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Edition 1.0 2011-02

TECHNICAL REPORT

colour inside

Dynamic modules –
Part 6-1: Dynamic channel equalizers

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DYNAMIC MODULES –

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IEC 62343-6-1, 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/969/DTR	86C/994/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.

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

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DYNAMIC MODULES –

Part 6-1: Dynamic channel equalizers

1 Scope

This part of IEC 62343 is a technical report and deals with dynamic channel equalizers (DCE). The report includes a description of the dynamic channel equalization and its benefits in a wavelength division multiplexed (WDM) transmission system and also covers different DCE component technologies that are being used.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
channel non-uniformity
difference (in dB) between the powers of the channel with the most power (in dBm) and the channel with the least power (in dBm). This applies to a multichannel signal across the operating wavelength range

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2.2
in-band extinction ratio
within the operating wavelength range, the difference (in dB) between the minimum power of the non-extinguished channels (in dBm) and the maximum power of the extinguished channels (in dBm)

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2.3
out-of-band attenuation
attenuation (in dB) of channels that fall outside of the operating wavelength range

2.4
operating wavelength range
specified range of wavelengths from λ_{imin} to λ_{imax} about a nominal operating wavelength λ_I, within which a dynamic optical module is designed to operate with a specified performance

2.5
channel frequency range
frequency range within which a device is expected to operate with a specified performance

NOTE For a particular nominal channel central frequency, f_{nomi}, this frequency range is from f_{imin} = (f_{nomi} - Δf_{max}) to fi_{max} = (f_{nomi} + Δf_{max}), where Δf_{max} is the maximum channel central frequency deviation.

2.6
ripple
peak to peak difference in insertion loss within a channel frequency (or wavelength) range

2.7
channel spacing
centre-to-centre difference in frequency (or wavelength) between adjacent channels in a device

2.8
channel response time
elapsed time it takes a device to transform a channel from a specified initial power level to a specified final power level desired state, when the resulting output channel non-uniformity tolerance is met, measured from the time the actuation energy is applied or removed

3 Background

The capacity of dense wavelength division multiplexed (DWDM) networks has grown exponentially since 2000 to meet the bandwidth demand created by the Internet. The highest demonstrated transmission capacity over a single fibre now exceeds 10 Tb/s. There is also a push to reduce the overall capital expenditure of building networks and lower the cost of transmitting data.

In order to reduce capital expenditure, the networks are evolving such that high-capacity transmission can be carried out over ultra-long distances of several thousand kilometres without optical-electronic-optical (OEO) regeneration. One of the challenges in ultra-long-haul transmission systems is to equalize the power of WDM channels in order to provide an acceptable optical signal-to-noise ratio (OSNR) and deliver a high quality of service for all optical channels. It is currently difficult to equalize the power of the various wavelengths present in a system because of wavelength dependence in the gain/loss of different elements forming the WDM transmission system.

The key elements that contribute to the wavelength dependent gain/loss include erbium-doped fibre amplifiers (EDFAs), transmission fibre, dispersion compensators and passive optical elements in a fibre optic transmission system. The problem of wavelength-dependent gain/loss becomes more critical in ultra-long-haul networks where signals will have to pass through up to 50 EDFAs and fibre spans without OEO regeneration. Next-generation networks will require some method of dynamic channel equalization to provide uniform OSNR for all the channels in the WDM system and thereby improve the system margin which can be used to lower the cost of ultra-long haul-systems.

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Recently, point-to-point systems have evolved towards ring and mesh networks. Reconfigurable optical add-drop multiplexer (ROADM)-based architectures have emerged to provide flexible and reconfigurable networks.

An example of the ROADM node architecture is shown in Figure 1a. A multichannel DWDM fibre enters the node and the optical power is immediately split to provide paths for wavelengths that transit through the node and dropped wavelengths that get routed to a demultiplexer. The through traffic enters a 1 × 1 WSS (i.e. it has just one input and one output port so there is no switching) that under remote control either passes through, equalizes, or blocks (extinguishes) any or all wavelengths. New wavelengths are added by passive combination after the WSS. The WSS blocks any wavelengths identical to the added wavelengths so that there are no duplicate wavelengths carrying traffic in the same channel. Discrete variable optical attenuators (VOAs) are used to equalize the optical power of the added wavelengths and an optical power monitor (OPM) provides feedback for the optical power equalization controls of the WSS and VOAs. Figure 1b shows a variation on this architecture where the locally added wavelengths are still combined at a multiplexer but are now directed to the Add port of a 2 × 1 WSS. The WSS selects specific wavelengths from either the In or Add port and routes these to the Out port for transmission to the next network node. The WSS in this architecture also equalizes the optical power of the added wavelengths, eliminating the need for discrete VOAs.

