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

Transmission media and optical systems characteristics –  
Characteristics of optical systems

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### **Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces**

Recommendation ITU-T G.698.2

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## Recommendation ITU-T G.698.2

### Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces

#### Summary

Recommendation ITU-T G.698.2 provides optical parameter values for physical layer interfaces of dense wavelength division multiplexing (DWDM) systems primarily intended for metro applications which include optical amplifiers. Applications are defined using optical interface parameters at the single-channel connection points between optical transmitters and the optical multiplexer, as well as between optical receivers and the optical demultiplexer in the DWDM system. This Recommendation uses a methodology which does not specify the details of the optical link, e.g., the maximum fibre length, explicitly. This version of this Recommendation includes unidirectional DWDM applications at 100 Gbit/s with 100 GHz and 50 GHz channel frequency spacing.

#### History

| Edition | Recommendation | Approval   | Study Group | Unique ID*                                                                |
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| 2.0     | ITU-T G.698.2  | 2009-11-13 | 15          | <a href="http://handle.itu.int/11.1002/1000/10396">11.1002/1000/10396</a> |
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#### Keywords

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\* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

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# Recommendation ITU-T G.698.2

## Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces

### 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 primarily intended for metro applications which include optical amplifiers.

This Recommendation defines and provides values for single-channel optical interface parameters of physical point-to-point and ring DWDM applications on single-mode optical fibres through the use of the "black link" approach. The black links covered by this Recommendation may contain optical amplifiers.

The use of these single channel optical interfaces for DWDM systems enables the elimination of transponders which would otherwise be needed in multivendor DWDM optical transmission networks. Further details can be found in Appendix II.

This Recommendation describes single channel interfaces to DWDM systems that include the following features:

- channel frequency spacing: 50 GHz and wider (defined in [ITU-T G.694.1]);
- bit rate of signal channel: Up to 100 Gbit/s.

Specifications are organized according to application codes.

### 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 (2016), <i>Characteristics of a single-mode optical fibre and cable</i> .                                   |
| [ITU-T G.653] | Recommendation ITU-T G.653 (2010), <i>Characteristics of a dispersion-shifted single-mode optical fibre and cable</i> .                |
| [ITU-T G.655] | Recommendation ITU-T G.655 (2006), <i>Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable</i> .       |
| [ITU-T G.664] | Recommendation ITU-T G.664 (2009), <i>Optical safety procedures and requirements for optical transport systems</i> .                   |
| [ITU-T G.671] | Recommendation ITU-T G.671 (2012), <i>Transmission characteristics of optical components and subsystems</i> .                          |
| [ITU-T G.691] | Recommendation ITU-T G.691 (2006), <i>Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers</i> . |
| [ITU-T G.692] | Recommendation ITU-T G.692 (1998), <i>Optical interfaces for multichannel systems with optical amplifiers</i> .                        |

|                 |                                                                                                                                        |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------|
| [ITU-T G.694.1] | Recommendation ITU-T G.694.1 (2012), <i>Spectral grids for WDM applications: DWDM frequency grid.</i>                                  |
| [ITU-T G.709]   | Recommendation ITU-T G.709/Y.1331 (2016), <i>Interfaces for the Optical Transport Network (OTN).</i>                                   |
| [ITU-T G.709.2] | Recommendation ITU-T G.709.2/Y.1331.2 (2018), <i>OTU4 long-reach interface.</i>                                                        |
| [ITU-T G.709.3] | Recommendation ITU-T G.709.3/Y.1331.3 (2018), <i>Flexible OTN long-reach interfaces.</i>                                               |
| [ITU-T G.957]   | Recommendation ITU-T G.957 (2006), <i>Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.</i> |
| [ITU-T G.959.1] | Recommendation ITU-T G.959.1 (2018), <i>Optical transport network physical layer interfaces.</i>                                       |
| [IEC 60825-1]   | IEC 60825-1:2014, <i>Safety of laser products – Part 1: Equipment classification and requirements.</i>                                 |
| [IEC 60825-2]   | IEC 60825-2:2010, <i>Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS).</i>                      |

### 3 Terms and definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined in [ITU-T G.671]:

- Dense Wavelength Division Multiplexing (DWDM);
- Channel insertion loss;
- Reflectance;
- Ripple;
- Channel spacing;
- Differential group delay;
- Reflectance.

This Recommendation uses the following term defined in [ITU-T G.691]:

- (Optical) transponder.

