Interference from VHF Transmissions

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The proliferation of VHF transmissions in the UK has caused an increase in TV interference. Bill Wright looks at the problems and suggests remedies.

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In recent years hundreds of VHF-FM radio transmitters have opened in the UK. The Radio Authority has brought the 105–108MHz section of the FM radio band into widespread use, and there are now about 400 VHF-FM transmission sites in full time operation. Radio stations of a more transient nature also abound. Each year about 350 RSLs (Restricted Service Licenses) are issued, allowing small-scale broadcasting for periods of up to a month. Every large conurbation also seems to have a variety of pirate stations, some of which are quite high powered.

These new transmitters pop up in all sorts of unlikely places. Even when they are low-powered they often produce much higher field strength in the nearby area than any other transmission, because they tend not to be co-sited with other transmitters. For this reason, the main impact of the new radio service for people living near the transmitter is often, sadly, that it interferes with their TV reception. These transmitters are often located within densely populated areas, so interference is a distinct possibility.

I'm not suggesting that the transmitters radiate significant power out of band. Any harmonic radiation is normally quite insignificant, at least as far as licensed stations are concerned. The problem starts at the receiving site, because the interference mechanism is almost invariably cross-modulation within a wideband masthead or distribution amplifier. The interfering signal normally enters the amplifier via the VHF-FM radio aerial. An amplifier with one or more input signals that are too strong will produce cross-modulation.

Diagnosis

The sudden onset of patterning on all analogue TV channels will usually have the uninitiated fitting a replacement amplifier. Consternation—the fault is unaffected! Without a spectrum analyser this fault can be hard to identify, let alone cure, but look carefully at the appearance on the screen of the interference (fig 1). The effect is quite unlike cross-modulation from a video carrier. The patterning may tremble slightly, in time with the sound being broadcast by the interfering station. Some of the pirates over-modulate (or over-deviate) badly, and this shows up on the TV screen as more obvious fluctuations in the patterning.

When VHF-FM distribution is required, the use of a UHF/VHF amplifier is universal in domestic systems, and common even in small and medium sized commercial systems, serving, say, 50 dwellings. These amplifiers have separate inputs for VHF and UHF, but the signals are combined internally before being amplified, so a strong radio signal can interfere with television, and vice-versa. Cross-modulation caused by a VHF-FM signal will affect other radio channels, and also the TV reception. On radio the effect tends to be a quiet 'burbling' noise in the background. The effect on an analogue TV picture is as shown in fig 1. Terrestrial digital reception is badly affected by even slight cross-modulation, because the digital signals are about 20dB below the analogue ones. The effect is the familiar 'stop-start' and 'blocking' which appears when a digital signal is in any way deficient. In a severe case, the dreaded red dot and blank screen will appear.

The simple test is to unplug the VHF aerial from the amplifier whilst leaving the UHF one connected. If this stops the TV interference then you know that the fault is cross-modulation, and that it is coming in through the VHF aerial. This

Fig. 1

suggests that it is a VHF or HF—rather than a UHF—signal. Without a spectrum analyser to positively identify the troublemaker, that is probably the limit of the diagnosis. It could be worth asking the customer if there are any new radio stations in the area, since legitimate station launches are always publicised. On the other hand, the culprit could be a pirate or a non-broadcast transmission. Two-way radio base stations normally transmit and receive alternately, so if the interference comes in short bursts look for a nearby radio amateur, taxi office, or CB radio enthusiast.

Masthead amplifiers

What if the interference continues when the VHF aerial is disconnected? A UHF aerial alone is unlikely to receive dangerous levels of VHF or HF signal, and even if it does, the VHF/UHF diplexer built into the distribution amplifier should eliminate it. But if a masthead amplifier is in use, things are different. The worst amplifiers in this respect are the cheap, high gain, ultra-wideband ones. These often have no input filters and are not screened. It follows, then, that the best amplifiers are the good quality, low gain ones built into a diecast box. In an extreme case it might be necessary to fit a filter before the masthead amplifier, but this should be a last resort because the small but inevitable through-loss is very undesirable at that point.

