Development of an Optical Fiber Management and Transfer System

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ABSTRACT The worldwide explosion of Internet use has been reflected in the burgeoning growth of users in Japan, requiring provision of optical network infrastructure. Optical technology is already in use on trunk lines, but implementation for subscriber access has been delayed. This paper describes a new optical distribution system for central offices, together with system equipment and components.

1. INTRODUCTION

The growing revolution in information technology has given new impetus to FTTH (fiber to the home). A need has arisen for new types of telecommunications infrastructure for both voice and data, and specifically for central office distribution systems that make possible more efficient management.

Conventional central office systems involved installation of station cable, splitter modules, optical branch modules, AURORA monitoring systems, and distribution frames, each of which was considered separately. The need for more efficient system management has brought about a unified approach to the system as a whole [1), 2), 7)]. The resulting requirements with respect to these central office equipment and components are:

1) design flexibility for the system as a whole;
2) minimal distance between splitter modules (jumper units) and optical branch modules (optical coupler units);
3) increase in the number of fibers per distribution frame: and
4) improved flexibility in connection (jumpering) to the entry of the optical branch module (coupler unit).

2. CENTRAL OFFICE DISTRIBUTION SYSTEM

2.1 System Configuration

Figure 1 shows the configuration of the central office distribution system that has been developed to meet the requirements described above. Conventionally the frame for optical fiber termination was known as an FTM (for fiber termination module); the new term is IDM (integrated distribution module).

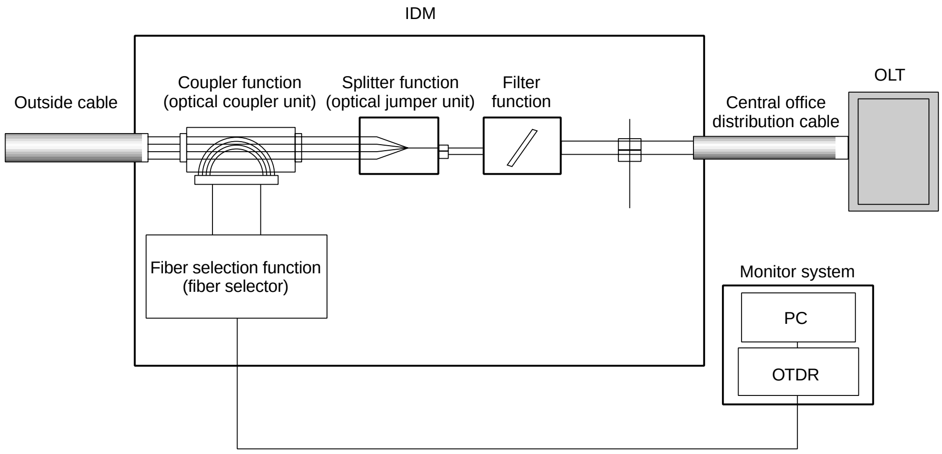

Figure 1 Configuration of optical fiber distribution management system

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The characteristics of the system are as follows:

1) There are two termination frames (IDM-A and IDM-B, instead of the former single FTM for enhanced design flexibility;
2) The splitter module (optical jumper unit) and the optical branch module (optical coupler unit) are both housed in the IDM-A
3) The IDM-A contains 4,000 fibers, twice as many as before;

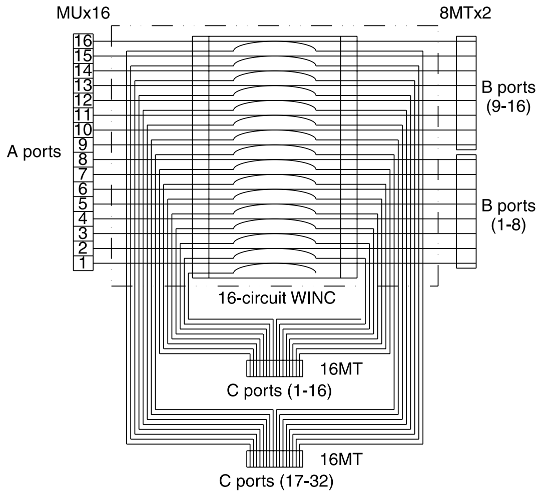

Figure 2 Configuration of optical coupler unit

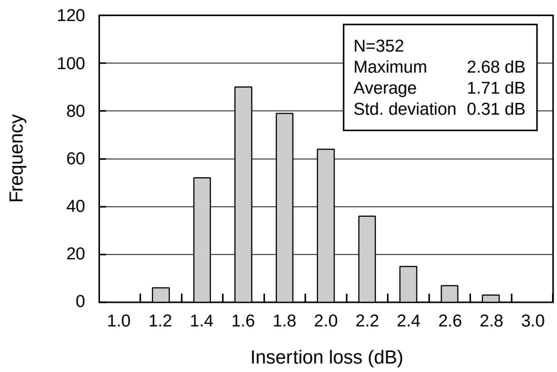

Figure 3 Optical coupler insertion loss, A port to B port (1310 nm)

