

White Paper

Optical Installation and Maintenance



Maintenance of Access Network Optical Fibers

Troubleshooting PON Drop Cable Faults using Short-Wavelength OTDR Method

1. Introduction

The huge growth in the number of subscribers with FTTH installations requires different maintenance methods than used previously. This article explains maintenance of the “last one mile” and explains some concrete measurement solutions.

2. Current Status of Access Networks

Always-on Internet connections coupled with widespread adoption of applications such as IPTV, VoIP, etc., is driving further increases in access network transmission bandwidth with accelerating transition from conventional metallic cable to FTTH. Figure 1 shows the change in broadband access network subscribers in Japan. March 2006 was the turning point when the number of the DSL subscribers started decreasing, while on the other hand, the number of FTTH's is steadily increasing. According to NTT, the conversion of core networks to optical technology is already completed, and optical fiber networks can cover more than 85% of subscribers. Currently, work is progressing nationwide to run optical fiber over the so-called “last mile” to subscribers’ households with the aim of reaching 30 million FTTH subscribers by 2010.

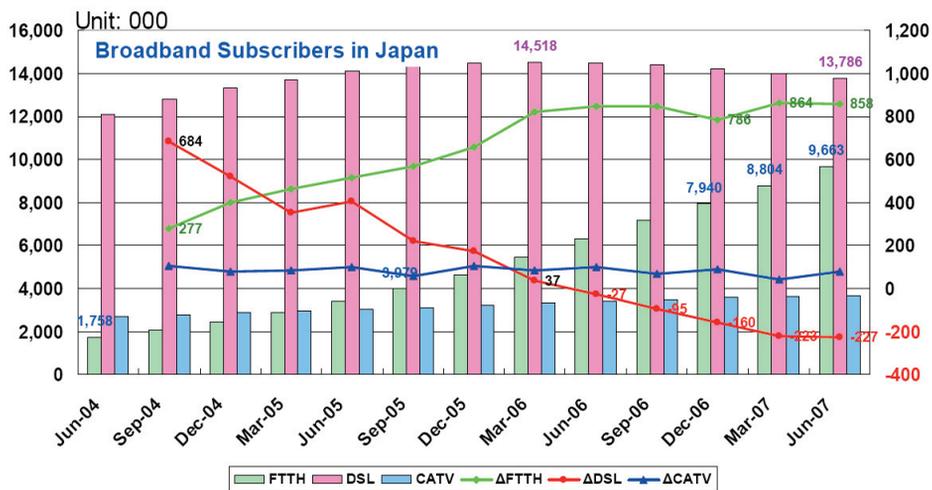


Figure 1: Trend in Broadband Access Subscribers

A Passive Optical Network (PON) system is the most efficient method for providing broadband transmissions over an access network. In this method, an Optical Line Terminal (OLT) in the Central Office (CO) and an Optical Network Unit (ONU) in the subscriber’s house provide cost-effective FTTH by allowing use of optical couplers to split 1 fiber into N connections. An example of the system structure is shown in Figure 2.

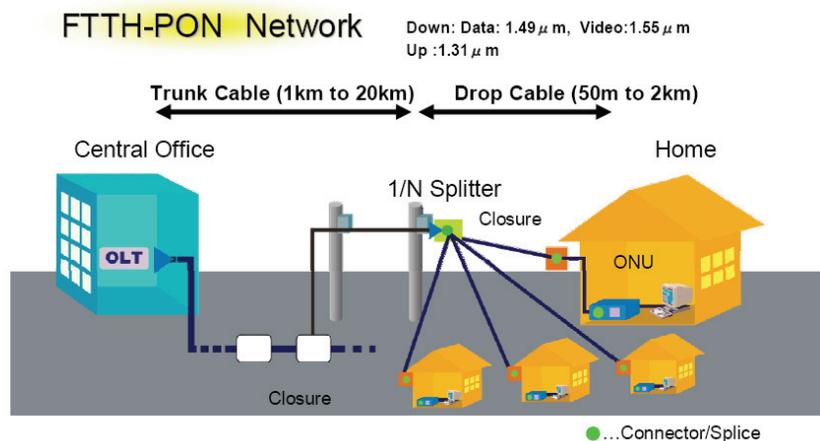


Figure 2: PON System Structure

3. Fiber Construction Targeting Start of FTTH Services

Construction of the trunk cable shown in the Figure 2 has been completed to cover 85% of households currently. All that remains to do is to run an optical fiber from the splitter (coupler) in the closure to the subscriber's household when service is requested, creating a direct FTTH connection between the Central Office and the subscriber's household using optical fiber. The optical fiber running between this closure and the subscriber's household is called the drop cable or drop optical fiber and can be up to 1.6 km long.

