

Design And Analysis of Optical Line Terminal (OLT) And Optical Distribution Cabinet (ODC) Devices In The Fiber To The Home (FTTH) Network Trainer Module In The G316 Laboratory, Building G, State Polytechnic Of Padang

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ABSTRACT

This study aims to design and analyze the performance of Optical Line Terminal (OLT) and Optical Distribution Cabinet (ODC) devices in the Fiber to the Home (FTTH) network trainer module at the SKSO G316 Laboratory, Padang State Polytechnic. The research methods included design simulation using Optisystem software, physical implementation of the trainer module, and attenuation measurement using an Optical Power Meter (OPM). The results show that attenuation under normal core conditions (orange) is stable in the range of 14.94–16.23 dB, while core bending (green) and core damage (blue) conditions cause a significant increase in attenuation to 16.28 dB and 16.01 dB at a wavelength of 1310 nm. The length of the dropcore cable (10 m, 15 m, 20 m) showed an effect on the increase in attenuation with an additional attenuation increase of 0.9 dB per 5 meters. The simulation results and actual measurements are consistent with the link power budget calculations and meet the technical specifications with total attenuation below the maximum limit of -28 dB. This trainer module is useful as a learning medium for analyzing FTTH network performance and the impact of physical disturbances on optical fiber transmission.

INTRODUCTION

In the current development of science and technology, the use of copper cables is considered ineffective in accommodating large bandwidth capacity and high speeds. One technology that is popular and extensively used in transmission media as a substitute for copper cables is fiber optics (Yustini et al., 2021). High-speed internet access has become a basic necessity in carrying out various activities, ranging from education and business to entertainment. The use of copper wire as a transmission medium in communication systems is no longer feasible for long-distance data transmission with large capacity and high speed. Due to this constraint, the use of copper wire as a transmission medium has been replaced by fiber optics with higher capabilities (Kussoy et al., 2021). FTTH is an optical fiber technology that transmits information with large bandwidth capacity and low interference from the provider to users in their homes, with much higher speeds and better stability compared to previous technologies, such as copper cables. FTTH has become the primary choice in the development of telecommunications network infrastructure today. Therefore, a deep understanding of the working principles, installation, and measurement of FTTH networks is crucial for students or practitioners in the telecommunications field.

In the G316 Fiber Optic Communication System Laboratory, currently only a few devices are available for attenuation measurement, such as devices for measuring cable attenuation with or without connections and attenuation against the use of Passive Splitters, but there are still no devices or facilities for measuring FTTH networks that cover the entire architecture from the service provider side (Optical Line Terminal/OLT) to the user side (Optical Network Unit/ONU) that are adequate to support practical activities in the room. This is an obstacle in the learning process, especially for practical work that requires simulation or direct implementation of FTTH networks in a controlled environment such as a room or laboratory.

Therefore, a project is needed to build an FTTH network in the G316 laboratory that can be used as a practical tool. The design of the FTTH network device covers the entire architecture, from the service provider side (Optical Line Terminal/OLT) to the user side (Optical Network Unit/ONU), along with the ability to measure network performance. This project aims to provide a simulation environment that is close to real conditions, so that students can directly measure and analyze the FTTH network, which will greatly help in improving the quality of practical work.



METHOD

Place and Time of Research

The location and time of the research for the final assignment on the Design, Manufacture, and Analysis of the Trainer Module was conducted at the Fiber Optic Laboratory of Telecommunication Engineering, Padang State Polytechnic. The design of this final assignment was carried out from June 2025 to August 2025.

