

# Development of New Field-Installable Connectors for FTTH

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## ABSTRACT

Fiber-to-the-home (FTTH) services have achieved wide penetration in recent years, and seem likely to grow even faster in the future. Thus, in the process of servicing subscribers' homes with fiber to provide optical internet access, there is a growing need for shorter work times and lowering requirement for expertise in installation personnel. Specifically in the splicing process--whether mechanical or fusion--it is necessary to handle the excess lengths of fiber that remain after splicing and this has been a time-consuming process. Another problem arises from the need, at the time of service changeover, to cut fibers and then repeat the installation process. In an effort to solve these problems we have developed optical connectors that can be joined directly to drop cables and indoor cables at any point from the aerial closure to inside the subscriber's premises, in several types according to the location in which they are used.

## 1. INTRODUCTION

In recent years Japan has seen a dramatic spread of broadband service. The number of FTTH subscribers has already exceeded 7 million, and is increasing at a rate of 300,000 households per month. This rate of increase is expected to further accelerate, creating a growing need for shorter work times and a lower level of expertise in installation personnel.

Figure 1 shows an example of a conventional network for providing subscribers' homes with access to optical services. The optical fibers laid as a cable from the local station are separated into single optical fibers at an aerial closure near the subscriber's premises, and connected to a drop cable to reach under the eaves of the subscriber's premises. Then in an under-eaves cabinet the drop cable is connected to an indoor cable, which leads into the rooms in the subscriber's premises and is joined to an optical network unit (ONU). In the conventional optical wiring configuration for subscribers' premises, the joining of optical fibers at these connection points (aerial closure, cabinet, etc.) has been accomplished by mechanical or fusion splicing. This has meant that when the splicing is done, excess length of fiber is required and care is needed to make sure that bending, tensile or other strain is not applied, so that the work needed a high level of expertise and was time-consuming.

There was also the problem that during service changeover or interruption, the fibers had to be cut at the connection points and the installation work repeated.

Accordingly, with a view to improving maintenance by

introducing the use of connectors at aerial closures and cabinets and achieving a new optical access configuration (Figure 2), we have developed field-installable optical connectors and can report that their various characteristics have been confirmed.

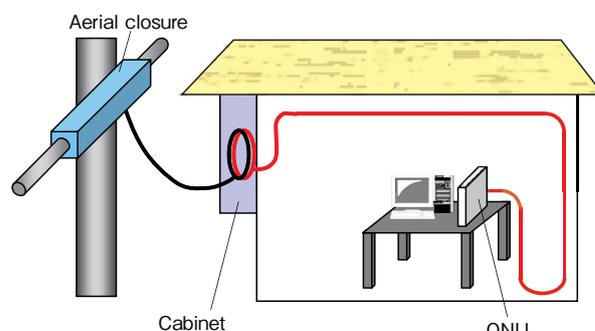


Figure 1 Layout of conventional access network.

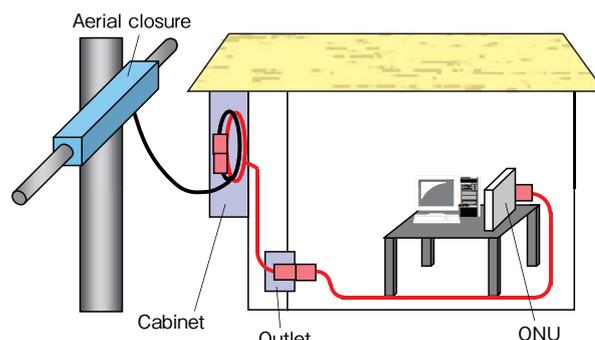


Figure 2 Layout of new access network.

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## 2. TYPES OF FIELD-INSTALLABLE CONNECTORS FOR FTTH

### 2.1 FA Connector

This was developed for cable connection at under-eaves cabinets in subscribers' premises and for outlets of newly built housing. It has a unique connection interface comprising a plug and a socket, and the connector can be directly joined to drop cables or indoor cables (i.e., is cable-holding). Specifically, the socket has a unique curved housing structure, and can accommodate JIS C 8435 compliant switchboxes and shallow SM36, and can be connected directly to SC connectors without interposing an adapter, thereby achieving optical connection at the outlet.