In metropolitan households, the drop cable is often less than 500 m long. Installation of the drop cable first requires confirmation of the optical level at the subscriber's household followed by throughput measurement at the ONU.

4. Various Drop Cable Faults

The optical fibers are run from the underground closure up the utility pole, strung from an aerial wire, split by the coupler, and finally terminate in each ONU in the subscribers' households. Relatively more faults (fiber breaks and large loss) occur in this section of fiber between the coupler and the ONU than in the trunk fiber. The three main causes of these faults are listed below:

- (1) Natural disasters - Since the fiber is strung from utility poles, it is subject to repeated stress from typhoons, heavy rain, etc., as well as aging changes, which cause breaks and loss.
- (2) Animal damage by birds, insects, etc. - Attacks by animals, like squirrels, rats, crows, etc., cause damage and fiber breaks. In west Japan, there have been many reports of damage caused by cicadas laying eggs in cables.

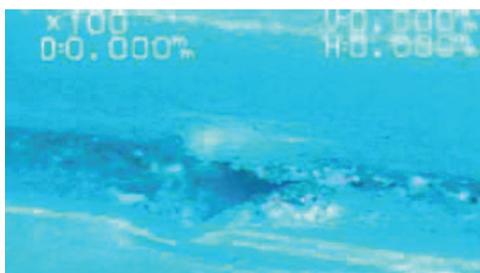


Figure 3: issue of maintenance of PON systems in Japan - types of insect damage

This data is quoted from "Techniques for FTTH" Produced by Mr. Koji Arakawa with NTT Advance Technology Ltd.

- (3) Excessive fiber bending in subscriber household - Sometimes, people rearranging their furniture or moving the ONU can bend the fiber excessively, causing a break or high loss.

The most important issue for service engineers is how to quickly and efficiently troubleshoot drop cable faults caused by these types of problems.

5. Drop Cable Maintenance

When a fault occurs in a subscriber's FTTH service, if other subscribers sharing the OLT are not experiencing the same fault, the problem is either in the drop cable between the coupler and the ONU, or in the subscriber's home network including the ONU. In most cases of home network faults, the problem is resolved by toggling the ONU, router and terminal power OFF/ON to restart the session.

This section explains maintenance of the drop cable from the splitter to the ONU.

(1) Locating Fault

When the ONU is not receiving an optical signal, the optical signal level is checked with a power meter after disconnecting the optical fiber from the ONU.

(Case 1) - When the optical signal level is confirmed to be within specification by the optical power meter, the problem is either in the ONU receiver or at the connection point between the ONU and fiber. The operation is rechecked after cleaning the connector and if this does not solve the problem, the ONU is swapped out and resumption of normal operation checked again.

(Case 2) - When the optical signal level is not confirmed as being within specification by the optical power meter or when the optical level is lower than the specification, there is a high chance that there is either a break or damage somewhere in the drop cable.

This requires locating the fault point and either repairing it by splicing the fiber or running a new drop cable.

(2) Identifying Break in Drop Cable

Fiber faults are located using an Optical Time Domain Reflect Meter (OTDR). However, testing using an OTDR requires inputting a strong optical pulse into the fiber under test and measurement requires extreme care so as not to disrupt other in-service signals.

Conventionally, when a break occurs in a trunk optical fiber, it is not necessary to consider the impact of the pulse test on the service because the fiber is out of service. However, maintenance of a PON drop cable requires care because the rest of the network other than the faulty drop cable is still in-service. If a test is run in the in-service condition using an OTDR at the subscriber's side using the same procedure as used for trunk lines, the in-service optical signals and the OTDR test optical pulse signals will interfere with each other on the line and services may stop.

To prevent this interference, it is necessary to isolate the drop cable under test from the rest of the network so that the test pulses from the OTDR do not have any effect on the OLT or the ONUs of other subscribers. When the drop cable and splitter (coupler) are connected using a connector, they can be disconnected, but this is not easy because the connections are usually high up utility poles and wires. When this connection is made by fiber splice, the disconnection work is even more difficult. There is a technique for isolating the drop cable by bending the fiber but it is not easy and requires a high degree of skill on the part of the service engineer. In addition there is also a serious risk of causing more damage by bending the fiber.

The solution to these problems is to use a short-wavelength OTDR with test pulses at a wavelength of 780 nm. PON systems use UP signals with a wavelength of 1310 nm and DOWN signals with wavelengths of 1490 and 1550 nm, and the receivers (O/E converters) in the OLT and ONU naturally use these long wavelengths. Figure 4 shows the wavelength dependence of the photodiode sensitivity (quantum effect) for these long-wavelength-band receivers.

