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ITU-T G.973.2

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TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical fibre submarine cable systems

Multichannel DWDM applications with single channel optical interfaces for repeaterless optical fibre submarine cable systems

Recommendation ITU-T G.973.2

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Recommendation ITU-T G.973.2

Multichannel DWDM applications with single channel optical interfaces for repeaterless optical fibre submarine cable systems

Summary

Recommendation ITU-T G.973.2 provides optical interface specifications towards the realization of transversely compatible dense wavelength division multiplexing (DWDM) systems intended for repeaterless submarine applications.

This Recommendation defines parameters for the single-channel optical interface of physical point-to-point DWDM applications on single-mode optical fibres through the use of the "black-link" approach.

Applications containing DWDM optical amplifiers are not defined in this Recommendation.

This Recommendation describes DWDM systems that include the following features:

– Channel frequency spacing: 100 GHz and below (defined in ITU-T G.694.1).

– Bit-rate of signal channel: up to 10 Gbit/s.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.973.2	2011-04-13	15

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Multichannel DWDM applications with single channel optical interfaces for repeaterless optical fibre submarine cable systems

1 Scope

The purpose of this Recommendation is to provide optical interface specifications towards the realization of transversely compatible dense wavelength division multiplexing (DWDM) systems intended for repeaterless submarine applications.

This Recommendation defines parameters for single-channel optical interface of physical point-to-point DWDM applications on single-mode optical fibres through the use of the "black-link" approach.

Applications containing DWDM optical amplifiers are not defined in this Recommendation.

This Recommendation describes DWDM systems that include the following features:

– Channel frequency spacing: 100 GHz and below (defined in [ITU-T G.694.1]).

– Bit-rate of signal channel: up to 10 Gbit/s.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.652] Recommendation ITU-T G.652 (2009), *Characteristics of a single-mode optical fibre cable*.

[ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted single-mode optical fibre cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2010), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] Recommendation ITU-T G.656 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport.*

[ITU-T G.661] Recommendation ITU-T G.661 (2007), *Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems.*

[ITU-T G.671] Recommendation ITU-T G.671 (2009), *Transmission characteristics of optical components and subsystems*.

[ITU-T G.691] Recommendation ITU-T G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers*.

[ITU-T G.692] Recommendation ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*.

[ITU-T G.694.1] Recommendation ITU-T G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid*.

[ITU-T G.694.2] Recommendation ITU-T G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid*.

[ITU-T G.698.1] Recommendation ITU-T G.698.1 (2009), *Multichannel DWDM applications with single-channel optical interfaces.*

[ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2009), *Optical transport network physical layer interfaces.*

[ITU-T G.972] Recommendation ITU-T G.972 (2008), *Definition of terms relevant to optical fibre submarine cable systems*.

[ITU-T G.973] Recommendation ITU-T G.973 (2010), *Characteristics of repeaterless optical fibre submarine cable systems.*

[ITU-T G.978] Recommendation ITU-T G.978 (2010), *Characteristics of optical fibre submarine cables*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 dense wavelength division multiplexing (DWDM): [ITU-T G.972].

3.1.2 multichannel receive main path interface reference point (MPI-R_M): [ITU-T G.959.1].

3.1.3 multichannel source main path interface reference point (MPI-S_M): [ITU-T G.959.1].

3.1.4 optical tributary signal: [ITU-T G.959.1].

3.1.5 optical tributary signal class NRZ 2.5G: [ITU-T G.959.1].

3.1.6 optical tributary signal class NRZ 10G: [ITU-T G.959.1].

3.1.7 polarization mode dispersion (PMD): [ITU-T G.650.2].

3.1.8 transverse compatibility: [ITU-T G.957].

