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**CONSTRUCTION, INSTALLATION AND
PROTECTION OF CABLES AND OTHER
ELEMENTS OF OUTSIDE PLANTS**

**OPTICAL LOCAL DISTRIBUTION
NETWORKS – FACTORS TO BE
CONSIDERED FOR THEIR
CONSTRUCTION**

ITU-T Recommendation L.15

(Previously “CCITT Recommendation”)

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation L.15 was prepared by the ITU-T Study Group VI (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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INTRODUCTION

The existing local distribution network for customer access consists almost entirely of copper pairs for all countries. However, recent progress in the application of optical plant technology to local distribution networks has provided substantial experimental experience in several countries. This has been taken into account to determine some of the factors to be considered for construction of optical local distribution networks.

Firstly, it may not be appropriate simply to replace copper conductor cables by optical fibre cables since the characteristics of optical fibre cables differ very significantly from those of copper conductor cables. Secondly, advances in technology provide potential for a greatly increased range of services that can include wideband direct to the customer. Network architectures therefore require to be determined taking into consideration both operational and maintenance system requirements.

This Recommendation sets out practical advice on choice and use of optical plant for the construction of optical distribution networks. Several different architectures are described in the annex to this Recommendation to assist in understanding the selection of hardware. The advice given is based on the experience gained mainly from early applications and the user should be aware that rapid progress will lead to early revision of this Recommendation.

Recommendation L.15

OPTICAL LOCAL DISTRIBUTION NETWORKS – FACTORS TO BE CONSIDERED FOR THEIR CONSTRUCTION

(Helsinki, 1993)

1 Scope

This Recommendation:

- deals with optical distribution networks constructed from single-mode fibre cables;
- sets out physical network architectures that have been used to meet differing system objectives;
- takes account of environmental conditions in customer serving areas;
- makes reference to system related requirements relevant to the work of Study Group XV;
- refers to passive optical components used for construction of the network;
- deals with installation and maintenance issues;
- considers electrical power supply; and
- considers optical safety requirements.

2 Abbreviations

Abbreviations are used in this Recommendation as set out below:

- FTTC Fibre to the Curb
- FTTH Fibre to the Home
- OFA Optical Fibre Amplifier
- OPS Optical Power Splitter
- ONT Optical Network Termination
- PON Passive Optical Network
- WDM Wavelength Division Multiplex device.

3 Concept of layers within a network architecture

3.1 Layer classification

It is helpful to consider functions of a network conceptually classified in terms of layers, each dealing with different aspects of its construction and operation. These aspects may first be divided into a Transport layer, containing further layers of physical plant and circuit configurations, and an Intelligent layer, consisting of the computer controlled software programs that are used to run the network.

The physical plant layer is the subject of this Recommendation and may be further divided into more layers considered as comprising an:

- optical fibre layer;
- optical fibre cable layer;
- structural facility layer.

3.1.1 Optical fibre layer

A suitable choice of fibre and splicing technology should be made. Single-mode fibre, normally to Recommendation G.652 is the most appropriate for a wide range of telecommunications services in the local distribution network since this fibre benefits from an economy of scale and has long-term potential for future services. With current usage of single-mode fibre, splicing techniques will allow average splice losses of less than 0.5 dB to be achieved. Passive components may be used in conjunction with optical fibre and thus are considered as part of the optical fibre layer.

3.1.2 Optical fibre cable layer

This requires cable design and fibre sizes to be determined appropriate to the network architecture adopted, see clause 4.

This layer will include optical plant hardware such as splice closures, cabinets and housings for OPSs, WDMs, OFAs, connectors and patch panels, all of which have specific environmental constraints.

3.1.3 Structural facility layer

Where this layer was evolved for copper networks it is usually in the form of a star radiating from the exchange. Therefore, it will allow the introduction of optical spines to generate the network architectures discussed in the Annex A. Hence, the changes required for optical networks concern mainly the manner in which the optical cables and optical fibres are deployed within the outside plant. However, use of optical plant may lead to development of new structures and plant layout. For example, a duct installed for the copper network may be sub-divided, compartmented, using appropriately sized plastic tubes, each to accommodate one of the smaller diameter optical cables. Also, special consideration shall be given to aerial support structures for optical cables.

