SMPTE ST 297-2:2017

SMPTE STANDARD

Multi-Link and Multi-Channel 1.5G, 3G, 6G and 12G-SDI Using CWDM

Table of Contents

Page

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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual.

SMPTE ST 297-2 Document was prepared by Technology Committee 32NF.

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

Introduction

This section is entirely informative and does not form an integral part of this Engineering Document.

Coarse Wavelength Division Multiplexing (CWDM) provides means of data transport of uncompressed video between capture systems and the associated storage and production equipment, for distances greater than 100 meters on a single optical fiber.

Two CWDM multiplexing applications are covered by this standard: Multi-Link (ML) and Multi-Channel (MC).

(1) Multi-Link operation provides a means of carrying synchronous dual-link or quad-link SDI interfaces over a single optical fiber. For example, dual and quad-link 3G SDI interfaces such as SMPTE ST 425-3 and SMPTE ST 425-5 can carry image formats beyond HDTV, high frame rates and or high bit depth images over multiple links. This standard combines those multiple-links into a single fiber.

(2) Multi-Channel operation provides a means to concatenate multiple synchronous or asynchronous SDI interfaces on a single optical fiber. For example, multiple (up to 18) separate SDI interfaces adhering to any of the supported data rates in any combination can be carried on a single fiber.

1 Scope

This standard defines the transport of Multi-Link (ML) or Multi-Channel (MC) SDI data streams over a single fiber using Coarse Wavelength Division Multiplexing (CWDM).

Specifically, this standard specifies a CWDM optical interface for Multi-Link 12G-SDI, Multi-Link 6G-SDI, Multi-Link 3G-SDI and Multi-Link 1.5G-SDI, as well as Multi-Channel 12G-SDI, 6G-SDI, 3G-SDI and/or 1.5G-SDI.

To conform to this standard, It is not necessary for implementations to include support for both Multi-Link and Multi-Channel modes, nor is it necessary to support all interface data rates defined in Table 1. Implementers should indicate supported interface rates and operating modes in commercial publications.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:”

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword “reserved” indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword “forbidden” indicates “reserved” and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; then formal languages; then figures; and then any other language forms.

3 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this engineering document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this engineering document are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

SMPTE ST 292-1:2012, 1.5 Gb/s Serial Digital Interface

SMPTE ST 292-2:2011, Dual 1.5 Gb/s Serial Digital Interface for Stereoscopic Image Transport

SMPTE ST 297-1:2015, Serial Digital Fiber Transmission System for SMPTE ST 259, SMPTE ST 344, SMPTE ST 292-1/2, SMPTE ST 424, SMPTE ST 2081-1 and SMPTE ST 2082-1 Signals

SMPTE ST 424:2012, 3 Gb/s Signal/Data Serial Interface

SMPTE ST 425-1:2014, Source Image Format and Ancillary Data Mapping for the 3 Gb/s Serial Interface

SMPTE ST 425-3:2015, Image Format and Ancillary Data Mapping for the Dual Link 3 Gb/s Serial Interface,

SMPTE ST425-4:2012, Dual 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport

SMPTE ST 425-5:2015, Image Format and Ancillary Data Mapping for the Quad Link 3 Gb/s Serial Interface

SMPTE ST 425-6:2014, Quad 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport

SMPTE 2081-10:2015, 2160-Line and 1080-Line Source Image and Ancillary Data Mapping for Single-Link 6G-SDI

SMPTE ST 2081-11:2016, 2160-line Source Image and Ancillary Data Mapping for Dual-link 6G-SDI

SMPTE ST 2081-12:2016, 4320-line and 2160-line Source Image and Ancillary Data Mapping for Quad-link 6G-SDI

SMPTE ST 2082-1:2015, 12 Gb/s Signal/Data Serial Interface — Electrical

Amendment 1:2016 to SMPTE ST 2082-1:2015

SMPTE ST 2082-10:2015, 2160-line Source Image and Ancillary Data Mapping for 12G-SDI

