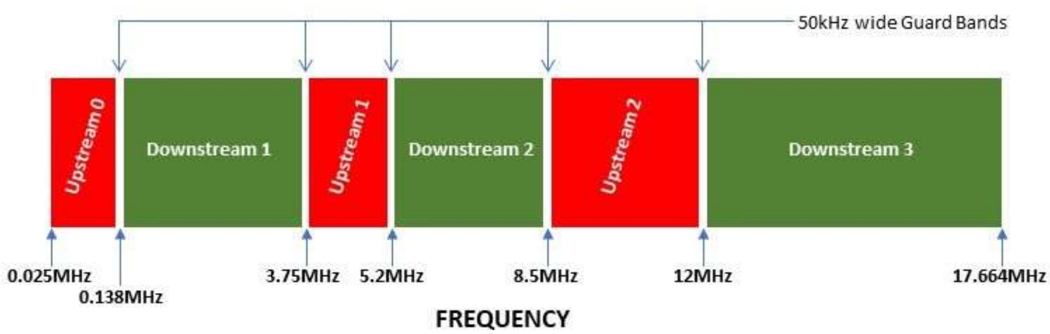
EMC Advice Leaflet EMC 15 VDSL Interference

Why does VDSL cause interference on the HF bands?

VDSL (Very-high-bit-rate Digital Subscriber Line) is the pre-eminent means used to deliver broadband internet services to residential customers in the UK. VDSL uses the existing unscreened, twisted-pair "telephone" cables to carry high speed broadband data signals between the network provider's "cabinet" (typically an above ground street-furniture box) and the VDSL modem [1] in the customers premises. This is typically a distance of up to a few hundred metres, and may use underground or overground cables, or a combination of the two.

VDSL uses the spectrum from 25kHz to 17.664MHz to carry bidirectional digital data traffic in 3 downstream bands (i.e. in the direction from the service provider to the customer) and 3 upstream bands (i.e. in the direction from the customer to the service provider). These 6 bands are frequency interleaved and are separated by small, approximately 50kHz wide, guard-bands where no VDSL signals are transmitted. The interleaved upstream and downstream bands, and the guard-bands are shown in the following diagram.



The VDSL signals are carried over the existing twisted pair cables into subscribers' premises. These cables were originally designed to carry only audio telephone signals up to 3.4kHz for the traditional analogue PSTN (telephone) service. Unfortunately, these cables have a number of undesirable properties when it comes to carrying high bandwidth data signals; e.g. they are unscreened, they have variable impedance (since different gauges of wires are used in different parts of the network), they may have variable twist lengths, they may include cables with different insulation properties, typically they are close bundled with other similar cables, and they may include T-connections (taps). Furthermore, after entering the customer premises through a "master socket", the wires are then connected to internal house wiring that is largely uncontrolled, i.e. they may use any available wire type (maybe not even twisted pairs), they may have long un-terminated extensions and they may be partially unbalanced (in particular by the third, so called, bell wire[2]). As radio amateurs we would never use such an arrangement to carry HF signals e.g. between a transceiver and an aerial.

[1] Typically, the VDSL modem, ethernet router and Wi-Fi router are combined into a single home unit. As we are only interested here in the VDSL functionality, for simplicity, we refer to this unit as a VDSL modem.

[2] The bell wire was introduced in the days of mechanical ringers where it was necessary to constrain the number of parallel ringers.

In the case where the twisted pair copper conductors are well-balanced, the VDSL signals remain near-field confined to the area around the twisted pair cables and will emit little signal into the surrounding environment. However, in practice, the cable balance may be far from perfect, there may be impedance discontinuities where cables are joined, the total run may use different sizes and twist rate of cables, and there may be many sharp bends. Hence it is not surprising that the broadband VDSL signals can have significant leakage out of the cables and therefore is at risk of causing substantial interference on the HF bands. Furthermore, because the cables have high, and variable, transmission losses across the spectrum, VDSL uses relatively high transmission powers (up to -15dBm) in order to overcome the losses which further exasperates the interference risk.

