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Channel-monitor vendors revisit the fundamentals

Optical channel monitors are an essential component of reconfigurable networks. Mark Lourie describes how the advent of 40 and 100 Gbit/s transmission is pushing the performance requirements for these devices to new levels.

The key to the resounding success of the reconfigurable optical add-drop multiplexer (ROADM) is flexibility. ROADMs simplify the engineering rules for provisioning a wavelength across a network from any one node to any other.



Active thin films

Previously network operators would have needed to plan the optical parameters of the network with meticulous attention to detail, and then manually adjust the physical hardware in the field every time they wanted a change. Now they simply add transponders at the ingress and egress of the fibre-optic network and let the ROADM systems along the transmission path take care of optical power balancing. In this way, wavelength turn-up and provisioning can become fast and fully automated.

This is possible because ROADM systems contain components to vary the optical

attenuation for each channel independently. They also contain optical channel monitor subsystems that can provide feedback to help balance the spectrum, as well as to report the channel inventory and signal quality to local and remote network management systems.

Monitoring the situation

ROADM systems are typically comprised of a wavelength switching subsystem, one or more optical amplifiers and an optical channel monitor configured with one to four input ports. All three subsystems play a critical role, and their standardization is addressed in the International Electrotechnical Commission (IEC) Subcommittee SC86C Working Group 5 on dynamic modules.

The channel monitor is typically connected to the fibre-optic transmission line via a 1% tap. Its main task is to perform an analysis of the spectrum and output an inventory of all the channels present, along with their respective powers. In some cases a measure of interpolated optical signal-to-noise ratio (OSNR) is also available.

The advent of the ROADM in 2004 was a transformational event for the channel-monitor market. Before the ROADM, WDM links were always in a point-to-point configuration. The conventional wisdom of the time held that one channel monitor could be afforded for every six or eight optical networking nodes. The channel monitor was a high-performance, high-cost device with similar specifications to an optical spectrum analyser (OSA), and would usually be located at the end of the fibre-optic transmission line where degradation of the DWDM signal would be worst.

The arrival of ROADM systems, with the ability to add and drop channels on the fly, turned the channel monitoring requirement on its head. Suddenly a channel monitor was needed for each ROADM degree (the number of incoming routes to the node). This pushed up the volume requirements significantly, which in turn put pressure on subsystems vendors to reduce the cost.

To meet this challenge, system designers whittled the channel-monitor requirements down to the most basic functions, such as power monitoring of the individual channels, and abandoned other features like wavelength accuracy, raw spectral outputs and other attributes more relevant to high-end OSAs.

This paradigm change brought about by ROADM systems fuelled the growth of channel-monitor shipments in recent years. This is expected to continue as ROADM systems are pushed further towards and into the edge of the optical network.

Increasingly dynamic system balancing is about much more than just convenience. Over the last few years this capability has evolved to become a fundamental requirement for network design as operators roll out ever larger islands of optically transparent networks, which may feature as many as 20 to 50 pass-through ROADM nodes. These complicated new network topologies could not be achieved without dynamic channel balancing, and therefore without channel monitors.

To most people the basic function of the optical channel monitor is to report channel power within certain accuracy. Implicit in this is a more fundamental requirement, simply to identify channels accurately. This may seem obvious, yet a channel monitor that fails to report a channel or reports a non-existent one will have a highly disruptive effect on the channel balancing dynamics in ROADM systems, and may cause false reporting of high-severity alarms.

New challenges

The recent implementation of 40 Gbit/s modulation rates in ROADM systems has brought new complexities to the seemingly simple task of channel identification. This goes to the heart of channel-monitor designs because it lays the foundation upon which all the other features are built. It is quietly driving the need for a new class of channel monitors, which can be categorized as “modulation format independent”.

For 40 Gbit/s transmission an optical channel monitor still has to perform the same basic tasks of channel identification and power reporting, but now there are more varieties of bit rates and modulation formats, which result in new spectral profiles. (Note that 40 Gbit/s transmission rates can be spectrally similar to 100 Gbit/s transmission technologies that combine multiple modulated signals on mutually orthogonal polarizations; we will refer to this as 40/100G.)

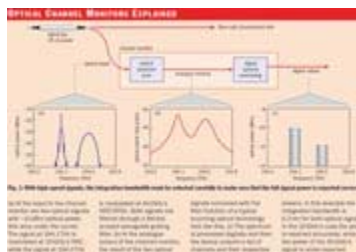


Figure 1

A continuous-wave laser with high spectral purity has a very narrow linewidth. As the modulation rate of a transponder increases, the linewidth of the transponder’s output broadens. For modulation rates up to 10 Gbit/s the transponder’s linewidth remains

narrower than the optical filter bandwidth of most channel monitors. For all practical purposes, the transponder's optical spectrum can be approximated to a delta function. But with modulation rates of 40 Gbit/s and above, the transponder's spectral output becomes broader than the optical filter bandwidth of most channel monitors. As a result, spectral processing algorithms need to account for the modulation format, and the integration bandwidth – the spectral width over which power is collected by the detector – has to be carefully considered (figure 1).

