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INSIDE

AVoptics Training – from classroom to online

Time Sensitive Networks Application in Connected Autonomous Vehicle Systems

OTDR: Parameters to Correctly Use the Most Popular Fiber Optics Equipment

"Technology is best when it brings people together."

Matt Mullenweg

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contents

May/June 2021 · Volume 53, Issue 4

FEATURES

+ department

ON THE COVER: An optical time-domain reflectometer (OTDR) is an optoelectronic instrument used to verify the performance of new fiber optics links and detect problems with existing fiber links. An OTDR is the optical equivalent of an electronic time domain reflectometer. It injects a series of optical pulses into the fiber under test and extracts, from the same end of the fiber, light that is scattered or reflected back from points along the fiber. The scattered or reflected light that is gathered back is used to characterize the optical fiber. This is equivalent to the way that an electronic time-domain meter measures reflections caused by changes in the impedance of the cable under test. The strength of the return pulses is measured and integrated as a function of time, and plotted as a function of length of the fiber.

AVoptics Training – from classroom to online

By Dr G.M.Proudley, PhD MIET, principal research engineer, AVoptics LightWorks

AVoptics Ltd is a UK-based fibre optics company specialising in optical systems for harsh environments. Training is just one facet of their skillset alongside harness manufacture, research and unique product development. In 2017, they became the first European company to offer SAE- and ARINC-accredited training courses for Aerospace Fibre Optics in association with ETA® International.

Currently, AVoptics offers the following courses: ARINC Fibre Optics Fundamentals (AFOF), Aerospace Fibre Installer (AFI) and SAE Aerospace Fibre Optic Fabricator (SFF). This latter course has been adapted to offer a unique UK-relevant SAE/ARINC Fabricator course (SAFF) which combines training content for both the civil and military aerospace sectors.

Figure 1. Another successful class at the AVoptics training school. The Covid-19 pandemic meant that new online solutions had to be implemented in order to allow teaching to continue.

The Covid-19 pandemic hit many industries hard, and companies had to adapt to new ways of working. For specialist training, classroom face-to-face teaching (Figure 1) became impossible almost overnight as government restrictions began to bite down on almost every form of gatherings. While certain courses with a large hands-on component remain effectively on hold, certain training options can still be implemented effectively online. Here, AVoptics instructors share some of the process planning involved to formulate an online version of its Fibre Optic Fundamentals course.

"We had to work out what was possible and what wasn't, adapting and making some concessions as we went but always with the focus of maintaining a high quality and interesting learning experience," said Dr Geoff Proudley, a key trainer at AVoptics. "Teaching knowledge competencies is eminently deliverable over video conferencing platforms such as Teams and Zoom, but adding in hands-on elements makes things a little more challenging."

Proudley explains AVoptics went through a series of steps to see what was possible. Step one was to evaluate a number of platforms for video quality, stability, cost and ease of use - both in regards to considerations from teaching and student perspectives.

"It's easy to concentrate on the teaching side of the experience, Proudley said. "But equally important is to consider what the student sees."

The nature of the courses also meant that an online meeting format was essential as opposed to a simple knowledge webinar. There was also the issue of class size. A trainer needs to be able to identify and address all students. Clearly, two-way interaction is essential to give the student a feeling of inclusion and the ability to ask questions. Class size limits are around 10 for the AVoptics Fundamentals course.

"Course structure is also something we've had to consider," Proudley added. "Classroom teaching is clearly more flexible in being able to immediately monitor and gauge student reactions, concentration and engagement levels. It's more difficult online to keep an eye on everything as we teach."

AVoptics online instructors realize that students who stay fully engaged is of paramount importance. For that reason, they tend to mix the theory and practical elements throughout the day to keep things fresh. Plus, they can get feedback at regular intervals and students see they are gaining practical knowledge in chunks as well as learning the theory. Timely breaks are essential to keep the course interesting.

"I'm sure we all have had experience of fatiguing 'wall-to-wall Powerpoint' presentations," Proudley said.

