Physics booster: measurement technology for VSDL2 vectoring

New technology for maximum bandwidth

In physics, a vector is a quantity that has a magnitude and a direction. If we apply this definition to the VDSL2 vectoring technology that is currently dominating discussion, this means maximum bandwidth to the customer. Even higher bandwidths and more finely tuned technology, however, result in increasing demands on DSL measuring technology in the field and entail a series of technical challenges.

The new VDSL2 vectoring technology is expected to boost Germany's current VDSL2 capability of 50 Mbit/s to up to 100 Mbit/s, depending on the line length.

Typical DSL profiles in Germany/Europe

	ADSL2+	VDSL2	Vectoring	Bonding
ITU standard	G.992.5	G.993.2	G.993.5	G.998.1/2/3
Max. down	16 Mbit/s	50 Mbit/s	100 Mbit/s	200 Mbit/s
Max. up	1 Mbit/s	10 Mbit/s	40 Mbit/s	50 Mbit/s
Length	3000 m	800 m	500 m	400 m

The demand for ever higher bandwidths and the resulting expansion of vectoring are being decisively influenced by two important factors.

The first major influence is the rapidly increasing demand for bandwidth in the business segment, in particular due to the growing use of cloud services, in which applications, platforms and infrastructure in the form of storage and computing capacity - infrastructure as a service (IaaS) - are being outsourced. The same trend is emerging in the consumer segment due to video offerings as well as the increasing popularity of audio streaming.

The second driver is the competition to offer the highest data rates at the lowest price. In this arena, the operators of DSL, cable (coax) and optical fibre networks are fighting to gain ground. As the large cable and smaller optical fibre network operators are already offering data rates over 100 Mbit/s, rapidly matching this mark is of paramount economic importance for DSL operators. The future belongs to data transmission via fibre to the home (FTTH), but expanding this network is too time-consuming and expensive to enable competitors to catch up any time soon.

VDSL2 vectoring provides a solution to this dilemma. It

- Makes possible a downstream rate of up to 100 Mbit/s over short distances and particularly in urban areas via the existing copper line, thus establishing parity with the cable network operators.
- Is a step in the process of successively upgrading the network to FTTH, as an optical fibre backbone connected to a street cabinet (fibre to the node, FTTN) brings fibre closer to the customer, thus laying the groundwork for FTTH.
- Is not a shared medium due to the backbone of the street cabinet and the well-known exclusivity of the DSL line in a local loop to the customer, so that its bandwidth is not shared among users.
- Achieves a much higher upstream transmission performance than cable networks, with a bandwidth of up to 40 Mbit/s.
- Utilises the existing copper cable infrastructure, thus requiring only relatively "minor" investments in the network and in vectoring technology.
- Can ideally draw power from the customer thanks to its customer proximity.

Thus, VDSL 2 vectoring is a suitable bridge technology, particularly in densely-populated Germany. In addition to the economic aspect, political agendas such as the various broadband initiatives of Germany or the EU also play a role.

Political and economic obstacles to VDSL2 vectoring

Although VDSL2 vectoring offers numerous advantages, there is also a significant disadvantage: It can only be effectively deployed when it is applied over the entire bundle, and not to just a single local loop (see box "How does VDSL2 vectoring work?"). This application to the entire bundle presents regulatory problems. Specifically, in Germany, individual DSL lines, i.e. local loops from street cabinets to the customers, must be treated as unbundled: according to regulatory rulings, every network provider can operate each individual local link using their own technology. However, this makes expanding VDSL2 vectoring difficult, as vectoring-capable technology must be used on all lines in a bundle if the advantages are to be utilised. This can only be achieved in a standards - compliant manner when one network operator controls all lines.

As this situation would distort the competitive situation in Germany, it would require a regulation approved by the German network operators, the German regulatory authority Bundesnetzagentur and the EU - a regulation to which all parties agreed in summer 2013. Essentially, the new regulation provides for the following:

- Maintenance of a vectoring list. This list is intended to ensure that all operators have the same opportunities and rights by documenting all planned and implemented VDSL2 vectoring projects. The German regulators has special intervention rights here.

