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Attenuation Measurement in Optical Fiber Communication

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Abstract: *An Optical Time Domain Reflectometer (OTDR) combines a laser source and a detector to provide an inside view of the fiber link. The laser source sends a signal into the fiber where the detector receives the light reflected from the different elements of the link. This produces a trace on a graph made in accordance with the signal received. The signal sent is a short pulse that carries a certain amount of energy. A clock then precisely calculates the time of the pulse, and time is converted into distance knowing the properties of this fiber. In this paper we discuss how we measure the splice loss using OTDR.*

Keywords: *OTDR, Attenuation, Optical Communication*

1. INTRODUCTION

The OTDR (Optical Time Domain Reflectometer) is a device that is able to “look” at a fiber optic cable and display a graphical representation of the events that occur on the cable. The basic concept is that a high-speed laser fires a precise pulse of light into the fiber after which the device monitors the same fiber for reflections. The time between the launched pulse and reflected pulses is computed to represent the distance to the events that caused the pulses. This gives the OTDR the ability to not only measure the length of the fiber but also measure the distance to each event on the fiber. This function allows the OTDR to be used as a trouble-shooting tool to find breaks in the fiber and to identify the location of individual connectors and splices.

The second feature of an OTDR is its ability to measure the tiny amounts of light that are reflected back by the fiber optic cable itself. This phenomenon is known as Rayleigh scattering and is caused by light reflecting off of molecules in the glass whose diameter is 1/10 the wavelength of the light. This is the same phenomenon that makes the sky appear blue. When the OTDR is able to detect these tiny reflections it can calculate the loss of the cable as well as the insertion loss of connectors and splices on the fiber cable. This technology does not come cheap, in fact the high-sensitivity detector and the supporting electronics required to “see” these tiny reflections are responsible for most of the cost of the OTDR itself. OTDRs were first used in long distance outside plant fiber optic installations such as telecom or CATV to help document and troubleshoot fiber networks. The first generations of OTDRs were massive, complex and very expensive. Most models required the use of a cart or dolly of some type to be moved, as they were heavy and bulky. These early machines did not offer any of the automatic setup features we are used to seeing today, meaning that the operator had to have a very thorough understanding of the operation of the equipment to properly configure it. Lastly, many of the first field-OTDRs cost upward of $60,000 putting them out of reach of everyone except large service providers.

Today, OTDRs are smaller, less expensive and easier to use. But that still does not mean that the average installer can pick one up and begin using it. The technician still needs to understand the complex relationship between pulse width, dynamic range, acquisition time, Rayleigh scattering, and a myriad of other factors that determine what type of picture the technician will get from and OTDR. But nonetheless, the improved functionality smaller size and lower cost have brought the OTDR into the realm of short-haul LANs. Whereas an OTDR was once only used to find problems in short haul networks, they are now being used as documentation tools to help map out fiber links, showing the location of connections and precise length of each link

1.1 The Event Dead Zone

The event dead zone is the minimum distance after a Fresnel reflection where an OTDR can detect another event. In other words, it is the minimum length of fiber needed between two reflective events. Still using the car example mentioned above, when your eyes are blinded by another car, after a few seconds you could notice an object on the road without being able to properly identify it. In the case of an OTDR, the consecutive event is detected, but the loss cannot be measured (as illustrated in Figure1). The OTDR merges the consecutive events and returns a global reflection and loss for all merged events.

