from better attention to C/N considerations. In the digital era it will be less easy to get away with this, as it may result in insufficient margin, and possibly falling off the digital cliff!

2.3 Channel State Information (CSI) and Modulation Error Ratio (MER)

CSI is an indication of the amount of noise and interference present on each carrier of the DTT signal. It can be a useful display for investigating decoding problems caused by co-channel interference. It can also be used as a measure of the total noise and interference, in which case an average of the level on each carrier is calculated. It is normally expressed as a percentage figure.

MER is a very similar parameter to C/N and is also a ratio measured in dB. Like CSI, it includes all other signal impairments, not just noise. It can therefore be used to give a more direct indication of decoding margin when, as is often the case, there is co-channel interference as well as noise in the channel.

2.4 Bit error ratio (BER)

Bit error ratio (not bit error rate) is a measurement of signal quality after demodulation. It simply indicates what proportion of the received binary digits (bits) are incorrect - 0 received as 1 or vice-versa. BER is ultimately the best measure of digital signal quality since it tells us directly whether a picture can be displayed. In practice, when investigating reception problems, a CSI display is often more useful and MER measurements may be more appropriate, with a direct indication in dB of the ability of a receiver to decode the signal.

The DTT transmission - reception path employs powerful built-in error correction techniques collectively **called forward error correction** (FEC). In the receiver, error correction takes place in two distinct stages called inner (or Viterbi) and outer (or Reed-Solomon) decoding. For signal quality assessment BER is best measured at the mid-point in this decoding chain, i.e. post-Viterbi, pre-Reed-Solomon. For satisfactory results a BER of 0.0002 (often written as 2×10^{-4} or 2E-4) or less is required. This is the case regardless of whether 64-QAM or 16-QAM is being used.

Note: the lower the BER the better the signal quality.

The purpose of measuring the BER is to determine whether the demodulated and error corrected bitstream is sufficiently free of errors for good quality pictures and sound to be produced. Measuring the BER is often regarded as the ultimate check of performance, but care must be taken in interpreting the results. A poor BER indication certainly indicates trouble, but a good BER indication does not necessarily mean that error-free pictures will appear. If impulsive interference causes infrequent bursts of errors of short duration, the BER indication, which is typically averaged over a few seconds, may scarcely be affected. However, the burst may defeat the receiver's ability to correct errors, causing subsequent problems with decoding sound or vision.

2.5 Operating margin

The operating margin is a measure of the amount by which the signal can be reduced from its normal operating level to the point at which the picture suddenly fails. This is illustrated in figure 3, page 6.

Signal levels at any individual receiver will vary with time for a number of reasons, so it is important for reliability not to have very small values of margin. It can be measured quite simply by temporarily inserting a variable attenuator on the input to the STB or idTV. If there is no amplification or similar source of noise before this point, and no significant amount of co-channel interference, then the operating margin so measured constitutes the decoding margin. However, when there is a significant amount of co-channel interference and/or added noise, then this will also be reduced by the attenuator and the resulting figure will be somewhat larger than the actual decoding margin. In these circumstances, it is more meaningful to temporarily insert the variable attenuator in front of any amplification, as the result will then be closer to the actual decoding margin.

Note that the use of a variable attenuator is only recommended in conjunction with, and not as an alternative to, signal level measurements

2.6 Measuring instruments

Analogue-only meters almost certainly will not be suitable for DTT. These usually have a measurement bandwidth much less than 8MHz so much of the DTT signal will be filtered out, giving serious errors. Also, the filter skirt selectivity of many analogue meters gives inadequate rejection of an upper adjacent vision carrier, leading to an optimistic DTT level reading. **Meters must have the specific capability to measure DTT signals as well as the existing analogue signals.**

Relatively inexpensive instruments suitable for measuring digital signal levels are available and some of these will also make an estimate of the carrier to noise ratio. Be aware that most such meters measure noise in a quiet channel or channels, rather than the actual channel occupied by the DTT signal. In the presence of relatively wideband noise, such as after any form of wideband amplification, the indicated C/N is reasonably valid. However, in other circumstances, misleading indications of the actual C/N ratio can result. This is particularly the case with meters that measure the noise in the adjacent channel, as this is often occupied by an analogue service or another DTT multiplex.

Instruments are now available containing a demodulator, and so are able to measure CSI, BER etc. Such instruments are inevitably more expensive than the simple level meter, and may only provide indications in two or three categories (for example high, medium or low) In the absence of this type of instrument it should be adequate, in many circumstances, to use a DTT receiver Bear in mind that the most important goal of the installation is to deliver unimpaired pictures and sound, with a high degree of availability. This is best checked by looking and listening, and ensuring that there is sufficient margin.

Care is needed when using a **spectrum analyser** to measure DTT signal levels. The apparent level will depend upon the analyser’s resolution bandwidth (RBW). With typical settings the DTT level may look alarmingly low at first because only a small fraction of the signal is within the RBW at any time. Some spectrum analysers have a built-in power spectral density function, which automatically compensates for this effect. In addition, when making carrier-to-noise measurements, it is important to establish that the noise being measured is that of the system, not the measuring instrument.

