

SHDSL cable testing using WeConfig

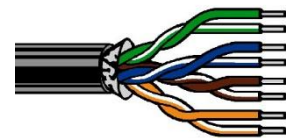
Introduction

The DDW devices from Westermo are designed to reuse existing cable infrastructure for the transmission of full duplex Ethernet at a data rate of up to 15.3Mbit/s on a single pair. Higher data rates of up to 30Mbit/s by combining 2 pairs, please refer the DDW-142 and DDW-225/6 guides for further details. To achieve the best performance, the cable pairs should be twisted. Cable used for RS-485, telecoms or cabling used for bespoke data buses such as PROFIBUS, DH-484, MODBUS PLUS or DH-485 are all ideal. It is possible to reuse non-twisted cores found in multicore cables or DH+ bi-axial cable. However, it is strongly recommended when considering using non-twisted pairs that each cable section is tested as detailed in this document, to check the performance before use.

This document outlines how WeConfig (version 1.4 or later) software tools can be used to verify the suitability of a cable when using SHDSL. The SHDSL technology was originally designed to deliver high speed data over existing POTS (Plain Old Telephone System) cabling. The POTS cabling is typically a twisted pair, however non-twisted multicore cables can be reused for the transmission of SHDSL. This document will give specific guidance when using non-twisted pairs as this cable type was not originally designed for the purpose of data or voice transmission.

Cable definition twisted pair

In twisted pair cabling pairs of conductors are twisted together for the purposes of cancelling out electromagnetic interference (EMI) from external sources; for instance crosstalk between neighbouring pairs. This type of cable is considered to be ideal for using with SHDSL.



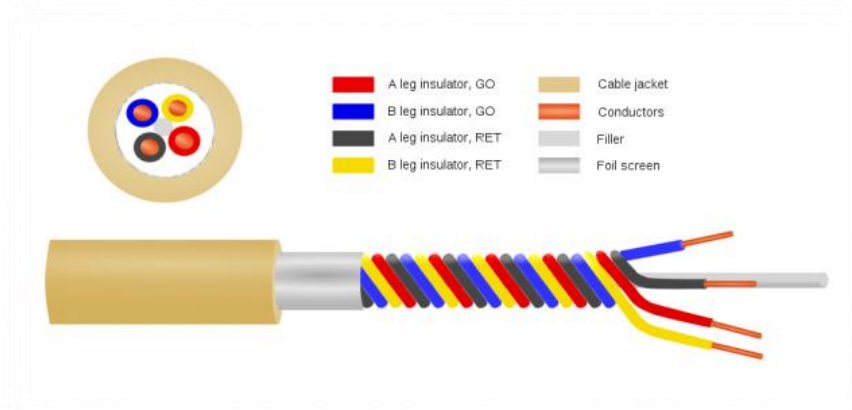
Using SHDSL over multicore cables

SHDSL technology was originally designed to operate over twisted pair telecommunication cables to deliver higher data rates than conventional modem technology over POTS cables. In some legacy upgrade situations, the installed cables were designed to carry simple switched DC voltages inside a multicore cable, so there was no need for twisted pairs. The lack of twisted pairs does not mean that SHDSL will not work over a multicore cable, however the rate and reach may be reduced. The lines will be prone to pick up more electrical noise than a twisted pair, due to the pair used being unbalanced.

Where there is no other choice but to use multicore cables, it is advisable to test each core before installation, as the characteristic will vary depending on the position of the individual core within the bundle and any other signals present on other cores. The time spent testing should be seen as a long term investment as the reliability of the complete system will be increased leading to a net decrease in the whole life maintenance and operation costs.