### 2.2 Field-Installable Connector for Aerial Closure

This is field-installable connector in which the cross-sectional area is reduced to achieve a high-density arrangement in aerial closures. It comprises a unique plug-socket interface. With respect to the connection configuration at the aerial closure, the plugs are of two types: one "for the drop cable" that can be connected to a drop cable and one "for the fiber" that holds the optical fiber; there is only one type of socket, "for the fiber".

### 2.3 Field-Installable Cable-Holding SC Connector

Applying the cable-holding technique of FA connectors, we developed a field-installable cable-holding SC connector that can be used around subscriber station equipment. It can be directly connected to drop cables or indoor cables and has a connection interface equivalent



Figure 3 Appearance of FA connector.

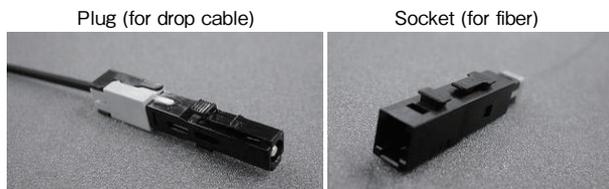


Figure 4 Appearance of field-installable connector for aerial closure .



Figure 5 Appearance of field-installable cable-holding SC connector.

to that of conventional SC connectors.

## 3. STRUCTURE OF FIELD-INSTALLABLE CABLE-HOLDING CONNECTOR

The basic structure of a field-installable cable-holding connector is describes as follows: First, by means of the housing the connection interface is formed and the components and fiber inside are protected. Inside the housing are accommodated a ferrule-combined mechanical splice and a cable-holding block, and, depending on the type of connector, it may incorporate a spring to press the ferrule toward the direction of the connection and a split sleeve to achieve axial alignment of the ferrule. The cable-holding block is a plastic part having a slit with tab-shaped protrusions, with the function of holding the cable sheath and fastening the cable to the connector. From the leading end of the cable the optical fiber is exposed, and is joined to the connector by a ferrule-combined mechanical splice.

As Figure 7 shows, the ferrule-combined mechanical splice consists of a V-groove base integrated with the ferrule and lids for pressing on the fiber. These are compressed by clamp springs. The V-groove base has a groove to carry an optical fiber, and by means of the two lids holds the bare fiber and the coated part. Within the ferrule the pre-installed fiber is fastened by bonding, and the leading end is polished together with the ferrule, the other end is cleaved, and the fiber is set on the V-groove.

Figure 8 shows the mechanism of a mechanical splice. There is a slit formed between the V-groove base and the side of the fiber-pressing lids, and by inserting a wedge at that point it is possible to make a slight opening between the meeting surfaces of the base and the lids and introduce the optical fiber along the V-groove. Here the optical fiber that has been cleaved in the field is inserted, and when the end of the fiber butts against the pre-installed fiber the wedge is withdrawn and both fibers are clamped between the base and the lids, creating a stable splice. In

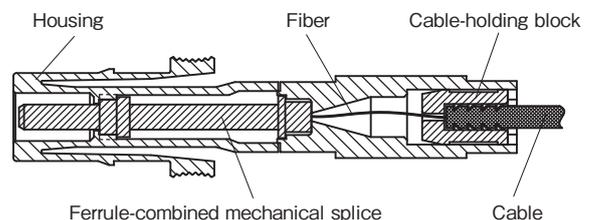


Figure 6 Structure of cable-holding connector.

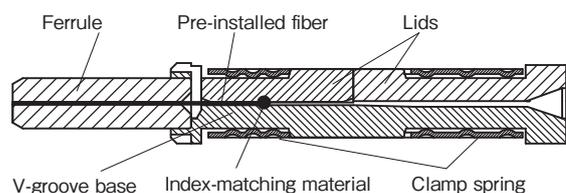


Figure 7 Ferrule-combined mechanical splice.

order to obtain satisfactory values for insertion loss and reflection characteristics, the area around the splice is filled with an index-matching material.

The optical fiber protruding from the rear of the ferrule-combined mechanical splice is deflected slightly inside the housing, and, at the rear of the housing is fixed, together with the sheath, to the cable-holding block. In those field-installable connectors for fiber, however, there is no cable-holding block, and the optical fiber comes directly out of the housing with no deflection.