Research Flow

The process stages that will be carried out in this research are described in the following diagram:

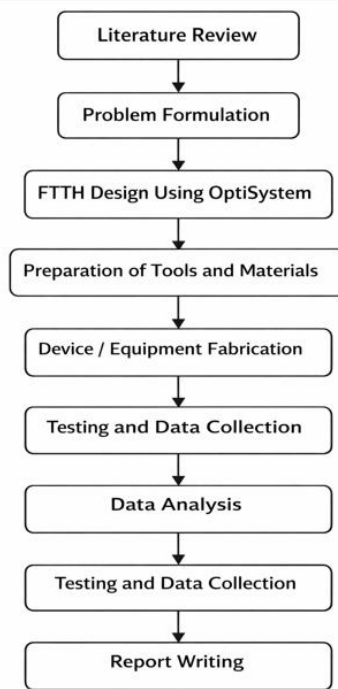


Figure 1. Flowchart

Design Flow

The block diagram below shows that the OLT used as an input is connected to the first ODC using a feeder cable connected using a closure, during the connection the green core is given a 20mm diameter bending problem and the blue core is damaged or broken to provide damping to the ODC. From the ODC there is a 1: 4 Passive Splitter where each output will be connected to one ODP. On ODP 1 the cable is in normal condition, ODP 2 has a cable in a broken condition, ODP 3 cables are in a condition where 1 connection is given, and for ODP 4 cables are given 2 connections. Each ODP will be connected to an external 1:4 Passive Splitter, where the 4 outputs from the passive will be connected with a dropcore cable to the rosette, each output has a different dropcore cable length, the first output with a cable length of 10m, the second output with a cable length of 15m, and the third output 20m, and the output from the rosette itself will be connected with a patchcore cable to the ONT.

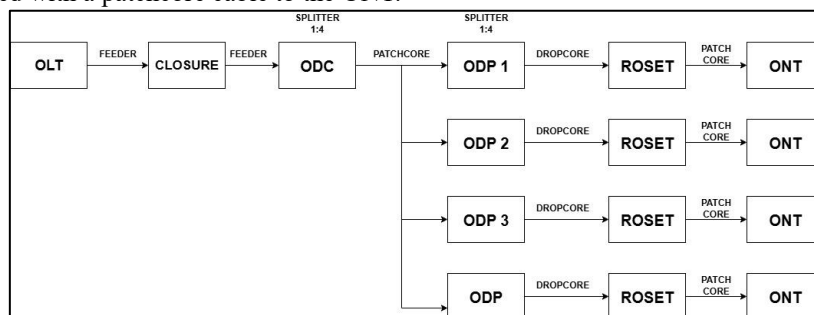


Figure 2. Trainer module design

Tools and Materials for the trainer module

The tools and materials used in making the trainer module are as follows:

Table 1. Trainer module tools and materials

No	Tool	Material
1	Optical Power Meter(OPM)	ODP
2	Light Source	ODC
3	Fusion Splicer	Rosette
4	Fiber Clever	ONT
5	Fiber Stripper	Patchcore Cable
6	Cutting pliers	Dropcore Cable
7	Screwdriver	Feeder Cable
8	Scissors	Passive Splitter
9	Cutter	Joint Closure
10		Pigtail Cable
11		Alcohol
12		Tissue

Trainer Module Architecture

The following are the results of the trainer module design:



Figure 3. Trainer module architecture

At the beginning of the design and manufacture of this fiber optic-based trainer module, it starts from the installation of the ODC (Optical Distribution Cabinet) as the starting point for optical signal distribution, then connected to the closure which functions as a place to connect the feeder cable to the distribution cable. From the closure, the signal is forwarded to several ODPs (Optical Distribution Points) which function as the final distribution points before going to the customer. This module is also equipped with a 1:4 external splitter that functions to divide one optical signal into four outputs, each of which can be channeled to different customers via a drop core cable. Each of these drop lines ends at an optical rosette, which functions as a cable termination point inside the customer's home and is then connected to the ONT (Optical Network Terminal), which is an optical signal receiving device that converts it into a data signal for internet needs.

Creating a trainer module

Before designing and building the trainer module, a simulation was first performed to estimate the damping that would be obtained during measurements using the Optisystem application. Optisystem design utilizes several devices or components. The following are the components or devices used in the design, along with the damping calculations for each device.

The image below is a design that has been created using the Optisystem application.

