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Design of Gigabit Ethernet Passive Optical Network (GEPON) Based Fiber To The Home (FTTH) Network in Pekanbaru Citraland Housing

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Abstract:

GEPON (Gigabit Ethernet Passive Optical Network) is a point-to-multipoint fiber optic access network based on IEEE 802.3ah that is very suitable to be implemented on FTTH (Fiber To The Home). A GEPON-based FTTH network was applied in the Pekanbaru Citraland Housing and simulated by the OptiSystem software. From the calculation of this FTTH network design, the value of the Power Link Budget is -13.5134 dBm at downstream and -16.9092 dBm at upstream. Furthermore, the Power Link Budget of the GEPON system is greater than -28 dBm and the NRZ value is below 0.56 ns. The results of the simulation show that the GEPON Pr is -13.531 dBm and GEPON BER is 0 at downstream. While the GEPON Pr is -16.927 dBm and the GEPON BER is 8.3538 x 10^{-315} at upstream. Finally, the design of the GEPON-based FTTH network can be applied in the Citraland Pekanbaru Housing because the simulation results shows that the design is in accordance with the IEEE 802.3ah standard.

Keywords: FTTH, GEPON, Power Link Budget, BER.

1. INTRODUCTION

GEPON (Gigabit Ethernet Passive Optical Network) is a point-to-multipoint high speed optical fiber access network and that is very suitable to be implemented in the configuration of FTTH (Fiber To The Home). Previously, the FTTH design used GPON (Gigabit Passive Optical Network) technology that was different from Ethernet technology, whereas the majority of LANs used Ethernet. GEPON combines the advantages of GPON and Ethernet technology so that GEPON has a low cost, high bandwidth, scalability, flexible and fast service reorganization. In addition, It has compatibility with Ethernet so network management is easy. The GEPON has been standardized according to IEEE 802.3ah. The GEPON can also provide broadband services with digital information such as voice, video and internet (Triple Play Services) to customers [1, 2].

The purpose of this research is to design FTTH networks with GEPON technology in Pekanbaru Citraland Housing. Furthermore, the design is analyzed through calculating Power Link Budget parameters, Rise Time Budget, Signal to Noise Ratio (SNR) and Bit Error Rate (BER) and then simulated by OptiSystem software.

The GPON-based FTTH network has been used in the CBD Polonia Medan Housing [3] and Cikoneng Private Village [4]. Then the GEPON-based FTTH/ FTTB network has also been implemented at the Royal Park Residence [5] and the Cawang National Brain Center [6]. The performance of GEPON-based FTTH on Triple Play services such as video broadcasting, voice over IP and high-speed internet (1490 nm wavelength) with 1:32 splitting ratio is evaluated using the Forward Error Correction (FEC) technique. Using the FEC technique, the optical fiber transmission distance is further from 20 km to 30 km and the data rate increases from 1.25 Gb/s to 2.50 Gb/s [7]. GPON-based FTTH has been studied providing a capacity of 1000 users. The size of the network and its components is defined after analyzing the requirements, number of locations, geographical directions and available infrastructure. To assess the design validity, the lowest Received Power is -26 dBm, and the Power Link Budget results show that the maximum loss is -23.196 dB which is far below the upper limit [8]. The Polonia Medan Housing has been designed for FTTH (Fiber To The Home) using GPON technology. In the design, the device, layout, and volume of the device used are determined. Then the feasibility of the system is analyzed by the Rise Time Budget and Power Link Budget parameters. The results of the calculation analysis of the FTTH design in the CBD Polonia Medan housing, that the Total Rise Time for downlink and uplink produces a total system time of 0.2534 ns and 0.251 ns. The Power Margin value for downlink and uplink is 9.1 dB and 8.68 dB thus indicating that the link meets the feasibility of Power Link Budget [9].

2. GEPON

GEPON is one of the standards developed by IEEE based on Ethernet technology while GPON was developed by ITU via G.984. Both of these standards are still being developed in line with the increasing need for users of telecommunications services with high bandwidth and speed. The GEPON physical media dependent layer can support a maximum of 1.25 Gbps (effective data rate of 1.0 Gbps) for downstream and upstream traffic. GPON uses TDMA as a multiple access upstream technique with a data rate of 1.2 Gbps and uses broadcasts towards downstream with a data rate of 2.5 Gbps. GEPON encapsulates and transports user data in Ethernet frames. GEPON was released as a type of high speed optical access system. In the downstream direction, GEPON acts as a shared medium, with frames sent by OLT reaching each ONU. In the upstream direction, because of the directional nature of the passive coupler, the data frames will only reach

OLT, not towards the other ONU as shown in Figure 1 [2, 10].

