Automation of the reading and interpretation of the OTDR plot

MAZOUZI Amine[1] and ABOUN ABID Miloud[2]

[1] Institute of telecommunications and TIC
POB 1518, El Mnouar,Oran, Algeria

[2] Polytechnic National, of Oran Maurice Audin. Es Senia Street Oran, Algeria
amazouzi@inttic.dz

Abstract. Unlike conventional networks, optical fiber transmission systems allow optical signals to be transported from the transmitter to the receiver. They have become the adaptable solution for transmissions of all types of data. By taking into account the problems and the external constraints which degrade the quality of the transmitted signal, the monitoring of the optical fibers is carried out by measurement tools making it possible to detect the various events and the defects along the fiber and this in order to do the maintenance. Necessary to provide better transmission on the medium. Currently the operation of monitoring an optical transmission link is carried out by an agent who constantly monitors the various changes in events that have occurred in the layout of the transmission line using OTDR equipments.

Keywords: Fiber optic link, OTDR, maintenance, automation, wavelets.

1 Introduction

The evaluation of new technologies and the demand for very high capacity and speed require the use of very powerful transmission systems, for this a switch to the use of a medium, having a large bandwidth and low attenuations a been made, it is optical fiber, which has become a solution for long distance transmissions with very high data rates [1]. An optical fiber is a very fine glass or plastic wire which is the property of being a conductor of light and is used in the transmission of data and light [2]. It offers a significantly higher data rate than coaxial cables. The monitoring of the optical fibers is carried out by measurement tools making it possible to detect the various events and the faults along the fiber in order to make the necessary maintenance to offer a better transmission on an ideal support, on using for that seems OTDR [3]. In the first part of the work, we will start with general information on the fiber optic transmission system, detailing the emission stage, the optical guide, and the reception stage, and explaining their functionalities. Thereafter, we will make a diagnosis of the effects on the fiber, as such on is interested in the attenuation of the signal which is caused mainly by: physical phenomena of absorption and diffusion in the support material and by extrinsic causes due to bends, loss of connection and cuts… etc. Then, we will present one of the monitoring tools named by the OTDR which detected the different events on the fiber and which measured the event losses and the linear attenuation. Finally, we will design a system for reading and automatically interpreting an OTDR plot for the location and detection of different events (power cuts, connections, etc.). Our contribution is to design an automatic system in order to read and interpret the OTDR layout and for the purpose of automating the control of the transmission link by optical fiber. Our contribution consists in automating the reading and interpretation of the OTDR plot, in asking to use the wavelet principle in order to locate and detect the various events found in a fiber optic transmission link.

2 Architecture of optical link fiber

The architecture of a link, whatever the level of the network for which it is intended, is made up of the same basic building blocks, namely a transmitter, a transmission link and a receiver.

Optical fiber is a light transmission channel, the use of which requires the use of end components, the main ones being light emitters and light receivers (optoelectronic components), suitably adapted. The fiber optic link also includes other components:

Passive components such as [4]: couplers, optical isolators, optical filters, dispersion compensator, attenuator, and active components, these components which use only photons, do not require an external power source to perform operations on the signal

Active components such as [5]: Modulators / demodulators, multiplexers, demultiplexers, optical amplifiers, switches.

Figure 1 provides an overview of a fiber optic link.

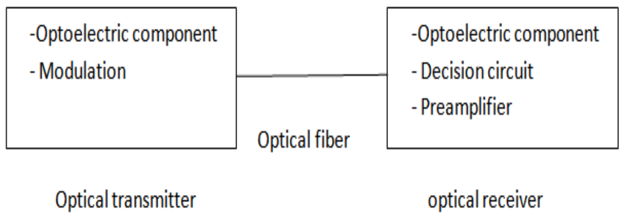


Fig .1. transmission link by optical fiber

2.1 Transmission module

The emission of light in a semiconductor is based on the phenomenon of radiative transitions. We can distinguish two types of most used emitters, laser and LED [6].

2.2 Reception module

This reception module transforms the light signal received into an electrical signal so that they can be interpreted by a computer. This transformation can be carried out by components, an electric current proportional to the power of the incident optical signal (conversion of photons into electrons) can be done.

We can cite some receivers: PIN or PID [7], [8].

2.3 Presentation of fiber optic

Optical fiber is a very thin transparent wire which can be used to conduct light between two places several hundreds or even thousands of kilometers away [9], it has a large number of remarkable properties which make it an excellent physical support for broadband transmissions, but its cost is much higher than copper support.