Chapter 3

Reception with new and existing systems

Important Note:
This section covers reception of DTT by a number of different aerial types and situations. The most reliable system will utilise an outside roof-mounted aerial that is installed using the guidelines detailed in this book. All other types of aerial installations, even though listed and discussed here, are unlikely to prove as reliable.

3.1 Single outdoor TV aerial installations

In many cases it should be possible to use the existing aerial, because the new digital signals occupy channels that are in the same group as the existing analogue channels. In a significant number of cases, some or all of the digital signals will be on channels outside the existing group, so it may be necessary to install a new aerial, especially in locations not close to the transmitter. This chapter provides information that can be used to determine whether an existing installation is suitable for DTT, and if not what sort of new system should be installed.

There are also a relatively small number of locations where DTT reception is only available from a station other than the one that existing aerials are pointing at. This can happen in a variety of circumstances, for example, in areas where an analogue relay station is not also being used to transmit DTT services. In such areas, certain locations may be within DTT coverage from the main station but existing aerials may be pointing at the relay station. In these cases, existing aerials will need re-pointing and possibly remounting for the other polarisation. It may also be necessary to replace such aerials with ones from the appropriate group, or adopt a two aerial system (See also 3.2 below)

In selecting a suitable aerial, only the types that have been approved under the CAI /DTG benchmarking scheme should be considered. This will ensure that the many aerial performance parameters that are needed for satisfactory DTT reception will be achieved. In addition, the following factors should be considered:

- **Group**
  Is there a need to change to group K, E or W? Use W in preference to K or E where possible, as there is little performance benefit in using either of the two latter groups. Note that further equalisation work, as mentioned at the beginning of Chapter 1, may be implemented at some future date and that eventually the analogue services will cease. In either case there is a possibility that the aerial group of some stations may change. There is therefore a potential long term benefit in using Group W aerials when replacements are needed but they should only be used in situations where they are capable of delivering at least the minimum recommended signal levels shown in Table 2.

- **Gain**
  Very high gain aerials will not generally be required. As explained in Chapter 1 (1.3), the assumption made about aerial gain, for coverage definition purposes, is 10 dBd at the bottom of Band IV and 12 dBd at the top of Band V. Therefore, in

general, these figures represent the maximum gain that is likely to be needed. Note however that group W aerials almost invariably will not have 10 dBd gain on lower Band IV channels. However, 10-12dBd should only be required near the edge of coverage, so in many cases lower gain aerials should be quite satisfactory, particularly when used in areas close to the transmitter. Hence the CAI /DTG benchmarking scheme has 4 gain categories from which to select an appropriate aerial.

• Directivity
Installers should already be familiar with the use of narrower beam aerials to avoid ghosting problems with analogue reception. DTT reception does not suffer from ghosting, but the use of such aerials can be more important than with analogue, because of frequency re-use over shorter distances. There are locations where reception is limited by the interference from another transmitter (either analogue or DTT) on the same channel, serving a nearby region. In these cases, the level of interference must be controlled by using an aerial that provides very little gain in the direction of the interfering signal, while providing sufficient gain in the direction of the wanted signal. This characteristic is known as directivity. The installer should become familiar with the DTT channels used by their local transmitter and both the DTT and analogue channels used by others in the surrounding area, to be aware of potential co-channel interference (CCI) problems. Rejection of an interfering digital signal should be sufficient to achieve at least 30dB level difference between the wanted and the interfering signals, in order to achieve a minimum decoding margin of 6 dB. Note that since the interfering signal is co-channel it will not be possible to measure it using a meter or spectrum analyser. However, using suitable equipment its effect could be measured in terms of CSI or MER. However, even this might not provide a truly reliable indication of interference levels. Often the sources of interference that limit coverage will only occur under extreme weather conditions and will, therefore, be unlikely to occur when the measurement is made. The rejection of analogue co-channel interfering signals is less critical, but at least 10 dB level difference is needed to achieve the same minimum decoding margin.

In view of the difficulty in measuring levels of interference, the best policy is to install an aerial that meets the CAI /DTG benchmarking specification. This will automatically provide adequate directivity.

• Cross-polar discrimination
DTT uses both horizontal and vertical polarisation for the same reason as analogue TV, i.e. to provide additional rejection of co-channel interference. It is therefore just as important as aerial directivity, for satisfactory DTT reception, and very similar levels of rejection need to be achieved by both mechanisms. The use of an aerial which meets the CAI /DTG benchmarking specification will ensure adequate cross-polar discrimination.

• Feeder pick-up rejection.
Aerials comprising half wave dipoles, such as the familiar Yagi and log-periodic products are intrinsically balanced devices. Coaxial cable, as used for down leads, is however unbalanced and some form of balance to unbalance conversion is therefore often incorporated into the aerial feed arrangement. The absence of some form of balance to unbalance arrangement encourages signal pick-up on the outside of the downlead and thereby degrades the radiation pattern directivity and

cross-polar discrimination of an aerial. This can, in turn, reduce the rejection of co-channel interference to the detriment of both analogue and DTT reception. Moreover, in the case of DTT, it can also result in a worsening of the effect of any impulse interference, as explained in Chapter 1 (1.5) Except in the most non-critical cases near to transmitters, where very high signal levels can be achieved, aerials with some form of balance to unbalance conversion, or other means of reducing feeder pick-up, should be used. The use of an aerial that meets the CAI /DTG benchmarking specification will ensure adequate feeder pick-up rejection.