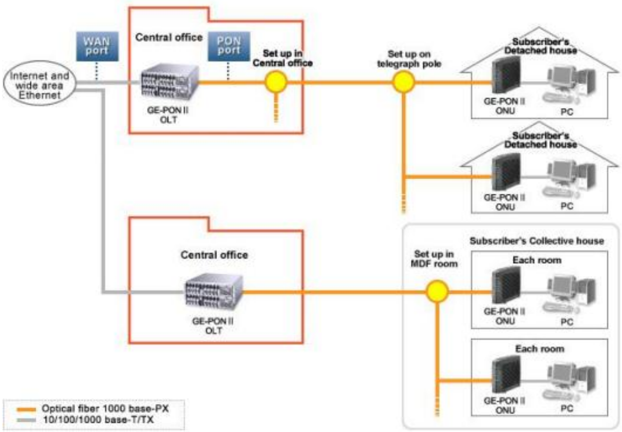

Figure 1. GEPON topology [2]

3. GEPON-BASED FTTH DESIGN

In this research, the GEPON-based FTTH network will be designed from the nearest Central Office, namely PT. Arengka Telkom at Soekarno - Hatta Road No. 676 Pekanbaru City to the customer's houses. The design location for this research is Pekanbaru Citraland Housing located in Soekarno - Hatta Road, Tangkerang Barat, Marpoyan Damai, Pekanbaru City, Riau. The design location is at 0° 29'25.2 "N and 101°25'19.6" E. Figure 2 shows a map of the Central Office PT. Telkom Arengka goes to Pekanbaru Citraland Housing viewed from Google Earth.

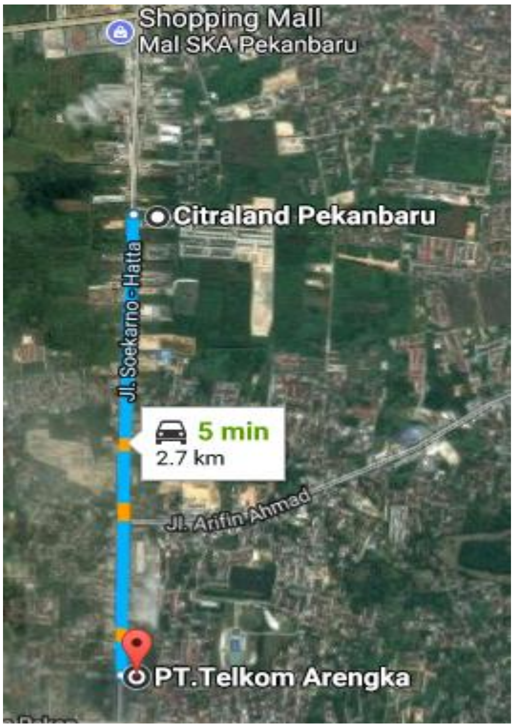

Figure 2. Pekanbaru Citraland Housing Map

Table 1. Equipments

No.	Equipments	Quantity
1	OLT Raisecom ISCOM5504-AC/S	1 unit
2	*Feeder/Distribution Cable* (G.652) Netviel/CCSI 4 *Core*/12 *Core*	*Feeder*: 3,728 km *Distribution*: 30.236 km
3	*Passive Splitter* 1x4 Raisecom POS-1/4-T-SP/SA/FP/FA/LP/LA	11 units
4	*Passive Splitter* 1x8 Raisecom POS-1/8-T-SP/SA/FP/FA/LP/LA	44 units
5	*Drop Cable* (G.657) Merk: Netviel/CCSI Tipe: 1 Core	105.6 km
6	ONU/ONT Raisecom ISCOM-5104	352 units
7	PC SC CCSI SC	APC = 353 units UPC = 55 buah

The equipments needed to build the GEPON-based FTTH network from the Central Office PT. Telkom Arengka goes to Pekanbaru Citraland Housing is shown in Table 1.

4. CALCULATION OF POWER LINK BUDGET FOR GEPON PLANNING

The calculation of Power Link Budget uses a sample of the farthest distance from the nearest Central Office to a customer in Pekanbaru Citraland Housing.

