Ensuring Distance Accuracy with an OTDR

Sampling resolution not only influences distance accuracy, it also impacts other parameters, such as acquisition time, distance measurement range, and dynamic range. Therefore, take care when modifying this parameter. This paper describes the impact of sampling resolution on OTDR measurements.

Parameters that affect Distance Accuracy when using an OTDR

The parameters that limit distance accuracy when using an OTDR are:

- Helix factor (the difference between fiber link length and cable length)—Highest impact
- Index of Refraction (IOR) setting—High impact
- Clock accuracy/Time Base error—Medium impact
- Sampling Resolution setting—Small impact
- Distance error at origin—Limited impact

Add the parameters above to get the overall distance accuracy for a given fiber length measurement with the OTDR.

Difference between Fiber Link Length and Cable Length (Helix Factor)

The OTDR measures fiber link length, however, operators typically want to know the cable length. The fiber itself is twisted inside the cable length, as Figure 1 shows; therefore, it creates a difference between the two lengths that can be significant (up to few percentage points) known as the helix factor. These differences can be unpredictable and therefore not really settable. Errors from this effect are proportional to the fiber length being measured.

Figure 1. Fiber twisted along the cable

A typical 1-percent error on a fiber length of 10 km generates an OTDR trace of 9.9 km for the cable itself, or a distance error of 100 m. Therefore, this parameter has the highest impact on distance accuracy.

Index of Refraction Setting

As the OTDR measures the time it takes for light to travel and come back to display the length, the index of refraction setting is used as a direct coefficient. Figure 2 illustrates how the OTDR arrives at the distance measurement.

$$D = \frac{cT}{2n}$$

D = fiber distance
c = speed of light in vacuum
T = round-trip time delay from OTDR
n = IOR

Figure 2. Distance Measurement from an OTDR

The error when using this parameter is then proportional to the measured fiber length. Technicians can set the IOR on the OTDR; however, they must enter the exact IOR for the tested fiber, which often is not well known. Fiber and cable manufacturers usually provide a three-digit IOR (JDSU units can provide as many as five digits).

An optimized IOR error of 0.0001 (1.4651 or 1.4649 instead of 1.4650) on a fiber length of 10 km generates an OTDR trace of 9.99931 km and 10.00068 km, respectively, for the cable itself, or a distance error of ±68 cm. *Therefore this parameter has a high impact on distance accuracy, especially on long links.*

Clock Accuracy/Time Base Error

As the OTDR measures the time it takes for light to travel down the fiber length and come back, a time base/clock is used. This function has its own error/accuracy. The error coming from this parameter is proportional to the fiber length being measured.

With a clock accuracy of typically 1 x 10^{-5} x distance (such as JDSU units), a fiber length of 10 km on the OTDR trace generates an error of 1 x 10^{-5} x 10,000 = ±10 cm. *Therefore this parameter has a medium impact on distance accuracy*, even on long links, because most current OTDRs are now well optimized, such as those from JDSU.

Sampling Resolution Setting

Sampling resolution for an OTDR is defined as the minimum distance between two consecutive sampling points acquired by the instrument. The error generated by this parameter is a fixed value, that is, the sampling value itself (it is not directly related to the link length itself). However this sampling resolution also considers the fact that the OTDR can record a maximum of acquisitions points for a given distance range. Figure 3 shows an example of a sampling resolution error.