SMPTE ST 2082-11:2016, 4320-line and 2160-line Source Image and Ancillary Data Mapping for Dual-link 12G-SDI

SMPTE ST 2082-12:2016, 4320-line and 2160-line Source Image and Ancillary Data Mapping for Quad-link 12G-SDI

4 Terms and Definitions

See Terms and Definitions in SMPTE ST 297-1 for anything not defined here

Lane: An optical transmit or receive path specified by wavelength

SM: Single-Mode

MM: Multi-Mode

5 Signal Mapping

Table 1 – Signal Mapping

Multi-Link Applications			
SMPTE Standards	**Channel**	**Lane**	
ST 292-1, ST 425-1, ST 2081-10, ST 2082-10	Single Channel	SM Fiber	MM Fiber
		L2	L0
ST 292-2	Left Eye 1.5Gb SDI	L0	
	Right Eye 1.5Gb SDI	L1	
ST 425-4	Left Eye 3Gb SDI	L0	
	Right Eye 3Gb SDI	L1	
ST 425-3	3G SDI Link 1	L0	
	3G SDI Link 2	L1	
ST 425-5/-6	3G SDI Link 1	L0	
	3G SDI Link 2	L1	
	3G SDI Link 3	L2	
	3G SDI Link 4	L3	
ST 2081-11/-12	6G SDI Link 1	L0	
	6G SDI Link 2	L1	
	6G SDI Link 3	L2	
	6G SDI Link 4	L3	
ST 2082-11/-12	12G SDI Link 1	L0	
	12G SDI Link 2	L1	
	12G SDI Link 3	L2	
	12G SDI Link 4	L3	
Multi-Channel Applications			
Any combination of ST 292-1, ST 424, ST 2081-1, or ST 2082-1	Chanel 1 through 8	L0-L7	L0-L7
	Channels 9 through 18	L8-L17	N/A

Transmit devices compliant with this standard may be designed to generate one, all, or any combination of SDI interfaces as defined in Table 1.

Devices compliant with the Multi-Channel application mode of operation may be designed to support any number of channels up to the maximum of 18 channels for SM fiber applications or 8 channels for MM Fiber applications. Where the number of supported channels is less than the maximum for each fiber type, the channel count shall always start at L0 and must be contiguous.

For example, a 6-channel SM fiber Multi-Channel application would only operate channels L0 through L5 and thus use only wavelengths L0: 1271nm, L1: 1291nm, L2: 1311nm, L3: 1331nm, L4: 1351nm, and L5: 1371nm as defined in Table 2.

A 6-channel MM fiber Multi-Channel application would only operate channels L0 through L5 and thus use only wavelengths L0: 850nm, L1: 910nm, L2: 940nm, L3: 980nm, L4: 830nm, and L5: 870nm as defined in Table 2.

6 Optical Transmission System Specification

6.1 Connectors

Optical domain connectors and polish for the Tx and Rx units shall be as specified in SMPTE ST 297-1.

Optical connector return loss for the Tx and Rx units shall be as specified in SMPTE ST 297-1.

6.2 Transmitter Unit

Unless otherwise stated in Table 2, the transmitter unit shall produce an intensity-varying optical output signal in accordance with the High-Power (Long-haul) Link parameters as specified in SMPTE ST 297-1 for Single Mode Fiber applications, and Short-haul link parameters as specified in SMPTE ST 297-1 for Multi-Mode Fiber applications, when modulated by an electrical signal with specifications per SMPTE ST 292-1/-2 for 1,5G-SDI, SMPTE ST 424 for 3G-SDI, SMPTE ST 2081-1 for 6G-SDI, and SMPTE ST 2082-1 for 12G-SDI at the Multi-Mode or Single-Mode optical wave-lengths and other optical parameters defined in Table 2 and SMPTE ST 297-1.