3.1.9 wavelength division multiplexing (WDM): [ITU-T G.972].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASE Amplified Spontaneous Emission

BER Bit Error Ratio

CSF Cut-off Shifted single-mode Fibre

CWDM Coarse Wavelength Division Multiplexing

DCF Dispersion Compensating single-mode Fibre

DGD Differential Group Delay

DSF Dispersion Shifted single-mode Fibre

DWDM	Dense Wavelength Division Multiplexing
EX	EXtinction ratio
FEC	Forward Error Correction
IrDI	Inter-Domain Interface
LEF	Large Effective area single-mode Fibre
MPI	Main Path Interface
NDF	Negative Dispersion single-mode Fibre
NE	Network Element
NRZ	Non-Return to Zero
NZDSF	Non-Zero Dispersion Shifted single-mode Fibre
OA	Optical Amplifier
OD	Optical Demultiplexer
OM	Optical Multiplexer
OTN	Optical Transport Network
PMD	Polarization Mode Dispersion
R_S	Single-channel reference point at the DWDM network element tributary output
RZ	Return to Zero
SDH	Synchronous Digital Hierarchy
S_S	Single-channel reference point at the DWDM network element tributary input
WDM	Wavelength Division Multiplexing
WNZDF	Wideband Non-Zero Dispersion single-mode Fibre

5 Convention

This clause is intentionally left blank.

6 Applications

This Recommendation provides the physical layer parameters for the single-channel interfaces of dense wavelength division multiplexing (DWDM) multi-channels optical repeaterless submarine systems. These DWDM systems with single-channel interfaces are intended to be used in point to point applications.

The specification method in this Recommendation uses a "black-link" approach, which means that optical interface parameters for only (single-channel) optical tributary signals are specified. This approach enables transverse compatibility at the single-channel point using a direct wavelength-multiplexing configuration. However, it does not enable transverse compatibility at the multichannel points. In this approach, the optical multiplexer (OM) and optical demultiplexer (OD) are treated as a single set of optical devices.

This Recommendation only considers DWDM applications where the black-link does not contain optical amplifiers.

7 Reference configuration

7.1 Unidirectional applications

Figure 7-1 shows a set of reference points, for the "black-link" approach, for single-channel connection (S_S and R_S) between transmitters (Tx) and receivers (Rx). Here the DWDM link includes an OM and an OD, which are used as a pair with the opposing element.

The fibre between point S_S or R_S and the DWDM link is considered to be part of the black-link in cases where the transmitter or receiver is some distance far from the OM or OD.

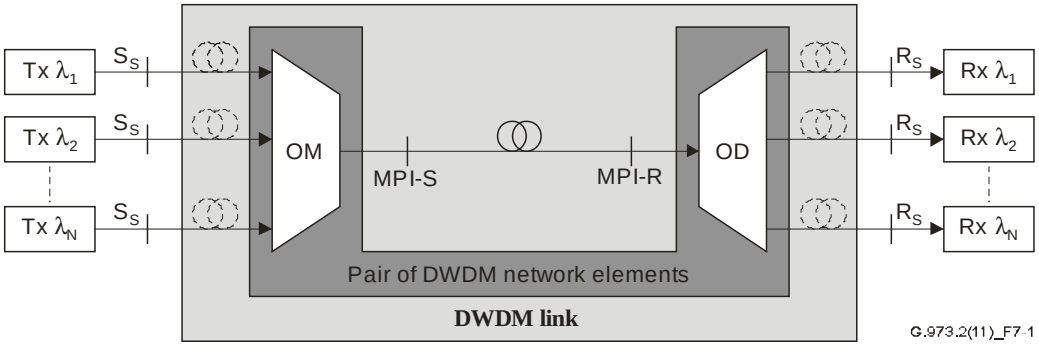

Figure 7-1 – "black-link" approach for unidirectional applications

This reference model does not include any optical amplifiers in the DWDM system. The reference points in Figure 7-1 are defined as follows:

– S_S is a single-channel reference point at the DWDM link tributary input;

– R_S is a single-channel reference point at the DWDM link tributary output;

– MPI-S is a link reference point at the DWDM network element aggregate output;

– MPI-R is a link reference point at the DWDM network element aggregate input.

Note that MPI-S and MPI-R are only defined to provide information for the fibre link and not to provide signal characteristics at these points.

7.2 Bidirectional applications

Figure 7-2 shows a set of reference points, for the single-fibre bidirectional "black-link" approach, for single-channel connection (S_S and R_S) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an OM/OD, which is used as a pair with the opposing element.