Multicore with a quad inner

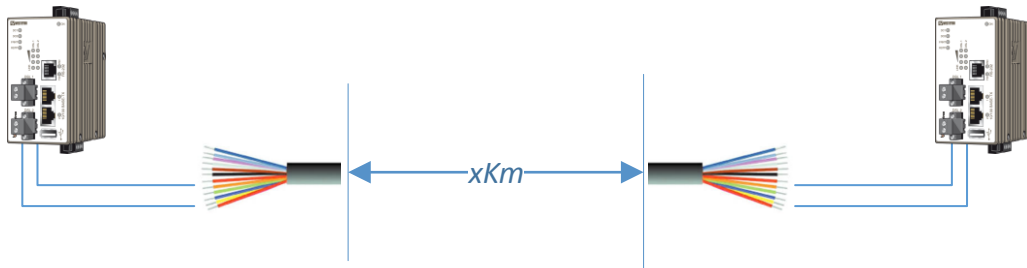
When using multicore cable, it is worth taking a close look at the inner four cores. These cores are sometimes closely twisted together and may have a screen around them. This is often termed a *quad* and is intended for use with voice communication. The *quad* cores are ideal for use with SHDSL and will give at least the same performance as a regular twisted pair. Unlike any other type of cable construction the pairs can be connected in parallel to for a single pair presentation.



In the above, cable Red - Blue are joined and Black – Yellow are joined. The tight winding around the central filler gives the cable its exception noise immunity characteristic. When, making the cable off, it is important to keep the conductors the same length and keep the unwound length to a minimum.

Testing multicore cables

When testing SHDSL over a multicore cable, ensure that the same pair of cores are used in the final installation, as the position of the cores within a multicore will give different results depending on the cross talk and level of noise that may be present in the cable.

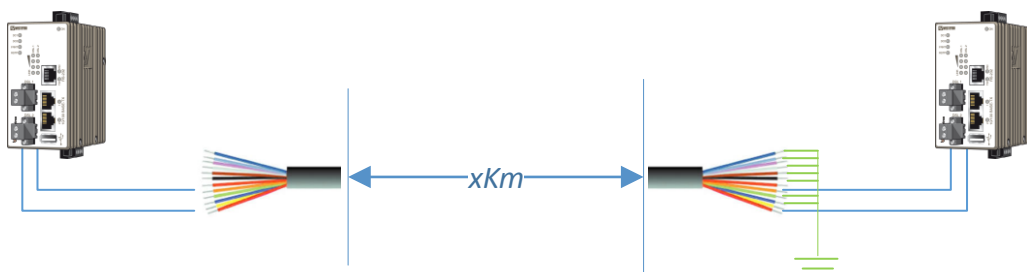


Never use two adjacent cores for SHDSL as the crosstalk will be extremely high. In extreme case, the crosstalk will prevent a successful connection from being established. Selecting cores on either side of the cable will yield better results when using non-twisted pairs. The presence of other signals in the cable such as AC power or switched DC can also create interference. Therefore, consideration should be given to testing the cable over a prolonged period so that all events that might affect the performance of the connection are present for at least some of the test period.

A test that yields an unsatisfactory result does not mean that a reliable connection can never be established, often selecting a different pair of cores further apart within the cable will yield a stable result.

Improving results

Results can sometimes be improved by earthing one end of the unused cores within a multicore. It is important that only one end of the cable is earthed or a circulating earth current could be introduced through the cable. The circulating earth will have the net effect of introducing noise and make communications almost impossible. This is also true for systems using twisted pairs.



What not to do to improve results!

Since the CSA (Cross Sectional Area) of the cores has a very large influence on the rate and reach it would seem logical to use multiple cores in a cable joined together to increase the CSA. Never be