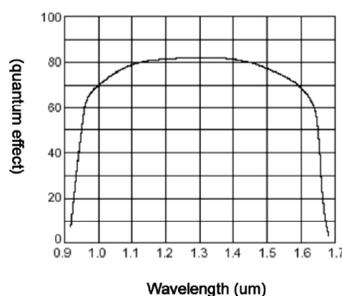


Figure 4 – the wavelength dependence of the photodiode sensitivity

As we can see from this graph, optical receivers using photodiodes with these types of characteristics have absolutely no sensitivity to light at 780 nm. As a result, testing at the subscriber side with an OTDR using optical signals at 780 nm has no effect at all on the in-service conditions and allows the service engineer locate the fault and recover the service quickly and easily.

Figure 5 shows a drop cable (2.2 km) measurement example using a 780-nm OTDR. Since the dynamic range at 780 nm is 8 dB, the 2.2-km fiber end can be observed with sufficient S/N ratio. With this performance, faults in a 2-km or shorter drop cable can be pinpointed with excellent accuracy.

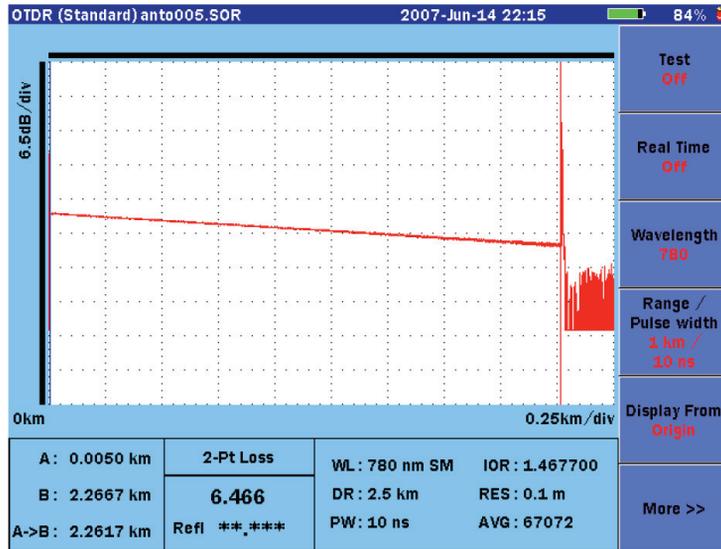


Figure 5. Measurement Example using 780-nm OTDR

(3) Loss Measurement at Drop Cable Connectors

When there is a problem at the ONU–fiber connector, sometimes the optical signal loss becomes very large and service stops. At OTDR testing, when the loss at the connector connected to the OTDR is large, it can be difficult to measure the loss quantitatively. As a result, loss measurement for this connector requires inserting a dummy fiber that is sufficiently longer than the OTDR attenuation dead zone (backscatter dead zone). Since the dead zone characteristics depend on the equipment, it is better if this dummy fiber is built into the measuring instrument. Figure 6 shows an example of connector loss measurement using a 780-nm OTDR with built-in dummy fiber.

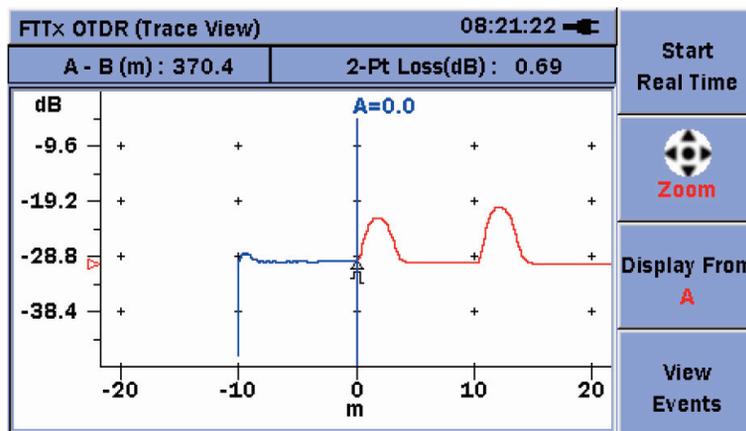


Figure 6. Example of ONU Connector Loss Measurement

The blue part is the trace of the dummy fiber built-into the OTDR; the red part is the trace of the fiber under test. A = 0.0 at the connector indicates that it has no measurable loss. (Note) Attenuation Dead Zone

The OTDR receiver can be saturated by large reflection from connection points, such as connectors. The attenuation dead zone is the time from when the receiver recovers from this saturation condition until the fiber loss can be measured with good accuracy converted to distance. It can also be called the backscatter dead zone, meaning the distance until the reflection due to backscattering can be measured.

