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OTDR Subtleties- Short Segment, Singlemode, Attenuation Rates

Introduction

Short, singlemode segments exist in many data centers, local area networks, and telephone central offices. Technicians can, and often do, interrogate these short segments with an OTDR. The common, working assumption is that the OTDR measurements will be accurate and repeatable. This assumption is not always valid because there is a minimum, singlemode, segment length, below which the OTDR attenuation rates are inaccurate and non-repeatable. The OTDR technician needs to recognize such situations. Without such recognition, the OTDR technician can misinterpret the attenuation rates. In this article, we present seven principles that enable understanding the behavior of short segment, singlemode attenuation rates and a method the OTDR technician can use to approximate such rates.

Seven Principles

Seven principles enable understanding the behavior of short singlemode segment attenuation rates. Principle 1: as would be expected of any measurement device, the OTDR has a minimum power level difference that it can detect, which this author labels ‘resolution’ [Figure 1).

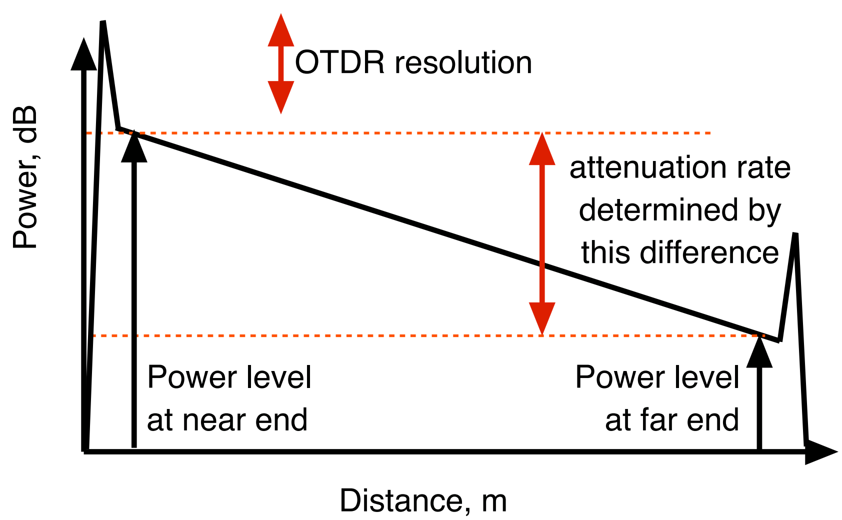

Figure 1: Power Difference for Long Segment

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Principle 2: OTDR attenuation rate measurement is determined by the difference in power levels at the beginning and end of a segment [Figure 1][1].

Principle 3: as the segment length becomes shorter, the power difference becomes less (Figure 2).

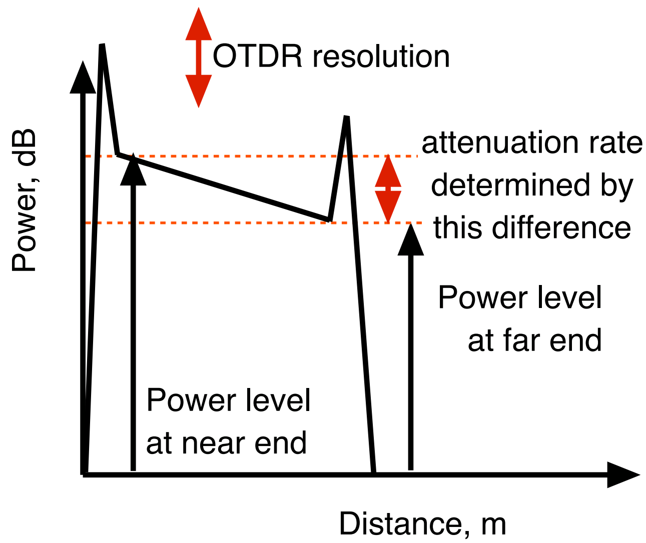

Figure 2: Power Difference for Short Segment

Principle 4: if the difference in power levels at the segment ends is less than the resolution, the OTDR cannot measure accurate attenuation rate repeatedly (Figure 2).

