Written in 2005, this feature was due to appear in ‘Television’ magazine when that journal was suddenly closed down by its new owner. The first two parts of the feature subsequently appeared in ‘Technology at Home’, but before the last two sections could be published that magazine ceased publication as well!
Written at the original editor’s request for readers who are small traders, the article is slanted a little bit towards the money-making aspect of TV system installation, and reading it now (2008) it seems to have a slightly cynical tone in places.
This article was written before the advent of Sky HD, BBC/ITV Freesat, or the devices that allow several Sky boxes to be controlled via the same return path.
Bill Wright 2008

Domestic RF distribution systems for television and radio, Part 4

Bill Wright

Larger systems

We visited Matt Clutter in his four bed detached home in Part One. Grandiose as Matt thinks his present residence is, he still has a long way to travel along life’s path, and if he carries on in his present financially productive manner him and the partner and the little Clutters will soon be in a house that will make the present one look like a peasant’s woodland hut. This section looks at the installation of the more complex systems that are often installed in the sort of property that Matt will own, all being well, when his kids are teenagers and his paunch and the hole in the back of his hair remind him of his dad.
Fig 17 shows a typical ‘head-end’ for such a system. The following sections all refer to fig 17, in which approximate analogue signal levels in dBmV are shown in red. You’ve heard my hard words about RF daisy chains. Well what follows decries RF loopthrough of any kind as the Devil’s work. Every signal goes straight to a filter that passes the required channel and nothing else. All out-of-channel modulator noise and unwanted aerial signals are stopped in their tracks. The filters allow the precise adjustment of signal levels. This, in short, is the bee’s knees!
It isn’t practicable to build complicated head-ends like this on site. It’s much better to construct them in the workshop, where they can also be thoroughly tested. It's better still if you can find someone who'll construct them for you, since this can be a time-consuming task. Fig 18 shows our oldest worker, my dad, putting a head-end together. Fig19 shows a similar head-end in the process of installation.
I just need to discuss terminology for a moment, if you’ll forgive the digression. Large commercial cable TV systems serving hundreds of dwellings have a ‘head-end’. This is the main assembly of complicated equipment that forms the heart of the system. At one time domestic systems had a simple amplifier at their heart, so there was no terminological problem. We called the amplifier ‘the amplifier’'. But since domestic systems these days have, as well as amplifiers and pre-amplifiers, modulators, channel filters and other things at their heart, ‘amplifier’ isn't accurate. So although it will seem a bit pretentious to any passing cable engineers, I’m following modern practice and calling our ‘amplifier-plus-lots-of-other-things’ a ‘head end’. On hearing the expression for the first time a friend of mine said, “I thought the head end was the simply the best place to be when the wife was giving birth.”

The UHF aerial signals

Since the system shown in fig 17 carries six ‘in-house’ channels it is essential that the UHF band is as clear as possible. Ideally, nothing should enter the system from the aerial except the signals that are actually needed. The bit of magic that accomplishes this comes in the form of a channelpass filter/leveller. I’m a great fan of channel filters, since they are the indispensable heart of any half-decent multichannel distribution system. They pass only the desired channels, thus cleaning up the UHF band ready for the in-house channels, and they allow you to adjust the

