Development of High-performance, Multifunctional Compact OTDR

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Optical time domain reflectometers (OTDR) are indispensable to measure the quality of optical fiber lines. As fiber to the home (FTTH) and fiber to the building (FTTB) have rapidly spread worldwide in recent years, the requirements for OTDR have increased and diversified accordingly. Our AQ1200 MFT-OTDR series, a high-performance, multifunctional compact OTDR, provides solutions to those requirements. In this paper, we introduce improved trace quality especially for the FTTH PON testing, applications for improving work-efficiency, and design technologies of compact optical modules.

INTRODUCTION

As greater amounts of data are being transmitted at ever higher speeds, optical communication systems have been widely installed worldwide. In recent years, to deal with the growth of portable communication terminals such as smart phones and cloud computing services, fiber-optic access networks including FTTB and FTTH, as well as backbone networks, are being increasingly introduced not only in developed countries but also in emerging countries. Accordingly, the needs for testing fiber-optic networks are becoming diversified. For example, for FTTH and other access networks, OTDR with advanced event detection functions is useful for precisely identifying the locations of subscribers and failures in a narrow or medium distance. For maintenance work, visible light sources (VLS) and optical power meter functions are needed. A compact design is also desirable.

To meet these needs, the AQ1200 MFT-OTDR series shown in Figure 1 offers a wide variety of applications and high measurement performance in a compact body.

Figure 1 External view of AQ1200

AQ1200 SYSTEM CONFIGURATION

Figure 2 shows the system configuration of the AQ1200.

In addition to the main OTDR functions, the AQ1200 can perform multiple functions as a light measuring instrument such as the optical power meter for measuring the amount of light transmitted through optical fibers and the visible light source for visually identifying locations of failure. The AQ1200 also has USB and LAN interfaces. These features satisfy customer needs.

This section explains the OTDR’s measurement principles. First, the pulse generator generates pulse signals for testing, which activate the laser diode (LD) device to emit a pulse light for testing. The pulse light enters the optical fiber being tested via the directional coupler. As the pulse light travels through the fiber, Rayleigh scattering occurs and part of it travels in the opposite direction of the pulse light, back to the OTDR. This phenomenon is called backscattering. The light reflected at failure points or the open end of the optical fiber also travels back to the OTDR. They enter the directional

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coupler and go through a different path from that for the pulse light to the avalanche photodiode (APD) device, where the light is transformed into an electrical signal. After being adjusted to an appropriate level, the electrical analog signal is converted into a digital signal by using the clock signal synchronized with the LD activating signals. The intensity of sampled signals of the backscattered light and reflected light differs depending on events occurring in the optical fiber. By laying out the intensity along a time axis, a waveform as shown in Figure 3 can be obtained. The horizontal axis is the distance, converted from light travelling time, and the vertical axis is the intensity level of the backscattered and reflected light. The location of connectors and the amount of loss there as well as the loss distribution in the optical fiber can be identified.

![Figure 3 Example of a waveform measured by OTDR](image)

**Figure 3** Example of a waveform measured by OTDR

**TECHNOLOGY FOR ACHIEVING A COMPACT AND HIGHLY RELIABLE OPTICAL MODULE**

As explained in the previous section, the OTDR needs optical devices for transmitting and receiving light for testing. Generally, a LD device is used for the transmitting part and an APD device for the receiving part, and a directional coupler is used for directing those lights. They are the most important devices for the OTDR. A fiber optic coupler was conventionally used for this function. The characteristics of this optical system are described below with reference to Figure 4.

This system is configured by fusing optical components such as a LD device, an APD device and a fiber optic coupler with optical fibers. It has several problems.

![Figure 4 An optical system using a fiber optic coupler](image)

**Figure 4** An optical system using a fiber optic coupler

A fused type is generally used for the fiber optic coupler, so the OTDR needs to accommodate a rod for fusing the optical fibers and their extra length, which makes compactness difficult to achieve. In addition, to offer several models that can feature wavelength selection or multiple wavelengths (two or three wavelengths) in order to meet diversified testing needs, signals of multiple LD devices with different wavelengths need to be multiplexed. So the number of couplers and fusing work increases, causing lower reliability. Furthermore, numerous complicated tasks cause time and cost increases when manufacturing.

The bi-directional (BiDi) mechanism overcomes these problems. This system uses a half mirror as a directional coupler and contains the LD and APD devices in a single body. The special connection reduces the number of parts, size of the body, and complex work such as the fusing of fiber optics. The half mirror also reduces connection loss compared to the system that uses a fiber optic coupler, and this improves performance.

The BiDi mechanism has some drawbacks, too. Stray light from optical devices and polarization dependent loss (PDL) may adversely affect the waveform quality of the OTDR. However, the optimal component layout ensures performance comparable to fiber optic couplers.

