Application Note

PASSIVE HARDWARE for FTTX

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Abstract

FTTx systems have brought gigantic quantities of bandwidth to the individual client's home and business. FTTx systems evolved from copper cable services and hybrid fibre/coax systems that brought information, entertainment, and other services from around the world including telephone voice service to individual residences and businesses.

Keywords

PON, ODN, Splitter, MDU, ONT, FDT, FDH, OLT, Cables (Drop, Distribution, Feeder), Attenuator, Optical terminator, Multiplexer, Circulator, Filter, Isolator

General

Over the last 15 years FTTX systems have brought gigantic quantities of bandwidth to the individual client's home and business. FTTX systems evolved from copper cable services and hybrid fibre/coax systems that brought information, entertainment, and other services from around the world including telephone voice service to individual residences and businesses.

Fibre to the "X" systems is the vehicle that has enabled this evolution to take place. FTTX systems have taken many forms depending upon how close to the eventual end point of use the fibre delivers the service. FTTX has included the following loop plant fibre networks:

- FTTN/FTTLA – Fibre-to-the node or last amplifier.
- FTTC/FTTK – fibre to the curb, closet or (street) cabinet. Reaches more than 300m / 1000 feet of the client.
- FTTB – fibre to the building business, basement. Fibre reaches the boundary of the building.
- FTTH – fibre to the home. Fibre reaches the boundary of the living space.
- FTTP – fibre to the premises it includes FTTH and FTTB, inside the living space.
- FTTD – fibre to the desk.

Recently, FTTX is also used for systems that bring fibre directly to the client such as FTTB, FTTH, FTTP, and FTTD.
This paper summarizes the commonly used passive components in passive optical networks (PONs). It concentrates on PONs and the hardware they are composed of because of their ability to provide robust and maintenance free service over their lifetimes.

Passive Optical Network Components

Figure 1shows PONs for fibre to residences and fibre to multi-dwelling units (MDUs). Two types of MDUs are shown. The first type is a high rise apartment type residence in which a large volume of clients reside. Most of the physical plant for this application will emanate from the FDH located in a communications room where feeder cable from the central office is split into multiple plenum rated distribution cables that will bring signals to customer's communications closet, often in the apartment.

The second type of MDU is a smaller apartment complex or garden style apartment. The FDH is usually located outside the apartment building. It receives feeder cable from the CO. A splitter at the FDH separates the signal from one feeder fibre into up to 32 pathways. In unique cases 64 pathways can be served as individual distribution cables. Feeder fibres that do not serve customers residing at the apartment being served are sent downstream as distribution fibres to their customer's location.

The plenum rated distribution cables are terminated at an FDT located on the wall of the apartments or inside the apartment in a communications closet. Drop cables are run from the FDT to the client as plenum rated cables. These cables can be run through the apartment's attic or other indoor installation infrastructure like ducts, trays and other cable support systems.