Downstream

Power Link Budget parameter for the downstream direction is shown in Table 2.

Table 2. Power Link Budget parameter downstream

No.	Parameter	Value	Qty
1	Ptx	7 dBm	1
2	Rx Sensitivity	-26 dBm	-
3	Attenuation of fiber optic G.652	0,28 dB/km	5,355 km
4	Attenuation of fiber optic G.657	0,28 dB/km	0,3 km
5	Attenuation of connector SC-APC	0,35 dB	2
6	Attenuation of connector SC-UPC	0,25 dB	2
7	Attenuation of splice	0,1 dB	1
8	Attenuation of splitter 1x4	7,25 dB	1
9	Attenuation of splitter 1x8	10,38 dB	1

Total attenuation:

αtot = L. αserat + Nc. αc + Ns. αs + Sp

αtot = ((L. αG.652) + (L. αG.657))+((Nc SC-APC. αc SC-APC) + (Nc SC-UPC. αc SC-UPC)) + Ns. αs + (Sp 1:4 + Sp1:8)

αtot = ((5,355 x 0,28) + (0,3 x 0,28)) + ((2 x 0,35)+(2 x 0,25)) + (1 x 0,1) + (7,25 + 10,38)

αtot = 1,5834 + 1,2 + 0,1 + 7,25 + 10,38

αtot = 20, 5134 dB < 26 dB

Received power:

Prx = Ptx – αtot

Prx = 7 – 20,5134

Prx = -13,5134 dBm > -26 dBm

Power margin:

M = (Ptx – Pr sensitivity) – αtot – SM

M = (7-(-26 dBm)) – 20,5134 – 6

M = 6,4866 dBm > 0

Upstream

Power Link Budget parameter for the upstream direction is shown in Table 3.

Table 3. Power Link Budget parameter upstream

No.	Parameter	Value	Qty
1	Ptx	4 dBm	1
2	Sensitivitas Rx	-27 dBm	-
3	Attenuation of fiber optic G.652	0,35 dB/km	5,355 km
4	Attenuation of fiber optic G.657	0,35 dB/km	0,3 km
5	Attenuation of connector SC-APC	0,35 dB	2
6	Attenuation of connector SC-UPC	0,25 dB	2
7	Attenuation of splice	0,1 dB	1
8	Attenuation of splitter 1x4	7,25 dB	1
9	Attenuation of splitter 1x8	10,38 dB	1

Total attenuation:

αtot = L. αserat + Nc. αc + Ns. αs + Sp

αtot = ((L. αG.652) + (L. αG.657))+((Nc SC-APC. αc SC-APC)+ (Nc SC-UPC. αc SC-UPC)) + Ns. αs + (Sp 1:4 + Sp1:8)

αtot = ((5,355 x 0,35) + (0,3 x 0,35)) + ((2 x 0,35)+(2 x 0,25)) + (1 x 0,1) + (7,25 + 10,38)

αtot = 1,97925 + 1,2 + 0,1 + 7,25 + 10,38

αtot = 20,90925 dB < 27 dB

Received power:

Prx = Ptx – αtot

Prx = 4 – 20,90925

Prx = -16, 90925 dBm > -27 dBm

Power margin:

M = (Ptx – Pr sensitivity) – αtot – SM

M = (4-(-27 dBm)) – 16,90925 – 6

M = 4,09075 dBm > 0

In the calculation of the power link budget, the farthest distance has a power level at downstream and upstream which is greater than the sensitivity of the receiver, where the sensitivity of OLT is -27 dBm and ONT/ONU is -26 dBm. This means that the receiving power level is still above the sensitivity of the device, so the planned system is feasible and meets the requirements of the receiving power level.

5. CALCULATION OF RISE TIME BUDGET FOR GEPON PLANNING

The following is a Rise Time Budget calculation when downstream and upstream.

Downstream

Rise Time Budget parameter for the downstream direction is shown in Table 4.