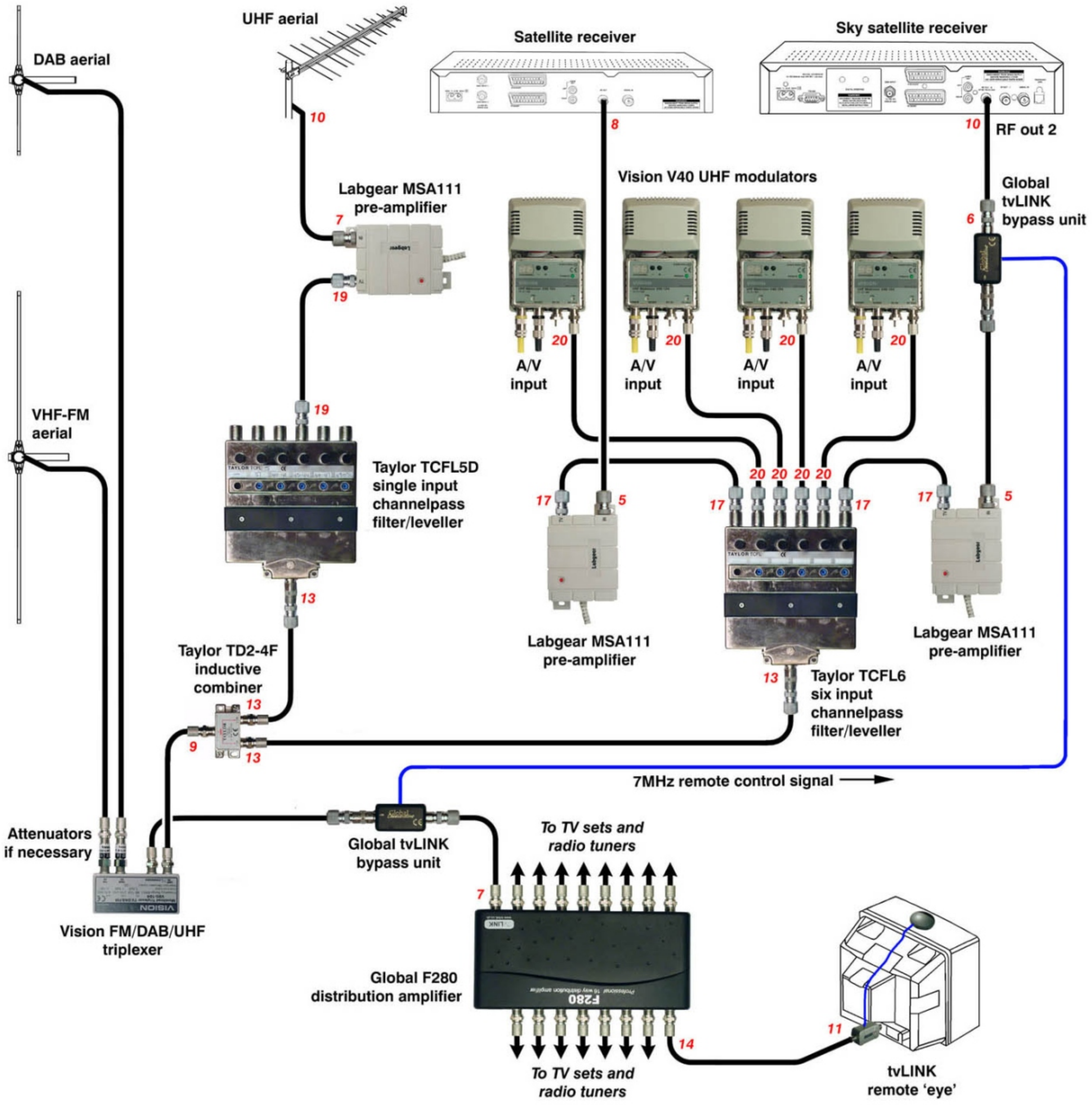

Fig 17. The head-end for a larger system. The system provides reception of the analogue and digital terrestrial TV channels, four channels from head-end modulators and two channels from the RF outputs of satellite receivers. VHF-FM and VHF-DAB reception is also available. The Sky receiver can be controlled from all viewing areas. Approximate analogue signal levels in dBmV are shown in red.

levels of each channel that they pass. I'm always banging on about the use of channel filters , so I'll try to contain myself on this occasion. But it will be hard.

The filter used on the aerial feeder will normally have one input, and will be customised for the channels used by the relevant transmitter. Adjacent analogue and digital channels are handled by the same filter way. Because of this a main transmitter with five analogue and six digital channels might need a filter unit with only five filter ways. An example is Emley Moor, where five filter ways handle the following channel clusters: 37, 40/41, 43/44, 46/47, 49/50/51/52.

