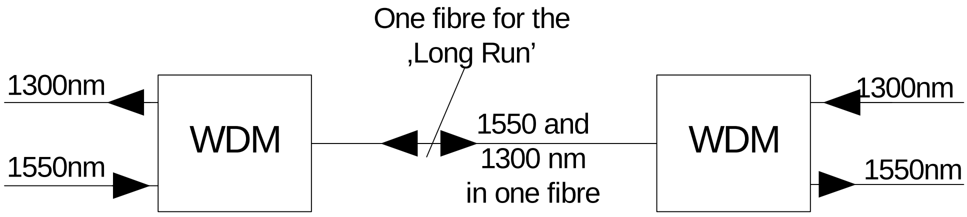
Scope: Using Wave Division Multiplexing (WDM) for the Protection Data Interface (PDI) of the 7SD5 / 7SD61.

Two important issues related to differential protection are the reliability and the cost of the communication between the relays. There is no doubt that a direct fibre optic communication has the highest reliability in respect of environmental aspects, i.e. EMC, ESD etc. the drawback of the direct fibre optic communication is the cost per fibre.
This application note describes a method of 'sharing optical fibres' to minimise the cost of the communication for a differential protection scheme by using WDM technology.

Principle:
WDM has the capability to separate two or more optical wavelengths. In our case we are only looking at the two wavelengths 1300nm and 1550nm (simple WDM and not C-WDM). Usually WDMs are passive optical components i.e. there is no need to connect an extra power supply.
A principle diagram of a WDM connection is shown in the following sketch:



This application describes two general applications:

- The connection via the fibre optic converter 7XV5461-0Bx00
- The direct fibre connection of the 7SD5 / 7SD61

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The connection via the fibre optic converter 7XV5461-0Bx00

The 7XV5461-0Bx00 combines two Protection Data Interface (PDI) channels (two pairs of optical fibres) into one fibre optic channel (one pair of optical fibres) for the 'long run'.
By using the WDM technology it is possible to combine two 7XV5661-0Bx00 for the 'long run'. With this constellation one 7XV5461-0Bx00 is operating at 1300nm (7XV5461-0BH00) and the other one is operation at 1550nm (7XV5461-0BJ00).
The following diagram shows the general application:

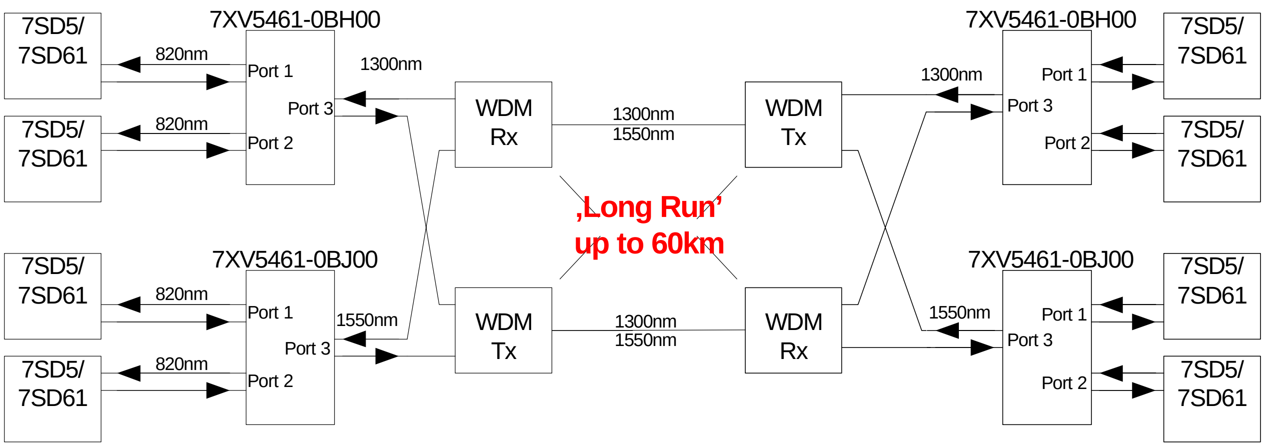

Figure 1: WDM with 7XV5461 providing four PDI with two optical fibres

Attention:
According to figure 1 the optical interface of the 7XV5461 **must consist of matching pairs** at the two line ends, i.e. 7XV5461-0B**H**00 ↔7XV5461-0B**H**00; 7XV5461-0B**J**00 ↔ 7XV5461-0B**J**00. The optical interfaces of the 7SDs are the same, FO5 820nm.

