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EXFO's PON power meter is being widely used for both commissioning and troubleshooting in the current wave of PON deployment. Although the PPM-350B Power Meter is, by design, a user-friendly instrument, understanding some of the complexities behind the measurements can help users utilize this tool more efficiently. Interchannel crosstalk, in particular, affects measurements and, consequently, results should be interpreted accordingly.

In this article, we will begin by briefly describing the PON network and then go on to explain the measurement principle used by EXFO's PPM-350B Power Meter; mainly, the filtering process. We will then cover how to determine the right isolation, as well as explain the effects of crosstalk on measurements so as to draw the right conclusions from the results provided by the instruments.

Network Description and Basic Measurement Principle

The typical G.983 PON network is configured to combine the downstream ATM signal at 1490 nm and the CATV signal at 1555 nm in the same fiber, while the upstream ATM signal travels in the opposite direction at 1310 nm in the same fiber, as shown in Figure 1.

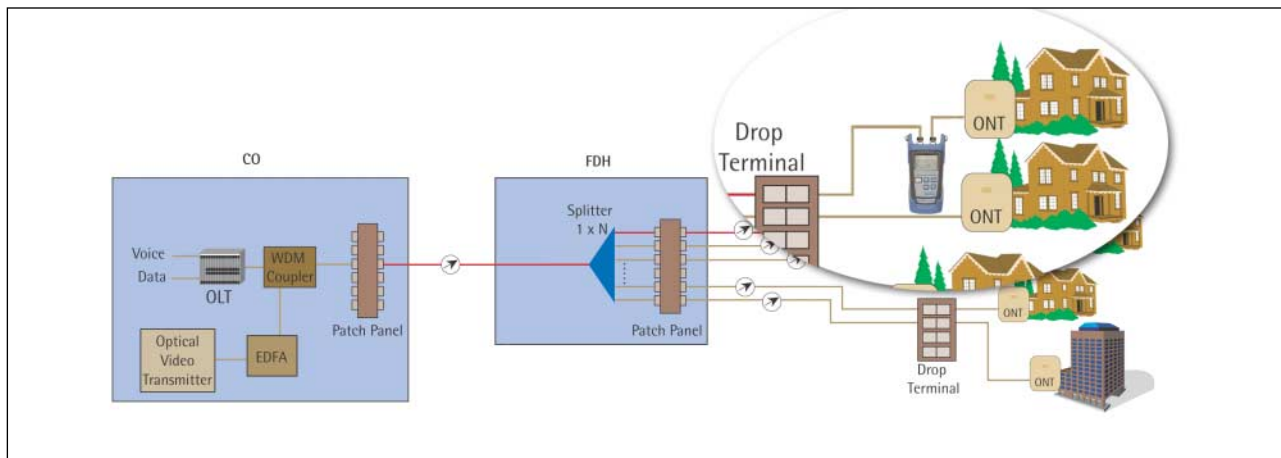


Figure 1. PON power meter inserted at the ONT

In order to minimize loss, the downstream ATM signal at 1490 nm and the CATV signal at 1555 nm are combined using a WDM coupler. The PPM-350B receives both signals at its OLT input port and demultiplexes each one to a dedicated detector. This is done by using filters, similar to how it is done at the ONT. The result of this process is displayed below.