#### 4. SPLICE MECHANISM OF FIELD-INSTALLABLE CABLE-HOLDING CONNECTORS

The splice mechanism of a field-installable cable-holding connector is designed in a way that differs structurally from that of ordinary factory-installed connectors. In ordinary cord-attached connectors, the optical fiber is fastened to the ferrule with a bonding agent and the fibers are "loose", that is to say the fibers do not stick to the cord sheath and can move inside comparatively freely. Accordingly even if, for example, ferrule push-back occurs when the connector is connected, the optical fibers are pushed back in the cord to the same degree that the ferrule recedes, and the excess length for the push-back can be absorbed smoothly over the whole length of the cord.

Drop cables and indoor cables, by contrast, have a "tight" structure in which the sheath and the fibers stick fast together so that the fibers cannot move inside. And since, as has been explained above, the cable sheath is clamped inside the housing by the cable-holding block, it is not possible to secure sufficient length for the absorption of the excess fiber length for the receding of the ferrule. For this reason when connection is made in the same way as with a conventional connector and ferrule push-back occurs, the fiber is sharply bent between the trailing end of the ferrule-combined mechanical splice and the edge of the cable sheath, leading to bending loss and fiber breakage.

In order to overcome this problem, we will describe a structure that newly adopts the field-installable cable-holding connector.

##### 4.1 FA Connector

Let us first describe the case of the FA connector. As has been stated above, the FA connector was developed with a view to providing service to outlets, so that reducing the size of the connector socket accommodated in the box

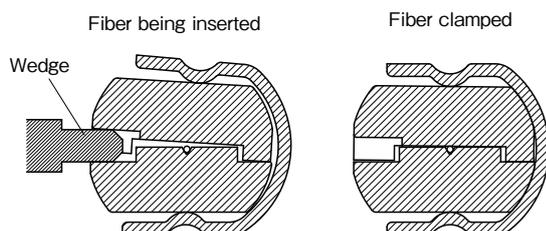


Figure 8 Mechanism of mechanical splice.

was of major importance. For this reason in the connector socket, the housing itself is of a unique shape, curving at 90 degrees, and the optical fibers inside are bent to a radius of approximately 10 mm. If in this situation the ferrule-combined mechanical splice is pushed back, excessive bending is applied to the fiber and significant losses occur. For this reason the socket is designed so that the spring is eliminated and push-back does not occur. In other words the socket is so constructed that the ferrule-combined mechanical splice and the cable-holding block are fixed to the housing after the connector is assembled so as not to move, thereby preventing variations in fiber bending radius. See Figure 9.

In the connector plug that is connected to the socket, on the other hand, there is a need for a spring to exert a pressing action on the ferrule. Accordingly in the connector plug a joint element is provided to the rear of the ferrule-combined mechanical splice, coupling it to the cable-holding block (Figure 10). By this means even when ferrule push-back occurs, the cable-holding block always moves back together so that there is no change in optical fiber excess length.

##### 4.2 Field-Installable Connector for Aerial Closure

In the case of the field-installable connector for aerial closure, there are two types of plug: for drop cable and for

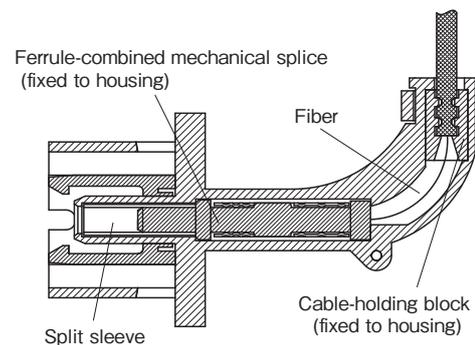


Figure 9 Connecting mechanism of FA connector socket.

