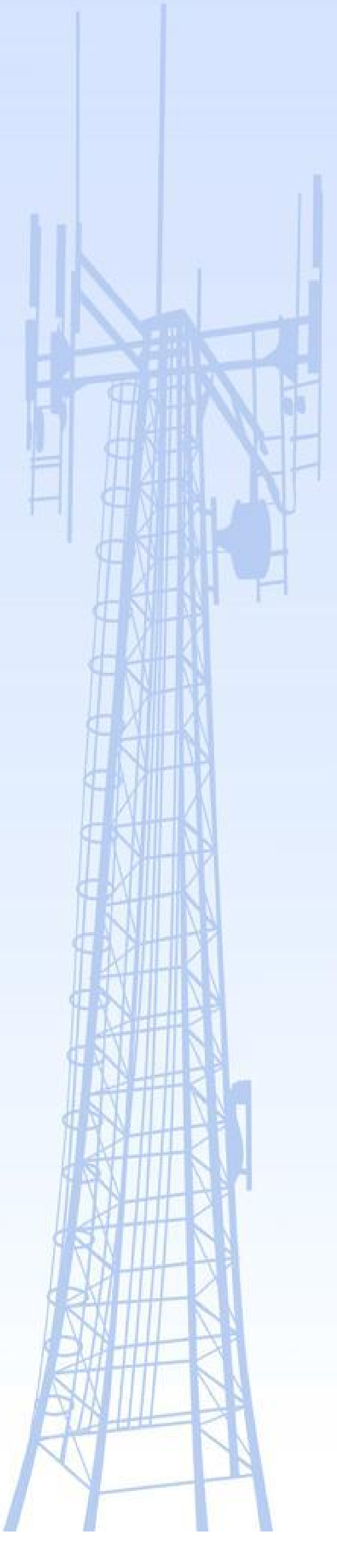

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The Impact of LTE on Communal Aerial Systems

A short study for Ofcom

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1 Executive Summary

The migration of TV services from analogue to digital has allowed a number of the channels formerly reserved for broadcast use to be released for other services. Taking advantage of this digital dividend, a harmonised frequency band has been established across Europe for use by fourth generation data services using LTE technology, and it is expected that networks for these services will be widely deployed over the next few years.

LTE base stations will generally not be co-located with TV transmitter sites, but will use a network of small stations, in a similar manner to existing mobile phone networks.

Communal aerial systems, where a single receiving point is used to supply many homes with TV signals, provide the principal means of access to TV for around 5m homes in the UK. Most communal aerial systems have been designed to receive TV signals on any of the available channels, some of which will be used for LTE. In most instances communal aerial systems will be much closer to the LTE base station than the TV transmitter, so there is potential for communal aerial systems to receive very high levels of signal from LTE base stations.

As part of this short study, the authors have made measurements to determine the amount of interference from an LTE base station that a typical communal aerial system can tolerate without degrading TV reception. The limit is about 10dB more than the digital TV signals, and we have shown that in many cases this figure will be exceeded by a considerable margin.

The effect of such interference will in relatively mild cases be to increase the occurrence of disturbances to picture and sound in a given time, or in worse cases to prevent reception of TV services completely.

Restoring the function of an affected communal aerial system will require hardware to be installed by suitably qualified technical staff. The type of hardware will vary from case to case; in the most severe cases filtering costing several hundred pounds per system may be required. If this task falls to the existing communal aerial system installation industry, extensive training will be required as this type of work is outside the experience of most installers.

This report provides a commentary on the various types of communal aerial system, and describes the measurements we have made. It discusses interference mitigation measures, and makes a number of recommendations for further work which should form part of the strategic plan for introduction of LTE services.

The authors wish to emphasise that there are various aspects of the effects of the introduction of LTE which have not been addressed by this short study, such as the impact of emissions from user equipment. The findings of this study should therefore not be seen as exhaustive.

2 Introduction

The auction has been announced of the 800MHz band in the UK for use by fourth generation (4G) mobile services using LTE technology. The frequency band has become available as a result of the transition of UHF broadcast TV services to digital terrestrial television (DTT), which has allowed a massive growth in the number of programme services available, while using less spectrum than was required for analogue services.

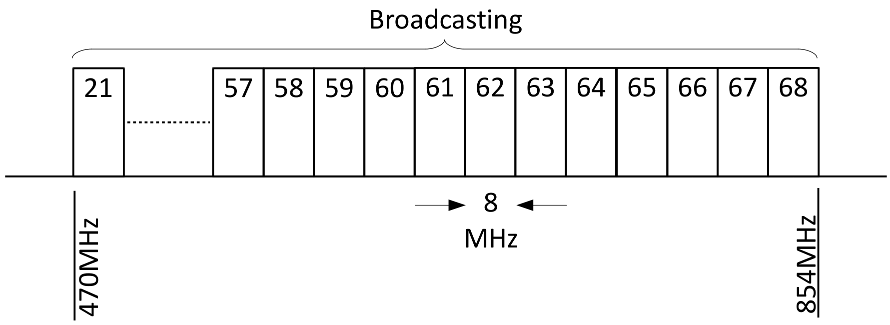

Figure 1: The arrangement of UHF channels used for analogue and digital TV transmissions in the UK

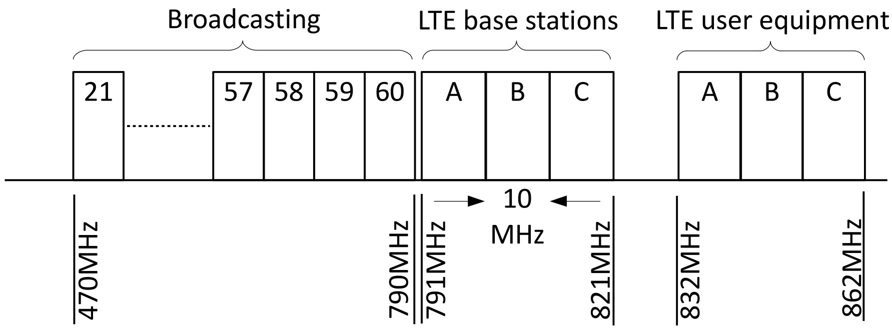

Figure 2: LTE signals will occupy the top end of the broadcast band. Channel 60, 1MHz away from the bottom end of the LTE base station band, will continue to be used for TV transmissions.

The frequencies used for the 4G services will be as shown in Figure 2. TV channels 61-68 are being cleared of TV transmissions, but channels 60 downwards will continue to be used for DTT.

4G services will be transmitted from LTE base stations with a coverage radius of typically 1-2km, so the masts will be located throughout urban areas, in much the same way as has happened for previous generations of mobile services. Many television receiving systems will be located very much closer to LTE base stations than to DTT transmitters, and will receive sufficiently high levels of 4G signals that TV reception is prevented.

About 5m homes in the UK receive their TV signals through a communal aerial system, and numerous other organisations such as hotels, hospitals and prisons make use of the same technology for distribution of TV signals. Communal aerial systems can be particularly vulnerable to interference at high power levels, which can impair or completely block TV reception.

This report is the product of a short study designed to identify the main areas of vulnerability of communal aerial systems to emissions from LTE equipment. It begins with a description of the main types of systems and their principal components. It then reports on some limited tests on system components, draws some conclusions about mitigation measures that will be needed, and makes recommendations for further actions to be taken.

3 An overview of Communal Aerial Systems

Communal aerial systems are widely used in the UK to deliver TV signals to multiple outlets from a single receiving point (usually known as the head-end). They are commonly found in:

- Houses that have been split into two or more flats
- Housing blocks, both high rise and low rise
- Housing estates of detached, semi-detached, terraced homes, etc.
- Sheltered housing and nursing homes
- Commercial premises such as shops, hotels, holiday villages
- Institutions such as prisons, hospitals and universities

There is also widespread use of systems within homes to deliver signals to various rooms. Although these are in many respects similar technically, they are commonly excluded from being classed as communal aerial systems as they serve only a single home.

The great majority of communal aerial systems are found in housing rather than in commercial or institutional situations, and this report focuses principally on housing applications. According to senior staff of companies involved in the communal aerial business, roughly 5m households across the UK receive television signals via some form of communal aerial system.

Communal aerial systems offer a number of advantages over individual provision by each household, including:

- Improved appearance by avoiding a proliferation of aerials and dishes;
- Lower cost per household;
- Compliance with planning regulations, which limit the number of satellite dishes that can be installed on a building without specific consent[1];
- Uniform provision of services to all homes (e.g. in many instances homes in a block that do not face in the direction of the terrestrial transmitter or satellite are unable to receive signals with acceptable quality using their own equipment);
- Improved performance as a result of professional installation;
- Safe installation by qualified and experienced installers.

1 Guidance on planning regulations for aerials and dishes can be found at http://www.planningportal.gov.uk/permission/commonprojects/antenna/.

Photo 1: Part of a housing block showing typical
"dish rash": nine dishes can be seen!

Generally communal aerial systems are owned by the landlord of the property in which they are installed, although there are a small number of systems that are leased from the installation company. In the public sector, many local authorities have passed responsibility for maintenance to Housing Associations, Tenant Management Organisations (TMO), Arms Length Management Organisations (ALMO), etc. It is not always straightforward to find the senior manager with direct responsibility for maintenance, but most commonly it will be managed by the Building Maintenance Department or the Asset Management Department. In the private sector, many landlords use a Managing Agent to handle maintenance issues.

Access to systems for maintenance or upgrade would normally be made through the appropriate organisation mentioned above. Some systems, particularly under larger landlords, are subject to maintenance contracts. Commonly such contracts prohibit the landlord from allowing other parties to carry out work on the systems so that responsibility for the performance of the systems remains clear. However, many landlords, particularly those with smaller property portfolios, operate on a "fit and forget" basis with no formal maintenance contract in place, and typically rely instead on a local installer to repair systems when a fault arises. Either way, it can be quite difficult for an outside organisation to identify the correct party to be dealing with in a given case. In our experience, there appears to be no industry-wide body such as a relevant industry association that is able to provide much help in this respect.

In summary:

- About 5m homes in the UK use a communal aerial system as their primary means of receiving TV signals.
- Finding where systems are and getting access to them is often not straightforward.

3.1 Types of Communal Aerial System

Communal aerial systems are most easily categorised into one of the following two types:

- Master Antenna TV (MATV) systems which deliver analogue and digital terrestrial TV signals in the frequency range 470MHz to 854MHz (also known as Bands IV and V)
- Integrated Reception Systems (IRS) which in addition to delivering terrestrial signals also deliver satellite signals in the standard satellite intermediate frequency band (950MHz to 2150MHz)

Both MATV and IRS often also carry FM radio (88MHz to 108MHz) and DAB (217.5MHz to 230MHz) signals.

3.2 MATV systems

The simplest MATV system comprises an aerial, an amplifier, a distribution network, and outlets, as illustrated in Figure 3.

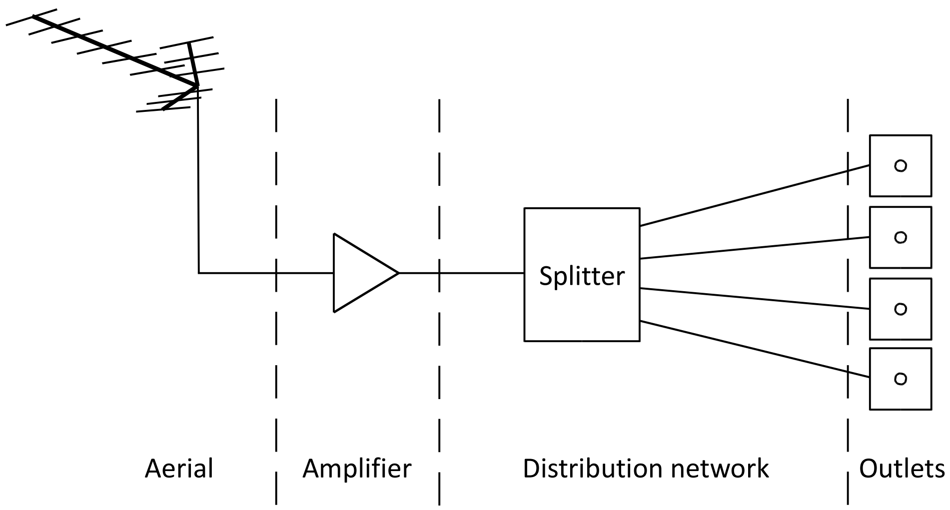

Figure 3: The main elements of an MATV system

The functions of the components shown in Figure 3 are:

- Aerial: receives TV signals
- Amplifier: increases the power of the signals, typically to overcome the losses in the distribution network
- Distribution network: delivers signals from the headend to all the outlets
- Outlets: provide a means for the user easily to make a connection to their television equipment

The term *headend* usually refers to the amplifier and any other electronic components that feed the distribution network. Sometimes it also includes the aerial system.