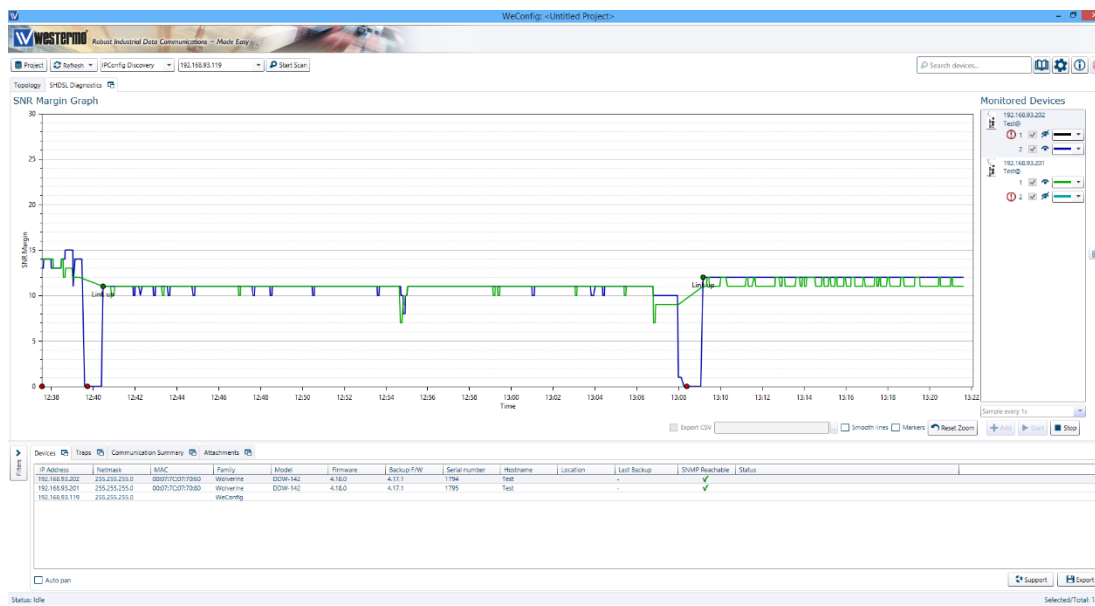
tempted to double up the cores to increase the CSA to gain extra performance, doing so will create unpredictable reflections and crosstalk within a twisted or non-twisted multicore cable. The Exception to this rule is the QUAD cores (see Multicore with a quad inner, above).

Cable testing.

There are dedicated xDSL cable testing equipment available that will give a high level of detail about the signals and the performance of a copper pair. The results can be hard to interpret and not give a clear indication as to the long term reliability of the connection. Alternatively, the Westermo WeConfig (1.4 or later) software tools can be used to test and record the performance of the line under test. Using WeConfig has the advantage of being able to capture and plot the performance of a line over a prolonged period of time.

WeConfig SNR monitoring

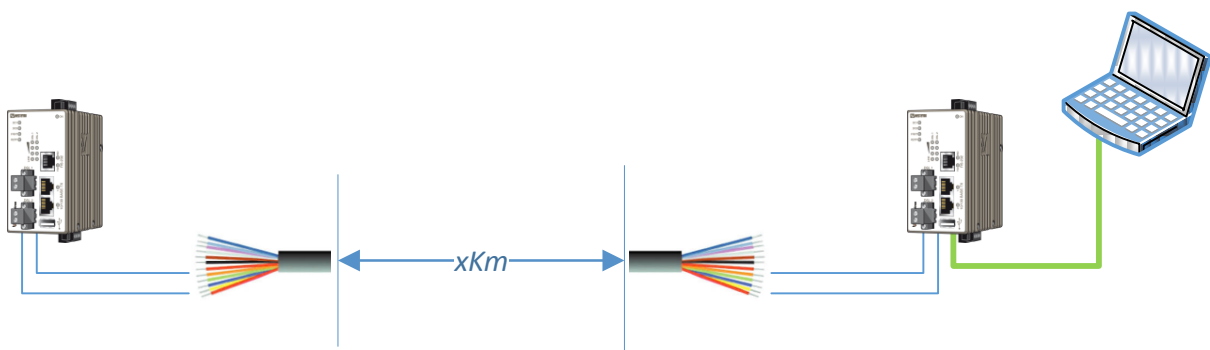
The SNR monitoring built into WeConfig can be used to measure and track the changes of the SNR value using the WeOS managed DDW devices. WeConfig offers more flexibility to monitor the SNR than the older DDW-Tool as it uses SNMP to retrieve the values from the device over the IP management interface.