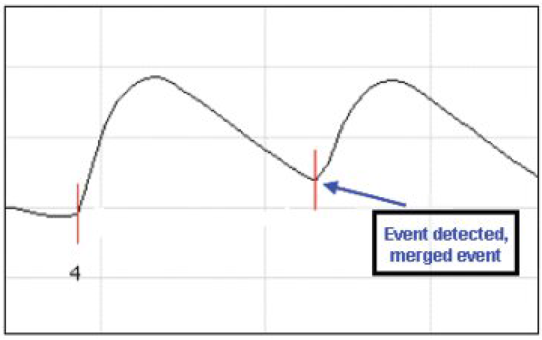

Figure1. Merged event from a long dead zone

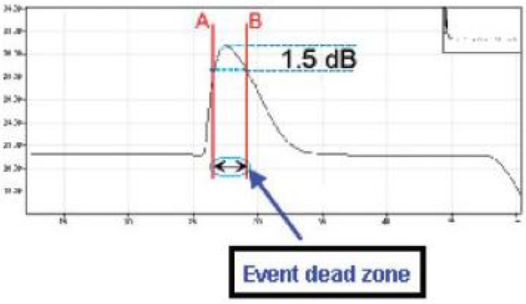

Figure2. *Measuring event dead zone*

The importance of having the shortest-possible event dead zone allows the OTDR to detect closely spaced events in the link. For example, testing in premises networks requires an OTDR with short event dead zones since the patch cords that link the various data centers are extremely short. If the dead zones are too long, some connectors may be missed and will not be identified by the technicians, which makes it harder to locate a potential problem.

1.2 Attenuation Dead Zones

The attenuation dead zone is the minimum distance after a Fresnel reflection where an OTDR can accurately measure the loss of a consecutive event. Still using the car example previously mentioned, after a longer time, your eyes will have recovered enough to identify and analyze the nature of the object on the road. As illustrated in Figure 3 below, the detector has enough time to recover so that it can detect and measure the loss of the consecutive event. The minimum required distance is measured from the beginning of a reflective event until the reflection is back to 0.5 dB over the fiber’s backscattering level, as illustrated in Figure 4 below.

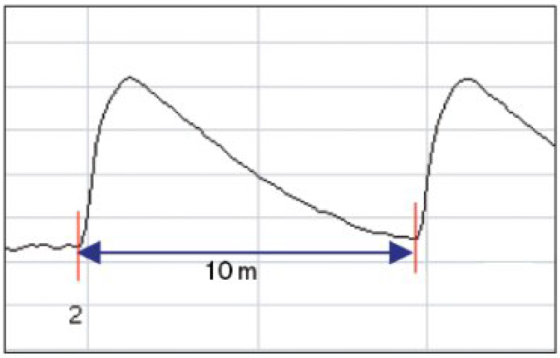

Figure3. *Attenuation dead zone*

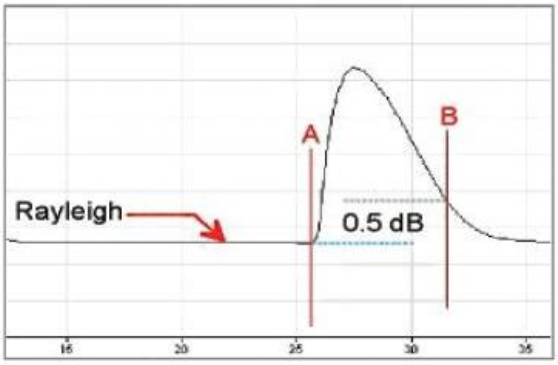

Figure4. *Measuring attenuation dead zone*

1.3 The Importance of Dead Zones

Short attenuation dead zones enable the OTDR not only to detect a consecutive event but also to return the loss of closely spaced events. For instance, the loss of a short patch cord within a network can now be known, which helps technicians to have a clear picture of what is inside the link. Dead zones are also influenced by another factor: the pulse width. Specifications use the shortest pulse width in order to provide the shortest dead zones. However, dead zones are not always the same length; they stretch as the pulse width increases. Using the longest possible pulse width results in extremely long dead zones, yet this has a different use, as will be examined further on.