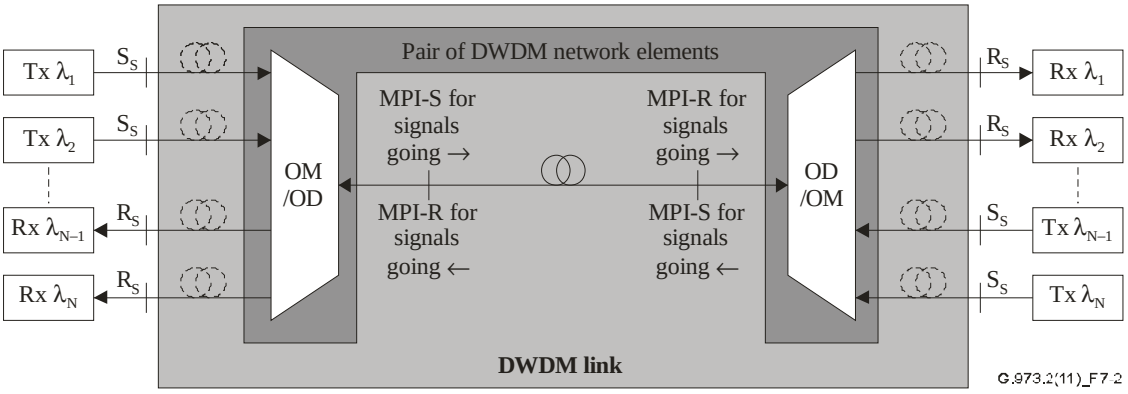

Figure 7-2 – "black-link" approach for bidirectional applications

The reference points in Figure 7-2 are as defined in clause 7.1.

8 Transverse compatibility

[b-ITU-T G.Sup41] describes several transverse compatibility configurations for point to point submarine transmission systems. This Recommendation deals with a single-span black-link transverse compatibility as shown in Figure 8-1.

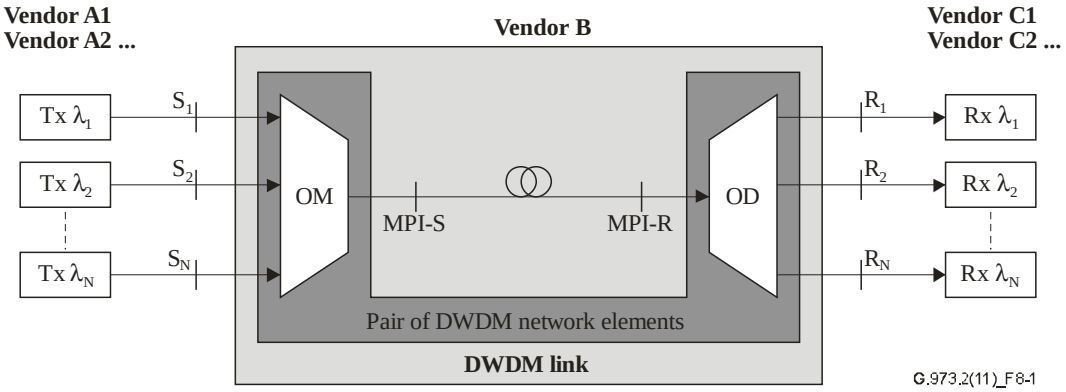

Figure 8-1 – Single-span black-link transverse compatibility

The vendors of the transceivers at the ends of an optical section may be different from the vendor of the equipment of the DWDM optical submarine link. Most of the transceivers are bidirectional; therefore, Vendor A1 is almost the same Vendor as C1.

9 Parameter definitions

The parameters in Table 1 are defined at the interface points, and the definitions are provided in the clauses below.

Table 1 – Physical layer parameters for DWDM applications using the "black-link" approach

Parameter	Units	Defined in
General information		
Minimum channel spacing	GHz	clause 9.1.1
Bit-rate/line coding of optical tributary signals	–	clause 9.1.2
Maximum bit-error ratio	–	clause 9.1.3
Fibre type	–	clause 9.1.4
Interface at point S_S		
Maximum mean channel output power	dBm	clause 9.2.1
Minimum mean channel output power	dBm	clause 9.2.1
Minimum central frequency	THz	clause 9.2.2
Maximum central frequency	THz	clause 9.2.2
Maximum spectral excursion	GHz	clause 9.2.3
Minimum side mode suppression ratio	dB	clause 9.2.4
Minimum channel extinction ratio	dB	clause 9.2.5
Eye mask	–	clause 9.2.6