The next application shows how to combine two PDI-Channels onto only one optical fibre for the 'long run'. Hereby the effect is used that the receiver of the 7XV5461-0Bx00 has a wide band receiving characteristic, i.e. a 1550nm receiver has the capability to receive 1300nm wavelength signal and vice versa.

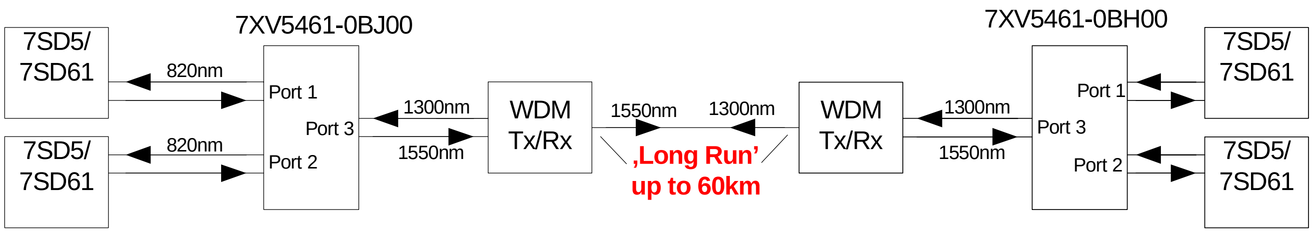

Figure 2: WDM with 7XV5461 providing two PDI with one optical fibre

Attention:
According to figure 2 the optical interface of the 7XV5461 **must consist of non matching pairs** at the two line ends, i.e. 7XV5461-0B**J**00 ↔ 7XV5461-0B**H**00. The optical interfaces of the 7SDs are the same, FO5 820nm.

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The direct fibre connection of the 7SD5 / 7SD61

The PDI of the 7SD5 / 7SD610 (FO18, 1300nm and FO19, 1550) has the same optical characteristics as the 7XV5461-0Bx00 (7XV5461-0B**H**00, 1300nm and 7XV5461-0B**J**00 1550nm). By using the WDM Technology it is possible to connect the PDI Interfaces of the 7SDs directly. The following sketch shows the principle.

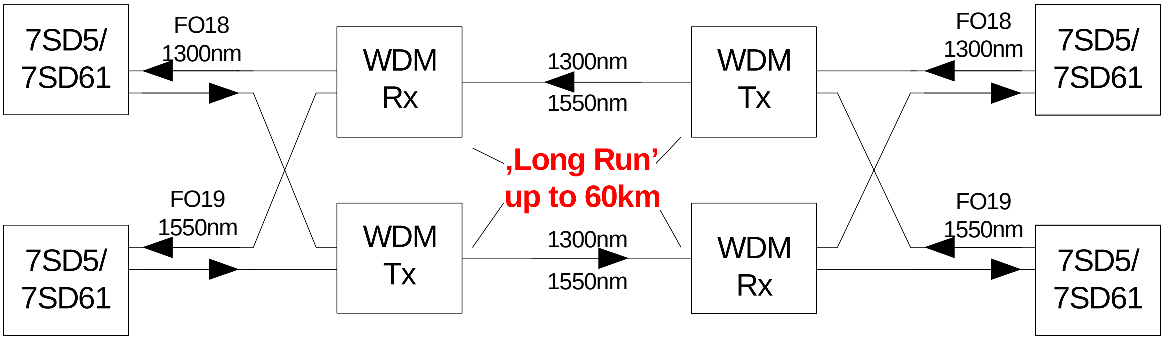

Figure 3: WDM with two PDI and only two optical fibres

> **Attention:**
> According to figure 3 the optical interface of the 7SDs **must consist of matching pairs** at the two line ends, i.e. FO18 ↔F018; FO19 ↔ FO19.

Analagous to the one optical fibre connection for the 7XV5461-0Bx00 (Figure 2) it is also possible to do the same directly with the PDI of the 7SD5 / 7SD610. The following sketch shows the setup.