Table 2 – Transmitter unit output signal specifications[1]

<table>
<tr><th></th><th>Single-Mode Fiber</th><th>Multi-Mode Fiber</th></tr>
<tr><td>Transmission circuit fiber[4]</td><td>SM (9.0/125µm)</td><td>MM (50.0/125µm)</td></tr>
<tr><td>Light source type'</td><td>Laser</td><td>Laser</td></tr>
<tr><td>Optical wavelength[5,6]</td><td>L0: 1271nm
L1: 1291nm
L2: 1311nm
L3: 1331nm
L4: 1351nm
L5: 1371nm
L6: 1391nm [2]
L7: 1411nm [2]
L8: 1431nm
L9: 1451nm
L10: 1471nm
L11: 1491nm
L12: 1511nm
L13: 1531nm
L14: 1551nm
L15: 1571nm
L16: 1591nm
L17: 1611nm</td><td>L0: 850nm
L1: 910nm
L2: 940nm
L3: 980nm
L4: 830nm
L5: 870nm
L6: 890nm
L7: 960nm</td></tr>
<tr><td>Maximum Optical Power [3]</td><td rowspan="2">As defined in SMPTE ST 297-1 for High-power (Long-haul) links</td><td>+9.1dBm</td></tr>
<tr><td>Minimum Optical Power</td><td>-3dBm</td></tr>
<tr><td>Minimum Extinction Ratio</td><td>5.0dB (3.1:1)</td><td>3.0dB (2.0:1)</td></tr>
</table>

	Single-Mode Fiber	Multi-Mode Fiber

Notes:

1) See SMPTE ST 297-1 for any parameters not defined here.
2) Single-Mode L6-L7 should only be used with fiber having a Maximum Attenuation Coefficient as defined by Recommendation ITU-T G.652D, also known as “Low Water Peak” fiber,G.652D.
3) A laser warning label that is clearly visible during maintenance, operations, and servicing is displayed on equipment. Text borders and symbols must be black on a yellow background. The laser warning label is shown here:

4) Optical fiber specification defined by IEC 60793-2 (2003-10) and IEC 60793-1 Measurement methods and test procedures - General and guidance.
5) Ignore any specified wavelengths and spectral line width constraints in SMPTE ST 291-1.
6) Passband allowed to be +/- 6.5nm.

6.3 Receiver Unit

Unless otherwise stated in Table 3, a receiver unit shall output an electrical signal per SMPTE ST 292-1, SMPTE ST 424, SMPTE ST 2081-1, or SMPTE ST 2082-1, when presented with an optical input signal in accordance with the Optical receiver input signal specifications defined in SMPTE ST 297-1.

Table 3 – Optical receiver input signal specifications[1]

Transmission circuit fiber	Single-Mode (9.0/125μm)	Multi-Mode[3] (50.0/125 μm)
Minimum Input Overload power[2]	0dBm	
Minimum Input Power	As defined in SMPTE ST 297-1	-11dBm

Notes:

1) See SMPTE ST 297-1 for any parameters not defined here.

2) Minimum Input Overload Power is intended to be on a per-wavelength basis. With multiple channels present the total optical power could be higher. Depending on product implementation, optical attenuators could need to be used to meet specified overload and detector damage performance.

3 The Minimum power is not data rate dependent.

7 Labeling

Equipment conforming with this standard shall indicate the application (low-power, or high-power), the polish of the connector, the payload types they support and the wavelength they use in accordance with the Transmitting Unit and Receiving Unit Labeling requirements defined in SMPTE ST 297-1 which have the following format <application>-<polish>-<signal type>-<wavelength>.

In addition to the above requirement, equipment designed in conformance with this standard shall also be labeled to indicate CWDM multiplexing operation and single fiber connectivity.

Thus, the receptacle related label shall have the format <application>-<polish>-<signal type>-<wavelength>-<multiplex>-<No. of Links>.