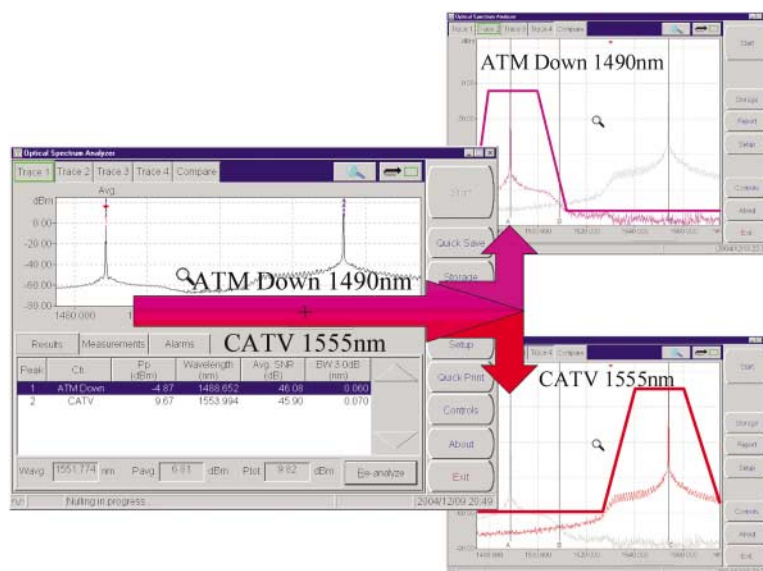


Figure 2. Filtering the input signal at the PON power meter

Figure 2 illustrates what happens in the case of very-high-rejection filtering (lab conditions) at the PON power meter. The optical spectrum on the left contains both signals and each is selectively routed to the desired detector so that an adequate power measurement can be obtained. In the example above, with a nearly ideal rejection ratio, the isolation of each port is greater than 70 dB. Also note that the filter bandpass is wider than 20 nm to allow for the higher tolerances levels required for the lower-cost sources used in PON implementations.

In the field, filtering does not have to be as efficient. The worst-case scenario when measuring power on a PON occurs when there is a strong, upper limit CATV signal and a weak, lower-limit downstream ATM signal. For example, in an FM system with 40 carriers transporting AM-VSB video signals, the CATV signal must be at least 14.1 dBm, while the Class A launch power for a 155 Mb/s, 1490 nm downstream ATM signal should be above -7.5 dBm (this is considered a worst-case scenario because the lower-limit launch power would be higher for the higher bit rates described in the standard). This leads to a 1555 nm CATV signal that is approximately 22 dB stronger than the 1490 nm signal. The same reasoning applies to the 1310 nm signal, which contributes crosstalk power to the 1490 nm and 1555 nm detectors, depending on the strength of the total 1310 nm network backreflection detected by the 1490 nm OLT port. For example, a Class C maximum launch power of 4 dBm with 32 dB ORL will contribute -28 dBm of the 1310 nm signal at the OLT port of the PON power meter, whereas the received 1490 nm downstream signal can be as low as -31.5 dBm at that same point.

Determining the Minimum Isolation Requirement

In general, the required isolation can be deduced from ITU-T recommendation* G.983. Based on these guidelines, if we take the more extreme cases described above, we can determine the effect insufficient isolation will have on the PPM-350B and, in turn, establish a reasonable minimum isolation for practical measurements.

* ITU-T Recommendation G.983.3

a. Case 1: A strong analog CATV signal and weak 1490 nm downstream ATM signal.

The following figure shows how improving the rejection of the 1555 nm CATV signal at the 1490 nm detector reduces the measurement error when the CATV signal is more than 21 dB stronger than the 1490 nm signal at the unit's OLT port.

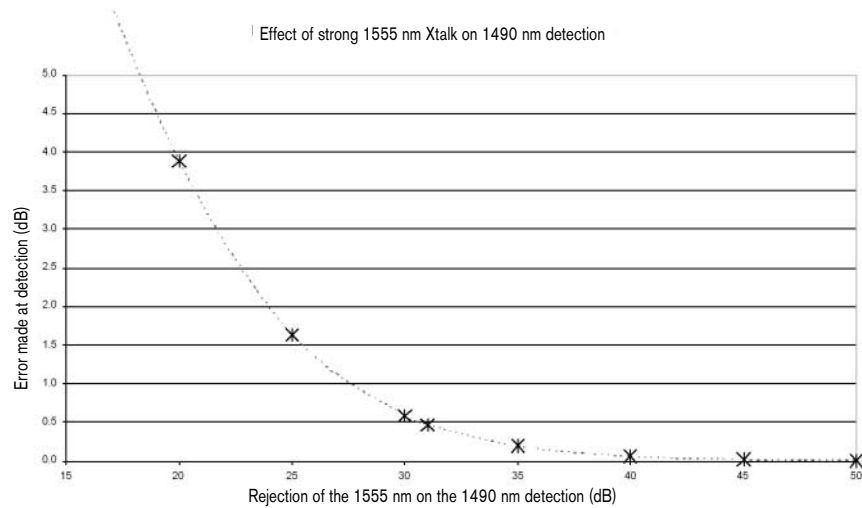
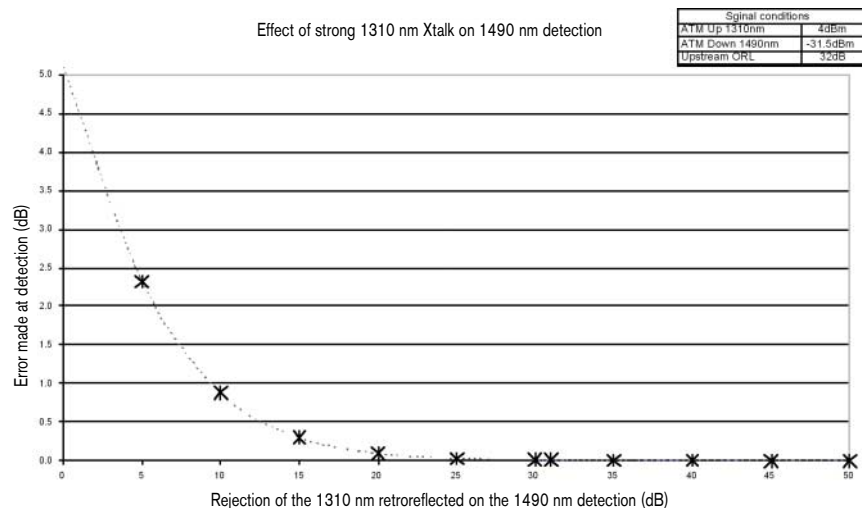