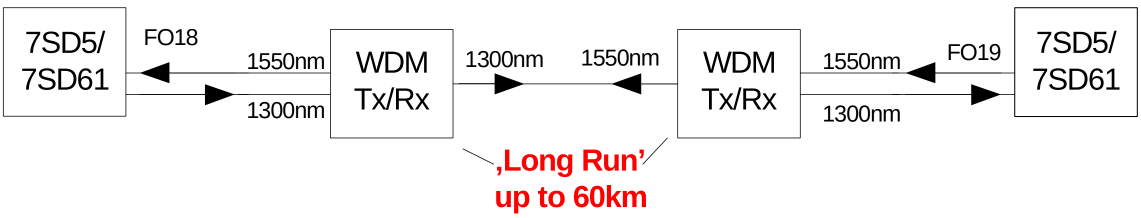

Figure 4: WDM with one PDI and only one optical fibre

> **Attention:**
> According to figure 4 the optical interface of the 7SDs **must consist of non matching pairs** at the two line ends, i.e. FO18 ↔ FO19

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The choice of the WD-Multiplexer (WDM):

A Wave Division Multiplexer (WDM) has the following functions:

1. A WDM combines two or more different wavelength from two optical fibres into one optical fibre or
2. A WDM separates two or more wavelengths out of one fibre into two or more fibres with one specific wavelength.

In general a WDM has three important parameters:

- The insertion loss [dB]
- The isolation (cross-talk) [dB]
- The directivity (rejection) [dB]

The following sketch shows the behaviour:

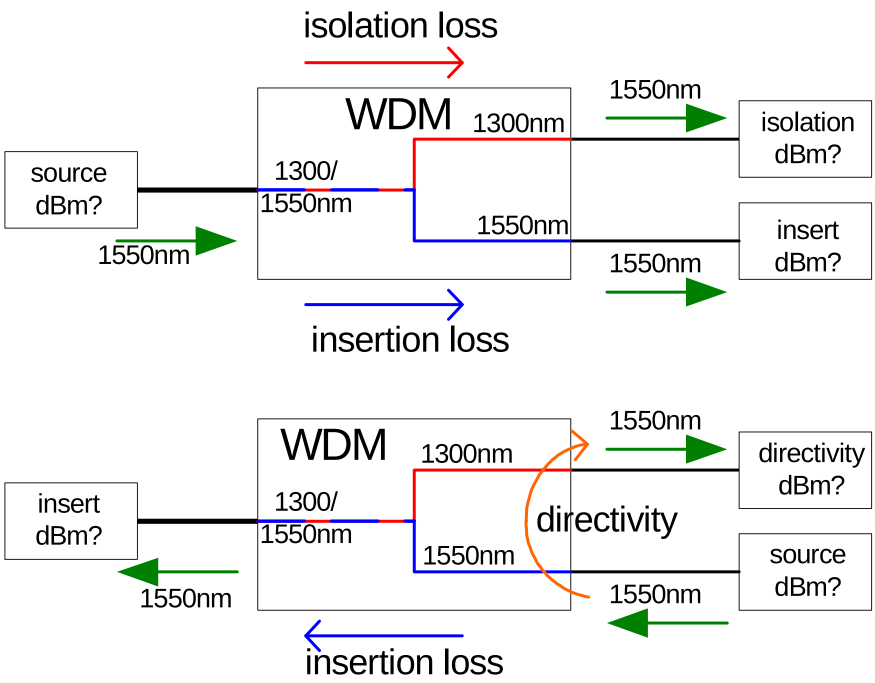

Figure 5: Characteristic values

When a WDM is used the user has to ensure two important things:

1. the transmission level of the ‘wanted wave length’ is high enough, so that the receiver has the possibility to receive the signal (Transmission Check)
2. the transmission level of the ‘not wanted wave length’ is low enough, so that there will be no crosstalk between the two wave lengths (Cross-talk Check - Isolation or Directivity)

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The following sketch shows the general checks for a fibre optic transmission with WDM.