This Recommendation uses the following term defined in [ITU-T G.694.1]:

- Frequency grid.

This Recommendation uses the following term defined in [ITU-T G.709]:

- Completely standardized OTUk (OTUk).

This Recommendation uses the following terms defined in [ITU-T G.709.2]:

- OTL4.4-SC;
- OTU4-SC.

This Recommendation uses the following term defined in [ITU-T G.709.3]:

- FOIC1.4-SC.

This Recommendation uses the following terms defined in [ITU-T G.957]:

- Joint engineering;

- Transverse compatibility.

This Recommendation uses the following terms defined in [ITU-T G.959.1]:

- Optical tributary signal;
- Optical tributary signal class NRZ 2.5G;
- Optical tributary signal class NRZ 10G.

### 3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

**3.2.1 optical tributary signal class DP-DQPSK 100G:** A class of continuous digital signals with non-return to zero differential quadrature phase shift keying modulation applied separately to two orthogonal polarizations of a carrier, operating at a total bit rate from nominally 103.1 Gbit/s to nominally 112.74 Gbit/s. Optical tributary signal class DP-DQPSK 100G includes a signal with FOIC1.4-SC bit rate according to [ITU-T G.709.3] and OTL4.4-SC bit rate according to [ITU-T G.709.2].

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

|            |                                                                                                    |
|------------|----------------------------------------------------------------------------------------------------|
| APD        | Avalanche Photodiode                                                                               |
| ASE        | Amplified Spontaneous Emission                                                                     |
| BER        | Bit Error Ratio                                                                                    |
| DGD        | Differential Group Delay                                                                           |
| DP-DQPSK   | Dual Polarization – Differential Quadrature Phase Shift Keying                                     |
| EX         | Extinction ratio                                                                                   |
| FEC        | Forward Error Correction                                                                           |
| FIR        | Finite Impulse Response                                                                            |
| FOIC1.4-SC | FlexO Interface of order C1 with 4 lanes                                                           |
| NA         | Not Applicable                                                                                     |
| NE         | Network Element                                                                                    |
| NRZ        | Non-Return to Zero                                                                                 |
| OA         | Optical Amplifier                                                                                  |
| OADM       | Optical Add-Drop Multiplexer                                                                       |
| OD         | Optical Demultiplexer                                                                              |
| OM         | Optical Multiplexer                                                                                |
| ONE        | Optical Network Element                                                                            |
| OTL4.4-SC  | Group of 4 Optical Transport Lanes that carry one OTU4-SC                                          |
| OTU4-SC    | Completely standardized 100G Optical Transport Unit for long-reach applications with Staircase FEC |
| OTUk       | Completely standardized optical channel transport unit – k                                         |
| PDL        | Polarization Dependent Loss                                                                        |
| PIN        | P type-intrinsic-n type                                                                            |

|                |                                                                             |
|----------------|-----------------------------------------------------------------------------|
| PMD            | Polarization Mode Dispersion                                                |
| R <sub>s</sub> | Single-channel reference point at the DWDM network element tributary output |
| SOP            | State of Polarization                                                       |
| S <sub>s</sub> | Single-channel reference point at the DWDM network element tributary input  |
| VOA            | Variable Optical Attenuator                                                 |
| WDM            | Wavelength Division Multiplexing                                            |

## 5 Classification of optical interfaces

### 5.1 Applications

This Recommendation provides the physical layer parameters and values for single-channel interfaces of DWDM multichannel optical systems in physical point-to-point and ring 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. Additional specifications are provided for the black link parameters, such as residual chromatic dispersion, ripple and polarization mode dispersion. 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.

This Recommendation considers DWDM applications where the black link may contain optical amplifiers.

### 5.2 Reference points

#### 5.2.1 Unidirectional applications

Figure 5-1 shows a set of reference points, for the linear "black link" approach, for single-channel connection (S<sub>s</sub> and R<sub>s</sub>) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an optical multiplexer (OM) and an optical demultiplexer (OD) (which are used as a pair with the opposing element), one or more optical amplifiers and may also include one or more optical add-drop multiplexers (OADMs).

The arrangement of elements within the black link shown in Figures 5-1 to 5-4 is not intended to place constraints on the construction of the black link, but simply to define the location of the single channel interfaces.

