Performance Simulation of Fiber to the Home (FTTH) Devices Based on Optisystem

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Abstract. High speed data rate is a very imperative requirement today and it is increasing according to the customer requirements for various applications such as live broadcasting, video on internet, video conferencing etc. This research is based on how we can design and analysis the optical fiber communication system. The network topology is simulated using Optisystem which is a simulation system used for designing, testing and performance of the optical network by compensate minimum bit error and improve quality factor of the network. This model is designed from the data that has been obtained from PT. Telkom. The value of Bit Error Rate (BER) achieved for the transmission of optical fiber (length=17 Km) for downstream transmission is 2.99513e^{-012} and the upstream is 0. So it can be concluded that both values meet the minimum value of BER specified for optical is 10^{-9}. For the optical length (L) = 17 km the maximum Q-factor for downsteam obtained is 6.87953. The Q factor meets the standards because the upstream and downstream values are above 6. The sensitivity of the device is -28 dBm, the calculation using Optisystem of receive shows the number -26.304 dBm so it can be said that this implementation test is feasible.

1. Introduction

After the first low-loss fibers were produced in 1970, fiber optic communications developed very quickly. The fiber optic communication systems has been common, new installations and applications appear continually [1]. With the increasing development of optical fiber communication technology, the needs of higher transmission rates, longer transmission distance, and greater transmission bandwidth are much stronger [2]. PT. Telkom tried to fulfill those needs by applying Fiber Access Network System.

Fiber to the home is one of the fiber optic network configurations that are distributed to the customer's home or to the terminal's location. FTTH supports Triple Play services that provide fixed telephone, data and interactive TV [3]. In FTTH implementation, Provider uses GPON technology [2]

Different from the ITU-T G. 984.1 about physical distance an access network i.e. 20 km. On the standard PT. Telkom, the Access is allowed no more than 17 km. However FTTH on STO Bandung Centrum, just 4 km with coverage of the newly implemented.

In our paper, main focus is to testing performance a GPON network in software "Optisystem" of the optical network by the minimum amount of BER, Q-factor, and power budget to achieve the requirement of the customers of the network [3]. This paper is organised as follows: Section II explain and discuss about the simulation setup of projected network, Section III shows simulation setup results and performance diagram and Section IV shows conclusion.

1.1. Optical Fiber Communication Systems
The application of optical fiber communications is in general possible in any area that requires transfer of information from one place to another. However, fiber-optic communication systems have been developed mostly for telecommunications applications [4]. Arranged as in figure 1, a basic communications system consist of a transmitter, a fiber optic as communications channel or transmission lines and a receiver.

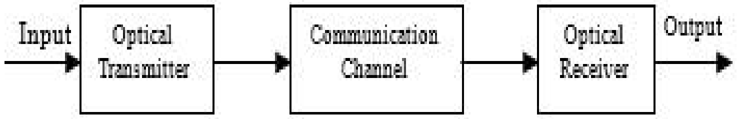

Figure 1. A generic block diagram of an optical communication system [4].

1.2. Fiber to the Home
FTTH is an optical signal transmission format from provider center to user area using optical fiber as channels. The development of this technology is inseparable from the advancement of fiber optic technology that uses copper wires, as well as services known as Triple Play Service [5]. In an OLT it consists of several ODNs that work for transport and distribution of data from OLT to ONU [6]. Another supporting component is Passive Splitter which serves to distribute optical power to all branches. In figure 2 the use of one optical fiber can move from OLT to a customer of about 32 homes.

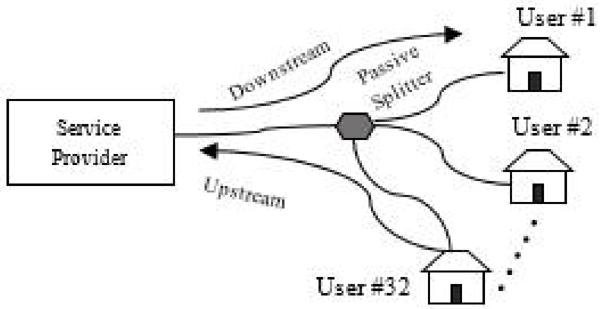

Figure 2. The network connecting the Provider uses a passive splitter [7].