Limited in online delivery is the ability to touch, feel and use hardware. In this case, it is essential that students have the use of fibre optic hardware and equipment to clean, inspect and test. AVoptics' solution is to make sample packs available to students (e.g. see Figure 2) which are sent to students prior to the beginning of the course in order to be prepared when instructors talk about the components and equipment in their online class.

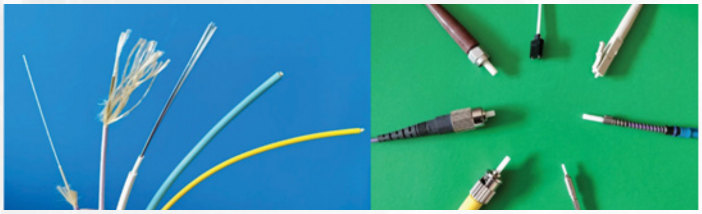


Figure 2. Online courses are augmented by physical sample packs of connectors and cables to enhance the learning experience. These are mailed to the student after UV sanitisation.

The remaining elements can be demonstrated by instructors using close-up cameras with some novel teaching tools. One such example is a novel MT microscope simulation tool developed by our AVoptics Lightworks team. This online interactive tool (see Figure 3) gives students the experience of inspecting multiple fibres in an MT ferrule and making decisions on the acceptance or rejection of the fibres' end-face quality as per current standards.

"We've also adapted some of the hands-on requirements

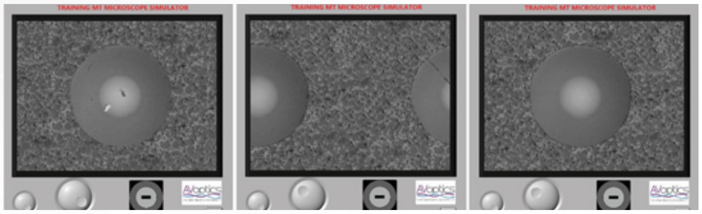


Figure 3. The MT microscope simulation tool allows online students to perform inspection of fibres in an MT ferrule and make judgements on end-face quality. Realistic focus and translation features are included.

Figure 4. AVLiteBox sanitisation unit. This device, developed by AVoptics in response to the Covid-19 pandemic, uses UVC and ozone to sanitise sample packs delivered to students taking online courses.

to make them online-friendly," Proudley said. "A neat example is getting students to use their TV remotes to see the infrared emission, which is normally invisible to the naked eye, but visible on their webcams. It's a simple way of demonstrating the visibility of different wavelengths and leads to a discussion on light source safety."

After hands-on skills assessments have been verified remotely and online course content and theory completed, there is the question of certification exams and qualifications. For this, AVoptics works with ETA and its remote test proctoring partner, ExamRoom.ai, to enable students to take the knowledge portion of the accredited certification exam remotely with online invigilation. This means they can schedule the exam after the course and take it anywhere they have camera and microphone installed on their computer. It's a practical solution for both students and trainers when classrooms are currently unavailable.

"It's a challenging but interesting time for us at AVoptics. Where some business areas have been restricted, we've had the fortunate opportunity to develop some Covid-related hardware and embrace the challenges of the pandemic by developing an online training course," said Proudley.

One such example is a decontamination box which uses UVC and ozone to eliminate Covid-19 (see Figure. 4) that has an immediate application to training. Avoptics uses the UV decontamination unit to sanitise its training packs before going out to students.

AVoptics looks forward to extending the techniques and tools to elements of other courses which could allow students to do additional courses such as SAFF in more manageable blocks, some of which are delivered online.

AVoptics detailed course information and dates:
http://www.avoptics.com/service/fibre-optic-training

Contact AVoptics at: Phone: +44 (0)1935 471606
Email: info@avoptics.com

OTDR: Parameters to Correctly Use the Most Popular Fiber Optics Equipment, Part 1

By Rodolfo Veloz, Electronics Engineer specializing in Telecommunications

The optical time domain reflectometer, known as OTDR, works as optical radar creating an image of all fiber optic events in an installed fiber optic network - filament by filament - by the effect of optical reflectometry. The image that the OTDR creates is called trace, and it contains data like fiber length, loss in fiber segments, connectors, fusion splices, mechanical splices, and loss caused by extrinsic attenuations during installation.