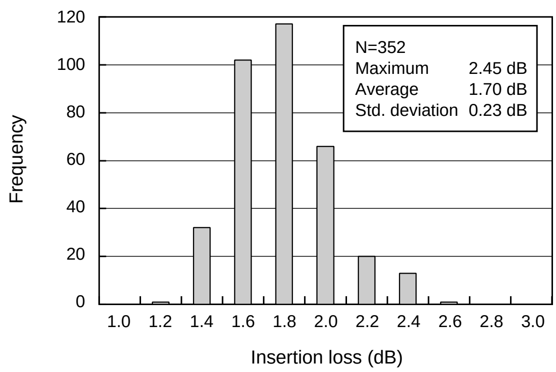

Figure 4 Optical coupler insertion loss, A port to B port (1550 nm)

4) The jumper unit has an optical cord aligning element, facilitating wiring work

There follows a detailed description of the optical coupler unit, optical jumper unit and fiber selector that make up the system.

2.2 Optical Coupler Unit

The optical coupler unit inserts the test light from the optical testing system to the communications link, and returns the light from the communication link to the measuring tool. Figure 2 shows is optical configuration.

The A ports are connected to the optical jumper unit, and the B ports to the outer cable. The C ports are connected to the fiber selector of the optical testing system.

Optical coupler insertion loss is shown for A port to B port at a wavelength of 1310 nm (Figure 3) and 1550 nm (Figure 4). Insertion loss for C port to B port at 1650 nm is shown in Figure 5. Table 1 shows the optical characteristics.

2.3 Optical Jumper Unit

The optical jumper unit branches the light from the communications equipment to the individual fibers. Units are of various types for specific applications and service. Figure 6 shows the optical configuration of a multiplexing unit.

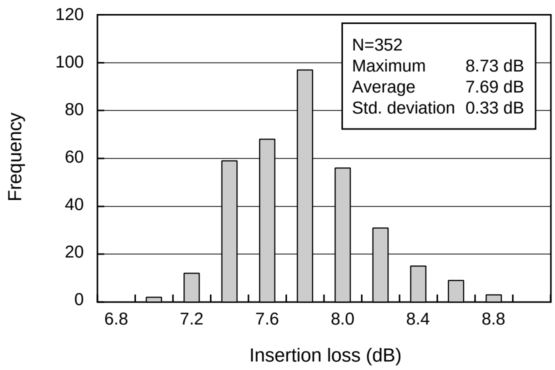

Figure 5 Optical coupler insertion loss, A port to B port (1650 nm)

Table 1 Characteristics of Optical Coupler Unit

Insertion loss (dB)	A port to B port		
		Average	1.71 dB
		Std. deviation	0.31 dB (1310±20 nm)
	B port to C port		
		Average	7.95 dB
		Std. deviation	0.45 dB (1310±20 nm)
		Average	7.69 dB
		Std. deviation	0.33 dB (1650±5 nm)
Return loss (dB)	A port		
		Average	49.3 dB
		Std. deviation	2.88 dB (1310±20 nm)
	C port		
		Average	42.8 dB
		Std. deviation	2.18 dB (1310±20 nm)

Optical jumper insertion loss is shown for A port to B port at a wavelength of 1310 nm (Figure 7) and for C port to B port at 1650 nm (Figure 8). Table 2 shows the optical characteristics.

2.4 Fiber Selector

2.4.1 General Description

The efficient, low-cost monitoring of immense numbers of optical fibers requires that the optical switches used in switching handle as many fibers as possible. And since they are housed inside the distribution frame they must be of compact, high-density design [3].

Previously used optical switches used single- or multi-fiber connector ferrules, but this design makes it difficult to achieve compactness or high density [4].

Accordingly a switch was developed that operates on direct movement of the fiber itself. Also developed was a fiber selector with a switch mounted in the case and installed in the monitor system.