2. THE DYNAMIC RANGE

An important OTDR parameter is the dynamic range. This parameter reveals the maximum optical loss an OTDR can analyze from the backscattering level at the OTDR port down to a specific noise level. In other words, it is the maximum length of fiber that the longest pulse can reach. Therefore, the bigger the dynamic range (in dB), the longer the distance reached. Evidently, the maximum distance varies from one application to another since the loss of the link under test is different. Connectors, splices and splitters are some of the factors that reduce the maximum length of an OTDR. Therefore, averaging for a longer period of time and using the proper distance range is the key to increasing the maximum measurable distance. Most of the dynamic range specifications are given using the longest pulse width at a three-minute averaging time, signal-to-noise ratio (SNR) = 1 (averaged level of the root mean square (RMS) noise value). Once again, note that it is important to read the footnotes of a specification for detailed testing conditions.

A good rule of thumb is to choose an OTDR that has a dynamic range that is 5 to 8 dB higher than the maximum loss that will be encountered. For example, a single mode OTDR with a dynamic range of 35 dB has a usable dynamic range of approximately 30 dB. Assuming typical fiber attenuation of 0.20 dB/km at 1550 nm and splices every 2 km (loss of 0.1 dB per splice), a unit such as this one will be able to accurately certify distances of up to 120 km. The maximum distance could be approximately calculated by dividing the attenuation of the fiber to the dynamic range of the OTDR. This helps determine which dynamic range will enable the unit to reach the end of the fiber. Keep in mind that the more loss there is in the network, the more dynamic range will be required. Note that a high dynamic range specified at 20 μs does not guarantee a high dynamic range at short pulses excessive trace filtration could artificially boost dynamic range at all pulses at the cost of a bad fault-finding resolution.

3. EXPERIMENTAL WORK

A field work has been done in Ethio Telecom Addis, where a fiber has been layed from Debriziet to Addisababa which is about forty kilo meters of distance. We used a single mode fiber cable “24F” which was manufactured by HFCL. Each fiber cable bundle is of the length 1.94 Kilo meters. So we require about 21 Joints for the following 40 Km distance. At each joint there is a loss present due to reflection. An OTDR is used to measure the losses at each joint for all 24 fibers in a cable. The standard followed is ITU-T G.652. The experimental setup is shown in the figure 5.The results & analysis is given below.

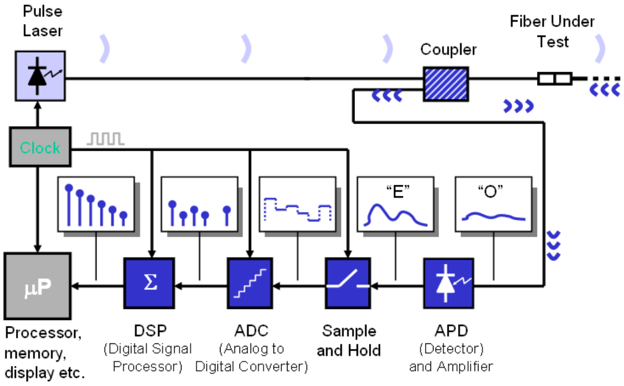

Figure 5. *Experimental setup for OTDR Measurement*

The fiber used is 24F ADSS Optical Fiber Cable, the applications are given below ADSS (All dielectric self supporting) cables are designed for aerial applications. This cable features high tensile aramid strength members and polyethylene outer sheath to ensure continuous performance even in most severe conditions.

The Key Features are:

- Self Support design
- Internal messenger saves installation time and cost
- Able to support 2 – 96F
- Both unitube and multi loose tube constructions available.

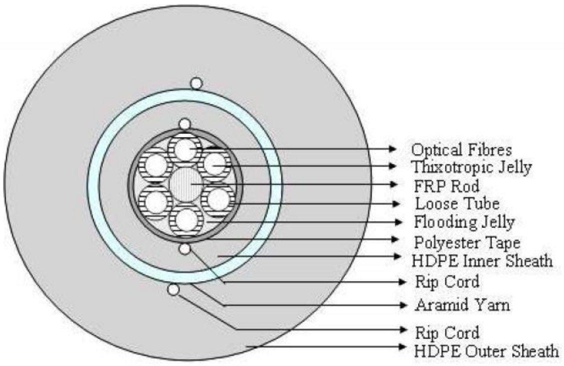

Figure 6. *24F ADSS Optical Fiber Cable*

4. RESULTS DISCUSSION

The OTDR measurements from both sides i.e. from Debriziet to Addisababa & from Addisababa to Debriziet have been taken. The Route attenuation losses have been calculated for two different wave lengths of the input light signal pulse, one is 1310 nm & other is 1550 nm.