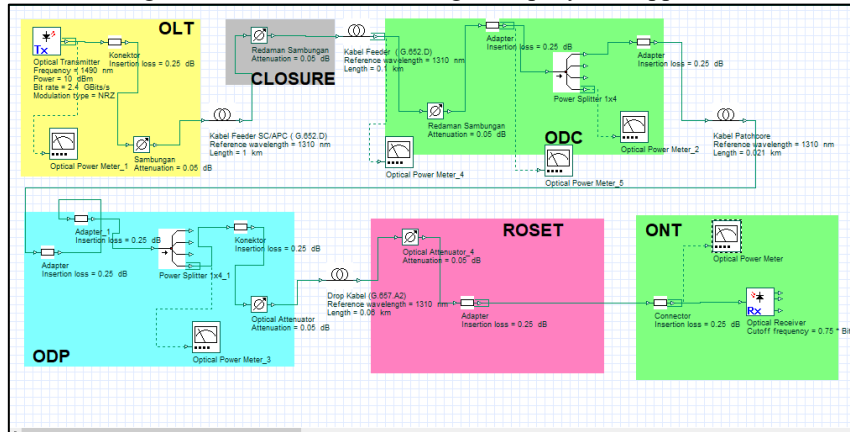


Figure 4. Trainer module design in Optisystem application



Figure 5. damping measurement results on Optisystem

After conducting the simulation, we will then perform calculations using formulas to verify the correlation between the calculations and the actual measurements made using the trainer module. Link budget calculations are performed using formulas (1), (2), and (3) to ensure the simulation matches the formula calculations. Table 2 shows the attenuation for each device used.

Table 2. Data Link Power Budget

Parameter	Information
Pt	±7.5 dBm
Pr	-28 dBm (Max)
Prx	>-28 dBm
$a_{serat} G. 652 D$	1310 1550 0.35 dB/km 0.28 dB/km
$a_{serat} G. 657A$	1310 1550 0.35 dB.km 0.28 dB.km
Connection Damping (a_s)	0.05 dB/Splice
Connector Damping (a_c)	0.25/Connector
Passive Splitter 1:4 Attenuation	7.5 dB
Number of Connections	5
Number of Connectors	8
Number of Passive Splitters 1:4	2
FO (Outdoor) Cable Length	1100 m
FO Cable Length (Indoor)	10 - 60 m
Margin Power	>0 dB

From the data above, we can calculate the link power budget, the calculation is as follows:
Downlink Calculation:

Total Damping Calculation

$$a_{tot} = L \cdot a_{serat} + N_c \cdot a_c + N_s \cdot a_s + a_{sp}$$

$$a_{tot} = (1.181 \text{ km} \times 0.28 \text{ dB/km}) + (8 \times 0.25) + (5 \times 0.05) + (2 \times 7.5)$$

$$a_{tot} = 17.6 \text{ dB}$$

Calculation of Acceptance Power:

$$P_r = P_t - a_{tot}$$

$$P_r = 7.5 - 17.6$$

$$P_r = -10.1 \text{ dBm}$$

Power Margin Calculation

$$M = (P_{tx} - P_{rx}) - a_{tot} - M_s$$

$$M = (7.5 - 28) - 17.6 - 3$$

$$M = 5.8$$

Uplink Calculation:

Total Damping Calculation

$$a_{tot} = L \cdot a_{serat} + N_c \cdot a_c + N_s \cdot a_s + a_{sp}$$

$$a_{tot} = (1.181 \text{ km} \times 0.35 \text{ dB/km}) + (8 \times 0.25) + (5 \times 0.05) + (2 \times 7.5)$$

$$a_{tot} = 17.6 \text{ dB}$$

Calculation of Acceptance Power

$$P_r = P_t - a_{tot} - M_s$$

$$P_r = 7.5 - 17.6$$

$$P_r = -10.1 \text{ dBm}$$

Power Margin Calculation

$$M = (P_{tx} - P_{rx}) - a_{tot} - M_s$$

$$M = (7.5 - 28) - 17.6 - 3$$

$$M = 5.8$$

RESULTS AND DISCUSSION

Link Power Budget Measurement Results on the ODC Before the 1:4 Splitter

On this stage, the author measured the ODC before entering the 1:4 splitter to determine the output value obtained by the trainer module. This measurement used the OLT as input and the OPM tool to determine the output value produced by the trainer module. The following output values were obtained after the measurements.