- Unbundled DSL connections. Access to a street cabinet remains unbundled; in principle, every provider must be able to utilise it.
- Free access. Access to a street cabinet can only be restricted for others under special conditions when the aim is to implement this completely with VDSL2 vectoring. However, a bitstream access must be offered in place of an unbundled local loop.

Challenges for measuring technology

Particularly in the introduction phase of VDSL2 vectoring, for which field tests will start in Germany in 2013, it is necessary to distinguish between the three VDSL2 operating modes currently commercially available.

Non vectoring

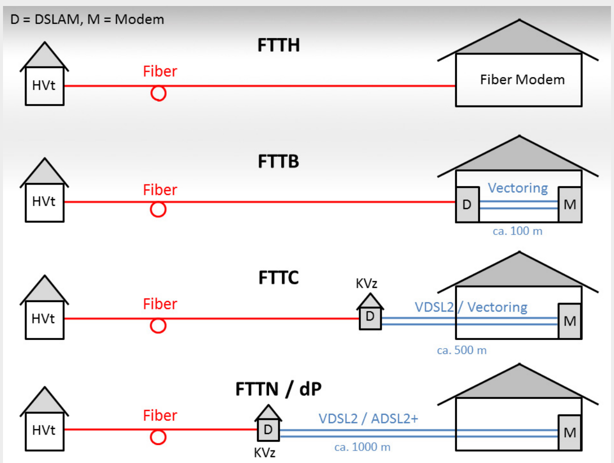
This is conventional VDSL2 with non-vectoring-friendly DSLAMs and modems. Mixed operation in which customers connect non-vectoring-friendly modems to vectoring-friendly DSLAMs is also conceivable. In this case, these customers are to be capped at the ADSL2+ bandwidth (max. 16 Mbit/s) in the frequency range up to 2.2 MHz.

Vectoring friendly

Particularly in the initial phase, modems with chipsets that are not fully vectoring-friendly, e.g. due to customer-loaded firmware upgrades, can avoid capping to ADSL bandwidths as they generate little interference on the vectoring bundle, but remain susceptible to crosstalk from other nearby pairs.

Full vectoring

Full vectoring operation requires vectoring-friendly DSLAMs and modems, which the network operator must first distribute in the field. Once the technology has been transitioned at both ends of the bundle, customers can enjoy the full range of advantages of VDSL.

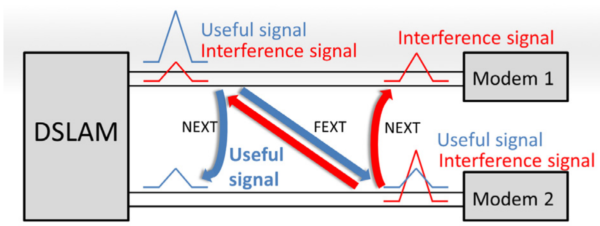


This necessitates a mobile DSL meter that detects and supports all three modes on site. In order to preclude interactions between full and non-vectoring in mixed-mode operation, the meter must be preconfigurable for simulating these three modes. It must also take into account the fact that that ADSL, ISDN and analogue telephony will remain possible. Although the crosstalk is relatively low here, suitable measuring technology is still required to ensure problem-free operation of ISDN and analogue telephony when connecting new VDSL2 v ectoring equipment as well.

However, the laws of physics still apply: Even short stub lines, as are still often embedded in building structures for analogue telephony, result in bandwidth loss and synchronisation problems. Consequently, when acquiring new vector measuring technology, it is important to make sure that the meter is equipped with a TDR function, in addition to ADSL, ISDN and POTS interfaces. The physical

How does VDSL2 vectoring work?

VDSL2 vectoring was specified in ITU standard G.993.5 in March 2010. In simplified terms, it works like this: For two active adjacent DSL lines, the useful signal on one acts as an interference signal on the other. Therefore, they impair each others' performance (Fig. 1). This effect, known as crosstalk, increases for each additional active local loop in this bundle - causing a signal mix that spreads itself over the entire VDSL bandwidth (up to 17 MHz for VDSL profile 17a) as blanket interference, which significantly degrades performance of both the entire bundle and (with considerable fluctuation) the individual lines.