- **Match**

It is important to understand that DTT signals are far less sensitive to reflections than digital satellite and digital cable signals. COFDM gives a high level of immunity to multipath effects - that's the whole point of it! However this should not be taken as a licence to ignore basic matching principles, as this is likely to result in a system with a poor frequency response.

- **Interconnections and amplification**

If RF distribution is chosen to interconnect equipment (see interconnection diagrams 4.1 to 4.8, pages 18 to 20) then care must be taken to find a clear channel slot when fitting in the extra modulated channel from the STB. So-called "taboo" channels (e.g. N±1, N±5) should be avoided.

Where any form of signal booster or pre-amplifier is used, it is important to ensure that the STB or idTV, or the amplifier itself, is not driven so hard that intermodulation distortion is significant. An amplifier will usually carry a power rating at which it may operate with a sufficiently low level of distortion to protect analogue services. Unless otherwise stated, this rating applies to two analogue signals of equal level. When more signals are present, the output power of the amplifier must be reduced ("de-rated"). For analogue signals it has been found that de-rating by at least 10logi10(N-1) dB, where N is the number of channels (this expression is evaluated in the table below), will ensure that intermodulation products are sufficiently low that they do not noticeably interfere with the analogue pictures. (Note that in most cases, the level of all the digital signals is sufficiently small compared to the analogue signals that they may be disregarded.) However, the fact that the digital signals are at a low level compared to the analogue means that in some circumstances this de-rating factor might not be sufficient to protect digital signals adequately. It may be necessary to de-rate the amplifier further.

No of channels received (N)	4	5	6	7	8	9	10	11	12
De-rating (dB)	4.8	6.0	7.0	7.8	8.4	9.0	9.5	10.0	10.4

Table 3: Evaluation of the analogue de-rating factor $10\log_{10}(N-1)$ dB. Note that this level of de-rating may in some circumstances be insufficient to protect digital services. See text.

It is important to use low gain amplification with good intermodulation performance so that the distribution system's intermodulation performance via the UHF loop-through in the STB, analogue satellite receiver, VCR and signal booster is not compromised and provides sufficient C/N for both analogue and DTT signals. Current (analogue) good practice should be followed for DTT – for example, CAI Codes of Practice for both domestic television aerials and SMATV systems. Figures

4.1 to 4.8, pages 18 to 20 show some examples of systems distributing DTT, FM Radio, Analogue TV and Satellite using RF.

3.2 Multiple outdoor TV aerial installations

For existing analogue transmissions there are a number of overlap areas in the UK where, by the addition of a suitable diplexer and second UHF TV aerial, it becomes possible to receive two sets of regional TV programmes.

Theoretical coverage areas for DTT transmissions are mainly interference limited and hence the size of the DTT overlap areas are predicted to be much smaller than the analogue ones from the same transmitters. In locations where two regional analogue services are currently being successfully received, the reception of DTT signals with these systems will be dependent on a number of key factors as follows:

1. DTT reception at any location can be determined by reference to the DTG postcode database and/or a site survey using proprietary test equipment as described in section 2.6, Measuring instruments.

2. If the desired (and potentially receivable) channels are within the existing received analogue group (for example Crystal Palace, Emley Moor, Mendip, Pontop Pike, Stockland Hill, Winter Hill and so on) of one of the existing two aerials then no change to the system may be required. The provision of a higher gain grouped aerial and/or a low gain masthead amplifier (see section on the use of masthead amplifiers and indoor signal boosters) may be needed to ensure DTT reception. Care must be exercised on amplifier de-rating to avoid overloading and intermodulation problems as there could be as many as 10 analogue channels and 12 digital multiplexes passing through the distribution system. In DTT overlap areas where the same DTT channel number is used on both transmitters then it may be necessary to change one or both aerial type(s) to one(s) with better all round signal rejection performance. This would be necessary to minimise digital to digital interference on that particular channel number.

3. If the desired DTT channels are NOT within the existing group of one of the existing two TV aerials then the aerial type(s) need to be changed OR a decision made to remove one aerial and/or change the diplexer. This means that only one regional DTT and possibly one analogue TV service is received and distributed throughout the household at this location.

3.3 Loft aerials

Refer to the note at the start of this chapter

Aerials should only be installed in lofts where this is necessary because of local planning restrictions etc. In such cases, a loft-mounted high gain directional aerial with good F/B ratio and good side lobe performance is recommended. The aerial should be mounted in such a position that allows it to be pointed at the transmitter whilst being pointed away from metallic objects such as metallic water tanks, pipes and wiring. Find the best position along the length of the loft space that gives the best interference free pictures on all the analogue channels. Loft mounted aerials also usually suffer more from impulse interference than roof mounted types, due to the similar or even higher levels of impulse interference being picked up, but with generally lower DTT signal levels.