Power Measurement at OLT Output

Table 3. Power measurement on OLT output

Ptx OLT (dBm)	1310 (nm)	1550 (nm)
Measurement 1	7.52	7.72
Measurement 2	7.46	7.66
Measurement 3	7.35	7.54
Measurement 4	7.41	7.62
Measurement 5	7.39	7.59
Measurement 6	7.40	7.60
Measurement 7	7.41	7.61
Measurement 8	7.40	7.62
Measurement 9	7.36	7.56
Measurement 10	7.35	7.55



Based on the results of the output power measurements of the Optical Line Terminal (OLT) device, it can be analyzed that the device shows stable and consistent results at both operating wavelengths. At a wavelength of 1310 nm, the output power value ranges from 7.35 dBm to 7.52 dBm, with a variation of 0.17 dBm. Meanwhile, at a wavelength of 1550 nm, the output power value is in the range of 7.54 dBm to 7.72 dBm, with a variation of 0.18 dBm.

The higher gain at 1550 nm compared to 1310 nm is characteristic of optical sources used in FTTH systems, where the longer wavelength often produces slightly higher power. The average difference between the two wavelengths is about 0.20 dBm.

Output Measurement on ODC Before 1:4 Splitter (orange/normal core)

Table 4. Output measurement on ODC before splitter (orange/normal core)

Core Orange	Ptx (dBm) 1310 (nm)	Ptx (dBm) 1550 (nm)
Measurement 1	6.59	6.89
Measurement 2	6.60	6.82
Measurement 3	6.58	6.80
Measurement 4	6.62	6.82
Measurement 5	6.59	6.78
Measurement 6	6.60	6.81
Measurement 7	6.60	6.79
Measurement 8	6.64	6.85
Measurement 9	6.62	6.84
Measurement 10	6.57	6.78

The results show that at a wavelength of 1310 nm, the Ptx value is in the range of 6.57 dBm to 6.64 dBm, while for a wavelength of 1550 nm, it is in the range of 6.78 dBm to 6.89 dBm. The difference in values is very small, only 0.07 dBm for 1310 nm and 0.11 dBm for 1550 nm, which indicates that the transmit power is in a stable state.

The stability of the transmitted power at both wavelengths indicates that the optical cable system is operating well with minimal attenuation. There are no signs of transmission interference, such as weak connections, dirty connectors, or cable damage. Therefore, it can be concluded that the ODC Core Orange cable is in excellent condition for use in optical communication systems.

Output measurement on ODC before splitter (green core/bending)

Table 5. Output measurement on ODC before splitter (green core/bending)

Core Green	Ptx (dBm) 1310 (nm)	Ptx (dBm) 1550 (nm)
Measurement 1	5.47	5.67
Measurement 2	5.54	5.74
Measurement 3	5.58	5.78
Measurement 4	5.55	5.75
Measurement 5	5.53	5.72
Measurement 6	5.52	5.72
Measurement 7	5.51	5.71
Measurement 8	5.51	5.71
Measurement 9	5.53	5.70
Measurement 10	5.53	5.73

From the table, it can be seen that the transmit power for the 1310 nm wavelength is in the range of 5.47 dBm to 5.58 dBm, while at 1550 nm it ranges from 5.67 dBm to 5.78 dBm. This data indicates that the transmitted signal experiences attenuation, but still within a relatively small range. This attenuation most likely occurs due to bending in the optical fiber, which causes a small portion of the light signal to bend and exit the fiber core, thereby reducing the transmit power measured at the end of the cable.