‘Electronic indigestion’

Customers often find the idea of a signal being ‘too strong’ rather difficult to grasp. ‘Can it be too strong?’ is the usual response. I have successfully used the expression ‘electronic indigestion’ in my attempts to explain. Incidentally, I once encountered an old chap who was very concerned because he had lost his ‘calmer downer’. It turned out that this was an attenuator that he kept in a drawer all through each summer until the leaves came off the trees. As signal levels rose each autumn in response to the reduced screening, his distribution amplifier would be driven into cross-modulation, and he would clamber laboriously into the loft to fit the attenuator. It turned out that he had forgotten to remove the attenuator the previous spring, and had not noticed the snowy TV pictures all summer. But I digress.

The noise floor and the cross-modulation ceiling
Assuming that the interfering signal is from a VHF-FM broadcast transmitter, we should think about the whole business of amplifying and distributing VHF-FM radio signals. The distribution of FM radio is unlike that of analogue UHF-TV, in that there is a large number of channels that might be at widely different strengths, yet they must be amplified together. A range of 30dB is quite normal. Whilst this is accepted, there are limits to the dynamic range that an amplifier (or the front end of a receiver) can be expected to handle. Signals above a certain strength will cause cross-modulation, whilst signals below a certain strength will be

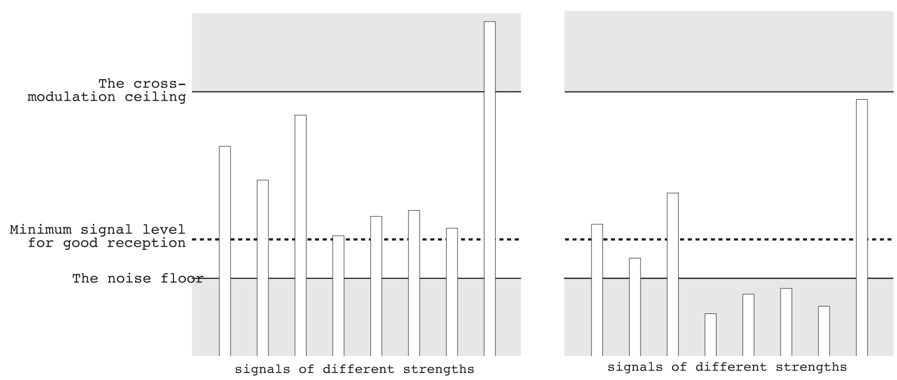

fig 2(a). Schematic, representing signals of different strengths, including one which is strong enough to cause cross-modulation.

fig 2 (b). If an attenuator is used to prevent the cross-modulation, all signals will be reduced by the same amount. The signal/noise ratio of the medium-strength signals may then be inadequate for good reception. The weak signals will fall below the noise floor, which means that they will, in effect, disappear.

Fig. 2

affected by the thermal noise background of the amplifier and the receiver. If a new local transmission produces a signal at the aerial terminals 30 or 40dB above what was previously the strongest, and it causes cross-modulation, a natural first reaction would be to fit an attenuator at the amplifier input. Unfortunately, by the time the strong signal has been sufficiently reduced, the weaker ones will probably have disappeared under the noise. This is a central problem for all forms of RF distribution, and is shown in schematic form in fig 2. The distance between the 'noise floor' and the 'cross-modulation ceiling' depends on many factors, but it is never infinite.

Separate VHF and UHF systems

When this problem arises, the first consideration is whether the VHF signals really need to pass through the amplifier. On a domestic system it is often the case that VHF radio reception is only needed at one or two outlets. The losses in a two-way (or even a four-way) splitter will not affect normal VHF radio reception, and if it is possible to fit additional downleads and outlets for VHF, the UHF and VHF systems can be completely separate. Where the installation of extra downleads would present a problem, the VHF signals can be diplexed into an existing downlead at the amplifier output, rather than input (fig 3). Suitable diplexers include the

