

Optical Time Domain Reflectometer Assessment of Attenuation in Fiber Optics Communication System

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Authors' contributions

This work was carried out in collaboration between both authors. Author JI designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author IJA managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Attenuation is an undesirable factor that weakens the strength of signal as it travels down fiber optics. Attenuation level in every fiber communication link must be kept at its tolerable range in order to maintain good signal transmission. When the level of attenuation in a link is higher than the acceptable tolerance value, the transmission suffers some setbacks such as loss of signal, freezing of signal etc. An optoelectronic device, Optical Time Domain Reflectometer (OTDR) was used in the measurement of attenuations in the single-mode fiber using the uni-directional technique. It is a convenient and powerful tool for rapidly assessing attenuation behavior in optical fibers. It combines a detector and laser source to provide an inside view of the fiber link described by a trace. The injected light pulse from the laser source is received at the detector. OTDR traces were produced in accordance with the light pulses received. From these traces, the attenuation levels for the different fiber cores were obtained. An average

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attenuation limit of 0.188 dB/km and average section loss of 0.3dB for 1550 nm wavelength window over the span length of 1597.35 m were achieved which are within the acceptable standard range of 0.20 dB/km to 0.30 dB/km.

Keywords: Attenuation; OTDR; Uni-directional test; OTDR trace.

1. INTRODUCTION

Attenuation is an undesirable factor in a fiber link that weakens the strength of signal or light pulse and must be kept at minimal or within the acceptable range [1]. The standard/acceptable tolerance range is 0.2 dB/km to 0.3 dB/km [2]. Fiber link is a medium, in which information (voice, data or video) is transmitted through a glass or plastic fiber, in the form of light [3]. Attenuation may be caused by absorption, scattering, or bending [4,5]. Absorption is categorized into intrinsic and extrinsic absorptions. The intrinsic absorptions are caused by basic properties of the fiber material while extrinsic absorptions are caused by impurities that are introduced in the optical fiber material either during manufacturing or installation or after installation. Scattering (i.e. Rayleigh scattering) is the reflection of a small amount of light in all directions as it travels down fiber [6]. This is due to the interactions of light with density fluctuation within the optical fiber. Bending could be micro-bending or macro-bending. The micro-bends are caused by minor discontinuities or imperfections in fibers whereas, macro-bends occurs when fibers are physically bent beyond the point at which the critical angle is exceeded..

An OTDR is a valuable optoelectronic device used in the characterization and qualification of optical fibers [7]. Typical parameters measured with OTDR include; total fiber loss, loss per unit length, connector insertion, loss connector return loss (reflection), splice loss, inter-splice loss,

absolute fiber length, evidence of macro/micro bending, and position of cable defects or breaks [8].

2. OTDR COMPONENTS

It consists of a laser light source (laser diode), LCD display, signal analyzer, a controller, and an optical detector as shown in Fig. 1 [9].

The laser light source produces short and high-intensity light pulses which are transmitted via fibers. The light pulses typically last between 10 and 100 nanoseconds. Most of the OTDR operates at about 850 nanometers (nm) window, 1310 nm window, and/or 1550 nm window. Some OTDR could operate at more than one wavelength windows. The detector receives the light pulses and produces an equivalent electrical output proportional to the strength of the light that strikes it [10]. Signal analyzer measures the output from the detector and sends the measured value to an appropriate memory unit. The microprocessor (controller) stores and carries out mathematical operations on the measured values when instructed. Other functions are to locate and identify any connectors, fusion splices, and breaks in the fiber. The CRT or LCD displays the results of the measurements and any indicated calculation in form of intensity of backscattered light reaching the detector. The displayed results can be more complex interpretations of the data performed.

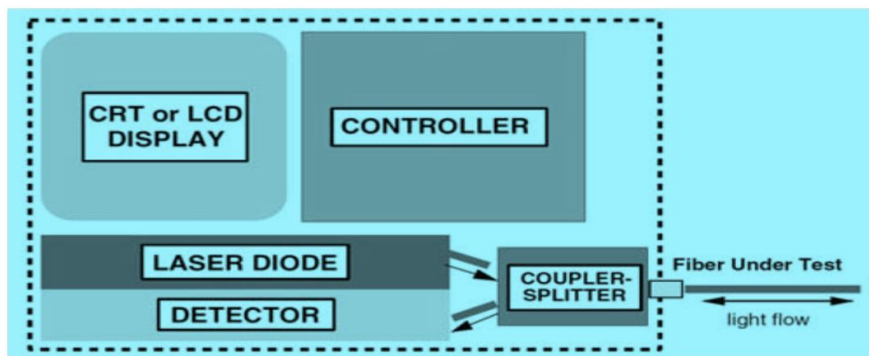


Fig. 1. OTDR block diagram

2.1 OTDR Characteristics

The common characteristics of an OTDR include distance range (or display range), resolution, pulse width, index of refraction, and wavelength. Test or measurements are taken once the OTDR has been properly configured. Few technical decisions are critical in determining the instrument set-up conditions that give best results. Most of these parameters or OTDR characteristics are stored once and remain in the instrument's memory until the pieces of information are needed.