Bending attenuation tends to be more significant at the 1550 nm wavelength because it is longer and more sensitive to fiber curvature. However, in this measurement, the difference between attenuation at 1310 nm and 1550 nm was not significant, indicating that the bending was within the tolerance limits of the optical network system.

Measurement output on ODC before splitter (blue/damaged core)

Table 6. Output measurement on ODC before splitter (blue/damaged core)

Core Blue	Ptx (dBm) 1310 (nm)	Ptx (dBm) 1550 (nm)
Measurement 1	2.55	2.73
Measurement 2	2.50	2.78
Measurement 3	2.51	2.73
Measurement 4	2.53	2.75
Measurement 5	2.48	2.71
Measurement 6	2.48	2.69
Measurement 7	2.53	2.72
Measurement 8	2.53	2.73
Measurement 9	2.52	2.72
Measurement 10	2.48	2.71

From the data that it can be seen that the transmit power at 1310 nm ranges from 2.48 dBm to 2.55 dBm, while at 1550 nm it ranges from 2.69 dBm to 2.78 dBm. These values are generally lower than similar measurements on cores that are in normal condition or have only experienced bending (such as the green core). This indicates that the blue core experiences higher attenuation (loss), which is most likely caused by broken, cracked, or imperfectly spliced fibers.

This high attenuation indicates that light transmission in the fiber is significantly impaired, either due to a significant loss of signal at the point of damage or due to improper refraction and reflection along the fiber path. This condition can lead to network performance degradation, such as slow internet speeds, connection drops, or even complete failure of the optical transmission line.

Measurement and Calculation Results on Rosette Output

At this stage, the author conducted measurements on the optical rosette to determine the amount of optical power generated by the trainer module. Measurements were carried out using the output from the ODP (Optical Distribution Point) in normal conditions as Input, which was then connected to an external 1:4 splitter. Next, the three outputs from the splitter were connected to several dropcore cables of different lengths, namely 10 meters, 15 meters, and 20 meters, each end of which was connected to the optical rosette. The output power coming out of the rosette was measured using an Optical Power Meter (OPM) to obtain the total attenuation value of the network circuit. The measurement results were used to evaluate the performance of the optical signal distribution in the trainer module.

Measurement and Calculation on Rosette Output Using Orange Core (Normal)

Based on the measurement data that has been carried out, it can be analyzed that the fiber optic system with a 1:4 external splitter configuration shows stable performance and is in accordance with design expectations. Attenuation measurements were carried out on three outputs with varying cable lengths, namely 10 meters, 15 meters, and 20 meters, which are connected to the rosette. The input signal is received from the Optical Distribution Center (ODC) at two working wavelengths, namely 1310 nm and 1550 nm, with input powers of 6.60 dBm and 6.82 dBm, respectively.

Table 7. Orange/normal core measurement on rosette 1 (Cable length 10 m)

Measurement to	1310 nm	1550 nm
1	-8.35	-8.15
2	-8.38	-8.19
3	-8.29	-8.07

Table 8. Orange/normal core measurement on rosette 2 (Cable length 15 m)

Measurement to	1310 nm	1550 nm
1	-9.10	-8.89
2	-9.18	-8.99
3	-9.33	-9.13

Table 9. Orange/normal core measurement on rosette 3 (Cable length 20 m)

Measurement to	1310 nm	1550 nm
1	-9.21	-9.00
2	-9.80	-9.60
3	-9.83	-9.62

Measurement and Calculation on Rosette Output Using Green Core (Bending)

Table 10. Green core/bending measurement on rosette 1 (Cable length 10 m)

Measurement to	1310 dBm	1550 dBm
1	-9.04	-8.85
2	-9.16	-8.96
3	-9.09	-8.88

Table 11. Green core/bending measurement on rosette 2 (Cable length 15 m)

Measurement to	1310 dBm	1550 dBm
1	-9.91	-9.72
2	-10.03	-9.83
3	-9.98	-9.77

Table 12. Green core/bending measurement on rosette 3 (Cable length 20 m)