3.2.1 Aerials

An aerial is not intended simply to pull in signal from a wanted direction. It should also be carefully designed to reject signals coming from unwanted directions. An aerial that is deficient in either of these respects may cause the received signal quality to be lower than desired.

There are large numbers of aerials that are very low cost, but also very poor performance. In order to give installers a much clearer idea of aerial performance, the confederation of Aerial Industries (CAI) established an aerial benchmarking scheme that defined three tiers of performance. A manufacturer may submit an aerial for testing, and if it meets the requirements of the standard, the manufacturer is licensed to use the CAI's aerial benchmark logo. Benchmarked aerials are now widely used on communal aerial systems.

In some areas of the country it is common to find systems with two aerials, receiving signals from the local transmitter, and also from a nearby transmitter which carries different regional content.

Aerials are designed to operate only over a limited range of frequencies, in groups as described in Table 1.

Group	Channel range	Frequency range
A	21 – 37	470MHz – 606MHz
B	35 – 53	582MHz – 734MHz
C/D	48 – 68	686MHz – 854MHz
E	35 – 68	582MHz – 854MHz
K	21 – 48	470MHz – 694MHz
W	21 – 68	470MHz – 854MHz

Table 1: Aerial groups

A group W aerial covers the whole of the frequency range 470MHz to 854MHz. The other groups all cover subsets of this range. If they operate over a narrower range of frequencies, aerials have more gain (a measure of the ability to receive signals). Grouped aerials therefore tend to be used most towards the edge of coverage areas where the signals are weakest.

Uncertainty about changes in frequency at digital switch-over has encouraged the use of group W aerials wherever feasible.

Emissions from main transmitters are generally horizontally polarised, and from relay transmitters are vertically polarised. For correct operation receiving aerials must be aligned to match the polarisation of transmitted signals. Deliberately cross-polarising potentially interfering transmissions can be used to provide a limited amount of protection.

3.2.2 Amplifiers

Amplifiers used in TV reception fall into three groups:

- Low power devices, such as masthead amplifiers
- Medium power devices known as an indoor, loft, multi-way or set-back amplifiers. These are often used to create a distribution network in the home, providing TV signals from a single aerial to multiple outlets around the dwelling. These are not normally considered part of a communal aerial system as they are generally used on systems within one home.
- High power devices such as distribution, repeater or launch amplifiers

3.2.2.1 Masthead amplifiers

Masthead amplifiers are inexpensive low noise amplifiers intended to be mounted close to the aerial. They provide amplification, and also minimise degradation of the system's noise figure due to cable and other losses. They have limited output drive level capability, and most commonly are wideband across the whole of the frequency band 470MHz to 862MHz, or even 30MHz to 862MHz, although masthead amplifiers with frequency responses that match aerial groups are available.

Some models have special filtering for the suppression of Tetra and other potentially interfering signals, and manufacturers are understood to be developing filtering for LTE signals. However, it is important to recognise that, according to senior staff of companies closely involved in the business, there is a total of roughly 4m masthead amplifiers installed across the country (this figure includes masthead amplifiers that are not part of communal aerial systems), so it will take some time before devices with new filtering characteristics can penetrate a significant proportion of the market.

Many masthead amplifiers, in particular but not exclusively older ones, suffer from a lack of screening, making them highly susceptible to a wide range of sources of interference.

In areas close to transmitters, small communal aerial systems feeding only a few flats may be able to omit the amplifier. The deciding factor is whether the signal, after it has passed through the distribution network, arrives with sufficient level (see Table 2 for level requirements). If the signal levels miss the target minimum values by less than about 15dB, and the losses on the distribution network do not require the amplifier to produce very high levels, then a masthead amplifier may be used.

Masthead amplifiers are usually powered via the coaxial cable on their output. Devices powered in this way are said to be *line-powered*.

Some masthead amplifiers have splitters built in to drive typically four or five outlets. Including mains power supply, these cost in the region of £15-£25 (wholesale).

There is an enormous range of masthead amplifiers available. One distributor for example lists over sixty different models.

3.2.2.2 Distribution, repeater and launch amplifiers

In larger systems, it is generally necessary to use an amplifier that has the capability of driving higher levels of signal into the distribution network. Such a device is known as a distribution, or launch amplifier, and the cost generally rises rapidly with power rating, especially above about 120dBµV (11dBm)(see Section 4.1 for further discussion of launch amplifiers).

In systems where several blocks are run off a single headend by using cables between the blocks, it is common to find a launch amplifier in each block or cascaded repeater amplifiers.

Launch amplifiers tend to be operated quite close to their maximum output power (for a given signal to intermodulation ratio) by adjusting their gain on installation. The operating point of a masthead amplifier or a set-back amplifier is adjusted, if at all, more often than not on a trial and error basis. Some masthead amplifiers will specify maximum signal levels, but are sometimes unclear about the criteria associated with that figure. It is therefore difficult to model any mechanism for failure in the presence of strong signals. We recommend that further work is done to characterise the effects of strong signals in such devices.

3.2.3 Cable

All electrical cable carrying signals in MATV or IRS is coaxial as this form can provide both the high frequency response required and screening from external sources of interference. The great majority of cable used in MATV and IRS is known as Type 100, which has a 1mm diameter inner conductor and an outside diameter of just under 7mm. Larger cables offering correspondingly lower electrical losses are available, but are significantly more expensive than Type 100 so are only used where necessary. Type 100 offers a good compromise between cost and performance.

The industry recognised over ten years ago that the quality of coaxial cable is important, and that there were a number of cables being offered as Type 100, but with considerably varying electrical and mechanical characteristics. The lack of enforced standards encouraged some manufacturers to compromise performance in the interests of price competition, and installers were generally not able to tell the good from the bad.

The Confederation of Aerial Industries (CAI, a UK trade association) therefore adopted a benchmarking scheme specifying many aspects of both electrical and mechanical characteristics, and invited manufacturers to submit samples of their cables for testing. Those cables that passed the benchmark tests were able to be sold under the CAI's cable benchmark trade mark, which has subsequently become a widely recognised mark.

The general view among manufacturers, distributors and installers we have interviewed is that benchmarked cable is now used in 75-80% of MATV and IRS installations. However, there are still a substantial number of systems in use where the cable pre-dates the benchmark scheme and is of poor quality.

Possibly the most important characteristic specified by the cable benchmark scheme is screening effectiveness. This is a measure of the degree to which the cable can keep signal power within its outer conductor, and by reciprocity, how little the cable takes in external signals.

It is known that some coaxial cables are particularly deficient in this respect, which is undesirable in the presence of strong interfering signals. Some tests comparing the effectiveness of screening of several types of cable and connectors have been performed by others[2], showing a significant variation between types. However, it is difficult to be certain whether screening capability to the requirements of the CAI benchmark scheme will be adequate in most cases of interference. Screening of cables in communal aerial systems may not seem to be top priority, given the poor performance of typical fly leads for example, but it would be important to know whether the cable screening was adequate because a system is only as robust as its weakest link. If the quality of the outlet and fly lead is good, insufficient screening on the cable used in a communal aerial system could still render the system as a whole vulnerable to interference, particularly from LTE UE (user equipment).

2 See Reference 9.

3.2.4 Cable installation

There are two main methods of installing cable into an existing building:

- Internal cabling takes advantage of risers and service cupboards that may exist typically in stairwells. The principal drawback of internal cabling is that the cable arrives at the front door of the home, and has to be routed through the living area to the television, which may require furniture to be moved, carpets and floors lifted, or disturbance to decoration, particularly if the occupant does not want surface wiring. This method tends only to be used when there is a need to avoid making any change to the outward appearance of the building.

- Over-wiring is the process of fixing cables to the outside of the building, as shown in Photo 2. Note the use of brown cable over the tiling, white elsewhere, and very neat bunches of cable. In this case, the installation of the cable and headend is complete, and the headend has been tested and is operating. The coils of cable show that the next stage, called plating, is ready to be done. The installers enter each home and drill a hole to the outside for the cable to enter. The hole is positioned so that it will be concealed behind the outlet, close to the mains sockets for the television.

Photo 2: A good example of tidy over-wiring

In contrast with the tidy installation shown in Photo 2, Photo 3 shows what can happen when an installation is added to many times, and the cable cannot be seen from the street. Poor workmanship and materials can lead to a range of problems, such as interference, water ingress, etc.

Photo 3: An example of untidy cabling, commonly found in older installations. Systems like this tend to be particularly vulnerable to interference.

Over-wiring is by far the most common cabling technique for existing buildings. New buildings tend to use internal wiring because there are few problems with routing cable in walls or floor voids.

3.2.5 Distribution networks

A distribution network usually comprises a number of splitters or taps and lengths of coaxial cable. A splitter effectively terminates a single cable and shares the signal power from that cable equally among a number of outgoing cables, typically from two to sixteen. A tap, on the other hand, provides a through line as well as one or more tap ports which are coupled to the through line to produce signals typically from 8dB to 30dB below the input to the through line. The insertion loss of the through line is usually a few dB, depending on the number of tap ports and their coupling factors.

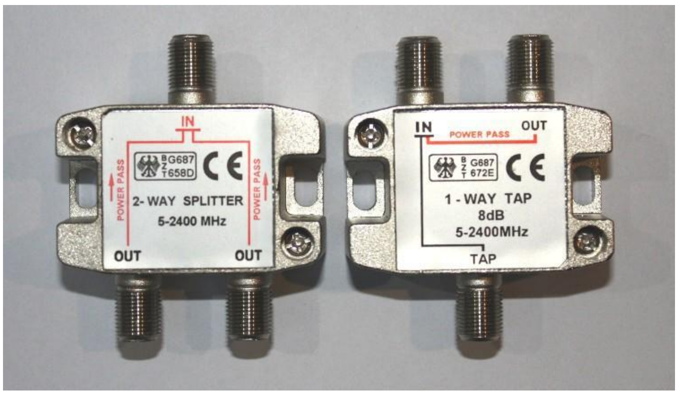

Photo 4: Typical splitter and tap

Splitters are mainly used to create networks where feeds to outlets originate from a single location (known as star networks), and taps are more suited to long, distributed networks, although they are also found in star networks. The structure of a MATV system's distribution network is largely determined by the arrangement of outlets that it serves.

Photo 5: This typical medium sized MATV headend has eight outputs from the two splitters near the bottom of the board. These feed other splitters in the wings of the building.

3.2.6 Signal levels and quality

The only points in a system where the signal levels and quality are required to meet defined standards are the outlets. This gives the system designer the maximum flexibility to choose components (aerials, amplifiers, cable, splitters, etc.) in the most cost effective way while delivering signals to the users that comply with agreed requirements.

The table below shows the acceptable range of signal levels at outlets for analogue and DTT signals, with the corresponding signal to noise ratio (SNR) requirements, as defined in the Digital Television Group's "Installing Digital Television – MATV and IRS" (R-book 5). These values have been widely adopted.

	Minimum signal level	Maximum signal level	Minimum SNR
Analogue TV	60dBµV (-49dBm)	80dBµV (-29dBm)	43dB
DTT 64QAM FEC 2/3	45dBµV (-64dBm)	65dBµV (-44dBm)	25dB

Table 2: Recommended signal level ranges and SNRs

At digital switch-over, DTT signals typically increase in power by 10dB, so systems that have previously been set to be in the range 45 – 65dBµV will then be in the range 55 – 75dBµV. Systems installed after digital switch-over will use 80dBµV (-29dBm) as the maximum level at an outlet.