Table 4. Rise Time Budget parameter for downstream

No.	Parameter	Value
1	Wavelenght	1490 nm
2	*Spectrum width* OLT (Δσ)	1 nm
3	*Chromatic Dispersion* (Dm)	17 ps/nm/km = 0.017 ns/nm/km
4	Ttx	260 ps = 0.26 ns
5	Trx	260 ps = 0.26 ns
6	T intermodal	0 (*singlemode)*
7	T intramodal	= Δσ x L x Dm = 1 nm x 5.655 km x 0.017 ns/nm/km = 0.096135 ns

Bit rate downstream is 1,25 Gbps, so that:

$$Tr = \frac{0,7}{Bitrate} = \frac{0,7}{1,25 \; x \; 10^9} = 0,56 \text{ ns (NRZ)}$$

$$Tr = \frac{0,35}{Bitrate} = \frac{0,35}{1,25 \; x \; 10^9} = 0,28 \text{ ns (RZ)}$$

Rise Time Budget for the downstream direction is:

$$Ttotal = \sqrt{t\,tx^2 + t\,intramodal^2 + t\,intermodal^2 + \,t\,rx^2}$$

$$T\,total = \sqrt{0{,}26^2 + 0{,}096135^2 + 0^2 + \,0{,}26^2} = 0{,}380055\,ns$$

After calculating, the total rise time for the downstream is 0.380055 ns which is above the maximum RZ bitrate (0.28 ns) and still below the NRZ maximum bitrate (0.56 ns) so that this link only meets the NRZ coding standard.

Upstream

Rise Time Budget parameter for the upstream direction is shown in Table 5.

Table 5. Rise Time Budget parameter for upstream

No.	Parameter	Value
1	Wavelenght	1310 nm
2	*Spectrum width* ONT (Δσ)	1 nm
3	*Chromatic Dispersion* (Dm)	3.5 ps/nm/km = 0.0035 ns/nm/km
4	Ttx	260 ps = 0.26 ns
5	Trx	260 ps = 0.26 ns
6	T intermodal	0 (*singlemode*)
7	T intramodal	= Δσ x L x Dm = 1 nm x 5.655 km x 0.0035 ns/nm/km = 0.0197925 ns

Bit rate upstream adalah 1,25 Gbps so that:

$$Tr = \frac{0{,}7}{Bitrate} = \frac{0{,}7}{1{,}25\ x\ 10^9} = 0{,}56 \text{ ns (NRZ)}$$

$$Tr = \frac{0{,}35}{Bitrate} = \frac{0{,}35}{1{,}25\ x\ 10^9} = 0{,}28 \text{ ns (RZ)}$$

Rise Time Budget for the upstream direction is:

$$Ttotal = \sqrt{t\,tx^2 + t\,intramodal^2 + t\,intermodal^2 + \,t\,rx^2}$$

$$T\,total = \sqrt{0{,}26^2 + 0{,}0197925^2 + 0^2 + \,0{,}26^2} = 0{,}3682278\,ns$$

After calculating, the total rise time for upstream is 0.3682278 ns which is above the maximum RZ bitrate (0.28 ns) and is still below the NRZ maximum bitrate (0.56 ns) so this link only meets the NRZ coding standard.

6. SIMULATION PARAMETERS AND RESULTS FOR DOWNSTREAM DIRECTION

The following are parameters for downstream related to the data transmission process using OptiSystem software such as layout parameter, transmitter parameter, and fiber optic parameter, connector and splice parameter [11].

Table 6. Parameter Layout for Downstream

Component	Menu	Parameter	Value
Layout	Simulation	Sensitivity	-26 dBm
	Signal Tracing	Bitrate	1,25 Gbps

Table 7. Parameter OLT as Transmitter

Component	Menu	Parameter	Value
Optical Transmitter	Main	Frequency	1490 nm
		Power	7 dBm
	PRBS	Bitrate	1,25 Gbps
	Coding	Modulation Type	NRZ
		Rise Time	260 ps
		Fall Time	260 ps

Table 8. Parameter of Fiber Optic

Component	Menu	Parameter	Value
Optical Fiber	Main	Reference Wavelength	1490 nm
		Length	5,655 km
		Attenuation	≤ 0,28 dB/km
		Dispersion	17 ps/nm/km

Table 9. Parameter of connector and splice

Component	Menu	Parameter	Value
Connector	Main	Insertion Loss	0,25 dB/0,35 dB
Optical Attenuator	Main	Attenuation	0,1 dB

Table 10. Parameter ONT as Receiver

Component	Menu	Parameter	Value
Optical Receiver	Main	Photodetector	PIN
		Gain	3 dB
		Responsitivity	0,85 A/W
		Dark Current	60 nA