OTDRs are used to verify the quality of the installation or to troubleshoot problems. However, OTDR testing is an indirect test that may not be comparable to transmission system loss or attenuation and should not be used to certify the fiber optic network alone, or to determine cable loss. For this, you must always have a light source power meter (LSPM) or optical loss test set (OLTS).

According to the TIA-568 Standard, in the Fiber Optic chapter, in the annex regarding measurements, Tier 2 tests are indicated as Optional, which are with OTDR.

Tier 2 tests complement Tier 1 tests with the addition of an OTDR trace of the cabling link. The wavelength (s) used to create the OTDR trace should be the same as that used with the OLTS when measuring link loss. The OTDR trace characterizes the elements along a fiber link, including fiber segment length, attenuation uniformity and attenuation coefficient, connector location, insertion loss, splice location, splice loss, and other power loss events, such as a sharp bend that may have occurred during cable installation. *OTDR trace does not replace the need for OLTS testing, but is used for supplemental evaluation of the cabling link.*

An OTDR provides essential information on fiber systems such as splice losses, connector losses, fiber imperfections, and losses due to installation (extrinsic attenuation), among others. It is, therefore, essential that the measured data is accurate and of high quality. The OTDR measures backscattered power as a function of time, which is converted to a distance scale through knowledge of the fiber's index of refraction. The main performance parameters are the precision of the power and length measurements. To achieve this, you must know:

- Refractive Index
- Dynamic Range
- Pulse Width
  - > Dynamic Range
  - > Resolution
- Average Time

REFRACTIVE INDEX

The greater uncertainty in determining the position of an event along the fiber optic network may be due to the incorrect setting of the fiber's index of refraction fiber refraction, *a value used to convert time into distance*. The refractive index, which is correctly the IOR or Group Index (effective group index of refraction), must be entered by the OTDR operator to match the type of fiber being measured. Normally, this data is supplied by the manufacturer of the fiber optic filament. It should be noted

Continued on page 6

Continued from page 5

that the length of the fiber optic cable strands within a cable can be greater than the length of the cable itself, as the fiber can take a spiral path within the cable. Consequently, it is sometimes more appropriate to use an effective group index or effective modal index to measure cable length. Remember that the refractive

	850 [nm]	1300 [nm]	1310 [nm]	1550 [nm]
Singlemode	-	-	1,467	1,468
Multimode 50/125	1,490	1,486	-	-
Multimode 62,5/125	1,496	1,491	-	-

index depends on the operating wavelength. Therefore, we will have different values for different wavelengths. For example, we see in this table a variation for each wavelength window.

DYNAMIC RANGE

Dynamic range determines the maximum observable length of the fiber and therefore the capacity of the OTDR to analyze some connection. This specification determines the total optical loss that the OTDR can analyze; that is, the total length of the fiber link that the unit can measure.

The higher the dynamic range, the greater the distance the OTDR can analyze.

Wavelenght	1310 [nm]	1550 [nm]	1310 [nm]	1550 [nm]	1310 [nm]	1550 [nm]	1310 [nm]	1550 [nm]
Dynamic Range	35 [dB]		40 [dB]		45 [dB]		50 [dB]	
OTDR maximum measurement range	80 [km]	125 [km]	95 [km]	150 [km]	110 [km]	180 [km]	125 [km]	220 [km]

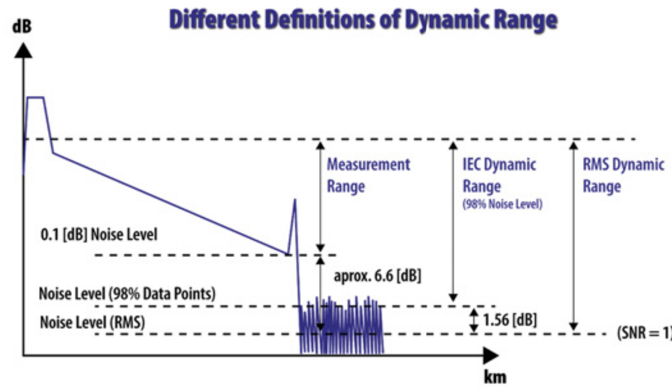
Insufficient dynamic range results in the inability to measure the length of the entire link, lack of precision of link loss, connector measurement losses far end and its attenuation.