WeConfig can be connected locally to the WeOS managed devices or remotely via a suitable L3 secure VPN connection such as WeConnect. The logging of the SNR data when using the Ethernet connection to the network opens up the possibility of leaving WeConfig monitoring a line from anywhere on the network. Unlike the previous DDW-Tool, more than one device at a time can be monitored by WeConfig simultaneously either by a local Ethernet connection or from a central location.

Setting up

The managed DDW devices and WeConfig can be used to monitor the performance of a twisted pair or multicore connection. Using the DDW devices has the advantage of using the actual equipment that will be deployed in the final application. WeConfig can be left to log and trend the SNR present in the cable for as long as desired or there is available hard drive space for the log file. For example, the test system can be left in place for 7 days to ensure that day to day conditions the multicore is subjected to over a normal working week and the weekend do not cause the communications to be unreliable. The long term test may point to the need to drop the configured data rate due to periodic noise when a pump starts or a train passes down a little used track.

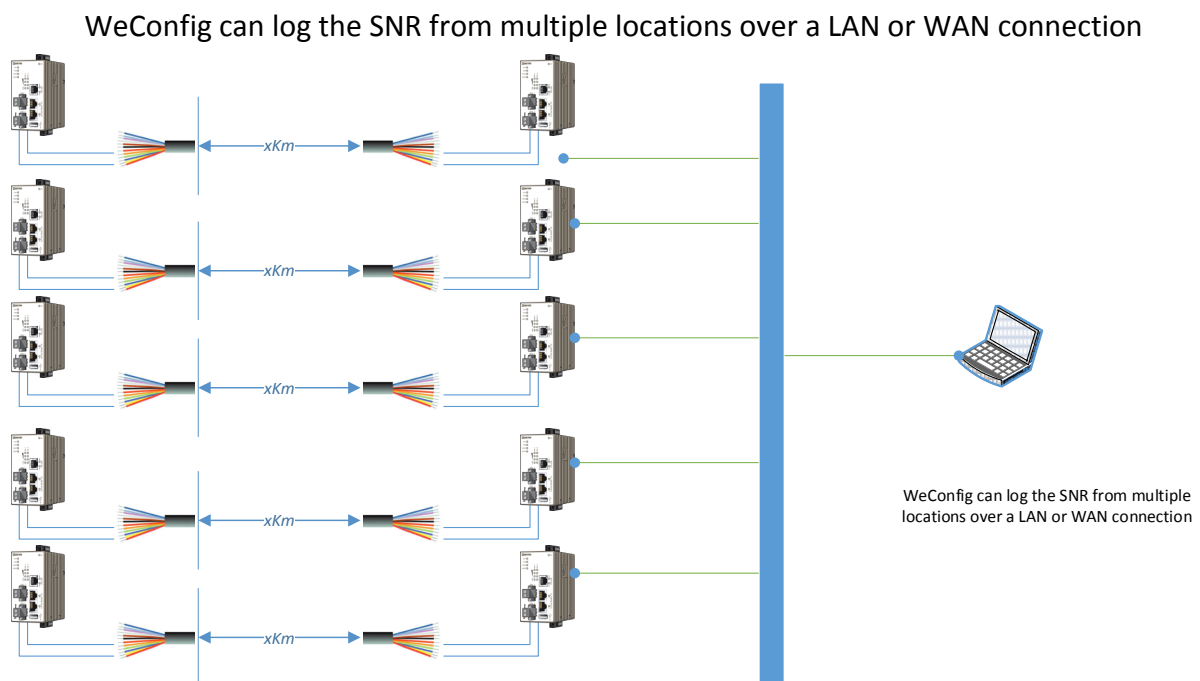


WeConfig interfaces to the managed DDW device via the IP interface in each unit. This means that all the DDWs in a system need a unique IP address. The devices do not have to be on the same subnet, but can be on a L3 wide area network. The WeConfig software can be used to discover managed new out of the box DDW devices and assign unique IP addresses and backup the configuration. It is outside the scope of this document to show how to fully configure a managed DDW, for more information refer to www.westermo.com for the WeOS configuration manual.