3 Some problems in optical fiber link

In a transmission link, we can classify losses into two classes [10] [11]:

- Intrinsic losses: they are due to construction materials we can cite: absorption losses or rayleigh diffusion losses.
- Extrinsic losses: they are caused by external effects; we find the loss by curvature, the loss of connection, the modal dispersion and the chromatic dispersion.

4 Optical link loss measurement methods

Two attenuation measurement methods can be used in the field of optical fiber: reflectometry and photometry (measurement by insertion) [12].
In our work, we are interested in the use of OTDR-named reflectometry.

5 Optical reflectometer OTDR (Optical Time Domain Réflectomter)

An optical reflectometer (Optical Time Domain reflectometer, OTDR) is an optical fiber test device used to characterize optical networks used in telecommunications. The objective of an OTDR is to detect, locate and measure elements anywhere along a fiber optic link. A reflectometer only needs access to one end of the link and functions like a one-dimensional radar system [13]. With an OTDR, it is possible to obtain a graphic representation of the entire fiber optic link. The principle of reflectometry makes it possible to precisely detect the position of a physical failure on the architecture, for example broken fiber or coupler. An optical signal is emitted in the fiber to be measured, and by principle of refraction on the diopter created by the break, part of this signal is reflected. The travel time of this reflected signal thus makes it possible to precisely determine the location of the breakage of the fiber (or of the coupler). It

sends a series of light pulses into the fiber optic cable to test and analyzes the reflected light compared to that which was emitted [14]. These light reflections are due to faults along the cable such as cuts, splices, or faulty connectors or adapters. The reflectometer makes it possible to evaluate the total length of the optical cable, to detect whether it has attenuation or loss of the signal and to measure the distance at which the detected faults are located. OTDR includes three essential sub-assemblies: a transmitter, a directional coupler and a detector module.
The following figure shows an OTDR.

Fig. 2. OTDR equipment.

6 Operating principle of an OTDR

The measurment by OTDR (Optical Time Domain Reflectometer) is commonly used to test optical transmission lines. It is a method which allows to characterize the optical fiber simply, from only one of its ends, and leads to the precise localization of the defects, to the measurement of the attenuation of the fiber and to the differential losses between two points. choose fiber. A sufficiently short and powerful light pulse is injected into the fiber, which is reflected on the discontinuities in the fiber (ends, inhomogeneities,...). The time between the emission of the pulse and the reception of the reflected signal gives the position of the fault in the fiber. The height of the reflected pulse informs about the importance and the nature of the defect. In addition, the measurement of the backscattered light by Rayleigh scattering towards the detector, even in the absence of reflective defects along the fiber, makes it possible to know the absorption of the fiber at the wavelength of the pulse. injected.
OTDR is the only way to locate events and measure backscatter attenuation of connector junctions.

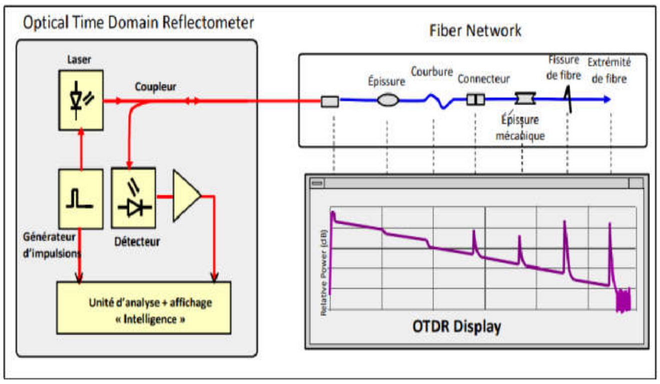


Fig. 3. OTDR operating principle.

7 OTDR events

Any break or connection of an optical fiber highlighted on the screen of an optical reflectometer by a modification or discontinuity in the representation of the normal backscatter of the fiber. Events can be caused by mechanical splices or welds, connectors, bends and breaks in the fiber. there are two types of events: reflective events and non-reflective events.

7.1 Reflective event

Reflective events appear as peaks on the course. They are caused by an abrupt discontinuity in the refractive index. They can indicate the presence of connectors, mechanical splices, or even cracks or fusion splices of poor quality. In principle, the loss and reflectance values are indicated for the reflective events.
Only the PC connectors generate a measurable reflection. An APC connector hardly causes any reflection unless it is dirty or if the geometry of the connector surface is not correct.

7.2 Non Reflective event

This event is characterized by a sudden decrease in the signal level of the Rayleigh backscatter index. It appears as a discontinuity in the downward slope of the trace signal. This event is often caused by splices, macro bends or micro bends in the fiber. A loss of value is displayed for non-reflective events however [15] no reflectance is specified for this type event.

