Introduction To OSA / WDM Analyzer

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The need for optical spectrum analyzer (OSA) in the field:
• High demand for high speed DWDM networks and new installed CWDM networks drive demand for spectral testing
• ROADM network deployment picking up in major markets

The pressures imposed by a competitive market entail that service providers upgrade and maintain their networks continuously to ensure that they are capable of delivering higher-speed, higher-quality applications and services to customers. This creates a need to verify and make sure that the network's fiber infrastructure and equipment can meet exacting performance standards and operate reliably. This paper discusses one particular aspect of the evolving requirements in system turn-up, namely, the need for an optical spectrum analyzer, a critical tool to characterize DWDM, that is, multiple channel systems. The different technologies to realize the spectrum analyzer are described in this document, together with their benefits and limits.

Principle of WDM

WDM (Wavelength Division Multiplex) technology is a very effective means of increasing the transmission of fibers, as it demands neither the installation of new links, nor any increase in transmission speed. The streams of digital information are transmitted along the fiber at different wavelengths, each wave-length (or channel) transmitting a signal. The channels are defined according to the G-692 recommendations of the ITU-T. This technology demands new measurements, since it is important, during the installation and maintenance of WDM systems, to check the following parameters:

1) Presence of the channels at the corresponding wavelengths, with no drift

2) Correct channel power levels, without power variation.

3) Satisfactory signal-to-noise ratio (SNR): Its value is obtained by measuring the ratio of channel peak power to the noise power level of the Amplified Spontaneous Emission (ASE1) signal to the right and /or left of the carrier. As a general rule, the noise measurement point chosen is the calculated mid-point between two adjacent channels. The noise power level measured is converted to a standard bandwidth of 0.1 nm.

The most important item of equipment for carrying out these tests on WDM systems is the optical spectrum analyzer (OSA). It can be connected at critical measurement points in the WDM system, to the ends of the links or to the amplifier locations.

The Basic Components of a WDM System

- The Erbium-Doped Fiber Amplifier (EDFA)
- The Input Wavelength Converting Transponder
- Optical Terminal (Multiplexer/De multiplexer)

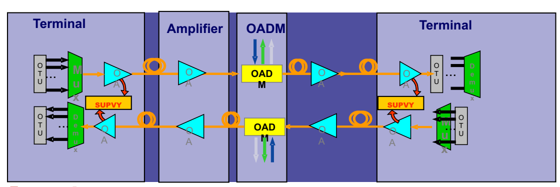

Figure-1

- Optical Add/Drop Multiplexer (OADM)

The following steps describe the DWDM system shown in Figure above:

• The transponder accepts input in the form of standard single-mode or multimode laser. The input can come from different physical media and different protocols and traffic types.

• The wavelength of each input signal is mapped to a DWDM wavelength.

• DWDM wavelengths from the transponder are multiplexed into a single optical signal and launch into the fiber. The system might also include the ability to accept direct optical signals to the multiplexer; such signals could come, for example, from a satellite node.

iv) A post-amplifier boosts the strength of the optical signal as it leaves the system (optional).

v) Optical amplifiers are used along the fiber span as needed (optional).

vi) A pre-amplifier boosts the signal before it enters the end system (optional).

vii) The incoming signal is de-multiplexed into individual DWDM lambdas (or wavelengths).

viii) The individual DWDM lambdas are mapped to the required output type (for example, OC 48 single -mode fiber) and sent out through the transponder.

Optical spectrum analyzer definition

As multiple wavelengths are used in a DWDM system, it is important to know the following parameters for each wavelength/channel: exact wavelength, power level, dynamic range or optical signal over noise ratio (OSNR).Most of the DWDM parameters are defined in the ITU-T recommendation G.692 "Optical interfaces for multichannel systems with optical amplifiers". The optical spectrum analyzer (OSA) provides these parameters and a trace of power as a function of wavelength. The optical spectrum analyzer can also provide, together with a broadband source at the opposite end, a spectral attenuation trace for fiber characterization, which is an important parameter for DWDM installation.

