Furukawa Electric Broadband Involvement in FTTH Systems

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ABSTRACT With respect to recent rapid expansion of FTTH systems, we present in this paper an overview of these systems, and report on the development of equipment relating to FTTH transmission and data transmission. Using optical transmission devices incorporating technologies generated by Furukawa Electric's R&D activities, we have been able to configure FTTH systems that are both more efficient and simpler than those formerly in use.

1. INTRODUCTION

In recent years there has been a rapid expansion of fiber-to-the-home (FTTH) systems that bring broadband fiber-optic services into the home. FTTH systems provide infrastructure for what may be described as a "triple play": broadcasting, data transmission and IP telephony. Since the beginning of the 1990s, Furukawa Electric has been engaged in systems studies and R&D aimed at the realization of FTTH services [1].

To provide broadcasting services on FTTH systems it is necessary the optical broadcast signals be amplified, and distributed to the video optical network unit (V-ONU) of subscribers in the most efficient manner.

To provide data transmission services, it is necessary to miniaturize and integrate optical receiver devices, transmitter devices, wavelength division multiplexing filters and communications control circuitry into the data optical network unit (D-ONU) of subscribers. Recently systems are available that offer optical wavelength division multiplexing of the broadcast and data transmission services on a single optical fiber, requiring a cheap yet practical WDM filter.

We have developed a variety of devices needed to realize this "triple play" in FTTH systems. This paper presents an overview of FTTH systems, and reports on the development of devices required for the realization video transmission and data transmission services.

2. OVERVIEW OF FTTH SYSTEMS

Figure 1 shows the configuration of an FTTH system providing broadcasting, data transmission and IP telephony services. This configuration is known as the passive optical network (PON) type, and is characterized by a single optical fiber being shared by a number of subscribers.

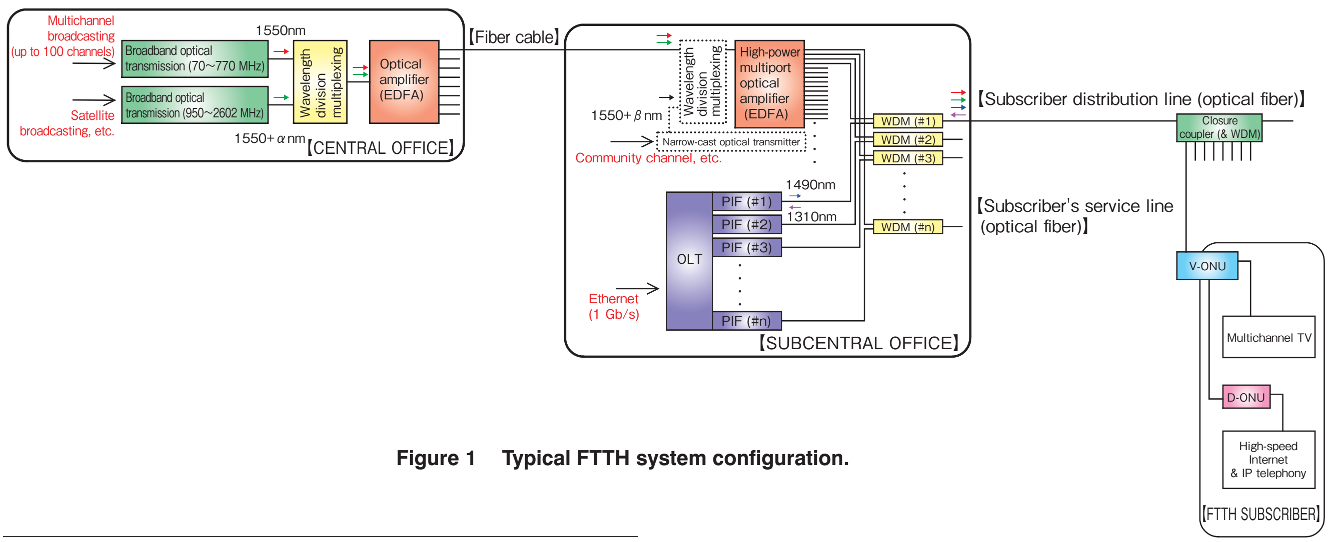

Figure 1 Typical FTTH system configuration.