The figure of 45dBµV (-64dBm) for minimum DTT signal level was arrived at empirically. Shortly after the launch of DTT services, it became clear that DVB-T was more vulnerable to impulsive interference than anticipated. In many cases the impulsive interference got into the system via the wall outlet or the fly lead from the outlet to the receiver, so increasing the delivered signal level improved the ratio of signal to interference, greatly reducing the occurrence of error artefacts on pictures and sound. The higher the signal level, the greater the protection, so some designers use a figure of 50dBµV (-59dBm) as a minimum level. Many receivers now internally implement impulsive interference counter-measures, and the change of DVB-T mode from 2K to 8K offers further protection.

3.2.7 Outlets

Outlets terminate the distribution network cables in the home, generally presenting an IEC coaxial socket[3] (also known as a Belling-Lee connector) on a plate on the wall for the user to plug a fly lead into, to connect to the receiver.

Since the discovery of the impulsive interference problem described above, the majority of outlets installed have been fully screened. However, prior to this, large numbers of very inexpensive outlets were installed that had very poor screening, especially those providing electrical isolation. Typically their construction was based on a printed circuit which in some cases was clearly designed by someone with little appreciation of RF techniques. Poorly screened outlets are still widely available, particularly in DIY stores where price competition is highly important.

Outlets and fly leads, which are notorious for their poor screening quality, provide major breaches in the screening defences of many communal systems, letting in interference from nearby devices. The effect is to raise the frequency of disturbances to pictures and sound.

3.2.8 Filtering

The simple system described in Figure 3 contains no specific filtering, and is likely to respond to signal frequencies outside Bands IV and V. The aerial may provide some degree of bandwidth limitation as it will be designed for one of the six groups described in Table 1. However, the degree of protection against signals outside the group is typically not great, and the frequency response outside the group should not be relied upon, as it is not generally a specified parameter.

Masthead amplifiers are now available with internal filtering designed to protect the system from Tetra and other emissions below 470MHz and from GSM900 emissions just above 862MHz. Apart from this, unless specific steps are taken, a system will be broadband, open to the whole of the frequency range 470MHz to 862MHz, and significantly beyond.

A small proportion of systems are fitted with simple bandpass filters, typically tuned to pass one of the aerial groups shown in Table 1. Usually this type of filter has been fitted because some interference from services outside the broadcast band has been experienced, or is anticipated. The frequency response of a Group A filter has been measured and is shown in section 4.2.

Some systems, particularly larger ones, are fitted with channel or cluster equalisers which contain a number of filters of adjustable bandwidth that allow typically groups of 1-7 adjacent channels to be selected, and each group's amplitude to be adjusted independently. Cluster equalisers have been used where analogue signals were received at significantly different levels, because a launch amplifier can be used closer to its rated power level when the amplitudes of all the analogue carriers are equal.

Cluster equalisers can be divided into two groups:

- Passive, using only passive components, and therefore unlikely to be affected adversely by strong signals;
- Active, using electronic components under the control of a microprocessor to tune the filters, and to amplify signals. This type of device is likely to be affected adversely by strong signals such as from LTE base stations.

3 The IEC has defined numerous connectors, but the term IEC connector has become accepted in the TV industry as meaning a connector compliant with IEC61169-2.

Cluster equalisers give significant rejection of signals a few channels removed from the wanted channels, and passive cluster equalisers have been used to provide systems with protection from out-of-band interference. The main disadvantage of passive cluster equalisers is that if a new channel is brought into use, as is commonly the case at digital switch-over, the filter must be re-tuned, which generally involves returning it to the supplier. Active cluster equalisers can easily be re-tuned on site.

Some systems contain channel processors which allow the signal levels of individual channels to be adjusted independently. Prior to digital, these were used as equalisers for analogue signals, and in the early days of digital when some of the multiplexes were transmitted at very low power, they were used to raise the power of digital signals to keep them well above the system noise floor.

Some early channel processors only contain UHF filters and amplifiers, but these did not provide sufficient selectivity for DTT. Selectivity was improved by converting signals down to an intermediate frequency (IF), for example 36MHz, where a SAW filter could be used. The filtered signal was then converted back to the same UHF channel. Some processors also contained automatic gain control for signal level stability.

3.2.9 Channel changers

Prior to the introduction of DTT, it was sometimes found that analogue TV services would suffer from a faint image a little to the left of the main image. This generally happened only in areas of particularly high field strength, and was due to direct reception via a poor quality fly lead or outlet plate interfering with the intended signal from the MATV system. The path through the system was significantly longer than the direct path, giving rise to the time delay between the two images.

This problem was resolved by changing the channels in the headend to ones not in use locally. In this way interference from direct reception could be avoided.

The channel changers were similar in operation to the channel processors described above. The signal was converted down to IF, and then converted back to UHF by a second local oscillator on a different frequency.

In principle, these devices should not be a problem in a system at digital switch-over, when in many cases a digital multiplex will move into channels formerly occupied by an analogue service. However, it was found that some channel changers introduced so much phase noise[4] that it would not be possible to decode the digital signal on its output. It has also been reported that frequency offsets of the output signals in some cases are too great for receivers.

Channel changers will be redundant once analogue services have ceased, and those with the phase noise and frequency offset problems will have to be removed if the system is to be used after digital switch-over.

3.2.10 Systems with local modulators

It was common practice, particularly prior to DTT, to receive a number of satellite services typically with domestic receivers, and add them to the terrestrial signals on a MATV system. The modulated outputs of the satellite receivers were designed to act as a means of connecting to an analogue TV set, so it was a simple matter to find empty channels on a MATV system, and use them for the outputs of satellite receivers. Such a system was known as a SMATV (Satellite MATV) system, or sometimes SMATV-TM (Satellite MATV - TransModulation).

4 For further information on channel changers and the phase noise problem see “Phase Noise in Channel Converters in Existing Communal Aerial Systems” available via http://www.digitaltelevision.gov.uk/publications/pub_phasenoise.html

In many cases SMATV systems were poorly filtered, offering little protection against received interference on the channels used for the satellite services, particularly during periods of enhance UHF propagation.

The number of available satellite channels soon greatly outstripped the channel capacity of SMATV systems, and with the absence of features such as the Electronic Programme Guide it became clear that the future of the SMATV system was limited. The Integrated Reception System (see below) has for over ten years been the standard method for communal delivery of satellite signals.

Local modulators have also been widely used to carry analogue TV signals from security cameras. Within the last year or so it has become commercially viable on larger systems to digitally encode and modulate the output from analogue cameras. For example, equipment is available to take composite video and audio from two analogue cameras, MPEG encode them and combine them into a single DTT multiplex, for under £800 (wholesale).

3.3 Integrated Reception Systems, IRS

An IRS[5] is a communal aerial system that delivers satellite signals in addition to everything a MATV system can deliver. Crucially an IRS is entirely compatible with satellite receivers designed to operate with individual dishes.

Satellite signals for home use in the UK and across Europe are principally transmitted in the frequency band from 10.7GHz to 12.75GHz, known as Ku-band. This frequency band is used for two sets of transmissions on orthogonal polarisations (horizontal and vertical) for enhanced spectral efficiency (a simple device at the dish is able to separate the two sets of signals). Transporting signals at these frequencies from the dish to the receiver without excessive loss would be very expensive, so at the dish the signals are converted down to a lower frequency where cable loss is manageable. This lower frequency has to avoid clashing with terrestrial TV signals, so it begins at 950MHz. Converting the whole satellite band in one step would still occupy frequencies up to about 3GHz, but by splitting the range in two, this upper frequency can be reduced to 2.15GHz.

The frequency conversion takes place in the LNB (Low Noise Block) where the received signals are mixed with a local oscillator at either 9.75GHz or 10.6GHz.

The frequency conversions of the upper part of the frequency range (11.7GHz to 12.75GHz, known as high band) and the lower part (10.7GHz to 11.7GHz, know as low band), and the selection of vertical or horizontal polarisation result in the IF band having four possible sets of signals. These can be carried on four separate cables, or as in consumer receivers, on one cable with the receiver sending commands to a switch at the far end of the cable to select which one of the four to use.

Knowing this, we can now understand the architecture of an IRS.

3.3.1 Architecture of an IRS

The architecture of a simple IRS is illustrated in Figure 4. The four groups of signals from the dish are fed down four parallel cables to the multiswitch. A receiver connected to any one of the multiswitch output ports signals which of the four sets of signals it needs, and the multiswitch routes that set to the receiver. All the output ports operate independently in this way.

5 An IRS may also be referred to as a SMATV-IF: Satellite MATV, Intermediate Frequency

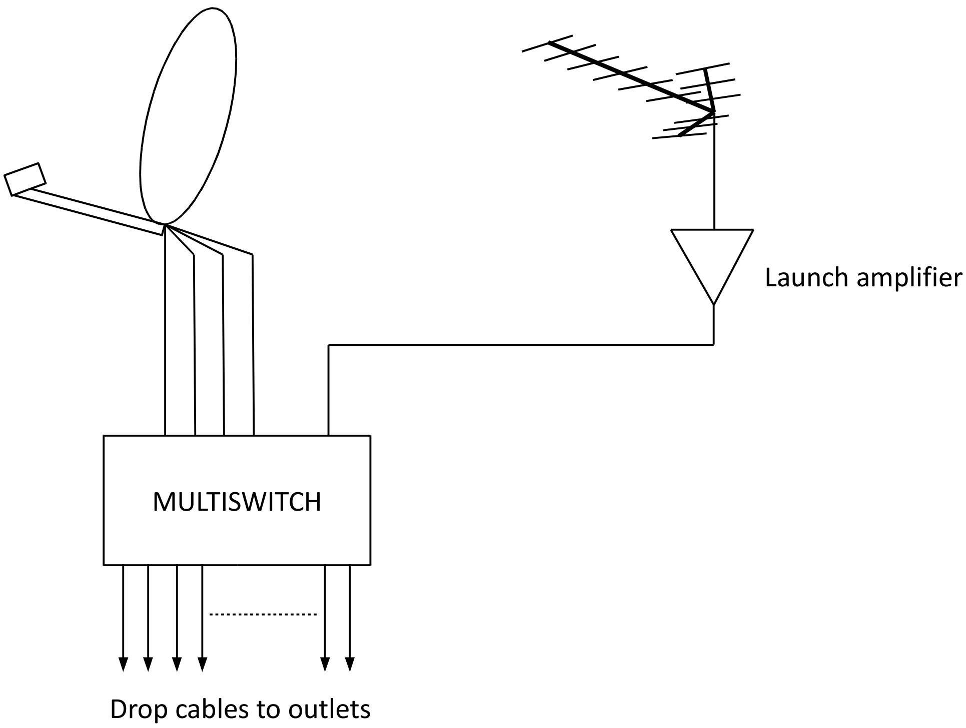

Figure 4: The principal components of a simple IRS

The terrestrial signals are amplified and fed to the multiswitch, and are simply reproduced on all the multiswitch outputs. Note that in some cases the terrestrial launch amplifier is inside the multiswitch.

In this way, each drop cable carries terrestrial signals from 470MHz to 862MHz and switched satellite signals from 950MHz to 2150MHz. In the outlet plate in the home, there is usually a diplexer which separates these two bands and presents them on appropriate connectors (IEC for terrestrial, F for satellite).

For satellite receivers with two tuners, such as receivers with hard disk storage (known as Personal Video Recorders, PVRs), a second connection must be made to the multiswitch. Satellite signals cannot be split to more than one receiver due to switching conflicts. In some cases more than two cables are fed to each home, so that satellite receivers can be used in other rooms, in addition to a PVR in the main room.

The type of system shown in Figure 4 is known as a five wire system – four satellite and one terrestrial. If an IRS is to carry signals from a second satellite orbit location, then four cables from a second dish can be fed to a multiswitch with nine inputs, resulting in a nine wire system. Multiswitches for five and nine wire systems are widely available, and it is possible to obtain switches for thirteen and seventeen wire systems.