Table 1 – Physical layer parameters for DWDM applications using the "black-link" approach

Parameter	Units	Defined in
Optical path from point S_S to R_S		
Maximum attenuation	dB	clause 9.3.1
Minimum attenuation	dB	clause 9.3.1
Maximum differential group delay	ps	clause 9.3.2
Maximum chromatic dispersion	ps/nm	clause 9.3.3
Maximum ripple	dB	clause 9.3.4
Interface at point R_S		
Maximum mean input power	dBm	clause 9.4.1
Receiver sensitivity	dBm	clause 9.4.2
Maximum optical path penalty	dB	clause 9.4.3
Maximum reflectance of receiver	dB	clause 9.4.4

9.1 General information

9.1.1 Minimum channel spacing

Minimum channel spacing is the minimum nominal difference in frequency between two adjacent channels. Channel spacing is defined in [ITU-T G.694.1] for DWDM as well as in [ITU-T G.694.2] for CWDM. A complete classification of WDM systems is in [ITU-T G.671].

9.1.2 Bit-rate/line coding of optical tributary signals

Optical tributary signal class NRZ 2.5G applies to continuous digital signals with non-return to zero line coding. Optical tributary signal class NRZ 10G applies to continuous digital signals with non-return to zero line coding. Return to zero (RZ) line coding will be considered in future study.

9.1.3 Maximum bit error ratio

The maximum bit error ratio (BER) is specified for each optical channel under the extreme case of optical path attenuation and dispersion condition. In the case of use of forward error correction (FEC), the BER is required to be met only after the correction has been applied.

9.1.4 Fibre type

Several types of optical fibres are used in submarine systems. This Recommendation covers all of the following:

- single-mode fibres defined in ITU-T Recommendations:
  - non-dispersion shifted single-mode fibre (SMF) defined in [ITU-T G.652];
  - dispersion shifted single-mode fibre (DSF) defined in [ITU-T G.653];
  - cut-off shifted single-mode fibre (CSF) defined in [ITU-T G.654];
  - non-zero dispersion-shifted single-mode fibre (NZDSF) defined in [ITU-T G.655];
  - wideband non-zero dispersion single-mode fibre (WNZDF) defined in [ITU-T G.656];
- positive dispersion single-mode fibre (PDF);
- negative dispersion single-mode-fibre (NDF);
- large effective area single-mode fibre (LEF);
- dispersion compensating single-mode fibre (DCF).

Depending on the system specifications, various combinations of these fibre types may be used to ensure that the system performs correctly. Further information about each type of fibre can be found in [ITU-T G.978].

9.2 Interface at point S_S

9.2.1 Maximum and minimum mean channel output power

Maximum and minimum mean channel output power are defined in [ITU-T G.959.1].

9.2.2 Minimum and maximum central frequency

Central frequencies of wave division multiplexing (WDM) signals are given in [ITU-T G.694.1]. The nominal central frequencies of all channels should be greater than or equal to the minimum central frequency and less than or equal to the maximum central frequency.

Note that the value of "c" (speed of light in vacuum) that should be used for converting between frequency and wavelength is 2.99792458×10^8 m/s.

9.2.3 Maximum spectral excursion

Maximum spectral excursion for non return to zero (NRZ) coded optical channels is defined in [ITU-T G.959.1] and [ITU-T G.698.1].

9.2.4 Minimum side mode suppression ratio

The side mode suppression ratio of a single longitudinal mode optical source is defined in [ITU-T G.957], [ITU-T G.691] and [ITU-T G.959.1].

9.2.5 Minimum channel extinction ratio

The minimum extinction ratio for NRZ coded WDM channels is defined in [ITU-T G.959.1].

9.2.6 Eye mask

The definition and limits for this parameter are found in [ITU-T G.959.1].

9.3 Optical path parameters (single span) from S_S to R_S

9.3.1 Minimum and maximum attenuation

For any optical channel, it is the minimum (or maximum) reduction in optical power between the input and output ports of the black-link for that channel in the frequency range of the central frequency of the channel ± the maximum spectral excursion. Minimum and maximum attenuation are defined in [ITU-T G.959.1].