1.3. Gigabit Passive Optical Network
As said above, G-PON systems are characterized, in general, by an optical line termination (OLT) system and an optical network unit (ONU) or optical network termination (ONT) with a passive optical distribution network (ODN) interconnecting them [8]. GPON has a specificity with passive splitter to divide the light signal, so that from one core can be divided into several cores (2, 4, 16, 32, 64) [9]. The principle of Passive Optical Network is a point-to-multipoint system. GPON uses TDMA as a multiple access technique with the nominal bit rate of OLT signals to ONU (downstream) specified in ITU-T G.984.2 Recommendation is 2488.32 Mbit/s. The nominal bit rate of ONU signal to OLT (upstream) is 1244, 16 Mbit/s.

1.4. Optsystem
OptiSystem is a software for simulating fiber optic communications systems and fiber optic sensing systems that are widely used. There are various types of function. Eg: design, test and optimize [1]. Optisystem software is based on modeling a real optical communication system. Optisystem is equipped with Graphical User Interface (GUI) which consists of project layout, component list, component model and graphical display. Library Optisystem consists of active and passive components with wavelength parameters [10].

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1.5. Power Link Budget

The power link budget is calculated as a requirement for the link of network, we design the power beyond the threshold of the required power [9]. The power link budget is implemented based on ITU-T G.984 standardization and applied by Industry regulation. The distance is not more than 20 km and the receiving power is not more than -28 dBm. The form of the equation for total damping calculations on the power budget link is:

$$a_{t} = L.a_{s} + N_{c}.a_{c} + N_{s}.a_{s} + S \quad (1)$$

$$P_{R} = P_{T} - (a_{t} + S) \quad (2)$$

$$M = (P_{T} - P_{s}) - (a_{t} + S) \quad (3)$$

Where a_{t} the total attenuation is occurs along the fiber-optic cables. Equation 2 [11] to find the incoming power obtained from transmit power or outlet power reduced by total attenuation and safety margin is 6 dB. Equation 3 [11] is the equation to find the power margin values obtained with the emissivity value sensitivity receiver devices then reduced damping and a safety margin. The values of the parameters in the equations 1, 2 and 3 on the basis of the specification of each device's network builders FTTH.

1.6. Bit Error Rate (BER)

Bit error rate occurring in transmitting a digital signal is BER. Sensitivity is the minimum optical power of the received signal at the required BER. The need for different BERs for each application, for example in a communication app requires BER 10^{-10} or better, on some data communications requiring BER equal or better than 10^{-12}. BER for an optical communication system of 10^{-9}. Factors affecting BER include noise, interference, distortion, bit synchronization, attenuation, multipath fading, etc. [3]

2. Simulation Setup

2.1. Network Testing Standards

The analysis performed is testing FTTH network performance using Optisystem. Where the configuration used in the simulator is a real configuration on STO Bandung Centrum. FTTH implementation with a maximum of 13.248 cores is only installed at a distance of 4 km, so the provider needs to perform an analysis of network conditions and field needs. After the simulator generates some parameters, then we calculate the value of Link Power Budget and BER value. In the analysis of power budget link value there are 3 (three) parameters analyzed are total attenuation, receptivity and power margin. The standard used in both simulation and calculation of power budget link is standard from PT. Telkom. Table 1. is a device specification in FTTH implementation at STO Bandung Centrum.

Table 1. Devices Characteristic.

No	Devices	Specification
1.	Fiber Optic cables	Max 0.35 dB/km
2.	Connector loss	0.25 dB (Refer IEC 61300 3-34 Grade B attenuation)
3.	Splice loss	0.1 dB
4.	Splitter 1:4	Max. 7.25 dB
5.	Splitter 1:8	Max. 10.38 dB
6.	Distance	Max. 17 km
7.	Rx Sensitivity	-28 dBm

2.2. Design Simulation

The following table 2. is a List of Materials (LoM) required in the design of FTTH networks divided by segment. Where in the table represent a configuration FTTH especially downstream configuration.

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Table 2. List of Material.

