

### 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 traditional “telephone” cables to carry high speed broadband data signals between the network provider’s “cabinet” (typically an above ground street-furniture box) and 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 data traffic in 3 downstream bands (i.e. service provider to customer) and 3 upstream bands (i.e. customer to service provider). These 6 bands are interleaved and are separated by small (approximately 50kHz) guard-bands. 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 3kHz) for the traditional analogue PSTN (telephone) service. The cables are unscreened, have variable impedance (since different gauges of wires are likely to be used in different parts of the network), have variable twist lengths, may include cables with different insulation properties, typically are bundled with other similar cables, may include T-connections (taps) and may have other undesirable properties when it comes to carrying high bandwidth signals. Furthermore, after entering the customer premises through a “master socket” they are then connected to internal house wiring that is largely uncontrolled, i.e. may use any available wire type (maybe not even twisted pairs), may have long un-terminated extensions and may be unbalanced (in particular by the third, so called, bell wire). As radio amateurs we would never use such an arrangement to carry HF signals e.g. between a transceiver and an aerial, and hence it is not surprising that the broadband VDSL signals have significant leakage out of the cables and therefore can cause substantial interference on the HF bands. Furthermore, because the cables have high transmission losses at MF frequencies, VDSL must use relatively high transmission powers in order to overcome these losses.

VDSL transmits differential encoded signals down the twisted pair cables. This helps to minimise the 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 exacerbated 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.<sup>1</sup>

In the UK, the provision of VDSL services is typically split between a service provider (BT, PlusNet, Talk Talk etc) who provides the upstream broadband services and who bills the customer (and may also provide the customer premises VDSL modem<sup>2</sup>), and BT Openreach who provides and maintains

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<sup>1</sup> 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

<sup>2</sup> 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.

the physical infrastructure (i.e. the cables) between the customer premises and the cabinet and exchange locations. It is estimated that there are currently in excess of 10 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.<sup>3</sup> For this reason, the relevant standards include a requirement 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 ones that could be notched.

Unfortunately, the implementation of notching is not mandatory, and as of the date of preparation of this document, Openreach have not implemented any notching of 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, can be remotely controlled to enable notching. Nevertheless, Openreach do not activate this notching capability, either nationally or on a case-by-case basis to solve specific cases of interference.

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, although at the time of writing, while this matter is still the subject of ongoing meetings between the RSGB and Ofcom, Ofcom have refused to accept that VDSL causes “harmful interference” 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.

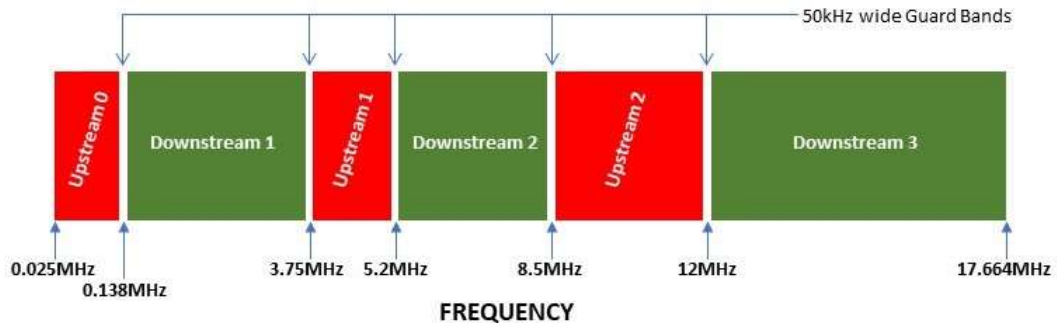
Unfortunately, VDSL interference has no distinct characteristics that can be heard, and therefore simply listening to the interference will not identify it as being caused by VDSL.

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

- Firstly, 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 any interference disappears when the VDSL modem is turned off, then it is likely that it is caused either by VDSL itself or by the power supply (typically a switched mode power supply) powering the VDSL modem.
- Secondly, 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. Thirdly, 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 diagram on the following page.

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<sup>3</sup> Indeed some amateurs have reported that operation of an HF transmitter can cause nearby VDSL services to drop out.



The best ones to investigate are at 5.2MHz, 8.5MHz and 12MHz. If the background noise decreases on one side of the guard-band frequency and then rises again on the other side, then this would indicate the presence of VDSL interference. If an SDR receiver is used, then the guard-bands may be clearly seen on a spectrum display. 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, please note that the precise position of any of the guard bands may be displaced by up to 20kHz either side of the nominal frequency, and also be aware that 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 on the following page 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, chairman 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.

### **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, several remedial measures can often result in reducing 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 measures**

Firstly, let's look at measures to do with 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 horizontal 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. Where the interference is primarily caused by a single VDSL line, an alternative approach is to use a current transformer clipped onto the telephone cable as the noise cancelling source to feed the signal enhancer.

- 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. co-ax) 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 co-ax 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 (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**

Secondly, 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 VDSL modem, and any telephone apparatus 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 <sup>4</sup>
- Isolate the VDSL modem and VDSL cabling away from other cabling will reduce the risk of stray coupling into other cables that could in turn re-radiate the VDSL signal

### **Filtering the VDSL signal**

Some people have had limited success 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 <sup>5</sup> 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?**

Currently, almost 30 million subscribers in the UK have broadband services delivered using VDSL technology. This number is only likely to increase, so regrettably, in the short to medium term, interference to the HF bands from VDSL is inevitable.

In the longer-term pressure on broadband service providers to provide yet higher speed broadband services currently looks as though it could use one of two possible technologies.

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<sup>4</sup> 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

<sup>5</sup> Also referred to as FTTH (Fibre to the Home)

- G.Fast is the next generation of VDSL like services and is capable of delivering broadband services up to 200Mbit/s, with future rates specified to be in excess of 1Gbit/s. However, unfortunately G.Fast continues to use the twisted pair cable for the final drop (cabinet to customer premises) and whereas VDSL uses spectrum on this link up to 17.66MHz, G.Fast uses spectrum up to 106MHz and perhaps 212MHz in the longer term. Therefore, there is a risk of broadband interference from G.Fast affecting both the HF and the VHF bands. While G.Fast specifications include notching, at the time of writing there is no indication whether or not BT Openreach will implement notching.
- The alternative to G.Fast is fibre to the premises (FTTP) where the twisted pair cable into the customer premises is replaced by fibre. If this were widely adopted, then the interference to HF bands from VDSL should cease, and of course a fully fibred connection can provide virtually unlimited broadband speeds. However, the penalty of implementing FTTP is the need to provide a fibre connection into every house. Regrettably all the current indications are that the network operators consider this uneconomic in the majority of areas and therefore absent political pressure (and investment), we are unlikely to see widespread implementation even in the medium term.

### **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>
- 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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