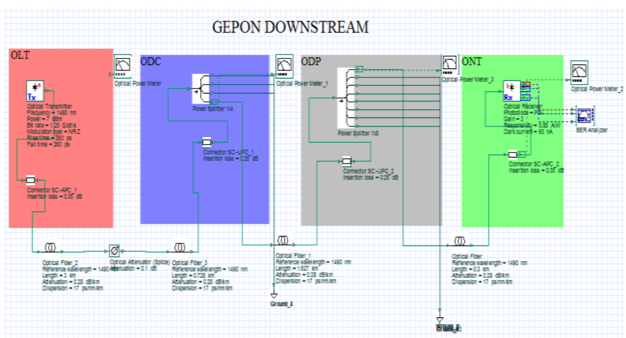

Figure 3. Downstream direction simulation using OptiSystem

Figure 3 shows a downstream direction simulation using OptiSystem software starting from OLT central office located in PT. Arengka Telkom, feeder cable, ODC, distribution cable, ODP, drop cable to ONT located at the customer's home (Pekanbaru Citraland Housing). The OLT block consists of constituent components, namely the Pseudo Random Bit Sequences Generator (PRBS Generator), which functions to generate data bits randomly according to the set bitrate. In this simulation the bitrate on the PRBS Generator is given a value of 1.25 Gbps according to the GEPON bitrate in the downstream direction. Then NRZ Pulse Generator is used as a modifier of electrical signals into optical signals from bits that have been generated by the PRBS Generator. NRZ is used because in the Rise Time Budget calculation, this link only meets the NRZ coding standard. In OLT, there is a laser that serves to generate light sources with a wavelength of 1490 nm and a power of 7 dBm. Then the SC-APC connector on the OLT block serves to connect the E-Access and O-Access contained in the OLT device with a damping size of 0.35 dB. Between OLT and ODC connected by a feeder cable. The feeder cable used in this simulation is the G.652 type fiber optic cable which has a damping of 0.28 dB/km and dispersion of 17 ps/nm/km when downstream. The total length of the feeder cable is 3.728 km. Because the maximum fiber optic cable length is 3 km, it requires 1 (one) time the splicing process with attenuation of 0.1 dB.

In the ODC block there is an SC-UPC connector with 0.25 dB attenuation and a 1x4 passive splitter. Between ODC and ODP connected by distribution cables. The distribution cable used in this simulation is the G.652 type fiber optic cable which has a damping of 0.28 dB/km and dispersion of 17 ps/nm/ km when downstream. The total length of the distribution cable is 1.627 km.

In the ODP block there is an SC-UPC connector with a large 0.25 dB attenuation and a 1x8 passive splitter. Between ODP and ONT connected by drop cables. The drop cable used in this simulation is the G.657 type fiber optic cable which has a damping of 0.28 dB/km and dispersion of 17 ps/nm/km when downstream. The maximum total cable drop length is 0.3 km.

The ONT block consists of an SC-APC connector with 0.35 dB attenuation and a receiver that has a gain of 3 dB (2x), responsiveness of 0.85 A/W and Dark Current (Ip) of 60 nA. On the side of the ONT, Optical Power Meter (OPM) is installed to find out the power received on the receiver side and BER Analyzer which is used to determine the system performance that is simulated through the BER value. The following is a display of Optical Power Meter (OPM) and BER Analyzer from the design that has been made.

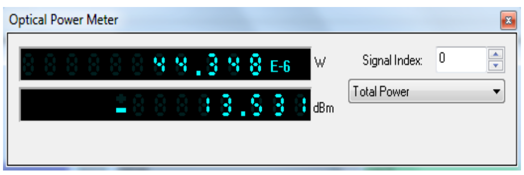

Figure 4. Optical power meter display for downstream

Figure 4 shows the display of OPM so that it can be seen that the Power Link Budget parameter for the farthest distance has an acceptance power level of -13.531 dBm, where the sensitivity of the ONT is -26 dBm. This means that the received power level is still above the sensitivity of the device, so the planned system is feasible and meets the requirements of the received power level.

Figure 5 shows the value of BER is 0 so that the network can be said to be very good because the value of BER obtained is smaller than 10^{-9} which means that it can only be 1 bit error of 10^{9} bits transmitted. Good performance is also shown by eye diagrams that show clear differences between the information bits "1" and bits "0" and do not have jitter.