VDSL transmits differential encoded signals down the twisted pair cables. This helps to minimise the effects of crosstalk between different pairs in the same cable sheath. However, any imbalance in the cables will result in a common mode signal which will radiate into the outside world, and thereby can cause interference. The level of interference can be exacerbated at frequencies where the cable lengths happen to be resonant, and the amount of interference will be affected by the level of line imbalance which can be caused by, for example, high resistance joints, or loading from lengths of coupled cables. This effect can be further worsened by variations in the transmission characteristics of the particular cables which can cause the VDSL system to use higher transmit power for certain frequencies in order to overcome the cable attenuation at those frequencies. [3]

In the UK, the provision of VDSL services is typically split between a service provider (e.g. BT, PlusNet, TalkTalk etc) who provide the retail broadband services and who bill the customer, and BT Openreach who provides and maintains the physical infrastructure (i.e. the cables) between the customer premises and the cabinet and exchange locations. It is estimated that there are currently between 20 and 30 million VDSL connections in the UK.

VDSL Standards

When internationally agreed VDSL standards were being prepared, it was widely recognised that signal leakage would occur both in and out of the twisted pair cables that carry the VDSL service. This means that not only was there a risk that VDSL could interfere with MF and HF radio systems, but that the VDSL system itself could be susceptible to interference from MF or HF transmitters that are located nearby to cables carrying VDSL services. [4] For this reason, the relevant standards include a capability to simultaneously notch out up to 16 arbitrary operator-defined specified blocks of frequencies in the VDSL system. The standards proposed (inter alia) amateur radio bands as one set of specific frequencies that could be notched.

Unfortunately, the implementation of notching is not mandatory, and, to date, Openreach have not implemented notching of the amateur radio bands on VDSL services in the UK. We believe that all VDSL modems and the equivalent DSLAM equipment at the network end of a VDSL service in use in the UK includes the technical capability to implement notching. Nevertheless, Openreach have chosen not to activate this notching capability, either nationally or on a case-by-case basis to solve specific cases of interference.

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[3] More information can be found in various articles in RadCom. For example, see RadCom March 2016 pp 80, RadCom December 2017 pp48 and RadCom January 2018 pp64

[4] Indeed some amateurs have reported that operation of an HF transmitter can cause nearby VDSL services to drop out.

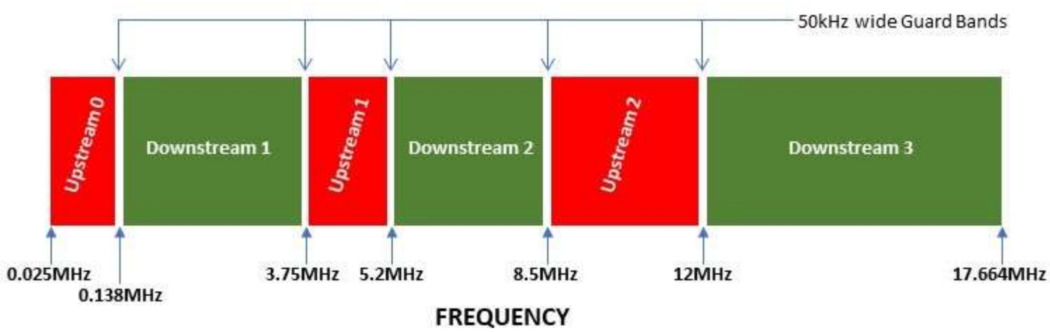
In 2014/15, the RSGB EMCC conducted testing with BT Research into the impact of VDSL on amateur radio and many subsequent meetings have been held with both Openreach and Ofcom. Regrettably, Ofcom has refused to accept that VDSL causes "harmful interference" [5] to amateur radio.

If you are suffering HF interference, how can you tell if this is caused by VDSL?
VDSL interference has spectral characteristics that are very similar to broadband white noise and therefore it can be difficult to easily identify it as VDSL. VDSL interference will be present 24 hours a day, 365 days a year, irrespective of whether customers are actually using VDSL or not.

Unfortunately, VDSL interference has no distinct characteristics that can be readily identified by listening on a normal receiver, and therefore simply listening to the interference will not identify it as being caused by VDSL.