![Figure 5 External view of the OTDR optic module for two wavelengths](image)

**Figure 5** External view of the OTDR optic module for two wavelengths

**MEASUREMENT OF PON SYSTEM**

In recent years, communication service providers have been using a passive optical network (PON) system to expand access-type fiber-optic networking to offer high-quality audio, video, and data services. A PON system consists of optical line terminals (OLTs; V-OLT for Video data and GE-OLT for Gigabit Ethernet) for processing signals at a central office (CO), optical network units (ONUs; V-ONU for Video data and GE-ONU for Gigabit Ethernet) or optical network terminals (ONTs) for processing signals at subscriber sites, a wavelength division multiplexing (WDM) transmission system for multiplexing and transmitting/receiving signals between CO and subscribers, and splitters for splitting multiplexed signals.
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Figure 6 Overview of a typical PON system

Figure 7 shows a waveform of the communication line of a PON system measured by the OTDR. The OTDR measurements offer information such as the amount of return loss and line loss at connecters, splitters, ONT connection points, and the far ends of the lines. Precise measurement of the lines of a PON system depends on the dead zone characteristics, which determines the performance of OTDR. When measuring a line of a PON system including splitters and ONUs, the dead zone must be narrow enough to precisely obtain the loss at the splitters and conditions of connection up to the ONUs.

Figure 7 Waveform measured by OTDR

In general, a narrower dead zone can be achieved by narrowing the pulse widths. At the same time, however, the received signals become weaker and the S/N ratio of measured waveforms decreases; therefore, the quality of waveforms deteriorates. Therefore, to improve the dead zone while maintaining the quality of waveforms, both conflicting factors must be balanced. To achieve this, the AQ1200 has an enhanced photo-receiver section and an improved quality of waveforms even after high reflection and large loss. This enables the AQ1200 to measure losses at events and splitters that conventionally could not be detected.

Figures 8 to 10 show the measurement results of a PON system with 32 branches.

Figure 8 Measuring system for evaluating a PON system

Figure 8 describes the system configuration to be measured. In it a 1-km optical fiber, a 4-port splitter, 1-km and 2-km fibers and an 8-port splitter are serially connected. To its output ports, fibers from 90-m to 1-km are connected respectively.

Figure 9 shows the overall measurement results of these lines by the OTDR. From left, the waveforms describe the losses along the 1-km fiber and at the 4-port splitter, loss along the 1-km and 2-km fibers and the connection loss between them, loss at the 8-port splitter, and the reflections at the far end of No.1 to No.8 fibers.

Figure 10 shows a magnified view between the 8-port splitter and the far end of No. 6 fiber. The red line shows the waveform before the improvement and the black one shows after the improvement. The red line does not accurately indicate the connection between 40-m and 50-m fibers extending from the No.1 output port. This is because the dead zone is not narrow enough to depict the connection. On the other hand, the black line (after the improvement) clearly shows the connection, thanks to the excellent dead zone characteristic.

When the far ends of fibers are close to each other, as in the case of No.1 and No.2, No.3 and No.4, and No.5 and No.6, the red line cannot clearly distinguish their reflection. This is because the dead zone characteristic at events is insufficient. In contrast, the black line clearly identifies reflection events, thus indicating the accurate location of each far end. This implies that it is important to satisfy both a wide dynamic range and narrow dead zone for measuring PON systems.

Figure 9 Measurement results (overall)

Note 1) Discriminable minimum distance. The OTDR may not be able to obtain correct information in zones shorter than this distance.
SOFTWARE FOR IMPROVING WORK EFFICIENCY

The installation of optical fibers involves complicated work, so contractors need an easy-to-use graphical user interface with which even inexperienced workers can operate measuring instruments.

Simple full-auto measurement function

As shown in Figure 11, this function automatically performs a series of processes from measurement, analysis to saving the result with the setting of wavelength only. There is no need to determine other conditions, such as distance range and pulse width.

Multi-fiber measurement function

When installing optical fibers, more than 100 fibers are fused or connected per day. Thus, efficiency is required in the following tasks.

1) Confirming the progress of tasks
2) Defining file names when saving results
3) Viewing waveforms

To improve efficiency in these tasks, we have developed a multi-fiber measurement function.

As shown in Figure 12, the progress of tasks for each fiber is displayed in the table. When a fiber is measured, its number is marked with “√”. When the number of a measured fiber is highlighted, the OTDR waveform of the measurement result is displayed. There is no need to read the file.

CONCLUSION

We developed the AQ1200 MFT OTDR series of multifunctional compact OTDRs to satisfy new needs for testing fiber-optic access system networks such as FTTB and FTTH. The AQ1200, with its compact body, offers various solutions for new needs.

We expect the AQ1200 to help fiber-optic communication networks expand not only in developed countries but also in emerging countries.