7.3 Interpretation of events

The OTDR plot tells a story about each fiber tested. A certain dip or peak known as an event can reveal the type of connection as illustrated in the above-mentioned figure.

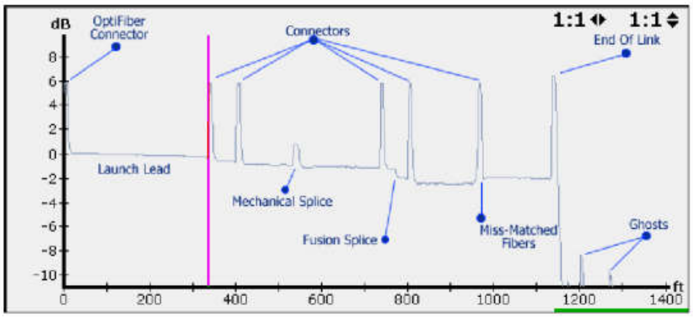


Fig. 4. OTDR plot interpretation.

8 Presentation of our method

Our work is to do an automatic detection of the events of an OTDR plot using Matlab software using the wavelet transform. Automatic reading and interpretation allows OTDR users to quickly control the transmission link.
Consideration was given to choosing such a method to automate the reading of the OTDR plot interpretation. We exploited the principle of wavelets [16] [17] since this tool is more apt to locate non stationary random changes.

8.1 Choice of wavelette

The choice of wavelet depends on the desired application.
In our work we have used two types of wavelets: HAAR and DAUBECHI. These choices were selected after several trials and tests.

8.2 OTDR plot reading

The first phase is the reading of files including the OTDR trace, see Figure 5.

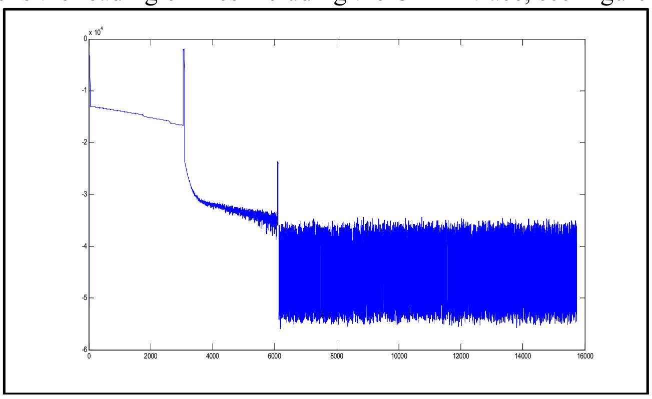
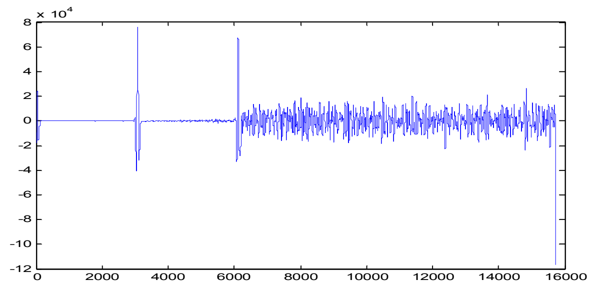


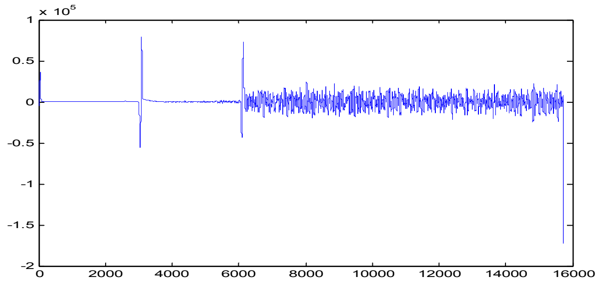
Fig.5. reading of the OTDR plot.

8.3 Wavelette transform inplementation

In our work, we applied the two wavelets mentioned above on our OTDR layout and this to make a comparative study.
We note that the results obtained using the DAUBECHIES wavelet are better compared to those obtained by Wavelet.
In Figure 6, we observe the results found using the HAAR and DAUBECHIE wavelets.



