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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Deployment of Passive Optical Networks (PON)

ITU-T Recommendation L.52

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Deployment of Passive Optical Networks (PON)

Summary

This Recommendation describes the deployment of passive optical networks (PON) for the design and construction of optical access networks for fibre to the home (FTTH).

Source

ITU-T Recommendation L.52 was approved on 14 May 2003 by ITU-T Study Group 6 (2001-2004) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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Deployment of Passive Optical Networks (PON)

1 Introduction

In order to provide various types of broadband services such as data or video communication, it is important to construct optical access networks economically and effectively for fibre to the home (FTTH). The feature of the passive optical network (PON) is that a (fibre optic) branching component is placed between an optical line terminal (OLT) and several optical network units (ONU). The use of a PON is one of the most cost effective ways of realizing FTTH. Here, an optical access network is defined as a network of optical fibres that extends from a carrier's central office into individual homes, apartment houses and business offices for FTTH.

2 Scope

This Recommendation deals with the location of (fibre optic) branching components (in central offices, in outside plant or in customers' buildings, apartment houses or residential premises) and (fibre optic) branching components, which are the most important items in terms of PON design and construction. Moreover, this Recommendation describes the optical transmission performance and a maintenance system developed to design and construct optical access networks for FTTH.

3 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[1] ITU-T Recommendation G.652 (2003), *Characteristics of a single-mode optical fibre cable*.

[2] ITU-T Recommendation G.662 (1998), *Generic characteristics of optical amplifier devices and subsystems*.

[3] ITU-T Recommendation G.664 (2003), *Optical safety procedures and requirements for optical transport systems*.

[4] ITU-T Recommendation G.671 (2002), *Transmission characteristics of optical components and subsystems*.

[5] ITU-T Recommendation G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid*.

[6] ITU-T Recommendation G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid*.

[7] ITU-T Recommendation G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates*.

[8] ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on passive optical networks (PON)*.

[9] ITU-T Recommendation G.983.2 (2002), *ONT management and control interface specification for B-PON*.

[10] ITU-T Recommendation G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation*.

[11] ITU-T Recommendation G.983.4 (2001), *A broadband optical access system with increased service capability using dynamic bandwidth assignment (DBA)*.

[12] ITU-T Recommendation G.983.5 (2002), *A broadband optical access system with enhanced survivability*.

[13] ITU-T Recommendation G.983.6 (2002), *ONT management and control interface specifications for B-PON system with protection features*.

[14] ITU-T Recommendation G.983.7 (2001), *ONT management and control interface specification for dynamic bandwidth assignment (DBA) B-PON system*.

[15] ITU-T Recommendation G.983.8 (2003), *B-PON OMCI support for IP, ISDN, video, VLAN tagging, VC cross-connections and other select functions*.

[16] ITU-T Recommendation G.984.1 (2003), *Gigabit-capable Passive Optical Networks (GPON): General characteristics*.

[17] ITU-T Recommendation K.51 (2000), *Safety criteria for telecommunication equipment*.

[18] ITU-T Recommendation L.10 (2002), *Optical fibre cables for duct and tunnel application*.

[19] ITU-T Recommendation L.12 (2000), *Optical fibre joints*.

[20] ITU-T Recommendation L.13 (2003), *Performance requirements for passive optical nodes: sealed closures for outdoor environments*.

[21] ITU-T Recommendation L.15 (1993), *Optical local distribution networks – Factors to be considered for their construction*.

[22] ITU-T Recommendation L.26 (2002), *Optical fibre cables for aerial application*.

[23] ITU-T Recommendation L.31 (1996), *Optical fibre attenuators*.

[24] ITU-T Recommendation L.36 (1998), *Single mode fibre optic connectors*.

[25] ITU-T Recommendation L.37 (1998), *Fibre optic (non-wavelength selective) branching devices*.

[26] ITU-T Recommendation L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

[27] ITU-T Recommendation L.41 (2000), *Maintenance wavelength on fibres carrying signals*.