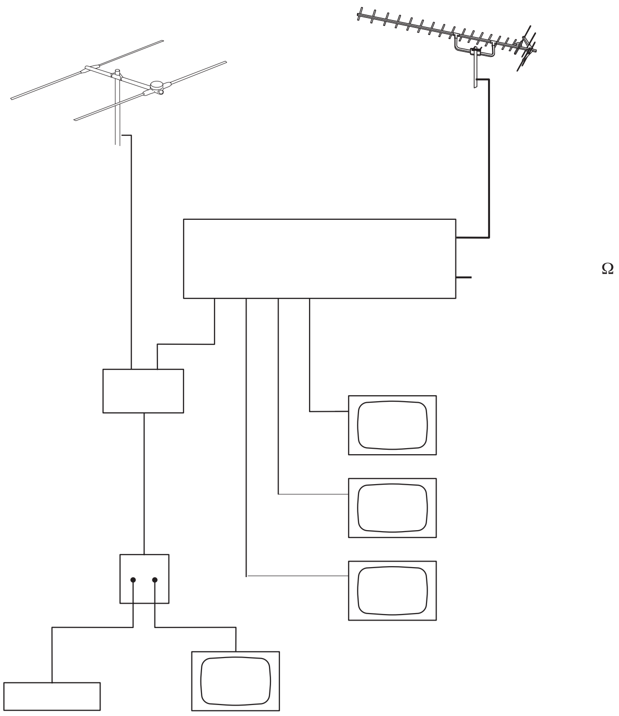

Fig 3. Where only one outlet needs VHF radio signals, the VHF aerial can be connected after the amplifier using a diplexer.

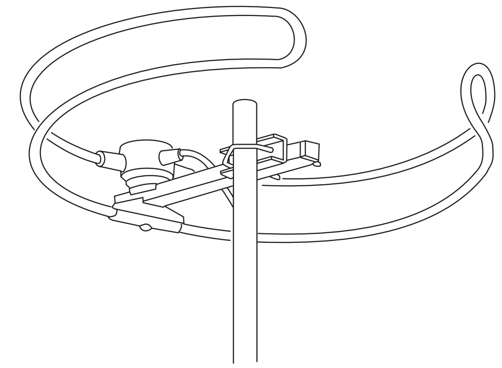

Fig. 4. The 'halo' aerial for VHF-FM radio is non-directional and horizontally polarised. The diameter is approximately 500mm.

Labgear CM9006, Taylor VHF/UHF-K, and the Antiference UF23.

On commercial distribution systems, separate amplifiers should be used for VHF and UHF if there is even a suspicion that cross-modulation from a VHF source might affect UHF reception. The outputs of the two amplifiers should then be diplexed together for distribution. Whether or not separate amplifiers are used, it's worth remembering that the strongest VHF signals can—and should—leave the head-end 10dB or more below the UHF signals.

Aerial type and alignment

The time has come to climb onto the roof. VHF aerials—apart from large multi-element types—are not very directional, but whatever directional properties the aerial has should be used to reduce the strong local signal as much as possible.

Perhaps the commonest type of VHF-FM aerial in use is the 'halo' (fig 4), which as its name suggests is in the form of a horizontal circle. This design contrives to be both omnidirectional (non-directional), and horizontally polarised. The drawback is that this combination of properties is obtained at the expense of gain, or 'sensitivity', which is very poor. This design is pointless under normal circumstances, because virtually every permanent FM station in the land transmits mixed polarisation, so a straightforward vertical half-wave dipole would be much better. The halo's lack of directivity doesn't help us, but since the RSL stations and the pirates usually transmit from a simple vertical dipole, a horizontally polarised receiving aerial can help reject their signal. When the polarity of the aerial is used to discriminate against an unwanted signal, the polarity null will be found to be a very small

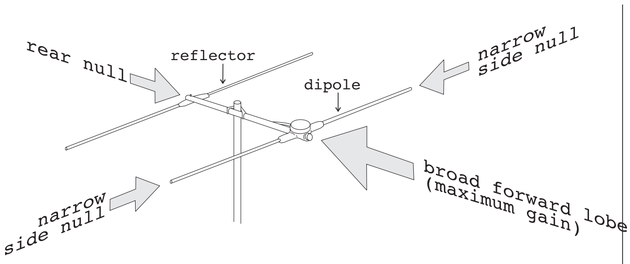

Fig. 5. Two-element aerial for VHF-FM radio. When this array is installed for horizontal polarisation there are deep, narrow nulls to each side. These can be aligned on an interfering signal in order to minimise it. This illustration greatly simplifies the polar response of the aerial, which in reality is fairly complex and irregular.

angle of rotation. Accurate alignment and a firm aerial fixing are essential.

Another common VHF-FM aerial is the two-element, or 'H', which consists of a halfwave dipole and reflector. Normally this aerial is aligned with the dipole nearest to the transmitter and broadside on to it. It may be possible, though, to align the rear null (direction of reduced sensitivity) on the unwanted signal without affecting the desired reception very much, since the forward lobe (direction of maximum sensitivity) is very broad. If the array is mounted horizontally, side nulls are also present (fig 5). This is because a dipole is very insensitive to signals coming 'end on'. The side nulls are deep, but require very accurate alignment. This might even extend to tilting the aerial a few degrees so that the end of the dipole is pointing slightly upwards exactly towards the transmitting aerial, in the (quite likely) event that this is high up and nearby. Adjustments of this sort are well nigh impossible without a good meter or analyser.