On the other hand some transmitters call for the full set of eleven separate filter ways. Examples are Waltham (23, 26, 33, 35, 42, 49, 54, 58, 61, 64) and Sheffield (21, 24, 27, 31, 39, 42, 45, 53, 57, 60, 67). The filter units can include up to six filter ways, so above that number it's necessary to use two units and combine the outputs. This might seem like a lot of expense, but by way of compensation there's a big advantage when every channel has to have its own filter way. It then becomes possible to adjust the levels of each channel individually. The drawback when one filter

way has to handle a cluster of several adjacent channels is that the relative levels of the channels within the cluster can't be altered. But separate filter ways allow you to distribute the digital muxes only 10dB below the analogue signal levels, for instance, or to compensate for low powered analogue Channel Five signals.
The filter shown in fig 17 is a Taylor TCFL5D. The '5' means that there are five filter ways, and the 'D' means that one or more of the ways is tuned for a cluster of adjacent channels. The filter units are available with two, four, or six filter ways. Each filter way handles one channel or one cluster of adjacent channels. All possible input configurations are available, from one input for the whole unit to a separate input for every filter way. It's as well to specify your desired input configuration accurately, because altering it yourself is possible but fiddly. For more information

Fig 18. It's far better to plan, build, and test the head-end in advance. This engineer is 86 years old!

about channel filter/levellers go to *http://www.taylorbros.co.uk/PDF%20PAGES%20AS%20INDEX/26-29.%20WEB.pdf* or simply Google for Taylor Transmitters and navigate to the 'other stuff' part of the catalogue.
The through loss of a TCFL5D is about 5dB. If two TCFLs have to be used for the aerial signals they will be fed from a splitter so there's another 4dB to allow for. The output of the filter (or filters) will be combined with the filter carrying the in-house channels, so there will be a further loss of 4 or 6dB. In total, the signals could lose as much as 17dB before they arrive at the main amplifier.
Here comes a golden rule. Even though the main amplifier might have enough gain to lift weak signals at its input to a respectable output level, never allow signal levels to drop below 6dBmV (analogue) or 14dBmV (DTT) at any point on the system. It's easy to think "Oh, the amp's got lots of gain. It'll boost everything to a good strength" but if the signals are too weak at any point they will acquire a nasty coating of noise when they are next amplified, because the ratio between their power and the noise generated in the amplifier will be inadequate. That's why the modest gain of the Global F280 is a jolly good thing. It means that for levels at the outlets to be

adequate, levels at the amplifier input must be adequate as well.
The through loss on the aerial feed in fig 17, from aerial to main amplifier, is 15dB, so the analogue signal levels at the aerial have to be no less than 21dBmV. That’s the sort of figure you'll get from a decent aerial with line-of-sight to a powerful transmitter. If that signal level isn’t available you will have to add a little pre-amplifier, before the losses occur of course. My favourite device here is a setback amplifier from Labgear, the MSA111. These are bought in their hundreds by people who really need a better aerial, but think they can save money by circumventing the laws of physics and ‘boosting’ the signal behind the TV set. In this application I've no doubt these amplifiers are generally a disappointment and go straight back to Argos, but as pre-amps to compensate for filter losses they are perfect.
An odd problem can arise here. The amplifier’s output is connected via a short link to a filter unit that accepts a narrow band of frequencies but rejects everything else. The input of the filter only presents a 75Ω load at the frequencies to which it’s tuned. Some amplifiers seem to rely on a nice even 75Ω load on their output to maintain stability, and will oscillate under less comfortable conditions. I’ve never had this problem with the MSA111, but if it arises and there’s a bit of spare signal to waste a 3dB attenuator in the amplifier output socket will provide a cure.
If the aerial signals are so weak that a masthead amplifier is necessary you should either use a two stage unit with sufficient gain to provide the necessary signal levels by itself, or use a single stage unit plus a setback amplifier. The latter option is probably more stable.