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The broadcasting center is equipped with an optical transmitter that converts broadcast signals for multiple channels into an optical signal in the 1550-nm band. This is a device that combines nearly 100 digital channels (analog channel equivalent of about 100 channels and digital channel equivalent of about 300 to 400 channels of SDTV quality and about 100 channels of HDTV quality) into an optical signal. Of optical transmitters there are those of the external modulation type, in which optical intensity is modulated in an external modulator distinct from the laser diode, and those of the direct modulation type, in which optical intensity is modulated by varying the current of the laser diode.

The first of these is characterized by the ability to carry an optical signal over long distances with low dispersion for transmission over a 1.3-μm band zero-dispersion single-mode fiber, so that transmission ranges of over 100 km are possible [2]. The second, on the other hand, is capable of transmission over a wide band of frequencies up to about 2600 MHz. This is a frequency at which even the IF signal of satellite broadcasts can be carried without modification.

After conversion, the optical signal is amplified using the optical amplifier and split at the splitter. The higher the output power of the optical amplifier, the better its efficiency will be. On the other hand, due to the phenomenon of nonlinearity in the optical fiber, the optical power that can be injected into the optical fiber is limited (stimulated Brillouin scattering, etc.) As the scale of an FTTH system becomes greater, its configuration and operating cost will change significantly in accordance with the amplifying/splitting efficiency, space efficiency, and power consumption efficiency of the optical amplifier.

The optical signal distributed by an optical amplifier etc. (the broadcast optical signal) serves all subscribers with the same broadcast signal. On the other hand, as the service area becomes larger, it may be necessary to provide service of an community channel for each audience service area. In such a case it is possible to add to a program by means of a narrowcast optical transmitter that can add a program directed to a specific area only on an independent signal of differing wavelength. A communications method using a narrowcast optical transmitter is shown in Figure 1.

The amplified and split optical signal is split in the optical fiber transmission path using an optical coupler, and is received by the subscriber V-ONU, converted into an electrical signal and fed to the television receiver set.

The data signals, on the other hand, are transmitted by a method known as a GE-PON system. PON interface (PIF) at the optical line terminal (OLT) installed at the central office is connected to as many as 64 subscriber D-ONUs (when 1 fiber has a 64-way split). The transmission speed is shared by subscriber terminals connected to 1 Gb/s.

Broadcast signal and data signal services may be provided by wavelength division multiplexing, and are multiplexed at the central office using a WDM filter and are split similarly at subscribers premises.

3. VIDEO TRANSMISSION TECHNOLOGY

In FTTH systems providing broadcasting services, the optical signal for video is amplified and distributed by optical amplifier. As was noted above, the higher the output power of the optical amplifier the more it is possible to increase the distribution efficiency of the FTTH system. The erbium-doped fiber amplifiers (EDFAs) used in existing FTTH systems are limited by the output of the pumping lasers, with a maximum signal output power of about +22 dBmW. Since to achieve higher output it is necessary to increase the number of pumping lasers, there was a resulting problem that it became more expensive and more bulky.

With the FITELwave OA-PLUS series of high-power multiport optical amplifiers, utilizing the technology of our clad pump optical amplifier [3), 4)], Furukawa Electric has solved this problem. Figure 2 shows the clad pump optical amplifier gain-block, and Figure 3 is a photograph showing a high-power multiport optical amplifier. With this amp, the maximum output of the amplifier gain-block is +33 dBmW, making it possible to obtain an optical output after splitting of +20 dBm x 16 ports. This device is of unit configuration for each 16 ports (MAX: 32 ports), accommodating a maximum of 64 ports (MAX: 128 ports) in a 5U size chassis. This is a standard sort of system design, capable of providing coverage to approximately 4000 households. Because this kind of multiport optical amp is of higher density it presents difficulties with respect to heat dissipation, but by revamping the electrical circuitry

Figure 2 High-power multiport optical amplify for CATV.