If the desired transmissions are of very low field strength, none of these tricks can be used. In order to lift the signals out of the noise it will be necessary to use a large multi-element array, aligned uncompromisingly for maximum signal. For the time being the strong unwanted transmission must be ignored.

Filters

The only remaining possibility is the use of an in-line filter on the VHF-FM aerial downlead. Ideally, this will stop the unwanted signal whilst letting all the others through. The snag is that a passive notch filter is not as selective as we would like. The VHF-FM radio band has a channel spacing of 100kHz, which is about 0.1% of frequency. Compare this to the UHF-TV band, where channel spacing is about 1% of frequency. A UHF notch filter is not a perfect device: it will attenuate one channel above and below the target quite severely. For FM radio, things are, as you would expect, about ten times worse. A typical notch filter is the TBBF2 from Taylor Bros. This is a two-stage unit that will reduce the rogue signal by a very useful 28dB, but channels 300kHz on each side will drop by 10dB. The notch filter is, then, a rather crude device when used on the VHF radio band. If a wanted signal is very close to the unwanted one, forget it. But if the interfering transmission is near the top end of the band (which most of the pirates are) the effect of a notch filter on frequencies below 98MHz is negligible.

The quarter wave coaxial stub

If you don't want so spend £18 on a filter, or if, like me, you are caught out without one a long way from home, there is an alternative. This is an old trick, perhaps so old that many of us have forgotten it. The quarter-wave stub, or tee section, consists of nothing more than a short length of coax connected to a point anywhere along the downlead (fig 6). The junction has no splitter or impedance matching, but should be well made and compact. The other end of the tee-piece is open; it is not terminated by 75Ω or by a short circuit. The length of the tee-piece needs to be exactly a quarter of a wavelength. That's a quarter-wave in cable, not in space. Radio waves travel at significantly less than the speed of light when they are in cable. The ratio is the 'velocity factor' and varies from about 0.60 to 0.80 in coax, depending on the construction of the cable. Practical experiment suggests that the velocity factor of CT100-type cables is around 0.78.

The signal travels along the tee-piece to its end. Since this is not terminated, the signal then

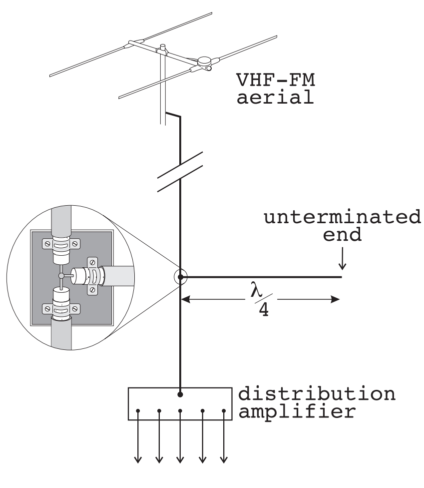

Fig. 6. The quarter-wave stub can be fitted anywhere.

reflects back towards the junction point, where it arrives 180° out of phase with itself, so to speak. The result is a deep notch in the response of the main transmission line. The quarter-wave stub is, in fact, a home-made notch filter. To find a quarter of a wavelength in cable:

$$\frac{75}{f(\text{MHz})} \times \text{velocity factor} = \text{length (metres)}$$

Fig 7 shows the calculated lengths for quarter-wave stubs for the VHF-FM band. This gives a very good approximation of the stub length for CT100-type cable, but the stub should be cut slightly too long and trimmed repeatedly by about 2mm until the exact length is reached. This is done with one eye on the signal level, which should drop with each cut. It's almost inevitable that you will make one cut too many, and see the signal level start to rise again. But you've found the exact length, so you can fit another stub that should be exactly right. The end of the stub should be well sealed against moisture, and the cable secured. For cable with an unknown velocity factor—or for a good demonstration of the way the signal level drops as the stub length is altered—start with a tee piece about 50% longer than shown in fig 7, and initially remove about 25mm each time. Ignore the signal level produced at the moment when the cutters short out the end of the cable, because the short-circuit itself produces a 180° phase change. After many bits of coax have hit the deck, the signal level should start to drop with each successive cut. The reduction in signal level is greater for each successive cut until the minimum is reached.