[28] ITU-T Recommendation L.42 (2003), *Extending optical fibre solutions into the access network*.

[29] ITU-T Recommendation L.43 (2002), *Optical fibre cables for buried application*.

[30] ITU-T Recommendation L.44 (2000), *Electric power supply for equipment installed as outside plant*.

[31] ITU-T Recommendation L.50 (2003), *Requirements for passive optical nodes: optical distribution frames for central office environments*.

[32] ITU-T Recommendation L.51 (2003), *Passive node elements for fibre optic networks – General principles and definitions for characterization and performance evaluation*.

[33] ITU-T Recommendation L.53 (2003), *Optical fibre maintenance criteria for access networks*.

[34] IEC 60825 (2001), *Safety of laser products*.

[35] IEC 60950 (2001), *Information technology equipment – Safety*.

4 Terms and definitions

For the purpose of this Recommendation, the definitions given in ITU-T Recs G.652, G.662, G.671, G.694.1, G.694.2, G.982, G.983.1 to G.983.8, G.984.1, K.51, L.13, L.26, L.42 and L.51 apply.

5 Abbreviations

This Recommendation uses the following abbreviations:

CATV Cable Television

FTTH Fibre To The Home

OLT Optical Line Terminal

ONU Optical Network Unit

PON Passive Optical Network

WDM Wavelength Division Multiplexing

6 Configurations of PON

In order to select a PON, telecommunication companies should consider the following:

1) the number and density of customers (including future demand);
2) construction and maintenance costs;
3) scalability (number of terminated fibres, total fibre length of network, etc.);
4) the optical network monitor and testing system.

Based on the requirements of PONs in each region, telecommunication companies should select one or more of the following locations for the (fibre optic) branching component, according to the practical feature when designing or constructing a PON. Moreover, telecommunication companies should select the (fibre optic) branching component taking into account the factors and performances as described in 9.3.

6.1 (Fibre optic) branching component in central office

The basic configuration for a (fibre optic) branching component used in a central office is shown in Figure 1. Here, there is at least one fibre between the central office and the customer's building, apartment house or residential premises. Therefore, a large number of fibres are installed and distributed from the central office. When an optical network monitoring and testing system is installed between a (fibre optic) branching component and an ONU in a central office, an individual optical fibre to a customer can be monitored and tested using the same method and functions as those employed for a point-to-point network as described in ITU-T Rec. L.40, because the test light can be launched in an individual optical fibre.

When the transmission capacity, transmission length or/and number of customers increases and optical network upgrade is necessary, the telecommunication companies should consider the method indicated in Table 1/L.42.

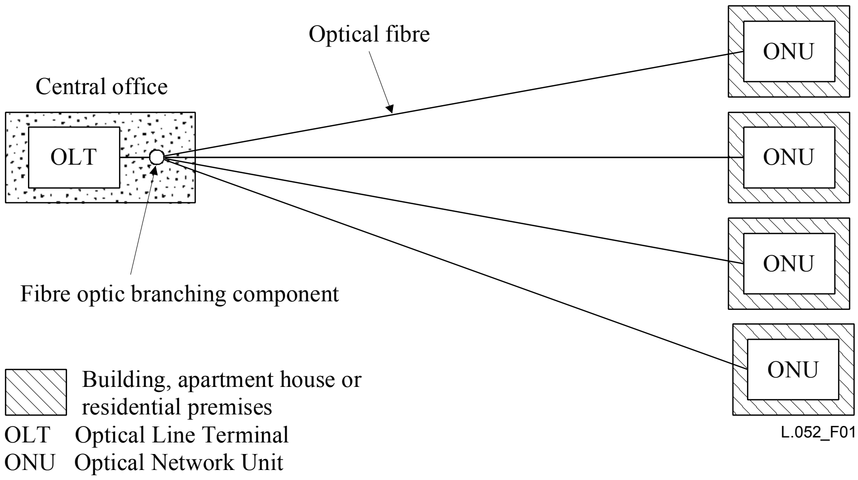


Figure 1/L.52 – PON configuration using (fibre optic) branching components for a central office (with 4 branches)

6.2 (Fibre optic) branching component in outside plant

The basic configuration for a (fibre optic) branching component used in an outside plant for a PON is shown in Figure 2. The (fibre optic) branching component is located in a closure or cabinet in the outside plant. Therefore, the number of distributed fibres between an OLT and a (fibre optic) branching component can be reduced.