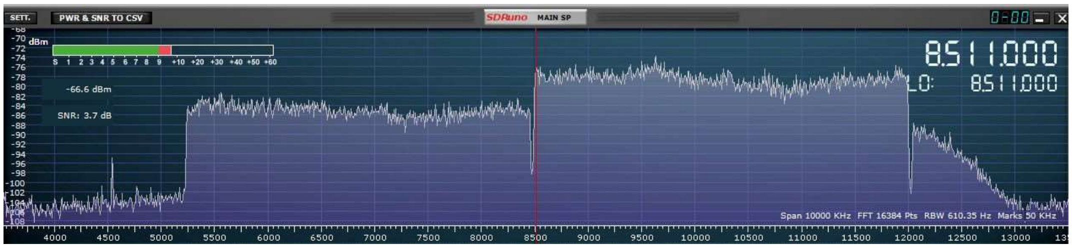
Nevertheless, it is possible to positively confirm whether or not interference is VDSL as follows:

- First, if the interference is caused only by VDSL services serving your own household, then temporarily turning off your VDSL modem will halt the VDSL signals (both upstream and downstream). Therefore, if the interference disappears when the VDSL modem is turned off, then it is likely that it is being caused by VDSL. [6]
- Second, VDSL uses the HF spectrum up to 17.664MHz. Therefore, if the interference is being caused by VDSL, then there should be a reduction in the level of interference above this frequency i.e. the 17m, 15m and higher frequency bands should be relatively free of interference.
- Third, the VDSL spectrum has guard-bands between the upstream and downstream bands. These are around 50kHz wide and occur at the frequencies shown in the following diagram. If there is VDSL interference present across a wide spectrum, since no VDSL signals are transmitted in these guard bands, then there should be a significant drop in the background noise levels at these specific frequencies.



[5] In this context, "Harmful interference" is defined by the Wireless Telegraphy Act 2006 as being interference which (inter alia) "…degrades, obstructs or repeatedly interrupts anything which is being broadcast or otherwise transmitted…"
[6] One word of caution here. Typically domestic routers are powered by a switched mode power supply external to the router. Some switched mode power supplies, even those supplied by a reputable provider, have been known to cause interference, so if the interference disappears when the router is switched off it is worth checking whether it is the switched mode power supply itself that is causing the problem. Leaving the switched mode power supply turned on at the mains, but disconnecting the power plug from the router may be sufficient

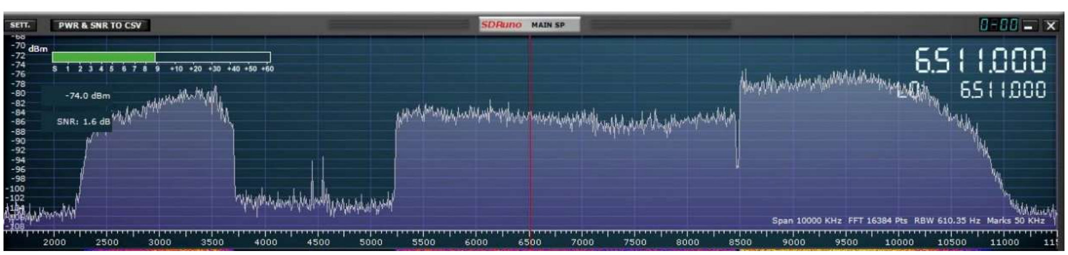
The best guard bands to investigate are at 5.2MHz, 8.5MHz and 12MHz. If the background noise decreases within the confines of the guard band and rises on either side of it, then this would indicate the presence of VDSL interference. If a receiver with a spectrum display is used, then the guard-bands may be clearly seen. The following diagram clearly shows the VDSL spectrum with guard-bands at 8.5MHz and 12MHz.



The following diagram shows an expanded example of the 8.5MHz guard-band.

In addition, with an SDR receiver, the 4.3125kHz pattering of VDSL carriers may be observable on a waterfall display.

When looking for VDSL guard-bands, note that the precise position of any of the guard bands may be displaced by up to 20kHz either side of the nominal frequency, also any particular VDSL system may not necessarily use all of the upstream and downstream bands so it may be necessary to check more than one of the guard-bands. For example, the diagram below shows the spectrum of a VDSL system using upstream band 2 (U2, from 8.5MHz to 12MHz), but not upstream band 1 (U1, from 3.75MHz to 5.2MHz).



- Finally, the RSGB has developed a software tool called Lelantos, written by Dr Martin Sach G8KDF, a member of the EMC Committee, which can detect VDSL signals. This software, when fed with a spectrum recording made from an SDR receiver, uses the synchronisation signals buried within the VDSL spectrum to positively identify whether or not an interfering signal is VDSL. Further information can be found in RadCom November 2018 and in EMC leaflet number 17.

What can you do to reduce or even eliminate VDSL interference?
Unfortunately, VDSL interference to HF band reception is often very pervasive and in many cases is very hard to completely eliminate. Furthermore, many amateurs suffer from VDSL interference not just from the VDSL service serving their own house but from VDSL emanating from multiple sources serving neighbouring houses. Regrettably this makes it even harder to eliminate.