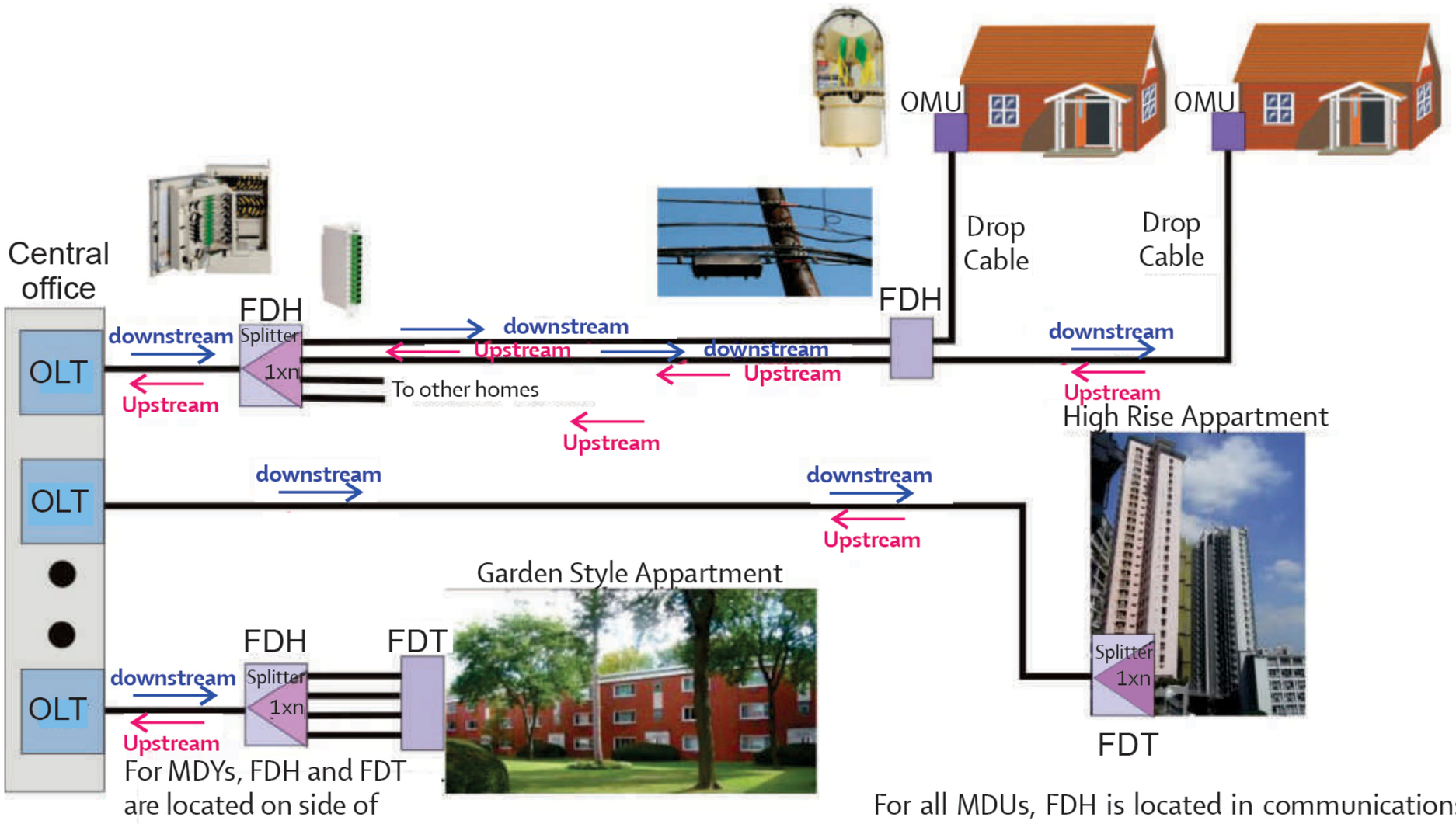


Figure 1 – Passive Optical Networks Showing Its Principle Network Components

The primary components that are used to construct a passive-optical network are listed below:

ODN - Optical Distribution Network is the physical portion of the FTTX network in the outside plant (OSP) between the OLT and ONU (central office and client). ODN includes the fibre optic cabling, passive splitters, taps, FDH, drop terminals, connectors, attenuators, and couplers.

The maximum number of subscribers is generally limited to 32 per fibre (with a 32 port splitter) delivered to the CO. BPON, EPON, and GPON are common types of passive optical networks (PONs) in use today. 10G EPON and 10G GPON are new technologies to be deployed in the next few years and future systems include for example NG-PONx and WDM-PON.

Table 1– Summary of Popular PON Characteristics

PON	Characteristic	Transmission Rate[2] Mbps	Specification	Protocol
BPON	Broadband	1244.16 / 622.08	ITU-T G.983	Uses ATM
GPON	Giga-bit	2488.32 / 2488.32	ITU-T G.984	Uses ATM or GEM[3]
EPON	Ethernet	1250 / 1250	IEEE-802.3ah-2004	Uses MPCP[4]

1 Up to 64x and even 128x splits are possible
2 Downstream rate/Upstream rate
3 Can use forward error correction (FEC).

ITU has divided G-PON systems into three classes of service initially and later into two more classes as extended G-PON service[5].

Table 2 - ITU G.984. X Defined G-PON Service Attenuation Limits and Fibre Length.

G-PON Class	System Loss Budget	Maximum Fibre Length
A	5-20 dB	20 km
B	5-20 dB	20 km
B+	5-20 dB	20 km
C	5-20 dB	20 km
C+	5-20 dB	20 km

OLT - Optical Line Terminal is the device at the head end or central office that controls the FTTX network. It assembles the downstream signal to the customer and interprets the upstream signal from the customer. It interfaces a single fibre in the ODN for point to multipoint (P2MP) systems networks and an upstream and a downstream fibre for point to point (P2P) systems. The document will discuss passive optical networks that are P2MP architecture because of their popularity and low cost. The OLT circuitry controls the optical signal flow to and from the remote ONT(U).