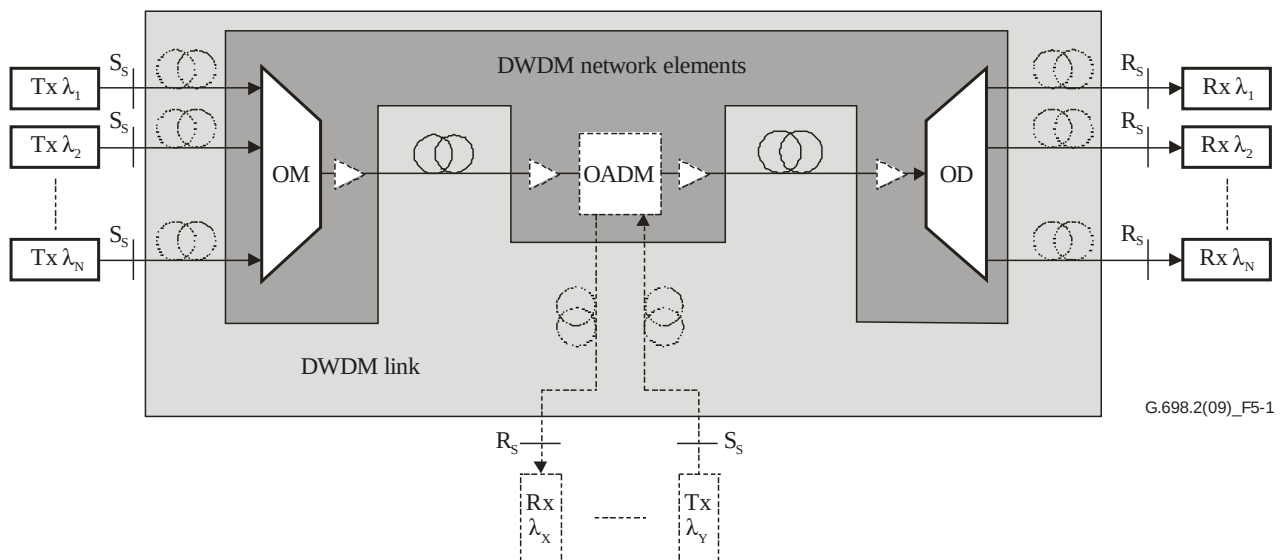


**Figure 5-1 – Linear "black link" approach**

As indicated in Figure 5-1, in cases where the transmitter or receiver is some distance from the OM, OD or OADM, the fibre between point  $S_s$  or  $R_s$  and the DWDM network element is considered to be part of the black link.

Figure 5-2 shows a corresponding set of reference points for the ring "black link" approach, for single-channel connection ( $S_s$  and  $R_s$ ) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include one or more amplifiers and two or more OADMs connected in a ring.