Figure 3. Rejection of 1555 nm signal at the 1490 nm port of the PON power meter

Although, according to G983.3 recommendations, the above curve represents the error for an extreme situation, it nevertheless helps define the required rejection ratio. Of course, the higher the rejection ratio, the lower the error, but over-design usually leads to higher costs, which is not compatible with the wide-spread deployment scenarios that prompted the development of this product. Once the requirements are understood, it is fairly obvious that there is little added value in going above a rejection ratio of 40 dB for the 1555 nm signal at the 1490 nm detector.

b. Case 2: A strong upstream 1310 nm signal with high ORL, and a weak 1490 nm downstream ATM signal

The following figure helps determine the required rejection ratio for the 1310 nm backreflected signal at the 1490 nm detector.



Signal conditions	
ATM Up 1310nm	405m
ATM Down 1490nm	-31.5dBm
Upstream ORL	32dB

Figure 4. Rejection of 1310 nm signal at the 1490 nm port of the PON power meter

Again, the above curve represents the error for an extreme situation and, again, the higher the rejection ratio, the lower the resulting error. With the same target-precision in mind, it is clear that, in this case too, there is little added value in going above a rejection ratio of 25 dB for the 1310 nm signal at the 1490 nm detector.

The two cases described above provide guidelines as to the limit of required isolation for proper measurement of the desired signal. Similar reasoning applies to the other wavelengths with a less stringent requirement on the 1555 nm; e.g., for the early PON deployments, where video data is transmitted using a strong, analog signal. A future-proof design for the deployment of digital video in the 1539 to 1565 nm band should, however, incorporate the adequate rejection of the 1490 nm signal at the 1555 nm port. Note that the analyses above already provide more than adequate rejection results merely by applying the direct “brute force” optical rejection of the unwanted signal. Measuring on dedicated detectors will also allow for signal processing and will therefore enable further improvements of the rejection ratio.

Effects of Crosstalk on Real-Life System Measurements

We have shown above that even in the more extreme crosstalk cases, the rejection process does not need to be perfect to obtain error-free measurements. However, PON power meters are designed to have a low-threshold detection that goes beyond the current network configurations presented in G983.3. In cases where a network is currently configured without one of the signals, it is important to take the following precautions:

a. When detecting a strong downstream ATM signal in a network without CATV

When CATV is scheduled to be implemented in the network at a later time, there is no need to read the 1555 nm signal measurement provided by the unit. The PASS-FAIL-WARNING threshold feature allows users to deactivate detection of channels that are not currently active. However, it is important to set the thresholds according to the correct network configuration; otherwise, the crosstalk at the power meter could lead to the false indication that there is a signal on the inactive channel.