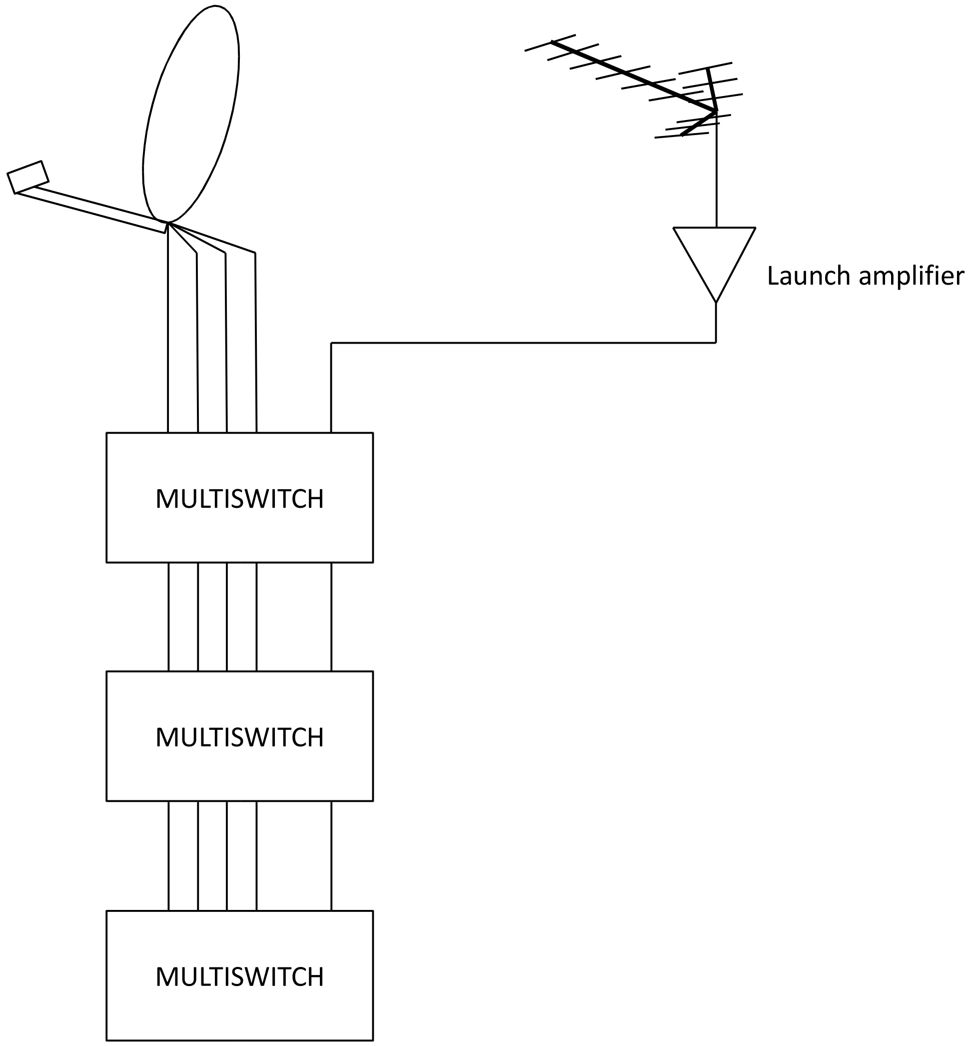

Figure 5: Cascade multiswitches are used in systems requiring large numbers of outlets

Multiswitches typically have from eight to thirty-two outputs. For systems requiring more, cascade multiswitches can be used. On a five wire cascade multiswitch there are five outputs mirroring the five inputs, so that another multiswitch can easily be connected, as shown in Figure 5.

In a tower block, multiswitches might be located in service or riser cupboards on each floor if the building is cabled internally. However, it is more common to use external cabling (over-wiring) on properties of all sizes, as this technique is less disruptive to decoration on both flats and common areas. In these cases, multiswitches are usually housed in small weatherproof cabinets mounted on the outside of the building, as shown in Photo 6.

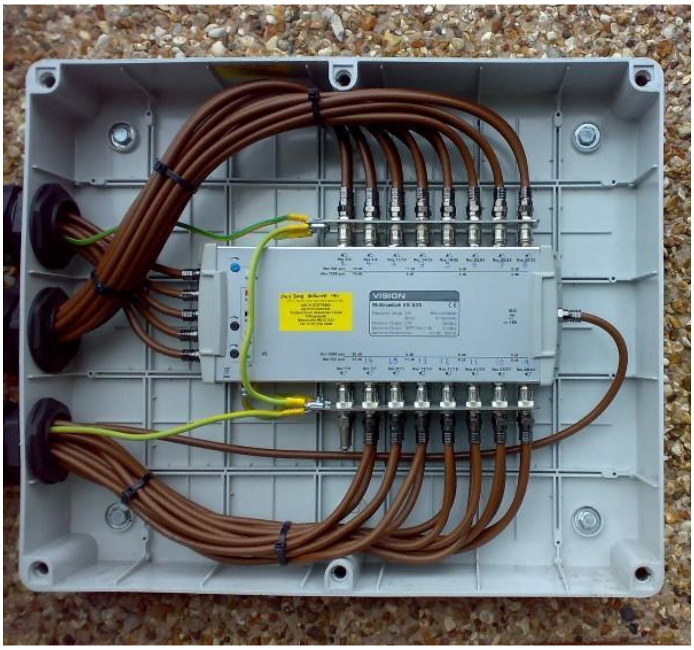

Photo 6: A small weatherproof housing with a five wire, thirty-two output multiswitch

Photo 8: A typical IRS headend in an externally mounted cabinet

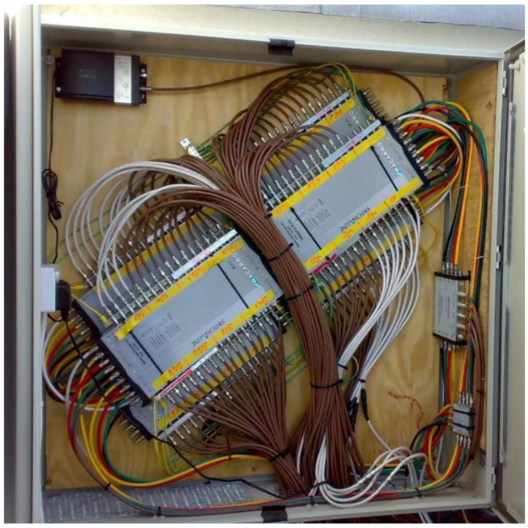

Photo 7: A sub-headend cabinet with large multiswitches

An alternative for larger systems is to use amplifiers and splitters with conventional multiswitches as shown in Figure 6. The amplifiers compensate for the losses in the splitters and cabling to the multiswitches.

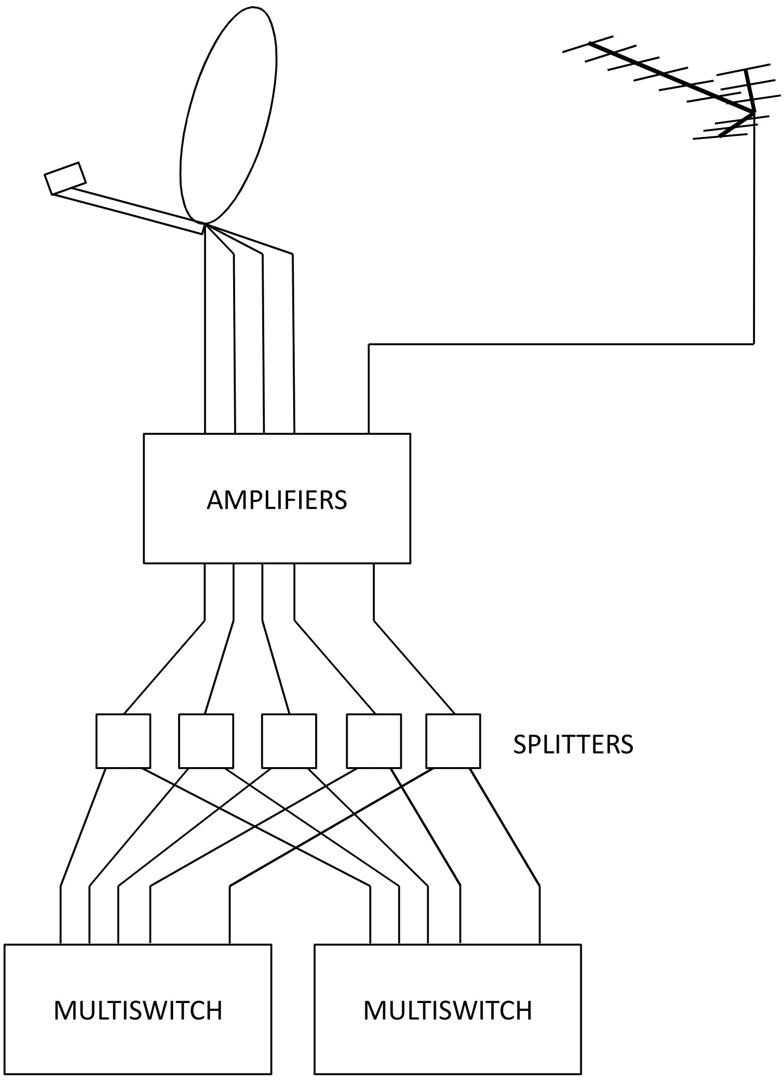

Figure 6: An IRS using splitters and conventional multiswitches

3.3.2 Single Cable Router, SCR

EN50494:2007 defines a method for connecting up to eight satellite tuners to a single cable. Each receiver is assigned its own frequency in the satellite IF band, and the router in the headend responds to signalling from each receiver by converting and routing the requested multiplex into that receiver's assigned channel.

Providing an SCR feed into a dwelling eliminates the difficulties of adding extra cables when a user wishes to operate more satellite receivers than was allowed for when the system was installed. However, an IRS equipped with SCR is significantly more expensive than one without, and there have so far been few installations of SCR systems in the UK.

3.3.3 Optical Fibres

Optical fibres are occasionally used to link headends, particularly where distances are relatively large, and there are restrictions on erecting aerials. The number of these systems is quite small.

In the last couple of years, a system using optical fibres to deliver to the home has become available. This system delivers both terrestrial and satellite signals, and is known as a Fibre IRS. Each home is equipped with a device which converts the optical signals back to electrical, which are presented in the same format as a conventional IRS. This system requires signal processing at the headend to remove analogue TV signals which would otherwise overload the modulation system, so presumably these systems may be very sensitive to high level interference from LTE signals.

In summary:

There are two types of communal aerial system:

- MATV systems, which carry terrestrial TV
- IRS, which carry terrestrial and satellite TV
- There are many variants, some with frequency selective components, but the majority are wideband

4 Measurements

Tests have been carried out on a sample launch amplifier and multiswitch to measure their behaviour under simulated overload conditions arising from high levels of LTE base station signals. We have also measured the frequency response of some filters, to assess their suitability for use in suppressing LTE interference.

4.1 Launch amplifiers

Launch amplifiers are used to raise the power level of signals to a relatively high value so that after the losses of the distribution network, signals are available at outlet plates with suitable strength and quality. The cost penalty of using either lower loss coaxial cable or higher power launch amplifiers encourages the installer to use launch amplifiers with as high power levels as possible without significantly degrading the system performance by generating excessive levels of intermodulation products.

In order to allow the system designer to calculate the maximum output power levels that a particular model of launch amplifier can achieve, the amplifier will be given a power rating by the manufacturer. This power rating specifies the maximum power of each of two equal power tones where either of the third order intermodulation products ($2f_1-f_2$ or $2f_2-f_1$) will be no more that -60dB relative to either tone[6]. The designer then applies a de-rating factor, D, where

$$D = 10\log_{10}(N-1)$$

and N is the number of analogue carriers[7]. In most cases in the UK, there are five analogue carriers, so the de-rating would be 6dB. Therefore, if a launch amplifier is rated at 120dBμV (11dBm), it can produce an output power of 114dBμV (5dBm) per analogue carrier (all five carriers assumed to be the same level) with the intermodulation products sufficiently low in power that they will not to be visible on an analogue television.

In most cases, DTT signals are transmitted at about -17dB relative to peak sync power of the analogue vision carriers. The total power of six such multiplexes represents a negligible increase in the operating power of the launch amplifier, so an amplifier set up as described above needs no adjustment to be able to handle DTT signals in addition to analogue. Furthermore, it has been shown that at digital switchover, when the analogue services are removed and the power of the DTT services increases typically by 10dB[8], launch amplifiers set up using this method will continue to operate satisfactorily[9]. Therefore, as there has been no need to make any changes to the operating point of launch amplifiers, we commonly find that after digital switchover DTT signals are in the region of 13dB below the rating of the amplifier (6dB due to de-rating, plus 7dB for the ratio of DTT power to the former analogue peak sync power). This has been used as the basis of the tests described below.