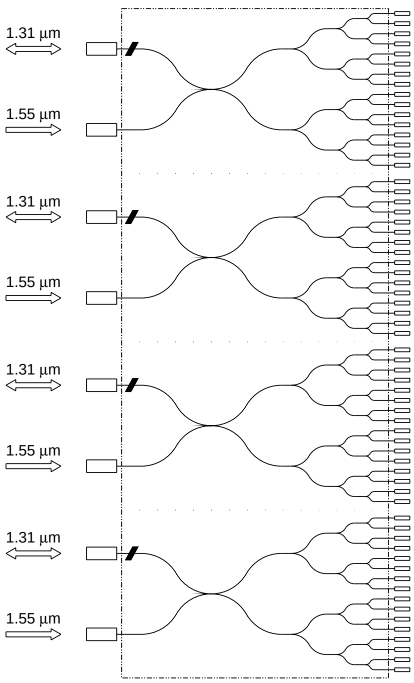

Figure 6 Optical configuration of optical jumper unit

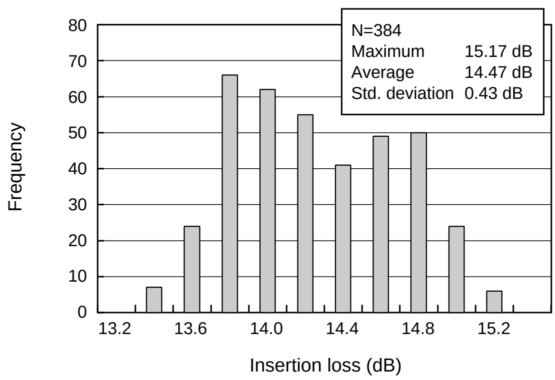

Figure 7 Optical jumper unit insertion loss, A port to B port (1310 nm)

2.4.2 Optical Switch Structure

To achieve a compact optical switch, the movable fibers are single-mode fibers 125 μm in diameter. The fixed fibers are aligned by bonding to V-grooves formed at 127-μm pitch in a plate (Figures 9 and 10).

The movable fiber is brought to the position over the V-groove for the target fiber and is pressed into the groove to align the axes and complete connection.

2.4.3 Forming of Fixed Fiber Array in V-grooved Plate

As described above, the fixed fibers are held in V-grooves formed at a pitch of 127 μm. For ease of manufacture the fixed fiber arrays are composed of 8-fiber ribbons. Two ribbons are superimposed and fibers from the upper and lower ribbons are laid alternately in the grooves (Figure 10) [6].

The actual procedure is first to bond the fibers of the bottom ribbon into every other groove (i.e., a pitch of 254 μm). Then the fibers of the upper ribbon are laid at an off-set of 127 μm from the lower ribbon fibers and bonded in place. This results in a fixed fiber array in which the fibers are arranged at a pitch of 127 μm.

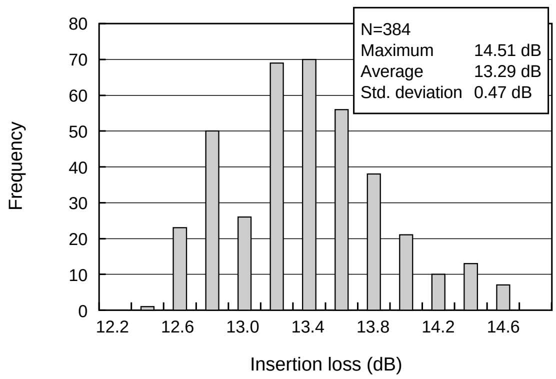

Figure 8 Optical jumper unit insertion loss, A port to B port (1550 nm)

Table 2 Characteristics of Optical Jumper Unit

Insertion loss (dB)	A port to B port		
		Average	14.2 dB
		Std. deviation	0.43 dB (1310±20 nm)
		Average	54 dB
		Std. deviation	0.78 dB (loss difference between 1310 nm band and 1550 nm band, and between 1310 nm band and 1650 nm band)
	B port to C port		
		Average	13.3 dB
		Std. deviation	0.47 dB (1550±20 nm)
Return loss (dB)	A port		
		Average	41.1 dB
		Std. deviation	2.25 dB (1310±20 nm)
	B port		
		Average	45.1 dB
		Std. deviation	4.94 dB (1550±20 nm)