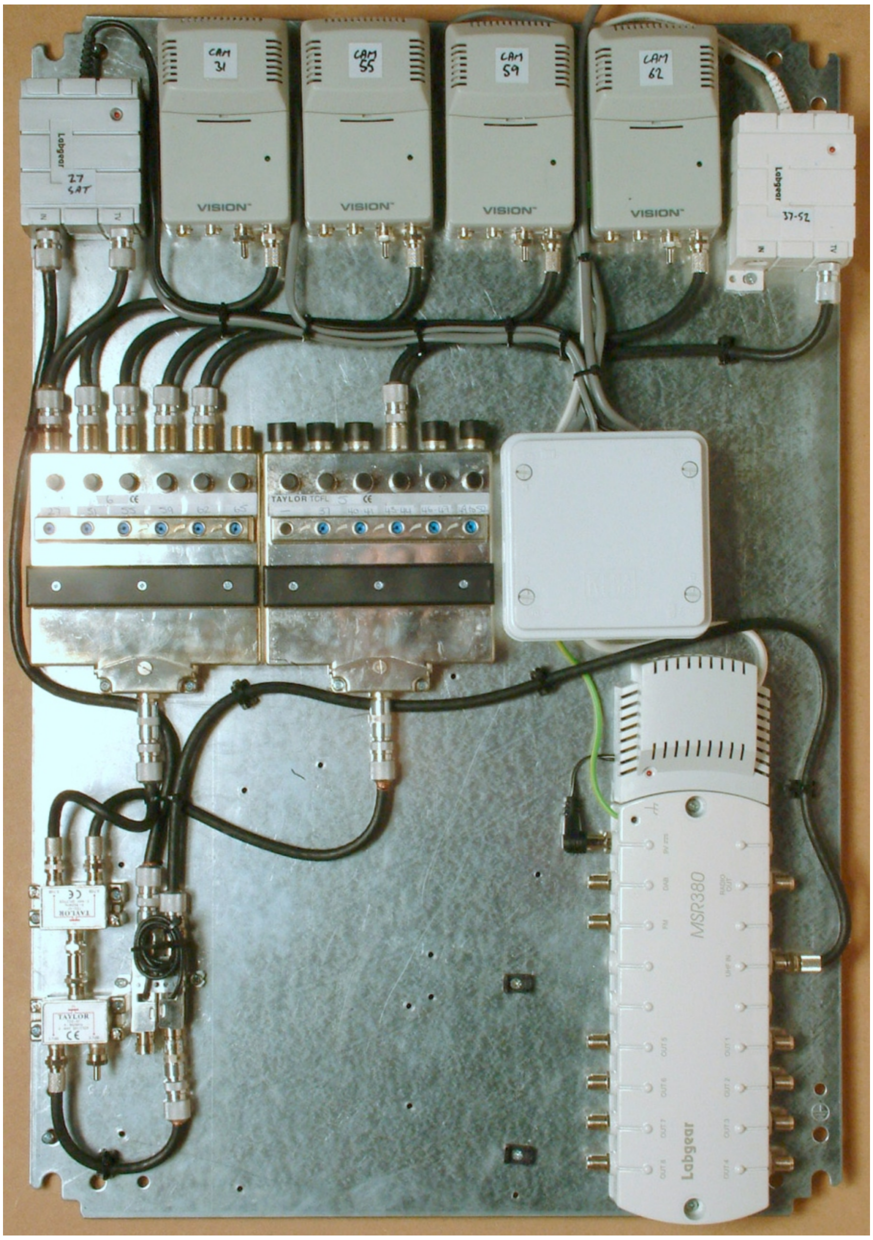

Fig 19. A domestic head-end on a steel backplate, ready to be fitted into the enclosure. This particular head-end carries four channels from modulators, the output from a Sky receiver, and digital and analogue off-air channels.