Optical spectrum analyzer methods

There are three different optical spectrum analyzer methods that can be used in the field. They are the interferometric method, the diffraction-grating method and the Fabry- Perot method. Calibration of the OSA is defined by IEC 62129 "Calibration of optical spectrum analyzer". See also IEC 61290 "Optical fiber amplifiers", which includes TIA/EIA 455-206 and 209. Telcordia GR-2952-CORE "Generic requirements for portable wavelength division multiplexer analyzers" provides the main specifications of an OSA.

OSA with the interferometric method

Principle-The principle of the interferometric method is that the equipment counts the interference maxima and

minima amplitude which are produced by a fixed mirror and a moving mirror (Michelson interferometer). Individual wavelengths can be selected through subsequent computation of the spectrum using a fast Fourier transform (FFT). This principle can be also used for multi-wavelength meters, instruments which are mainly providing wavelength and power levels information, and no dynamic range/OSNR values

Benefits and limits-The benefits of this method are its wavelength range, accuracy and stability (a typical reference source for calibration is the HeNe source). It also has a good dynamic range and OSNR values, but these tend to be less than diffraction-grating based OSAs. As there are moving parts, this method is not fully optimized for the field or outside plant applications, but more optimized for inside plant applications. This is also the most expensive technology.

OSA with the diffraction-grating method

Principle-The principle of the diffraction-grating method is based on the fact that the light is broken into its spectral colors by a grating. The grating rotates so that different wavelengths are brought to the detector at different times and analyzed. Such a combination can also be called a monochromator. Double pass monochromators (the light is reflected twice to the grating) provide better accuracy and higher dynamic range than single-pass monochromators.

Benefits and limits-The benefits of this method are its wave-length range, good dynamic range and OSNR values, but it is limited for the resolution and wavelength accuracy parameters. As there are moving parts, this method is not fully optimized for the field or outside plant applications, but more optimized for inside plant applications.

OSA with the Fabry-Perot method

Principle-The principle of the Fabry-Perot method is the use of a cavity resonator. It is made of two partially mirrored plates, arranged at an adjustable distance using piezo elements, thereby forming a resonant cavity. The selectivity is directly determined by the transfer properties of the Fabry-Perot filter. It is transparent when all the sub-beams arising between the plates due to multiple reflections are constructively superimposed. At all other wavelengths high attenuation occurs.

Benefits and limits-This method provides good wavelength accuracy, but is limited as far as the dynamic range/OSNR and wavelength range values are concerned. If the wavelength range is extended, using similar component specifications, then the dynamic range will be reduced. Its small filter bandwidth means very close channels can be detected (down to 12.5 GHz). Even the modulation or laser chirp of a given channel can be seen. It has no moving parts, making it rugged (not sensitive to drop, vibration, etc) and ideal for field and outside plant use, but also for DWDM system monitoring purposes. It is also compact and lightweight, as it uses only components, and does not need free-air mechanics. Moreover, it has a low power requirement making it ideal for battery-operated instruments.

When shall I use a DWDM Analyzer / OSA with my links?

Spectral Attenuation (SA) measurements are commonly used when DWDM systems are installed or during

- Fiber installation for spectral attenuation measurements
- Upgrade of classical TDM 1310/1550nm networks to DWDM applications
- Maintenance and troubleshooting of DWDM networks
- DWDM Network monitoring and surveillance

Reference Test Points

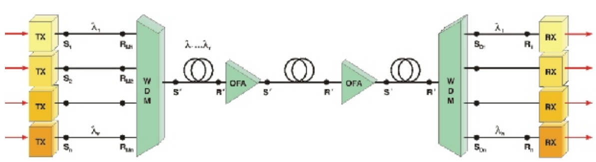

Figure-2

According to ITU-T Rec. G.692, reference test points are to be provided in DWDM systems:

- S1 to Sn are reference points directly at the output of the individual optical transmitters 1 to n of the DWDM system.
- RM1 to RMn are reference points for the individual fibers directly before the input of the WDM multiplexer.
- S' is the test point directly at the output of the WDM multiplexer and R' a further test point directly at the input of the de-multiplexer.
- SD1 to SDn are the corresponding reference points directly at the output of the de-multiplexer
- R1 to Rn are the reference points at the input of the individual receiver modules of the DWDM system.

What are Test Parameters for DWDM systems/networks ?