9.3.2 Maximum differential group delay

Differential group delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. For distances greater than several kilometres, and assuming random (strong) polarization mode coupling, DGD in a fibre can be statistically modelled as having a Maxwellian distribution.

In this Recommendation, the maximum differential group delay is defined to be the value of DGD that the system must tolerate with a maximum sensitivity degradation of 1 dB.

Due to the statistical nature of polarization mode dispersion (PMD), the relationship between maximum DGD and mean DGD can only be defined probabilistically. The probability of the instantaneous DGD exceeding any given value can be inferred from its Maxwellian statistics. Therefore, if we know the maximum DGD that the system can tolerate, we can derive the equivalent mean DGD by dividing by the ratio of maximum to mean that corresponds to an acceptable probability. Some example ratios are given in Table 2.

Table 2 – DGD means and probabilities

Ratio of maximum to mean	Probability of exceeding maximum
3.0	4.2×10^{-5}
3.5	7.7×10^{-7}
4.0	7.4×10^{-9}

9.3.3 Maximum chromatic dispersion

This parameter defines the maximum value of uncompensated chromatic dispersion of the optical path that the system shall be able to tolerate. This is considered a worst-case uncompensated dispersion value. Maximum chromatic dispersion is defined in [ITU-T G.959.1].

9.3.4 Maximum ripple

The ripple (of a DWDM device) is defined in [ITU-T G.671] and [ITU-T G.698.1]. In this Recommendation, it is applied to the entire black-link from reference point S_S to the corresponding R_S.

9.4 Interface at point R_S

9.4.1 Maximum mean input power

The maximum acceptable value of the average received power at point R_S to achieve the specified maximum BER.

9.4.2 Receiver sensitivity

Receiver sensitivities for synchronous digital hierarchy (SDH) single channel systems up to 10 Gbit/s are defined in [ITU-T G.957] and [ITU-T G.691]. Sensitivities for SDH and optical transport network inter-domain interface (OTN IrDI) receivers are defined in [ITU-T G.959.1].

Receiver sensitivities are defined as end-of-life, worst-case values taking into account ageing and temperature margins as well as worst-case eye mask and extinction ratio penalties resulting from transmitter imperfections given by the transmitter specification of the particular interface. Receiver sensitivity is defined as the minimum value of average received power at point R_S to achieve a 10^{-12} BER.

Penalties related to path effects, however, are specified separately from the basic sensitivity value.

9.4.3 Maximum optical path penalty

The path penalty is the apparent reduction of receiver sensitivity due to distortion of the signal waveform during its transmission over the path. This parameter is defined in [ITU-T G.959.1].

9.4.4 Maximum reflectance of receiver

Reflections from the receiver back into the DWDM link are specified by the maximum permissible reflectance of the receiver measured at reference point R_S. Optical reflectance is defined in [ITU-T G.671].

10 Reliability of submarine system

The reliability of submerged equipments of an optical fibre submarine cable system is generally characterized by:

– The expected number of repairs requiring intervention by a cable ship. The usual requirement for the reliability of a repeaterless system is less than one failure requiring cable ship intervention during the system design life.

– The system design life over which the optical fibre submarine cable system is designed to be operational in conformance with its performance specification. Usually, the system design life is a period of 25 years starting at the provisional acceptance date of the system, i.e., the date following installation when the system is claimed to be compliant with the performance specifications.

11 Characteristics and performance of submarines cables

The recommended characteristics and performance of the submarine cable are given in [ITU-T G.978].

12 Optical safety considerations

Information on optical safety considerations can be found in [b-ITU-T. G.664], [b-IEC 60825-1], [b-IEC 60825-2] and [b-IEC/TR 61292-4].

Bibliography

[b-ITU-T G.Sup41] ITU-T G Series Recommendations – Supplement 41 (2010), *Design guidelines for optical fibre submarine cable systems.*

[b-ITU-T G.664] Recommendation ITU-T G.664 (2006), *Optical safety procedures and requirements for optical transport systems.*

[b-IEC 60825-1] IEC 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements.*

[b-IEC 60825-2] IEC 60825-2:2004, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*, plus its amendments.

[b-IEC/TR 61292-4] IEC/TR 61292-4:2010 (Edition 2), *Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers.*

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