If there were no noise present in the two power level measurements, there would be a minimum length that we could determine from the resolution. However, noise is present. This is Principle 5. OTDR backscatter power levels are so low that they must be amplified to be measured. Amplification introduces noise into the measurement. Electronic noise created by amplification is, by definition and decades of experience, is not constant, but varies with time.

Principle 6: as a result of varying noise power levels, the noise level at all locations along a fiber can vary. The noise in the near end power measurement can be high while that at the far end can be low. In this case, the attenuation rate increases relative to that without any noise (Figure 3). As a result, noise level can result in incorrect excessive attenuation rates, which can result in segment rejection.

[1] We recognize that we obtain the most accurate attenuation rates with the least squares analysis (LSA) of the data. The use of LSA does not invalidate the analysis presented herein.

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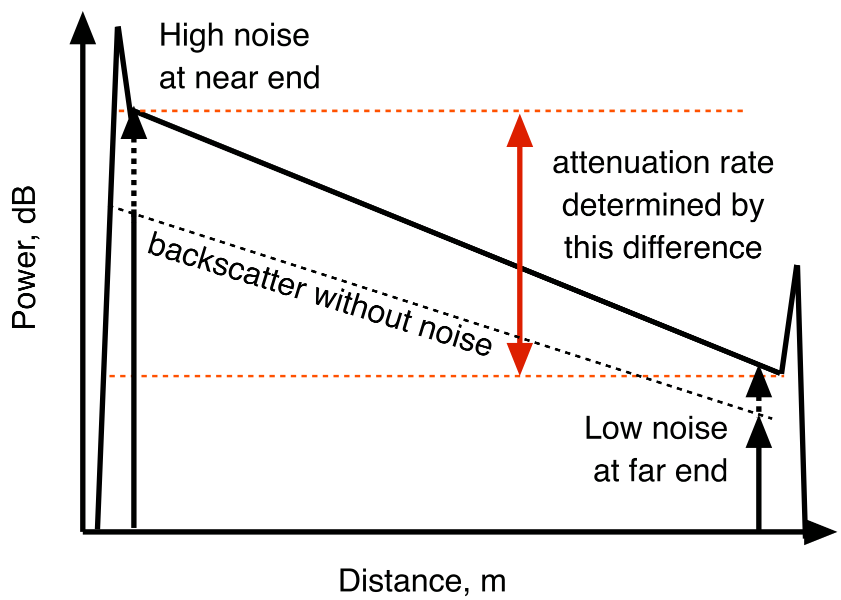

Figure 3: Attenuation rate With High-Low Noise at Opposite Ends of Fiber

If the opposite noise condition occurs, noise level low at near end and high at far end, the attenuation rate is reduced relative to that without noise (Figure 4). In this condition, noise level can result in incorrect low attenuation rate, which can result in acceptance of excessive attenuation rate. This simple comparison reveals how repeated measurements made on the same fiber can result in non-repeatable attenuation rates.