Segment	Material Type	Material
Feeder Segment	Temination Material	Optical Distribution Frame
		ODC
	Cable	FO Duct G.652.D
		FO Aerial G.652.D
	Other	Splitter 1:4
		Pathcored
		Connector
Distribusi Segment	Temination Material	ODP
	Cable	FO Duct G.652.D
		FO Aerial G.652.D
	Other	Splitter 1:8
		Connector
Drop Segment	Temination Material	OTP
	Cable	FO Duct G.657.A
		FO Aerial G.657.A
	Other	Connector
		Klam
Indoor Segment	Temination Material	ONT/ONU
	cable	Drop Indoor G.657.A
	other	Connector
		Patchcord
		UTP, PVC, Coaxial cables

The maximum length of feeder cable for RING configuration is 20 km. Max 2 stage splitter with 1 core feeder. Maximum to 32 Home Pass / More in accordance with the link budget obtained. The type of connector used per element is SC-UPC. The type of pole used for aerial systems can use concrete or steel poles along with their respective accessories. In the FTTH configuration, there are several main devices. The first is the Optical Line Termination (OLT) that serves as the end-point of the passive optical network service. OLT provides an interface between Passive Optical Network (PON) systems with service providers (data service, video, or voice / phone). The second device is ODC (Optical Distribution Cabinet). ODC is a passive device that is installed outside STO (outdoor) and can also be indoors or in MDF (indoor). ODC serves as a splitter or distribution point of the feeder cable into a distribution cable.

The third device is the ODP (Optical Distribution Point) which is a device that divides the distribution cable into a drop cable using a 1: 8 splitter. And the fourth device is the ONU (Optical Network Unit) which is the device installed at the customer side.

The distance used in this research reaches the maximum distance that the PT. Telkom Access standard is 17 Km. shown in figure 3. Feeder cable from STO minimum 288 core capacity for both duct and aerial system with cable type G.652.D. While the type is loose tube (max 2x288 core) or ribbon cable (> 288 cores). The configuration used is downstream and upstream with one way simulation. For downstream, passive splitter used is a ratio of 1: 4 on ODC so that from 1 pieces OLT cores can distribute light signals up to 32 ONT / ONU at once. The light signal from 1 ODP is transmitted to 8 ONT by using a passive splitter of 1: 8. The configuration of upstream is shown in Figure 4.

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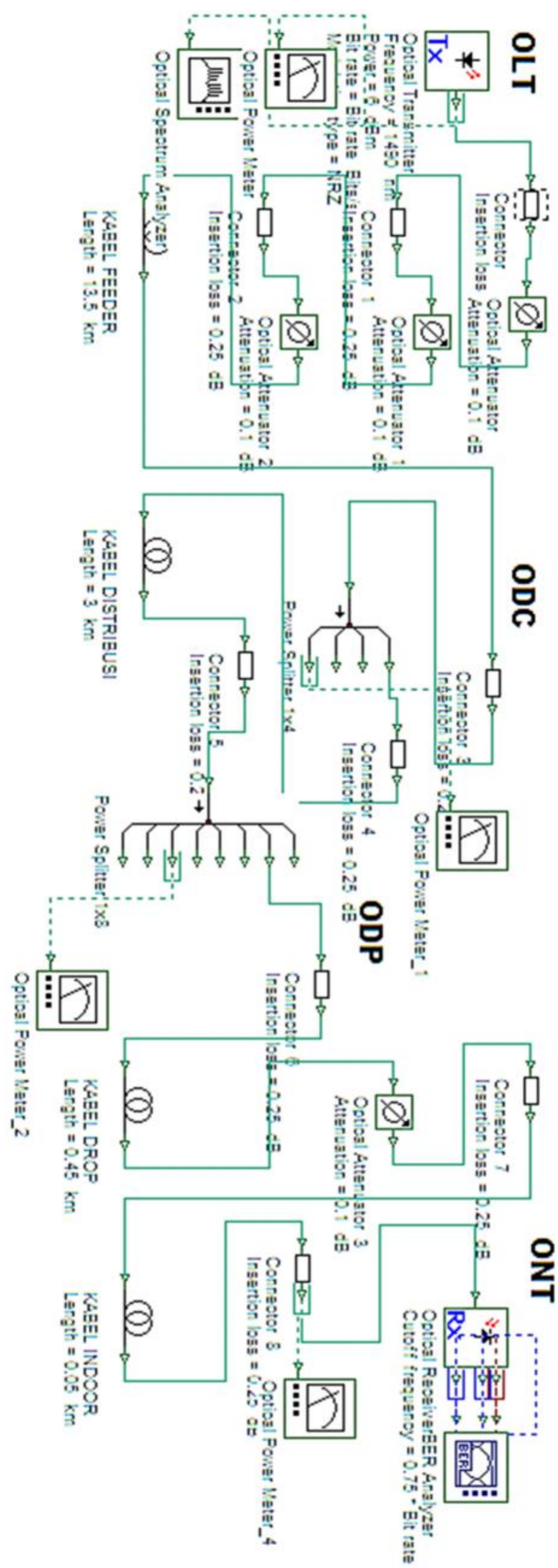

Figure 3. Downstream Configuration.