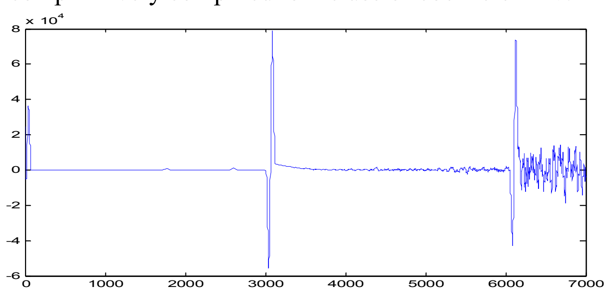
(a)



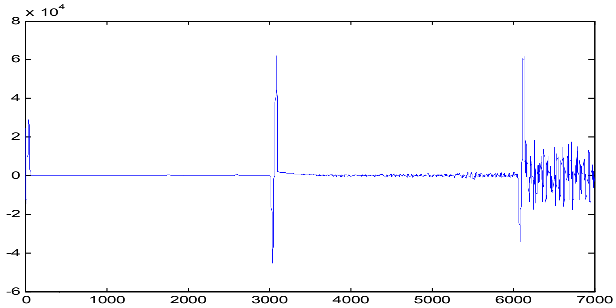
(b)

Fig.6. wavelette transformation, (a) Haar transform, (b) DAUBECHIE transform

Since the DAUBECHIE wavelet transform gave convincing results, we tried to vary the wavelet coefficients in order to better locate the variations.
The following figure represents the DAUBECHIE wavelet application results for the coefficients 40 and 60. As such we can see that all the variations were detected using the coefficient 60 comparatively compared to the use of coefficient 40.



(a)



(b)

Fig.7. Application of DAUBECHIE wavelette, (a) for coefficient 60, (b) for coefficient 40

9 Results and discussion

We have selected part of the OTDR plot, see Figure 8 in a broken square, in order to analyze it.

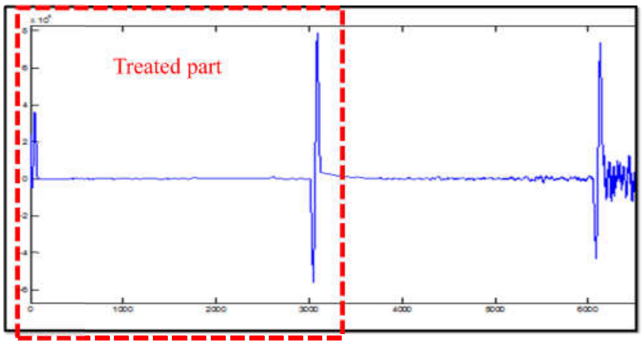


Fig. 8. processed part

Detection was found by looking for variation that exceeds a certain amplitude threshold.
For this part and after analysis, we were able to locate four positions.

In the following figure, we present the final results for the treated part.

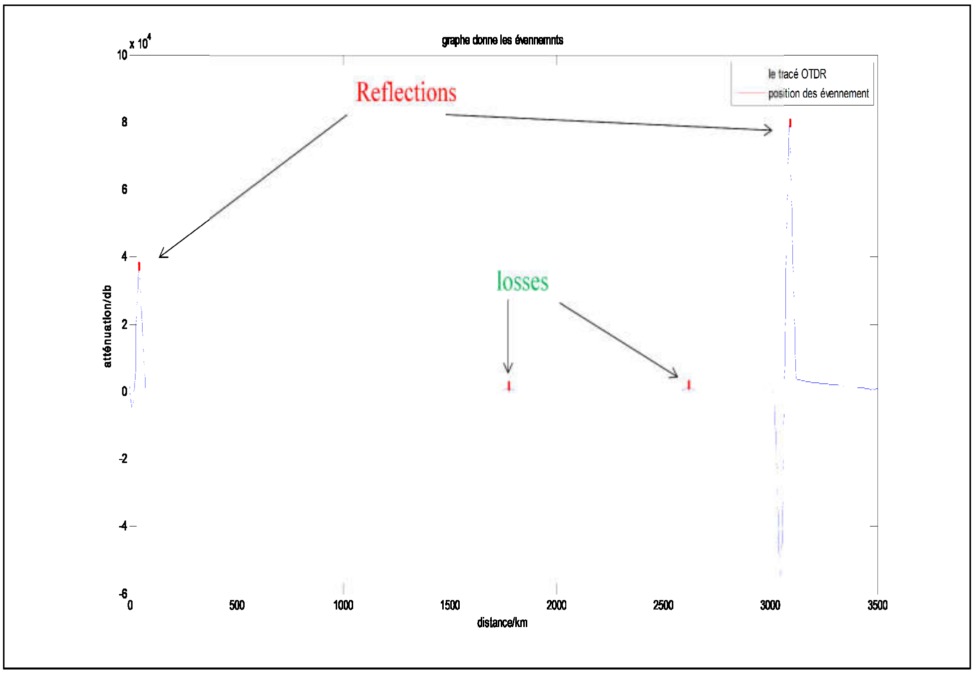


Fig. 9. Results found for the treated part

10 Conclusion

In telecommunications, optical fiber is used for the transmission of information, whether telephone conversations, images or data.
We have seen the technique used to monitor the fiber using an OTDR which measures losses and fault detection.
Our objective is to automate the reading and interpretation of an OTDR trace, these operations make it possible to facilitate the tasks of telecommunications operators and to promote monitoring techniques of fiber optic network in order to do maintenance. necessary to ensure good data transmission over optical fiber.