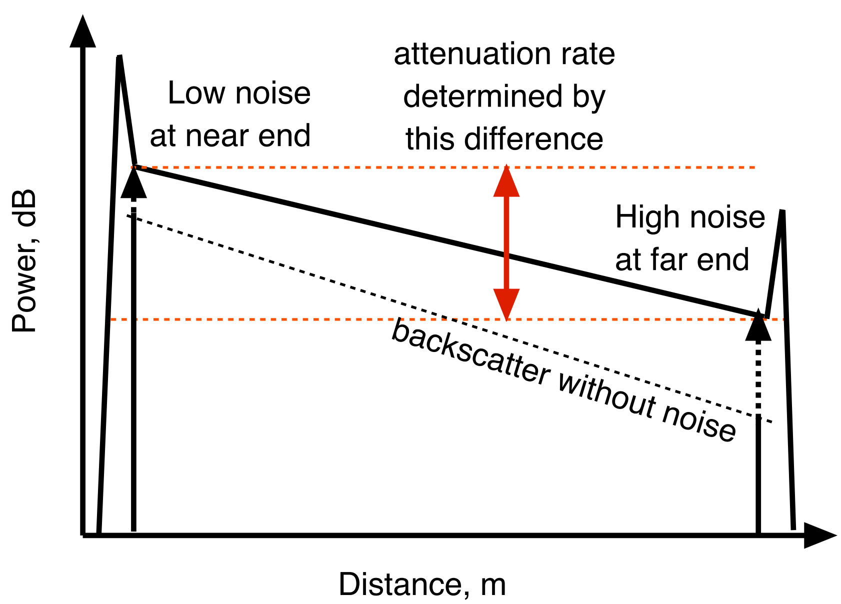

Figure 4: Attenuation rate With Low-High Noise at Opposite Ends of Fiber

While non-repeatable attenuation rate values can occur, they are unlikely to be significant unless one condition exists: that of differences in power levels at opposite ends of the fiber that are close to or less than the OTDR resolution. Under this condition, attenuation rates become inaccurate and non-repeatable. This is Principle 7.

Pearson Technologies observed examples of severe lack of repeatability in our testing for Mastering The OTDR-Singlemode Subtleties, a report in development. Our multiple rate measurements of a 100m segment of cable under multiple settings of pulse width and time on 3 OTDR models exhibited a wide range of value [Table 1].

		103m	**103m**				**103m**	**103m**
Pulse	time	attenuation	Table delta		Pulse	time	attenuation	Table delta
width		rate	successive		width		rate	successive
ns	sec.	dB/km	tests, dB/km		ns	sec.	dB/km	tests, dB/km
10	10	0.412			100	10	0.318	
10	10	0.672	-0.26		100	10	0.373	-0.06
10	20	0.520			100	30	0.294	
10	20	0.779	-0.26		100	30	0.248	0.05
10	30	0.268			100	60	0.305	
10	30	0.613	-0.35		100	60	0.287	0.02
10	60	0.255			300	10	0.009	
10	60	0.676	-0.42		300	10	0.009	0.00
30	10	0.373			300	30	0.016	
30	10	0.559	-0.19		300	30	0.000	0.02
30	30	0.527			300	60	0.000	
30	30	0.480	0.05		300	60	0.000	0.00
30	60	0.357			300	60	0.000	0.00
30	60	0.430	-0.07					
					Average		0.338	-0.113

Table 1: 1310nm Attenuation Rates of 100m, Singlemode Cable

This table exhibits 1310nm attenuation rates that range from 0.779 to 0.009 dB/km. The expected attenuation rate was ~ 0.33 dB/km. This table demonstrates that most of the attenuation rate vales differ significantly from the expected value. In addition, successive tests under the same conditions, listed in the columns labelled ‘delta successive tests’, exhibited large differences, as high as 0.42 dB/km. When the difference between successive tests was small, the attenuation rates were not close to the expected value. In summary, the

100m segment attenuation rate was inaccurate or, when close to the expected value, non-repeatable.

The results in this table are for 1310nm testing with OTDR 1.[2] Testing of all three OTDRs at both 1310nm and 1550nm exhibited ranges of attenuation rate and non-repeatability similar to those in Table 1.

This testing supported three conclusions:

1. Attenuation rates at 100m were not accurate or repeatable.
2. Additional testing indicated that for segment lengths less than 966m, no acceptable conditions of pulse width and trace time result in acceptable accuracy and repeatability for two of the three OTDRs tested.
3. For the third OTDR, OTDR 2, we found acceptable conditions of pulse width and trace time resulted in acceptable accuracy and repeatability for lengths between 606m and 966m.