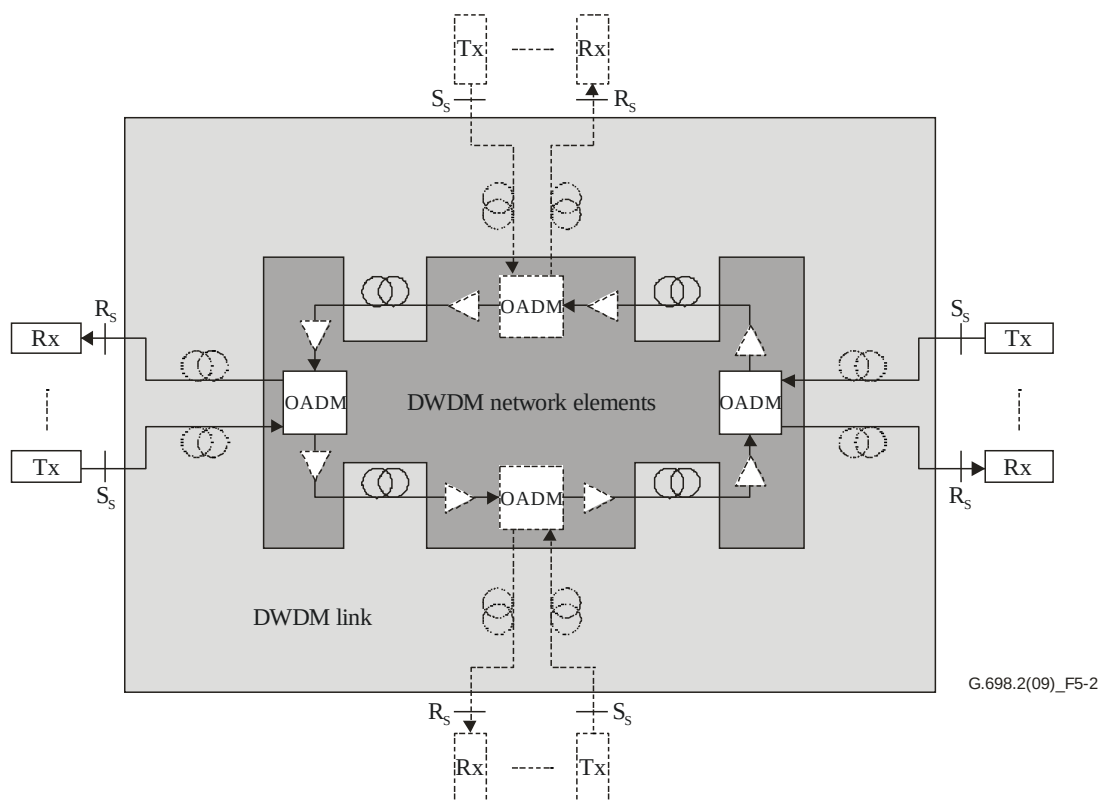


**Figure 5-2 – Ring "black link" approach**

The reference points in Figures 5-1 and 5-2 are defined as follows:

- $S_s$  is a single-channel reference point at the DWDM network element tributary input;

- $R_S$  is a single-channel reference point at the DWDM network element tributary output.

Here, single-channel reference points  $S_S$  and  $R_S$  are applied to systems for the (linear or ring) "black link" approach where every path from  $S_S$  to its corresponding  $R_S$  must comply with the parameter values of the application code.

### 5.2.2 Bidirectional applications

While this Recommendation does not currently contain any bidirectional applications, it is expected that they will be added in a future revision. Figure 5-3 shows a set of reference points, for the single-fibre bidirectional linear "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), one or more optical amplifiers and may also include one or more OADMs.

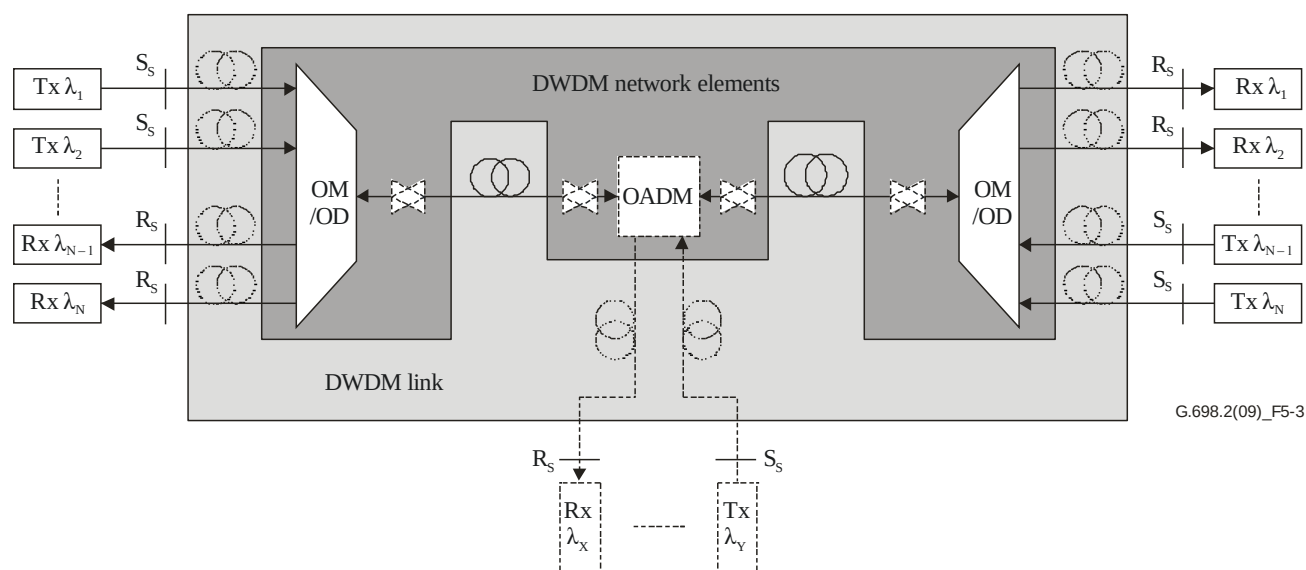


**Figure 5-3 – Linear "black link" approach for bidirectional applications**

Figure 5-4 shows a corresponding set of reference points for the single-fibre bidirectional ring "black link" approach, for single-channel connection ( $S_S$  and  $R_S$ ) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include one or more amplifiers and two or more OADMs connected in a ring.