4 Optical fibre cable

Cables of single-mode optical fibre shall be used which comply with Recommendation L.10 for the cable and normally Recommendation G.652 for the fibre. They shall be constructed and installed in accordance with the manual “Construction, installation, jointing and protection of optical fibre cables” [1].

It is best to avoid the need for a large number of different designs of optical cable that may involve different skills for their use. Experience has shown that the local distribution network may use the same design as for other networks. Ribbon cable may be attractive for high fibre count cables, with small and lightweight low fibre count cables being required for customer access.

5 Passive optical components

Guidance on passive optical components is in preparation for a new chapter to be published in the revision of the manual “Construction, installation, jointing and protection of optical fibre cables” [1].

In this Recommendation, a passive optical component is considered to be an optical component with no active electronics. That is, there is no electrical to optical conversion within the device. Although actively powered, OFAs are classified as passive optical components since they operate through stimulated emission of a rare earth doped fibre, which is in itself passive when considered in relation to the above definition.

Examples of passive optical components which may be required in a local distribution network are:

- fusion and mechanical splices;
- optical connectors;
- OPSs;
- WDMs;

- optical attenuators;
- optical filters;
- OFAs;
- optical isolators.

Further aspects to consider for use of passive optical components listed in the above examples are given below:

- Fusion and mechanical splices are considered in detail in Recommendation L.12. The choice of the splicing technique used in an optical local distribution network depends upon a number of factors such as performance, cost, physical location, specific system requirements, and maintenance considerations. Splice points are often required to provide a point of flexibility.
- Optical connectors provide a means of flexibility for rapid re-configuration within a network. Mated connectors can provide a test access point for maintenance or test access may be gained by a connector through a spare OPS leg.
- OPSs split the optical power from the input fibre to two or more output fibres. The split may be equal or asymmetric between the output fibres, it can be designed to split at a specific ratio for a specific wavelength, or it can be made insensitive across a wavelength range. For the local distribution network splits of between 2 and 32 output fibres are generally appropriate.
- WDMs are necessary to multiplex and demultiplex various services carried by different wavelengths on a single fibre. They may be either simple two wavelength region devices or high resolution devices for resolving many tens of closely spaced wavelength regions.
- Optical attenuators with either fixed or variable attenuation are necessary to adjust optical power budgets to the required ranges.

NOTE – Temporary attenuators, such as clip-on attenuators, can be applied to live fibre networks by macro-bend techniques. These are useful for reducing optical power to a safe level when working on a system and for reducing reflected power returned into a system from a bare fibre end. These techniques are particularly applicable to live working.

- Optical filters are necessary to pass the required wavelength region of a service and to reject other service wavelength regions or optical test wavelengths within a network. The spectral response of the filter may select very narrow or very broad wavelength regions depending upon the application.
- OFAs provide compensation for optical fibre and other passive component losses.
- Optical isolators are of particular benefit for a complex network since they provide immunity from the many sources of optical reflection intrinsic to the design of local distribution networks. They may also be used to isolate sections of a network for the purpose of live working during maintenance.

6 Network installation and maintenance

Installation and maintenance procedures are extremely important matters which should be taken into account when considering costs for the future deployment of optical fibre in local distribution networks.

Whenever possible, installation procedures should require only a low skill level from personnel. All stages of network construction may be monitored optically and sheath joints closed after testing has been completed. Splicing methods with splice loss prediction can be beneficial.

Maintenance of the network should be carried out whenever possible while the system is live and faults detected, diagnosed and repaired without service interruption. Optical network maintenance using, for example, OTDRs and clip-on techniques can be used to supplement point-to-point transmission monitoring processes.