As the great majority of systems have been designed to carry four or five analogue services, and after digital switch-over will only carry six digital multiplexes, some manufacturers have provided de-rated signal level data with amplifiers for these conditions.

It should be noted that the operating point of a launch amplifier is normally not set up with a great deal of precision. In fact, some installers have aimed to get the most out of an amplifier by increasing the output until patterning is just visible on analogue services, and then reducing the output slightly. Some systems, notoriously multi-channel systems in hotels, operate with clearly visible patterning. Fortunately DTT

6 See 5.11.2 of EN60728-3:2006, Active Wideband Equipment for Coaxial Cable Networks

7 There are a number of minor variations on this expression, but this version seems to be widely used.

8 There is a small number of cases where the increase in DTT power is greater than 10dB.

9 See Reference 10

services are less sensitive than analogue in this respect.

4.1.1 Tests

Tests have been carried out on a launch amplifier typical of those found in MATV and some IRS communal aerial systems. The aim was to discover how much power from an LTE base station could be present at the input to the amplifier before the quality of a DTT signal was significantly degraded.

In the time available for this brief study it was not possible to obtain equipment to generate six DTT signals and three blocks of LTE base station signals. Instead, filtered broadband noise was used to simulate most of the signals.

The principle of the measurement system was to use a filtered wideband noise source to represent five DTT multiplexes on a block of five contiguous channels, 47-51. The output of a DTT modulator was set to channel 56 (64QAM rate 2/3), and this was to act as victim. The interferer was also simulated by filtered noise, from 791MHz to 821MHz, the range of frequencies transmitted by LTE base stations.

Filtered wideband noise can be used to represent OFDM signals quite accurately. Both DTT and LTE base stations use OFDM, but LTE signals vary their total power related to the level of traffic. This time variance has been shown to affect some receivers through e.g. interaction with AGC. Most communal aerial systems do not have AGC[10] and may not be vulnerable in the same way as some receivers are to the LTE signal envelope. This is an aspect that our tests have not been able to explore, and we recommend that further work is carried out to determine whether any such unwanted behaviours exist in headends.

The two blocks of noise could be varied in power independently; the DTT simulation so that the operating level could be set in the launch amplifier under test to a level typically found in well-designed communal aerial systems, and the LTE simulation to observe the effect on the real DTT signal.

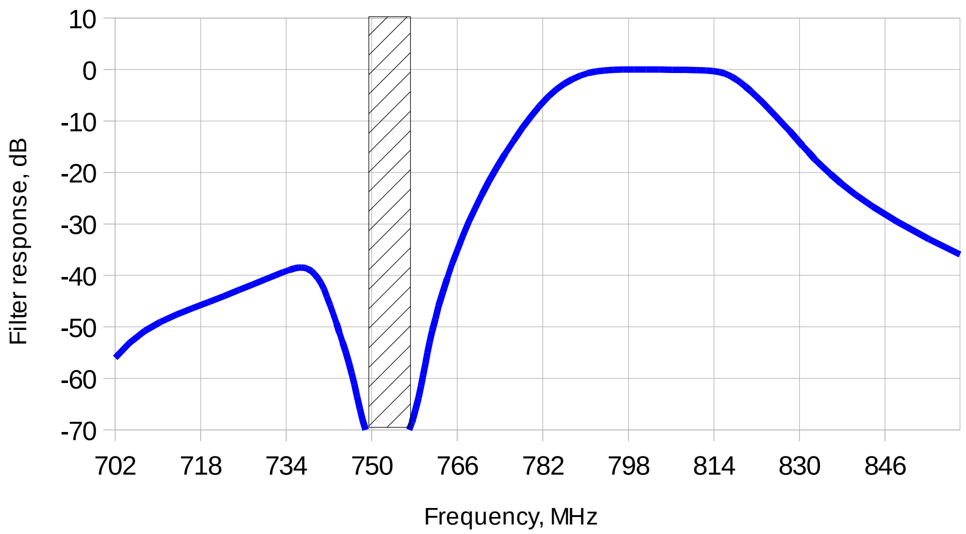

Figure 7: Frequency response of the DTT simulation filter. Channel 56, used by the DTT signal, is marked by the shaded box.

10 A small proportion of communal aerial systems, e.g. some of those using channel converters/filters at IF, use AGC. These are beyond the scope of this study.

The TV channels used were selected on the basis of what could be achieved using off-the-shelf components, as the time available for this study did not permit the procurement of equipment for a more precise simulation. The most critical aspect for both the DTT and LTE simulation filters was to ensure a deep null on the victim channel to avoid adding unwanted noise to the real DTT signal; this could otherwise affect the results of trying to measure how intermodulation noise degraded the victim signal.

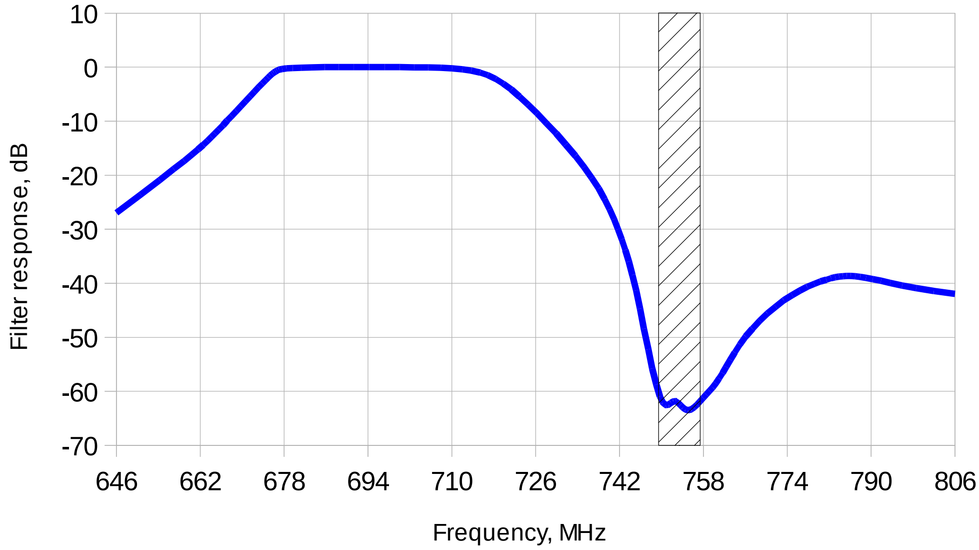

Figure 8: Frequency response of the LTE simulation filter. Channel 56 is marked by the shaded box .

These two filter shapes clearly differ from the signals they simulate by having relatively gentle slopes in the attenuation bands either side of the passband. The real signals would have a much more rectangular appearance. However, the power in the attenuation bands is very small compared to the total power, and where it is important, in channel 56, it has been greatly attenuated.

4.1.1.1 Test 1: Interference into channel 56

The launch amplifier under test was an Ikusi CBS-702, which is rated at 117dBµV (8dBm) (see above). Using a CW signal at 754MHz, the output 1dB compression point was measured at 132.7dBµV (23.9dBm), and the saturated output power was 137.5dBµV (28.7dBm).

With noise simulating DTT signals on channels 47-51 and a real DTT signal on channel 56, all at 104dBµV/8MHz (-5dBm/8MHz) power spectral density (i.e. (rated power) – (de-rating factor for analogue) – (analogue to digital power ratio)) at the output of the launch amplifier, the noise block simulating the LTE base station signal was raised in power level while measuring the MER[11] of the DTT signal. The results are shown in Error: Reference source not found.

The DTT signal on channel 56 is degraded by about 3dB when the simulated LTE base station signal is 12dB greater in power spectral density, and the degradation rises rapidly above this point. At 20dB higher, the MER meter had lost lock. The reason for this behaviour can clearly be seen in the composite spectrum in Figure 10, which superimposes spectrum measurements at 3dB intervals of increasing power of the

11 Modulation error ratio, MER, is a measure of the extent to which a constellation differs from the ideal. If the geometry of the constellation is on average correct, then MER is the same as signal to noise ratio.

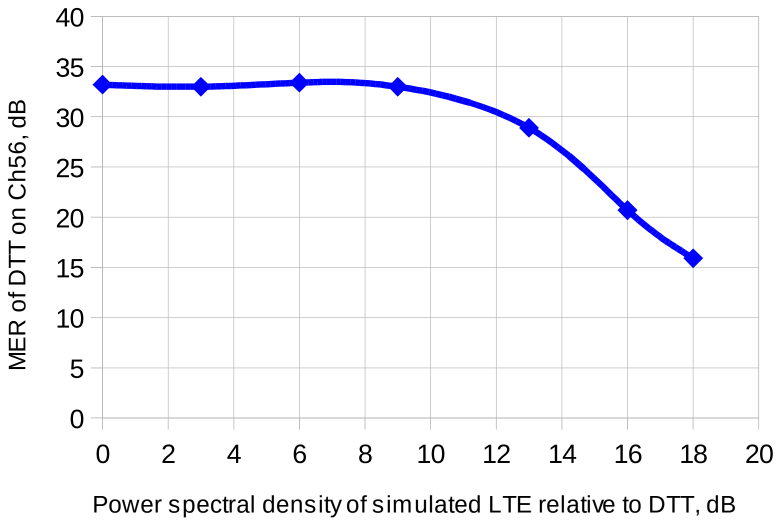

Figure 9: Degradation of MER of DTT on Ch.56 with increasing power of the simulated LTE base station signal

simulated LTE base station signal. As the signal drives further into the launch amplifier's non-linear region, the simulated LTE signal develops the familiar approximately triangular intermodulation noise skirts, and the MER values of the DTT signal on Ch56 (750-758MHz) principally reflect the resulting signal to interference ratios.

0dB on the horizontal axis corresponds to the simulated LTE block having the same power spectral density as the DTT signal.

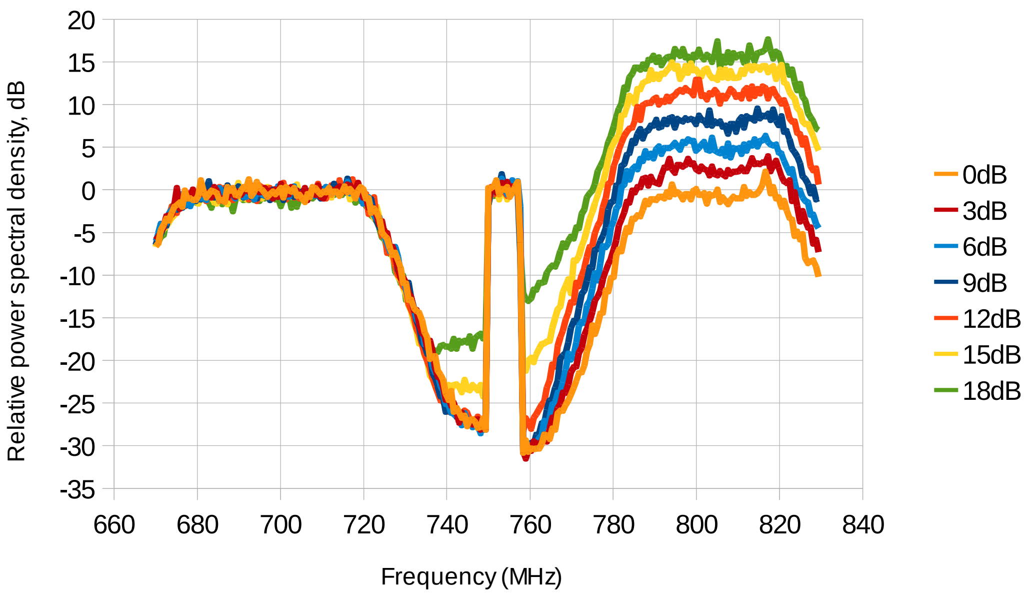

Figure 10: Spectrum showing increasing intermodulation as the power level of the simulated LTE base station is raised (DTT on Ch.56)

Despite the difference between the simulated LTE signal and a real LTE base station signal, particularly in the roll-off at the extremities of the signal's occupied bandwidth, it remains clear that DTT signals on channels higher than Ch56 will be more severely affected by the intermodulation skirts of the LTE signal, and for the same reason channels lower than Ch56 will be somewhat less severely affected.