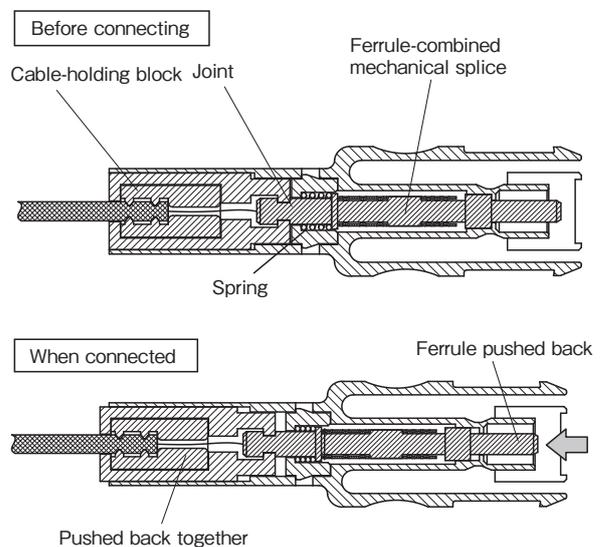


Figure 10 Connecting mechanism of FA connector plug.

fiber, whereas the sockets are only for fiber. Accordingly a spring is used only in the sockets, whereas in the plugs, which may possibly be connected to a drop cable, a system similar to the FA connector socket is adopted, in which the ferrule-combined mechanical splice and cable-holding block are fixed to the housing. In other words in the socket, even if push-back of the ferrule-combined mechanical splice occurs, the fiber is simply pushed outside the housing without being bent, and in the plug no push-back will occur. Note that in plugs for fiber there is no cable-holding block, but, as in the plugs for drop cable, the spring is eliminated.

#### 4.3 Field-Installable Cable-Holding SC Connector

The field-installable cable-holding SC connector, unlike the FA connector or the field-installable connector for aerial closure, does not make connection by bringing together a plug and socket, and it therefore requires a spring. Accordingly, as for the FA connector, it is provided with a joint element at the rear of the ferrule-combined mechanical splice, coupling the cable-holding block.

## 5. INSTALLATION METHODS AND TOOLS

In field-installable cable-holding connectors the distance, after the connector has been installed, between the position at which the cable-holding block is accommodated and the position at which the leading end of the optical fiber is fixed (the position of the fiber pre-installed in the ferrule-combined mechanical splice) is pre-determined, irrespective of the connection configuration (jointed or fixed), by the dimensions of the constituent parts of each connector. For this reason it is extremely important when installing the connector to control the length from the cable-holding block to the leading end of the fiber.

That is to say if the fiber is too long, the deflection of the fiber inside the housing after connector assembly increases giving rise to bending loss, whereas if it is too short, the fiber will not reach the pre-installed fiber and it is impossible to achieve a proper mechanical splice. Nevertheless, fiber length is determined by the termina-

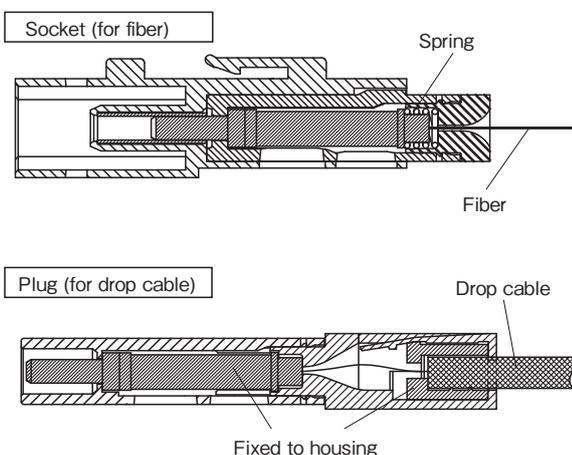


Figure 11 Structure of field-installable connector for aerial closure.

tion dressing operation in the field, and from the standpoint of simplifying the operation and reducing the time required, it is impossible to leave precise adjustment of dimensions up to the operator.

Accordingly we have developed dedicated fiber preparation tools that allow anyone to carry out proper adjustment of fiber dimensions easily and quickly. And by making fiber length the same for every connector it is possible for the preparation tools to be used in common for all connectors.

#### 5.1 Holder and Stripper

We have established the dimensions shown in Figure 12 as the optical fiber length common for all of the field-installable cable-holding connectors. And to achieve this easily, we developed a dedicated holder and a dedicated stripper. See Figure 13. By using these tools and conventional fiber cleaver, the proper fiber length is obtained easily and precisely.