An integration bandwidth that is too wide or too narrow can provide severe limitations for power balancing. If the bandwidth is too narrow, the monitor will only report a fraction of the power of 40/100G channels. If it is too wide then amplifier noise will increase the error in the reported power of the channel, especially for signals with low OSNR.

The optimal integration bandwidth depends on the application, and may even go as far as requiring channel-by-channel adaptation of the integration bandwidth, especially where transmission combines a mix of channels at various bit rates and modulation formats. Channel monitors that can meet these new challenges are said to be modulation format independent.

To further complicate matters optically broad signals change spectral shape as they travel through a cascade of optical filter elements such as interleavers or demultiplexers, which are found inside ROADMs subsystems. The channel monitor may report different values depending on the number of filter cascades that the wavelength has passed through, and there is no simple correction that can be applied (figure 2).

Even worse, amplifier noise that has been filtered by the same sequence of optical filter functions can give rise to a new class of potential false positives.

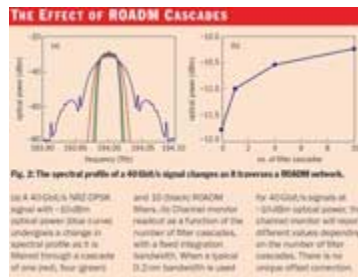


Figure 2

Live testing also poses new challenges at 40/100G. The conventional method for assessing a channel monitor's performance is to compare the output of the device with a known reference such as a calibrated OSA. However, typical OSAs only offer a fixed number of

resolution bandwidth settings. If a channel monitor reports the power in a non-standard integration bandwidth or with mixed-integration bandwidths on a channel-by-channel basis, then the measurement obtained with the OSA will need to be analysed with the same integration bandwidth settings.

Verifying channel-monitor performance with real 40/100G signals also turns out to be a challenge simply because 40/100G transponders are at a premium and so are seldom available for testing purposes. In any case developing channel monitors for 40/100G requirements needs unprecedented cooperation with equipment vendors that goes beyond simply developing a specification. Equipment vendors must be willing to share the spectral information of the transmitters and the various filters that lie in the transmission path. Channel-monitor vendors must then apply powerful simulation tools to analyse the many hundreds of possible cases that the monitor may encounter. These must reflect any combination of laser modulation formats, channel-power non-uniformities, frequency detuning from the International Telecommunication Union (ITU) grid, as well as all possible permutations of filter cascades.

New solutions

Channel monitors fall under two broad technology categories: scanning and static. A demultiplexer terminated with one photodetector per wavelength is a typical static example. Channel monitors that use a tunable filter or dispersive element with a multi-hundred element photodetector array are typical examples of scanning technologies.

Static channel monitors are relatively simple and inexpensive because they offer little spectral processing overhead, if any. On the other hand they feature a fixed-integration bandwidth that translates into a “one size fits all” limitation to power reporting. Another drawback is the inability of fixed filters to centre the integration bandwidth around the actual laser signal, which can yield power measurement errors. The absence of spectral processing precludes static technologies from having sophisticated features such as the ability to positively identify channels or modulation formats, or to discriminate between channels and filtered optical noise.

Most high-performance channel monitors are based on scanning technology. Aegis has two different types of scanning technology available in-house: the tunable semiconductor thin-film technology on which the company was founded, and a scanning micro-mirror technology that was obtained through the acquisition of CardinalPoint Optics in April 2008.



It's all done with mirrors

At the OFC/NFOEC 2009 show, Aegis is announcing a new range of channel monitors that are modulation format independent. These products feature a spectral processing algorithm entirely redesigned from the ground up to address the performance requirements of current and future ROADM designs.

The CTM 2250/1250 series is based on Aegis' established tunable thin-film filter technology, with a recently improved filter function. The CTM 2250 is capable of monitoring two ports simultaneously and is best suited for metro and regional ROADM systems, whereas the CTM 1250 is designed to be as compact as possible for applications where space is at a premium, for example in edge-ROADM systems.

The OCM 2550, based on scanning micro-mirror technology, is best suited for very-high-performance applications such as long-haul ROADM systems, where 100G might be deployed first. The ability for the scanning micro-mirror to tune and hold on any given channel also makes it a good candidate platform for future applications that measure in-band OSNR.

In summary, the widespread adoption of ROADM systems was the first significant event to set the requirements for optical channel monitoring. The recent implementation of 40/100G transmission is forcing optical-channel-monitor vendors to add new layers of technical sophistication to their products. With the possible trend towards 100 Gbit/s modulation rates and beyond, channel identification may become so challenging that additional methods beyond spectral processing may be required to distinguish channels from filtered optical noise. Delivering these increasingly complex channel monitors at a manageable cost will require more dedicated efforts, and will draw upon expertise from an increasingly diverse technical team.

About the author

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