Determining Minimum Segment Length

In order to properly interpret OTDR attenuation rates, the technician needs to know the minimum segment length, below which the rate becomes inaccurate. How do we determine this minimum length? The method we used for the results in Table 1, testing fiber coils of different lengths, would not be suitable for field work. Instead, we offer the following method for approximating the minimum length. This method is analogous to the ‘cut back’ method of determining attenuation rate in fibers with a stabilized source, tightly controlled launch conditions, and a calibrated optical power meter.

In this method, Pearson Technologies tested three fiber lengths, 2020m, 3127m, and 6317m, in the manner shown in Figure 2. Pearson Technologies analyzed the OTDR traces of three fiber lengths. The analysis method involved determining two attenuation rates. The first rate was of most of the segment length (Figure 3).

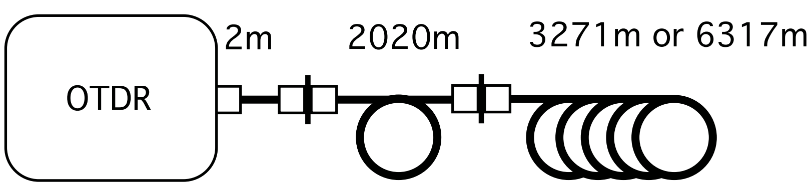

Figure 2: Test Set Up

For this value, we placed cursors near, but not at, the ends of the fiber. This cursor placement eliminated potential end effects, such as extended dead zone due to high reflectance connectors or bend radius violations at the inner end of the reel due to less than perfect winding.

[2] OTDR 1 is one of three OTDR models, test results for which we present in Mastering The OTDR-Singlemode Subtleties.

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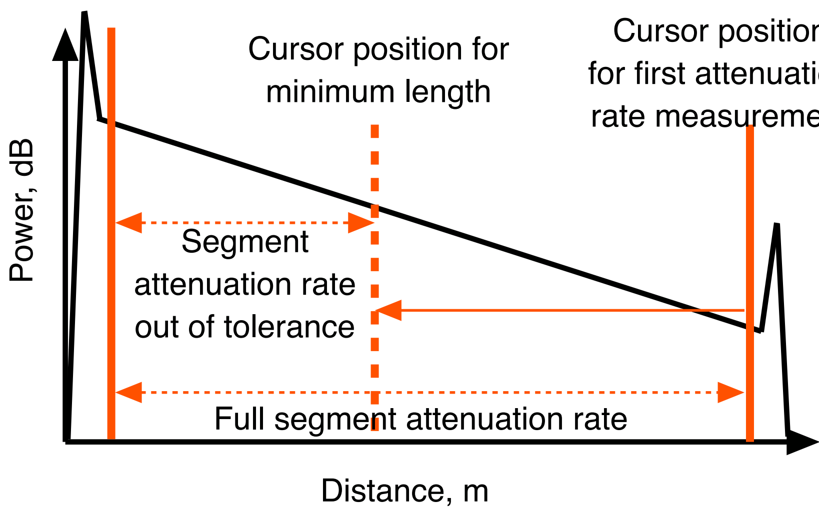

Figure 3: Cursor Positions for Full and Minimum Length Attenuation Rates

The second measurement was of the sub-segment of the entire length. This sub-segment was the shortest length, at which the sub-segment attenuation rate was within a tolerance of the rate for the entire segment, which was the first measurement. This method required moving the far end cursor on the trace to decreased length (i.e., closer to the OTDR) until the sub-segment attenuation rate deviated from the value of the first attenuation rate by more than the tolerance (Figures 3 and 4). We analyzed the traces with three tolerances: ±0.01 dB/km, ±0.03 dB/km, and ±0.02 dB/km.