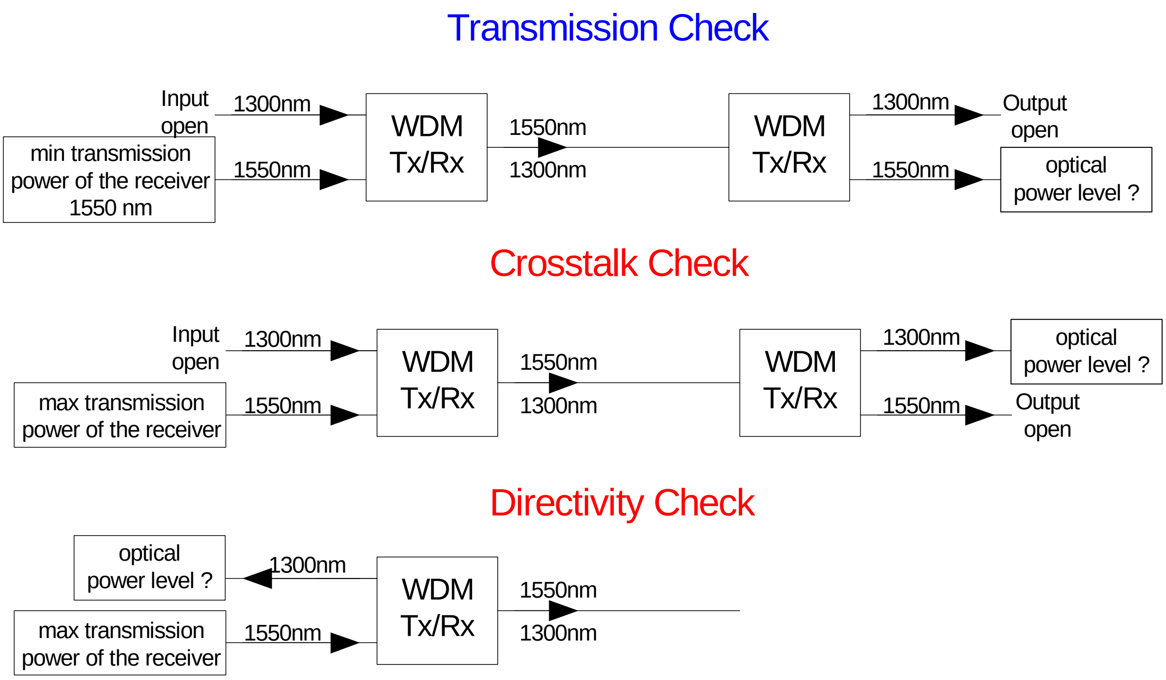

Figure 6: Principal Checks

In the above sketch the shown transmission, crosstalk and directivity check is only done for one wave length (1550 nm). The user also has to do the check for the other wave length 1300 nm.

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A calculation example for fibre optic connection with WDM:

The following technical data are taken from the 7SD5 / 7SD610 or from the 7XV5461-0Bx00 User Manuals.

	7XV5461-0B**J**00	FO 19	7XV5461-0**H**00	FO 18	7XV5461-0**G**00	FO 17
Opt. Wavelength	1550 nm	1550 nm	1300nm	1300nm	1300nm	1300nm
Transmitting power coupled in single mode fibre max (min)	**0dB$_{avg}$** (-5dB$_{avg}$)	**0dB$_{avg}$** (-5dB$_{avg}$	**-0dB$_{avg}$** (-5dB$_{avg}$)	**-0dB$_{avg}$** (-5dB$_{avg}$)	**-8dB$_{avg}$** (-15dB$_{avg}$)	**-8dB$_{avg}$** (-15dB$_{avg}$)
Receiver sensitivity max (min)	34dB$_{avg}$ **(-34,5dB$_{avg}$)**	34dB$_{avg}$ **(-34,5dB$_{avg}$)**	-34dB$_{avg}$ **(-34,5dB$_{avg}$)**	-34dB$_{avg}$ **(-34,5dB$_{avg}$)**	-28dB$_{avg}$ **(-31dB$_{avg}$)**	-28dB$_{avg}$ **(-31dB$_{avg}$)**

For example, the insertion, directivity and transmission loss of the WDM are taken from the Huber und Suhner WDM-1×2-01-P4-P-002-1-X3 20/85[1] [2]for further details please have a look at:
http://www.hubersuhner.com→Fibre Optic Products→Passive Network Components WDM.
Insertion Loss: ≤ 1.5 dB
Isolation: > 40 dB
Directivity: ≥ 55 dB

For the optical fibre cable the following data are assumed:
Type: Single Mode Fibre (SMF) 9/125 µm
Loss @ 1550 nm: 0.2 dB/km (10 dB for 50 km) and (1.0 dB for 5 km)
Loss @ 1300 nm: 0.3 dB/km (15 dB for 50 km) and (1.5 dB for 5 km)

In general a system reserve of min 3 dB is recommended to overcome losses of connections in fibre optic patch panels.