Nevertheless, there are several remedial measures which can often result in a reduction in the level of interference to tolerable levels. Some of these measures are relatively easy to implement while others are more difficult, so it is really a matter of trying the easiest first and then working through the list. It is also very location sensitive, so what works in one place may provide little or no benefit in another place.

The following measures have all be used, either individually or in combination, in different circumstances and have been proven to provide relief from VDSL interference.

Antenna considerations
First, let's look at measures relating to the antenna;

- Given that most VDSL radiation will occur either from the overhead telephone cables or from internal house wiring, moving the antenna away from these sources is likely to reduce the level of received interference. In particular, since the interference signals drops more rapidly with distance while the antenna is within the "near field" than it does in the transition zone or the far field. Moving the antenna far enough away from the interference source to get it out of the near field area will have the most effect. In practice, you should try to separate the antenna and the interference source by at least 1/3 wavelength.
- If the antenna has directional capabilities (which applies to most horizontal antennas such as a horizonal dipole or long wire) installing the antenna with its minimum gain point pointing towards the source of the interference may be beneficial. For example, with a dipole, this could mean stringing the wire so that its long axis, points at the serving telephone pole.
- A loop antenna (perhaps just used on receive) will tend to be quieter and pick up less VDSL interference than a conventional HF antenna. In addition, it has the added bonus that it can be rotated either to maximise the wanted signal or to minimise any interference
- Any directional antenna (such as a beam) can similarly be orientated so as maximise the wanted signal or minimise the interference
- It is possible to use a phasing noise cancelling signal enhancer which uses a second small antenna (e.g. a short whip antenna) to receive local (primarily interference) signals which are then fed in anti-phase against the signal received by the main antenna to cancel out the local interference. These devices are sold by several well-known amateur radio suppliers and can be very effective, although they are often complex to set up and require careful retuning every time the frequency is changed. They work best where there is a single source of interference i.e. where it is caused by a single VDSL line. Where the interference is caused solely by service in your own home, then an alternative source for noise cancellation is to feed the signal enhancer from a current transformer clipped onto the telephone cable
- Changing from an unbalanced antenna (such as a long wire) to a balanced antenna (such as a dipole) may be beneficial in reducing local interference (including that from VDSL)
- With a balanced antenna (such as a dipole) that is being fed via an unbalanced feeder (e.g.coax) adding a balun at the feed point can significantly reduce common mode currents in the outer conductor, and in doing so may reduce any locally sourced interference. The balun can consist of nothing more than winding a few turns of the coax into a tightly bound coil immediately adjacent to the feed point of the antenna. This is sometimes referred to as

an “ugly” balun. Alternately, try inserting common mode filters (e.g. see RadCom April 2015) or installing a suitable choke balun to minimise unwanted noise pickup. For example, see “High performance common mode chokes” in RadCom Plus Volume 1 No. 1 dated May 2015, or search the internet for G3TXQ ferrite, K9YC ferrite or GM3SEK ferrite.

- As a further option, it may be worth trying whether a separate receive antenna (located further from the source of the interference than the main antenna) may help to reduce the effects of VDSL interference. In particular, using a separate receive loop antenna positioned to point a null at the interference source can be effective.
- As with any interference, finally it may be worth checking whether separating the radio earth from the mains supply earth (with appropriate mains electrical precautions) reduces the level of induced interference.

Internal wiring

Second, in particular where the VDSL service is provided using underground telephone cables, it is likely that the primary source of the interference comes from the internal house wiring. Clearly where this is inside your own house then you have much more control over the wiring, but it may be possible to also seek help from friendly, cooperative neighbours.

Here the primary benefit is likely to be obtained by reducing the amount of cabling to an absolute minimum by locating the VSDL modem / router, and any associated telephone apparatus (e.g. a DECT base station) as near to the master socket as possible, and by getting BT to locate the master socket as near as possible to the place where the cable first enters the house. Fortunately, with most broadband clients now being served using Wi-Fi, and telephones using cordless DECT phones this is increasingly achievable.