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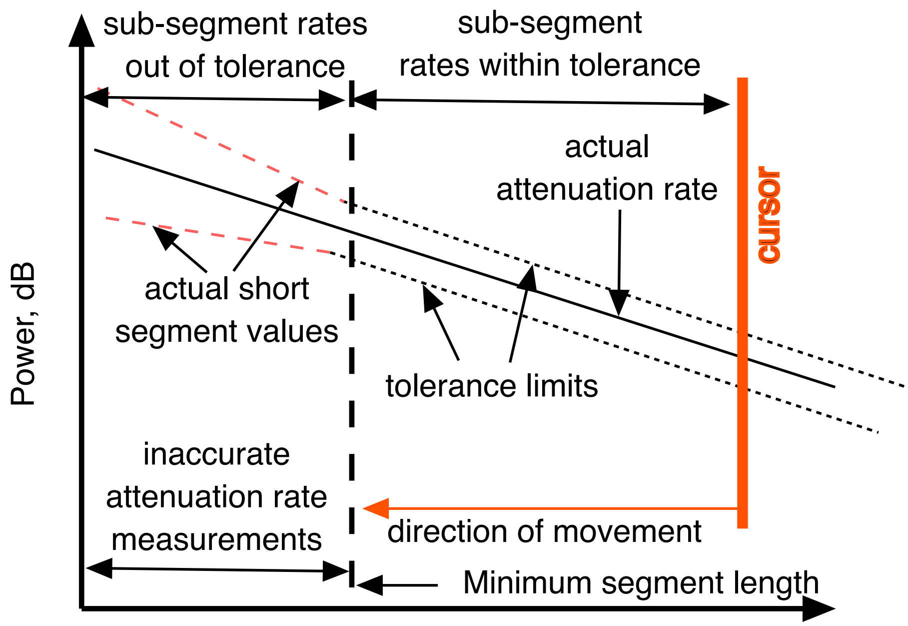

Figure 4: Details of Minimum Length Determination

We present a summary of the results in Table 2. While this table represents limited testing, 3 fibers and a total of 72 tests, these results indicate the following:

1. During multiple tests, the minimum length for accurate attenuation rate measurement varied widely, probably due to the noise inherent in OTDR traces.
2. The minimum length varies with wavelength.
3. The minimum length varied with OTDR. OTDR 3 produced accurate measurements at consistently shorter segment lengths than did OTDR 2.
4. The minimum segment lengths at 1310nm and 1550nm did not exhibit a consistent relationship; that is, minimum lengths at one wavelength are not consistently higher than or lower than, those at the second wavelength. Our interpretation is that this lack of consistency is due to the noise inherent in OTDR measurements.
5. The minimum length for accurate attenuation rate measurement depends on the accuracy with which technician wants the measurement to be. For example, if the desired accuracy is ±0.01 dB/km, the minimum length ranges from 370 - 1264m at 1310nm and from 688-1701m at 1550nm (Table 2).
6. Increasing tolerance resulted in a reduction of the minimum length and in the range of minimum lengths.

OTDR	Tolerance dB/km	1310nm min. length range	1550nm min. length range
OTDR 2	±0.01	870-1173m	593-1701
	±0.03	512-795m	327-895m
OTDR 3	±0.01	370-1374m	688-1874m
	±0.02	327-579m	520-1204m
	±0.03	211-437m	241-1030m

Table 2: Summary of Results with Three Tolerances

Conclusion

With the method presented herein, the OTDR technician can characterize his OTDR. He can use this method on a fiber length of ~2000m or greater. By moving the far-end cursor towards the near end, he determines an estimate of the minimum segment length, below which the OTDR attenuation rate will not be accurate or repeatable.

Acknowledgements

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About the Author

Eric R Pearson, President, Pearson Technologies Inc., has been active in fiber optic communications for 41 years. He has been recognized as a Master Instructor by both the Fiber Optic Association and BICSI. He is credentialed by the FOA as a Certified Fiber Optic Specialist in Testing, Connectors, Splicing, and Instruction. Pearson Technologies provides installation and design training, and technical services in lawsuits involving patents and cable damage liability and costs. When complete, Mastering The OTDR-Singlemode Subtleties will be available on Amazon

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