Analysis of OTDR Based Monitor System for Optical Fiber Communication

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Analysis of OTDR Based Monitor System

Some optic fiber communication systems use OTDR based monitor system (the abbreviation as OTDR system below) as QS. In this appendix the OTDR based QS system is analyzed to see if it can meet the QS system requirements described in chapter one. First of all what is an OTDR?

An OTDR is a basic test instrument of measuring optical fiber performances of back reflection and back scattering. Its fundamental operation principle is that an OTDR emits an optical pulse into an optical fiber under test, when the optical pulse is traveling forward in the uniform material of the fiber, a small portion of the optical pulse power is scattering backward. When the optical pulse encounters a change of the optical fiber material, a back reflection occurs.

The OTDR measures the signal of the back scattering and the back reflection and displays the performance in a curve after the post procession. Since the back scattering signal is very weak, an OTDR must average the signal up to 3 minutes to improve the signal to noise ratio. In order to get wide dynamic range, the optical pulse width is set up to 10 us and the peak power ranges from 50 mW to 150 mW or more, now 400 mW pulsed OTDR laser has appeared on the market.

1.0. The main advantage is that it can find the malfunction point in the optical fiber

1.2. Since an OTDR can test optical fiber performance only, it can do nothing for any terminal devices, therefor an OTDR system can’t meet the completeness requirement of a QS.

1.3. An OTDR can measure an optical fiber performance quantitatively, but it provides a curve of 8k to 64k data, it is difficult to process them.

1.4.An OTDR can’t run real time operation because of two reasons:

1) An OTDR is a very expensive device, the price ranges from US$10K to US$40K, it is absolutely impossible that one fiber is equipped with one OTDR all the time. It must use an optical switch to connect one OTDR to different fibers in turn in a station, therefore it can’t implement a real time operation.
2) Even if an OTDR is connected to an optical fiber permanently , it needs three

minutes average time, it is not real time operation neither.

1.5. In the optical fiber communication point of view, the optical pulses from an OTDR is very strong noise while the optical fiber communication signal is a strong noise to the OTDR as well. In order to avoiding the OTDR and the normal optical fiber communication interfere each other, first the wavelength of optical pulses from the OTDR must use different from the optical wave length of the optical communication, for example if the communication wavelength is 1310 nm, the OTDR uses 1550 nm or 1625 nm.

If the communication wavelength is 1550 nm, the OTDR uses 1310 nm or 1625 nm. It is supposed that the communication wavelength is 1310 nm and the OTDR wavelength is 1550 nm in the analysis. Second the wavelength division multiplex (WDM) and the optical wavelength filter must be used in the optical communication system while the optical wavelength filter must be inserted before the OTDR.

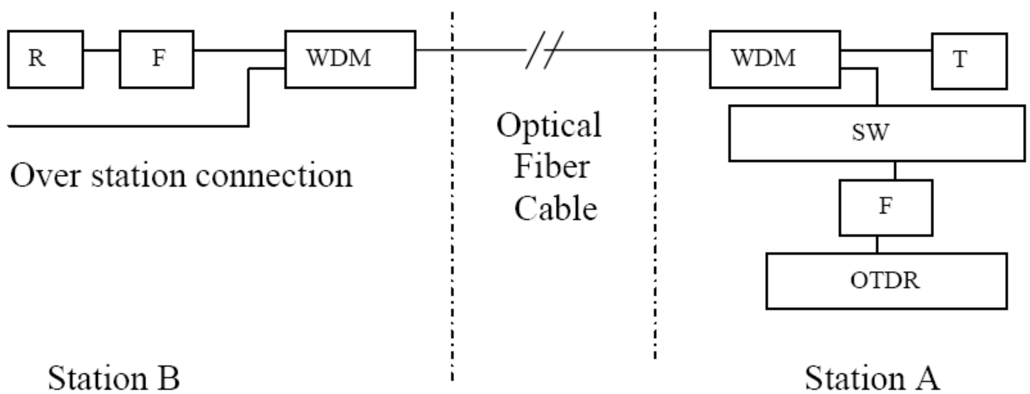

Fig. 1.1OTDR in Transmitter Side

Fig.1-1 shows the optical circuit when an OTDR is used in the transmitter side and Fig.2-2 for an OTDR in the receiver side.

In Fig.1-1 and Fig.1-2, T is a transmitter, R is a receiver, SW is an optical switch, F is a wavelength filter.

Usually an transmitter output optical power is about 1 mW. An OTDR optical pulse power is supposed in mid range of 100 mW, therefore the signal to noise ratio is –20 dB while a receiver needs a signal to noise ratio of 12 dB at least to meet the requirement of Baud error rate less than 10^{-9}.

