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Effect of Coiling and Macrobending on Fiber To The Building (FTTB) Network Activation

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ABSTRACT

Fiber to the Building (FTTB) provides a fast and efficient service. However, the network quality may be affected by high attenuation at the termination (ONU) due to coiling, macrobending, and the length of patch cords, impacting network stability. This study aims to measure and analyze the effect of coiling and macrobending on patch cord cables of different lengths, as well as their influence on attenuation and FTTB network performance. The method includes simulating patch cord cables with lengths of 3m, 5m, and 10m. The tested treatments include conditions without coil, with coil, macrobending without coil, and macrobending with coil applied to the final termination before and after activating the FTTB network. Before activation, the lowest attenuation was 19.78 dB in the 3m cable without coil and macrobending, while the highest attenuation was 21.93 dB in the 10m cable with 5 coils (6cm curvature) and macrobending (0.8cm diameter). After activation, the lowest attenuation was 19.74 dB in the 3m cable without coil and macrobending, while the highest attenuation was 23.92 dB in the 10m cable with 5 coils (6cm curvature) and macrobending (0.8cm diameter). The test results show that the attenuation is affected by the number of coils, macrobending, and cable length.Damping increases with an increase in coils, cable length, and macrobending.

INTRODUCTION

Rapid technological advancements have led to an increasing need for services that are practical, convenient, and efficient. Large-capacity and fast transmission media, such as Fiber To The Building (FTTB), offer the right solution. On the other hand, in Optical Network Unit (ONU) installations, there is often high attenuation on the user side due to twisting, macrobending and length of patch cord cables. These factors can increase attenuation and weaken data transmission and affect overall network performance and service quality.

In implementation, FTTB networks do not always operate optimally. Sometimes, the internet access speed can decrease due to various obstacles or damage that occurs in the FTTB network infrastructure. One of the problems in using optical fiber is the loss of light energy in the fiber core due to fiber bending, which disrupts the transmission process and causes significant attenuation when transmitting data through optical fiber. Another problem is the loss of light energy inside the optical fiber caused by several factors, such as dirty optical fiber core material, light deflection in the wrong direction, and inaccurate splicing (Asril, Yustini, Maria, & Herwita, 2019).

In the design and activation of FTTB networks, the bending problem in optical networks must be handled properly. Bending consists of microbending and macrobending. Microbending is a small bending of the optical fiber caused by non-uniformity in fiber formation or uneven stress during installation. It is shown that optical fibers have good resistance to microbending. Nonetheless, it is important to handle all aspects of bending with care in order to maintain signal quality in optical networks.

Macrobending is the attenuation of optical signals due to the merging of light from the guided core mode to the radiated cladding mode due to bending of the optical fiber (Roman, Zhu, O'Malley, Gerald, & Huang, 2021). When fiber optic cabling, bending or winding should follow the specified path. Macrobending and the number of twists in the optical fiber during installation may cause signal loss (Eliche, Orike, & Okotcha, 2022). However, bending with a radius larger than the radius of the optical fiber can increase the attenuation value. The diameter of curvature and macrobending in fiber optic cables are the main factors that affect atenuation. A reduction in the diameter of curvature can lead to an increase in attenuation, which results in a decrease in signal quality (Yustini, Asril, Setiawan, Maria, & Rifka, 2023).

In designing and managing fiber optic cables, it is very important to consider the impact of cable bending and curvature on signal performance. Optical fiber forces on single-multimode cables can cause the cable to bend, which in turn leads to multimodal interference (MMI) (Costa, Franco, Serrão, Cordeiro, & Giraldi, 2019). This can make the output power intensity increase or decrease depending on the extent to which the cable is bent. In addition, the diameter of the curvature in indoor cable macro-bending affects the attenuation value and the number of turns of indoor cable macro-bending also affects the attenuation value (Maria, Asril, Wiharti, & Prayama, 2022). In addition, the calculation of received power is in accordance with the ITU-T G984.6 standard, which sets a maximum limit of 28 dB (Fajrina, Nopiani Damayanti, & Maulana, 2023).

Based on the above research, it can be concluded that twisting and macrobending in fiber optic networks can affect network performance. However, these studies generally only examine the effect of twists and macrobending in general without paying special attention to patch cord cables, which are important components in FTTB networks. In addition, no research has specifically addressed the number of twists with optimal curvature diameter and the use of patch cord length after network activation. This research proposes to study the effect of the number of twists and macrobending using patch cord cables of varying lengths on the activation of Fiber to the Building (FTTB) networks.