– In accordance with SMPTE ST 297-1, the element <application> shall have the value:

- H for high-power (long-haul) link applications
- L for low-power (short-haul) link applications

– In accordance with SMPTE ST 297-1, the element <polish> shall have the value:

- PC for Physical Contact (flat polished) Connectors
- SPC for Super Physical Contact (flat polished) Connectors
- UPC for Ultra Physical Contact (flat polished) Connectors
- APC for Angle Physical Contact (angle polished) Connectors

– In accordance with SMPTE ST 297-1, for each supported signal type, the element <signal type> shall have the value:

• C to indicate support of 1.5G signals (as specified in SMPTE ST 292-1)

• D to indicate support of 3G signals (as specified in SMPTE ST 424)

• E to indicate support of 6G signals (as specified in SMPTE ST 2081-1)

• F to indicate support for 12G signals (as specified in SMPTE ST 2082-1)

– The element <wavelength> shall have the value:

- 850 to indicate support for single link or single channel MM fiber only
- 850-980 to indicate support of dual-link or quad-link CWDM MM fiber
- 1310 to indicate support for single link or single channel SM fiber only
- 1270-1330 to indicate support of dual-link, or quad-link CWDM SM fiber
- 830-980 to indicate support for 8 link multi-channel CWDM MM fiber
- 1270-1611 to indicate support for 18 link multi-channel CWDM SM fiber

For multi-channel systems with less than the total number of channels, the <wavelength> element shall list the first and last wavelength used.

– The element <multiplex> shall have the value:

• CW-ML for CWDM Multi-Link operation as per SMPTE ST 292-2, SMPTE ST 425-3/-4/-5/-6, ST 2081-10/-11/-12 or SMPTE ST 2082-10/-11/-12 operation

• CW-MC for CWDM Multi-Channel operation for the carriage of multiple SMPTE ST 292-1, ST 424, ST 2081-1 and / or SMPTE ST 2082-1 channels

– The element <No of links> shall specify the number of links and for Multi-Link CWDM application, shall have the value:

- 1 for single-link
- 2 for dual-link
- 4 for quad-link.

For Multi-Channel CWDM applications, the element <No of links> shall specify the number of SDI channels carried and shall have the value:

- 1 through 18 for SM applications
- 1 through 8 for MM applications.

For multi-channel systems with less than the total number of channels, the <No of links> element shall list the highest number of links actually used.

EXAMPLE 1: A flat polished low-power (short-haul) multi-mode quad-link transmitter that supports SMPTE ST 2082-12 over MM fiber is labeled L-PC-F-850-980-CW-ML-4.

EXAMPLE 2: A flat polished low-power (short-haul) 8-channel transmitter that supports SMPTE ST 292-1, SMPTE ST 424, SMPTE ST 2081-1 and SMPTE ST 2082-1 over MM fiber is labeled L-PC-CDEF-850-960-CW-MC-8.

EXAMPLE 3: An angle polished high-power (long-haul) 9-channel transmitter that supports SMPTE ST 292-1, ST 424, SMPTE ST 2081-1 and SMPTE ST 2082-1 over SM fiber is labeled H-APC-CDEF-1270-1430-CW-MC-9

EXAMPLE 4: An angle polished high-power (long-haul) 18-channel transmitter that supports SMPTE ST 2082-1 over SM fiber is labeled H-APC-F-1270-1611-CW-MC-18.

It is preferable though not mandatory that such a label be clearly visible on the equipment in close proximity to the receptacle to which the information applies. It shall also be acceptable to include such label information in commercial publications.

Note: The label provides information to the system integrator or installer what connecting cable is required.

8 Optical Fiber Circuit and Link Budget (Informative)

When designing an optical fiber link to cover a known distance, there are two factors that will decide whether a particular transmit-receive pair will be adequate to successfully transport data while meeting or exceeding the minimum BER requirements of SMPTE ST 297-1.