Monitoring multiple locations

The WeConfig tool is not limited to monitoring a single device or line but can be used to monitor multiple devices simultaneously over an extended period of time. To monitor the DDW devices remotely some sort of wide area connection is required. This will most likely require the gateway address to point to the local router. The output from the monitoring is stored in a CSV file and can be used with applications such as Excel to display or analyse the data.

The display of the SNR can be filtered to show one or more of the monitored connections live. The ability to monitor multiple lines reduces the time required to test and report.



SNR and reliable communications.

All the DDW range of devices support auto-negotiation on the SHDSL line and can be configured for different minimum line SNR. The objective should always be to establish a reliable connection with a good SNR rather than the highest possible bit rate with a low SNR.

The SNR modes are defined as reliable, normal and fast;

- Reliable is a 10dB difference
- Normal is a 6 dB difference
- Fast is a 3 dB difference

The greater the difference between the signal and the standing noise on the cable, the greater the reliability and tolerance to disturbances.

Using auto negotiation on a new line will give an indication of the maximum data rate a line will be able to support. In most use cases reliability as opposed to the maximum data rate is the most important factor. The automatically negotiated data rate should be seen as a starting point. The operational data rate should be set manually to a level one or two steps below e.g.

The auto negotiation may settle on a data rate of 6,200Kbit/s. Setting the line rate to 5,376 Kbit/s will still give a good line rate but also delivers a greater SNR, making the line more reliable and doing so increase the availability. It is strongly recommended that the target should be for a lower more reliable data rate.

SHDSL Spectrum usage

SHDSL is a baseband technology and uses a very wide frequency spectrum up to 2.55MHz @15.3Mb. A typical legacy modem using V.32 or V.34 modulation would use 300-4000Hz (POTS system voice band) by comparison.

As with all communications using RF signalling, the signal is attenuated over distance and the higher the frequency the greater the attenuation. The net effect is the rate and reach will drop over distance. The effect of the attenuation can be seen in the SNR dropping over distance as the level of usable signal drops in comparison to the background noise on the cable under test. Configuring a lower data rate between the DDWs will reduce the frequency range the SHDSL protocol will demand from the cable. In doing so, the very high frequencies which are more attenuated over distance will no longer be used, leaving the less heavily attenuated part of the spectrum to carry the SHDSL protocol and in doing so will increase the SNR value. The Reach calculator described later can be used to give a prediction of data rate a cable with a given CSA (Cross Sectional Area) will be able to carry.

The relationship between the data rate and the frequency range present on a cable can be calculated using the following formula;

$$\text{Bitrate} + 8192 \text{ (overhead constant)} / \text{"number of bits per symbol"}$$

"Number of bits per symbol" is according to the PAM (Pulse Amplitude Modulation) mode used in selected speed.

- <= 2.3 Mbit/s: PAM16 = 3 bits per symbol
- <= 5.7 Mbit/s: PAM32 = 4 bits per symbol
- <= ~10 Mbit/s: PAM64 = 5 bits per symbol
- <= 15.3 Mbit/s: PAM128 = 6 bits per symbol

Example:

$$(192000+8192)/3= \sim 66000 \text{ Hz}$$

The used spectrum will be from DC – 66 kHz.

At data rates of 15.3 Mbit/s, the spectrum will be: $15,300,000 + 8192 / 6 = 2.55 \text{ MHz}$

The used spectrum will be up to – 2.55 MHz

The calculated frequency range is an approximation. Under certain conditions.

