Dynamics enhancement of OTDR-based monitoring systems for passive optical networks

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We describe a technique for the dynamics enhancement of OTDR-based passive optical network monitoring systems using Raman amplification. By choosing a suitable pump wavelength co-propagating with the test signal, we experimentally show that it is possible to obtain a 16 dB increase of the dynamics. This enables the detection of more faults and fibre breaks.

Introduction

Fiber-To-The-Home (FTTH) technology using Passive Optical Networks (PON) is the most promising way to provide high quality broadband access. PON are nowadays extensively studied and some commercial deployments are already reported. It is clear that the development of reliable monitoring systems is required for the practical implementation of such networks.

In that context, the detection, the localization and the quantification of faults and fibre breaks in the network are mandatory. Several systems using an OTDR (Optical Time Domain Reflectometer) as the interrogating device have been proposed for both WDM-PON and TDM-PON. In these systems, the OTDR dynamics limits the measurement range and the resolution in terms of fault detection and quantification. Indeed, faults and fibre breaks located at a distance for which the OTDR signature is close to the noise level cannot be detected. Moreover, in the past few years, the splitting ratio of the PON has increased significantly leading to a degradation of the backscattered power measured at the OTDR in the frame of TDM-PON monitoring. The signal used for fault diagnostic is therefore closer to the noise level. Consequently, the measurement dynamics decreases and less fault and fibre break events can be detected by the monitoring system.

In this paper, we describe a technique to overcome these problems by enhancing the dynamics of OTDR-based PON monitoring using Raman effect to amplify the OTDR test signal. Our experimental work shows that it is possible to obtain a 16 dB increase of the dynamics. This enables the detection of more faults and fibre breaks by decreasing the effective noise level of the monitoring system. Our technique has been tested using the monitoring method described in [1]. This method is based on the use of a commercially available OTDR located at the Central Office (CO) and variable reflectors located at the Optical Network Terminals (ONTs).

Principle of enhancement

The principle of our technique is presented in figure 1. The optical pulses emitted by a commercially available OTDR are launched in the PON after passing through both of the optical circulators. An unpolarized pump signal, consisting in a continuous wave (CW) 1455 nm Raman fibre laser, is launched in the fibre network via a WDM coupler. If the test wavelength is within the Raman gain spectrum corresponding to the pump, the pulses undergo two phenomena when they propagate down the optical link: the pulses are amplified through stimulated Raman scattering in co-propagating scheme and they are also continuously backscattered through Rayleigh scattering. At any point z of the optical link, the backscattered fraction of the optical power obviously depends on the total Raman gain resulting from the propagation of the pulse from the beginning of the link (z = 0) to the distance z. The backscattered fraction is then amplified in a counter-propagating scheme when propagating back in the fibre. The backscattered signal is finally directed onto the detector of the OTDR after passing again through both circulators and through an optical filter that removes most of the spontaneous Raman scattering and the remaining backscattered pump power. The centre wavelength of the filter obviously corresponds to the test wavelength.

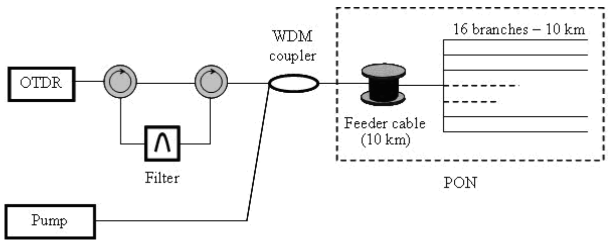

Figure 1: Principle of dynamics enhancement.

The necessity to use the filter to remove most of the Raman spontaneous emission prevents the use of commercial OTDR because the spectral width of its embedded source is too large. The filter would indeed drastically reduce the optical backscattered power reaching the OTDR and, consequently, the measurement dynamics would be too poor. As a consequence, a more complex set-up has been developed. It is simply a result of swapping the OTDR source with an external narrow width laser as described in [2]. The complete measurement set-up is presented in figure 2. After emission by a commercial OTDR, the first circulator directs the attenuated optical pulses onto a detector. The resulting electrical signal is used to modulate an external laser source by means of a pulse generator and an acoustooptic modulator (AOM). In order to have sufficient optical power at the link input, the light emitted by the external laser is amplified by an erbium-doped fibre amplifier (EDFA). The resulting optical pulses and the pump signal are launched in the fibre link via a WDM coupler. The backscattered signal is then directed onto the detector of the OTDR after passing through the optical filter. As the pump operates at 1455 nm, we set the wavelength of the test signal to 1550 nm which enables to observe Raman amplification and to test the feasibility of our technique. Test wavelength of 1625 nm is commonly used in practice. In such a case, the wavelength pump should be suitably chosen according to the Raman shift.