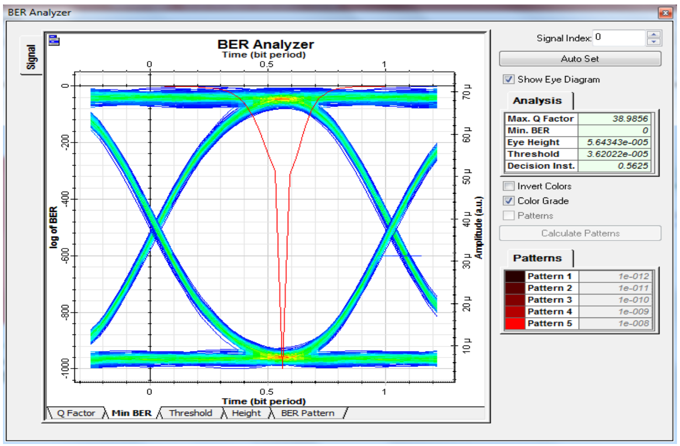

Figure 5. BER Analyzer for downstream direction simulation

7. Simulation Parameters and Results for Upstream Direction

The following are parameters for upstream related to the data transmission process using OptiSystem software such as layout parameter, transmitter parameter, and fiber optic parameter, connector and splice parameter.

Table 1. Parameter of Layout for Upstream

Component	Menu	Parameter	Value
Layout	Simulation	Sensitivity	-27 dBm
	Signal Tracing	Bitrate	1,25 Gbps

Tabel 2 Parameter of ONT as Transmitter

Component	Menu	Parameter	Value
Optical Transmitter	Main	Frequency	1310 nm
		Power	4 dBm
	PRBS	Bitrate	1,25 Gbps
	Coding	Modulation Type	NRZ
		Rise Time	260 ps
		Fall Time	260 ps

Table 3. Parameter of Fiber Optic

Component	Menu	Parameter	Value
Optical Fiber	Main	Reference Wavelength	1310 nm
		Length	5,655 km
		Attenuation	≤ 0,35 dB/km
		Dispersion	3,5 ps/nm/km

Table 4. Parameter of connector and splice

Component	Menu	Parameter	Value
Connector	Main	Insertion Loss	0,25 dB/0,35 dB
Optical Attenuator	Main	Attenuation	0,1 dB

Table 5. Parameter of OLT as Receiver

Component	Menu	Parameter	Value
Optical Receiver	Main	Photodetector	PIN
		Gain	3 dB

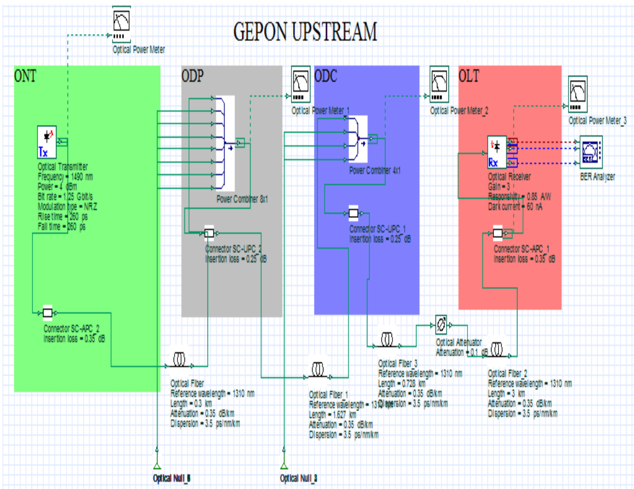

Figure 6. Upstream direction simulation using OptiSystem

Figure 6 shows the downstream direction simulation using OptiSystem software starting from ONT located in the customer's home (Pekanbaru Citraland Housing), drop cable, ODP, distribution cable, ODC, feeder cable to OLT. The ONT block consists of constituent components, namely the Pseudo Random Bit Sequences Generator (PRBS Generator), which functions to randomly generate data bits according to the set bitrate.

In this simulation, the bitrate on the PRBS Generator is given a value of 1.25 Gbps according to the GEPON bitrate in the upstream direction. Then NRZ Pulse Generator is used as a modifier of electrical signals into optical signals from bits that have been generated by the PRBS Generator. NRZ is used because in the Rise Time Budget calculation, this link only meets the NRZ coding standard.

At the ONT there is a laser which functions to generate light sources with a wavelength of 1310 nm and 4 dBm of power. Then the SC-APC connector with a damping size of 0.35 dB. Between the ONT and ODP are connected by a drop cable. The drop cable used in this simulation is the G.657 type fiber optic cable which has attenuation of 0.35 dB/km and dispersion of 3.5 ps/nm/km when upstream direction. The maximum total cable drop length is 0.3 km.