Clear demonstrations

If you have a VHF noise generator and a spectrum analyser, the whole thing becomes

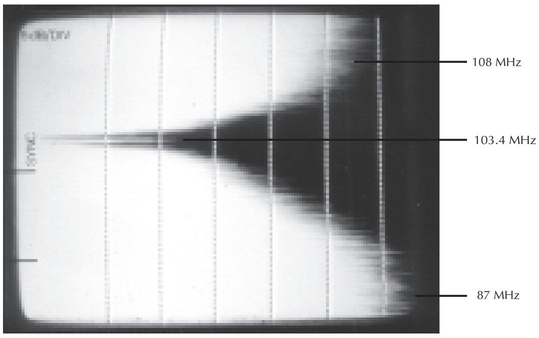

Fig.8. Spectrum analyser screenshot showing a response notch obtained with a quarter-wave stub, centred on 103.4MHz. This was set up in a workshop half a mile from a medium-powered transmitter on that frequency, and a tiny signal can be seen at the bottom of the notch. This signal has entered between the notch filter and the analyser, despite the use of good screening techniques.

much easier and more certain, because the response notch can be seen clearly (fig 8). As bits are snipped from the stub you can watch the notch move up to the desired frequency. You can also watch the notch move up and down the band slightly as you squeeze and twist the quarter-wave stub. This is a good demonstration of the importance of not deforming co-axial cable as it is installed. The mere demonstration that an open-ended coaxial cable will return virtually 100% of the applied signal shows the importance of correct termination and impedance matching on any coaxial network. This point should be rammed home to those who don't bother to fit a 75Ω termination at the end of tap-off lines.

Figs 9 and 10 show the 'before and after' effects of a stub tuned to 103.4MHz. Note the changed reference level position. In Fig 11 the reference level is moved down a further 20dB, to reveal about fifty weak FM stations, all of which might disappear below the noise floor of a distribution amplifier if the input was unduly attenuated.

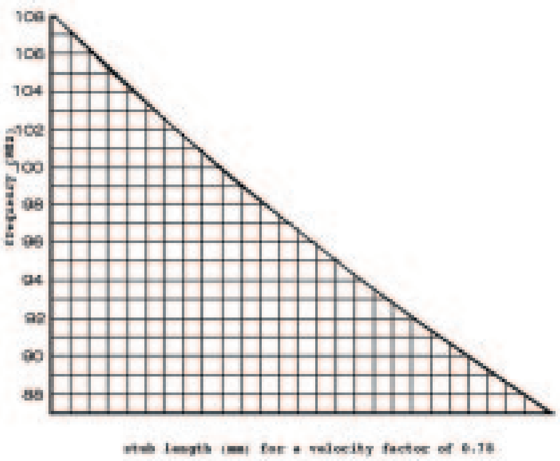

Fig. 7. CT100 cable and near equivalents have a velocity factor of approximately 0.78. this graph shows CT100 quarter-wave stub lengths for the VHF-FM broadcast band.

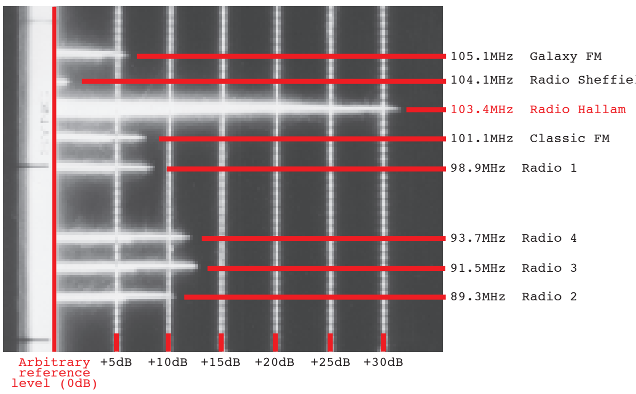

Fig. 9. This is a spectrum analyser display of the output from a VHF-FM aerial. The aerial has been aligned to minimise reception of a 103.4MHz transmitter about 1km away, but that signal is still about 20dB above the next strongest. If a 20dB attenuator was fitted to prevent cross-modulation many weak signals would be lost.