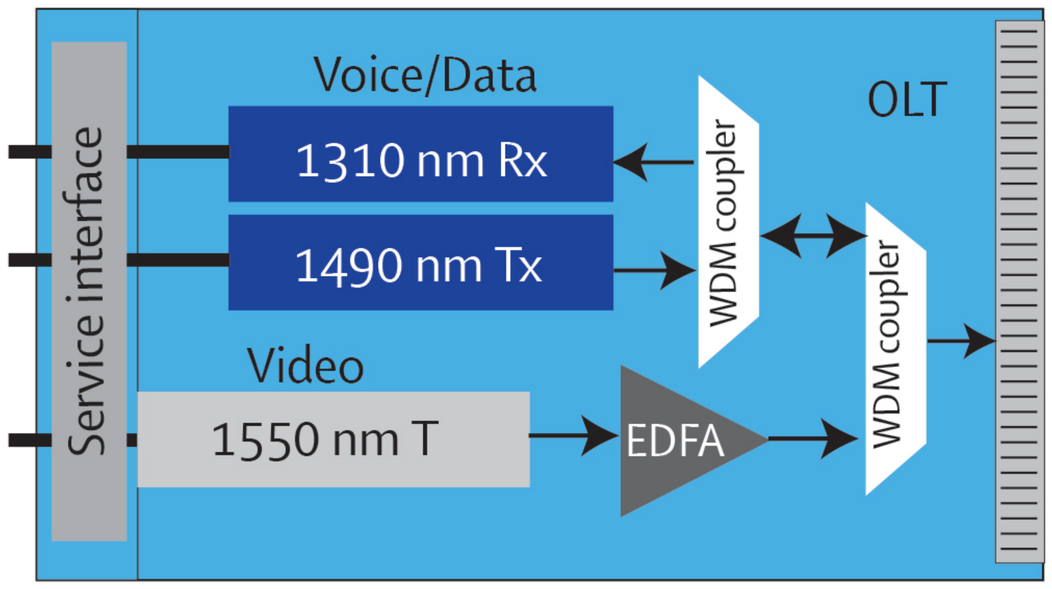


Figure2 – Schematic View of OLT Card that Fits in to a Fibre Distribution Frame at the CO

Figure3 - Commercially Available GPON OLTs

4 EPON is specified in IEEE 802.3 ah – 2004, where it was designed to be a simple packet based transmission system. It is used for both upstream and downstream communications. Multipoint media access control (MAC) protocol (MPCP) used in EPON controllers access to a point to multipoint networks.

5 See ITU G.984.5 through G.984.7 for complete description of G-PON extended reach service.

FDH - Fibre Distribution Hub is the point where FTTX plant transitions from feeder cable from the CO to distribution cable to the customer. The transition is done using splitters to share signals from a single fibre with up to 32 customers. In unique situations up to 64 clients can be served from each distribution fibre. The hub contains locations for cables to be spliced, a splitter module to divide the downstream signal and combine upstream signals, and a fibre distribution panel to provide a cross-connect between feeder and distribution cable (the CO and the customer). The hub can be a cabinet, closure, or pedestal. FDHs are found in aerial, underground, and buried plant. They can be located on poles, manholes, or ground mounted. FDHs can be used outdoors or indoors.

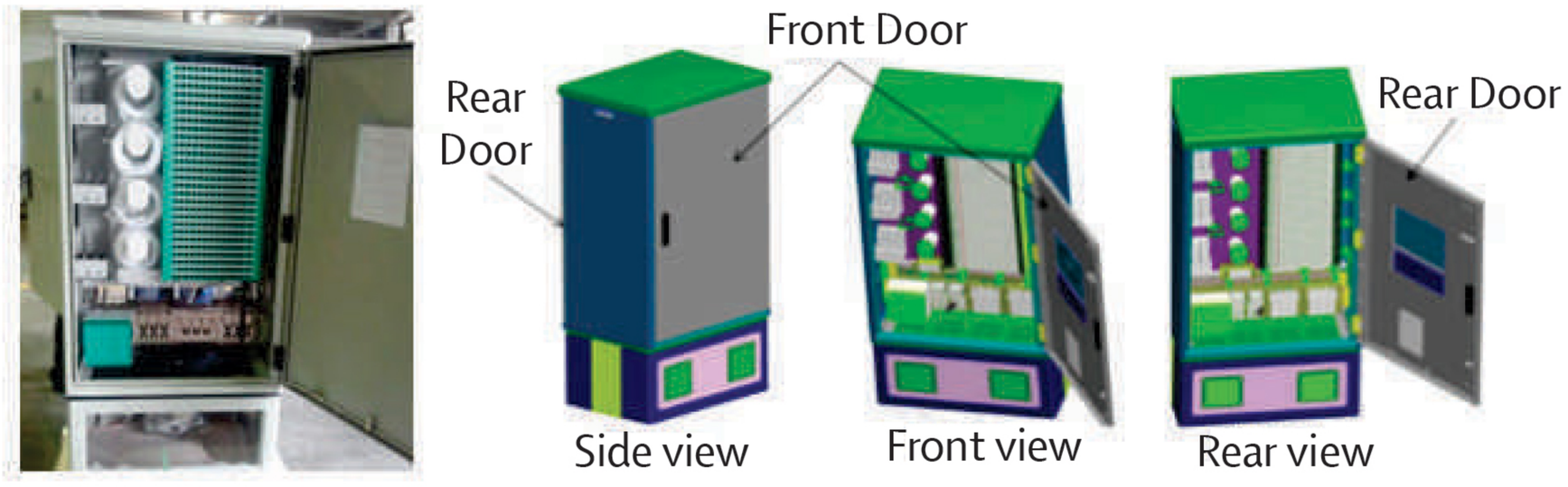
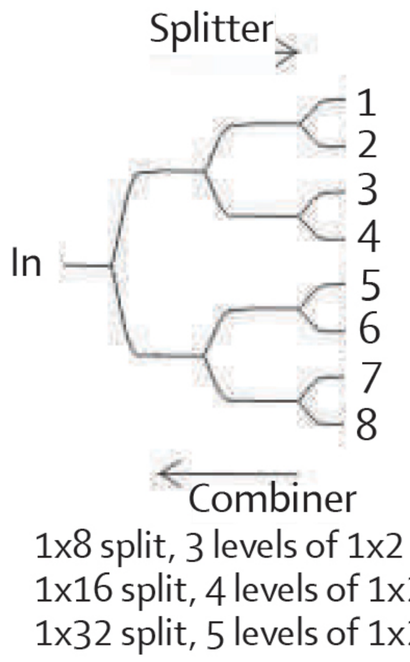