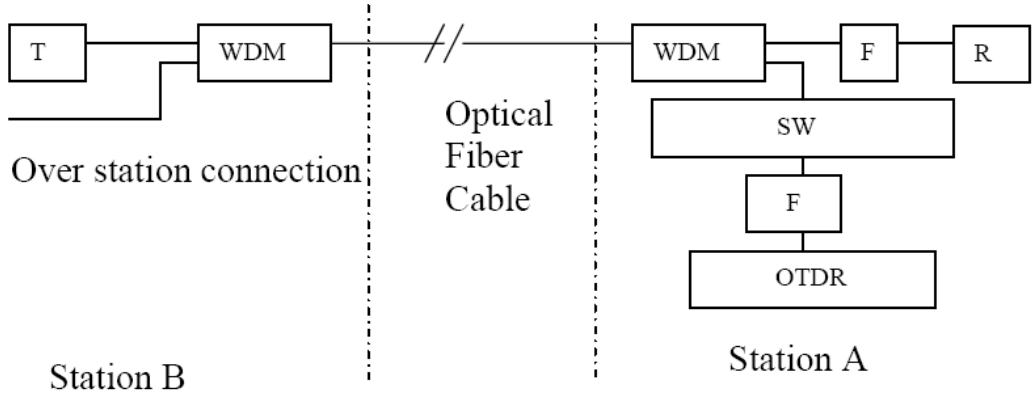

Fig.1-2 OTDR on Receiver Side

It is necessary to attenuate 1550 nm signal by 32 dB before the receiver, assuming the insertion loss of the WDM and the optical fiber attenuation are the same for both of 1310 nm and 1550 nm. A real fusion type WDM has the wavelength cross talk rejection 15 dB only, therefore a 1330 nm pass and 1550 nm stop wavelength filter must be inserted in front of the receiver.

Usually the sensitivity of a receiver is –32 dBm, the noise power must be less than –44 dBm to meet the requirement of signal to noise ratio of 12 dB, the OTDR pulse power is 20 dBm and the WDM cross talk rejection is 15 dB, therefore the filter should have the attenuation of 49 dB to 1550 nm, usually a filter has 40 to 45 dB attenuation to stop wavelength, therefore two filters are required to insert in series before the receiver.

One or two 1550 nm pass and 1310 nm stop filters must be inserted in front of the OTDR to eliminate the interference from the communication optical pulses to the OTDR.

The real situation would be worse than the analysis because two points are not considered: 1) the optical insertions loss of the WDM and the filter(s) on the communication wavelength are not counted. 2) the receiver intrinsic T WDM Over station connection noise is not taken into account while the real total noise of a receiver should be the power sum of the receiver intrinsic noise and the OTDR noise.
Therefore the on line monitoring of an OTDR system is feasible, but it is quite expensive. The cost involves three aspects:

1) Financial cost: a WDM costs about US$1k and a filter costs several hundred US dollars.
2) Signal to noise cost: the OTDR optical pulses would decrease the communication

S/N ratio more or less even if WDM and filters are used
3) Reliability cost: more optical components are inserted in an optical fiber communication system, the reliability would be degraded, just what is pointed in 1.5 .

1-6. Reliability of an OTDR system:

1) Two components are the weak points of an OTDR based system: the OTDR laser and the optical switch. The life time of a power laser is about several thousand hours. As an individual test equipment, the life time is enough, but once it is integrated in to a monitor system, it needs to run all time continuously, the output optical power of the OTDR laser would decreases soon. As per an optical switch, it contains a step motor and some mechanical structure to turn on/off the optical channels, if it is operating very often in an OTDR system, they are worn out soon.

2) Three or more optical components are inserted in each optical communication channel in an OTDR system, it would degrade the optical communication system reliability potentially.

3) An OTDR has very complicated electronic circuit, the reliability is not so good.

1-7.Response speed of an OTDR system

An OTDR system is not a fast response test instrument because the OTDR is connected to every channel in turn and each measurement needs the average time up to 3 minutes..

1-8. Pre warning capability of an OTDR system

An OTDR system can have the pre warning capability for optical fiber networks, not for optical fiber communication. Since the data quantity of each test is very big, the processing and the modeling are quite complicated.

1-9 Predication of an OTDR system

It is similar to the pre warning capability, an OTDR system can have the prediction capability for optical fiber networks, but not optical fiber communication. The processing and the modeling are more complicated than the pre warning.

1-10. Expansion of an OTDR system

If an OTDR system is computerized , it has the expansion capability.

1-11. Independence of an OTDR system

An OTDR system is independent on the communication system.

1-12. The optical insertion loss of an OTDR system

Since three optical components will be inserted in an optical fiber communication channel, the QS internal insertion loss is 3 dB at least

1-13. Cost estimation analysis of an OTDR system

The cost estimation analysis is divided to station based and channel based.

1)Station based:

An IBM personal computer costs US$2k excluding the quality monitor networks interface.

- An OTDR: the average cost is about US$25,000, two stations can share one, so US$12500/station.
- An optical switch: the base cost is around US$2000, two stations can share one, so US$1000/station
- One filter for the OTDR at least: US$700
- The electronic parts excluding OTDR cost : around US$200

The total cost per station is about US$16k

2)Channel based:

When an OTDR is used in the transmitter side, one WDM is required if over station connection is not needed, two pieces of WDM are required when an OTDR is used in the receiver side. When two stations share one OTDR the equal number of the two cases, therefore one and half WDM per channel is counted on average. The unit price of a WDM is about US$1000. US$1500 in total

- One Filter: around US$700
- One channel optical switch: about US$270

The total cost per channel is about US$2500

1-14. Conclusion:

Based on the analysis in the chapter, the conclusion is an OTDR system is not a qualified QS. The only advantage of an OTDR system is it can find the malfunction point of an optical fiber.

It should be emphasized that an OTDR based QS is not qualified, but an OTDR is still a basic and very useful optical fiber test instrument.