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TECHNICAL REPORT

Dynamic modules –
Part 6-7: Design guide – Optical channel monitor

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FOREWORD

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IEC 62343-6-7, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86C/1252/DTR	86C/1274B/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 62343 series, published under the general title *Dynamic modules,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

DYNAMIC MODULES –

Part 6-7: Design guide – Optical channel monitor

1 Scope

This part of IEC 62343, which is a technical report, describes optical channel monitor modules, one of several important classes of dynamic modules that are used in dynamic optical networks. This report includes a description of the necessity of optical channel monitors, specifically in the context of dynamic optical networks, and how this is driving feature and performance requirements. This technical report surveys the different categories of optical channel monitor technologies that are being used and highlights some of their unique characteristics. Also described are different possible approaches for characterizing and specifying the performance of optical channel monitor modules.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62343, *Dynamic modules – General and guidance*

ITU-T Recommendation G.697, *Optical monitoring for dense wavelength division multiplexing systems*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62343 apply.

3.2 Abbreviations

Abbreviation	Term
ASE	amplified spontaneous emission
DWDM	dense wavelength division multiplexing
InGaAs	indium gallium arsenide
LOS	loss of signal
NIR	near infrared
OSNR	optical signal-to-noise ratio
PDL	polarization dependent loss
ROADM	reconfigurable optical add/drop multiplexers
SOP	state of polarization

4 Existing standards

ITU-T Recommendation G.697 was initially approved in June 2004 by ITU-T Study Group 15 (2001-2004). This recommendation and its subsequent revisions cover a broad scope of optical monitoring methods, including time domain methods, frequency domain methods, indirect methods, embedded methods and external methods. The recommendation reviews the full scope of optical impairments in DWDM transmission systems, and it prioritizes these impairments by relative probability of occurrence, thus prioritizing the monitoring features for the channel monitor. The recommendation describes the optical impairments of high relative frequency of occurrence to be:

- attenuation of transmission paths;
- optical channel power changes due to gain variations;
- frequency (or wavelength) deviation from nominal.

ITU-T Recommendation G.697 also proposes, but does not require, specifications relating specifically to embedded optical monitoring, including:

- performance of embedded optical monitoring at the DWDM receiver input;
- performance of embedded optical monitoring without OSNR;
- performance of embedded optical monitoring with OSNR.

ITU-T Recommendation G.697 also dedicates a significant section to interpolated OSNR measurements and the difficulty of such interpolated OSNR measurements in certain network architectures. ITU-T Recommendation G.697 refers to IEC 61280-2-9[1][1] as a useful reference for additional information on OSNR measurements.

It may be useful to point out that ITU-T Recommendation G.697 was drafted in 2004 in the context of point-to-point DWDM transmission networks, just before general adoption of reconfigurable optical add/drop multiplexers (ROADM) in the network around 2005. The ROADM has since become the core element of a new generation of optical systems that have been characterized as dynamic and for which dynamic modules are required. These dynamic optical systems embody the limitations in OSNR measurements that were already anticipated in ITU-T Recommendation G.697. Recently, dynamic optical networks have expanded the role and requirements for optical channel monitor modules due to the nature of their dynamic capabilities.

5 The role of optical channel monitors in dynamic optical networks

5.1 General

Dynamic optical networks exhibit the following characteristics:

- The capability to express optical signals of a given wavelength through optical networking nodes in the optical domain, thus bypassing the conversion to the electrical domain;
- The capability to switch optical signals of a given wavelength between a set of ingress and egress optical ports;
- The capability to manage the optical channel attributes, including channel power, as the channels are configured to traverse particular paths through the network;
- The capability to support a large number of interconnected optical rings or a multi-wavelength mesh topology.

The optical channel monitor function assists with each of these capabilities as described below.

[1] Numbers in square brackets refer to the Bibliography.

5.2 Signal performance monitoring and fault isolation

The capability to express optical signals of a given wavelength through nodes in the optical domain allows optical signals to bypass the conversion to the electrical domain. When suitable for the application, this provides a savings in cost. However, any signal performance monitoring and fault isolation capabilities that reside in the electrical domain are no longer available to the network management system. This is mitigated by monitoring the signal performance in the optical domain. The optical channel monitor performs that function. In a broader sense, devices that are categorized as optical performance monitors also perform that function using more sophisticated measurements. Table 1 compares the general features of the optical channel monitor and the optical performance monitor.

Table 1 – High level comparison of optical channel monitor and optical performance monitor features

Features	Optical channel monitor	Optical performance monitor
Channel identification	Required	Required
Channel power	Required	Required
Channel frequency	Optional	Optional
Optical signal-to-noise ratio	Optional	Required
Chromatic dispersion	Not applicable	Optional
Polarization mode dispersion	Not applicable	Optional

Table 1 indicates that the optical performance monitor distinguishes itself from the optical channel monitor with advanced features. This typically requires a device architecture that does not fall within any of the three broad optical channel monitor architectures shown in Figure 2. As a result, the optical performance monitor is beyond the scope of this technical report. References to optical performance monitor technologies and measurement methods can be found in the bibliography, including IEC 61280-2-9 and IEC 61280-2-11 [2]. For a comprehensive treatment of advanced optical performance monitor techniques, please refer to the text by Calvin C.K. Chan (Academic Press) [3] which includes the following topics:

- optical performance monitoring
  - based on optical sampling;
  - based on pilot tones;
  - based on electronic digital signal processing;
  - based on nonlinear optical techniques;
  - of optical phase modulated signals;
  - for coherent optical systems;
  - chromatic dispersion monitoring;
  - polarization mode dispersion monitoring.