Figure4 - FDH, Outside Plant Rated for Up to 576 Customers

Splitters are used to separate the information moving downstream from feeder fibres to distribution fibres and combines information moving in the upstream direction into feeder fibres that connect to the CO. Splitters can be packaged in various configurations and are manufactured using two common procedures. Planar lightwave circuits (PLC) splitters are manufactured by laying optical circuits on a wafers using semi-conductor technology. They are used for higher split ratio devices. Fused biconic tapered (FBT) couplers are made by fusing two fibres together. They are used for relatively low fibre split ratios. Both type splitters are based on cascading 1 by 2 splitters



1x8 split, 3 levels of 1x2 split
1x16 split, 4 levels of 1x2 split
1x32 split, 5 levels of 1x2 split

Figure5 - Schematic of an Optical Splitter Layout

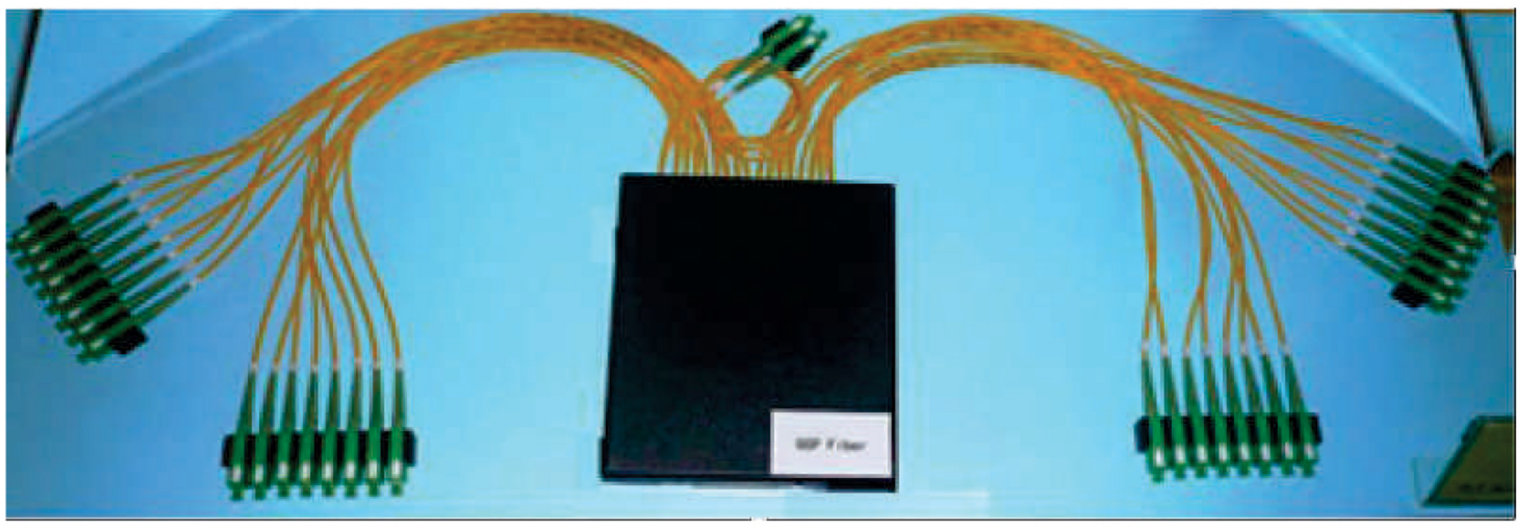


Figure6 - PLC Splitter Module, Type IV

Sr.No	Parameter	Unit	STL-OSP-SPL-TYPE-V-XYZZ					
1	Port configuration		1x2	2x8	1x16	2x16	1x32	2x32
2	Fiber Type		G652D,G657A					
3	Operating Wavelength		1260 to -1650					
4	Insertion Loss(dB)	P	≤ 10.3	≤ 10.9	≤ 13.5	≤ 14.2	≤ 16.8	≤ 17.3
		S	≤ 10.5	≤ 11.1	≤ 13.7	≤ 14.4	≤ 17.7	≤ 17.7
5	Uniformity Loss	dB	≤ 1.0	≤ 1.2	≤ 1.3	≤ 1.5	≤ 1.5	≤ 1.8
6	PDL		≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.3
7	Return Loss		APC≥ 55					
			PC (UPC)≥ 50					
8	Directivity		≥ 55					
9	Operating Temperature		-40 to +45					
10	Storage Temperature		-40 to +45					
11	Module size		171x140x15					
Note: x- No of Splitter in Module(x- 1 for type V),Y-input(1 or 2),ZZ- Output(8,16,32)								

Figure7 - Specification Sheet for PLC Splitter, Type IV

FDT - Fibre Distribution Terminal is the device that provides the transition between the distribution cable and the drop cable. It is usually located within a 100mtrs (few hundred feet) of the customer. It can be mounted on an aerial strand or pole, buried directly in the ground or mounted in a manhole or handhole. An FDT can also be located in a pedestal. FDTs can be used outdoors or indoors.