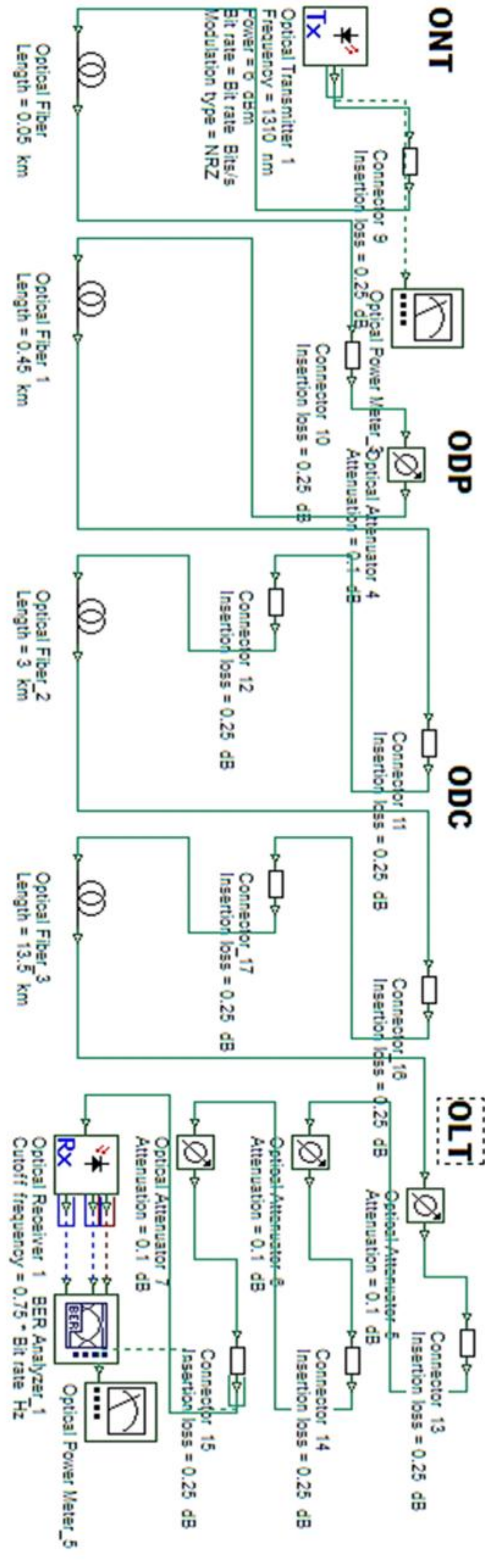

Figure 4. Upstream Configuration.

3. Performance Analysis

3.1. Power Budget Link

The analysis performed is testing FTTH network performance using Optisystem. Where the configuration used in the simulator is a real configuration on STO Bandung Centrum. FTTH implementation with a maximum of 13.248 cores is only installed at a distance of 4 km, so the provider needs to perform an analysis of network conditions and field needs. After the simulator generates some parameters, then we calculate the value of Link Power Budget and BER value. In the analysis of power budget link value there are 3 (three) parameters analyzed are total attenuation, receptivity and power margin. The standard used in both simulation and calculation of power budget link is standard from PT. Telkom. Table 1. is a device specification in FTTH implementation at STO Bandung Centrum.

Link budget calculation uses data on simulation. The data used is the measurement of power by using Optical Power Meter is original to end. Power budget link analysis is used to determine the performance level of new cable network installation before it is operated into the device. This analysis aims to adjust whether the system is running well or not. Tx and Rx power retrieval is done from Optisystem. At power margin the value of Power Margin must be greater than or equal to 0 dB (Power Margin> 0 dB or Power Margin = 0 dB). The receive power value is greater than or equal to the receiver's sensitivity of -28 dBm (PRx> Psensitivity or PRx = Psensitivity). The total attenuation value must be less than or equal to 25 dB. Table 3. is the result of simulation and calculation of power budget link that has been done.