Both architectures of Figures 1a and 1b are termed fixed add/drop because the dropped and added wavelengths are associated with specific or fixed ports on the multiplexers. While these wavelengths are still connected manually to specific service line cards (e.g. 10 Gb Ethernet or SAN protocol), one school of thought holds that this is of no major concern because it is usually done in conjunction with the manual provisioning of the service line cards themselves. The main advantage of these ROADM architectures is that the multiple wavelengths passing through the node are routed and equalized in an automated fashion. Figures 1c and 1d show two-degree ROADM configurations that eliminate the fixed physical associations for the dropped and added wavelengths with the demux and mux ports. The industry calls this feature colourless because any colour (frequency) or wavelength can be directed to any Drop port and from any Add port.

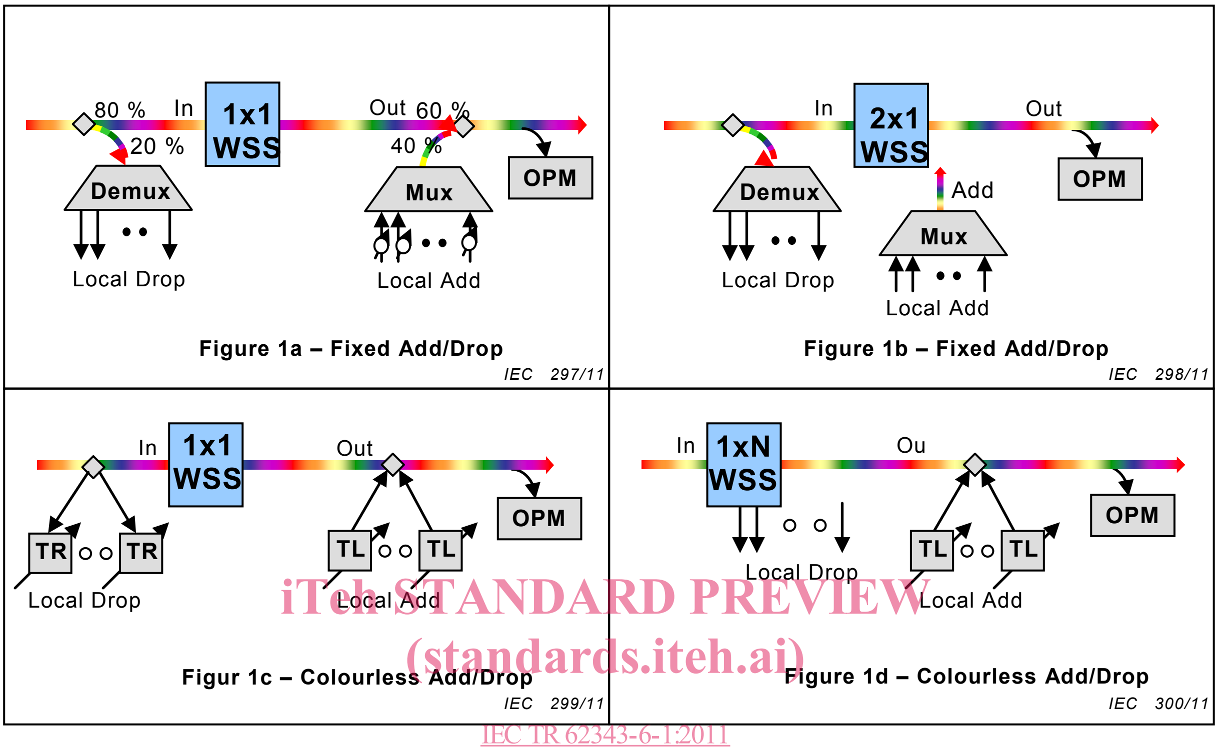

Figure 1a – Fixed Add/Drop

Figure 1b – Fixed Add/Drop

Figur 1c – Colourless Add/Drop

Figure 1d – Colourless Add/Drop

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Figure 1 – ROADM architecture

This technical report explains how the wavelength dependent gain in EDFAs can impair the system performance of a long haul system and how the use of dynamic channel equalization devices such as dynamic gain equalization filters (GEFs) can improve the end of system OSNR to extend their reach to ultra long distances.

4 Gain equalized EDFAs

Manufacturers of wideband EDFAs insert static gain equalization filters (GEFs) between the stages of an EDFA to flatten the gain spectrum. The most commonly used GEFs, based on thin film technology, consist of translucent multi-layer structures of materials with different indices of refraction that create interference effects.