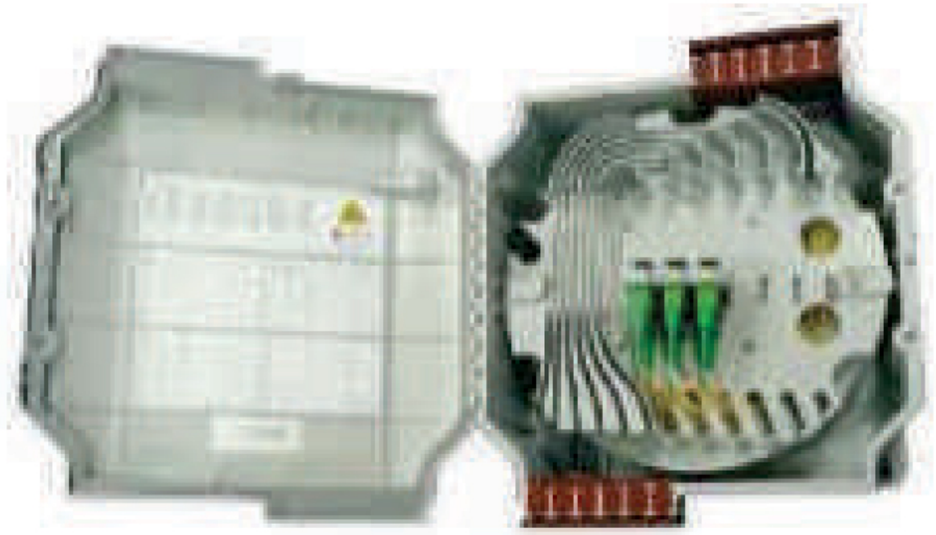


Figure8 – Fibre Distribution Terminal

DROP CABLE is the final optical cable to the customer, connecting the FDT to the customer's ONT(U). Many service providers use a pre-terminated drop cable system to save time and cost.

Figure9 – Customized, Rugged / Hardened Drop Cable

ONT(U) - Optical Network Terminal (Unit) is the termination of the FTTX system at the customer's end of the network. The ONT is the Customer Premise Equipment (CPE) endpoint of the ODN. The ONT provides a point of delivery to the customer for the downstream signals (voice and data and video) and a launch point for the upstream communication of data and voice from the customer to the central office or headend. It provides optical to electrical conversion for downstream signals and electrical to optical conversion for upstream communications. Since the PON is passive, the ONT must contain an AC voltage connection to perform the optical to electrical and electrical to optical conversions for the client's services. The ONT will replace the client's existing copper Network Interface Device (NID). Existing POTS / Coax inside wiring will be cross connected to the Single-Family Unit (SFU) ONT.

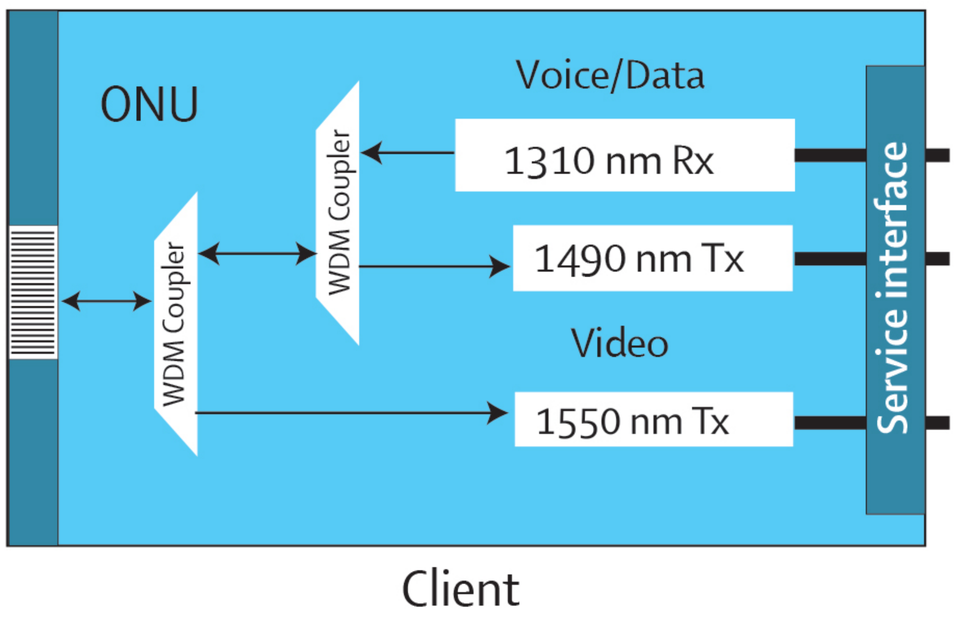


Figure10 - Schematic View of ONU (ONT) Card that Resides at or Near Clients Service Point.

Figure11 – Indoor Rated Multi-Dwelling Termination Units

MDU - Passive Optical Network Components

The primary components that are used to create a PON have been listed above. They are the same as used for multi-dwelling unit (MDU) installations. Recently, the FTTX MDU industry has produced a large amount of products. The main differences in the MDU deployment are the FDT's, Drop Cables, and ONT's.

iFDH - Indoor Fibre Distribution Hub, same as FDH, just used indoors.

iFDT - Indoor Fibre Distribution Terminal, same as FDT, just used indoors.