4.1.1.2 Test 2: Interference into channel 37

This was a repeat of test 1, but with the DTT signal moved to Ch37 to avoid being so strongly affected by the intermodulation skirts of the simulated DTT signal.

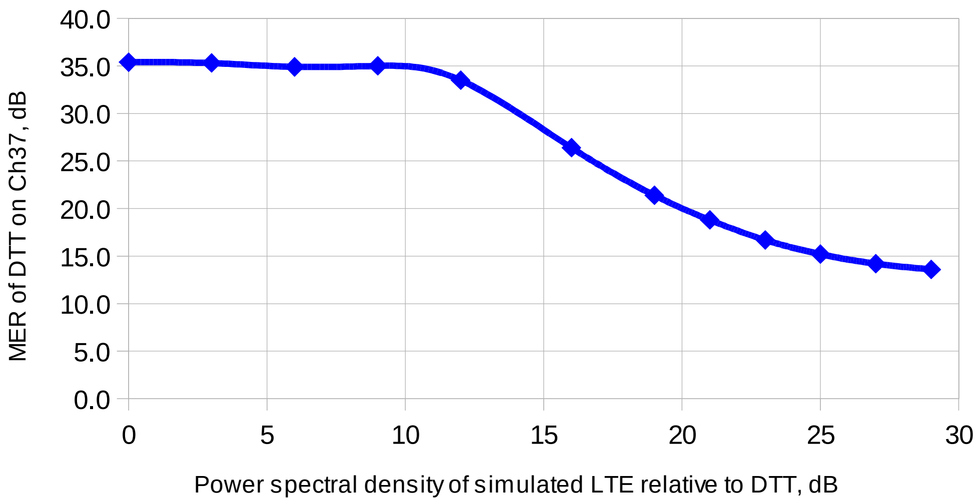

Figure 11: Degradation of MER of DTT on Ch.37 with increasing power of the simulated LTE base station signal

In this case, compression of the DTT signal can clearly be seen, as shown in the following graph:

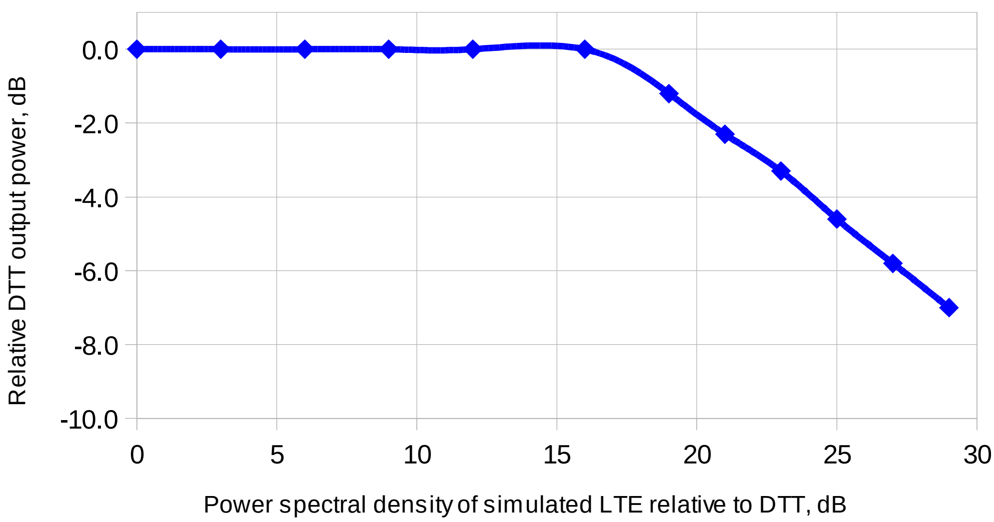

Figure 12: Reduction of the level of the DTT signal due to compression as the power of the simulated LTE base station signal is raised

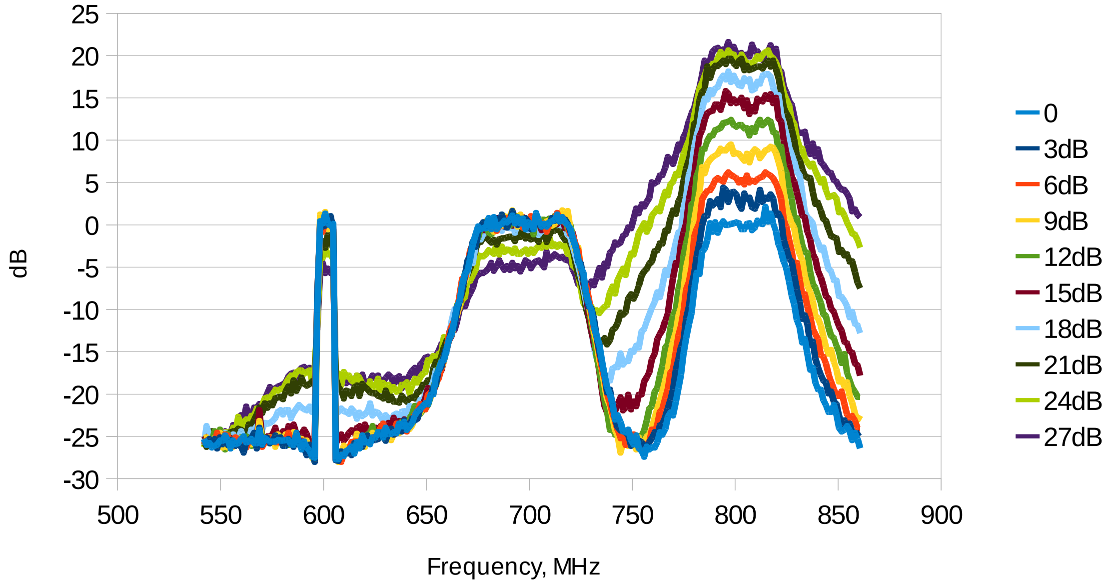

Figure 13: Spectrum showing increasing intermodulation as the power level of the simulated LTE base station is raised (DTT on Ch.37)

In the spectrum shown above, compression of both the simulated and actual DTT signals can clearly be seen.

The DTT signal on channel 37 appears to be a little more robust than on channel 56, as shown in the table below. Note that the DTG's R-book 5 ("Installing Digital Television – MATV and IRS") specifies 25dB SNR[12] for 64QAM rate 2/3 signals.

MER of DTT	**PSD of simulated LTE relative to DTT on Ch56**	**PSD of simulated LTE relative to DTT on Ch37**
30dB	12dB	14dB
25dB	15dB	17dB
20dB	16dB	20dB

Table 3: Maximum PSD levels for simulated LTE base station signals for given values of MER for DTT

If a signal is being received at 25dB SNR, and intermodulation noise is added at -30dB relative to the signal power, the effective SNR becomes 23.8dB. As the specified SNR value of 25dB contains several dB margin to the actual failure point, it could be argued that a degradation of 1.8dB will in most instances still result in acceptable performance, even if subject to some degree of increase of occasional disturbances[13]. Therefore the maximum acceptable level for LTE base station signals in a launch amplifier set up in the way described for these tests might be 14dB (relative power spectral density), except for channels in the upper fifties.

12 MER has been taken to be effectively the same as signal to noise ratio (SNR).

13 Many factors can variably erode the margin to failure of a DTT signal, such as trees, sea paths, co-channel interference during enhanced propagation, etc.

However, in practice, a high proportion of amplifiers are set to run at higher levels than this method has used, and will be correspondingly somewhat more sensitive to overload. We therefore suggest that for a rule of thumb, the figure of 10dB is used as the limit, except for channels in the upper fifties where the number should be reduced.

In summary:

- Measurements have shown that launch amplifiers, a key component of MATV systems, are vulnerable to being overloaded by signals from LTE base stations.
- Harmful degradation of DTT signals will typically be caused when the LTE base station signal is more than about 10dB more powerful than the DTT signals.
- DTT signals in channels close to the LTE base station frequencies are more sensitive to interference.

4.2 Group filters

As noted in section 3.2.8, some systems are fitted with group filters. The frequency response of a Group A bandpass filter intended to pass channels 21 to 37 (470MHz to 606MHz), has been measured, and is shown in Figure 14.

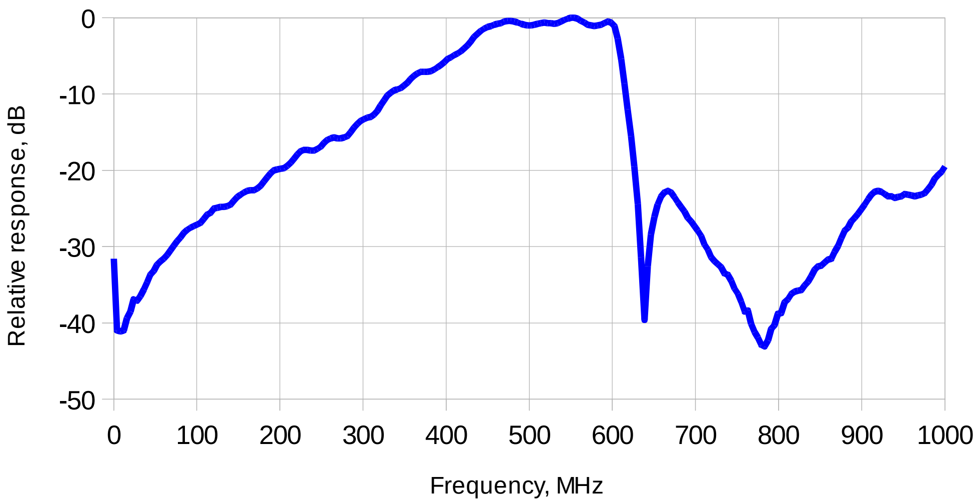

Figure 14: Frequency response of an inexpensive group filter

This filter provides over 30dB of rejection of signals around 800MHz, but has poor rejection on the low frequency side of the passband. It is constructed in a folded metal box about 20mm x 37mm x 65mm with an F-type socket at either end, and would cost under £10.

The frequency difference between the upper -3dB point of the passband and -20dB is about 21MHz, so a filter of this type scaled to 800MHz might be able to give around 20dB rejection of LTE base station signals when the highest DTT signal is on channel 56. However, as this filter was not expressly designed to reject LTE base station signals, it may be possible to achieve a better response than this.

4.3 Cluster equalisers

Cluster equalisers contain a number of filters of adjustable bandwidth that allow typically groups of 1-7 adjacent channels to be selected, and each group's amplitude adjusted independently.

Cluster equalisers can be divided into two groups:

- Passive, using only passive components, and therefore unlikely to be affected adversely by strong signals;
- Active, using electronic components under the control of a microprocessor to tune the filters and to amplify signals. The active components make this type of device vulnerable to high power interference from LTE systems.

Cluster equalisers have been used where analogue signals were received at significantly different levels, but passive equalisers have also been used to provide systems with protection from out-of-band interference.

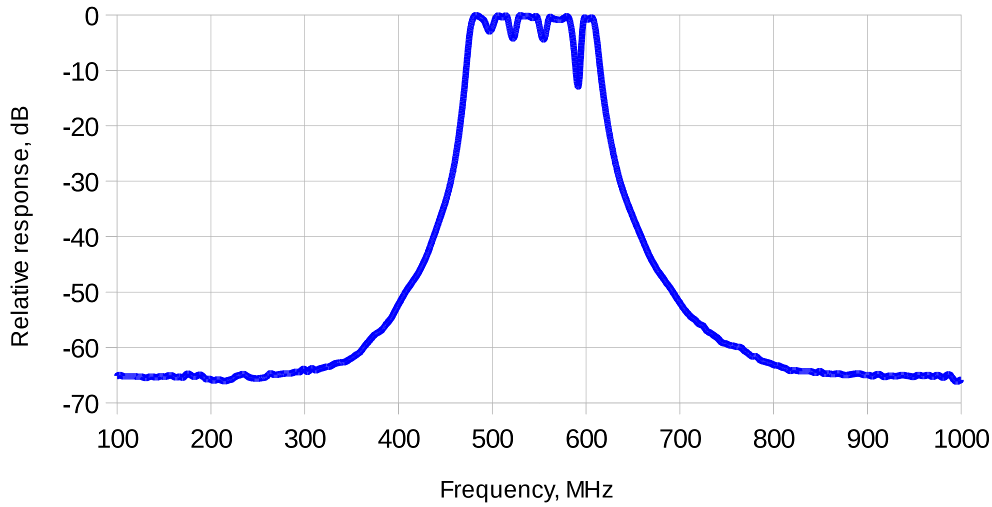

Figure 15: Frequency response of a passive cluster equaliser

The figure above shows a typical frequency response of a passive cluster equaliser tuned to pass channels at the low end of Band IV. This device would give in excess of 60dB suppression of LTE signals at around 800MHz. When tuned to pass higher channels, the attenuation of LTE signals would of course be less. Nonetheless, systems fitted with passive cluster equalisers should be substantially more robust in the presence of LTE signals than those without.