Note: under certain scenarios the PAM encoding could be lower or high than the rates indicated above this will have an impact on the frequency range e.g.

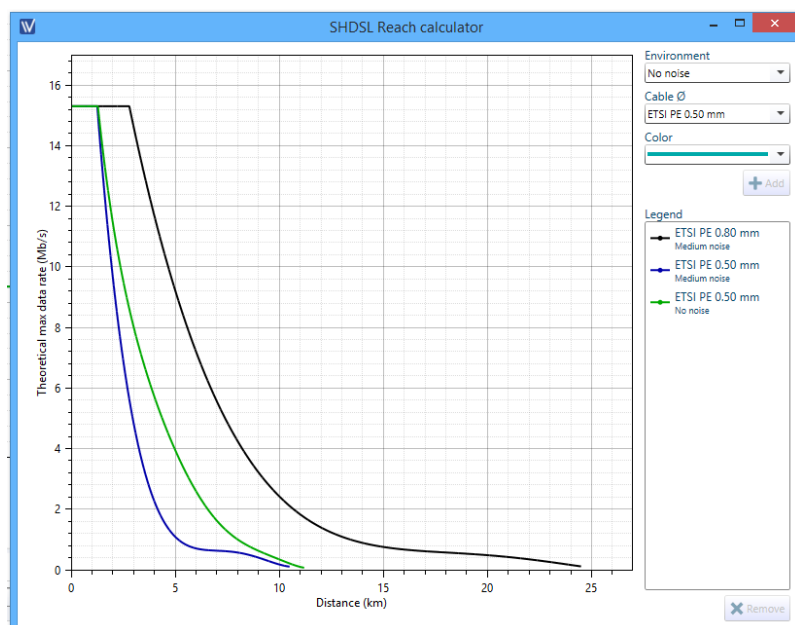
$$10,000,000+8192 \text{ at } 5 \text{ bits per symbol} = 2 \text{ MHz}$$

$$10,000,000+8192 \text{ at } 6 \text{ bits per symbol} = 1.66 \text{ MHz (fixed data rate and a very quiet background noise level)}$$

Knowing the frequency spectrum can be useful when working out if existing lightning or isolation transformers are compatible with the SHDSL signals. This is often overlooked and can be the source of an unexpectedly low performance over a line. The majority of the line isolation transformer are designed for a POTS frequency range of 300-4000Hz. The design of the transformer will disproportionately attenuate the higher frequencies. See the Surge and lightning protection section for more details.

Reach calculator

The rate reach calculator built into WeConfig can be used to decide on a starting value for the manual line rate selection. The calculator gives an indication of the possible data rate and distance a line will reliably sustain when using a cable of a given CSA (Cross Sectional Area). The environmental noise expected can be adjusted to give a more realistic result.



The reach calculator is designed to give an indication for the likely performance of SHDSL on twisted pair cables. If the target cable is a multicore, there will be a great deal of variance depending on which core are selected and where they are positioned in the cable in relation to other signals that may be present.

EMF (Emergency Freeze)