Diverse routing providing a standby network will allow planned rather than reactive maintenance techniques to be used for repair of faults within the network. Diverse routing is particularly important for the high revenue earning or high-risk sections of a network.

This subject requires further study based on experience with optical local distribution networks to increase the detail of the advice given in this clause.

7 Electrical power supply

Optical local distribution networks can provide a problem for the supply of power to the ONT. All experiments to date rely on commercial power or an auxiliary copper power supply network. Loss of commercial power presents a high risk of losing service to these systems. A solution to this problem is required to enable high deployment of optical local distribution networks to take place.

8 Optical safety

This subject needs further study.

International standards shall be referred to as appropriate, e.g. IEC Publication 825.

9 Other local distribution network references

Particular attention is drawn to the Local Network Guide being produced by Working Party XV/4 [2].

References

- [1] CCITT manual Construction, installation, jointing and protection of optical fibre cables, ITU, Geneva 1988.
- [2] CCITT Study Group XV, Reports R 60 and R 65, Working Party XV/4 (Local Network Guide).

Annex A

(This annex forms an integral part of this Recommendation)

A.1 Introduction

The contents of this annex are a result of the close liaison achieved between the study of Study Group VI and Study Group XV. Study Group VI acknowledges the contribution of Study Group XV for the compilation of the useful and essential reference material contained in this annex.

A.2 Network architectures

A.2.1 General considerations

The aim for the choice of a network architecture together with optical plant hardware with which it is constructed, shall be to provide a transparent infrastructure which will enable both current and future needs to be met. This will allow the choice of different transmission systems to be introduced according to changing service requirements. The transmission performance of systems is being studied by Study Group XV. This performance sets constraints for the physical and optical performance of the hardware, such as:

- attenuation (due to losses in WDMs, OPSs, fibres, splices, backscatter; counteracted by OFAs);
- optical return loss (due to reflections at WDMs, OPSs, splices, connectors and Rayleigh backscatter from fibre);

- near-end crosstalk or directivity (due to WDMs);
- far-end crosstalk or isolation (due to WDMs);
- dispersion (due to fibre);
- non-linearities (due to OFAs and high-powered lasers);
- mechanical and environmental constraints.

Some of these parameters may be very critical for various transmission systems and their wavelength dependency should be evaluated and taken into account, e.g. attenuation and return loss for analogue TV, return loss for bidirectional systems. Therefore, it is important to pay attention to these inherent performance aspects, as well as those set by Study Group XV, when designing and constructing an optical local distribution network.

A.2.2 Different architectures

The optical network may or may not enter the customer's premises and the physical interface between ONT and customer terminals may be based on either fibre, copper or cordless radio. The ONT converts the optical signal to an electrical signal and the inverse. The ONT can be sited at the curb or at the customer's premises and may be either dedicated or shared between customers. The optical network may be operated with active multiplexing, as a passive system or as a hybrid active/passive network. Both way services may be implemented using WDM or duplex over a single fibre. The passive network does not use signal regeneration within the external plant of the local distribution network.

An optical network consists of optical links interconnected at network nodes. By convention, the terms "Tree and Branch" and "Star" have become accepted as standard terminology to describe network configurations for the interconnection of optical links at network nodes. These are similar in configuration and for the purpose of this Recommendation they are defined as follows:

- Tree and Branch networks have passive components at the network nodes to interconnect the optical links;
- Star networks have active devices at network nodes to interconnect the optical links.

Configurations for several different architectures are shown in Figures 1 to 4 and are considered individually in the following.

A.2.2.1 Point-to-point (Figure 1)

This architecture uses at least one dedicated optical fibre from exchange to customer. Such an approach may be suitable for users requiring large bandwidths and/or high security. The low optical loss of this architecture allows the maximum distance between exchange and customer to be increased with respect to a tree and branch network. Advantage may also be taken to make use of simpler technology for opto-electronic devices. The point-to-point architecture provides the possibility for fewer and larger exchanges.