Drop Cable, the cable that enters the customer's apartment from theFDT that is usually located in a closet or stairwell in a high-rise building. In a garden-style apartment MDU deployment, the drop cable may come from an FDT Located Just Outside the apartment building, and routed through the attic into the apartment's designated communications closet.

ONU- Optical Network Unit is similar to the SFU-ONT but for a MDU / MTU, or small business. It contains 12 - 24 POTS lines, multiple "Ethernet" or "VDSL" connections, and one / two high-powered RG video outputs. These ONT's come in two forms, wall mountable or rack-mountable units. They are typically installed in a stairwell area, or basement next to the existing SAI (Service Area Interface) for that floor.

PON Cables - There are three basic categories of optical cables used in P2MP PONs.

Feeder cables are used to connect traffic from the OLTs in the CO to the FDH where it is divided into cables that serve individual clients by connecting to the output of splitters. The feeder cable is usually a small to medium sized cable that can be placed in the aerial, buried, or underground plant. Each fibre in the feeder cable will usually serve up to 32 (or more) distribution fibres at the FDH. Feeder cables can be long or short; however, the economics for PON materials favor situations in which the feeder cable is longer than the distribution cable.

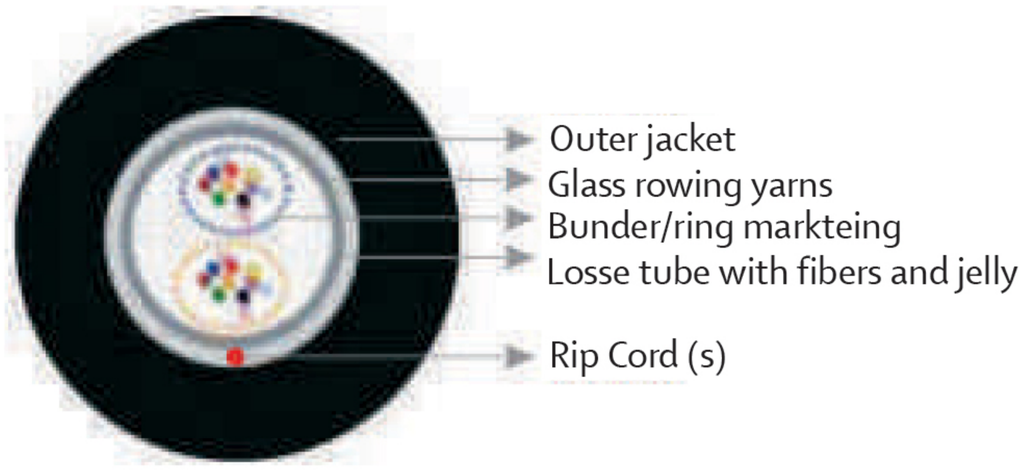


Figure12 – Typical FTTX Feeder Cable

Distribution cables connect the FDH to the FDT where each fibre in the distribution cable is connected to a drop fibre cable that directly serves the customer. A separate cable will be used to serve each geographically separated neighborhood or large multiple dwelling unit (MDU). Distribution cables will be much larger in number of fibres than the feeder cables to which they connect. The distribution cable can be placed in the aerial, buried, or underground plant. Distribution cables can be long or short; however, the economics for PON materials favor situations in which the distribution cable is shorter than the feeder cable.

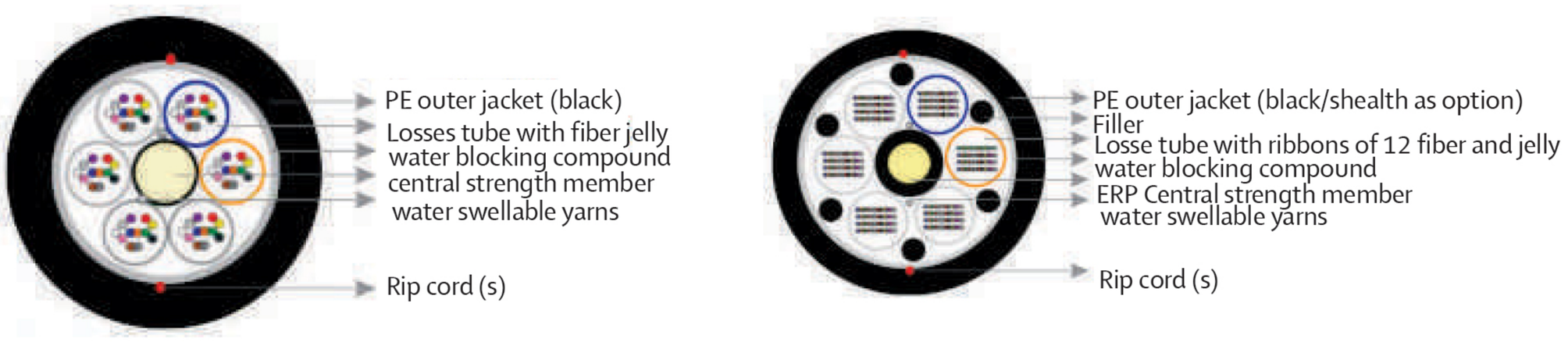


Figure13 – Typical FTTX Distribution Cables

Drop cables are small fibre count cables that connect the distribution fibres at the FDT to the ONT located at or near the customer's home or business. There is a drop cable mate for each optical fibre in the distribution cable. The drop cable is usually a indoor (plenum), wall mounted (riser), buried or aerial cable. Many service providers are using pre-manufactured rugged/hardened drops with rugged connectors. Drop cables are usually less than a 100mtrs (few hundred feet) in length.