These factors are the *power budget* and the *dispersion tolerance* of the Tx/Rx pair.

8.1 Power Budget (Informative)

The power budget is composed of two principal elements:

Transmit power: This is the guaranteed end of life (EOL) average output optical power of the transmit laser, normally expressed in mW or dBm. Start of Life (SOL) values will typically be larger, allowing for some relaxation in the output power as the device ages.

Receive sensitivity: This is the guaranteed end of life (EOL) power level at which satisfactory error performance can be achieved with a known data pattern. Sensitivity levels for pathological signals will typically be poorer than for PRBS signals (Pseudo Random Bit Sequence). When determining the loss-limited reach of the system, subtracting the receive sensitivity from the transmit power will provide the power budget (sometimes referred to as "link budget").

Table 4 – Power budget calculation

TX: Optical Output Power	-7dBm to +7dBm
Rx: Optical Sensitivity	-11dBm to -32dBm
Power Budget	**Tx-Connection Losses-RX-Margin**

For a full design consideration, it is necessary to determine whether a Tx/Rx pair will be power limited or dispersion limited. Calculating a reach for both power **and** dispersion will highlight the fiber length at which the system becomes limited for one of these phenomena.

By way of example, the following optical network is considered for calculating the link distance.

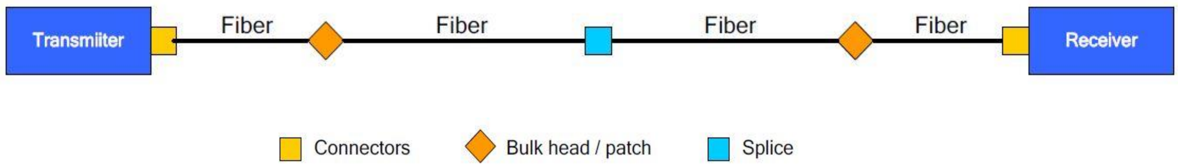

Table 5 – Typical passive device power loss

Single Mode Fiber Loss FP type Laser @ 1310nm DFB type Laser @ 1550nm	0.35dB/km 0.25dB/km
Insertion Loss	
Connectors	0.5dB
Splices	0.2dB
Patch Panels	1dB
Passive Device Attenuation	
CWDM 16	7dB
Splitter 80%	2dB
Splitter 20%	9dB

8.2 Single Mode Link Distance Calculation (Informative)

For this example, the following basic assumptions apply:

- The SM fiber loss is fixed at a uniform, worst case 0.35 dB/km
- 1310 nm FP type Laser transmitter – minimum output power: -5 dBm, spectral width 4 nm
- PIN Receiver – minimum sensitivity (pathological) of -14 dBm
- 2 connectors with 0.5 dB loss / connector
- 2 patch losses with 1 dB loss / patch
- 1 splice loss with 0.3 dB loss / splice
- 3 dB system margin

The worst case, EOL power budget for this example would therefore be Tx-Losses-Rx-Margin

- Transmitter power 0 dBm
- Receiver Sensitivity (-14 dBm)
- Connector loss (2x .5) – - 1 dB
- Patch loss (2 x 1dB) – - 2 dB
- Splice loss (0.3dB) - - 0.3 dB
- System margin – - 3 dB
- EOL power budget 7.7 dB
- The *estimated* reach is 7.7/0.35 = 22 **km**

8.2.1 Dispersion (Informative)

For a SM fiber having a zero-dispersion wavelength centered at 1302 nm and a laser optical wavelength of 1310 nm +/-40 nm (from SMPTE ST 297-1), the dispersion coefficient can be calculated using the zero-dispersion slope parameter which can be obtained from the fiber data sheet.

Note: Zero-dispersion wavelength and zero-dispersion slope parameters are provided in the optical fiber data sheet.