Control of fiber dimensions is also required with respect to the field-installable connector for fiber, and we have also developed a fiber holder that can be used in combination with the drop cable holder<sup>5)</sup>.

#### 5.2 Wedge

The field-installable cable-holding connector that we have developed has a wedge inserted at the factory in the mechanical splice portion, so that the process of wedge insertion need not be performed in the field. This both prevents connector installation errors due to faulty inser-

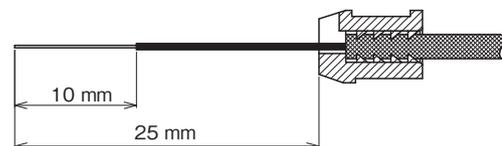


Figure 12 Proper fiber length.

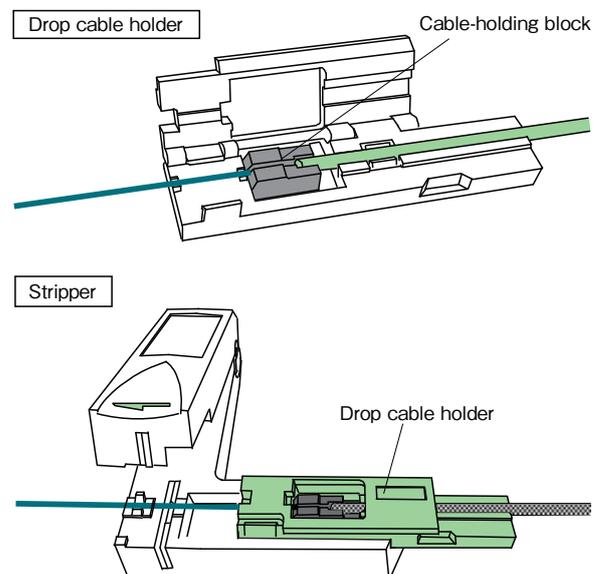


Figure 13 Tools for fiber preparation.

tion of the wedge and contributes to shortening the time required. After the fiber termination has been introduced, the wedge can be easily withdrawn in a single action.

Figure 14 shows the procedure for wedge removal using the example of a field-installable connector for aerial closure. By pressing on the protrusion at the rear of the wedge (to the right in the photo), the wedge is withdrawn by leveraged action from the ferrule-combined mechanical splice. The connector housing is sandwiched by the walls on the wedge, so that even when the wedge is withdrawn it does not separate from the connector preventing unintended drop down at the site.

### 5.3 Assembly Support Tool

Since all of the field-installable connectors that we have developed make connection by mechanical splice, it is necessary to insert the optical fiber into the ferrule-combined mechanical splice base. To simplify this operation we have produced a fiber assembly support tool for each of the connectors. Since with respect to the FA connector the installation process is different for the plug and the socket, we have designed fiber guide structures that are optimized for each, and have consolidated them into a single tool. Similarly for the field-installable connector for aerial closure, the fiber guides for fiber and for drop cable are consolidated into one <sup>2), 5)</sup>.

## 6. CHARACTERISTICS

### 6.1 Initial Optical Characteristics

Here we present as an example in Figure 15 the random insertion loss characteristics for the plug (for drop cable) and socket (for fiber) connection of a field-installable connector for aerial closure. The results obtained were satisfactory: 0.20 dB (average) and 0.51 dB (maximum) measured at a wavelength of 1310 nm, and 0.19 dB (average) and 0.51 dB (maximum) at 1550 nm. Good results were also obtained for return loss, in excess of 40 dB in all

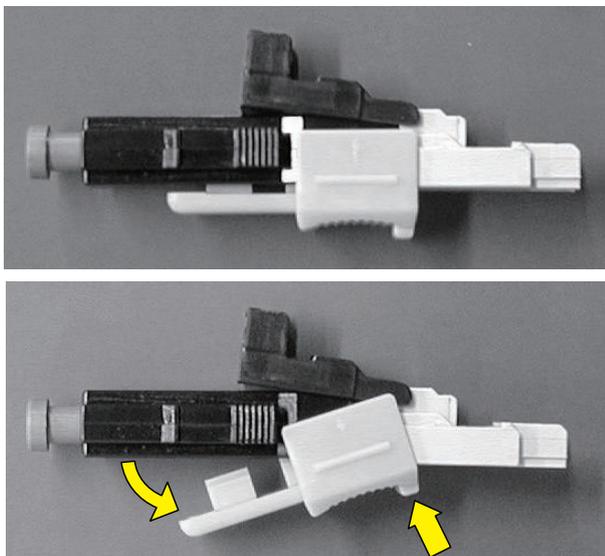


Figure 14 Procedure for wedge removal.

cases.