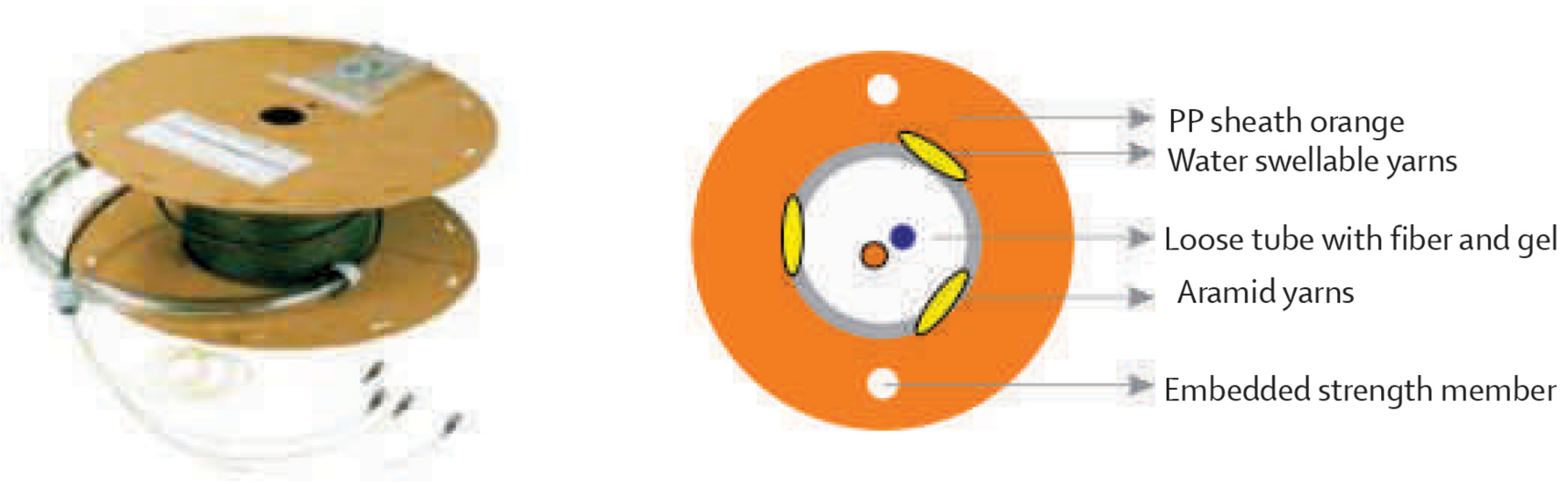


Figure14 – Custom Factory Fabricated, Rugged/Hardened Drop Cable (Left) and Direct buried Uni tube Drop Cable (Right).

Other Passive Components

The passive components described in the section are less common in FTTX applications.

Optical Attenuator

An **optical attenuator** is used to reduce the Power level of an optical Signal in an Optical fiber.Optical attenuator are either fixed, step-wise variable, or continuously variable.
They often are used to check the power level margins by providing a temporarily, calibrated loss to increase link loss, or are installed permanently match the received signal level to the receiver's operating power window.

Fixed Optical Attenuator

Attenuator use either doped fibers or misaligned fibre splices, since both of these are reliable and inexpensive. Both types of attenuator can be incorporated into jumper cables. An alternative attenuator is the build out style, a small male or female adapter connection that is used as an interface with other cables.

Figure15 – Build-Out Style Optical Attenuator Incorporated as Part of SC and SC APC

Connectors

Other type attenuators using gap loss between mating optical connectors are available, but are not used very often because of their instability and reflectance.

Optical Terminators

Fibre optic terminators are passive components that absorb light coming from unterminated connector plugs. By minimizing the reflected power, the terminator can reduce signal degradation in digital and analog systems. Terminators also maintain the cleanliness of unterminated plugs and protect them from possible physical damage.

Wavelength Division-Multiplexer

Wavelength-Division-Multiplexer or Demultiplexer (WDM) distributes light based on its wavelength. It is used to transmit signals composed of multiple wavelengths combined together on a single fibre, to individual wavelengths on separate fibres.

Figure16 – Schematic Drawing of WDM Device Combining Three Wavelengths From Separate Fibres into Three Wavelengths on One Fibre.

A demultiplexer works similarly to a multiplexer, except in the opposite direction. It combines many wavelengths of light from individual fibres into a single channel of light on one fibre.

Optical Circulatory

An optical circulator can be used to separate optical signals traveling in opposite directions in an Optical fiber. An optical circulator has three ports designed so that light entering any port exits from the next port. For example in Figure17, light entering port 1 is emitted from port 2, but if some of the light from port 2 is reflected back to the circulator, it exits from port 3. Optical circulators are non-reciprocal devices.