(4) Locating LAN Fault

To locate LAN faults caused by excessive bending of the fiber, it is necessary to use an OTDR with an extremely short dead zone. Measuring the loss of the connector at the ONU requires insertion of a dummy fiber as previously described, but since there is always reflection at this location, there is a section of fiber immediately after this connec-

tion that cannot be measured. This is known as the OTDR “event dead zone” and is a basic performance parameter for OTDRs; it is very dependent on the pulse width and receiver performance. Figure 7 shows an example of measurement using a 780-nm OTDR with an event dead zone of less than 1 m.

Splice connections immediately after the connector to the ONU can be clearly detected.

There is a method of searching for indoor faults by eye using a visible laser light source without using an OTDR. When a visible laser light is input to a drop cable, the fault point where the light is leaking can be seen by eye. Using a flashing red laser light increases the fault visibility further.

(5) Locating Macrobending Faults

Although the 780-nm OTDR has the advantages of supporting in-service fault location, it has the disadvantage of not being able to easily detect macrobend faults due to the small bending loss. The fiber bending loss depends directly on the wavelength, becoming larger at longer wavelengths. Although a 1310-nm signal can be transmitted without macrobending loss problems, a 1550-nm signal cannot. Detection of macrobending is best performed using an OTDR with a 1650-nm optical signal but as previously described, it is necessary to take precautions against impacting in-service signals. In addition, recently, so-called R15 fiber with strong bending tolerance has been developed for use as drop cables, reducing the necessity for macrobending detection. The characteristics of this R15 fiber do not change even at a bend radius of 15 mm, supporting lossless fiber installations. Figure 8 shows the loss versus wavelength results for various bend radii.

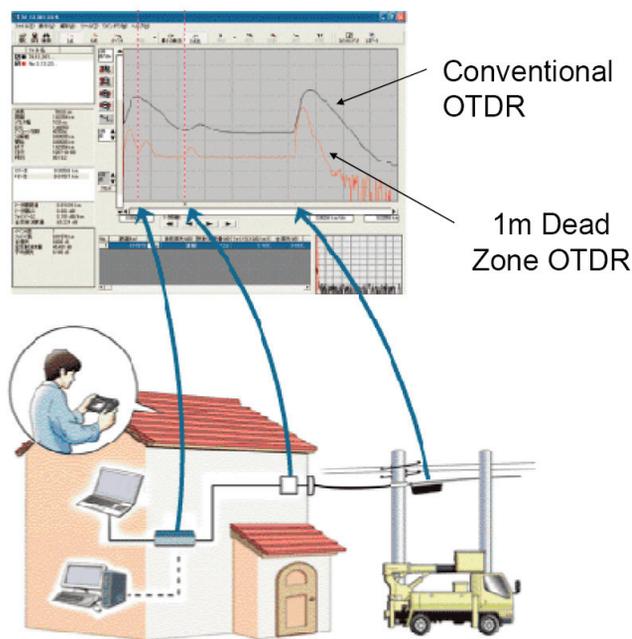


Figure 7. Example of Measurement using 780-nm OTDR with Max. Event Dead Zone of 1 m

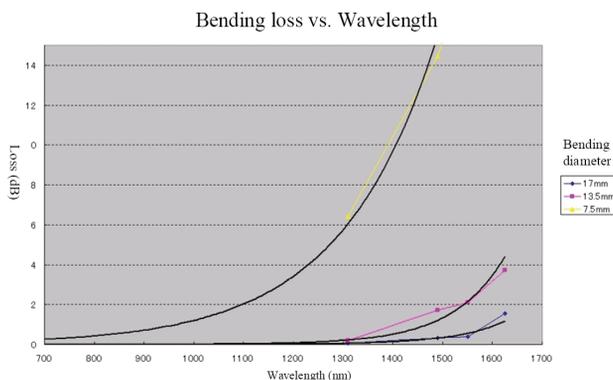
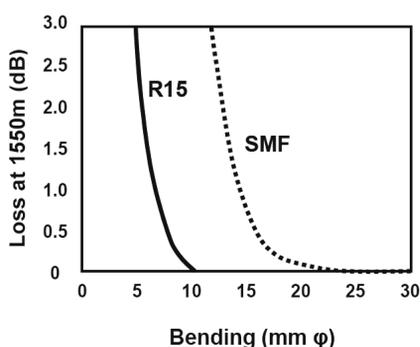


Figure 8. Relationship between Fiber Radius of Curvature and Loss

6. Summary

Access network maintenance is becoming increasingly important with the rapid spread of broadband services. For carriers to win in this extremely price competitive market, it is essential for them to cut access network maintenance costs and time. The 780-nm OTDR is the ideal solution for maintaining in-service PON systems because it enables less-experienced service engineers to solve problems easily and quickly and is expected to play an increasingly important role in future markets.

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