LITERATURE REVIEW

Optical Fiber

Optical fibers are cables made of very fine glass or plastic fibers, designed to transmit light signals from one point to another. These cables convert electrical signals into light, which is then transmitted through the fiber. As a transmission medium, optical fiber offers advantages such as high bandwidth capacity, resistance to electromagnetic interference, lighter weight, and the ability to transmit data in digital format with high efficiency.

Fiber Optic Structure

The structure of a fiber optic cable generally consists of several parts, namely:

1. Core
   The core is the main part of the optical fiber, this part is where information in the form of light will be transmitted, this layer serves to determine the light propagating from one place to another.
2. Cladding
   Cladding is a protective layer around the core of an optical fiber, with a lower refractive index than the core. Its function is to reflect light, allowing optical signals to travel from one point to another along the fiber.
3. Coating
   The coating serves to protect the core from damage and serves as color coding. The refractive index of the core is always greater than the refractive index of the cladding.

Types of Optical Fiber

Optical fibers can be divided into two types, namely singlemode and multimode.

1. Singlemode
   Singlemode fiber optic cables have a small diameter core (4-10 μm) and 125 μm cladding. Single Mode is designed to transmit signals in a single mode at a wavelength of 1310 nm or 1550 nm, thus reducing chromatic dispersion that can degrade performance. Due to their large capacity and low distortion, they are ideal for long-distance transmission using laser diode-based devices.
2. Multimode
   Multimode fibers have a larger core (50-70 μm) and wider cladding (100-200 μm) than singlemode fibers. While they can transmit signals in multiple modes, they generally offer lower transmission capacity and range.

Fiber To The Building

FTTB (Fiber To The Building) is a fiber network architecture that connects multi-storey buildings with fiber optic networks to provide bandwidth according to their needs (Anggita, Budi Rahman, Akbar, Asnoer Laagu, & Apriono, 2020). FTTB provides solutions for efficient and reliable data delivery, supporting a wide range of applications and services that require high-speed internet connections.

Fiber Optic Device

Fiber Optic devices are divided into 2 types of components used, namely:

1. Active Device
   Active devices are components that require electric current to work. The following is an example of an active Fiber Optic device:
   a. Optical Line Terminal (OLT)
      Optical Line Terminal is a device that connects networks with data, telephone, and video services. OLT converts electrical signals into optical signals to be transmitted through optical fiber.
   b. Small Form-Factor Pluggable (SFP)
      Small Form-Factor Pluggable is an interface on the motherboard of a network device, such as a router or switch, that connects with fiber optic cables. Its function is to facilitate high-speed data communication, long-distance telecommunications and play a role in OLT to convert electrical signals into optical signals.
   c. Optical Network Unit (ONU)
      Optical Network Unit is a customer-connected device with RJ11 and RJ45 ports that connects a fixed

telephone, wireless router, PC, or TV decoder via UTP cable.

2. Passive Devices

   Passive devices are devices that do not require electric current to work. Here are examples of Fiber Optic passive devices, namely:

   a. Optical Distribution Cabinet (ODC)

      Optical Distribution Cabinet is a box or dome that manages singlemode optical connections, including connectors and splitters, and provides fiber management space for passive optical access networks.

   b. Closure

      Closure is a device that functions as a place to connect and protect fiber optic cables, protecting the connection from mechanical damage, dust, moisture, and other environmental factors.

   c. Optical Distribution Point (ODP)

      Optical Distribution Point is a passive device that functions as a distribution cable termination and drop cable starting point, and houses splitters to distribute cables to subscribers.

   d. Optical Distribution Frame (ODF)

      Optical Distribution Frame serves as a termination and switching point between outdoor and indoor fiber optic cables.

   e. Paasive Splitter

      Passive splitters are optical couplers that split or combine optical signals into multiple paths. These splitters are available in 1:2, 1:4, 1:8, 1:16, and 1:32 configurations.

Bending pada Fiber Optic

Bending is an attenuation that occurs due to changes in the structure of the fiber optic cable due to bending, resulting in changes in the refractive index and angle of the incident light beam hitting the cladding. Bending consists of 2 types, namely:

1. Microbending

   Microbending occurs when an optical fiber undergoes small flexes caused by imperfections during fiber production or uneven pressure distribution during wiring.

2. Macrobending

   Macrobending occurs when an optical fiber is bent with a radius greater than the radius of the fiber itself. Signal loss (attenuation) can be measured by analyzing the modal distribution pattern in a fiber optic cable.