For example, let us assume that a power measurement is being taken with a CATV-ready PON power meter whose thresholds are configured for a full network, even though there is no CATV. Let us further assume that the user is detecting a strong (4 dBm) downstream ATM signal near the CO before it is split by the network’s passive splitter. If the 1490 nm signal has a 40 dB rejection ratio at the unit’s 1555 nm port, an equivalent power of around -36 dBm is received at the 1555 nm detector. Therefore, if the lower-end threshold on the power meter is set to less than -36 dBm, this power would be read at the 1555 nm port, which could lead the user to believe that there is a weak CATV signal actually being transmitted over that channel. Even if, at this level, the 1555 nm signal would be too low for proper detection at the customer premises, this apparent signal is not real and therefore has no impact on the measurements of the real signals, so the reading it generates is inconsequential. However, to avoid any potential confusion, we do encourage users to select the proper threshold configuration for their network.

b. When detecting a strong downstream ATM signals without a WDM combiner

In the event that the network operator has planned to deploy 1555 nm channels at a later date and has decided not to include the WDM combiner in the path right away, a “spill-over” effect from the 1490 nm source into the 1555 nm detection port may occur. Consequently, when taking power measurements with the PON power meter, the unit displays this value. That is, the PON power meter detects the signal from the 1490 nm source in its CATV band (within its specified acceptance thresholds). Since the unit is designed to measure over a large wavelength band of at least 20 nm, it will integrate all the detected low-level power from the 1490 nm source into the 1555 nm channel region. This would remain true even if the PON power meter were to have a perfect rejection of the 1490 nm signal (see figure 5).

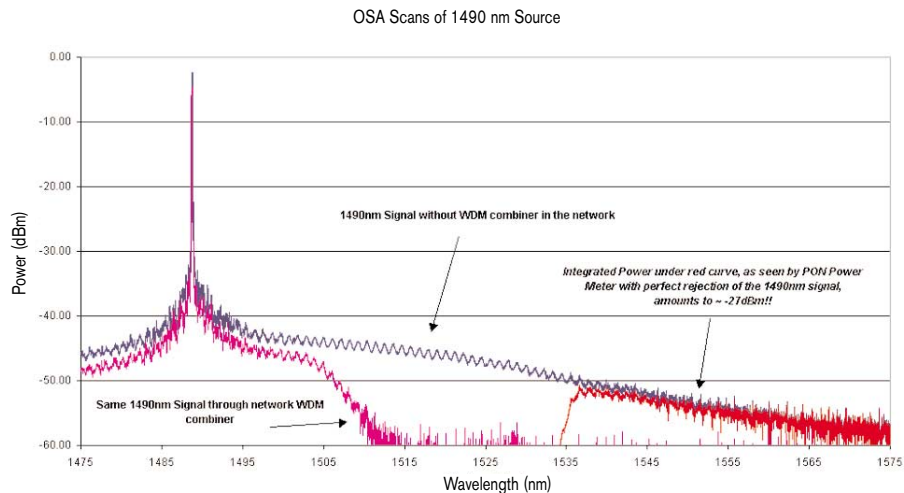


Figure 5. Detection of 1490 nm “spill-over” at 1555 nm with PON power meter

As shown in the graph above, even without any signal/power contribution at 1490 nm (where most of the energy of the downstream ATM source signal lies), there is more than enough power within the wide wavelength-acceptance range of the 1555 nm channel to be detected at the power meter. In the case illustrated in Figure 5, the source (DFB laser) had a relatively low sidemode rejection (~40 dB) and produced an actual power value of ~27 dBm, which was correctly measured by the PON power meter. Again, to avoid any potential confusion, we do encourage users to select the proper threshold configuration for their network. In this case, the real but also inconsequential signal would not be seen.

Conclusion

Although crosstalk itself, within the bounds of the ITU G.983 recommendations, does not affect the PPM-350B's power measurements, setting the instrument thresholds according to your specific network configurations can help you avoid potential misinterpretation, and thus allow you to better diagnose and troubleshoot your FTtx network.

Further Reading

For additional information on PON networks and the PON power meter, please refer to our article entitled Testing FTtx Networks with the PPM-350, available from our website at <http://www.exfo.com/en/support/WaveReview/2004-June/WRarticle3.asp>. From there, you can also access other useful documents such as the PPM-350 Power Meter product page and specification sheet, as well as the FTtx PON Guide order form.

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