Future-proof broadband:

SHDSL - appropriate data rate with long reach

Reliability, long reach and a high data throughput - this is what companies expect of a future-proof broadband technology.
SHDSL is a solution that meets these requirements. Its symmetrical structure allows simultaneous distribution of downlink and uplink. A special modulation technique with SHDSL ensures stability. With Enhanced SHDSL, a bandwidth of up to 6 Mbit/s over a distance of up to 8 km is feasible via four wire pairs.

SHDSL offers an attractive way

Today, full-coverage broadband connections are part of the indispensable infrastructure. This is particularly important for small and medium-sized companies. This is why commercial and industrial areas outside large cities as well need to be equipped as quickly as possible with fail-safe, stable broadband connections supporting distances of 6 to 8 km and allow data rates in the Megabit range dependent on wire cross-section (figure 1). In the interests of fast coverage, these connections may also be based on the existing twin copper wire infrastructure. Unlike private customers, companies frequently send large e-mail attachments, upload extensive quantities of data to servers or make several phone calls simultaneously. This is why downlink and uplink must have a symmetrical structure. In addition, existing E1 connections are to be switched off in the foreseeable future. Consequently, converting to a new solution will be inevitable for many companies and SHDSL offers an attractive way of meeting this symmetry demand.

SHDSL - ADSL - VDSL

SHDSL meets all these requirements (in accordance with ITU-T G.991.2). Unlike ADSL and VDSL, this DSL variant still provides adequate data rates even at distances of a few kilometres. SHDSL allows several telephone links in parallel and is even suitable for secure telecontrol, alarm and signalling functions with the aid of various mechanisms (e.g. a VPN tunnel) and performing them via the public data network.

The essential difference between SHDSL and ADSL and VDSL relates to the structure: SHDSL is symmetrical and ADSL and VDSL have an asymmetrical structure (figure 2). In the case of SHDSL, uplink and downlink have equal shares. This symmetry is important for applications in which many parallel voice links need to be set up (e.g. E1 connections or connections to mobile radio masts). The reason is that telephony requires the same broadband demand on the downlink and on the uplink, thus symmetrically loading e.g. mobile radio masts and other remote network components of a network operator in the same way as E1 connections.

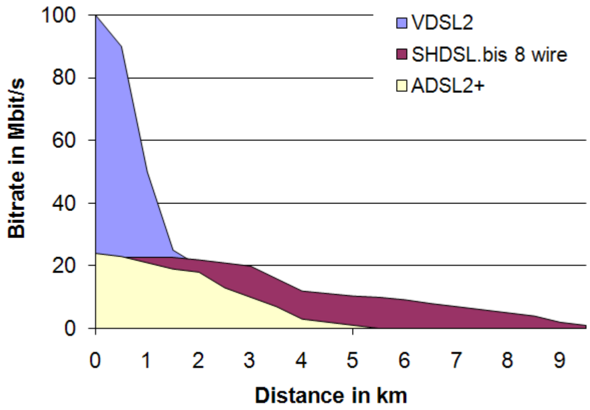

Figure 1: xDSL frequency spectrum.

Assuming excellent line characteristics and minimum distances, the standard ADSL2+ (in accordance with ITU-T G.992.5) allows a date rate of up to 24 Mbit/s on the downlink and a data rate of up to 1 Mbit/s on the uplink. With its higher downlink rates, ADSL is primarily suitable for the private customer. This is because downloading videos, images and website content requires a far larger bandwidth than a single telephone connection via VoIP or private e-mail traffic.

VDSL2 (in accordance with ITU-T G.993.2) can also be operated theoretically both symmetrically and asymmetrically by the network operator. Unlike the case with ADSL, several alternate uplink and downlink bands are used. The band allocation plan defines in what frequency bands a downlink and an uplink must be located. Symmetrically, bandwidths of up to 100 Mbit/s (profile 30 a) are conceivable in any direction. In practice however, it is primarily asymmetrical connection variants that are offered with 25 Mbit/s in the downlink and 5 Mbit/s in the uplink (profile 8b) and 50 Mbit/s in the downlink and 10 Mbit/s in the uplink (profile 17a).

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	G.SHDSL.bis	ADSL2+	VDSL2
Standard	ITU-T G.991.2	ITU-T G.992.5	ITU-T G.993.2
Precursor	IDSL, HDSL, HDSL2	ADSL, ADSL2	VDSL1
Down- & Uplink	symmetric	asymmetric	asymmetric
Synchronicity	asynchron	asynchron	asynchron
Transfer mode	ATM, EFM	ATM	EFM
Max. bit rate (1 line)	5.696 MBit/s	25 MBit/s	200 MBit/s (30a)
Range	7.6 km (2 lines)	4 km	1.5 km
Bonding	up to 4 lines	no	no
Bandwidth/frequency	up to 400 kHz	up to 2.2 MHz	up to 30 MHz
Type of modulation	16-/32-TC-PAM	DMT-QAM	DMT-QAM
Repeaters (SRU)	yes	no	no
DSL filter technology	no	yes	yes
FEC	no (TC)	yes	yes
EOC	yes	no	no

Figure 2: xDSL types in comparison.

into 64 kbit time slots and thus providing up to 36 B channels for telephony, since a maximum bandwidth of 2.304 MBit/s is supported by SHDSL.