2.2 Distance Range

The distance range limits the amount of fiber that is displayed on the screen. It is the maximum distance at which the OTDR can detect a reflection. It's usually set approximately 25% more than the length of the fiber to be tested. It affects the measurement accuracy and the time required to complete a measurement.

2.3 Resolution

Resolution refers to the data points spacing. Where the points are closer, then the resolution is high and vice versa. High resolutions provide more details and accuracy of events in an optical fiber, but at a longer test period than lower resolutions. The OTDR resolution depends on some other factors such as pulse width. A short pulse width improves resolution.

2.4 Pulse Width

The period of the laser pulse can be adjusted either by selecting a longer or shorter pulse width. This controls the amount of backscatter level coming back and the dead zone size. A strong backscatter level can be produced when light pulse of longer width is injected into the fiber. However, this produces the longest dead zones. Conversely, short pulse widths give short dead zones with weak backscatter levels. So, long pulse widths are preferred because they give maximum range and are used to detect defects and breaks in fibers quickly. Short pulse widths are also useful in resolving two or more events that are closely spaced within the optical fiber.

2.5 Index of Refraction

The index of refraction is the ratio of the speed in vacuum to the speed of light in a particular fiber.

The speed of light transmission in a medium depends on density of the medium. Change in the density leads to change in the speed. The density of the medium is determined by the type and amount of dopants used during manufacturing. The distribution of the dopant may not be uniform in the entire fiber or between any two fibers. The OTDR uses the index of refraction as the calibration factor that indicates how fast the light is traveling in order to make accurate distance measurements.

2.6 Wavelength

The OTDR does test in any of the three operational wavelength windows namely 850 nm, 1310 nm, and 1550 nm. Multi-mode fiber works perfectly in 850 nm and 1300 nm while single-mode works in 1310 nm and 1550 nm bands.

2.7 Interpretation of OTDR Traces

An optical fiber link typically consists of several lengths of fiber, reflective events (caused by connectors), non-reflective events (caused by bad splicing), and positive events (caused by dreaded gainers). Each of these has its characteristic backscatter signature that can be readily identified and measured by the OTDR.

2.8 Measuring Fiber Loss and Fiber Length

Fiber loss is the total loss between two given points in a fiber link which includes at least one section of fiber and a connector pair at either end, as shown in Fig. 2 (OTDR Trace). From Fig. 2 the fiber loss can be seen as the difference between the backscatter signal P1 at a position just prior to the reflection at the first connector, and the backscatter signal P3 at some position in the tail-cord just beyond the extent of the attenuation dead zone of the OTDR. There are two types of dead zones: Event dead zone (the minimum distance after a reflective event where an OTDR can detect another event) and attenuation dead zone (the minimum distance after a reflective event where an OTDR can accurately measure the loss of a consecutive event). The fiber loss includes the insertion loss and connector loss from the connector pair. The use of a tail cord is very necessary in obtaining accurate measurement of the loss of the second connector. If a tail-cord was not present then the link loss would have to be measured to a position Z2 just prior to the reflection at the second connector and would be reported as the loss of