METHOD

The research uses simulation methods related to the effect of twisting, without twisting, macrobending with twisting, and macrobending without twisting on patch cord cable segments with lengths of 3 m, 5 m, and 10 m before and after activation of the FTTB network. The simulation can be seen in the research flow below:

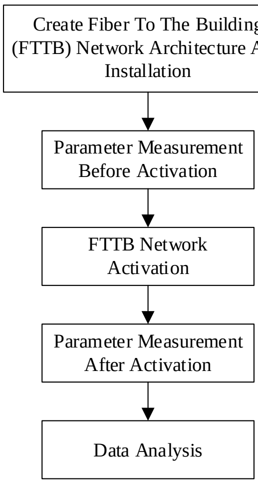

Figure 1. Research Flow

In Figure 1, the Research Flow conducted in this study. The first step is to create fiber to the building (FTTB) network architecture and installation. Installation is carried out according to the designed FTTB architecture. After the installation is complete, the FTTB network is measured before activation using a source from the Handle Light Source (HLS) with treatment without winding, with winding, macrobending without winding, and macrobending with winding. If the test shows results according to specifications, the FTTB network is ready to be activated. After activation, tests are conducted using a signal source from an Optical Line Terminal (OLT) installed with a Small Form-factor Pluggable (SFP). After all the data is collected, the results obtained are analyzed.

FTTB Network Installation

The FTTB installation consists of OLT, ODC, ODP, Roset, and ONU devices, with OLT as the starting point and ONU as the end point. The measurement process is carried out in two stages, namely before and after network activation. In the pre-activation stage, the signal is generated by the HLS, while post-activation, the signal is generated by the OLT connected via SFP. Receive power and optical attenuation measurements were performed using an OPM at a wavelength of 1310 nm. The measurement block diagram is presented in Figure 2

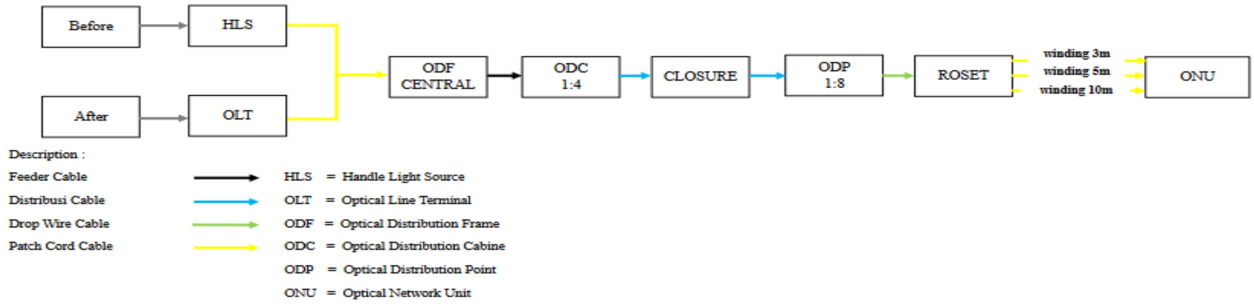

Figure 2. Fiber To The Building (FTTB) Network Block Diagram

RESULT

This section discusses results and discussions related to the installation and activation of FTTB networks, as well as coiling and macrobending issues in patch cord cables.

Input Power Measurement Results Before Activation

The measurements before activation used a signal source from the HLS at a wavelength of 1310 nm. Calibration was performed between the HLS and OPM to measure the input power, which is shown in Table 1.

Table 1. HLS Calibration Measurement Results

Trial to	Calibration result (dBm)
1	-7.39
2	-7.39
3	-7.39
Mean	-7.39

Results of Acceptability Measurement Parameters without Macrobending and with Macrobending Before Activation

The received power measurements without twisting and with macrobending before activation using patch cord cables with 3m, 5m, and 10m are shown in Table 2.

Table 2. Receiving Power Without Coiling and with Macrobending Before Activation

Cable Lengght (m)	P_{Tx} (dBm)	No Treatment		With Macrobending Treatment (0,8 cm)	
		P_{Rx} (dBm)	Attenuation (dB)	P_{Rx} (dBm)	Attenuation (dB)
3 m	-7,39	-27,17	19,78	-28,23	20,84
5 m		-27,86	20,47	-28,49	21,10
10 m		-27,90	20,51	-28,98	21,59

Results of Acceptability Measurement Parameters of Coiling and Macrobending Parameters Before Activation

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Measurements of the receiving power of the coiling and macrobending before activation of the patch cord cables are shown in Table 3.