Consequently, 4 B channels more than a classical E1 connection are offered, eliminating the need of a twin copper pair. The quality of telephony via these B channels corresponds to that of ISDN and can be exceeded only with difficulty. SHDSL-TDM is, admittedly, no longer fully up-to-date and many modern methods offer greater advantages. Nevertheless, it is still very widespread.

Bandwidths and frequency spectrum

Thanks to its special modulation method, SHDSL is far more stable and more fail-safe than ADSL and VDSL. In the case of ADSL and VDSL, the available bandwidth drops substantially with each metre as of a distance of 300 m. Thus, it is no longer possible to talk of a broadband connection as of a distance 4 to 5 km. The risk of connection breakdowns and packet losses also increases greatly that reliability is no longer guaranteed. The reduction in available bandwidth is plainly attributable to the fact that the loss of the tones used not only increases with line length but also depends on the magnitude of the frequencies used.
The higher the frequency, the higher too will be the attenuation. In the case of ADSL2+, the cut-off frequency lies at 2.2 MHz. By contrast, SHDSL manages with a cut-off frequency of 400 kHz owing to its special modulation method - less than a fifth. In the case of VDSL2, the maximum possible line length is shortened even more. The 8b profile uses a cut-off frequency of 8 MHz, analogous to this the 17a profile uses a cut-off frequency of 17 MHz and profile 30a uses a cut-off frequency of 30 MHz.

Other distinguishing features: Unlike ADSL and VDSL, SHDSL is not a splitter technology. Since SHDSL uses the entire frequency spectrum, it is not possible to use the lower frequency band that is used, in the case of ADSL and VDSL, for analogue or ISDN telephony to decouple voice and data services.
When specifying the SHDSL frequency spectrum, it was also ensured that very little crosstalk can occur to other connections - if at all. Consequently, it is possible to route SHDSL and other DSL variants in one cable bundle without mutual interference.

Applicability of SHDSL variants

SHDSL can be operated in three different applications. The TDM method is the obvious choice for cases in which only a digital standard fixed connection, e.g. where an E1 connection, is to be replaced. This special time-multiplex method makes it possible to split the available bandwidth

A second important method is ATM based on asynchronous time multiplexing like ADSL. This means that transmitter and receiver are able to run with different clock rates. Accelerated expansion of ADSL mean that larger parts of the backbone already use an ATM layer in order to transport partly packet-switched (IP) and partly line-switched (e.g. ISDN) data traffic optimally with only one transmission technology.
This allows ATM technology, by the introduction of an intermediate layer with cells of a fixed size (precisely 53 bytes), between the bit transmission layer and the data link layer. These cells are then loaded with the incoming data and prioritised with the aid of the AAL, a special adaptation layer. Data such as IP pakkets is transmitted in AAL5 and voice is transmitted in AAL1 or 2. This ensures that the voice information does not need to wait owing to the IP packets. The type, duration and other transmission information is stored in the 5-byte-large header so that the useful length of the cell is reduced to 48 bytes.
Owing to its various management functions (OAM) and adaptation capabilities (AAL), the method offers many advantages. However, today's conventional large data quantities result in a substantial overhead. Nevertheless, the SHDSL-ATM method that allows a bandwidth of up to 2.304 MBit/s over one twin copper wire is still the most widespread.

The current EFM method helps to reduce overhead and leads to a larger net data rate. EFM allows Ethernet frames to be transmitted directly without packing them in ATM cells. EFM is specified in IEEE802.3ah. The method passes the IP packets from the backbone over the last mile to the Ethernet devices at the costumer’s premises. EFM directly forwards the Ethernet frames from DSLAM to the customer modem and does not pack them into the smaller ATM cells.
This reduces the overhead produced with each data exchange by additionally managing headers and by packing the frames in and out of ATM cells. All three methods are currently still used; many network providers however are already migrating TDM and ATM to EFM.

