107

THE NEW DANGER FOR ULTRA-LONG-HAUL TRANSMISSION: MULTIPATH INTERFERENCE (MPI)

APPLICATION NOTE

Francis Audet, Eng., Sr. Product Manager

It is well known that large power penalties and bit-error-rate (BER) floor can be observed on fiber-optic links that present multiple large reflections. The use of high-quality connectors is usually sufficient to prevent the occurrence of penalties in typical fiber-optic links. However, for ultra-long-haul (ULH) transmission, the impact of multiple reflections and of Rayleigh double backscattering is greatly enhanced by the presence of Raman amplifiers. This application note will review the background of multipath interference (MPI), detail its impact on ULH transmission and introduce ways to efficiently measure MPI.

Multipath Interference Background

By way of simple illustration, MPI can be shown in a link with two bad connectors, each with a reflection of –40 dB (see Figure 1). In this example, most of the light will pass via the main path, but some of it will reflect off the second connector and return toward the transmitter, where it is again reflected by the first connector before returning to its original direction (secondary path). The secondary path has exactly the same wavelength and information as the main path, but it has been delayed.

MPI is quantified by the ratio between the secondary path and the main path, and is expressed in dB. This is very similar to the way an interferometer works: separating the light, imposing a delay on one path, then recombining the light. The principal difference is that MPI tends to present a large power difference between the main and secondary paths.

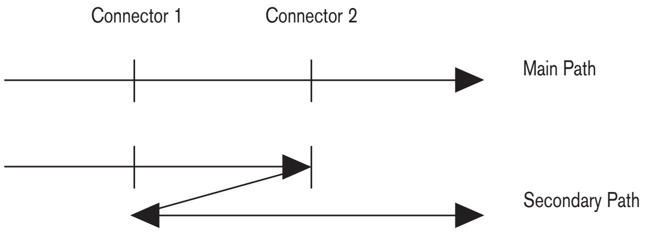

Figure 1. Simple link with two discrete reflections.

In the above example, each connector produces a reflectance of –40 dB. As a result, the secondary path signal will be 80 dB below the main path signal for an MPI level of –80 dB. This level of MPI does not cause any degradation in transmission.

In a system using Raman amplifiers[1], the secondary path signal is amplified twice when traveling between the two connectors (unlike EDFAs, Ramans can amplify in both directions because they do not include isolators). If for example, the amplification is 20 dB (typical), the total MPI will be –40 dB, which is catastrophic to the signal integrity, and will greatly increase BER.

---

[1] *Distributed Raman Amplification involves creating a gain cavity within the transmission fiber, which amplifies the signal channels before they reach a receiver or EDFA. This allows longer transmission distances.*

Another significant contributor to MPI is the double Rayleigh scattering observed when using Raman amplifiers. This occurs because Raman amplifiers use the length of the transmission fiber to amplify the signal.

The Impact of Multipath Interference on Transmission

In the case of an ultra-long-haul system using many Raman amplifiers, due to double Rayleigh backscattering, MPI will accumulate linearly with each span (the longer the link, the more Rayleigh there is). Engineering of the transmission system normally takes this predictable effect into account by balancing the number of amplifiers, their spacing and gain.

A link of a single span has a 1 dB power penalty when MPI is around –20 dB. When 20 spans are cascaded, the MPI of each span has to be lowered to approximately –33 dB in order to keep the power penalty at 1 dB. In addition, a bad connector can add an MPI of up to 10 dB.