Active cluster equalisers have been quite widely used, offering the major advantage over passive cluster equalisers of being able to be tuned on site without specialist equipment. This is particularly useful when new channels come into use, as is often the case at digital switchover.

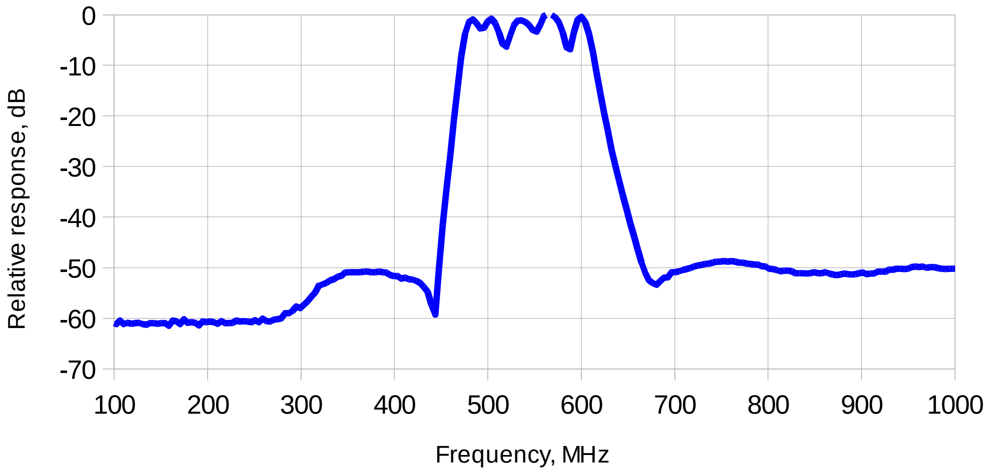

Figure 16: Frequency response of an active cluster equaliser

Figure 16 above shows the frequency response of a typical electronically tuned cluster equaliser. Although this type of filter shows very steep attenuation bands, it contains active electronic components for tuning the filters and amplifying signals, and will be vulnerable to non-linear effects in the presence of strong interfering signals such as LTE. It is therefore not recommended as a means of protecting a system against high level interference.

In summary:

- Passive cluster equalisers should be able to give a helpful level of protection to systems using TV channels well removed from frequencies used by LTE systems.
- Although active cluster equalisers appear to have a good frequency response, their use to protect communal aerial systems from LTE interference is not recommended due to their inability to handle strong signals.

4.4 Multiswitches

Multiswitches (see section 3.3) combine UHF TV signals in the frequency range 470MHz to 862MHz with satellite signals in the IF band 950MHz to 2150MHz. Satellite signals use four inputs per orbital location received, and terrestrial signals have a separate single input. The detail of the internal architecture will vary from model to model and from one manufacturer to another.

If there is any non-linear device in the terrestrial signal path, such as an amplifier or semiconductor switch, then there is the possibility of a powerful UHF signal generating harmonics, some of which could fall into the satellite IF band. In the case of LTE base station signals at around 800MHz, the second harmonic at a range of frequencies around 1600MHz is most significant.

Measurements were therefore made on two multiswitches from different manufacturers. The simulated LTE signal was fed into the terrestrial input of each switch, at about +10dBm (119dBµV). On one of the multiswitches, a substantial signal centred on about 1610MHz could be seen – see Figure 17.

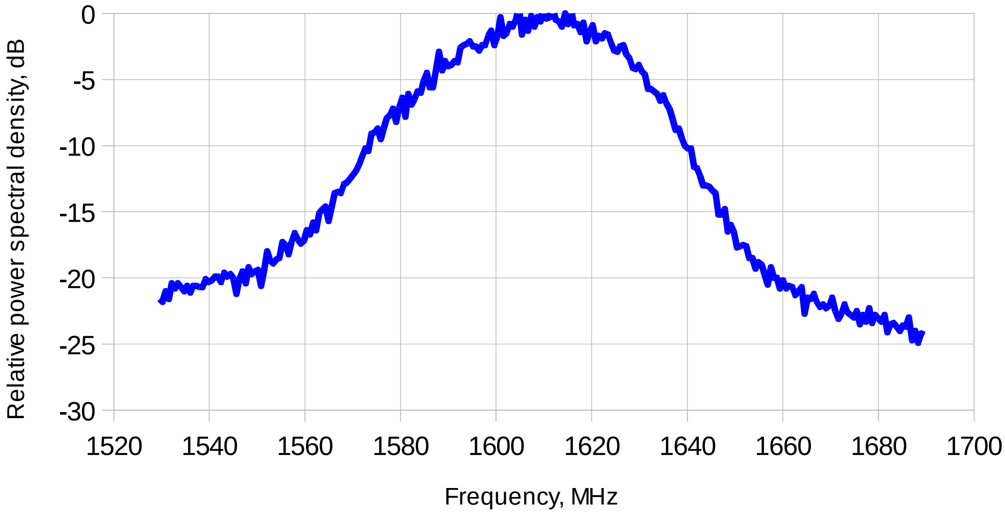

Figure 17: Spectrum of harmonic of the simulated LTE base station signal in the satellite IF band. This could prevent reception of several transponders.

The channel power in the central 27.5MHz[14] was measured at -38.5dBm (70dBµV). This is sufficient in many cases significantly to degrade or even prevent decoding of satellite signals, possibly over a number of transponders in each of the four sets of satellite signals.

On the second multiswitch tested, signals at 1600MHz were found to be around 15dB lower.

The level of the 1600MHz signal will depend on a number of factors, including:

- the level of the 800MHz signal on the multiswitch input;
- the linearity of the multiswitch;
- the degree of internal filtering after the non-linearity in the multiswitch.

There are believed to be a number of makes and models of multiswitch on the market with particularly poor internal filtering.

In cases where terrestrial reception by an IRS is impaired by interference from LTE base station signals, it may be that satellite services are also affected. In order to understand the extent of the problem, we recommend that a much larger selection of the most widely used devices should be tested.

In summary:

- We have identified a mechanism by which LTE signals could cause harmful interference to satellite signals in an IRS.
- This needs further investigation to determine how widespread the problem may be.

14 This figure has been used as the bandwidth of a typical satellite transponder, although other bandwidths such as 33MHz are used.

5 Expected levels of LTE base station signals in Communal Aerial Systems

In order to calculate the likely range of levels of LTE base station signals received by UHF aerials on communal systems, a number of assumptions must be made. In practice, conditions will vary greatly from one case to another, so the assumptions made here must be taken as providing indicative results only.

The principal assumptions made are as follows:

- LTE base station EIRP will be 59dBm EIRP omnidirectionally per 10MHz block, and three full blocks are being transmitted. The total EIRP across 30MHz therefore is 63.8dBm.
- For DTT aerial gain we have assumed a Group W aerial compliant with Standard 2 of the CAI's aerial benchmarking scheme. From channels 53 to 68 this will have a minimum gain of 12dBi. Gain reduction off-axis is assumed to be as specified in ITU-R BT.419-3, i.e. a gain of -4dBi outside the main lobe.
- No polarisation discrimination has been accounted for.
- The propagation model is the Hata suburban model proposed by Ofcom.

With these assumptions it is possible to calculate likely total received power levels (in 30MHz) of the LTE base station signal, as shown in Table 4.

Distance	Approximate path loss	Total received LTE base station signal power	
		UHF aerial gain = 12dBi	UHF aerial gain = -4dBi
10m	56dB	19.8dBm/128.6dBµV	3.8dBm/112.6dBµV
100m	70dB	5.8dBm/114.6dBµV	-10.2dBm/98.6dBµV
300m	80dB	-4.2dBm/104.6dBµV	-20.2dBm/88.6dBµV
1000m	95dB	-19.2dBm/89.6dBµV	-35.2dBm/73.6dBµV

Table 4: Estimated power levels of LTE base station signals received by a communal aerial system

For each value of distance between the LTE base station and the DTT aerials, the expected received level range for the LTE base station signal is given for two cases: first, where the LTE base station is in the direction of maximum gain of the DTT aerial, and second, where it is at minimum gain.

Our experience is that typical DTT signal levels received at headends prior to digital switch-over, including feeder loss, would be in the region of 55dBµV (-54dBm), with 85dBµV (-24dBm) representing an unusually high value. Assuming an increase in DTT power levels of 10dB at switch-over, we can then calculate the expected ratios of power spectral densities for the cases in Table 4.

Distance	DTT level = 65dBµV (-44dBm)		DTT level = 95dBµV (-14dBm)	
	UHF aerial gain = 12dBi	UHF aerial gain = -4dBi	UHF aerial gain = 12dBi	UHF aerial gain = -4dBi
10m	**58dB**	**42dB**	**28dB**	**12dB**
100m	**44dB**	**28dB**	**14dB**	-2dB
300m	**34dB**	**18dB**	4dB	-12dB
1000m	**19dB**	3dB	-11dB	-27dB

Table 5: Power spectral density ratios of LTE base station signals relative to DTT. Figures highlighted in red indicate where interference is predicted.

From the measurements in section 4.1.1 we concluded that an unfiltered system is likely to be able to tolerate an LTE base station signal with power spectral density up to 10dB greater than that of the DTT signal. In Table 5, cases where the ratio exceeds 10dB have been coloured red.

From Table 5 we can conclude:

- For systems receiving typical average levels of DTT signals (after switch-over) of around 65dBµV (-44dBm), an LTE base station over 1km away can cause harmful interference in a communal aerial system that has no protective filtering.

- For systems receiving typical high levels of DTT signals (after switch-over) of around 95dBµV (-14dBm), an LTE base station over 100m away can cause harmful interference in a communal aerial system that has no protective filtering.

- The requirements for filtering to overcome the excess LTE base station power in affected communal aerial systems will vary considerably from case to case.

In summary:

- Measurements have shown that launch amplifiers, a key component in communal aerial systems, are vulnerable to interference from LTE base stations.
- Communal aerial systems without appropriate protective filtering can be affected by an LTE base station over 1km distant. Probably 75-80% of systems have no protective filtering.
- The requirements for filtering to overcome the excess LTE base station power in affected communal aerial systems will vary considerably from case to case.

6 Potential impact of LTE on Communal Aerial Systems

Homes using communal aerial systems as their primary source of TV signals, both terrestrial and satellite, may have their reception impaired (i.e. subject to more frequent disturbances) or rendered unusable by the presence of strong interfering signals from LTE systems.

The main mechanism seems to be reception of high levels of LTE base station signals by the communal aerial system's UHF aerial. These signals then encounter non-linear devices such as launch amplifiers, which generate excessive levels of intermodulation noise and suffer from gain loss. Note that any device with semiconductor components in the signal path is in principle prone to this behaviour when used outside its intended operating range.

Communal aerial systems are usually considered to extend from the headend as far at the outlet on the wall, but any user will have two additional components: the receiver and a fly lead which connects the receiver to the outlet. The behaviour of receivers in the presence of LTE base station and user equipment signals has been studied elsewhere[15], and it is well known that a high proportion of fly leads are of very poor quality, in particular when it comes to screening. In this respect, we do not expect the experiences of users of communal aerial systems to differ from those who have their own private aerial systems.

This report has concentrated on the potential for interference from LTE base station signals. However, LTE user equipment signals in the frequency range 832MHz to 862MHz are in band to many communal aerial headends, and therefore have the potential to cause harmful interference.