When an optical network monitoring and testing system is established between an OLT and a (fibre optic) branching component in a central office, any individual outside plant optical fibre to (fibre optic) branching components can be monitored and tested by using the same method and functions employed for a point-to-point network as described in ITU-T Rec. L.40. However, additional functions, besides those indicated in ITU-T Rec. L.40, are required when an individual optical fibre from a (fibre optic) branching component to an ONU is monitored and tested.

When the transmission capacity, transmission length or/and number of customers increases and optical network upgrade is necessary, the telecommunication companies should consider the method indicated in Table 1/L.42.

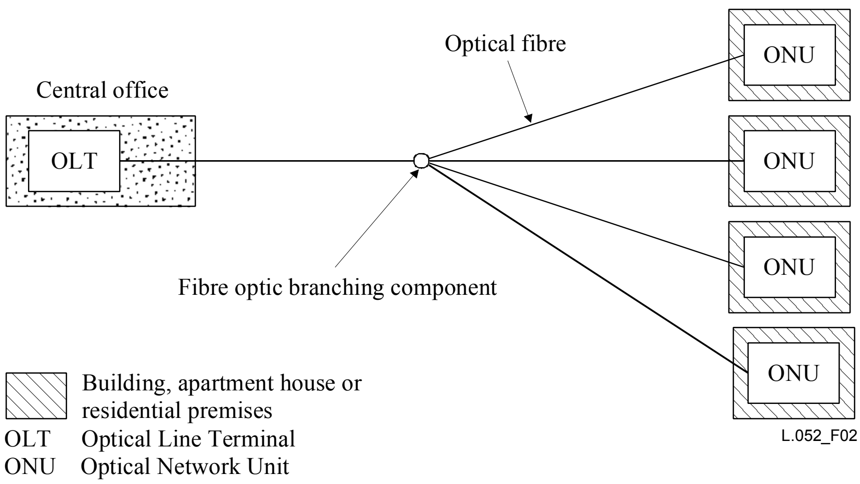


Figure 2/L.52 – PON configuration using (fibre optic) branching components for an outside plant (with 4 branches)

6.3 (Fibre optic) branching component in customer's building, apartment or residential premises

The basic configuration of a (fibre optic) branching component used in a customer's building, apartment or residential premises is shown in Figure 3. The (fibre optic) branching component is installed inside the customer's building, apartment or residential premises. Therefore, a small number of fibres can be installed and distributed between an OLT and a fibre optic branching component. Moreover, this is available when several ONUs in one customer's building, apartment or residential premises are used.

When an optical network monitoring and testing system is set up between an OLT and a (fibre optic) branching component in a central office, any individual optical fibre connected to the (fibre optic) branching component can be monitored and tested using the same method and functions used for a point-to-point network as described in ITU-T Rec. L.40. However, additional functions, besides those indicated in ITU-T Rec. L.40, are needed when an individual optical fibre from a (fibre optic) branching component to an ONU is monitored and tested.

When the transmission capacity, transmission length or/and number of customers increases and optical network upgrade is necessary, the telecommunication companies should consider the method indicated in Table 1/L.42.