Power levels of the individual carriers

- To ensure even power distribution over the entire bandwidth
- To notice immediately whether any channels have been dropped out

Channel wavelength / Channel spacing

- To indicate possible wavelength shifts for individual laser sources
- To measure Signal-to-noise ratio
- To ensure that error-free transmission is possible in each data channel.
- Overall power
- To check the optical fiber amplifiers of the system
- To check against safety limit of currently +17 dBm

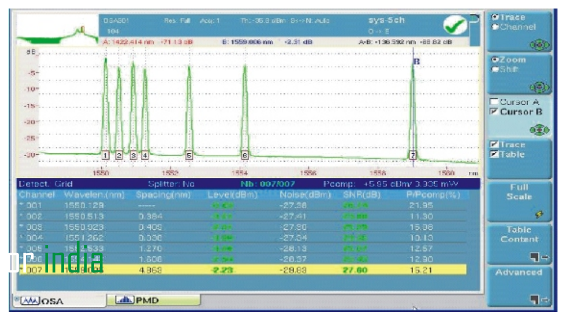

Figure-3

EDFA Analysis

The results analysis of an EDFA consists in performing two spectrum analyses: one before the signal is amplified and another one after the signal is amplified. Both traces are further compared, providing the resulting power gain and noise figure.

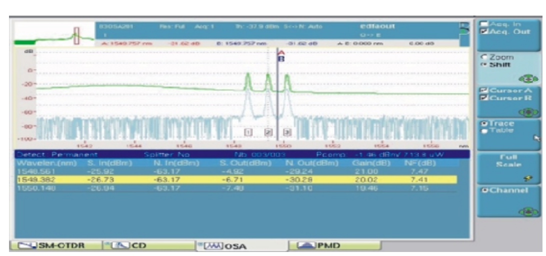

Figure-4

EDFA analysis results:

- S. In: Signal power before EDFA (expressed in dBm)
- N. In: Noise level before EDFA (expressed in dBm)
- S. Out: Signal power after EDFA (expressed in dBm)
- N. Out: Noise level after EDFA (expressed in dBm)
- Gain: Power gain from EDFA (expressed in dB)
- NF: Noise figure from EDFA (expressed in dB)

<Channel> allows moving the cursor from one channel to another, both in the trace and in the table of results.

Distributed Feedback Laser (DFB) testing

DFB (sub-menu)

- Bandwidth level: Level (expressed in dBc) where the main component bandwidth should be calculated
- Min SMSR Minimum offset value to consider finding the Side Mode
- Max SMSR Maximum offset value to consider finding the Side Mode

DFB measurements:

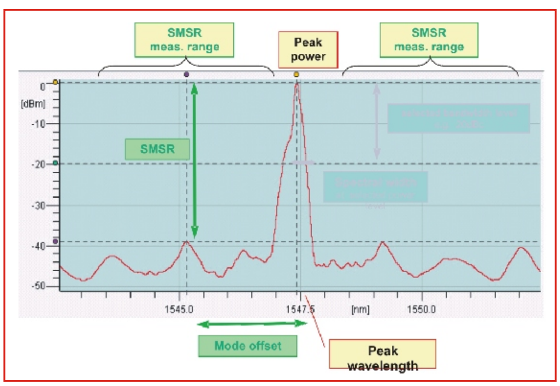

Figure-5

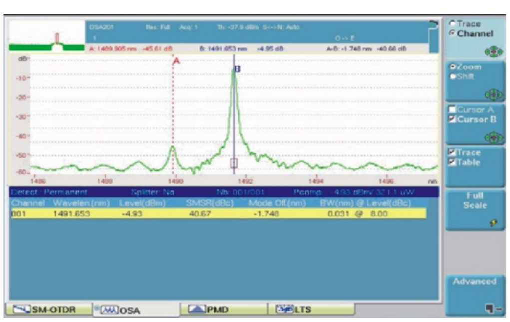

Figure-6

Cursors A and B are automatically positioned on the first DFB laser, respectively on the max SMSR and the pick of the main component.

DFB results:

A table is displayed showing for each DFB:

- Channel: Number of DFB laser detected
- Wavelength: Wavelength (expressed in nm) of the DFB main component
- Level: Peak amplitude (expressed in dBm)
- SMSR: Side Mode Suppression Ratio (expressed in dBc)
- Mode off: Mode Offset (expressed in nm)
- BW @ level: Calculated bandwidth (expressed in nm) according to the bandwidth level (expressed in dBc) defined in the setup menu.