A good empirical method is to select an OTDR whose dynamic range is 5 [dB] greater than the maximum loss you will find.

The dynamic range is an important characteristic as it determines how far one can measure OTDR. The specified dynamic range by OTDR providers achieved with the longest pulse width is expressed in decibels [dB]. Distance range or display range sometimes specified is usually misleading, since it represents the maximum distance it can show the OTDR, not what can be measured. There are several definitions commonly used for dynamic range controls. The following is a list of them:

- •mRMS Dynamic Range
- IEC Dynamic Range
- Loss Measurement Range
- Fresnel Dynamic Range

RMS (Root Mean Square) Dynamic Range: The RMS noise level is the dynamic range of the OTDR corresponding to a Signal



to Noise Ratio (SNR) of value 1. This definition is perhaps the most widely used.

IEC (International Electrotechnical Commission) Dynamic Range: This signal refers to the maximum noise level instead of the RMS level and provides a dynamic range that is approximately 1.56 [dB] less for RMS definition.

Loss Measurement Range: It is defined by the amount of attenuation that can be placed before a given event, so the event can still be accurately observed within acceptable limits. This dynamic range is described in the Telcordia GR-196 specification, and there are four types of events listed in the specification:

1. Measurement of a splice loss of 0.5 [dB]
2. Fiber attenuation coefficient measurement
3. Detection of a non-reflective fiber end
4. Detection of one end of reflective fiber

Fresnel Dynamic Range: It can be observed before the Fresnel reflection from a fiber end can no longer be visualized. A Fresnel reflection will emerge from the noise long after the dynamic range of the Rayleigh scattering has been exceeded. The height of the Fresnel reflection peak will depend on the actual level of the Rayleigh scattering signal that is present at that point, and this, in turn, will depend on the optical pulse width. Likewise, the actual difference between Fresnel dynamic range and the other definitions of dynamic range will depend on OTDR operation and conditions, but in general, Fresnel dynamic range will be greater than the other definitions.

PULSE WIDTH

The relationship between dynamic range and a dead zone is directly proportional. To test long fibers, a larger dynamic range is needed, so a wide pulse of light is required.

As the dynamic range increases, the pulse width and the dead zone increases. That is, the OTDR will not detect nearby events.

For short distances, short pulse widths should be used to reduce dead zones. The pulse width is specified in nanoseconds (ns) or microseconds (µs).

The OTDR works by emitting repeated pulses of light, each pulse being equal in duration. Choosing the correct pulse width is essential to obtain the best measurement results. The act of choosing a wrong pulse for a certain distance can cause one to lose sight of events on the trace. A short pulse, for example, gives a higher resolution. However, when performing a dynamic range measurement (longer length) with a short pulse, we run the risk of having a lot of noise in the measurement. If you want to make a long distance measurement, the long pulse is adequate, but it must be kept in mind that when averaging the measurements, more time will pass and therefore the resolution will be lower.

Depending on the measurement you want to make, whether it is dynamic range or resolution, we will use a long or a short pulse, respectively.

- Dynamic Range “Long Distance” - Long Pulse
- Resolution “Short Distance” - Short Pulse

If you want to measure the end of the fiber only (distance), no matter what happens along the way, you use a long pulse.

If you want to see what happens in the splice of a fiber between

	500 [m]	2 [km]	5 [km]	10 [km]	20 [km]	40 [km]	80 [km]	120 [km]	160 [km]
3 [ns]	✓								
5 [ns]	✓	✓							
10 [ns]	✓	✓	✓						
20 [ns]	✓	✓	✓	✓					
50 [ns]		✓	✓	✓	✓				
100 [ns]			✓	✓	✓				
200 [ns]					✓	✓			
500 [ns]						✓	✓		
1 [µs]						✓	✓	✓	
2 [µs]							✓	✓	✓
5 [µs]							✓	✓	✓
10 [µs]								✓	✓

a server and a router, you must use a short pulse, to see exact details at short distances.