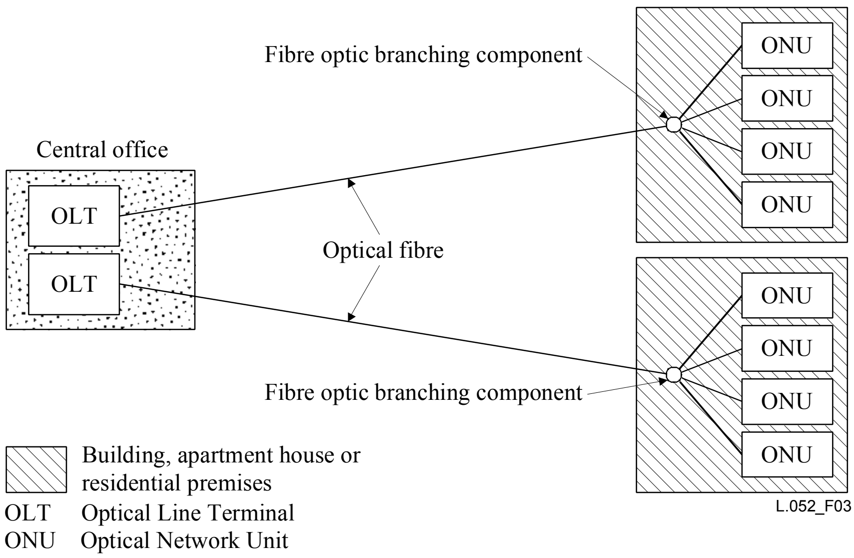


Figure 3/L.52 – PON configuration using (fibre optic) branching components for a building, apartment house or residential premises (with 4 branches)

7 Optical fibre distribution method in outside plant

The geographic conditions, population density, future fibre demand etc., may differ in each region. Therefore, telecommunication companies should consider an economical and effective optical fibre distribution method based on geographic conditions, population density, future fibre demand etc.

8 Optical transmission performance for PON

Optical access network routes must be selected and designed to meet the required levels of transmission performance (fibre type, attenuation range, differential optical path loss, return loss, dispersion, etc.) for PONs described in system Recommendations such as ITU-T Recs G.983.1 to G.983.8 or G.984.1.

NOTE – The calculation of the total network optical loss, including that of the (fibre optic) branching component, must take into account ITU-T Rec. G.982.

9 Optical components used in PON

The main optical components that constitute a PON are single-mode optical fibre cable, optical fibre joints (fusion splice, mechanical splice, fibre optic connector) and (fibre optic) branching components. These components should meet the following requirements.

9.1 Optical fibre cable

The single-mode optical fibre cable that is used should be as described in ITU-T Recs L.10, L.26 or L.43 and the fibre should normally be in accordance with ITU-T Rec. G.652.

9.2 Optical fibre joint

Optical fibre joints are formed by using a fusion splice, a mechanical splice or a fibre optic connector. The characteristics of fusion and mechanical splices should comply with ITU-T Recs G.671 and L.12. The fibre optic connector should be selected taking ITU-T Recs G.671 and L.36 into account.

For analogue CATV transmission, the return loss of the optic connector must be carefully considered in order to meet the system requirements.

When the transmission distance is limited by the total optical loss of a network with many optical fibre joints, the design should reduce the number of optical fibre joints.

9.3 (Fibre optic) branching component

When selecting a (fibre optic) branching component, telecommunication companies should consider:

1) the transmission system being used;
2) the number of customers, including future demand;
3) the transmission performance of the PON and the optical performance of the (fibre optic) branching component.

Based on the PON requirements in each region, telecommunication companies should select the (fibre optic) branching component taking into account the factors described below.

9.3.1 Types of (fibre optic) branching component

Two types of (fibre optic) branching component can be used in a PON. One type has a wavelength multiplexer and demultiplexer, the other does not.

The (fibre optic) branching component without a wavelength multiplexer and demultiplexer has three or more ports and optical power is shared among these ports in a predetermined fashion, without any amplification, switching or other active modulation, as shown in Figure 4a.