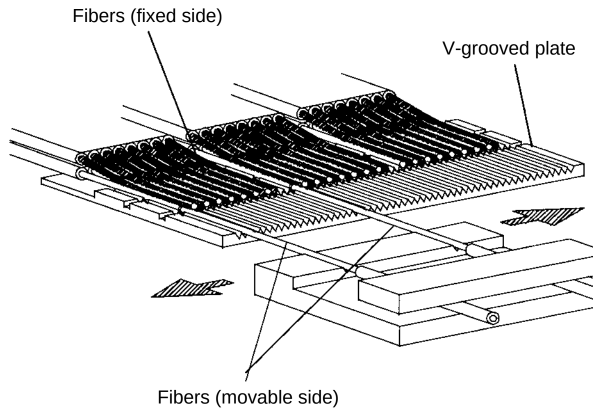

Figure 9 Basic structure of optical switch

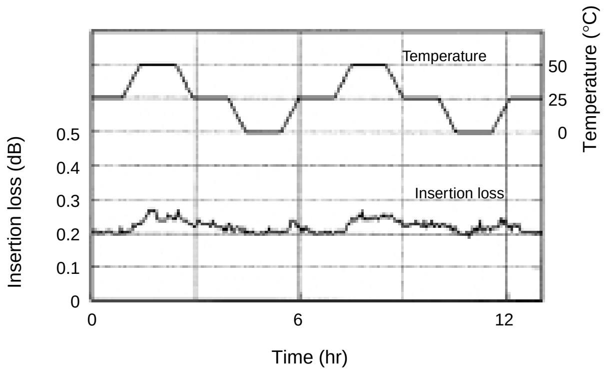

Figure 11 Repeatability of insertion loss in heat-cycle tests

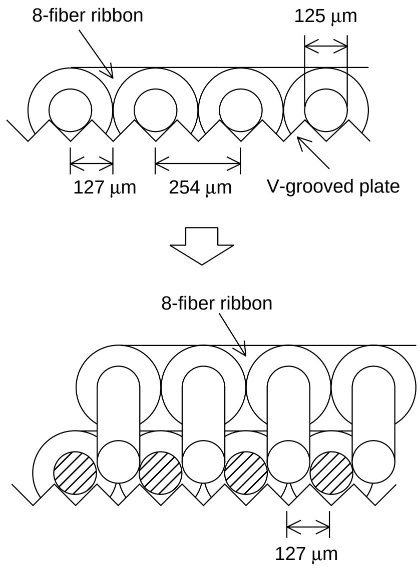

Figure 10 Alignment of fixed-fiber array

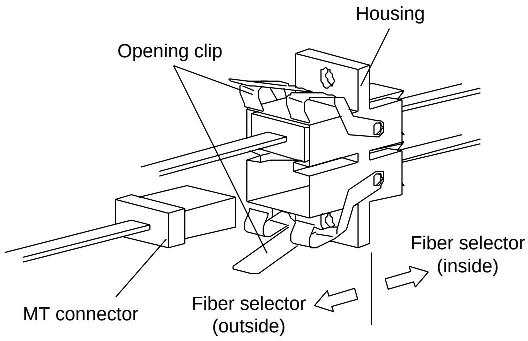

Figure 12 Simplified MT adapter

2.4.4 Temperature Compensation

Optical switches are composed of elements--case, mechanism, V-grooved plate, etc.--each made of different materials with a different coefficient of thermal expansion. This means that changes in temperature give rise to positional displacement between the fixed and movable fibers, and this is particularly pronounced with respect to the direction of arrangement of the fixed fiber array.

The fixed fibers are arranged in the V-grooves and if the pitch is large the V-groove aperture increases so that a certain amount of displacement can be absorbed without causing problems. When fibers are arranged at a pitch of 127 µm, however, the V-groove apertures are smaller and this amount of displacement cannot be accommodated.

Accordingly a control method was developed whereby thermistors are used to detect temperature, and movement of the movable fibers is compensated according to the temperature detected, shifting the movable fibers to maintain optimum position at all times[6)].

This temperature compensation suppresses positional displacement between the fixed and movable fibers, and makes possible connection with high reproducibility from 0 to 50°C. Figure 11 shows the repeatability of insertion loss in heat-cycle tests from 0 to 50°C.

2.4.5 Simplified Adapter

The fiber selector is connected to the optical coupler module or the cable in order to introduce the test light. Normally these connections are made using an MT connector.

In the optical switches used up till now these connections were made using an MT clip, and it was therefore necessary to use a special tool for connection/disconnection. This made the work more inconvenient, and it was more difficult to achieve high-density accommodation of the connections.