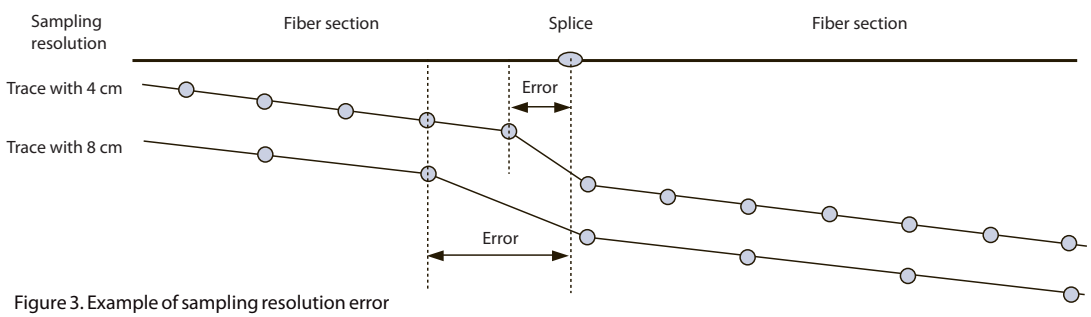

Figure 3. Example of sampling resolution error

A maximum of acquisition points of typically 128,000 and a fiber length of 10 km and a distance range of 10 km on the OTDR generates an error of 10,000,000/128,000 = ±8 cm.

A maximum of acquisition points of typically 128,000 and a fiber length of 2 km and a distance range of 2 km on the OTDR generates an error of 2,000,000/128,000 = ~1.5 cm; however, the minimum sampling available is 4 cm, so the error will be ±4 cm.

Consequently, not having a component located exactly at one of those sampling points can result in an error of ± sampling resolution.

Therefore this parameter has a small impact on distance accuracy, as most current OTDRs are now well optimized, such as those from JDSU.

Sampling resolution not only influences distance accuracy, it can also impact other parameters, such as acquisition time, distance measurement range, and dynamic range, to name a few. So choose this parameter with care, because selecting the shortest sampling resolution may not provide the most optimized OTDR results overall. More information is provided on the JDSU Application Note titled "Sampling Resolution: Its Impact on OTDR Testing".

Distance Error at Origin

The OTDR sets the time origin when performing acquisitions known as the distance error at origin, or the origin error, which is a fixed value and not directly related to the link length itself. Add this parameter only when measuring lengths from the OTDR connector, which is rarely done because most technicians use launch cables. Setting a zero distance at the end of the launch cable eliminates the origin error because the operator can make relative measurements from the launch cable, as Figure 4 illustrates.

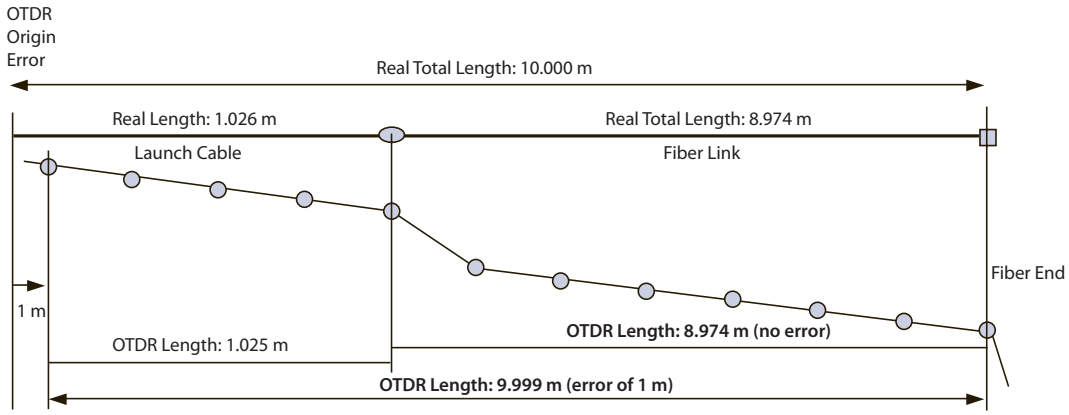

Figure 4. Example showing no origin error with launch cable

With an origin error of typically ±1 m, a fiber length of 10 km generates an OTDR trace of 9.999 km or 10.001 km. Using a launch cable results in no error at this level. *Therefore this parameter has a limited impact on distance accuracy,* as most current OTDRs are now well optimized, such as those from JDSU.

Conclusion

Measuring the distance length of a fiber using state-of-art OTDRs shows negligible errors in clock accuracy, sampling resolution, and origin error in comparison with IOR and differences between fiber length and cable length. These three parameters provide enough accuracy, within a magnitude of few centimeters up to 1 meter, which is good enough for qualifying and troubleshooting fiber links

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