Table 3. Result of Power Budget Link.

Distance (Km)	T_X (dBm)	R_X (dBm)	α_{t_t} (dB)	P_{RX} (dBm)	M
5	3.347	-16.103	19.45	-22.103	5.897
6	3.347	-16.454	19.801	-22.454	5.546
7	3.347	-16.804	20.151	-22.804	5.196
8	3.347	-17.154	20.501	-23.154	4.846
9	3.347	-17.504	20.851	-23.504	4.496
10	3.347	-17.854	21.201	-23.854	4.146
11	3.347	-18.204	21.551	-24.204	3.796
12	3.347	-18.554	21.901	-24.554	3.446
13	3.347	-18.904	22.251	-24.904	3.096
14	3.347	-19.254	22.601	-25.254	2.746
15	3.347	-19.604	22.951	-25.604	2.396
16	3.347	-19.954	23.301	-25.954	2.046
17	3.347	-20.304	23.651	-26.304	1.696

Simulation with range of 5 - 17 km. The distance is sampled because the FTTH network that has been installed on STO Bandung Centrum is 4 km. The total damping generated at a distance of 5 km is 19.45 dB. Damping increases along the configuration when distance is added per 1 km. Until it reaches the maximum FTTH standard of 17 km with a total attenuation of 23,651 dB. In the standard used PT. Telkom, the total damping value should not be more than 25 dB. So with the simulation of FTTH, the network can be said either from the side of total attenuation. Power on the receiver from the simulation results between -22.103 dB to -26.304 dB at the end point of 17 km. The value of the calculated power is smaller, so if the system is used for transmission under normal circumstances. The value is within the allowable value limit on the FTTH network, i.e. Rx sensitivity -28 dBm.

3.2. Bit Error Rate

Measurement BER on simulator is one method how we can see fiber optic network performance besides with power budget link. In the simulator, the measurement uses BER Analyzer by displaying the eye diagram. Analysis method using eye diagram is a simple method but able to accurately assess from a digital transmission system. The measurement with the eye diagram is made in the time domain and shows the distortion effect of a wave which in its application can be seen by the oscilloscope.

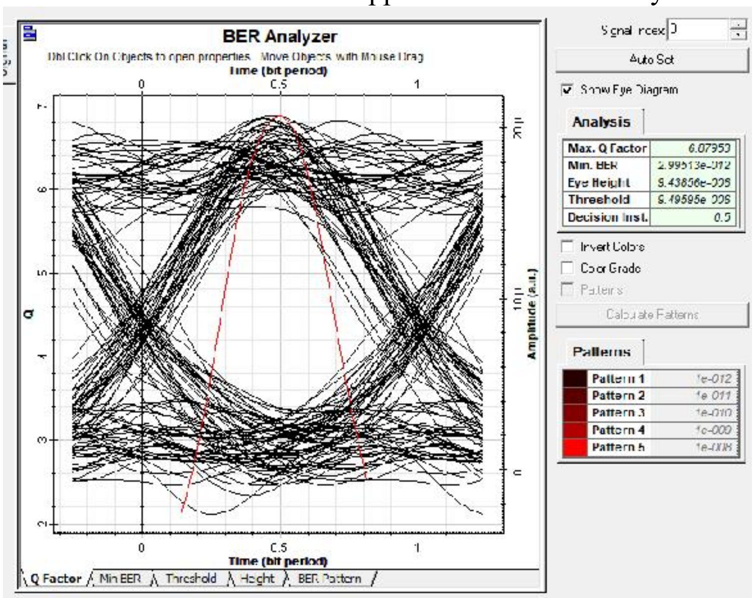

Figure 5. Results BER Analyzer from Downlink configuration.

The eye diagram in figure 5. Shows the result BER Analyzer downlink configuration with a maximum distance of 17 Km. Obtained BER with a value of 2.99513e^{-012} and Q-Factor of 6.87953. The result states that within a trillion bits sent, there is 1 wrong bit. The signal waves shown in Figure 6. there is interference but still visible an eye shape indicating the Signal to Noise Ratio (SNR) and the receiver can still read the signal in this configuration. This figure is much lower than the minimum recommended BER for fiber optic communication systems i.e. 10^{-9}. The simulation results prove that with the fiber cable length L = 17 Km (maximum length), the network is still said to be in decent condition.