Figure 3 High-power multiport optical amplifier (FITELwave OA-PLUS series).

and repeated simulation and experimentation with the heat dissipation mechanism, it has been possible to arrive at an optimal heat dissipation structure. It was also possible to effect a significant reduction in power consumption, resulting in the design of an optical amplifier that is optimal for configuring FTTH systems. Redundancy is provided for all power supplies and fans, and the structure allows for hot swapping. A simple network management protocol (SNMP) and web browser monitor are standard equipment for improved operating convenience. In addition to this series of optical amplifiers, we have also developed the FITELwave OA-BASE series of multi-port optical amplifiers, which does not adopt unit construction and is easier to use in comparatively mid-sized FTTH systems, and the FITELwave 4200 series of 1U-size pizza-box type optical amplifiers, which can be used in relaying applications, etc. (see Figures 4 and 5).

Figure 4 FITELwave OA-BASE series high-power multiport optical amplifier.

Figure 5 FITELwave OA-4200 series high-power multiport optical amplifier.

4. GE-PON TECHNOLOGY

For FTTH systems that provide data transmission, gigabit Ethernet passive optical network (GE-PON) technology is used, providing 1 Gb/s data speeds to multiple subscribers. This standard was established in 2004 as IEEE802.3 ah 1000 BASE-PX, offering a protocol that features a high degree of Ethernet affinity. It uses the 1490 nm band for the down wavelength and 1310 nm for up.

To achieve a commercially viable central station or optical line terminal (OLT) for GE-PON applications, Furukawa Electric began with a proprietary effort to develop its key component--the optical transceiver module. Figure 6 shows a transceiver module for a GE-PON OLT [5].

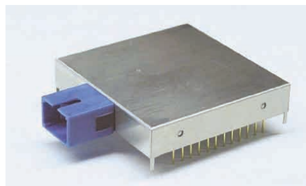

Figure 6 GE-PON OLT transceiver module.

Figure 7 GE-PON central station OLT (FITELwave AG1600E).

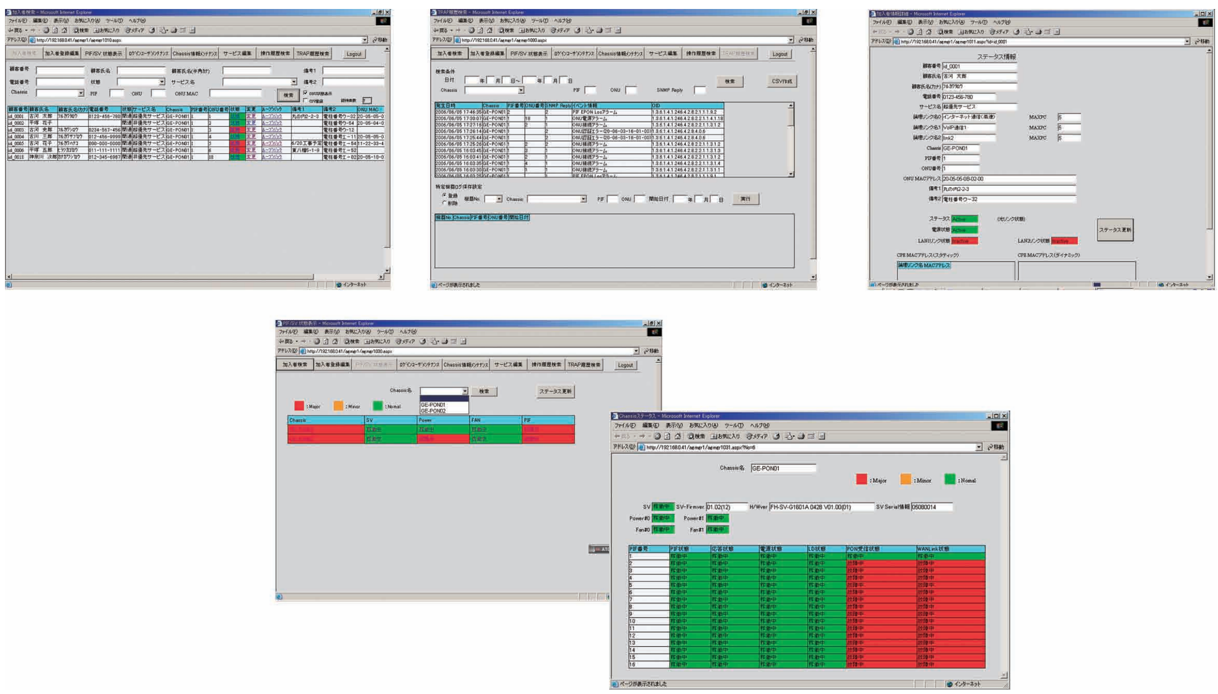

Figure 8 GE-PON management software (FITELwave AGmanager).