For this example it is assumed that a zero-dispersion slope of 0.092 ps/(nm^2•km) is specified:

- Calculating dispersion at 1270 nm (1310 nm -40 nm from ST 297-1) = -2.94 ps/nm.km
- Calculating dispersion at 1350 nm (1310 nm +40 nm from ST 297-1) = 4.416 ps/nm.km

The dispersion limited link length is determined by the following equation:

$$L = \frac{0.491}{B.D.\Delta\lambda}$$

Where B is the bit rate (bits/second), D is the dispersion (ps/nm.km) and $\Delta\lambda$ is the source line width (nm), and L is the dispersion limited link length (km).

Note: This topic is dealt with in more detail in SMPTE EG 2069, which also provides spectral line widths for various links (Table 1 – SMPTE EG 2069).

Choosing the worst case absolute dispersion of 4.416/nm.km, then for 12 Gb/s data, we get a dispersion limited link length of **9.36 km**.

This application is therefore dispersion limited.

8.3 Multimode Link Distance Calculation (Informative)

In the case of Multimode fiber, the link distances are not often limited by overall power budget, but by modal dispersion (see Table 6). Optical fiber manufacturers specify the Effective Modal Bandwidth for multimode fiber at a given wavelength and this property is expressed in units of MHz •km. There are several different multimode fiber types with differing core sizes and modal bandwidths. It is important to select the appropriate fiber for the required application.

Table 6 contains values for attenuation and minimum modal bandwidth for various fiber types. Actual values will be provided by the fiber manufacturer.

Table 6 – Multimode fiber parameters

Parameter	50/125 μm			62.5/ 125 μm
ISO/IEC 11801 Performance Category	OM2	OM3	OM4	OM1
Attenuation (dB/km) @ 850 nm @ 1300 nm	<3.0 <1.0			<3.5 <1.0
Effective Modal Bandwith (MHz •km) @ 850 nm @ 1300 nm	>500 >500	>1500 >500	>3500 >500	>200 >600

For this example, the following basic assumptions apply:

- The worst case fiber loss for OM3 fiber at 850nm is 3 dB/km
- 850 nm FP type Laser transmitter – minimum output power · -5dBm
- PIN Receiver – minimum sensitivity (pathological) of -18 dBm
- 2 connectors with 0.5 dB loss / connector
- 2 patch losses with 1 dB loss / patch
- 1 splice loss with 0.3 dB loss / splice
- 3 dB system margin

The worst case, EOL power budget for this example would therefore be Tx-Losses-Rx-Margin::

- Transmitter power - 3 dBm
- Receiver Power (-11 dBm)
- Connector loss (2x .5) - 1
- Patch loss (2 x 1 dB) - 2
- Splice loss (0.3 dB) - 0.3
- System margin - 3
- EOL power budget 1.7 dB
- The *estimated* reach is 1.7 dB / 3 dB/km = **567 m**

8.3.1 Intermodal Dispersion (Informative)

The formula for calculating a rough approximation of the maximum link distance as a function of data rate is as follows:

- Maximum distance = (Modal Bandwidth of Fiber) / (½ Data Rate).
- For OM3 MM fiber with a 50 μm core, the effective modal bandwidth is 1500MHz•km at 850 nm.
- For 12 Gb/s data, we get a dispersion-limited link length of **250m**.
- For wavelengths other than 850nm, this distance could be shorter.

Bibliography (Informative)

SMPTE EG 2069:2012, Guide to SMPTE ST 297 Optical SDI Networks

IEC 61300-1:2011, Fibre Optic Interconnecting Devices and Passive Components — Basic Test and Measurement Procedures — Part 1: General and Guidance

IEC 61753-1:2007, Fibre Optic Interconnecting Devices and Passive Components Performance Standard — Part 1: General and Guidance for Performance Standards

Recommendation ITU-T G:652:2009, Transmission Systems and Media, Digital Systems and Networks Transmission Media Characteristics — Optical Fibre Cables

Recommendation ITU-T G.651 and ANSI/ElA/TIA-492AAAA-A