[1] WDM for 1300/1550nm, High Isolation, Premium Grade, with one ST Fibre Optic Connector for the 'long run' and two LC Fibre Optic Connectors for direct connection to the PDI of the device or to the Fibre Optic/Fibre Optic Converter, 1 m Pigtail.
[2] The mentioned WDM is suitable for the most application, only if the fibre is extremely long (longer than 50 km or high losses at the fibre due to many splices) the High Isolation can be replaced by a Standard one. With the Standard-WDM the insert and the isolation loss is lower (insert loss: 0.3dB, isolation loss 17dB).

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<u>Example 50 km for two connections using two fibres:</u>
The following figure shows the constellation. The PDI of the device or the Fibre Optic Converter 7XV5461 can be connected directly to the 1300/1550 in- output of the WDM.

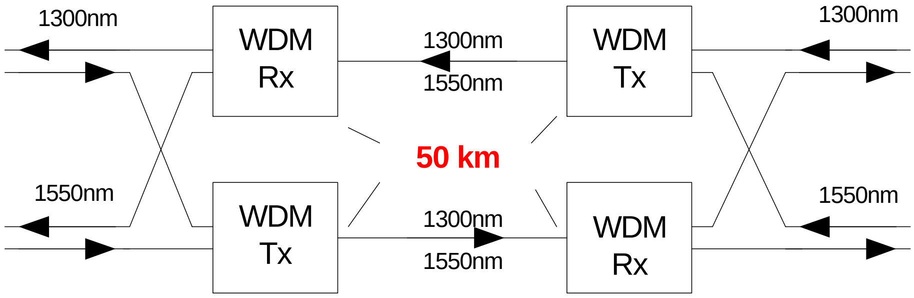

Figure 7: 50 km example using two fibres

Calculation for the 1300 nm (FO18/ 7XV5461-0H00):
Transmission Loss:
The Transmission Loss is the summation of all losses starting at the transmitter and ending at the receiver. To check if the signal really reaches the receiver the min transmitter output subtracted by the transmission loss has to higher than the maximal receiver sensitivity.

The loss is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1300nm	15,0 dB
Insertion loss of the second WDM	1,5 dB
System reserve	3,0 dB
Overall Loss Transmission	21,0 dB

Transmission check:
min Transmitter Output Level$^{(1300nm)}$ – Overall Loss < min receiver sensitivity$^{(1300nm)}$
-5dBm –21dB > - 34.0dBm **OK transmission check for 1300nm is passed!**

Isolation Loss (Cross-talk check):
The crosstalk check proves that the loss of the 1300nm signal is high enough so that the 1500nm receiver does not see this signal. For the crosstalk check the max. Output Level of the 1300nm transmitter subtracted by the losses of the fibre optic cable and WDM must be lower than the min. sensitivity of the 1550nm receiver (with min. 3 dB system reserve to have one more degree of freedom!)

The loss for the crosstalk check is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1300nm	12,0 dB
Isolation loss of the second WDM	40,0 dB
System reserve	-3,0 dB
Overall Loss Crosstalk	50,5 dB

Crosstalk Check:
max Transmitter Output Level$^{(1300nm)}$–Overall Loss Crosstalk < max receiver sensitivity $^{(1550nm)}$

-0 dB – 50.5 < -34.5 dB **OK crosstalk check for 1300nm is passed!**

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Calculation for the 1550 nm (FO19/ 7XV5461-0J00):

Transmission Loss:

The loss is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1550nm	10,0 dB
Insertion loss of the second WDM	1,5 dB
System reserve	3,0 dB
Overall Loss Transmission	16,0 dB