The OLT is 3 U size, and accommodates 16 PON interface (PIF) cards, to which can be connected a maximum of 64 receivers' D-ONUs (see Figure 7). In the standard design (budget loss is 29 dB), it supports connection of up to 1024 subscribers' D-ONUs. Redundancy is provided for all power supplies and fans, and the structure allows for hot swapping. In addition to a line-up of dedicated management software (FITELwave AGmanager) that simplifies setting, status monitoring and history retrieval for OLT and D-ONUs, and is also capable of batch management of multiple OLTs and D-ONUs, a simple network management protocol function is also provided. Figure 8 shows the conceptual image of the software.

For its part the D-ONU is of compact, lightweight design, and has a receptacle for holding excess fiber length (see Figure 9). It has two LAN ports, with independent settings for quality of service (QoS), allowing, for example, port 1 to be operated to optimize Internet connectivity while port 2 operates at a constant bit rate (CBR).

GE-PON service range is up to a maximum of 20 km, and the maximum number of branches is 64. Businesses providing FTTH services often desire non-standard usage modes, such as providing service at a distance or further improving fiber use efficiency. And by converting the several wavelengths of the GE-PON OLT PIF card, we have also developed a GE-PON extender (FITELwave AG400), with four different PON lines multiplexed on a single fiber (see Figure 10). The use of this device allows up to 256 D-ONUs to be connected by a single fiber, and can extend the service range to a maximum of 50 km.

5. WDM TECHNOLOGY

In FTTH systems the optical signals for broadcasting and the optical signals for data transmission are in some cases multiplexed for transmission.

A number of technologies have be investigated with respect to WDM filters, but the method that we are actively using at this point in the introduction of FTTH systems involves planar lightwave circuit (PLC) technology that we have developed in house [6), 7)]. Figure 11 shows the module.

PLC technology lends itself very well to mass production, and is the technology adopted for multiport optical couplers and the like. The WDM filter developed by FITEL makes use of these PLC technologies, and is characterized by having WDM filters for eight lines accommodated in a single module. In this way it has been possible to simplify the design of optical WDM filters for central offices. Figure 12 shows WDM filter assemblies for a central office. The WDM filters for the terminal side are normally installed in the subscriber's terminal, but in addition to such standard products, Furukawa Electric has developed a product which accommodates WDM filters for eight subscribers and eight multiport couplers in a module that can be installed in a drop closure, and also offers an array of solutions that can significantly reduce the cost per subscriber. Figure 13 shows a view.

Figure 9 GE-PON D-ONU (FITELwave AG20E).

Figure 10 GE-PON extender using WDM (FITELwave AG400).

Figure 11 Triple-play WDM filter array module using FITEL's PLC technology for central offices.

Figure 12 Triple-play WDM filter assembly unit for central offices.

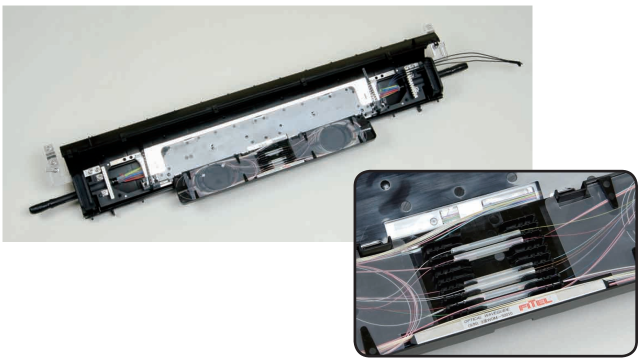

Figure 13 All-in-one PLC module (integrated optical splitter and WDM filters) installed in a drop closure installed near subscribers.

6. CONCLUSION

We have presented an overview of FTTH systems and of Furukawa Electric's involvement with them. The products that Furukawa Electric has developed in this area are all based on key components researched at the FITEL Photonics Laboratories and Yokohama Research Laboratory, and components developed at Ofs. We will be most gratified if reference to this paper is helpful in developing products required in FTTH systems.

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