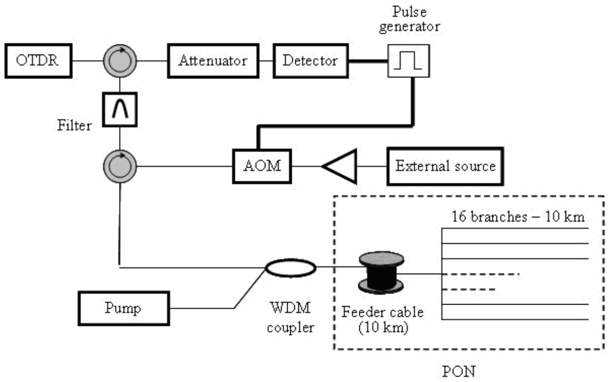

Figure 2: Complete set-up.

Results

Our technique has been tested on a 1 by 16 PON composed by 10 km fibres. The feeder cable is 10 km long. As a first step, no default was introduced in the network and OTDR measurements were performed with and without activation of the pump. Figure 3 shows the measured traces. The amplified OTDR signal has been obtained for a 1.5 W pump power. One can clearly see in Fig. 3 that there is a significant increase of dynamics when the pump is activated. This increase has been found to be equal to 16 dB. The amplification mainly occurs in the feeder cable where the pump power is more important. One can indeed observe that the OTDR signals in the branches region mainly consist in two parallel slopes which means that the OTDR pulses only undergo attenuation after the splitter.

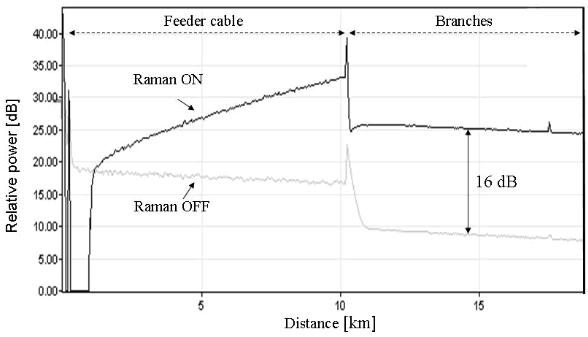

Figure 3: OTDR trace with and without activation of the pump.

Two tests have been performed to assess the improvement provided by the Raman amplification. We first introduced a fibre break in one of the branches at a distance of 16 km. The corresponding classical OTDR trace zoomed around 16 km is presented in figure 4(a). One can notice that the fibre break is not detectable as the corresponding peak is hidden in the OTDR noise. When a pump signal co-propagates with the test pulses, the signal-to-noise ratio is increased and the Fresnel reflection associated to the fibre break becomes detectable as shown in figure 4(b). The second test consisted in replacing the fibre break with a damaged FC/PC connector. The results are presented in figure 5. When the pump is not activated, the corresponding event cannot be detected as the associated re-

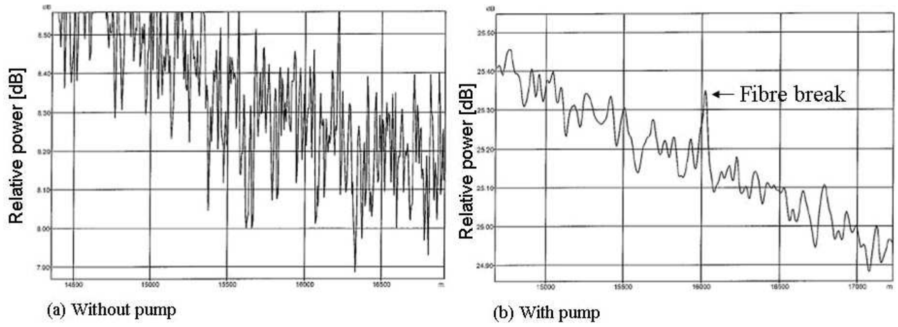

Figure 4: Zoom of the OTDR trace signal around the fibre break (located at 16 km) and using a span of about 200 m: (a) without pump, (b) with pump.

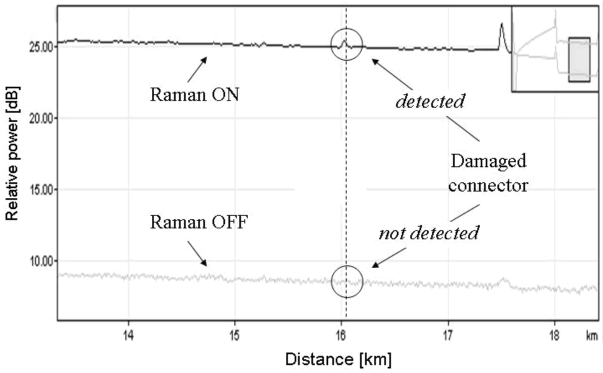

Figure 5: Zoom of the OTDR signal around the damaged FC/PC connector (16 km) and with a span of about 5 km.

turn loss is drawn by the noise level. When the pump is activated, one can clearly observe a reflection peak in the OTDR trace which enables the detection of the fault.

Conclusions

In this paper, we described a technique to enhance the dynamics of OTDR-based PON monitoring using the Raman effect. A 16 dB increase of the dynamics has been obtained. We showed that this dynamics improvement enables the detection of more faults and fibre breaks by decreasing the effective noise level of the monitoring system. The potential impact of the Raman pump on the signal carrying information is currently under investigation.

Acknowledgement

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