OTDR Measurements on PON Network with Utilization of Optical Fiber G.652.D

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Abstract: - This article is devoted to the measurement and analysis of passive optical networks PON (Passive Optical Network) with and without utilization PLC (Planar Lightwave Circuit) splitter. The real network simulation is done as a prevention of complications in the final construction of optical network, which is designed for specific user requirements. The article describes connections between two campuses. The optical networks were first designed, and afterwards simulated and implemented. These buildings are connected by single mode fiber G.652.D (706.4 m) terminated with SC / PC and optical splitter (PLC) with the ratio of 1:8 and insertion loss of 10.8 dB. Main contribution of this paper was comparison of the difference between measured parameters of optical networks and demonstration when it is better to use an optical splitter, and when it is better to connect the fibre directly.

Key-Words: - OTDR, Optical splitter, PLC, PON

1 Introduction

In the last decade the optical communications systems became well discussed topic among domestic and foreign authors. The components of optical systems were theoretically analysed, and in practice effectively used particularly in the sphere of telecommunications. The use of optical fibre and sources of coherent light were a great motivation for many scientists to develop optical communication systems.

The optical fibres are nowadays considered as an efficient transmission medium designed to transmit a large amount of data over a long distance. Compared to other transmission media (e.g. a free space and copper cables) they have exceptional qualities [1-3]. The optical networks are divided by way of sharing used fibres and network termination units to point-to-point (P2P) and point-to-multipoint (P2MP) networks.

For the P2P optical networks is transmission path and each communication unit at the end side intended for one end user. For P2MP optical networks is part of the optical infrastructure including central communication units shared by a greater number of end users.

2 Passive Optical Network

Passive Optical Network PON is one of the most important directions in the deployment of optical access networks. Therefore between the control panel of Internet service provider and the end customer is not required to use any powered active network elements such as the AON. PON networks are multi-point networks (Point to Multipoint), which means that to one central element is connected a large number of users (32-128), who will share a single transmission medium for access to required services.

On the whole transmission path are only passive optical elements that serve to divide the optical signal into all directions without amplification or modification of signal. In the downlink, the entire communication is from the central unit OLT (Optical Line Terminator) using the hub equally distributed to all connected users, regardless of for whom are data intended [4], [5]. The actual selection of data is transferred on the terminal equipment ONU (Optical Network Unit), or the end terminal ONT (Optical Network Termination).

On the user side are selected specific data from the accepted framework for a particular user and other data are discarded. Data transmitted from the OLT are coded therefore another user on the network could not read data that are not intended for him. The Fig. 1 provides a scheme for PON architecture.

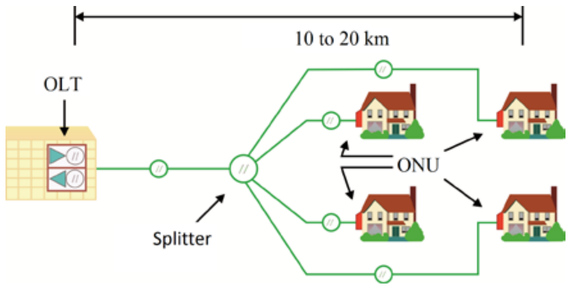

Fig. 1: Scheme of the PON architecture.

2.1 Structure of PON

The basic elements for the implementation of PON include:

2.1.1 ONT (Optical Network Termination)

Ending on the user side, which is responsible for the adaptation of protocols and their conversion interface between the user (or the local network) and optical access network. In this device is the end of an optical fiber network during the direct interconnection of the customer network with this device. NT (Network Termination) is used in telecommunications for the generic labelling of network termination, which is mostly localized on the user side.

2.1.2 ONU (Optical Network Unit)

In this case, we are talking about a generalized version of the ONT, the end on the user side. The main difference, compare to the previous optical unit, is in its location in the hierarchy OAN and implementation of end-user connectivity using metallic or wireless network that immediately follows on the ONU device. The main difference can be seen in the number of connected users, which is in this case compare to ONT multiple. With the transition to a different type of signal on the interface transmission media is evident conversion of the optical signal into an electrical or radio, and vice versa.

2.1.3 OLT (Optical Link Termination)

Optical terminating unit is located on the provider side and is owned by Telecommunication Company. It is responsible for connection to backbone networks, used-protocol conversion and distribution of the management of clock signals. Fundamental part of this activity is the management and supervision of individual terminal units ONT and ONU.