Where internal wiring is inevitable then the following measures may help;

- Remove any internal wiring to unused extension sockets or eliminate any unnecessary telephone extensions as these can cause imbalance
- Remove or eliminate the bell wire (this is an unbalanced wire that is used to connect to the bells / electronic ringers) in extension telephones. If only one telephone is being used (as is typically the case with a DECT base station), then it is unnecessary to extend the bell wire beyond the first telephone
- Rewire the internal wiring with screened cable
- Re-route any internal wiring as far as possible away from the shack and the antenna
- Where microfilters are used, try to position these as near as possible to the master socket. Better still, replace any microfilters with an NTE5C master socket and a Mk4 VDSL faceplate which have the filtering built in. Further information can be found in the February 2020 edition of RadCom page 54.
- Reposition the VDSL modem as near as possible to the master socket and use screened ethernet cabling to connect to any wired ethernet clients [7]
- Isolate the VDSL modem and VDSL cabling away from other cabling as this will reduce the risk of stray coupling into other cables that could in turn re-radiate the VDSL signal

[7] The risk of interference from an ethernet connection is considerably less than the interference possible from a VDSL connection, and therefore relocating the VDSL modem in order to minimise the length of cable carrying the VDSL service at the expense of increasing the length of cables carrying ethernet services is likely to prove to be beneficial overall

Filtering the VDSL signal
Some people have been successful in reducing interference from VDSL on individual HF bands by inserting a band-stop filter tuned to a particular amateur radio band into the internal cable connecting to the VDSL modem. This has the effect of discouraging the modem from using the spectrum within the amateur band or simply reducing the level of the VDSL signals in that particular band. Filters can be made using a quarter wavelength stub (adjusted for the velocity factor of the cable) or by using a stopband filter such as a multi-pole Butterworth notch filter.

The location of the filter is important. For amateur bands that fall into one of the downstream bands of the VDSL service (e.g. 160m, 40m 20m and the lower part of 80m) then the filter should be located as close as possible to the master socket, while for amateur bands that fall into one of the upstream bands of the VDSL service (e.g. 30m) then the filter should be located as close as possible to the VDSL modem.

ISP
Your ISP (or the ISP serving your neighbours' properties where the VDSL interference is coming from other locations) may be able to help. In some cases, BT Openreach will check the line balance on installations near you and this may potentially rectify any problems.

Other potential solutions
In extremis, if all else fails, converting your broadband service (and / or your neighbours service) from VDSL to a Fibre to the Premises (FTTP) [8] service can completely eliminate VDSL and therefore any interference that it causes. However, be aware that if some neighbours continue to use VDSL then this can continue to be a problem, and if you happen to be adjacent to a telephone cable route or near to a telephone street cabinet containing VDSL equipment, then interference can still occur.

Finally, if it is not possible to reduce the level of VDSL interference to an acceptable level (especially on particular bands) the only solution may be to use a remotely located receiver station such as a web SDR receiver.

Is VDSL interference likely to get better or worse in the future?
With pressure on service providers, both from the government and from consumers, to provide ever higher broadband speeds, then we expect that VDSL will be very gradually superseded by (hopefully noise free) fibre to the premises. Nevertheless, this process is expected to take many years, not least because of the need to supply a fibre connection into each home.

Another factor that may influence the rate of progress towards full FTTP is the need to move to IP telephony, driven by the obsolescent nature of the existing PSTN equipment. IP telephony does not require FTTP and can be provided over VDSL (or even the lower broadband speed ADSL). However, while some customers may be encouraged to move to FTTP at the same time as they are required to move to IP telephony, others may be concerned about the potential failure of IP telephony under power out conditions at the customer's premises, and thereby be deterred from moving to FTTP.

Further information
Further information on the effects of VDSL on amateur operation can be found in the following:

- Impact of VDSL2 on HF radio. http://rsgb.org/main/files/2012/12/VDSL-RFI-RSGBOfcom-meeting-June-21-2017.pdf

[8] Also referred to as FTTH (Fibre to the Home)

- RFI update. RSGB Convention lecture 2017 https://www.youtube.com/watch?v=2D1R5nUdQbs&feature=youtu.be
- EMC – Diagnosing and reporting RFI problems. RSGB Convention lecture 2016 https://www.youtube.com/watch?v=zlj09k06f9M&feature=youtu.be
- "VDSL interference to HF radio" RadCom, March 2016 pp 80
- "Survey to measure levels of RF interference from VDSL" RadCom, December 2017 pp48
- "VDSL Radio Frequency Interference" RadCom, January 2018 pp64
- "EMC column" RadCom February 2020 pp 54

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