5.3 Channel inventory and routing management

This is the capability to switch optical signals of a given wavelength between a set of ingress and egress optical ports. It drives the simple requirement for independent verification so that wavelengths are properly routed to the intended ports. The optical channel monitor performs that function.

5.4 Dynamic channel power self-management

The capability to support a large number of interconnected optical rings or a multi-wavelength mesh topology drives the requirement for self-managed optical networks. A common attribute of this architecture is the need for optical nodes to return to a known state at the egress optical port. In practice, this requirement is often met by equalizing the DWDM channels around a desired per-channel optical launch power. The actuators that vary the attenuation of each individual DWDM channel are found in dynamic gain equalizers or within wavelength selective switches. Optical channel monitor modules are used to close the control loop.

6 Review of optical channel monitor technologies

6.1 General

A common feature of all optical channel monitor modules is that they operate off of a fraction of the optical transmission signal. To achieve this, they are typically connected to a 1 % to 5 % passive optical tap coupler as shown in Figure 1.

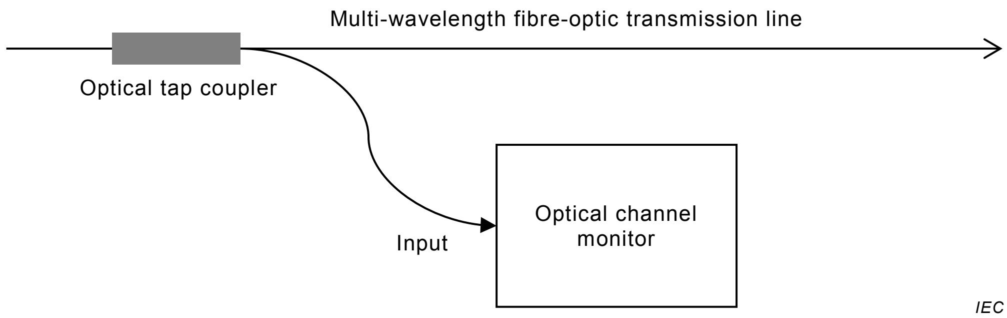
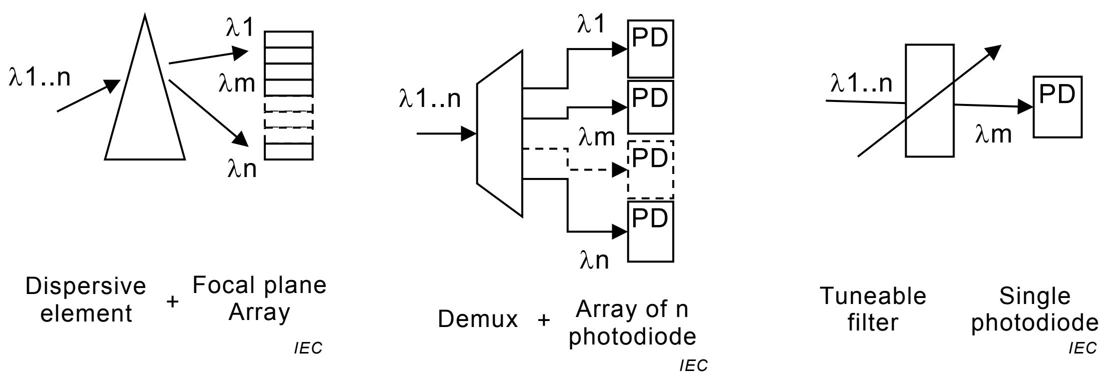


Figure 1 – Fraction of the optical power in the multi-wavelength transmission line tapped and fed to the input of an optical channel monitor for spectral analysis

There are many technologies that can be used to construct an optical channel monitor that reports the optical power and wavelength of each optical channel. Each technology can be categorized within three broad categories that could be described as:

- spatial wavelength dispersion and focal plane array detection,
- dedicated photodiode per demultiplexed wavelength,
- tuneable filter and single photodiode element.

Each of these technology categories are determined by their commonality in the optics function as well as the photo-detection architectures, as shown in Figure 2. These three technology categories are described below in more detail. For each of these technology categories, the optics and the photo-detection architectures are discussed separately.



a) – Spatial wavelength dispersion and focal plane array detection

b) – Dedicated photo- diode per demultiplexed wavelength

c) – Tuneable filter and single photodiode element

Figure 2 – Optical channel monitors – Three broad architecture categories