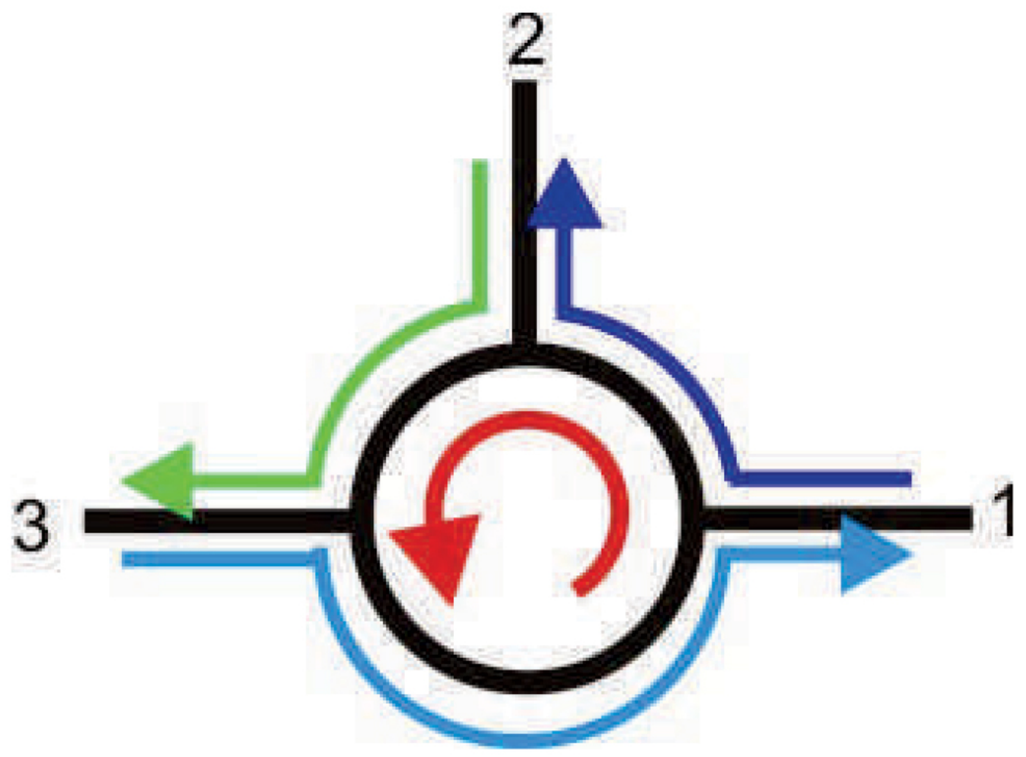


Figure17 – Schematic Drawing of an Optical Circulator.

Circulators can be used to provide bi-directional transmission over a single fibre. The high Isolation resulting from the circulator between the input and reflected optical powers and coupled with its low insertion loss, enable circulators to be used in Communication systems and fiber-optical censors.

Filters

A fibre optic filter described here has two or more ports, one port for input and one or more output ports.

Figure18 – Block Diagram of Optical Filter Breaking Out Wavelength "*i*" From a Signal Containing "*n*" Wavelengths

Figure18 shows the block diagram of a two port filter where P_{n0} is an input signal, P_{iout} is an output signal and λ_x denotes their wavelength.

Single-mode optical filter classes are generally distinguished as follows:

Short-pass filter – isolates longer wavelengths from the input optical signal so that the output optical signal spectrum contains shorter wavelengths.

Long-pass filter– isolates shorter wavelengths from the input signal so that the output optical signal spectrum contains longer wavelengths.

Fixed Band pass filter– transmits a band of wavelengths around a fixed central wavelength of an input signal while blocking other wavelengths.

6 Light that passes through a non-reciprocal device in one direction is not restored to its original condition when it passes through the device in the opposite direction.

Tunable Band pass filter– transmits a band of wavelengths around a central wavelength that can be tuned over a given wavelength range of an input signal, while blocking other wavelengths. Tunable filters can be active devices.

Band stop (or notch) filter – blocks a band of wavelengths of an input signal while transmitting other wavelengths. In some band stop filters the blocked wavelength band is reflected, as in Bragg-grating devices, as opposed to being discarded.

Gain Flattening filter- equalizes optical power within the wavelength region of interest. Gain flattening filters are used in conjunction with optical fibre amplifiers to "flatten" the wavelength-dependent gain of the amplifier.

Optical Isolator

An **optical isolator** is an optical component that allows the transmission of light in only one direction. It prevents unwanted feedback from reflected signals into an optical oscillator, such as a laser cavity. Reflections can cause performance degradations in lasers. The most effective way to address this issue is to position an isolator downstream from the optical transmitter. Optical circulators can also be used for this purpose.

Fibre Optic Filter Technology

The following is a selection of other filter types that may be used:

- Dielectric interference coating fused fibre couplers,
- Acousto-optic,
- Liquid crystal,
- Fibre Fabry-Perot cavities, and
- Fibre Bragg-gratings.

Additional information

If there are additional questions on this topic or other fibre optic issues, please contact Technologies at:

Contact Information
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