Use the service information received by the STB or idTV to identify the DTT services offering the best chance of good reception. In weak signal areas it may be necessary to add a low noise, low gain masthead amplifier with good input signal handling properties in order to receive all the desired DTT and analogue services from the chosen transmitter. It may also be necessary to choose between the available DTT and analogue services in some locations.

3.4 Portable reception

Refer to the note at the start of this chapter

For people who have caravans or motorised mobile homes, their primary means of watching terrestrial TV away from home is via a portable outdoor aerial of some kind.

Firstly, recommend that the vehicle is parked as high as possible and away from any obstructions to provide, as close to as is possible, a clear line of sight to the desired transmitter. Then proceed as in 3.2 above, using the received service information to identify suitable services. Remember that some coastal areas may not be able to receive digital terrestrial transmissions. Existing omni-directional aerials frequently include head amplifiers within the aerial itself (this is analogous to an outdoor aerial with masthead amplifier) and indoor boosters/distribution amplifiers ahead of the TV. Therefore careful attention should be paid to the noise figure and signal handling parameters of any aerial used.

In weak signal areas or if frequent difficulties are encountered at different sites visited, then the omni-directional aerial should be replaced with a directional aerial mounted on or off the vehicle and as high as practically possible.

3.5 Set top aerials

Refer to the note at the start of this chapter

Sometimes a set-top aerial is the only practical means of receiving television signals. This will, however, only be possible in areas of high field strength. Note that the post-code database does not apply to set-top reception. Where the signal strength is sufficiently high, digital set-top reception should be much more successful than analogue, due to the digital receiver’s ability to cope well with reflections.

Locate the aerial within the room to provide the best possible reception of analogue signals. *Note: this is frequently NOT on top of the TV!*

Use the service information received by the STB or idTV to identify the DTT services offering the best chance of good reception. Indoor aerials are frequently combined with indoor signal boosters that are either integrated within the aerial housing or added separately. Careful attention should be paid to the noise figure and signal handling parameters of such amplifiers. It may also be necessary to choose between the available DTT and analogue services in some locations.

3.6 Masthead preamplifiers and active aerials

A masthead preamplifier or active aerial can give a useful improvement in carrier-to-noise ratio *(refer to note at the bottom of this page)* for both analogue and digital signals, particularly where an unusually long aerial downlead is required, or in poorly served locations where the recommended levels in Table 2, page 7 cannot be achieved. The output capability of the preamplifier must be such that no significant intermodulation occurs. As a rule of thumb, if intermodulation is visible on the analogue pictures (usually in the form of unwanted patterning, especially in areas of saturated colour), the digital signals will be seriously affected by intermodulation products and may be unreceivable. Intermodulation problems are best avoided by keeping the amplifier gain to a minimum. Masthead preamplifiers or active aerials can also give a useful improvement to installations affected by impulsive interference from domestic electrical equipment, where that interference is getting into the system via the down lead, outlet plate or fly lead. However, they should be used with care, ensuring in particular that resulting analogue signal levels are not excessive.

3.7 Indoor signal boosters and distribution amplifiers

Where the off-air signal levels are already reasonably strong then indoor signal boosters of various types are frequently used as a convenient alternative to masthead preamplifiers to distribute and provide good quality VHF/UHF signals to one or more additional viewing points within a domestic household. Low noise, low gain signal boosters with good signal handling can give a useful improvement in C/N *(see note below)* for analogue and digital signals in poorly served locations where the recommended levels in table 2, page 7 cannot be achieved (see figure 4.6, page 19 for an example of a 4 way indoor booster). These signal boosters may be used ahead of the first item in the RF chain or before the last item in the chain to distribute all RF signals to one or more outlet point. Their use and position within the RF distribution chain must be carefully considered such that the output capability of the chosen signal booster does not cause significant intermodulation products within the system. As a rule of thumb, if intermodulation is visible on the analogue pictures (usually in the form of unwanted patterning, especially in areas of saturated colour) then the digital signals will be seriously affected by intermodulation products and may be unreceivable. Low noise, low gain signal boosters with good signal handling are essential to minimise intermodulation problems. It is important to get the best quality signal feed from the aerial and achieve the recommended signal levels in table 2, thereafter the use of signal boosters should be used only where necessary.

Note: The preamplifier cannot itself improve the carrier to noise ratio of a signal! It can however improve the performance of a receiving system for example by compensating for the loss in an aerial downlead and / or by providing a lower noise figure than that of the STB or idTV being used. Provided that the preamplifier's noise contribution to the receiver's intrinsic noise is small, then the receiver will see a better carrier to noise ratio than without the amplifier If the preamplifier's gain is much higher than the loss it is intended to correct, then there might be a risk of overloading the STB or idTV causing intermodulation products to be generated and hence lowering the decoding margin. Moral: don't use a preamplifier with unnecessarily high gain.