Bandwidth tuning with Enhanced SHDSL

If we consider the two methods of ATM and EFM which are already designed for symmetrical transmission of larger quantities of data, we get the impression that the bandwidth of 2.304 Mbit/s is relatively low by comparison with the other DSL variants. However, this impression changes if we allow for the fact that the data rate can be increased still further by adding further twin copper wires. This bundling uses "byte Interleaving" that ensures that the individual bits of a data packet are transmitted via different wire pairs. This leads to greater security with respect to burst errors. After all, at least two twin copper wires, if not four, are available where E1 lines were in use to date. Thus, if one operates four pairs in parallel we already achieve a substantial data rate of up to 9.216 MBit/s.

This bandwidth can even be boosted still further: an extension of the existing ITU Standard G.991.2, also referred to as ESHDSL, allows an increase of the maximum bandwidth on one twin copper wire up to 5.696 Mbit/s, for instance, by means of trellis-coded pulse amplitude modulation (such as 32-TC-PAM). In the case of eight wires - i.e. four pairs - this achieves a total of 22.784 MBit/s.

This method referred to under the working title G.SHDSL.bis as a so-called bis-Standard was standardised in the Annexes Annex F and Annex G in G.991.2 by the ITU. In the case of ESHDSL with ideal line conditions, it is possible to ensure a bandwidth of up to 6 Mbit/s over a distance of 8 km. It is precisely this increase in performance that makes SHDSL so attractive for the requirements of the commercial customers, unlike ADSL and VDSL.

Increase in performance

SHDSL does, however, offer even further advantages. The use of two repeaters (SRU) which regenerate and forward the signal allows line lengths of up to 24 km in practise. Theoretically, up to eight repeaters can even be used. The repeaters are installed into the line and subdivide the overall section into up to nine individual segments each representing a type of single connection in itself.

The above-mentioned, bundled use of several wire pairs generally uses what is called bonding with byte interleaving. In addition, it is possible to select between the special IMA method, in the case of SHDSL-ATM connections, and the bonding method, defined in accordance with IEEE 802.3ah in the case of EFM connections. The advantage of this bundling relates to a substantial increase in stability. If one twin copper wire fails, the rest maintain the connection. Consequently, these two special methods mean that, if a link fails, there are still up to three links available. An advantage not to be underestimated - in particular in the case of safety-related telecontrol and alerting connections.

The origin of SHDSL and an overview of types of modulation

G.SHDSL, defined in ITU-T G.991.2, which is similar to the SDSL standardised in TS 101524 owing to ETSI, also already inherited symmetrical HDSL2. HDSL2 was, admittedly, already designed for using only one pair of wires but was able to make available only a maximum data rate of 1.544 MBit/s over a distance of approx. 3.5 km without repeaters. This corresponds to the performance of a T1 connection, the US-American counterpoint to the European E1 connection. This data rate of the single-pair HDSL2 was made possible by trellis-coded pulse amplitude modulation (TC or UC-PAM), used here for the first time on DSL, such as the 16-TC-PAM (4B1H) in which several bits are assigned simultaneously to one symbol.

By contrast with this 16-valent pulse amplitude modulation (PAM), we have the pulse code modulation (PCM) which was still used on the forerunners of HDSL2 - HDSL and IDSL (ISDN DSL) - with 2B1Q- (4 PAM) or 4B3T line coding also known from ISDN. The modulation technique of TC-PAM which is still used on SHDSL today does, admittedly, dispense with forward-directed error correction (FEC), e.g. in the form the 16 or 32-TC-PAM, but which uses, instead, trellis coding which also allows error detection by adding redundancy and thus ensures the continuously more stable performance increase, unless susceptible to errors, even in the case of fluctuating line characteristics.

This is one major advantage that makes SHDSL far more stable and, thus, more fail-safe than its predecessors and the asymmetrical ADSL and VDSL variants. Unlike the above-mentioned SHDSL modulation method, ADSL and VDSL use DMT (Discreet Multitone Multi-carrier Method). It splits the assigned frequency band into single channels and modulates the bit information by means of QAM (Quadrature Amplitude Modulation).

Test equipment for all SHDSL variants

The diversity of variants of SHDSL has its advantages but also leads to a greater complexity, primarily when commissioning and maintaining multi-pair systems. Simple measuring instruments and test aids quickly reach their limits when testing a 2, 4 or 8 wire interface or, in rare cases, a 6-wire interface.

Suitable test equipment covers multiple variants and simulates the required network components thanks to extensive setting options. Unlike ADSL or VDSL, this requires the option of STU-R and STU-C operation, particularly in the case of repeater application on SHDSL links (figure 3). The test unit should be able to simulate the CO end (Central Office) also, i.e. the DSLAM, so as to check the modem installed at the remote end or a repeater. It should be able to synchronise with the distant station in both operating modes and display the result of the comparison between STU-R and STU-C in a result log. In the handshake phase (in accordance with ITU-T G.994.1, G.hs), both sides swap capability lists and also convey important connection information (e.g. on so-called Power-Back-Off Mode or Line Probing).