References

1. D.Carrara, 'Study and production of integrated photonic sources on InP for high speed and high speed telecom applications', Doctoral thesis, Pierre and Marie Curie University France, Electronics and Communications speciality ,2012.
2. O.Bouchard, 'Study of laser diodes with planar cavity entirely defined by photonic crystal: new approach for emission control, doctoral thesis , Toulouse university, France, 2008.
3. J.Verneuil, 'Simulation of 40 Gbits/s' fiber optic telecommunications systems', Doctoral thesis, Limoges University, France, 2003.

4. Y.Zouine, ‘Contribution by systems simulation to the study of the constraits of optoelectronic components on optical transmission using the CDMA technique’, Limoges University, France, 2005.
5. Zeroug and Bendib**, ‘**Deployment of an FTTx Network in an activity area’, Graduation project for obtaining the State Engineer Diploma in Telecommunications, 2017.
6. J. Wang, ‘Sapphire Fiber Based Sensing Technologies for High Temperature Applications. Blacksburg, VA’: University Libraries, Virginia Polytechnic Institute and State University, 2011
7. K. Yuksel, M. Wuilpart, V. Moeyaert, Me, x, and P. gret, "Optical frequency domain reflectometry: A review," in Transparent Optical Networks, 2009. ICTON '09. 11th International Conference on, 2009, pp. 1-5.
8. B. Soller, D. Gifford, M. Wolfe, and M. Froggatt, "High resolution optical frequency domain reflectometry for characterization of components and assemblies," Optics Express, vol. 13, pp. 666-674, 2005/01/24 2005.
9. R. Sur, K. Sun, J. B. Jeffries, R. K. Hanson, R. J. Pummill, T. Waind, D. R. Wagner, and K. J. Whitty, "TDLAS-based sensors for in situ measurement of syngas composition in a pressurized, oxygen-blown, entrained flow coal gasifier," Appl. Phys. B Lasers Opt. 116, 33–42, 2014.
10. K. Sun, R. Sur, J. B. Jeffries, R. K. Hanson, T. Clark, J. Anthony, S. Machovec, and J. Northington, "Application of wavelength-scanned wavelength-modulation spectroscopy H2O absorption measurements in an engineering-scale high-pressure coal gasifier," Appl. Phys. B **117**, 411–421, 2014.
11. K. Sun, X. Chao, R. Sur, C. S. Goldenstein, J. B. Jeffries, and R. K. Hanson, "Analysis of calibration-free wavelength-scanned wavelength modulation spectroscopyfor practical gas sensing using tunable diode lasers," Meas. Sci. Technol. **24**, 125203, 2013.
12. C. S. Goldenstein, C. L. Strand, I. a Schultz, K. Sun, J. B. Jeffries, and R. K. Hanson, "Fitting of calibration-free scanned-wavelength-modulation spectroscopy spectra for determination of gas properties and absorption lineshapes.," Appl. Opt. **53**, 356–67, 2014.
13. C. S. Goldenstein and R. K. Hanson, "Diode-laser measurements of linestrength and temperature-dependent lineshape parameters for H2O transitions near 1.4 μm using Voigt, Rautian, Galatry, and speed-dependent Voigt profiles," J. Quant. Spectrosc. Radiat. Transf. **152**, 127–139 (2015).
14. A. Upadhyay and A. L. Chakraborty, "Residual Amplitude Modulation Method Implemented at the Phase Quadrature Frequency of a 1650-nm Laser Diode for Line Shape Recovery of Methane," IEEE Sens. J. **15**, 1153–1160 (2015).
15. A. Behera and A. Wang, "Calibration-free wavelength modulation spectroscopy: symmetry approach and residual amplitude modulation normalization," Appl. Opt. **55**, 4446 (2016).
16. Claude Portenier, ‘wavelettes Marburg, 1998.
17. https://www.math.ubordeaux.fr/~jbigot/Site/Enseignement_files/ondelettes IMAT.pdf consulted 20/05/2020.