Accordingly the simplified adapter shown in Figure 12 was developed, improving working convenience and installation density[5)].

The simplified MT adapter is constructed of a housing and an opening clip, and with a view to high-density installation, each housing is designed to accommodate two MT connectors.

The procedure involves inserting the MT connector into the housing and opening the clip. It is extremely simple, and no special tools are required.

Photos 1 and 2 show a commercial fiber selector developed using these elements, and a 2000-fiber optical switch that is accommodated inside the fiber selector.

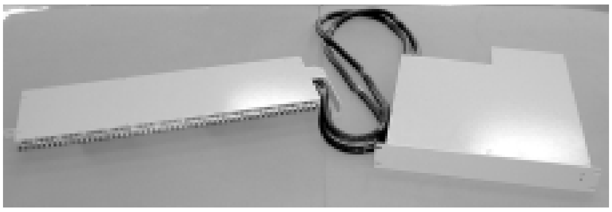

Photo 1 Fiber selector

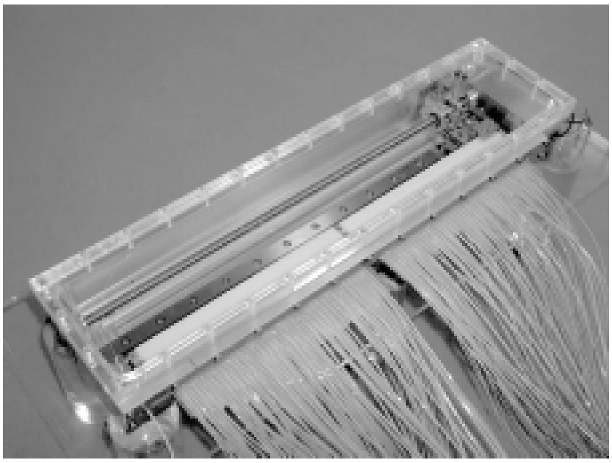

Photo 2 Optical switch

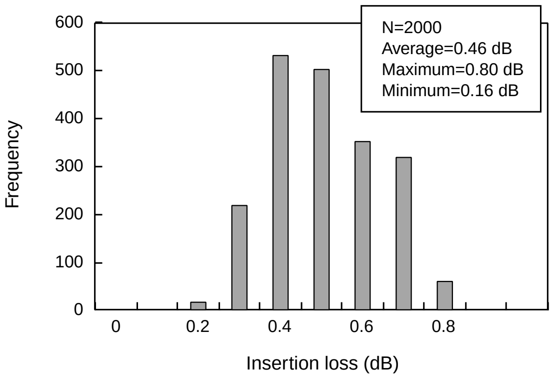

Figure 13 Fiber selector insertion loss

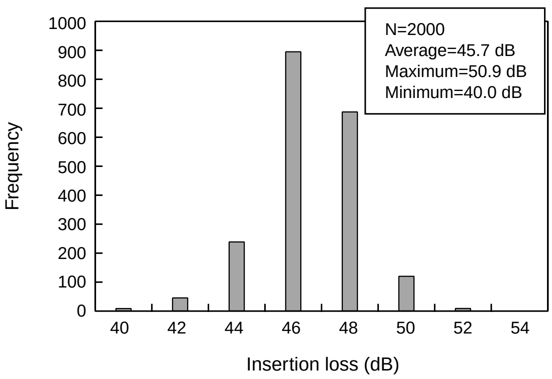

Figure 14 Fiber selector return loss

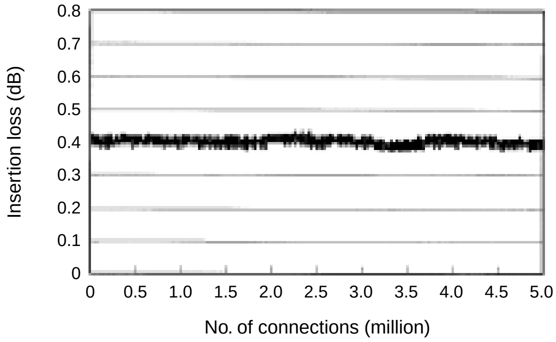

Figure 15 Fiber selector durability

Figures 13 through 15 show the optical characteristics of the fiber selector.

3. CONCLUSION

An optical coupler unit, optical jumper unit and fiber selector have been developed for a central office distribution system. Future efforts will be directed at reducing costs.

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Manuscript received on January 6, 2001.