DWDM MUX & TX Transponder Testing

Test Procedure

a. Connect one Tx/transponder output connector to DWDM analyzer or OSA
b. Record output power and wavelength
c. Repeat this for all Tx
d. Connect the MUX output to OSA/DWDM analyzer
e. Record powers &wavelengths
f. Calculate delta = IL for each wavelength

Requirements

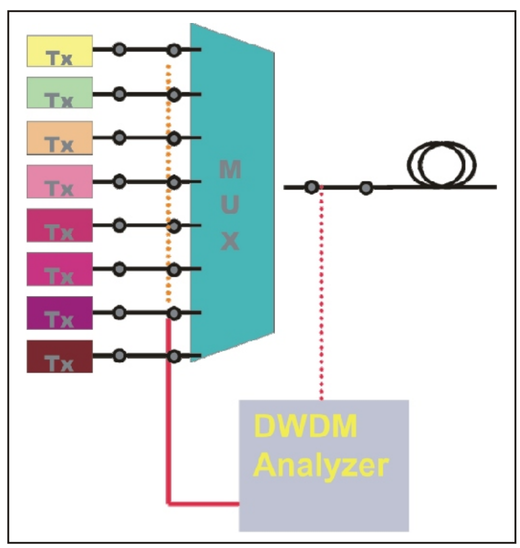

Figure-7

a) Output power range: ~ -5 to +5 dBm
b) Channel wavelength: <20% of channel spacing
c) Max IL MUX (per wavelength): 3 dB

DWDM DEMUX Testing

Test Procedure

a. Connect DEMUX input to OSA
b. Record powers & wavelengths

c. Connect DEMUX output to OSA
d. Record power & wavelength
e. Repeat this for all outputs
f. Connect Rx input to OSA (if far from DEMUX)
g. Record power & wavelength
h. Repeat this for all Rx

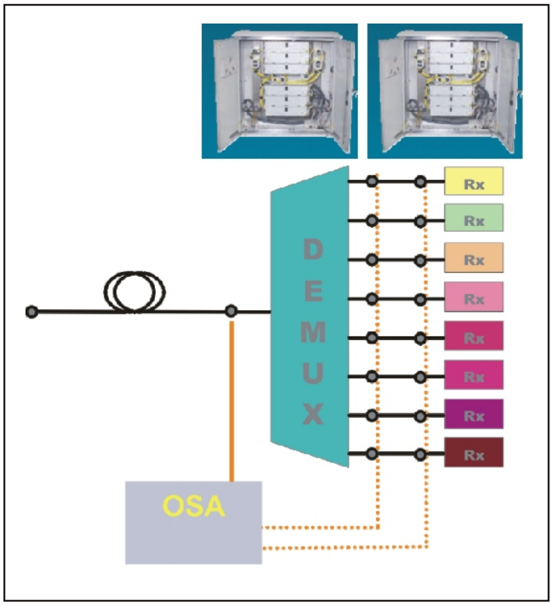

Figure-8

Requirements [see as per system requirements]
a. Output power range: ~ -5 to +5 dBm
b. Channel wavelength: <20% of channel spacing
c. Max IL DEMUX (per wavelength): 3 dB
d. Link loss according to network design

Insertion Loss (Mux / Demux / OADM)

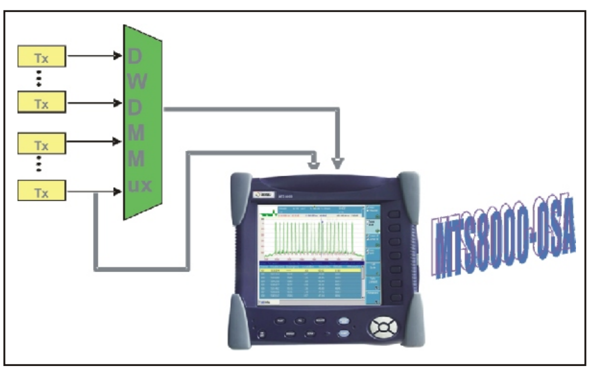

Figure-9

Test Procédure
- Measure power of Tx output with OSA
- Measure and record power per wavelength at the output of Mux