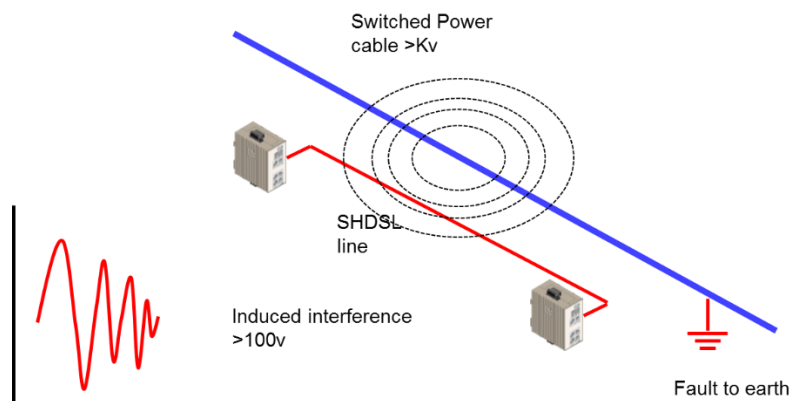
As with any communications that use modulated analogue signals to transmit data over a copper pair, there will be a possibility of external noise interfering with the transmission. The SHDSL protocol used to modulate the data has multiple mechanisms to detect and correct any errors caused by interference or corruption of the baseband signals. However, if the interference continues for too long or the level of corruption overwhelms the error correction, then the synchronisation between units will be lost. Normally, this would force a renegotiation of the link between the DDW units. To help overcome the short duration glitches on the line, the managed DDW devices support emergency freeze. The emergency freeze triggers when the communication between two units has broken down due to a loss of synchronisation. The last known good synchronisation values are frozen in memory. After the glitch or burst of noise has passed, the DDW units will attempt to re-establish the link using the frozen values. The difference this makes is to potentially limit a break in communications to a few milliseconds or tens of milliseconds, as opposed to a full renegotiation, which could take 60 seconds or more. The emergency freeze is enabled as default and rarely, if ever, needs to be disabled.

Failure to negotiate

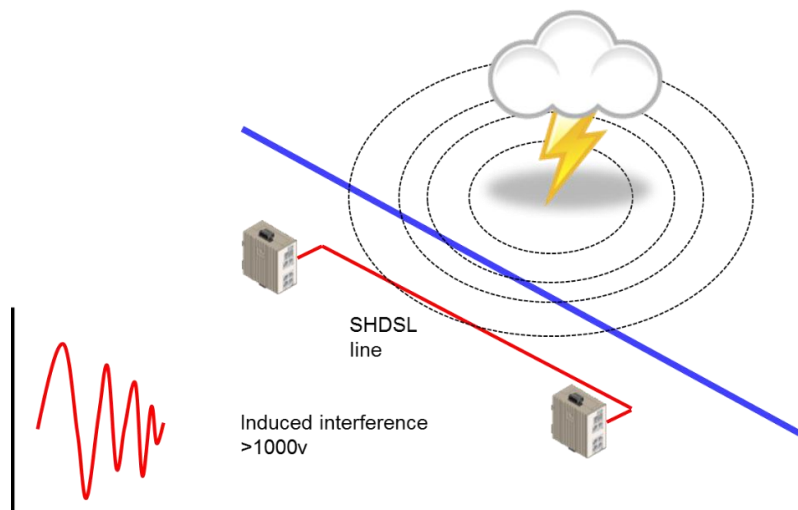
In some cases, the DDW units will not be able to establish a connection. This may be due to the core or cores selected being faulty or the line having a particularly high level of background noise. DDW units can do nothing about a faulty cable, but the managed versions can be adjusted to compensate for the noise level on the cable. A failure to negotiate is most likely due to a “quiet” period not being detected after the initial G.hs probe tone has been sent by one of the DDW units to the unit on the other end of the line. During the negotiation, a sequence of tones are exchanged between the units to detect if there is a unit at the other end and the SNR of the line. A high level of background noise during the test phase means that no quiet period is detected and the negotiation is halted while the DDW retries the probe (G.hs) tone. Where the noise floor of the cable is at a higher level than the pre-set, the G.hs quiet period detection can be adjusted to cope with this high level of noise using the G.hs threshold setting. The level can be set using CLI, GUI or using WeConfig 1.4 or later, on the managed DDW device. Adjusting this parameter should be seen as the last resort after all other means of establishing a connection have been tried.

Surge and lightning protection

As with all cables between two geographic locations, there will be voltages induced into the cable from external sources. Normally, this can be seen as the base level of interference or background noise on the cable. Under some circumstances, such as a fault condition on the local electricity grid, the energy induced in the cable can be much higher than the normal background. This is particularly the case in the railway environment, where it is entirely possible to induce 10s to 100s of volts in the cable.