Measurement to	1310 dBm	1550 dBm
1	-10.60	-10.40
2	-10.54	-10.35
3	-10.47	-10.26

Measurement and Calculation on Rosette Output Using Blue Core (Broken/Damaged)

Table 13. Measurement of blue/damaged core on rosette 1 (Cable length 10 m)

Measurement to	1310 dBm	1550 dBm
1	-11.89	-11.69
2	-11.87	-11.66
3	-11.89	-11.69

Table 14. Measurement of blue/damaged core on rosette 2 (Cable length 15 m)

Measurement to	1310 dBm	1550 dBm
1	-12.83	-12.63
2	-12.80	-12.60
3	-12.84	-12.64

Table 15. Measurement of blue/damaged core on rosette 3 (Cable length 20 m)

Measurement to	1310 dBm	1550 dBm
1	-13.51	-12.30
2	-13.48	-12.28
3	-13.45	-12.24

Analysis of Measurement Results on Rosette Output

Based on the measurement results and output calculations on a fiber optic system with a 1:4 external splitter configuration connected to three rosettes via dropcore cables with varying lengths of 10 m, 15 m, and 20 m, it can be analyzed that the overall network performance shows characteristics that are in accordance with the basic principles of fiber optic transmission. In orange core conditions (normal), the average attenuation values at wavelengths of 1310 nm and 1550 nm were recorded at 14.94 dB and 14.95 dB for rosette 1 (10 m), 15.80 dB and 15.82 dB for rosette 2 (15 m), and 16.21 dB and 16.23 dB for rosette 3 (20 m), respectively. This indicates an increase in attenuation with increasing cable length, where every additional 5 meters of cable has an impact on attenuation of around 0.8–0.9 dB.

Meanwhile, in the green core (bending) condition, there is an inconsistency in the output value, especially in rosette 1 with an average attenuation of 16.28 dB (1310 nm) and 14.62 dB (1550 nm). This is influenced by the non-uniform micro-bending effect on the fiber, however, in rosettes 2 and 3, the attenuation of both wavelengths shows almost the same value (≈ 15.50 dB and ≈ 16.07 dB), which indicates that the bending effect is more evenly distributed due to the longer cable length.

For the blue core (broken/damaged), a significant increase in attenuation is observed, especially at rosette 3 (20 m), with average values of 16.01 dB (1310 nm) and 15.00 dB (1550 nm). The difference in attenuation of approximately ≈ 1 dB between the two wavelengths indicates that physical damage to the fiber can result in unbalanced attenuation. Overall, these results demonstrate that the physical integrity of the optical fiber is critical to maintaining network performance, and any issues such as excessive bending or mechanical damage such as core rupture can cause unexpected signal degradation. Therefore, network installation and maintenance need to be carried out strictly following technical standards to minimize unwanted losses.

CONCLUSION

Based on the results of the analysis obtained by the author, the following conclusions can be drawn:

1. The design of the FTTH network simulation in the G316 Laboratory was successful. done by combining OLT and ODC devices in one *trainer module* comprehensive. Simulation with software *Optisystem* and implementation has created a learning environment Which follow the FTTH architecture accurately, according to the needs Telecommunication Engineering student practicum.
2. Link power budget measurements at the output of FTTH network devices have been successfully performed and analyzed. The measurement results show that the total attenuation for all problems (normal core, bending, and damage) remains below the maximum allowable limit, namely -28 dB. This indicates that the network design that has been created meets technical feasibility and existing standards.
3. The impact of attenuation on various physical issues in optical fiber has been successfully identified and quantified. This research has clearly shown that:
 - a. Normal conditions (orange core) produce stable and consistent attenuation.
 - b. The bending condition (green core) results in a large increase in attenuation, indicating the response of the optical fiber to physical changes.
 - c. The damaged/broken condition (blue core) results in the highest attenuation and signal inconsistency, especially at the 1310 nm wavelength, indicating a significant impact of mechanical damage on network performance.

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