The VHF radio signals

Reception of VHF FM radio and VHF DAB radio doesn't usually present much of a challenge in my urban environment, and I usually install nothing more elaborate than a vertical dipole for each. If however the signals are weak you will of course need to fit a directional aerial with gain. Even then a bit of amplification (before combining losses) might be necessary. Masthead amplifiers are of dubious utility for VHF, since cables losses are so slight, and it is usually better to use a simple 'booster' such as the Labgear MSA111 at the head end. If you have to use VHF amplification like this bear in mind that you have provided a high gain path for all sorts of rubbish from 5MHz to 400MHz. This will enter the system and can wreak havoc. Consider the use of a bandpass filter between the amplifier and the triplexer. For FM the filter should pass 87 to 108MHz. For DAB the allocated band is 170 to 240MHz, but in the UK only 218 to 240MHz is in use. Where there are strong interfering signals in the 140 to 180MHz region it will probably be worth obtaining a filter that passes only 218 to 240MHz. The Taylor Bros item TBP3 passes the full band, but Taylors can usually be persuaded to tweak filters to suit your requirements.

As you will have gathered, the main thing in fact when adding VHF to a distribution system is to make sure that it doesn't snarl up the TV reception, as it will given half a chance. The VHF bands are full of transmissions that can overload your main amplifier, often intermittently and sometimes only during unsocial hours when you aren't there. This will put patterning all over the analogue TV channels and give the digital ones the dreaded stop-go syndrome, and convince the customer that you've sold them a faulty 'booster box'.

Fortunately this problem remains hypothetical most of the time but if it becomes very real for you use your analyser's 'store' facility. Connect it to one or other of the VHF aerials and set it to look at the full band from as low as it will go to about 400MHz. This should reveal any real nasties.

Occasionally you might have to use a VHF notch filter to kill these. Normally it is enough to attenuate the VHF aerial feeds so that the desired signals appear at the main amplifier outputs at adequate but not excessive levels. Use a diplexer or triplexer to combine the radio and TV signals, so that UHF signals picked up by the VHF aerials can't cause ghosting or other faults. A Vision V25-104 triplexer can be seen in Fig 17. Never, ever, use a splitter. Promise me now that you won't do that.

Satellite receiver RF output signals

Again we need to consider through-loss, though actually there isn't much consideration needed because a pre-amplifier will always be needed. The output of a Skybox is usually around 11dBmV, and it is much lower from some other satellite receivers. Incidentally, if the customer has a satellite receiver and wants you to add the output to the system, check that it has a modulator. Some don't.

Modulators

A modulator accepts baseband video and audio signals and turns them into a TV channel. There are a lot of different types on the market but in my opinion the best for this sort of job is the Vision V40-104 . The ones shown in fig 17 have their covers removed. Reasonably priced, this unit is head and shoulders above the rest. It performs immaculately, never drifting off frequency or losing its tuning memory when there's a power cut (the two main vices of certain other makes), and so far I've never had one break down. Astonishingly for a product in this price range it is possible to adjust the audio deviation, input level, and subcarrier frequency. The video carrier frequency can be fine-tuned and the modulation depth adjusted. Very conveniently the RF output level can be adjusted up to 25dBmV, so there's no need for a pre-amplifier before the channel filter. I usually set the modulator output to about 20dBmV, which means that I can use the variable attenuator in the channel filter unit for a small amount of final adjustment.

The modulator video input is the standard 1V, with the audio also standard at 775mV across 10kΩ. Apart from rare oddball items any surveillance camera will connect directly to the modulator, and if you want to add sound you can buy a little audio module for about a fiver that includes a microphone. This can be fitted into an ABS box and fixed under the eaves near the camera. Sound adds a nice touch and greatly increases the impact of the picture. The audio module can be powered from a masthead amplifier power supply unit or any other 12VDC source. But if the cameras use a 12V supply you will most likely put the power supply unit on the main board, so there's your 12V for the audio.

If the customer already has a surveillance system and merely wants you to add the pictures to the TV distribution system, all you need do is obtain baseband video signals from the CCTV system. If there's a multiplexer or hard drive recorder you should find that every camera input has a corresponding looped output. If there's only one multiplex output (this shows all the camera pictures as a mosaic) and it feeds the monitor, look for a looped output on the monitor itself. These outputs will be 75Ω BNC female.