The (fibre optic) branching component with a wavelength multiplexer and demultiplexer has two or more input (output) ports and one output (input) port where the light in each input port is restricted to a preselected wavelength range (the output of each port is a different preselected wavelength range), and the output is a combination of the light from the input ports (the input is an optical signal comprising two or more wavelength ranges) as shown in Figure 4b. This is mainly used in WDM systems.

Telecommunication companies should select the (fibre optic) branching component taking into account the transmission system being used.

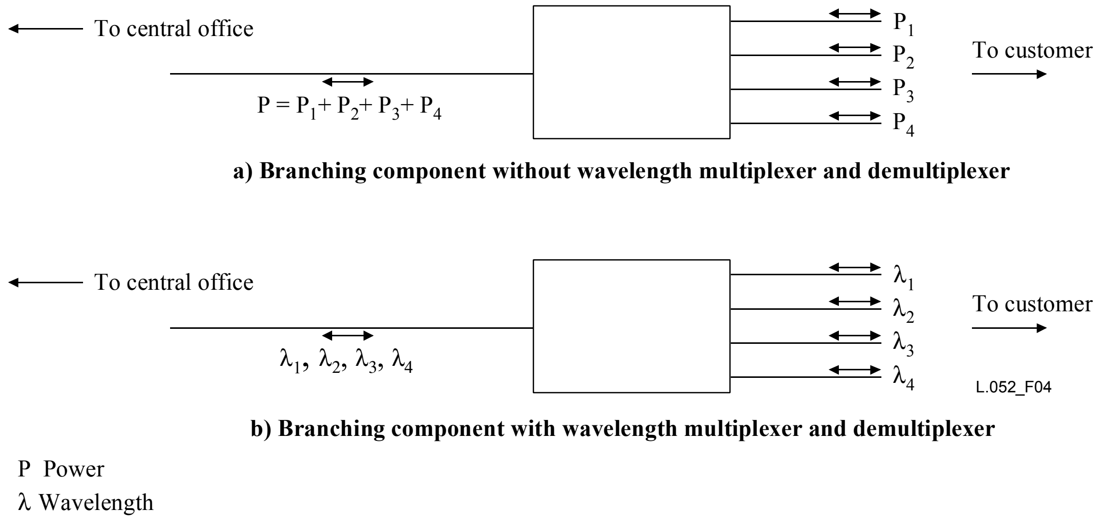


Figure 4/L.52 – (Fibre optic) branching component

9.3.2 Number of branches

The number of branches for the (fibre optic) branching component should be selected after having considered:

1) the number of customers, including future demand;

2) the maximum transmission distance and the total optical loss.

It is possible to respond to user demand in a flexible manner by increasing the number of branches. However, when a (fibre optic) branching component without a wavelength multiplexer and demultiplexer is used, the insertion loss increases if the number of branches is increased. By contrast, when a (fibre optic) branching component with a wavelength multiplexer and demultiplexer is used, the insertion loss does not increase greatly, but it is difficult to control and manage the wavelength when the number of branches is increased.

9.3.3 Optical performance

The optical performance of the (fibre optic) branching component should be in accordance with ITU-T Rec. G.671.

When the (fibre optic) branching component has an unused port and the return loss from this port is small, it is necessary to increase the return loss by using a suitable termination method for the port in order to meet system requirements.

9.3.4 Environmental conditions

Environmental conditions, namely temperature, humidity and mechanical conditions, may affect performance. These environmental conditions will differ from region to region, especially when using a (fibre optic) branching component for an outside plant. The (fibre optic) branching component should be designed and protected to enable it to operate under such conditions taking into account ITU-T Rec. L.37.

Moreover, adverse biological influences may cause a (fibre optic) branching component to fail. Therefore, the (fibre optic) branching component should be protected from biological factors relating to particular environmental situations.

9.3.5 Component footprints

The (fibre optic) branching component should be designed to be accommodated in an optical closure or a cabinet tray.

9.4 Other optical components

1) *Optical amplifier*

   An optical amplifier may be used to compensate for the insertion loss of the (fibre optic) branching component. The optical amplifier performance should be in accordance with ITU-T Rec. G.662.