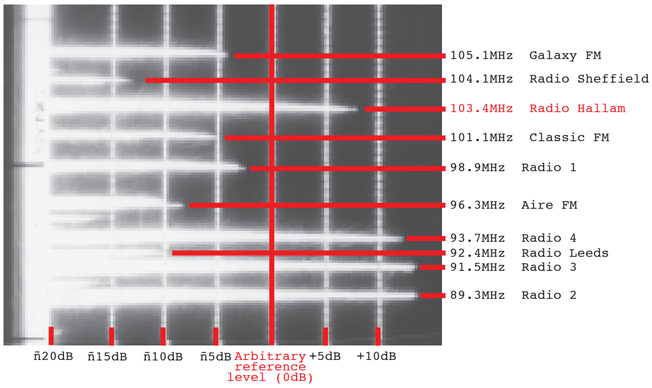

Fig. 10. This is the same aerial feed as shown in fig 9, but a quarter-wave stub tuned to 103.4MHz has been added. The signal on that frequency has dropped 24dB. The signal on 104.1MHz, seven channels higher, has lost 15dB, whilst that on 98.9MHz, 22 channels lower, has lost 10dB. This sounds bad, but since the addition of the notch allows the aerial output to enter the distribution amplifier 20dB higher, the net result will be to lift these signals 5dB or so further above the noise floor.

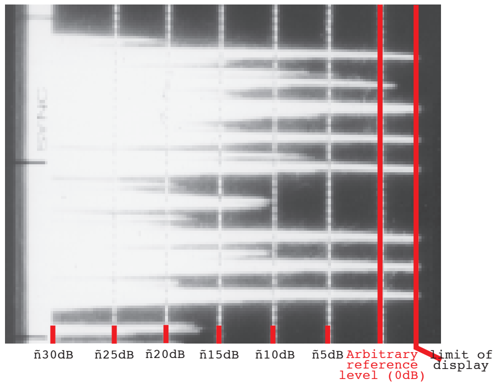

Fig. 11. Moving the reference point to the top of the display reveals a large number of weak signals. A good tuner will receive all the signals shown here, but if the distribution amplifier input is unduly attenuated to accommodate an over-strong signal, the weak ones will be lost under the noise.

If a tuned stub for a VHF frequency is used on a cable that also carries UHF TV, a series of response notches will be present across the UHF band. This will preclude the use of this technique if a notch coincides with a UHF channel that is in use.

Whether the unwanted signal is rejected at the aerial or by a filter, every cable and component which follows should be 100% screened. If they aren't, the unwanted signal might sneak in. A plastic-cased amplifier, installed in the loft, is a likely culprit.

Braid connections should be perfect.

Other VHF interference sources

Although this article focuses on the particular problem of interference caused by strong VHF broadcast radio transmissions, the techniques outlined can equally well be used to counter the effects of any VHF signal that causes interference. VHF FM radio aerials pick up all sorts of out-of-band signals. The most likely culprits are shown in fig 12. If the cause of the problem is the kid next door and his CB radio, use an Antiference TVI/V filter, which stops CB but passes VHF-FM. If there is a general problem with strong out-of-band signals use an 88 to 108MHz pass filter. This will attenuate everything except the VHF-FM radio band. A suitable filter is the Taylor TBP2.

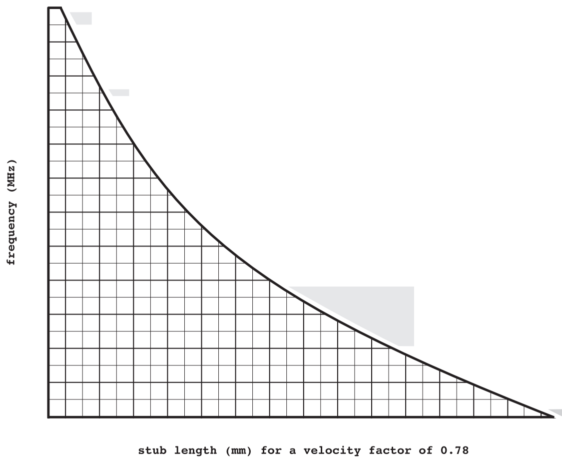

Fig. 12. Amateur radio and private mobile radio base station transmissions are amongst the many VHF signals that can enter a distribution system via the VHF-FM aerial. Quarter-wave stubs or other notch filters can be used to great effect here because the width of the notch is unlikely to be a problem.