2.1.4 ODN (Optical Distribution Network)

It is constituted by all optical transmission means between units OLT, ONT and ONU. This area includes connecting and interfacing elements: optical fibers, connectors, couplers, filters, splitters elements: active or passive optical splitters, wavelength filters, multiplexers. The usual ODN topology is a star, a multistage star, a bus or a circle.

2.1.5 OAN (Optical Access Network)

Is a set of optical distribution networks ODN connected to one central node. The basic blocks of the OAN are in Fig. 2.

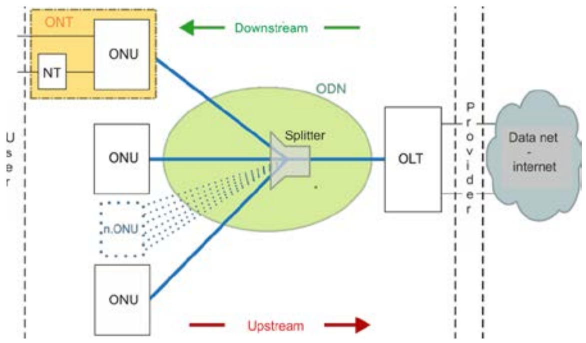

Fig. 2: Scheme of elements OAN.

3 Optical splitter

The fiber splitter is a passive network element specifically designed for PON networks. In FTTH systems, which are operated in PON networks, are generally a two-way passive elements that have one input port and several output ports (2-128). The function of the splitter is to split the optical signal from input to several outputs and in the reverse direction to merge it [8-11]. The splitter can be designed for a specific wavelength, or works with all wavelengths commonly used in optical transmission. Splitter is the largest insertion loss across the optical path. It is necessary to take into account the allowed optical signal attenuation due to a path attenuation, which is considered for EPON about 25 dB.

The exclusive advantage of splitters is that merging and splitting of optical signals happens passively, thus eliminates the need for the implementation supply network and overall equipment reliability is very high. According to the production technology, splitters can be divided into Fused Bionic Taper (FBT) or Planar Lightwave Circuit (PLC).

3.1 Fused bionic taper (FBT)
FBT splitters are made by connecting the optical fibers at high temperature and pressure, when the fiber coats are melted and connected fibers cores get close to each other. This technology makes fiber bundles 2 to 4, which are cascaded for achieving more output ports. The technology is used primarily for smaller number of output ports [12-14]. Fig. 3 shows a splitter FBT where *x* is the connection for determining the degree of flattening and *z* are common parts.

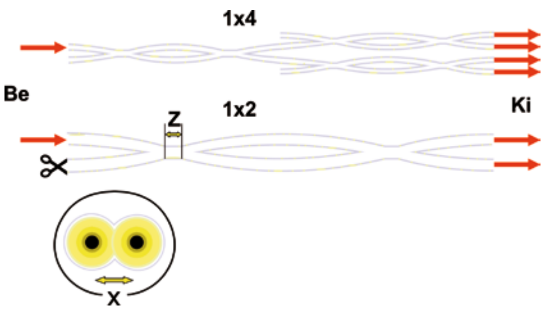

Fig. 3: Principle of FBT technology splitter.

3.2 Planar Lightwave Circuit (PLC)
PLC splitters are produced by planar technology. The desired structure is formed by technological process on a silicon substrate. The splitter with up to 128 output ports can be produced by this technology. It is used mainly for splitters with a higher number of output ports. Fig. 4 shows the principle of a splitter manufactured by PLC technology. For splitters can be defined these basic parameters:

- **Branching ratio**. It is a mathematical expression of the splitter outputs N, which is usually given as a ratio 1: N. Typical passive optical splitters achieve a splitting ratio of 1:2, 1:4, 1:8, 1:16, 1:32, 1:64 or 1:128.
- **The splitting ratio.** It expresses the rate at which the power of optical signals at the outputs of the splitter is to each other. We distinguish symmetric splitters, which outputs in terms of separation performance are identical and asymmetric, having various optical performances on its outputs.
- **Insertion loss.** Splitter attenuation depends on the number of outputs and each output channel attenuation depends on whether the splitter is symmetrical or asymmetrical.
- **Uniformity of splitter.** This parameter is related to the insertion loss of splitter. It represents a attenuation variation between the individual outputs of the symmetrical splitter, or variations of attenuation produced by splitter from the ideal state of asymmetricity. Impact of manufacturing uncertainties creates minor deviations from the ideal attenuation of the proposal and the final real splitter. These variations represent an additional insertion loss, with which it is necessary to calculate the ODN design. Today, manufacturers often indicate an average or maximum uniformity; thereby guarantee that purchased splitter does not exceed this value.

