CASCADED ROADMs AND EFFECTIVE BANDWIDTH

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In-band optical signal-to-noise ratio (OSNR) testing for reconfigurable optical add/drop multiplexers (ROADMs) is extremely important. In this document, we will discuss a frequently encountered scenario–several ROADMs in a network.

From its point of transmission to its reception point, a given wavelength goes through several filters, launching optical multiplexers (muxes) and receiving demultiplexers (demuxes), but the wavelength also goes through all the ROADM filters along the path. However, each of the filters encountered have slight differences in bandwidth, center wavelength and shape. A case in point is the examination of the 50 GHz Gaussian filter, as illustrated below:

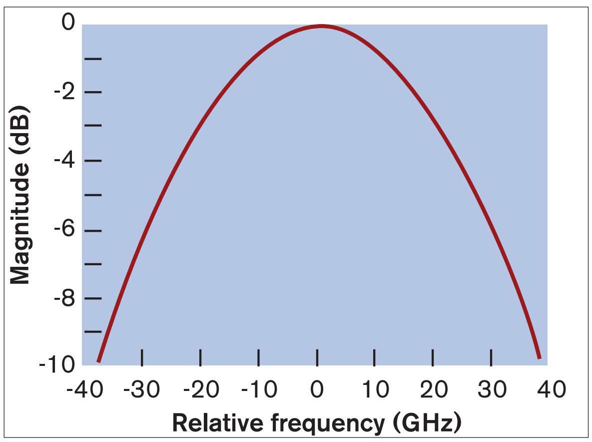

Figure 1. Typical 50 GHz Gaussian filter

When cascaded with a second filter of the exact same shape and bandwidth, yet a little bit off center, the following occurs:

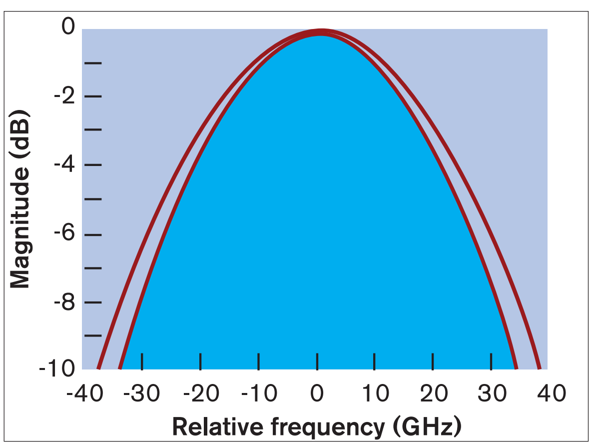

Figure 2. Residual bandpass of two combined filters

The effective bandwidth (shown in the blue area) is reduced. Below is the same filter (as well as a flat-top one with similar bandwidth), but it is cascaded 20 times:

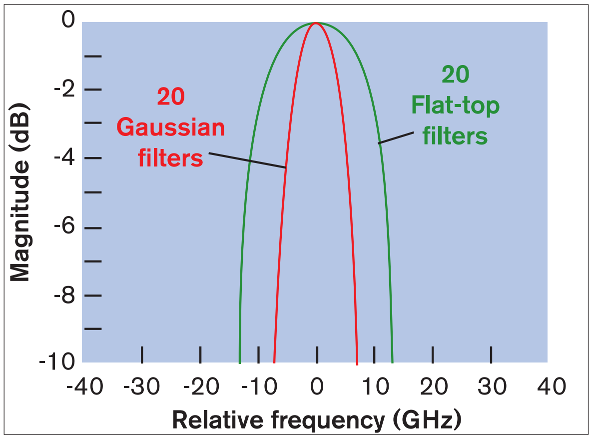

Figure 3. Example of residual bandpass of 20 cascaded filters

As demonstrated above, the effective bandwidth is drastically reduced. Another perspective of this is illustrated below:

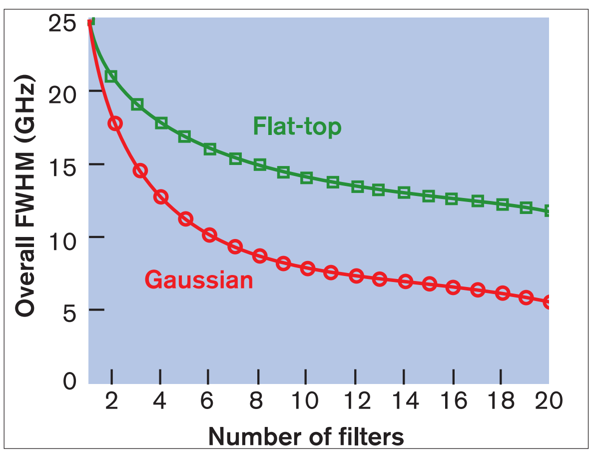

Figure 4. Typical bandpass of cascaded filters as a function of the amount of filters

After only six cascaded filters and ROADMs, the effective bandwidth is reduced by approximately 40% with flat-top filters (and it drops by around 60% with Gaussian filters). This reduction in bandwidth has significant impact on the dense wavelength-division multiplexing (DWDM) signal. In order to avoid important power loss, its center wavelength must be perfectly characterized; however, the most important impact is once again on the OSNR. As examined in the Wave Review article *Cascaded ROADMs and Effective Bandwidth*, ROADMs carve the noise to the filter shape. Therefore, a single large filter shape can carve the noise such that the resulting optical spectrum is similar to the one illustrated in figure 5:

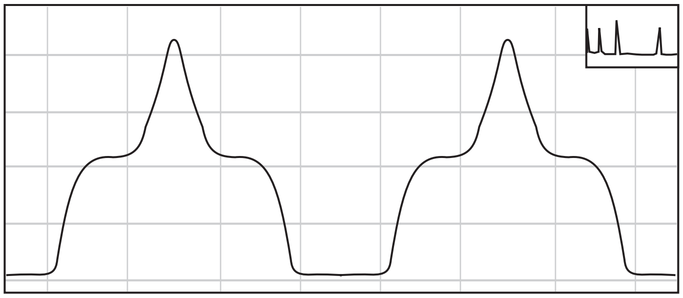

Figure 5. Resulting optical spectrum carved by noise

The shoulders are clearly visible and an estimation of the OSNR can be deduced based on the illustration alone; the results can then be compared for validation. However, the same signal that goes through an effective filter shape is 60% narrower, which results in the shoulder disappearing (this is assuming that the wavelength is properly centered on the effective filter), making an OSNR estimation impossible. The screen shot below represents this:

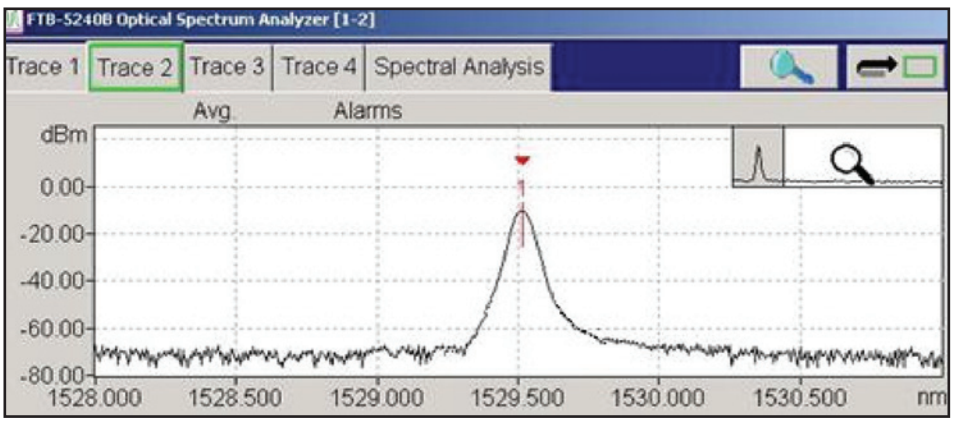

Figure 6. Carved noise screen shot

Measuring with an in-band approach yields an OSNR of 37.56 dB vs. 54.91 dB with a traditional measurement approach. Therefore, it is best to never assume that the shoulders will be present for estimating and measuring the OSNR because even 100 GHz filters, if and when cascaded, can become extremely thin.

Another important point to consider in DWDM with cascaded filters is that the narrowing of the bandwidth will be wavelength-dependent; there will be an overall average, but some channels may have larger or narrower residual bandwidth. Qualifying this with an optical spectrum analyzer (OSA) and a broadband source is critical, especially if the network is intended for eventual 40 Gbit/s upgrades because 40 Gbit/s and faster modulations increase the spectral shape of the wavelength, as illustrated in figure 7:

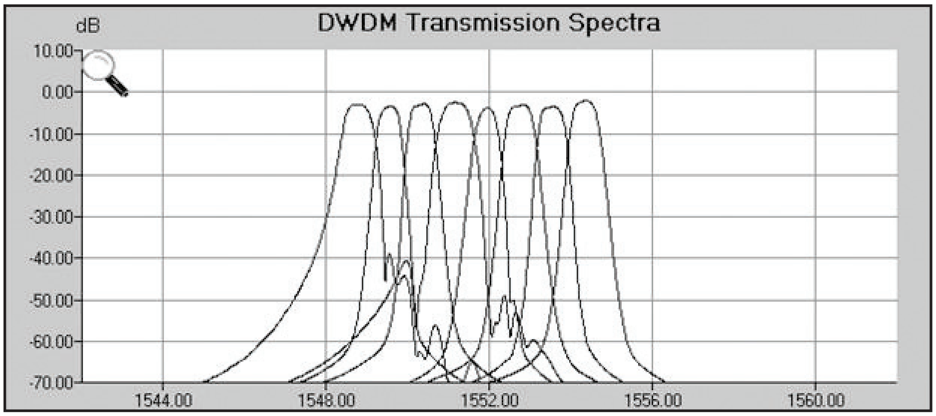

Figure 7. Every DWDM channel may have a different residual bandwith.

As demonstrated above, wider residual bandwidth should be used for high-speed transmissions since they are inherently wider, while narrower residual bandwidth can carry slower traffic without any issues.

Conclusion

A broadband light source and an OSA such as the FTB-5240/5240B can fully characterize the residual bandwidth on a per-channel basis. In addition, the same OSA can be used for OSNR validation at the ROADM level, if the OSA offers in-band OSNR testing capabilities (available in the above-mentioned EXFO OSA models).

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