If you take a video feed from the looped outputs and for some reason it isn't properly terminated with 75Ω there will be a horrible ghost image on the monitor and on all recordings. Make sure that the connection into the modulator is good. This means soldering the phono plugs. The Vision modulators provide a correct 75Ω load.

Modulators can also be used to add channels derived from DVD recorders and other equipment that doesn't have an RF output. It will probably have crossed your mind that if the modulator is located behind the DVD recorder or whatever there will only need to be one cable to the head-end. Personally I think that's a rather slovenly way to do it. I don't like the idea of leaving a modulator sitting in the dust in the back of the TV cabinet, waiting for the fingers of some unskilled person to alter the output channel or select System PAL G.

Most modulators are equipped for RF loopthrough, which of course we aren't going to use (the Devil's work, remember?). Fit a 75Ω termination on the unused RF input socket.

Clear channels

The channel filter on the UHF aerial input greatly reduces the amount of RF trash that enters the system, so finding clear channels shouldn't be a problem at all. Even so, it's best to avoid channels that have analogue TV signals at significant levels in the area. Obviously I mean channels that aren't used on the system. These signals can enter via flyleads and wallplates and cause noticeable patterning.

The second channelpass filter/leveller

The first filter unit handles the aerial signals, and the second one (the right hand one in fig 17) handles the 'in house' channels – those that originate from free-standing or built-in modulators. Unlike the aerial filter the 'in house' unit has a separate input for each filter way. After the tuned stages the signals are combined inside the unit. Since the last tuned stage of each filter way presents an open circuit to all frequencies other than its own, and since the distance from the filters to the point where the signals are combined is a small fraction of a wavelength, the combiner need consist of nothing more than a junction. There is no impedance mismatch or signal reflection. In this way six signals can be combined, yet the through loss is only about 5dB. 'So what?' you might think. A six-way inductive splitter/combiner would only lose 10dB. It seems like a lot of expense just to save 5dB. But that's not the point. If you connect the outputs of six modulators together using any kind of combiner that isn't frequency selective you will end up with RF minestrone soup. All modulators generate out-of-channel noise – multiply that noise by six and you'll find yourself cranking up the gain on channels that look vaguely noisy, only to find that this makes others more noisy than they were. Digital BER (signal quality) will be poor, and frankly the whole thing will be pretty substandard.

Although it is possible to re-tune channelpass filters, it makes life much easier if you decide in advance exactly which channels are to be used, and order the filter accordingly. It's well worth while when planning a system to draw up a channel planning chart that shows all the UHF TV channels. This is especially true if you are working in an area where you are not familiar with the local channel allocations. Fill in the terrestrial channels to be carried, with all their n±5 and n±9 relations. Any strong local signals that are not to be carried should also be marked, together with any other channels where there is an obvious possibility of interference. Then you can pencil in the channels you intend to use for your 'in house' signals. Reference to published channel allocations and a close look at the analyser screen is needed. A blank channel planner can be found at www.wrightsaerials.tv/reference/UHFTVchannelplanner.htm

Combining the two filter outputs

Even if the signals from the two filter units are such that they could be combined with a diplexer, there really isn't much point. A screened two-way inductive splitter does the job perfectly. Incidentally, every component should be fully screened. Don't use anything that isn't.

There might be more than two filter units in which case the usual method is to use a splitter with the appropriate number of ports. But what if one filter carries channels where you'd like to keep losses to a minimum? This might be because the signal levels are just adequate. Rather than add another stage of amplification for one or more channels before the filter unit, it might be better to combine all the other filter unit outputs with, say, a three-way splitter, then combine that splitter's output with the 'problem' filter unit's output using a two-way splitter.

The tvLINK bypass unit

The device comprises two little black coaxial connector boxes linked with a thin cable. One of these should be the first thing the Skybox RF output encounters when it reaches the head-end. The other should be connected directly to the main amplifier's input. This allows the 7MHz return signals to bypass everything on your head-end board. As I mentioned in an earlier section the 'DA' on the unit indicates the connection to the items that are to be bypassed. The other end of each connector box should be connected to the Skybox and the main amplifier, respectively. There should be DC continuity between the inner coaxial connectors at the ends not labelled 'DA', and no connection between inner and outer.