2) *Optical attenuator*

   An optical attenuator with either fixed or variable attenuation is necessary to adjust optical power budgets to the required ranges. The performance of the optical attenuator should be consistent with ITU-T Recs G.671 and L.31.

3) *Optical filter*

   An optical filter may be necessary to allow the required wavelengths used for a particular service to pass and to reject other service wavelength regions or optical test wavelengths within a network. The filter should have a spectral response that can select very narrow or very broad wavelength regions depending on the application. The optical filter performance should be in accordance with ITU-T Rec. G.671.

4) *Optical distribution frames (ODF)*

   An optical distribution frame, which can both contain and protect the optical fibres, passive optical components and route, and store the pigtail in an indoor environment, is necessary to attach the cables at the end of the cable sheath. The performance of the optical distribution frame should take into account ITU-T Rec. L.50.

10 Optical network maintenance support, monitoring and testing system

When using a (fibre optic) branching component in a central office, as shown in Figure 1, the optical network maintenance support, monitoring and testing system should be as described in ITU-T Rec. L.40. The maintenance wavelength shall be chosen according to ITU-T Rec. L.41.

When using a (fibre optic) branching component in an outside plant, as shown in Figure 2, or in buildings, apartment houses or residential premises, as shown in Figure 3, the optical network maintenance support, monitoring and testing system should be as described in ITU-T Rec. L.53. The maintenance wavelength shall also be chosen in accordance with ITU-T Rec. L.41.

11 Electrical power supply

The electrical power supply and battery backup to an ONU should be selected taking into account the outage rate of commercial power suppliers, the cost when using commercial power suppliers and the time needed to repair a power source failure as described in ITU-T Rec. L.44.

12 Safety

12.1 Electrical safety

Electrical safety should take into account ITU-T Rec. K.51 and IEC 60950.

12.2 Optical safety

Optical safety should take into account ITU-T Rec. G.664 and IEC 60825.

Appendix I

Japanese experience
Requirements of a (fibre optic) branching component for outside plant

I.1 Access network configuration using a (fibre optic) branching component

Figure I.1 shows an access network configuration using (fibre optic) branching components for a central office and an outside plant of an access network. We investigated a new compact (fibre optic) branching component for an outside plant to allow us to reduce the number of optical fibres in the feeder and distribution area in an optical access network.

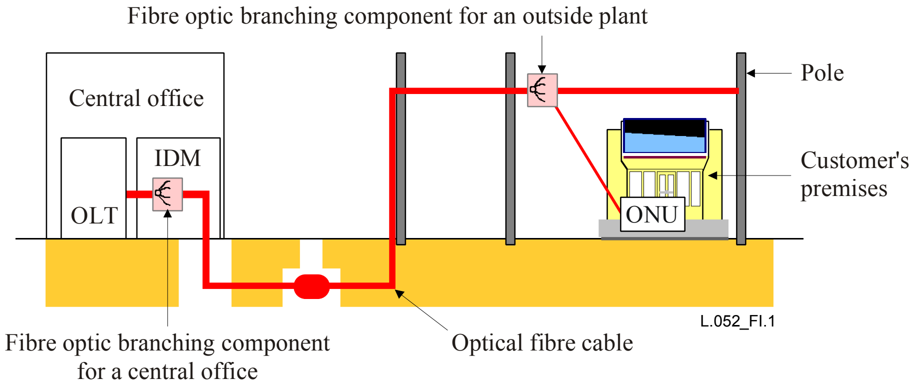


Figure I.1/L.52 – Configuration of optical fibre network using a (fibre optic) branching component for a central office and an outside plant

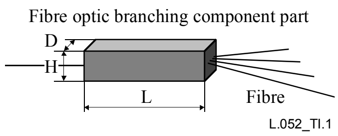
I.1.1 (Fibre optic) branching component requirements

Table I.1 shows the requirements for a (fibre optic) branching component. The splitter must allow 1310 and 1550 nm wavelength light to pass so that it can be applied to an ATM-PDS system using those wavelengths.