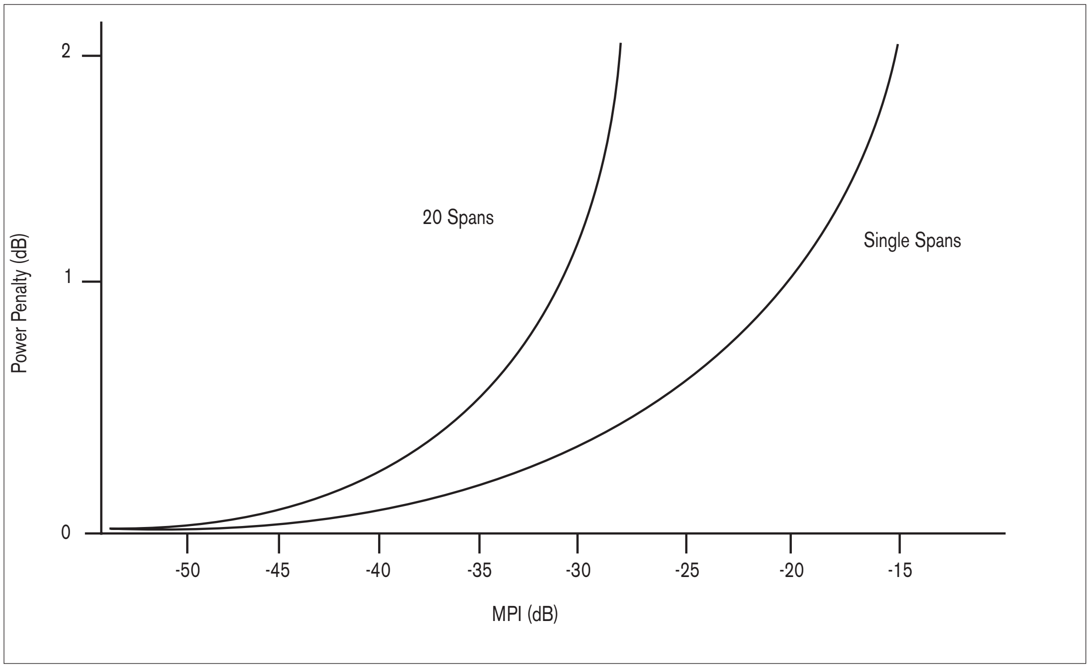

Figure 2. Power penalty versus MPI level for different links.

The presence of connectors makes the prediction of total system MPI more difficult since the reflectance of individual connectors may vary greatly. A single bad connector in a 1000 km ULH link can cause a severe power penalty and a BER floor.

Measuring Multipath Interference

The tricky part is that MPI generates RF noise, also called intensity noise. An OSA, which can detect ASE noise problems, cannot detect MPI noise. In fact, all other optical instruments typically used to validate a transmission link fail to detect the presence of an MPI problem. This means that you can perform system verification–measure power, run OTDR, PMD and CD tests, measure the optical signal-to-noise ratio (OSNR)–and detect no problems whatsoever. However, when the system is lit up, a huge and unacceptable BER occurs.

Every single component in a DWDM ULH system can contribute to the total MPI. To measure the total MPI, each component must be part of the analysis. It is therefore important to test with an ITU-centered source that goes through the mux, demux and all filters. If the attenuation is reasonably flat with wavelength, as well as the amplification, which is normally the case, MPI penalty will be similar for all signal channels. Testing at a single ITU-centered wavelength is thus sufficient.

Until now, the only way to detect an MPI problem before lighting up a system was to use an RF spectrum analyzer. Unfortunately, the setup is complex and costly, and it is difficult to interpret the data. EXFO offers a portable instrument aimed at solving this issue, the MPI-800. Using an integrated DFB laser as emitter (ITU centered), the MPI-800 measures the low frequency Relative Intensity Noise (RIN), which correlates directly to MPI. Dangerous levels of MPI can be easily and efficiently measured before network degradation can occur.

References

(1) J.M. Gimlett et al., “Effects of Phase-to-Intensity Noise Conversion by Multiple Reflections on Gigabit-per-Seconds DFB Laser Transmission Systems”, Journal of Lightwave Tech., Vol. 7, No. 6, June 89, pp. 88-95.

Corporate Headquarters > 400 Godin Avenue, Vanier (Quebec) G1M 2K2 CANADA | Tel.: 1 418 683-0211 | Fax: 1 418 683-2170 | info@exfo.com
Toll-free: 1 800 663-3936 (USA and Canada) | www.exfo.com

EXFO America	4275 Kellway Circle, Suite 122	Addison, TX 75001 USA	Tel.: 1 800 663-3936	Fax: 1 972 836-0164
EXFO Europe	Le Dynasteur, 10/12 rue Andras Beck	92366 Meudon la Forêt Cedex FRANCE	Tel.: +33.1.40.83.85.85	Fax: +33.1.40.83.04.42
EXFO Asia-Pacific	151 Chin Swee Road, #03-29 Manhattan House	SINGAPORE 169876	Tel.: +65 6333 8241	Fax: +65 6333 8242
EXFO China	Beijing New Century Hotel Office Tower Room 1754-1755 No. 6 Southern Capital Gym Road	Beijing 100044 P. R. CHINA	Tel.: +86 (10) 6849 2738	Fax: +86 (10) 6849 2662

EXPERTISE REACHING OUT

Printed in Canada 05/05