In the ODP block there is an SC-UPC connector with a damping of 0.25 dB and an 8x1 passive combiner. Between ODP and ODC connected by distribution cables. The distribution cable used in this simulation is the G.652 type fiber optic cable which has attenuation of 0.35 dB/km and dispersion of 3.5 ps/nm/km when upstream direction. The total length of the distribution cable is 1.627 km.

In the ODC block there is an SC-UPC connector with a damping of 0.25 dB and a 4x1 passive combiner. Between ODC and OLT connected by a feeder cable. The feeder cable used in this simulation is the G.652 type fiber optic cable which has attenuation of 0.35 dB/km and dispersion of 3.5 ps/nm/km when upstream direction. The total length of the feeder cable is 3.728 km. Because the maximum fiber optic cable length is 3 km, it requires 1 (one) time the splicing process with attenuation of 0.1 dB.

The OLT block consists of an SC-APC connector with 0.35 dB attenuation which serves to connect E-Access and O-Access and a receiver that has a gain of 3 dB (2x), responsiveness of 0.85 A/W and Dark Current (Ip) of 60 nA. On the OLT, side Optical Power Meter (OPM) is installed to determine the received power on the receiver side, and BER Analyzer which is used to determine the system performance that is simulated through the BER value. The following is a display of Optical Power Meter (OPM) and BER Analyzer from the design that has been made.

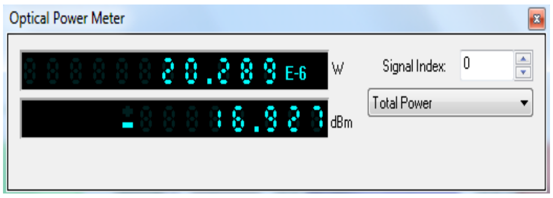

Figure 7. Optical power meter display for upstream

Figure 7 shows the display of OPM so that it can be seen that the Power Link Budget parameter for the farthest distance has an acceptance power level of -16.927 dBm, where for the sensitivity of OLT is -27 dBm. This means that the received power level is still above the sensitivity of the device, so the planned system is feasible and meets the requirements of the received power level.

Figure 8 shows the BER value is 8.338 x 10^{-315} so the network can be said to be very good because the BER value obtained is smaller than 10^{-9}. Good performance is also shown by eye diagrams that show clear differences between the information bits "1" and bits "0" and do not have jitter.

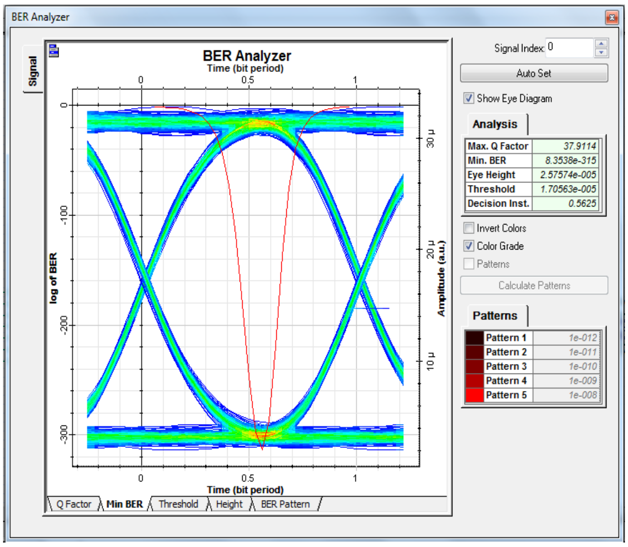

Figure 8. BER Analyzer for upstream direction simulation

CONCLUSION

The design of GEPON-based FTTH technology is very feasible to be implemented in Pekanbaru Citraland Housing. The simulation results show that the technology has met the IEEE 802.3 standard, namely the Power Link Budget value is greater than -28 dBm (-13.5134 dBm at downstream and -16.9002 dBm at upstream). Rise Time Budget NRZ is below 0.56 ns (0.3800 ns when downstream and 0.3682 ns when upstream). SNR is more than 21.5 dB (38,828 dB at downstream and 32,230 dB at upstream) and BER is smaller than 10^{-9} (0 when downstream and upstream).

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