A.2.2.2 Multiple star (Figure 2)

This is a network that shares fibre among several customers by using active electro-optic multiplexers with the network. High multiplexing is used between the exchange and a remote node and may use multiplexed or dedicated fibre from the remote node to the ONT. Active electronics in the remote terminal reduces the amount of fibre required between it and the exchange. The ONT is located at the customer's premises for FTTH. For FTTC, the ONT is located at the curb or at the premises of a multi-customer location. Copper pairs, coaxial pairs, or cordless radio from a group of customers are multiplexed onto a single fibre at the ONT.

Upgrading to provide wideband services is not as easy as with point-to-point or tree and branch. However, sharing the fibre from remote node to the customer may be sufficient to enable the introduction of optical fibre to replace copper in the local distribution plant, prior to the availability of broadband services.

A.2.2.3 Tree and Branch (Figure 3)

This is a passive network that shares fibre among several customers using OPSs and does not use electro-optics within the network. The use of OPSs enables a complete wideband optical link to be provided for FTTH over a PON. Non-selective broadcast TV or other wideband unidirectional services from the exchange end may be provided by electro-optical multiplexing. Optical maintenance of the network can be complex on account of the difficulty to carry out testing through the OPSs in the network.

A.2.2.4 Ring (Figure 4)

The ring or loop starts and ends at the same exchange. This architecture, however, is logically equivalent to one, or a combination of two or more of the above. Examples of this are shown by Figure 4a (point-to-point type) and 4b (double star type). Of particular benefit for reliability and maintenance is the opportunity afforded for alternative routing.

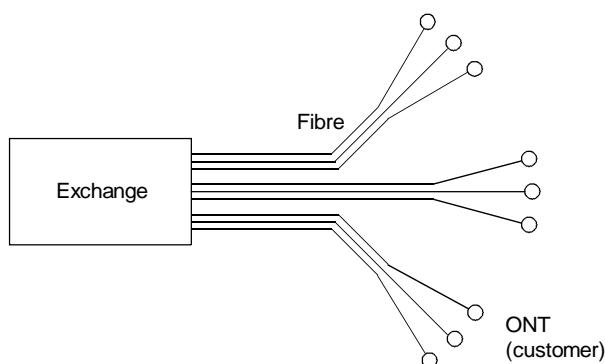
A.2.3 Use of different architectures

The network architecture should be chosen taking into account the services to be provided, the density of customers, exchange service areas, network operation and maintenance, and technology available.

Optical fibre cables have been deployed into local distribution networks to provide conventional telephone services in addition to video services and high-speed digital services in several countries. At the present stage, different network architectures have been used depending on the services to be provided and the customer distribution.

To provide broadband or high-speed services such as video services and high-speed digital services, all the above architectures have been used. For conventional telephone services, which can also be provided by copper networks, some form of sharing of an optical fibre between a group of customers can be applied to avoid additional civil work programmes and to reduce the number of active equipment in the network.

Further study will be needed before coming to a conclusion on the choice of network architecture.



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FIGURE 1/L.15
Point-to-Point (Start)