Final adjustments

With all signal sources connected the strength of every channel should be checked at each output of the main amplifier. Where the downlead lengths range from, say, 5 to 15 metres, reasonable levels at the amplifier outputs are around +14dBmV (analogue TV) and –6dBmV (DTT). Give the higher channels a couple of dB extra to help them on their way. Of course each channel can be adjusted individually at the filter/leveller.

The strongest VHF-FM signals should normally be around 0dBmV, although if any of the wanted channels are very weak the gain can be increased until the strongest ones are +10dBmV. Only do this where it's absolutely necessary though. DAB signals should not exceed 0dBmV, and –10dBmV is perfectly adequate. The reason for keeping the VHF signals in check like this is to reduce the chance of any strong out-of-band signals causing cross-modulation. If you have a good reason for increasing VHF signal levels beyond the levels suggested above by all means do so, but beware of the potential interference mechanisms. If you have a very strong VHF-FM signal in the locality, it might be worth 'notching it out'.

Now for a few acid tests! Since all the in-house channels pass through the same filter/leveller unit, it is easy to disconnect them all at once. Do this, and observe the results with the analyser tuned to a DTT channel and set to read BER (Bit Error Rate). Perform this test on several channels. If BER improves significantly with the in-house channels disconnected it means that they are somehow degrading the carrier to noise ratio of the DTT channels. You must then disconnect each in-house channel individually to find the culprit. It might be that a rogue modulator is producing a lot of out-of-channel noise, or simply that you have the relative signal levels adjusted incorrectly.

The next test is to carry out the same procedure but this time whilst monitoring the off-air analogue channels. This time scrutinise the actual TV picture, still the best test for noise and patterning on an analogue signal. And then of course, monitor each and every in-house channel whilst connecting and disconnecting the UHF aerial.

At the same time as these tests are performed, disconnect the VHF aerials and see if this has any effect on TV reception.

Before embarking on this sort of exercise familiarise yourself with your test equipment. Even the most expensive bit of kit can never perform perfectly, but if you are aware of the limitations it doesn't usually matter too much. The worst thing is to think that you have a fault when in fact you are looking at some sort of measurement artefact. For instance, when carrying out the first of the tests above with generally high signal levels some equipment can be fooled into incorrectly giving a marginally better BER reading when the in-house channels are disconnected. If you suspect this fault, attenuate the test equipment input and try again. The trick is to fit a variable attenuator at the test equipment's input and watch the BER reading as you vary the signal level. The best reading you get is the correct one. Once you learn your equipment's idiosyncrasies you can make allowances. A bit like living with a woman, really . . .

Installation practice

This article is really about the theoretical side of the installation, since I've assumed that you are quite experienced in the mundane business of fixing things to walls and chimneys. This isn't the place for a detailed treatise on installation practice. However . . .

Those who've seen my website will know that I've got pretty firm views on installation standards. "A bee in his bonnet" was one comment. Alright, maybe I should get a life. But really, all you installers out there, have you thought seriously about your installation standards recently, or are you just chugging along doing the same old thing without considering how you could do better? The fact is, it often doesn't take any longer to do it properly than it does to do a sloppy job. Good installation practice isn't rocket science, and if you have a conscientious attitude most things can be achieved by the use of common sense and a critical approach. For a good 'how not to do it' guide take a look at the Rogues Gallery on www.wrightsaerials.tv. Contributions welcome, by the way!

If you are a capable and conscientious installer you'll recognise the truth of my words from what you've seen on the rooftops, so I hope you'll forgive my preaching and realise that it isn't aimed at you.

Many otherwise acceptable installations are let down by poor cable fixing methods, and figs 20 and 21 show examples of truly horrible work. A bit of care is often all that's needed. There isn't space here to give chapter and verse on every aspect of installation practice, but I will deal with cable fixing, since it forms a large part of any multi-outlet domestic system, and is often the part of the job most visible to the customer.