Cross-talk = Near-end cross-talk (NEXT) + Far-end cross-talk (FEXT)

VDSL2 vectoring acts here by counteracting the crosstalk through the use of a vectoring-friendly DSLAM on one end and a vectoring-friendly modem on the other end. This enables the system to register all crosstalk signals concurrently and to calculate a compensation signal for each conductor pair in the bundle using sophisticated algorithms. This is applied phase-inverted (180°) to the useful signal, so that it cancels out the crosstalk interference. At the same time, this process results in a remarkable increase in performance levels; in other words, all customers receive a VDSL2 bandwidth that is only slightly below the theoretical laboratory maximum, instead of greatly fluctuating bandwidths. Upstream transmission at higher levels is now also possible on shorter lines, as these no longer interfere with the weaker signals on longer adjacent lines through high crosstalk - another reason why VDSL2 vectoring offers such impressive performance with respect to a maximum upstream bandwidth of up to 40 Mbit/s.

conductor quality of old copper lines also plays a role in the measuring technology: a- and b-conductors should be symmetrical with respect to one another and show a high insulation resistance. External voltages also prevent trouble-free operation, but can only be eliminated if they are detected on site using a meter.

Successful deployment depends on the right tools

The fact that VDSL2 vectoring differs from other DSL types in operation in that it requires longer synchronisation times can pose complications. This time is required for exchanging all information relevant for registering, calculating and generating the compensation signal during the handshake. Consequently, under certain circumstances it can take twice as long as is usual for VDSL until "showtime" status is achieved . This period can become even longer if parallel joining is set in a full-vectoring DSLAM. In this mode, modems synchronise in groups. If a modem - or a meter in modem mode - misses a group synchronisation, it cannot resynchronise until the next group. If the times add up unfavourably, synchronisation on a VDSL2 vectoring-friendly bundle can take up to several minutes.

That makes equipping telecommunications technicians and field engineers with suitable measuring and testing instruments even more important, so that they can reliably rule out faults here. The ARGUS combi-testers of intec GmbH, which are available in a range of variants to offer all functions necessary for precise measurement, present one such solution.

On the path to high bandwidths

When VDSL2 vectoring is combined with the VDSL2 bonding technology specified in ITU standard G.998.1/2/3 (G.bond), it is possible to realise not only higher bandwidths but also greater distances, thus making it possible to provide VDSL2 to more customers. To achieve this, at least two conductor pairs must be available for one customer, which is not always the case in Germany. Beyond that, the laboratories of the major DSL chip, DSLAM and modem suppliers are already hard at work on even more high-performance technologies, such as phantomising. In this method, the two conductor pairs from VDSL2 bonding are used to create a third, imaginary conductor pair to increase the data transfer rate even further - which goes to show that DSL is a long way from becoming obsolete, and that it will be some time before they're completely replaced by optical fibre. Enhanced through vectoring and bonding, DSL remains without doubt a competitive bridge technology.

Terms and abbreviations:

Term	Definition	Explanation
ADSL	Asymmetric DSL	DSL with unequal distribution of upstream and downstream capacity
DSL	Digital subscriber line	
DSLAM	DSL Access Multiplexer	Exchange-side terminator of DSL lines
FTTH	Fibre to the home	
FTTN	Fibre to the node	
IaaS	Infrastructure as a service	
ITU	International Telecommunication Union	
POTS	Plain Old System Telephone	Analogue telephone interface
Street cabinet	Cable distributor (grey cabinet)	
SHDSL	Single-pair high-speed DSL	
TAL	Local loop	Pair of copper conductors, DSL line pair
TDR	Time domain reflectometer	
UPBO	Upstream power back-off	Reduction in upstream performance
VDSL	Very high-speed DSL	
X-talk	Crosstalk	

This article was written in cooperation with the editorial office of the professional journal „de“.

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