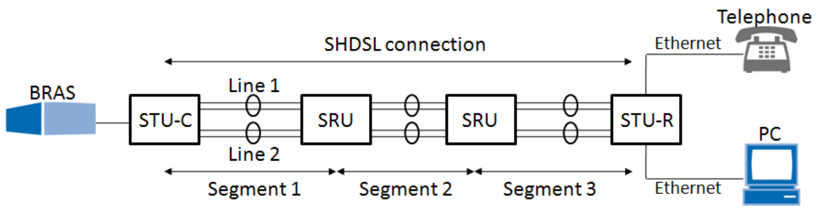

Figure 3: SHDSL access scheme.

In addition, what is also relevant is information on the data rate on any DC voltage and both loss and signal-to-noise ratio relating to the connection. Access to error counters may also be helpful for fault finding. Ideally, the measuring instrument will also evaluate information from the EOC - a special channel for exchange of connection information during the connection between CO and remote end. This information allows conclusions to be drawn as to the number of repeaters used on the section by station counting. If the SHDSL line has stopped operating, it is possible to exclude the very last doubts as regards operability of the connection via the broadband access server (BRAS) by means of PPPoE login. This allows data services to be subjected to a download test and an upload test. Voice services can thus be investigated in respect of their function and Quality of Service (QoS) by setting up a VoIP connection.

To date, there have only been a few mobile test units on the market providing the most important information and thus saving the technician a great deal of time. A very extensive SHDSL test spectrum is offered by the xDSL combination tester ARGUS 145 PLUS by intec, for instance, that is also designed for in-service tests. Besides SHDSL, it also has interfaces for ADSL and VDSL, in addition to ISDN and analogue. Certain hand-held testers made by intec even support E1 connections, quality assessments of IPTV and even cross-protocol and cross-interface voice quality tests.

Future-proof solution

Great efforts are currently underway to make SHDSL even more powerful, more stable and more secure. A new EFM variant has recently been available, offering further developed analysis mechanisms, noise suppression techniques and error correction functions so as to further boost performance. A 128-TC-PAM for SHDSL which is to take the wind out of the sails of the "old twin copper wires" as regards data rates, is already in sight. Consequently, there is massive investment in SHDSL - and there is good reason for this. This is because the standard allows fail-safe, stable broadband connections for data rates in the Megabit range. Consequently, SHDSL is the solution of choice if you wish to make the corporate broadband network future-proof. Many network operators have already recognised this trend and offer SHDSL solutions tailor-made for customers at favourable terms.

AAL	ATM Adaption Layer
ADSL	Asymmetric DSL
ATM	Asynchronous Transfer Mode
CuDA	Twin copper wire
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer
E1/T1	Form of primary multiplex connection
EFM	Ethernet in the first mile
EOC	Embedded Operations Channel
ESHDSL	Enhanced SHDSL / SHDSL.bis standard
HDLC	High-Level Data Link Control
HDSL	High Datarate DSL / High Datarate DSL 2
IMA	Inverse Multiplexing over ATM
IPTV	Internet Protocol Television
ISDN	Integrated Services Digital Network
OAM	Operation, Administration and Maintenance
PAM	Pulse Amplitude Modulation
PPPoE	Point-to-Point Protocol over Ethernet
SDSL	Symmetric DSL
SHDSL	Single-Pair High-Speed DSL
SRU	SHDSL Regenerator Unit
STU-C/R	SHDSL Transceiver Unit-Central Office/Remote
TC-/UC-PAM	Trellis-Code/Unger-Böck-Code-PAM
TDM	Time Division Multiplex
VDSL2	Very High-Speed DSL
VoIP	Voice over Internet Protocol
BRAS	Broadband Remote Access Server

Figure 4: Glossary.

About us

intec Gesellschaft für Informationstechnik mbH is developing high-quality products for the international telecommunications market for more than 20 years and is one of the leading suppliers of xDSL, ISDN and IP measurement technology in Europe. The successful ARGUS measurement equipment enables its users to conveniently and safely commission and troubleshoot xDSL and ISDN accesses as well as those services that are based on these interfaces such as VoIP and IPTV. ARGUS testers are designed to meet the day-to-day needs of staff in the field; consequently intec engineers focus on ensuring high-quality measurement in a compact device that is exceptionally uncomplicated to use. The portfolio of ARGUS testers, software and analysers benefits from progressive development and is kept up-to-date with support for the latest standards for all the common access types and protocols as well as for the newest features of the Next Generation Networks (NGN) and Triple Play.
Throughout the world, numerous telecommunication companies have come to appreciate and rely on the advantages offered by intec equipment; to name just a few Deutsche Telekom, Saudi Telecom, Telefonica, KPN, British Telecom and Telekom Austria.

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