Good results are also shown in figure 6. The upstream portion of optical fiber communication with the same transmission distance as downstream, but the eye pattern is more clear and open. The resulting BER is zero. This indicates that there is no error in digital transmission.

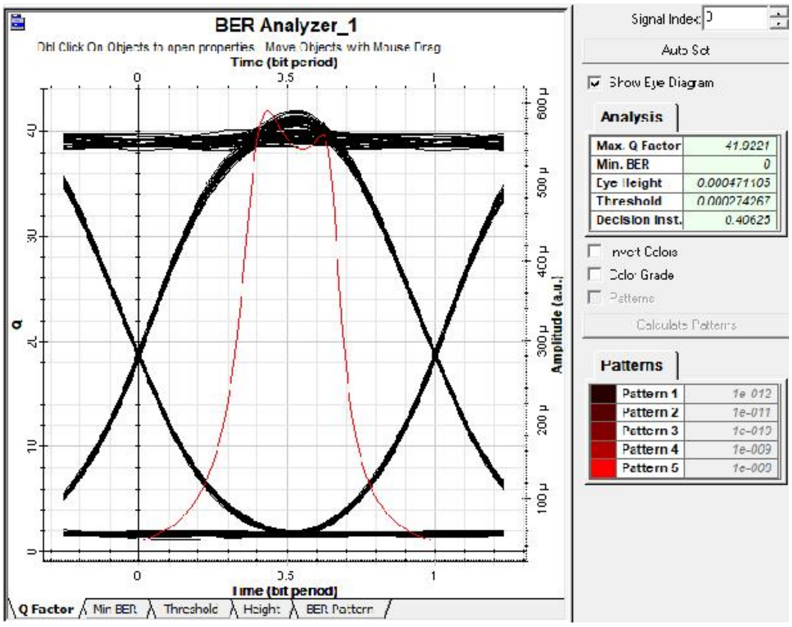

Figure 6. Results BER Analyzer from uplink configuration.

To see the effect of distance on an FTTH network on BER produced, then the simulation by changing the distance with range 5 Km - 16 Km. Seen in Table 4. Comparison of BER to FTTH distance. Changes made is to change the distance of the feeder cable. This is because the maximum distance feeder cable can reach 20 Km.

Table 4. Comparative results.

No	Distance	BER
1.	5 Km	$3.40433e^{-064}$
2.	6 Km	$2.616884e^{-059}$
3.	7 Km	$1.87306e^{-045}$
4.	8 Km	$9.92868e^{-039}$
5.	9 Km	$1.6335e^{-036}$
6.	10 Km	$8.43325e^{-023}$
7.	11 Km	$3.73269e^{-025}$
8.	12 Km	$1.53416e^{-019}$
9.	13 Km	$2.86891e^{-017}$
10.	14 Km	$7.50784e^{-015}$
11.	15 Km	$1.02354e^{-015}$
12.	16 Km	$1.30557e^{-012}$

Changes from BER in configuration can be seen clearly. It states that the length of fiber optic cable used has an influence on performance. The farther the ONU location, the greater the value of BER obtained and the smaller the received power.

4. Conclusions

Based on FTTH device simulation using Optisystem for system performance parameters of BER, Q-factor, and power link budget resulting from OptiSystem simulation. Obtained overall parameters at simulation with length L = 17 km, 1490 nm wavelength for downstream and 1310 nm for upstream. Based on the analysis of FTTH network testing using the PT.Telkom Standard that has been done can be drawn some conclusions as follows:

- Based on the simulation on OptiSystem obtained the value of power budget link on the downstream configuration of 2.99513e^{-012} and for upstream of 0. So it can be concluded that both values can meet the minimum value of BER is 10^{-9}.
- Based on the simulation on OptiSystem got the value of Q-Factor in the downstream configuration of 6.87953 and for upstream of 41.9221. So it can be concluded that both values can meet the minimum value of Q-Factor is 6.
- Based on simulation on OptiSystem we get 23,651 dB total damping. In the standard used PT. Telkom, the total damping value should not be more than 25 dB. So with the simulation of FTTH, the network can be said either from the side of total attenuation. Power on the receiver from the simulation result between -22.103 dBm to -26.304 dBm. So it can be concluded that both values can meet the minimum value of acceptance that has been set by PT.Telkom is -28 dBm.

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