Transmission check:

min Transmitter Output Level$^{(1550nm)}$ – Overall Loss < min receiver sensitivity$^{(1550nm)}$

-5dBm –16dB > - 34.0dBm **OK transmission check for 1550nm is passed!**

Isolation Loss (Crosstalk check):

The loss for the crosstalk check is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1550nm	10,0 dB
Isolation loss of the second WDM	40,0 dB
System reserve	-3,0 dB
Overall Loss Crosstalk	38,5 dB

Crosstalk Check:

max Transmitter Output Level$^{(1550nm)}$ – Overall Loss Crosstalk < max receiver sensitivity$^{(1300nm)}$.

-0 dB – 38.5 < -34.5 dB **OK crosstalk check for 1550nm is passed!**

For the given constellation the directivity check is not necessary.

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Example 5 km for one connection using one fibre:

The following figure shows the constellation. The PDI of the device or the Fibre Optic Converter 7XV5461 can be connected directly to the 1300/1550 in- output the WDM.

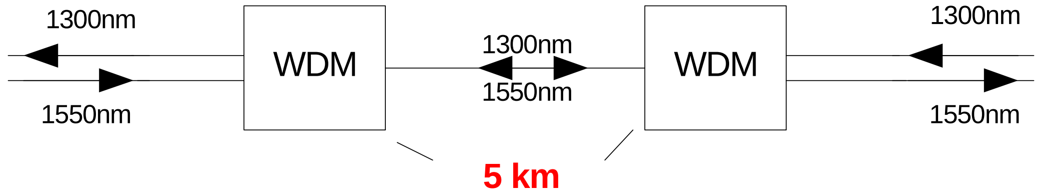

Figure 8: 5 km example using one fibre

Calculation for the 1300 nm (FO17/ 7XV5461-0G00):

Transmission Loss:

The loss is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1300nm	1,5 dB
Insertion loss of the second WDM	1,5 dB
System reserve	3,0 dB
Overall Loss Transmission	7,5 dB

Transmission check:

min Transmitter Output Level$^{(1300nm)}$ – Overall Loss < min receiver sensitivity$^{(1300nm)}$

-15dBm –7.5dB > - 28dBm **OK transmission check for 1300nm is passed!**

Directivity Loss (Cross-talk check):

The loss for the crosstalk check is calculated to:

Network component	Loss [dB]
Directivity loss WDM	55,0 dB
System reserve	-3,0 dB
Overall Loss Crosstalk	52,0 dB

Crosstalk Check:

max Transmitter Output Level$^{(1300nm)}$ – Overall Loss Crosstalk < max receiver sensitivity$^{(1550nm)}$.

-8 dB – 52.0 < -34.5 dB **OK crosstalk check for 1300nm is passed!**

Calculation for the 1550 nm (FO19/ 7XV5461-0J00):

Transmission Loss:

The loss is calculated to:

Network component	Loss [dB]
Insertion loss of the first WDM	1,5 dB
Transmission Loss of the FO cable @ 1550nm	1,0 dB
Insertion loss of the second WDM	1,5 dB
System reserve	3,0 dB
Overall Loss Transmission	7,0 dB

Transmission check:

min Transmitter Output Level$^{(1550nm)}$ – Overall Loss < min receiver sensitivity$^{(1550nm)}$

-5dBm –7dB > - 34.5dBm **OK transmission check for 1550nm is passed!**

Directivity Loss (Cross-talk check):

The loss for the cross-talk check is calculated to:

Network component	Loss [dB]
Directivity loss WDM	55,0 dB
System reserve	-3,0 dB
Overall Loss Crosstalk	52,0 dB

Crosstalk Check:

max Transmitter Output Level$^{(1550nm)}$ – Overall Loss Crosstalk < max receiver sensitivity$^{(1300nm)}$.

-0 dB – 52.0 < -34.5 dB **OK cross-talk check for 1550nm is passed!**

For the given constellation the isolation check is not necessary.

Last comment:

Besides, these applications for the WDM there are many more, e.g. sharing of existing optical fibres with other telecommunication equipment, where the telecommunication equipment uses the 1550nm and the protection equipment (PDI) the 1300nm wave length. The calculation for this application remains the same.

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