While not shown in a graph, the values for plug-socket connection in FA connectors were also confirmed to be satisfactory: 0.25 dB (average) and 0.52 dB (maximum) at 1310 nm, and 0.25 dB (average) and 0.48 dB (maximum) at 1550 nm.

Similarly the insertion losses from field-installable cable-holding SC connector to SC master connector were good, at about 0.18 dB (average) and 0.30 dB (maximum) at 1310 nm, and 0.16 dB (average) and 0.25 dB (maximum) at 1550 nm.

## 7. RELIABILITY

The results and conditions for various reliability tests are shown for the field-installable connector for aerial closure in Table 1 by way of example. Measurements were made at two wavelengths, 1310 nm and 1550 nm, and it was confirmed that both mechanical characteristics and environmental characteristics showed outstanding reliability. Representative of these is the graph showing the results of the long-term temperature and humidity test in Figure 16. With respect to the FA connector and the field-installable cable-holding SC connector, reliability was confirmed to be equivalent to that of the field-installable connector for aerial closure for drop cable.

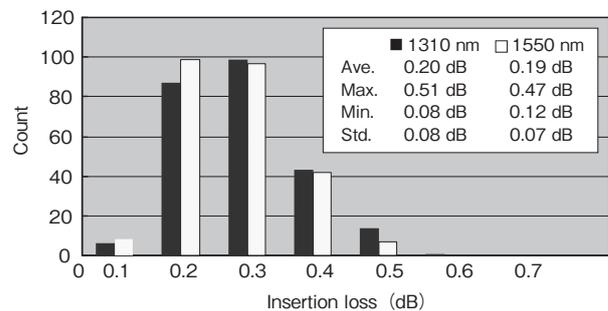


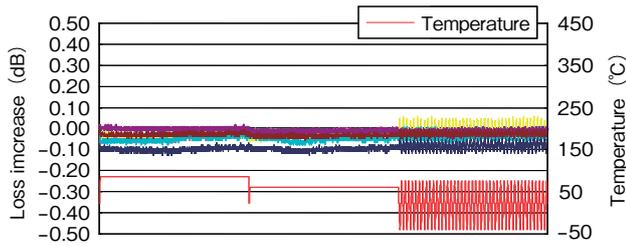
Figure 15 Random insertion loss characteristics of field-installable connector for aerial closure.

Table 1 Reliability tests of field-installable connector for aerial closure.

Test item	Conditions	Loss increase (max.)
Tensile	For drop cable: 10.0 N For fiber: 3.0 N	0.2 dB
Flex	For drop cable: 4.9 N For fiber: 0.05 N	0.2 dB
Vibration	1.5 mm, 10-55 Hz, 2 hrs, 3 axes	0.2 dB
Impact	100 G, 6 ms, 3 times, 3 axes	0.2 dB
Durability	500 times, cleaning every 10 times	0.2 dB
Temperature cycling	-40~70°C, 6 hrs x 10 cycles	0.2 dB
Humidity condensation	-10~65°C, 95%RH, 24 hrs x 10 cycles	0.2 dB
High temperature	70°C, 240 hrs	0.2 dB
Low temperature	-40°C, 240 hrs	0.2 dB
Long-term environmental reliability	85°C, 60°C, 95%RH, -40~70°C, 336 hrs for each	0.2 dB

## 8. CONCLUSION

To respond to installation issues and requirements accompanying the recent penetration of FTTH, we have undertaken developments aimed at use of connectors from the aerial closure to the ONU in the subscriber's premises. We developed field-installable optical connectors suitable for each connection point, and have confirmed satisfactory optical characteristics and reliability. We have also developed appropriate working tools to enable the work to be carried out easily and precisely.



**Figure 16** Result of long-term environmental reliability test of field-installable connector for aerial closure (at 1550 nm).

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