Lightning strikes are also a source of interference and can potentially cause catastrophic damage to the line interface and even connected equipment.

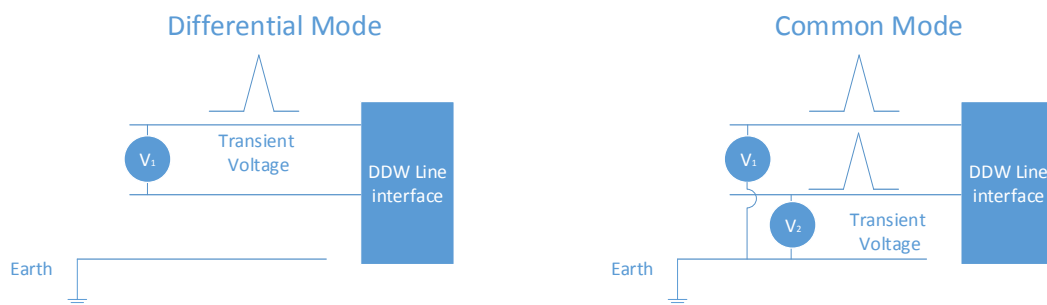


TBU (Transient Blocking Unit)

The DDW range of device have a state of the art TBU and Gas discharge on the line interface. However, this should not be confused with lightning protections or protection against all type of

surge conditions that can occur on a cable. The TBU will very effectively protect against Differential mode, also known as Transverse, Normal or Metallic modes. This is where the potential on one of the conductors in a pair will rise in respect to the other.

The inbuilt protection will have little or no effect on Common mode, also known as Longitudinal mode type surges. This is where the potential on both conductors rise by the same amount simultaneously.



It is strongly recommended that external line protection units are always installed where lines are running between two geographic locations. The cost of the protective devices is far smaller than the cost of a replacement DDW or the system down time.

External surge suppression devices

To mitigate the effects of a Common mode, or differentially induced high voltages from a lightning strike or induced surges, an external protection device can be fitted to each end of the line. The selection of the correct device is important as a device with the incorrect characteristics will clip or degrade the signal. See the required characteristics below.

Required characteristic:

- Must have a line clamping voltage above 15 Vpp “Volts peak to peak” (SHDSL signal can be as high as 12 Vpp)
- Dynamic frequency range up to ~2.55 MHz

There are many devices of this type available from;

- DEHN
- FURSE
- ADC
- TYOCO
- 3M

The following units can be used from DEHN.

Up to 5.7Mbit/s:

- BXTU ML2 BD S 0-180 (2-wire)
- BXTU ML4 BD 0-180 (4-wire)

Up to 15.3Mbit/s

- BXT ML4 BD HF 24 (4-wire)



Singularly the most important point is to ensure that the suppression device is connected to a good low resistance earth point, meeting the suppliers' cross sectional area requirements.

NOTE: The protection devices will give protection against a near strike, but there is very little that can be done to mitigate a direct lightning strike on the cables or installation. In areas where lightning is a common occurrence, consideration should be given to airborne lightning suppression using lightning conductors.

Hot site isolation

Where the DDW is located in a high voltage substation (hot site), it is recommended that a 10-15 kV line isolation transformer is installed. The isolation transformer not only protects the equipment but also anybody who might be testing or maintaining the line during a fault condition. There are very few hot site isolation transformers that are capable of passing the frequency range required for SHDSL. The majority of the line isolation transforms are designed for a POTS frequency range of 300-4000 Hz. The design of POTS transformer will disproportionately attenuate the higher frequencies and result in unexpectedly poor performance.



A suitable hot site isolation transformer is available from;
Kenton Research
LIU102A and LIU202A
Line isolation up to 15 kV

The use of isolation transformers will add losses by 3 dB per transformer. Since the loss is close to linear, the background noise and signal will be affected equally so the SNR should remain the same.

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WeConfig software can be downloaded from the following location;

[WeConfig Download](#)