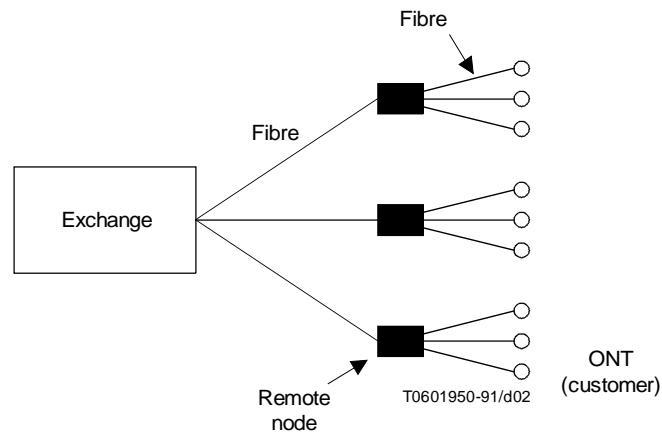


FIGURE 2a/L.15
Multiple (Double) Start

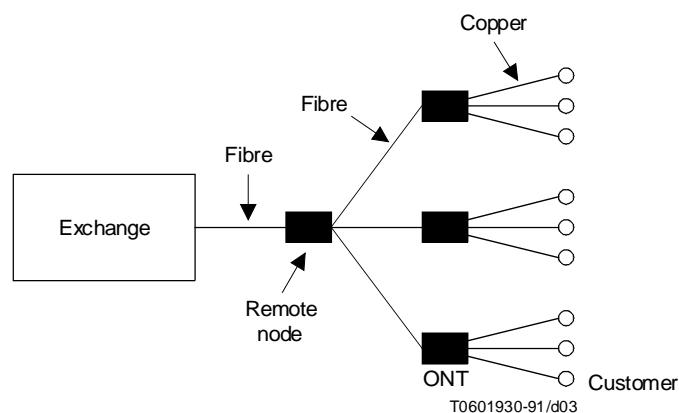


FIGURE 2b/L.15
Multiple (Triple) Start

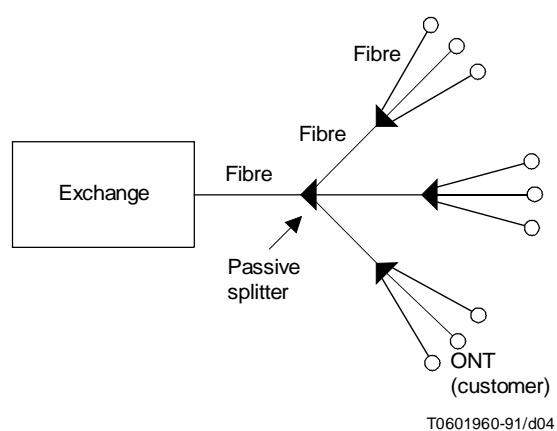


FIGURE 3/L.15
Tree and Branch

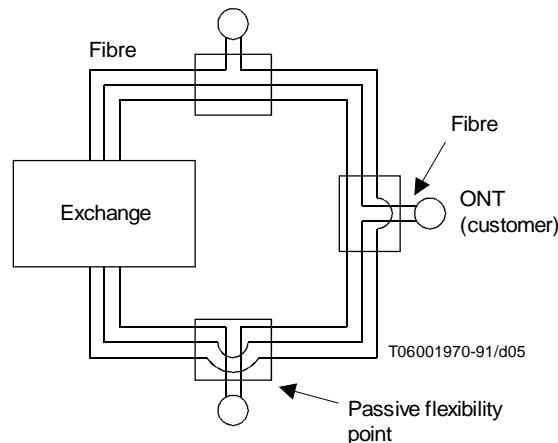


FIGURE 4a/L.15
Ring (Point-to-Point type)

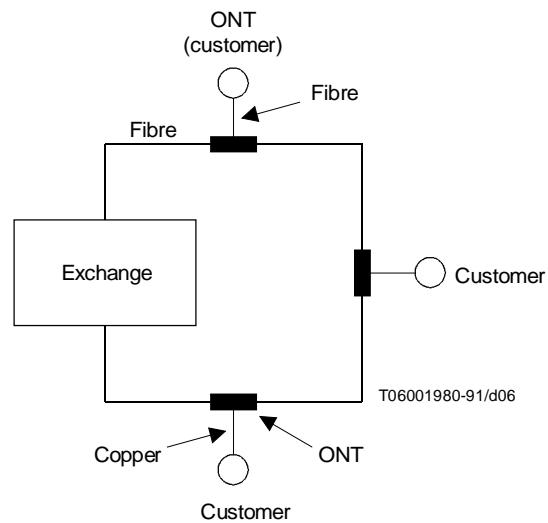


FIGURE 4b/L.15
Ring (Multiple Double Star type)

Note to figures 1 to 4:

Alternatives of fibre or copper to the customer are shown.