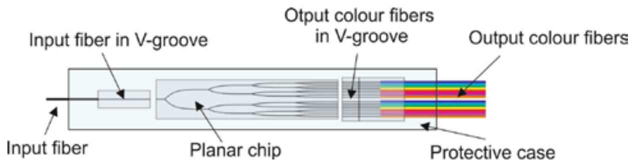

Fig. 4: Principle of PLC technology splitter.

Connecting splitters to the optical infrastructure ODN can be realized by connectors, welds or joints. It is often placed along with cartridges with stored reserves of optical fiber cables and pigtails in stands of optical distributors in van with standardized height in multiples U (Rack Unit = 45 mm).

4 Evaluation of PON by OTDR
Nowadays, in case of damage or interruption of optical fiber, we need to find out at what distance from the beginning the problem disorder is [9], [10]. The backscatter method, also called OTDR (Optical Time Domain Reflectometer), is based on the periodic transmission of the short optical pulse to the optical fiber.

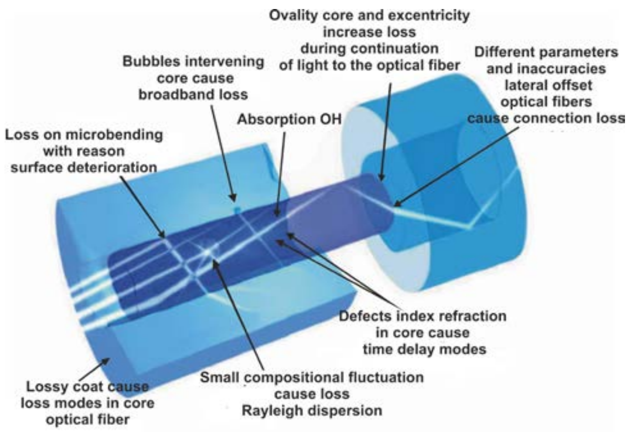

Fig. 5: Scatterings that can be detected by OTDR.

Due to the Rayleigh scattering in micro-inhomogeneities in the volume of optical fiber core, a part of the optical power is reflected back to the beginning of the optical fiber and due to Fresnel reflection, big inhomogeneities caused by dirt such as connectors or other interruptions in the optical fiber, can be located (Fig. 5).

4.1 Measurements using OTDR

For evaluation of the optical route between two buildings in the physical approach has been used the OTDR meter FTB-200 and ballast optical fiber with a length of 506 m (FC / PC connectors), which is used to eliminate the dead band [6], [7]. The measurement was performed on wavelengths 1310 nm and 1550 nm with a pulse width of 100 ns. The measured length of the route was 3000 m; the average total measure time was over 60 seconds.

According to Fig. 6 we can determine what type of inhomogeneity of fibre line is observed.

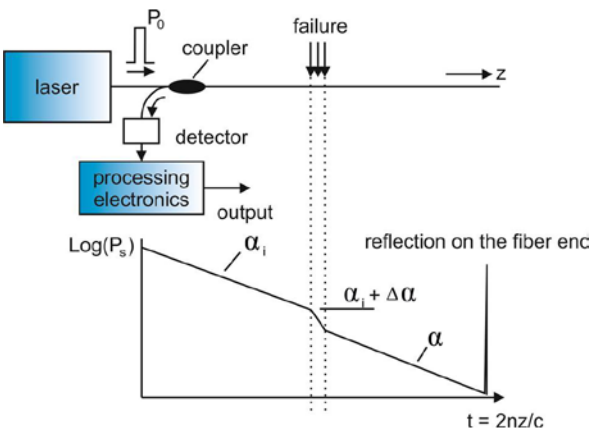

Fig. 6: OTDR backscatter diagram.

In Fig. 7 is measured the optical path PON and the final values are in Tab. I. The measurements are processed at a wavelength of 1310 nm and 1550 nm.

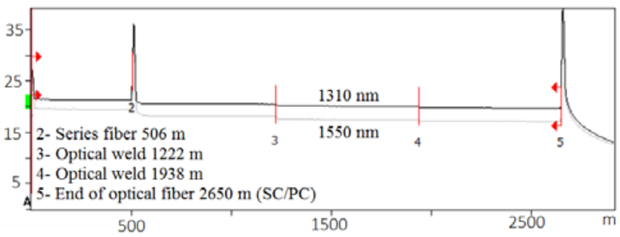

Fig. 7: The backscatter curve OTDR for PON at 1310 nm and 1550 nm.