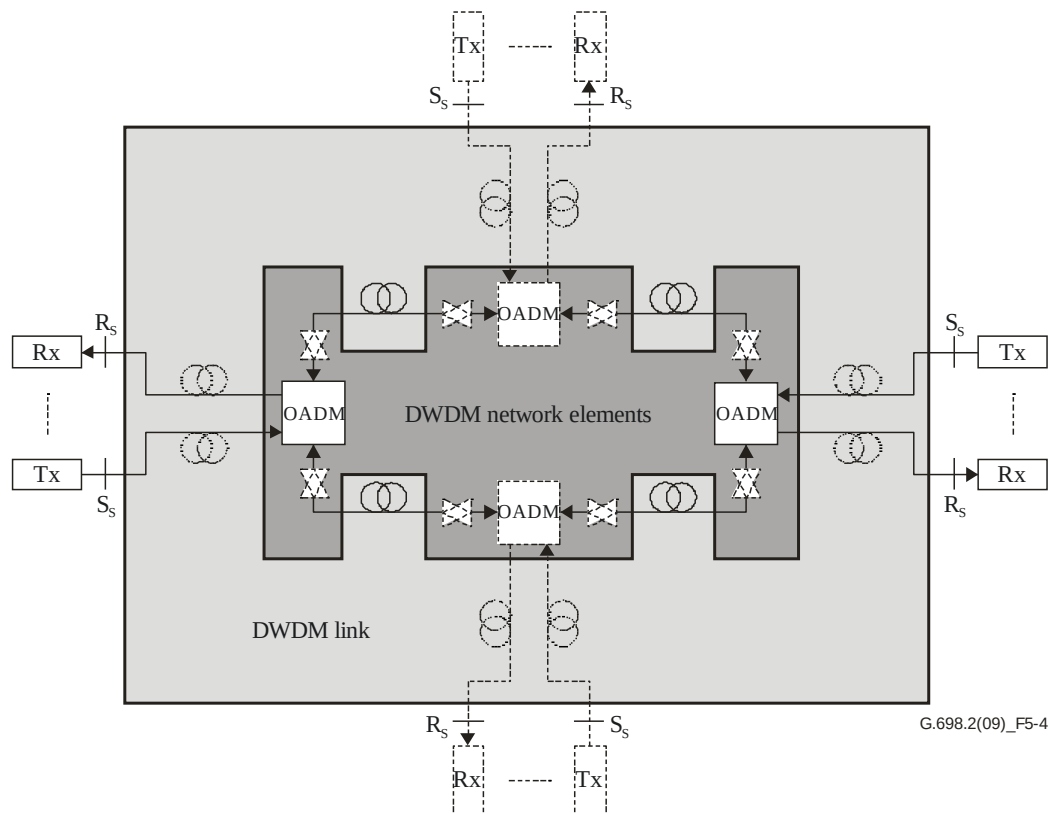


**Figure 5-4 – Ring "black link" approach for bidirectional applications**

The reference points in Figures 5-3 and 5-4 are as defined in clause 5.2.1.

### 5.3 Nomenclature

The application code notation is constructed as follows:

$$\text{DScW-ytz(v)}$$

where,

**D** is the indicator of DWDM applications.

**S** indicates options of maximum spectral excursion such as:

- **N** indicating narrow spectral excursion.
- **W** indicating wide spectral excursion.

**c** is the channel spacing in GHz.

**W** indicates the black link dispersion compensation regime as follows:

- **C** indicating that the chromatic dispersion values are appropriate to a black link that is dispersion compensated.
- **U** indicating that the chromatic dispersion values are appropriate to a black link that is dispersion uncompensated.

NOTE 1 – This letter is used to indicate the dispersion tolerance of the transmitters and receivers and not to constrain the construction of the black link. While application codes that include "C" have transmitters and receivers that have dispersion tolerance appropriate to DWDM links including dispersion compensation, they may be used with black links that do not contain dispersion compensators provided that the application code parameters are met. Likewise, while application codes that include "U" have transmitters and receivers that have dispersion tolerance appropriate to DWDM links without dispersion compensation, they may be used with black links that contain dispersion compensators provided that the application code parameters are met.

**y** indicates the highest class of optical tributary signal supported:

- **1** indicating NRZ 2.5G.
- **2** indicating NRZ 10G.
- **8** indicating DP-DQPSK 100G.