Chapter 4

Installation of DTT receivers

The SI (or Service Information) tables are the fundamental “tools” available for set-top boxes and integrated digital receivers to establish tuning in of services. It is a stream of data encoded into each of the multiplex operator’s transmissions, which identifies the transmitter, the available multiplexes and their channel positions. Once the SI is received and decoded, the receiver can display a list of available services. Receiver set up can then continue. *Note: Some may take 10 or more minutes to establish and display a list of available digital terrestrial television channels. For this reason, it is a good idea to ensure that the system is optimised for reception of both analogue and digital services first.*

4.1 Receiver connection

There is a wide range of combinations of equipment found in the home, from the simple installation where there is an aerial feeding one television set, up to complicated arrangements of aerials, amplifiers, splitters, VCRs, satellite and cable receivers (both digital and analogue), and distribution systems to multiple television sets distributed around the house. To this will be added either DTT set-top boxes, or integrated digital televisions (idTV), where the digital receiver is inside the television cabinet. It is not possible to cover all the combinations, but the following guidelines should be used where possible:

- make the best possible use of SCART (also known as Peritelevision) connections, to minimise the number of RF loop-through connections. Refer to figure 4.8 for an example using SCART connections.

- install the DTT receiver at the front of any chain of devices fed by RF loop-through. This will avoid any loss or degradation of the signals that may be introduced by other equipment (see Figure 4.1).

- If an idTV does not have a loop-through RF connection, then it will have to be connected as the last item in the distribution system (see figure 4.4, page 19)

- where RF loop-through connections are used, tune re-modulated signals to clear UHF channels (avoiding the so-called “taboo” channels, N+1 and N+5), and check the signal levels as recommended in Table 2, page 7.

4.2 Transmitter selection

Use the service information table received by the set-top box or integrated digital TV to identify the DTT services offering the best chance of good reception. If such information cannot be displayed directly, then the regionality of the stored multiplexes may help the installer to identify the transmitter(s) being received. This may not be possible if the DTT services being received are from a main station and either one of its dependants (relays) or a co-sited filler station. In such cases it may be possible, by identify the channel numbers of the received multiplexes, to identify the transmitter(s) being received. This can be done by using the STB or idTV to check the signal level on the channels of the likely transmitter(s) Due to coverage differences it may be necessary to choose between the available DTT and analogue services in some locations.

A particular problem may also arise in the case of DTT reception of both a main station and either one of its dependants (relays) or a co-sited filler station. (For example the Winter Hill transmitter and either the Winter Hill filler or a dependant (relay) station such as Pendle Forest) In this situation, certain STBs and idTVs will only acquire the multiplex(es) from the first transmitter found during the initial scan. This may result in only the multiplex(es) from the weaker transmitter being stored. To avoid this happening, once the relative levels have been ascertained using a signal level meter, a filter can be temporarily placed in the feed to the STB or idTV to reject the unwanted transmitter during the initial scan only.

The DTG postcode database found on the DTG Web site: (http://www.dtg.org.uk/retailer/coverage.html), can give a helpful indication of whether a useful level of signal is likely to be obtained at a site, although it is based on predicted coverage rather than measurements. However, there will be local variations that this database cannot account for, so a site survey should be carried out using suitable DTT test equipment (see chapter 2 – measurements). As a result of these checks it may be necessary to change the aerial type and/or direction to achieve optimum DTT signals with sufficient operating margin on all desired DTT multiplexes that can be received.

Figure 4.1: Simplest RF connection

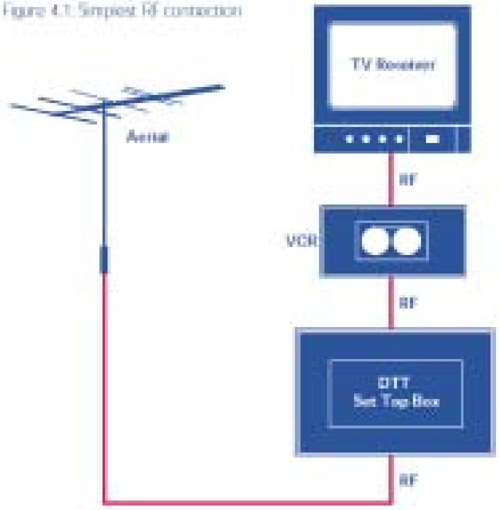
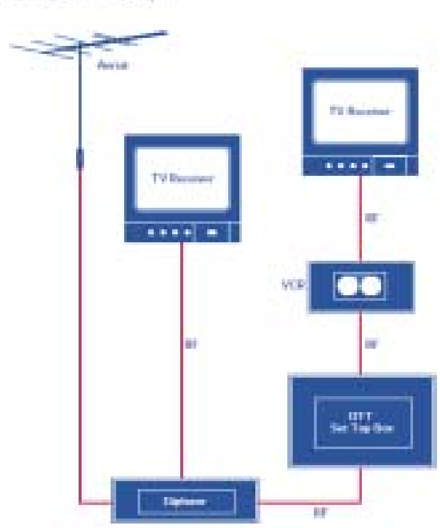


Figure 4.2 Simple distributed RF system



(Note that the use of passive devices ahead of a STB or idTV is not recommended unless very high signal levels are available from the aerial)