Experimental Results for an Optical Fiber (1550nm)

1. Route - Addis Tel. Exchange to Debriziet Tel. Exchange 24F OFC Route
Cable - 24F
Make - HFCL
Transmit Power: - 5.40 dBm
Wavelength :- 1550 nm
Measurement - Attenuation test (Power loss Measurement)
Distance : - 40.612 Km
Date : - 28/12/2013
Transmitting station : - Addis Ababa
Measured at station : - Debriziet

Fibre No.	Level at Receive end (dBm)	Loss for the section (dB)	Attenuation per Km (dB/Km)
F1	-14.75	-9.35	0.23
F2	-14.25	-8.85	0.22
F3	-13.45	-8.05	0.20
F4	-13.79	-8.39	0.21
F5	-13.92	-8.52	0.21
F6	-13.99	-8.59	0.21
F7	-13.52	-8.12	0.20
F8	-13.93	-8.53	0.21
F9	-14.68	-9.28	0.23
F10	-14.38	-8.98	0.22
F11	-14.62	-9.22	0.23
F12	-14.55	-9.15	0.23
F13	-13.90	-8.50	0.21
F14	-14.01	-8.61	0.21
F15	-14.87	-9.47	0.23
F16	-13.12	-7.72	0.19
F17	-13.76	-8.36	0.21
F18	-13.51	-8.11	0.20
F19	-13.52	-8.12	0.20
F20	-16.80	-11.40	0.28
F21	-12.52	-7.12	0.18
F22	-14.01	-8.61	0.21
F23	-13.64	-8.24	0.20
F24	-13.23	-7.83	0.19

Limit :- 0.30 dB/Km

2. Route - Addis Tel. Exchange to Debriziet Tel. Exchange 24F OFC Route
Cable - 24F
Make - HFCL
Transmit Power : - 5.40 dBm
Wavelength :- 1310 nm
Measurement - Attenuation test (Power loss Measurement)
Distance : - 40.612 Km
Date : - 28/12/2013
Transmitting station :- Addis Ababa
Measured at station :- Debriziet

Fibre No.	Level at Receive end (dBm)	Loss for the section (dB)	Attenuation per Km (dB/Km)
F1	-20.10	-15.90	0.39
F2	-19.52	-15.32	0.38
F3	-18.78	-14.58	0.36
F4	-19.17	-14.97	0.37
F5	-17.92	-13.72	0.34
F6	-18.31	-14.11	0.35
F7	-18.24	-14.04	0.35
F8	-18.69	-14.49	0.36
F9	-18.78	-14.58	0.36
F10	-18.97	-14.77	0.36
F11	-18.72	-14.52	0.36
F12	-18.63	-14.43	0.36
F13	-18.45	-14.25	0.35
F14	-18.24	-14.04	0.35
F15	-19.29	-15.09	0.37
F16	-19.70	-15.50	0.38
F17	-18.94	-14.74	0.36
F18	-19.36	-15.16	0.37

F19	-18.71	-14.51	0.36
F20	-19.30	-15.10	0.37
F21	-18.30	-14.10	0.35
F22	-19.75	-15.55	0.38
F23	-18.92	-14.72	0.36
F24	-18.66	-14.46	0.36

Limit :- 0.43 dB/Km

5. CONCLUSION

From Addis Ababa to Debriziet the attenuation limit achieved is 0.43dB/ Km for both 1310 nm signal & for 1550 nm. The Refractive Index of the core of the single mode fiber used is 1.467.

The Power loss Measurement from Addis Ababa to Debriziet for both 1550 nm & 1310 nm signal is averaged to 0.365dBm, which can be seen from the above observations.

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