From the measured values can be seen that the attenuation of 1310 nm is about 0.7 dB less. The total length of the route is 2143.8 m as the length of series fibre is measured. The optical unit consists of three optical fibres (approx. 706 m) connected with optical welds. At a wavelength of 1550 nm the optical weld at 1225 m did not occur. Higher attenuation is caused by the optical fibre bend placed after the series fibre. The optical welds have a tendency to occur at the wavelength of 1310 nm.

Tab. I: Values for PON at 1310 nm and 1550 nm.

No	Loc. (m)	Event Type	Loss (dB)	Refl. (dB)	Att. (dB/km)	Cum. (dB)
		1310nm				
1	0.0000	Launch Lvl.	---	-48		0.000
		Sec. 506.3 m	0.172		0.341	0.185
2	506.3	Refl. fault	0.615	-29		0.787
		Sec. 716.2 m	0.179		0.250	0.956
3	1222.5	Non Refl.	0.279			1.245
		Sec. 716 m	0.239		0.334	1.484
4	1938.6	Non Refl.	0.102			1.586
		Sec. 711.6 m	0.242		0.340	1.828
5	2650.1	Refl. fault	---	>-20		1.828
		1550nm				
1	0.0000	Launch Lvl.	---	-49		0.000
		Sec. 506.3 m	0.096		0.190	0.096
2	506.3	Refl. fault	1.194	-32		1.291
		Sec.1434.3m	0.886		0.468	2.177
3	1938.0	Non Refl.	0.182			2.358
		Sec. 711.8 m	0.135		0.190	2.493
4	2650.1	Refl. fault	---	>-18		2.493

In Fig.8 is designed the optical network with PLC splitter and the final values are in Tab. II.

Tab. II: Values for PON with PLC at 1310 nm and 1550nm.

No	Loc. (m)	Event Type	Loss (dB)	Refl. (dB)	Att. (dB/km)	Cum. (dB)
		1310nm				
1	0.0000	Launch Lvl.	---	-43		0.000
		Sec.506.3m	0.172		0.340	0.172
2	506.3	Refl. fault	0.546	-31		0.718
		Sec. 719.0 m	0.180		0.250	0.898
3	1225.3	Non Refl.	6.751			7.649
		Sec.721.8m	0.290		0.402	7.939
4	1947.1	Non Refl.	0.156			8.095
		Sec.704.9m	0.226		0.321	8.322
5	2650.1	Refl. fault	---	-16		8.322
		1550nm				
1	0.0000	Launch Lvl.	---	-42		0.000
		Sec.506.3m	0.110		0.216	0.110
2	506.3	Refl. fault	1.319	-33		1.429
		Sec.720.1m	0.173		0.240	1.602
3	1226.4	Non Refl.	6.996			8.598
		Sec.1423.7m	0.510		0.735	9.108
4	2650.1	Refl. fault	---	-15		9.108

The attenuation varied from 8 dB to 9 dB during the measurements. The optical splitter is used at a distance of 719.1 m. The attenuation is higher at 1550 nm due to bending after a series fibre. More participants can be incorporated into the optical networks by using fibre optic splitter but the attenuation is in the range of approx. 10 dB.

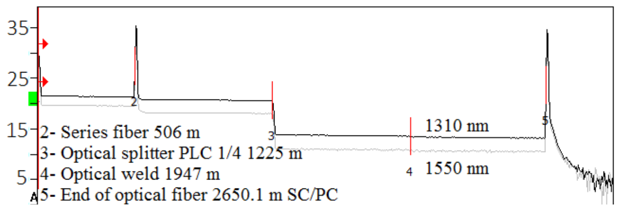

Fig. 8: The backscatter curve OTDR with PLC at 1310 nm and 1550 nm.

4 Conclusion

Two types of optical networks were implemented between the buildings. The measurement of the optical network PON achieved the attenuation of about 8 dB less than network with PLC. Benefit of this type of optical network is a low attenuation caused by welds and bends of the optical fibre. The disadvantage of the network is a connection of two users only. Hence, this is the P2P type of the optical network. The optical network with PLC had higher attenuation caused by the optical splitter which is the drawback of this network. The main advantage is the distribution of the optical fibre to several users. There are a couple of requirements to be considered while deciding which type of the network to choose: number of users, cost and attenuation.

Both optical networks were created at a length of 2150 m, therefore it is based on customer preferences what type of network to choose for implementation.

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