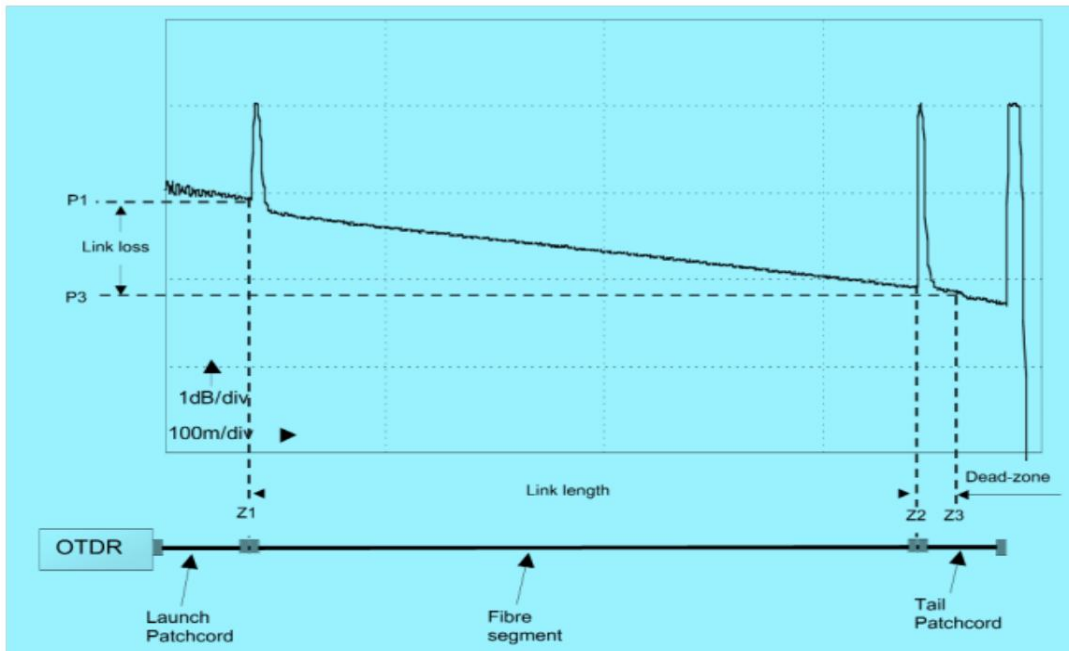


Fig. 2. OTDR Trace

the fiber plus one connector pair. Fiber length is measured as the distance between the positions Z1 just prior to the connector at the front end to the equivalent position Z2 just prior to the connector at the far end. And this corresponds to the length of the fiber section excluding the patch cords.

3. MATERIALS AND METHODS

3.1 Materials

1. Single-Mode Patch cords
2. Power meter
3. Optical Time Domain Reflectometer (OTDR)
4. Media Converter/Transmission Equipment
5. Flash drive

OTDR test procedures

Fiber Type: SM 36 CORE FIBER
 Device: MTS 6000 Num.2487
 Module: 8126LR Num.16131

The OTDR parameters were set as:

Wavelength: 1550 nm
Range (km): 2.044
Acq. Time: 10 s
Resolution: 16 cm
Index: 1.46648000



Fig. 3. OTDR connected to fiber under test

A power meter was used in testing for continuity along the cable before the measurements were taken. A single-mode patch cord was attached to the OTDR and to cable plant (Core 01, fiber no. 1) under test via the patch panel at as shown in Fig. 3. The OTDR was preset manually as stated above and it emitted light power pulses along the cable in a forward direction by the injection laser. The light pulses then bounced back and were measured by the factoring out of time and distances. The avalanche photodiode receiver detected the backscattered light and its output was driven by an integrator which improved the Signal to Noise Ratio (SNR). This gives an arithmetic average over a number of

measurements at one point. The signal was then fed into a logarithmic amplifier and the average measurements for successive points within the fiber were plotted and recorded with the chart recorder. The trace was made in a readable format by media converter and retrieved with an external drive. The same procedure was repeated for cores 02 to 36 and the results tabulated as seen in Table 1. These tests were carried out only in way direction called uni-directional testing.

4. RESULTS

The results for attenuation and section loss from the uni-directional test are given in Table 1.

5. DISCUSSION

An average attenuation limit of 0.188 dB/km and average section loss of 0.3 dB were achieved. When compared with standard specification, it shows that the results were within the acceptable transmission range for quality optical fiber communication transmission. However, one of the challenges posed by this technique most times is inaccuracies due to the manner in which OTDR backscatter data is recorded and reported. Differences usually arise when backscatter results suggest “exaggerated loss” or “gainer” values caused by optical refractive index changes at splice points.

Table 1. Uni-directional test results (Distance = km)

Fiber No.	Distance (m)	Attenuation (dB/km)	Section loss (dB)
1	1598.87	0.189	0.302
2	1598.87	0.189	0.302
3	1598.87	0.189	0.302
4	1598.87	0.189	0.302
5	1595.83	0.187	0.298
6	1595.83	0.187	0.298
7	1595.83	0.187	0.298
8	1595.83	0.187	0.298
9	1595.83	0.187	0.298
10	1595.83	0.187	0.298
11	1595.83	0.187	0.298
12	1595.83	0.187	0.298
13	1595.83	0.187	0.298
14	1595.83	0.187	0.298
15	1595.83	0.187	0.298
16	1595.83	0.187	0.298
17	1595.83	0.187	0.298
18	1595.83	0.187	0.298
19	1595.83	0.187	0.298
20	1595.83	0.187	0.298
21	1595.83	0.187	0.298
22	1595.83	0.187	0.298
23	1595.83	0.187	0.298
24	1595.83	0.187	0.298
25	1595.83	0.187	0.298
26	1595.83	0.187	0.298
27	1595.83	0.187	0.298
28	1595.83	0.187	0.298
29	1595.83	0.187	0.298
30	1595.83	0.187	0.298
31	1595.83	0.187	0.298
32	1595.83	0.187	0.298
33	1595.83	0.187	0.298
34	1595.83	0.187	0.298
35	1595.83	0.187	0.298
36	1595.83	0.187	0.298

6. CONCLUSION

An optoelectronic device, Optical Time Domain Reflectometer (OTDR), was used to measure the attenuation of 36 core single-mode fiber over a span length of 1597.35 m using uni-directional test method. Experimental results presented though not accurate showed acceptable values of attenuation and section loss for good and uninterrupted fiber transmission.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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