Within the scope of this report we have not been able to estimate the proportion of the roughly 5m homes that use communal aerial systems which will be significantly affected by the introduction of LTE in the 800MHz band. This will require modelling which apart from estimating the numbers affected, may also be able to give an indication of the statistics of the the severity of the interference. This in turn could be used to estimate the costs of remedial work that will be required to restore the function of the affected systems.

6.1 Mitigation measures

It is clear from Table 5 that the range of levels of LTE base station signals expected to be found in communal aerial systems is very large. Much as the industry might wish for a single solution to apply in all cases, this is likely not to be commercially viable. Instead there is expected to be a range of mitigation measures that can be applied as appropriate to each case.

6.1.1 Filtering

The most demanding cases will occur where the LTE base station and the UHF aerial for the communal aerial system are in close proximity, and the DTT multiplexes are on channels close to the LTE base station frequencies. It is possible that in the region of 60dB of rejection of the LTE base station signals will be required, with no more than a few dB attenuation of the DTT signals. In the case of DTT signals on channel 60, the rate of roll-off of the filter will be very demanding. However, a report from a filter manufacturer[16] provides evidence that it may be possible to make such a filter, albeit at a price of several hundred pounds.

The report describes a family of filters intended for use in LTE base stations to limit the out of block ERP. The highest specification filter in the family drops from 1.7dB loss to 70dB in 1.7MHz, and while this filter is bandpass to LTE base station signals, the manufacturer has indicated that in principle it should be possible to make a bandstop filter with a similar rate of roll-off. A bandstop filter can provide the highest rate of roll-

15 See References 7 and 8
16 See Reference 4

off, but would not provide protection to DTT signals against other interferers.

A great deal of work would be required to establish the suitability of such a filter. This would include determining acceptable limits to the truncation of DTT signal spectra, termination impedance limits, and the stability of the filter performance with temperature. Most headends, while not exposed directly to the weather, are in locations without temperature control, such as externally mounted equipment cabinets and plant rooms, where temperatures might range from below zero to over 50°C.

In the least demanding cases, where the excess level of LTE base station signal is, say, 10-15dB and the DTT signals are separated from the LTE base station signals by at least a few channels, the domestic filter proposed by Ofcom may be effective.

Various people in the trade who we have spoken to commented that channel filters could be used to remove interference on nearby channels because of the good selectivity of the SAW filters. Our concern is that these devices will not be able to handle strong interference signals without generating excessive levels of intermodulation in their mixers. We therefore strongly recommend that tests are carried out on a range of samples of such devices to determine their ability to tolerate strong signals.

6.1.2 Other measures

Filtering at the headend of the communal aerial system will be the primary tool for control of interference from LTE signals. However, there are a number of other measures which can be taken, including:

- Re-pointing the communal aerial system's UHF aerial so that a null in its gain pattern is aimed towards the LTE base station. Most aerials tend to have a series of minor lobes outside of the main lobe of their gain pattern, and careful re-positioning to take advantage of the drop in gain between the minor lobes can sometimes give a useful improvement in signal to interference ratio with only a modest loss of the wanted signal. However, the nulls can be quite frequency selective, so this technique might be applicable only to cases of relatively mild interference.

- Re-pointing the communal aerial system's UHF aerial to receive DTT signals from a different transmitter that uses lower channels, so that a filter with a more gently sloping attenuation band can be used. After switch-over, the possibility of out of area reception will be widespread, so this may often be technically feasible. However, in previous cases where viewers have had to change the regional source of their programming, this has led to significant dissatisfaction being expressed by viewers who feel no affinity for the new region.

- Migrating users to satellite if the interference with UHF services cannot be reduced to a satisfactory level. Although we have identified a mechanism where in some cases severe interference from LTE base station can affect satellite reception via an IRS, migrating all users to satellite would allow the terrestrial part of the IRS to be disconnected, which should prevent the problem with satellite. However users may object on the basis that not all services available on terrestrial are available on satellite; if they have a television with integrated terrestrial receiver, they may not wish to have a satellite set top box; if there are multiple televisions, then all TVs and the distribution system feeding them will have to be changed, an expensive process for whoever is paying.

- Implementing a single frequency network (SFN) repeater on the LTE base station mast. The main problem that filtering is trying to correct in a communal aerial system is the difference in received power level between the DTT and LTE signals, arising from the LTE base station usually being much closer than the DTT transmitter. If the DTT signals were to be transmitted from the LTE base station, then the difference would largely be eliminated. The problem then becomes too much power for both the DTT and LTE base station signals, but it should be relatively simple to resolve all such cases with an inexpensive attenuator. Use of DTT channels close to the LTE base station frequency band would no longer be a problem.

6.1.3 Training

It has become clear that the degree of interference with communal systems by LTE base stations will vary considerably, and will have to be dealt with on a case by case basis. It will not make sense to try to apply a universal solution to all cases. Therefore people responsible for implementing appropriate mitigation measures will need to take an analytical approach which will be outside the experience and training of many of them.

We therefore recommend that careful consideration is given to establishing a training programme of appropriate scale and timing to ensure that the industry is able to implement mitigation measures in a cost effective manner, and with the least disturbance to viewers.

7 Conclusions and recommendations

This short study has looked principally at the likely effects of LTE base station signals on communal aerial systems. It has found that launch amplifiers are vulnerable to interference from LTE base stations, and estimates that 75-80% of communal aerial systems are wideband, containing no filtering to reduce the impact of the interference. Interference into communal aerial systems receiving average levels of DTT signals can be harmful when the LTE base station is over 1km away; systems receiving high levels of DTT signals will be more robust than this, and systems receiving low levels will be more vulnerable. Systems receiving DTT signals on channels close to the LTE frequencies will be more vulnerable than those using channels more widely separated from LTE frequencies.

Roughly 5m homes in the UK use communal aerial systems as their primary source of off-air TV signals. The number of homes where TV viewing could be affected (i.e. either subject to frequent disturbances or completely blocked) is therefore very significant.

Interference mitigation measures have been described, ranging from the use of filters to installing on-channel TV repeaters at LTE base stations. It is clear that no single solution will be appropriate in all cases. Filters could range from simple inexpensive devices for the least severe levels of interference where the TV signals use channels that are widely separated in frequency from the band used by LTE systems, to complex and expensive devices where interference levels are high and TV signals are on channels close to those used by LTE.

This study has not addressed in any depth the interference potential of signals from user equipment, either portable or fixed.

The following recommendations should form part of a strategy to evaluate in much greater detail the likely impact of LTE systems on users of communal aerial systems:

1. Model typical urban and rural LTE network characteristics to estimate the number of communal aerial systems that will be affected, together with the expected range of levels of LTE base station signals received by communal aerial systems.

2. Identify regions where channels close to LTE base station signals are in use for TV.

3. Develop filter specifications to deal with the range of channels and expected levels of LTE signals, and determine the practicality and cost of manufacture.

4. Carry out tests on representative samples of cable to determine whether screening is sufficiently effective to prevent harmful interference from portable and fixed user equipment.

5. Carry out tests on a range of multiswitches to determine the likely extent of interference to satellite signals.

6. Carry out tests to determine the sensitivity to interference of active devices in headends such as active cluster equalisers, channel filters, etc. This should include tests on launch amplifiers to determine changes in sensitivity to LTE base station signals with variation of the amplifier loading by DTT signals, and time varying (e.g. idle mode) LTE base station signals.

7. Carry out an engineering and cost-benefit analysis of using on-channel TV repeaters at LTE base stations in cases where the TV channels are close to the frequencies used by LTE base stations.

8. Develop a plan for training staff in the installation industry to be able to evaluate interference in systems, and identify and implement mitigation measures.

Annex: Views of the Trade

Many facts and figures relation to the communal aerial industry in the UK are not available in published form. Even though there is often a considerable spread among the answers, the most reliable sources of information seem to be major companies in the industry, so we have interviewed senior staff from six companies, all of which are major manufacturers or distributors to the communal aerial industry in the UK.

The questions and summaries of their responses are presented below, anonymously.

How many homes in the UK use Integrated Reception Systems?

Company	Response
1	3m
2	3m
3	3.5m
4	3.5m
5	3.8m
6	3.5m

How many homes in the UK use MATV systems?

Company	Response
1	1.5m. Hotels, prisons, shops, banks, etc. use an additional 300k outlets
2	2m
3	1.5m
4	2.5m
5	1.7m
6	1.5m

How many homes in the UK use masthead amplifiers, and what are the trends?

Company	Response
1	Between 4m and 5m. The UK market is about 400k units in total, declining slowly due to digital switch-over and the recession.
2	Don't know, but expects the market to decline.
3	4m. Some models are increasingly being used with IRS.
4	4m. Increasing use in small MATV systems.
5	250k. Declining sales due to increased power levels at switch-over.
6	2m. Steady sales generally, but 4-output versions increasingly used in small MATV systems.

What proportion of installations are MATV and IRS?

Company	Response
1	The rate of IRS installations is steady, and the rate of MATV installations is decreasing. Larger social landlords generally install IRS, but some private landlords seem more cost sensitive and are installing MATV.
2	IRS installations are beginning to pick up. They had slowed due to the recession in the construction industry. MATV installations are also increasing.
3	80% of installations are IRS, and this figure is increasing.
4	Virtually all installations are IRS – very few are MATV.
5	IRS installations are increasing towards 90% of the market.
6	70% of installations are IRS, 30% MATV. The proportion of IRS is increasing.

What proportion of communal aerial systems are wideband (470MHz – 862MHz)?

Company	Response
1	Even though systems are always designed with filtering, sales figures indicate that only about 25% of systems have been implemented with filtering. Many filters in existing systems have been removed due to channel changes at switch-over.
2	99% of systems installed in the last 5 years are wideband. Passive filter were removed from the catalogue four years ago. Sales of active filters are very low. Use of equalisers was more common in the early days of DTT due to the large power differences, which were subsequently reduced.
3	Only about 25% of systems have any filtering. 90% are fitted with wideband aerials.
4	Roughly 20% of systems have filtering, split evenly between passive and active.
5	95% of systems have no form of filtering, and those that do are systems with larger numbers of outlets.

How extensive is the use of benchmarked cable?

Company	Response
1	Good installers will use only benchmarked cable. Most non-benchmarked cable is used for domestic installations (i.e. not communal systems).
2	Systems installers mostly use benchmarked cable. Domestic installers may not. The benchmarking scheme has been successful.
3	Around 80% of systems being installed use benchmarked cable. Many cables installed before the benchmarking scheme would have qualified.
4	The use of benchmarked cable has increased, but a lot of single-screened non-benchmarked cable is being used on new builds where the cost is critical.
5	In systems about 75% of cable is benchmarked. Elsewhere it is about 50%.

6	60% of cable sales are for benchmarked cable.

How much do you know about the introduction of LTE, and what do you think the impact on MATV/IRS will be?

Company	Response
1	Has a good understanding, and believes that it will be a huge threat to amplified installations.
2	Aware of LTE in the context of digital dividend. It could be a substantial interference threat. Depending on the LTE power level, there could be extensive localised problems. Note that MATV/IRS aerials often are on the same roof as masts for mobile services.
3	Knows a little. Believes there could be a problem with satellite as some multiswitches have poor isolation between terrestrial and satellite inputs. Recent advice to fit wideband aerials and not to use filtering such as channel equalisers has not helped.
4	Generally aware of the problem. Expects increased services calls and difficulty finding solutions.
5	Well aware of the situation. Expects only 10% of systems to suffer problems, mainly in group C/D. Some cheap multiswitches may have insufficient isolation to prevent satellite services being affected.
6	Knowledge is very limited, but believes there could be a lot of overloading.

Are you expecting to introduce new products as a result of the introduction of LTE?

Company	Response
1	Yes, likely to limit the frequency response of amplifiers at the top of Band V. Looking at active filters and single channel filters. However, what happens to the 600MHz band will affect their plans.
2	At the moment no, but possibly after digital switch-over. They will need information about the 600MHz band first, as they don't want to risk introducing products that rapidly become obsolete.
3	Yes, currently working with a specialist filter company.
4	Yes, will be working on new aerial designs.
5	Yes, launching a MATV amplifier with 790MHz filtering.
6	Yes, R&D is starting work on designs to protect against LTE, but needs to have more information about 600MHz.

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