Below is a reference to select in the OTDR the Dynamic Range measured in [m] or [km] and the pulse width, measured in [ns]:

The definition or resolution of the traces of an OTDR depends largely on the pulse width that is chosen. However, the maximum definition that the OTDR can give us does not exceed the number of limit samples that are defined by each manufacturer. In other words, no matter how short we choose the pulse, the number of samples will be the same.

AVERAGE TIME

The average time in the OTDR, measured in [s], will allow a determined time range to carry out the measurement. This parameter has a direct impact on the SNR (signal to noise) ratio and, therefore, the longer the averaging time, the higher the SNR, *but the dynamic range is also increased.* Therefore, *when measurements are made over long distances, it is advisable to enter into compatibility with the average time, and be clear about this direct proportionality of average time and dynamic range, maximizing the average time for measurement, which increases the dynamic range and allows better analysis of events over long distances.*

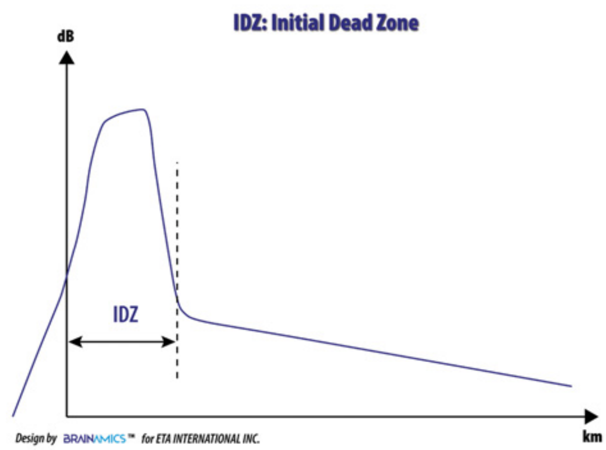
DEAD ZONE

Connectors often have high insertion loss and high reflectance. As a result, testing with an OTDR becomes difficult even at the highest spatial resolution. Why is this measurement difficult? The OTDR photodiode, upon receiving a reflectometry pulse, requires time to recover from saturation. This saturation of the photodiode means that a part of the length of the fiber is not completely characterized given its recovery time. This part of the length of the optical fiber is known as the dead zone. All OTDR providers provide a dead zone specification, accordingly, it must be one of the main parameters to use, both to select quality and to define the launch and reception coils to be used.

Dead zones originate from reflection events along the link, such as connectors or mechanical splices. These affect the OTDR's ability to accurately measure attenuation in short-distance links and to differentiate events in nearby spaces, such as connectors on patch panels. When the strong optical reflection of this event reaches the OTDR, its detection circuit saturates for a specific period of time until it recovers and the backscatter can be accurately measured once again. As a result of this saturation, there is a part of the fiber link after the reflection event that the OTDR cannot “see”, and this is from where the term "dead zone" comes. When specifying OTDR performance, dead zone analysis is very important to ensure that the entire link is measured.

We will find three classic definitions for the Dead Zone and will review them below:

- Initial Dead Zone (IDZ)
- Attenuation Dead Zone (ADZ)
- Event Dead Zone (EDZ)



Initial Dead Zone: The initial dead zone (IDZ) is the length of the fiber that cannot be measured after the connector is attached to the OTDR. *This is largely a historical specification.* This length refers to the time it took for the OTDR to go from transmitting the outgoing pulse to receiving the incoming backscatter and reflection. For older OTDRs, the IDZ was much larger than the ADZ and EDZ.

OTDRs prior to 1990 with an ADZ of 10 meters might have an IDZ of 150 meters. Thanks to advances in electronics and optics, modern OTDRs have an IDZ that is essentially the same as ADZ, so that today we only find ADZ and EDZ specifications on datasheets.