- Calculate delta = IL
- IL measurements at OADM are performed in the same way

Requirements (depends on system configuration)

- max IL Mux/Demux (per wavelength) 12 dB
- max IL OADM (per wavelength) 4 - 7dB

Link Test: Wavelength

Test Procédure

- Connect OSA to measure wavelength at the end of the span

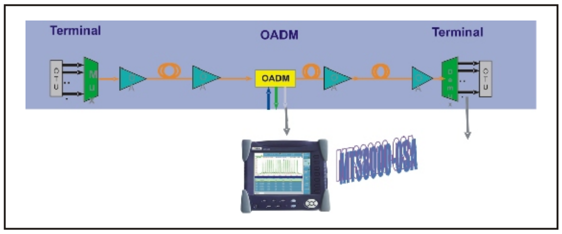

Figure-10

- Measure the wavelength of all used channels at Demux and OADM

Requirements (depends on system configuration)

- max IL per wavelength 12 dB at MuX and Demux section
- max IL per wavelength 12 dB at MuX and Demux section

Link Test: Power / OSNR

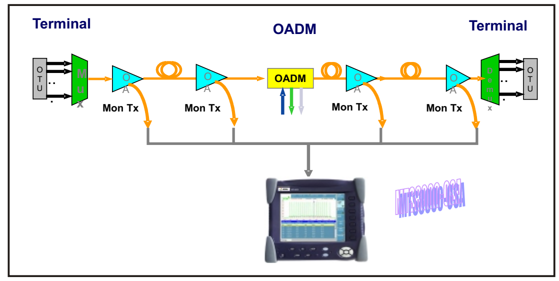

Figure-11

Test Procédure

- Use monitor access point at amplifiers (OA) for measurements

(power level is about 23dB below actual OA out)

- Record power / OSNR of each channel

Requirements (depends on system configuration)

STM-16 STM-64 STM-256 (FEC) min OSNR at Rx site: 18dB25dB22dB

Abbreviation Description

AON- All optical network
APS- Automatic protection switching
ASE- Amplified spontaneous emission
ATM- Asynchronous transfer mode
BER- Bit-error ratio
CD- Chromatic dispersion
dB- Decibel
DCF- Dispersion compensating fiber
DCM- Dispersion compensating module
DEMUX- Demultiplexer
DSF- Dispersion shifted fiber
DW- Digital wrapper
DWDM- Dense wavelength division multiplexing
E/O- Electrical-to-optical converter
EDFA- Erbium doped fiber amplifier
FEC- Forward error correction
FWM- Four wave mixing
Gbps- Gigabit per second
GigE- Gigabit ethernet
IEC- International electrotechnical commission
IL- Insertion loss
IP- Internet protocol
ITU- International Telecommunication Union
ITU-T ITU Telecommunication Sector
JTF- Jitter transfer function
MPI- Main point of interest
MUX- Multiplexer
mW- Milliwatt
nm- Nanometer
NMS- Network management system
NZDSF- Non-zero dispersion shifted fiber
O/E- Optical-to-electrical converter
OADM- Optical add/drop multiplexer
OCC- Optical connection controller
OFA- Optical fiber amplifier
OFE- Optical front end
OQM- Optical Q-factor meter
ORL- Optical return loss
OSA- Optical spectrum analyzer
OSC- Optical supervisory channel
OSNR- Optical signal-to-noise ratio
OTDR- Optical time domain reflectometer
OTN- Optical transport networks
OXC- Optical cross connect
PDL- Polarization dependent loss
PMD- Polarization mode dispersion
PoS- Packet over SONET/SDH
PRBS- Pseudo random binary sequence
QoS- Quality of signal
RFA- Raman fiber amplifier
RX- Receiver
SBS- Stimulated Brillouin scattering
SDH- Synchronous digital hierarchy
SOA- Semiconductor optical amplifier
SONET- Synchronous optical network
SPM- Self phase modulation
SRS- Stimulated Raman scattering
Tbps- Terabits per second
TDM- Time division multiplexing
TX- Transponder
WDM- Wavelength division multiplexing
XPM- Cross phase modulation