Figure 4.3 Satellite and DTT system: RF distribution

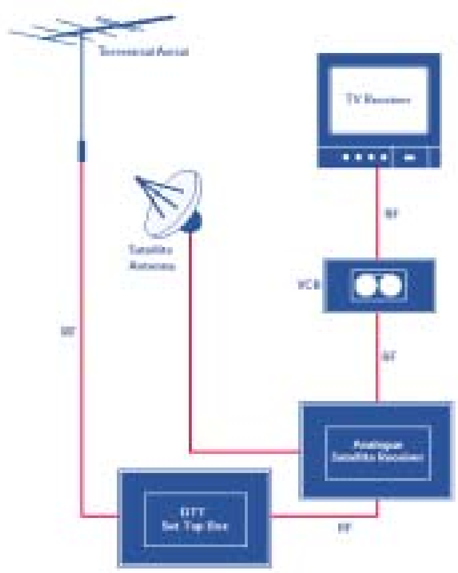


Figure 4.4 Analogue TV to two TV receivers and satellite and DTT to integrated receiver: RF distribution

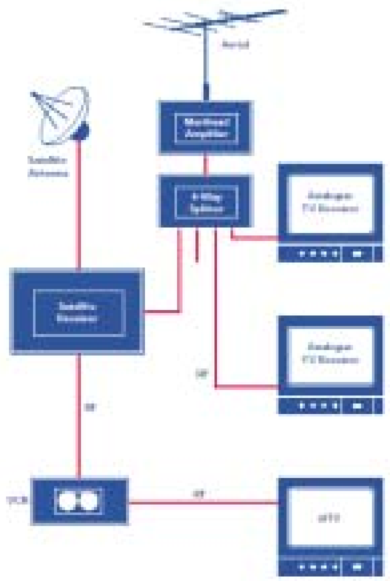


Figure 4.5 DTT, Analogue TV and satellite to four analogue TV receivers: RF distribution

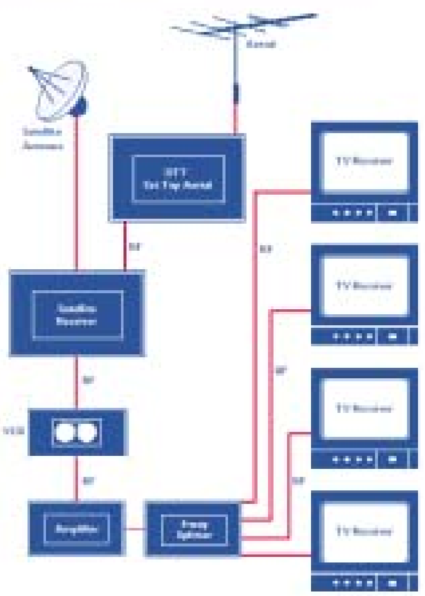
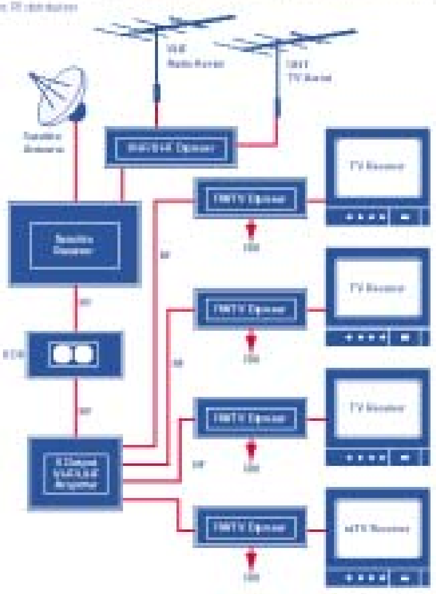
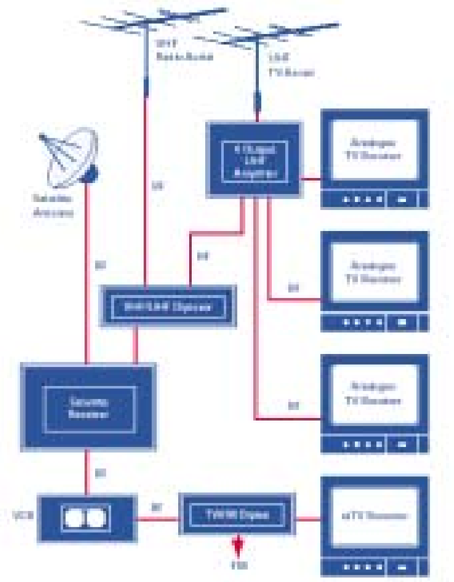
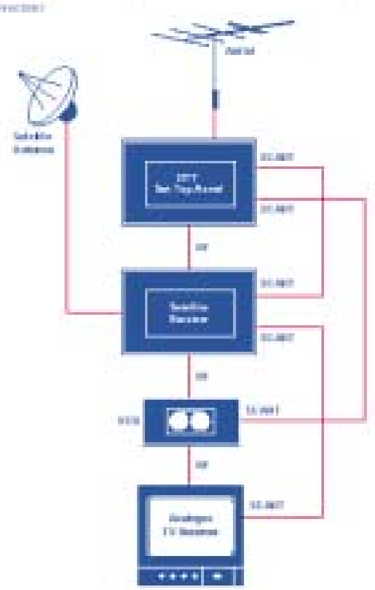


Figure 4.6 DTT, Analogue TV and FM radio distributed to three analogue and one integrated digital receiver: RF distribution







Chapter 5
Improving reception

5.1 Aerial repositioning and pointing

A significant improvement in received signal level and quality can often be achieved by repositioning the outside aerial, either by using a longer pole or by moving the mounting point to a different location on the roof. The existing aerial may need to be realigned in order to pick up the DTT services. Occasionally, a different station may give better DTT reception than the one being used for the analogue services.