Fig 20 (left). This shot was taken from the flat roof. The diagonal cable is clipped at the top and at the bottom but not in between! This was one of a sequence of photographs taken on behalf of the Residents' Association, who were after the installer's blood!

Fig 21 (above). This was probably the work of the dish installer, making a quick buck running a cable from the Sky box to a bedroom. Apart from the fact that it looks hideous the cable will rub on the sharp edges of the tiles. Snow falling from the roof often takes cables like this with it.

Cable fixing
Fixing cables invisibly, or at least discreetly, can sometimes be costly in time and effort, and the experienced installer will assess instinctively just what standard is appropriate for each job. Customers and dwellings vary, and you need to take these factors into account. I'm sure you know what I mean.
The route from the amplifier to each outlet should be considered individually. Be on the lookout for fitted furniture, immersion cupboards, storerooms, and the 'under the stairs'. All of these can be a great help. Integral garages can provide good cable routes. In some houses there is easy access to a crawl space under the floor, which the householder might be unaware of. Look for access hatches made by cutting across groups of floorboards. A common location is under the stairs or in the pantry. A cellar might look like hell but it can be a gift from heaven. But don't waste your time trying to fish cables down wall cavities unless you're desperate. It usually isn't cost effective. And when you say to the customer during your reconnaissance, "I'll just have to get into the loft" and they reply "It's upstairs," try not to smile out loud.
External cable runs should always be neat, tidy, and secure. No part of the cable should be able to move in the wind. Plan the route from end to end before you start fixing. Take cables down in a corner where possible, or hide them behind a fallpipe. Even if this means taking the pipe partly off the wall it can be a quick and effective method. It takes only a few moments to unscrew one leg of a plastic pipe clip, allowing you to push the pipe sideways far enough to clip behind it. Where cables go up the wall and into the loft they should run through the under-drawing, not over the guttering and then inside by means of a displaced tile.
Cables should run exactly vertically and horizontally, except where they follow a diagonal building feature such as a bargeboard. Fixings should be no more than 400mm apart. Corners should have a radius approximately equal to the height of a brick, held with clips never make a cable leave a clip at a sharp angle. Think about the colour of the cable. BT might run white cables across dark brickwork but you shouldn't!
Use good quality clips that grip the cable properly. Unifix and Tradefix are my favourites. Always use eye protection. If the head comes off one of those little nails when you hammer it the kinetic energy can carry that tiny piece of metal right through your cornea and into your retina. Ughh!
If you are fixing a large bunch of cables along the same route use cable tie plugs from Screwfix (item 89036). Such a good idea I had to give them a 'plug' (groan!). These little plastic gismos are quick and easy to fix and the result looks so much better than a row of parallel cables clipped individually or in twos.
Normally you should seal holes in the wall with silicon, using the appropriate colour. Drill uphill from the outside to keep the damp out. Don't kink the cable where it enters the hole. Try to avoid having a cable drop down to a hole because this can encourage damp to penetrate.
When fixing to wood use a staple gun, with round headed staples. This is quick and effective, and is more unobtrusive than the use of plastic headed clips. Be careful that the staples don't squeeze the cable out of shape though. It is possible to fix invisibly along the inside of the lip of a fascia board — a position where there isn't room to swing a hammer — using a staple gun. More sophisticated systems will have special purpose outlet plates, providing for instance the connection for the RF output of the satellite receiver. These should be labelled.

In conclusion
The purpose of this article has been to help the thinking — but possibly inexperienced — installer work to a higher standard, be he a DIY man or a professional. For larger installations (needing experience and test equipment) the core idea is to abandon the RF daisy chain and pass all signals through channel filters. Add to your own installation knowledge a good understanding of the principles I've outlined and you will be able to install quite sophisticated systems with first class results. This will set you aside from the run of the mill aerial rigger, so you'll be able to charge more than him, and that of course is what it's all about. I'll be happy to discuss the issues in this article with you. I can be reached at wrightsaerials@f2s.com.