The splitter must be the same size as a reinforced fusion splice or mechanical splice so that it can be accommodated in a closure or cabinet tray.

In environmental tests, the (fibre optic) branching component must have the same, or smaller, loss changes as those of the MT connectors and mechanical splices that we use in aerial closures and cabinets in access optical networks. The operating temperature range should be –40 ~ 70° C, because (fibre optic) branching components are used in aerial closures for outside plants. The (fibre optic) branching components must also have stable characteristics in water immersion and salt spray tests, because the splitters may be used in underground closures immersed in water and in aerial closures in salty air near the sea.

Table I.1/L.52 – Requirements for (fibre optic) branching components for an outside plant

Items		Requirements	Remarks
Operation optical wavelength		1310, 1550 nm	
Size	Height	≤ 4 mm	
	Depth	≤ 4 mm	
	Length	≤ 40 mm	
Environmental characteristics	Temperature	Small loss change, – 40 ~ 70° C	Same or smaller loss changes as those of MT connectors and mechanical splices
	Vibration	Small loss change	
	Impact		
	Water immersion		
	Salt spray		

I.2 Performance of a (fibre optic) branching component for an outside plant

We used planar lightwave circuit (PLC) technology to miniaturize the (fibre optic) branching component. Figure 2 shows a prototype 4 branch (fibre optic) branching component. Its height, depth and length are less than 4 mm, 4 mm and 40 mm, respectively.

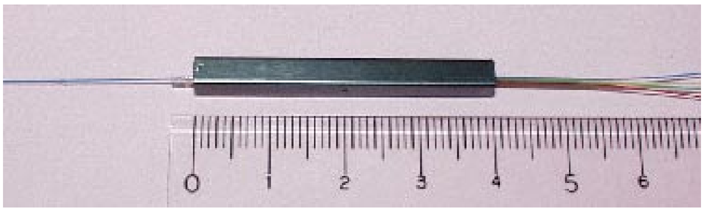


Figure I.2/L.52 – Photograph of prototype (fibre optic) branching component

I.2.1 Optical characteristics

Table I.2 shows the initial optical characteristics of a prototype (fibre optic) branching component at wavelengths of 1310 and 1550 nm. The maximum insertion loss, including two connection points between the PLC chip and the fibres, was 6.92 dB. The excess loss of the (fibre optic) branching component was less than 1 dB, because the loss of the 4 branches was 6 dB. The minimum return loss was 56.5 dB and the maximum polarization dependent loss was 0.17 dB. We confirmed that the prototype (fibre optic) branching component has satisfactory optical loss characteristics.

Table I.2/L.52 – Optical characteristics

Items	Wavelength (nm)	Loss (dB)			
		Port 1	Port 2	Port 3	Port 4
Insertion loss	1310	6.57	6.62	6.87	6.64
	1550	6.55	6.71	<u>6.92</u>	6.61
Return loss	1310	58.7	58.6	58.5	58.7
	1550	<u>56.5</u>	56.6	56.6	56.6
Polarization dependent loss	1310	0.14	0.14	<u>0.17</u>	0.14
	1550	0.11	0.12	0.07	0.08
__ The underline indicates maximum insertion and polarization dependent loss and minimum return loss values.					

I.2.2 Environmental characteristics

We measured the environmental characteristics at 1310 nm as shown in Table I.3. The test conditions were the same as those of GR-1209-CORE[1] and GR-1221-CORE[2]. We measured the loss change of each port before and after each test. From these results, we confirmed that the (fibre optic) branching component characteristics were the same as those of an MT connector or mechanical splice.