5.2 Replacement aerials

The DTT signals may be out of group from the existing analogue channels so a change to a different group aerial will be required. In order to receive all the DTT multiplexes, it may be necessary to use a higher gain aerial. In DTT overlap areas where the same DTT channel number is used on both transmitters, it may be necessary to change the aerial type to one with better all round signal rejection performance. This would be necessary to minimise digital to digital interference on that particular channel. It may also be needed where reception is being degraded by co-channel analogue transmissions. The use of an aerial that meets the CAI /DTG benchmarking specification will ensure a minimum level of directivity that is normally adequate for this purpose.

5.3 Cables and Connections

The use of good quality double-screened coaxial cable of a type approved under the CAI cable benchmarking scheme is recommended for the aerial downlead and all RF connections between equipment within the household. Inferior cable with poor screening, often referred to as “low loss”, should be avoided. It should be noted that cable used for the majority of analogue installations is unlikely to be of an approved type and will almost certainly result in an increased susceptibility to impulse interference. Unless the level of the signal on a down lead is very high, it is strongly recommended that a replacement cable of an approved type should always be fitted, preferably bypassing any unshielded outlet plates that have not been replaced by screened types. Coaxial fly leads should conform to BS EN 60966-2-4:1997. “F” connections should be crimped type taking care to choose the appropriate “F” connector to match the diameter of the coaxial cable.

5.4 The use of amplification

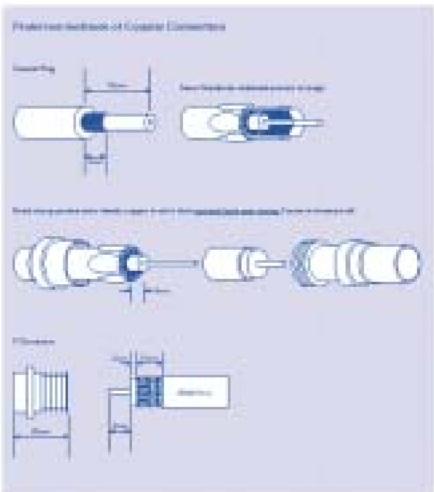
Although in general it is best to avoid the use of amplifiers for DTT, if used properly, they can be beneficial in certain circumstances:

Insufficient decoding margin

A postcode may be shown as being in coverage, but the level from the aerial may be insufficient to achieve the necessary decoding margin if, for example, there are local obstructions or a wideband aerial is being used for channels in group A. In these circumstances, a masthead amplifier or active aerial may improve the decoding margin. The general use of masthead amplification has already been covered in Chapter 3 (3.6) but it is useful to understand the limited extent to which reception can be improved in this way. The simplest way of understanding this is to consider the noise figure at the aerial connection. The STB or idTV may itself have a noise figure of say 7 dB. If the aerial down lead has a loss of say 3 dB, then the noise figure at the aerial is increased by this amount and becomes 10 dB. If a masthead amplifier is used, the noise figure of the overall system will depend on the noise figure and gain of the amplifier. However, it will always be somewhat more than the amplifier noise figure. So if this is say 3 dB, then the overall noise figure will be a little more than this and so the improvement will be a little under 7 dB (i.e. 10-3 dB) In practice therefore, the maximum improvement obtained is of the order of 6 dB, which can be very worthwhile if the decoding margin would otherwise be very small.

Reducing the effect of impulse interference generated in the home.
Where impulse interference is being generated in the home and picked up on the aerial down lead, the effect on reception will depend on the level of the signal in the down lead, the feeder pick-up rejection of the aerial and the screening properties of the cable, outlet plate, fly lead etc. The best way of reducing the effect of such impulse interference is to replace these existing components, as necessary, with better performance versions. However, when it is impractical to do so, or if there are passive splitters in the existing system that cannot conveniently be relocated, then the use of an amplifier is possibly an alternative solution. In this case, the reduction in the effect of impulse interference is directly related to the gain of the amplifier. This will only be the case however if the amplifier does not cause overloading of the STB or idTV, or is overloaded itself due to too high an input level. In practice, this limits the gain of amplifiers that can be used to a maximum of about 15 dB, unless a suitable attenuator is fitted before the input to the first item in the RF chain fed from the downlead.