**t** is a letter indicating the configuration supported by the application code. In the current version of this Recommendation, the only value used is:

- **A** indicating that the black link may contain optical amplifiers.

**z** indicates the fibre types, as follows:

- **2** indicating ITU-T G.652 fibre.
- **3** indicating ITU-T G.653 fibre.
- **5** indicating ITU-T G.655 fibre.

**v** indicates the operating wavelength range in terms of spectral bands (see [b-ITU-T G-Sup.39]):

| <b>V</b> | <b>Descriptor</b> | <b>Nominal wavelength range (nm)</b> |
|----------|-------------------|--------------------------------------|
| S        | Short wavelength  | 1460 to 1530                         |
| C        | Conventional      | 1530 to 1565                         |
| L        | Long wavelength   | 1565 to 1625                         |

If more than one spectral band is used, then **v** becomes the band letters separated by "+", e.g., for an application requiring the use of both of the C and L bands, **v** would be "C+L".

NOTE 2 – The nominal wavelength ranges given here are for classification and not specification. The actual minimum and maximum wavelength for each application should be calculated from the maximum and minimum channel frequencies for that application.

A bidirectional system is indicated by the addition of the letter **B** at the front of the application code. For DWDM application codes, this will be:

B-DScW-ytz(v)

For some application codes, a suffix is added to the end of the code. The only suffix currently defined is:

- **F** to indicate that this application requires FEC bytes as specified in [ITU-T G.709] or for DP-DQPSK 100G in [ITU-T G.709.2] or [ITU-T G.709.3] to be transmitted.

#### 5.4 Single-channel interfaces at the reference points Ss and Rs

The single-channel interfaces described in this Recommendation are intended to enable transverse compatibility at the single-channel interfaces at either end of the DWDM black link as shown in Figures 5-1 to 5-4.

Further requirements related to transverse compatibility can be found in clause 6.

Table 5-1 summarizes the single-channel application codes, which are structured according to the nomenclature in clause 5.3.

**Table 5-1 – Classification of applications**

|                                            | <b>Dispersion compensated</b>                                                                                                                               | <b>Dispersion uncompensated</b>                                                                                                                                                                                |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Optical tributary signal class<br>NRZ 2.5G | DN100C-1A2(C)<br>DW100C-1A2(C)<br>DN100C-1A3(L)<br>DW100C-1A3(L)<br>DN100C-1A5(C)<br>DW100C-1A5(C)                                                          | DN100U-1A2(C)<br>DN100U-1A3(L)<br>DN100U-1A5(C)                                                                                                                                                                |
| OTU1 with FEC enabled                      | DW100C-1A2(C)F<br>DW100C-1A3(L)F<br>DW100C-1A5(C)F                                                                                                          |                                                                                                                                                                                                                |
| Optical tributary signal class<br>NRZ 10G  | DN100C-2A2(C)<br>DW100C-2A2(C)<br>DN100C-2A3(L)<br>DW100C-2A3(L)<br>DN100C-2A5(C)<br>DW100C-2A5(C)<br>DN50C-2A2(C)<br>DN50C-2A3(L)<br>DN50C-2A5(C)          |                                                                                                                                                                                                                |
| OTU2 with FEC enabled                      | DN100C-2A2(C)F<br>DW100C-2A2(C)F<br>DN100C-2A3(L)F<br>DW100C-2A3(L)F<br>DN100C-2A5(C)F<br>DW100C-2A5(C)F<br>DN50C-2A2(C)F<br>DN50C-2A3(L)F<br>DN50C-2A5(C)F | DN100U-2A2(C)F<br>DN100U-2A3(L)F<br>DN100U-2A5(C)F<br>DN50U-2A2(C)F<br>DN50U-2A3(L)F<br>DN50U-2A5(C)F                                                                                                          |
| OTL4.4-SC or FOIC1.4-SC                    |                                                                                                                                                             | DN50U-8A2(C)F<br>DN50U-8A3(L)F<br>DN50U-8A5(C)F<br>DN100U-8A2(C)F<br>DN100U-8A3(L)F<br>DN100U-8A5(C)F<br>DW50U-8A2(C)F<br>DW50U-8A3(L)F<br>DW50U-8A5(C)F<br>DW100U-8A2(C)F<br>DW100U-8A3(L)F<br>DW100U-8A5(C)F |

The amplified multichannel systems with single-channel interfaces in this Recommendation are specified in Tables 8-1 to 8-8.