Table I.3/L.52 – Environmental and mechanical performance

Items	Conditions	Results
Temperature cycling	–40 ~ 85° C, 100 cycle, 1° C/min, dwell time at extremes: 5 hrs	< 0.2 dB
Vibration	10 ~ 55 Hz, 1.52 mm amplitude, for 2 hrs	< 0.1 dB
Impact	1000 G, 0.5 ms, 8 cycle, 3 axes	< 0.2 dB
Water immersion	43° C, PH 5.5, 168 hrs	< 0.2 dB
Salt spray	85° C, 5% NaCl dissolved in 95% distilled water, 168 hrs	< 0.2 dB

We also evaluated the method for accommodating the (fibre optic) branching component in an optical aerial closure or cabinet tray in terms of practical use. Figure I.3 shows a photograph of a (fibre optic) branching component accommodated in an optical aerial closure and cabinet tray. We confirmed that the (fibre optic) branching component could be successfully accommodated in both the closure and cabinet tray.

[1] GR-1209, Passive Optical Components Testing, NTS Fibre Optics Testing Lab.

[2] GR-1221, Testing, Reliability assurance requirements for passive optical, NTS Fibre Optics Testing Lab.

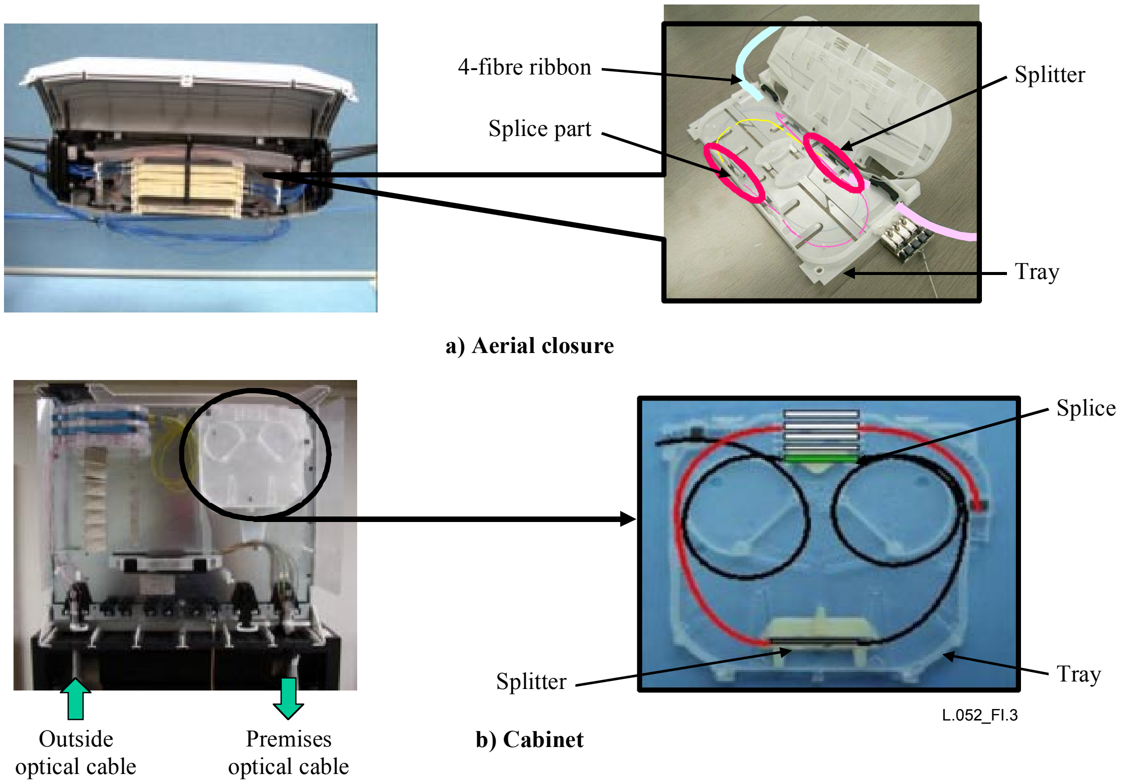


Figure I.3/L.52 – Photograph of a (fibre optic) branching component accommodated in an optical closure and a cabinet

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