When an amplifier is fitted to an existing system suffering from a very low decoding margin and also from impulse interference, it can provide improvements in both areas. It should be emphasised however that fitting an amplifier can only reduce the effects of impulse interference picked up by the aerial down lead. It will have negligible effect on impulse interference picked up by the aerial itself, either from vehicles or from domestic appliances etc.

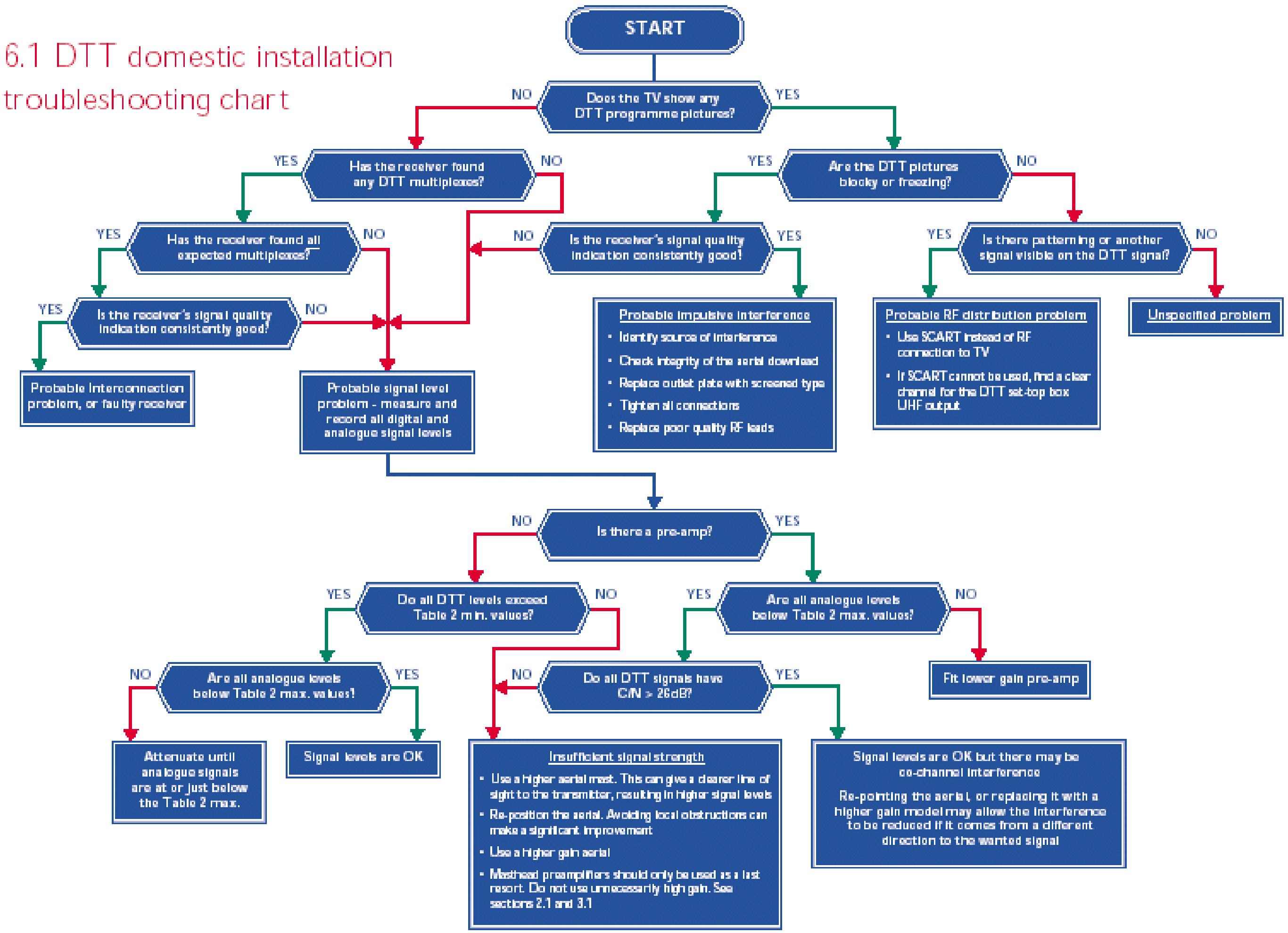


Chapter 6

6.1 DTT domestic installation troubleshooting chart

The chart overleaf assumes that the DTT receiver has been installed and connected correctly, and that there is a problem with reception. It will help you to resolve the more frequently encountered problems, but cannot cater for all situations!

6.1 DTT domestic installation troubleshooting chart



The Digital TV Group

The DTG is an Industry association set up to promote public standards and horizontal markets in digital television. It was responsible for producing the DTG D-Book, a detailed implementation specification of the DVB-T system used in UK Digital Terrestrial, the first implementation of DVB-T in the world and the first horizontal market in digital television consumer goods.

Since then, the DTG has broadened its outlook to promote the adoption of public standards in the Application Programme Interface (API) and to consider a wide range of convergence issues. Membership of the DTG is available through annual subscription to any company supporting the development of digital television using public standards.

A growing list of companies belong to the DTG "World Affiliate" Scheme, which provides a worldwide user group for companies transmitting digital television, or considering doing so.

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