Table 3. Receiving Power Coiling and Macrobending Before Activation

Number of Turns	Cable Length (m)	P_{Tx} (dBm)	No Treatment				With Macrobending Treatment (0,8 cm)			
			P_{Rx} (dBm) with Curvature Diameter		Attenuation value with Diameter of Curvature (dB)		P_{Rx} (dBm) with Curvature Diameter		Attenuation value with Diameter of Curvature (dB)	
			6 cm	15 cm	6 cm	15 cm	6 cm	15 cm	6 cm	15 cm
3	3	-7,39	-27,37	-27,28	19,98	19,89	-28,46	-28,35	21,07	20,95
5			-27,45	-27,37	20,06	19,98	-28,54	-28,44	21,15	21,05
3	5		-27,93	-27,89	20,54	20,50	-28,70	-28,59	21,31	21,20
5			-27,96	-27,91	20,57	20,52	-28,76	-28,67	21,37	21,28
3	10		-27,98	-27,96	20,59	20,57	-29,24	-29,12	21,85	21,73
5			-28,01	-27,98	20,62	20,59	-29,32	-29,21	21,93	21,82

HSL Calibration Results for Device Measurement in FTTB Installation After Activation

Measurements after activation used a signal source from the OLT with SFP at a wavelength of 1310 nm at the receiver. Calibration was performed between the installed OLT with SFP and OPM to measure the input power shown in Table 4.

Table 4. OLT Calibration Measurement Results

Trial to	Calibration result (dBm)
1	7,56
2	7,61
3	7,62
Mean	7,60

Results of Acceptability Measurement Parameters Without Macrobending and with Macrobending After Activation

The received power measurements without coiling and with macrobending after activation using 3m, 5m, and 10m long patch cords are shown in Table 5.

Table 5. Receiving Power Without Winding and with Macrobending After Activation

Cable Lenggth (m)	P_{Tx} (dBm)	No Treatment		With Macrobending Treatment (0,8 cm)	
		P_{Rx} (dBm)	Attenuation (dB)	P_{Rx} (dBm)	Attenuation (dB)
3 m	7,60	-12,14	19,74	-15,02	22,62
5 m		-12,38	19,98	-15,56	23,16
10 m		-12,46	20,06	-16,05	23,65

Measurement results of damping values after activation of coiling and macrobending parameters on patch cord cables

The measurement of the twisting and macrobending receiving power after activation of the patch cord cables is shown in Table 6.

Table 6. Receiving Power Coiling and Macrobending After Activation

Number of Turns	Cable Length (m)	P_{Tx} (dBm)	No Treatment				With Macrobending Treatment (0,8 cm)			
			P_{Rx} (dBm) with Curvature Diameter		Attenuation value with Diameter of Curvature (dB)		P_{Rx} (dBm) with Curvature Diameter		Attenuation value with Diameter of Curvature (dB)	
			6 cm	15 cm	6 cm	15 cm	6 cm	15 cm	6 cm	15 cm
3	3	7,60	-12,36	-12,28	19,96	19,88	-15,17	-15,06	22,77	22,66
5			-12,43	-12,33	20,03	19,93	-15,26	-15,15	22,86	22,75
3	5		-12,52	-12,48	20,12	20,08	-15,77	-15,67	23,37	23,27
5			-12,56	-12,52	20,16	20,12	-15,83	-15,74	23,43	23,34
3	10		-12,66	-12,54	20,26	20,14	-16,25	-16,17	23,85	23,77
5			-12,71	-12,62	20,31	20,22	-16,32	-16,25	23,92	23,85

DISCUSSION

This study analyzes the data obtained from the measurement results related to attenuation and network quality on twisting and macrobending problems in patch cord cables, both before and after activation. Data before activation is taken from HLS, while data after activation is taken from OLT.

Analysis Before Activation

Measurements were taken at the final termination device in the FTTB network using patch cord cables with different lengths of 3m, 5m and 10m. Each cable length is given various treatments, namely without coiling, with coiling, macrobending without coiling, and macrobending with coiling. Measurements were taken at the final termination device on the FTTB network. Before activation, measurements were taken using an HLS light source with an OPM measuring instrument. The wavelength used during the measurement was 1310 nm. The input power corresponded to -7.39 dBm, as specified in Table 1. The measurement data are listed in Table 2 and Table 3, which show the variation of cable lengths, namely 3 m, 5 m, and 10 m. PTx refers to the input power obtained through calibration, while PRx is the output power obtained from measurement. The antenna value is calculated based on the difference between the input and output power.

The attenuation obtained is calculated using the formula (1):

$$\text{Attenuation (dB)} = \text{Input power } (P_{Tx}) - \text{output power } (P_{Rx}) \qquad (1)$$

Table 2 shows the receiving power without coiling and with macrobending conditions before activation using 3 m, 5 m, and 10 m patch cords. Based on the table, the receiving power of the three cable lengths has increased. The attenuation value on the patch cord cable with a length of 3 m is 19.78 dB, on the 5 m cable it is 20.47 dB, and on the 10 m cable it reaches 20.51 dB. After macrobending with a diameter of 0.8 cm, the attenuation value of the 3 m long patch cord cable was recorded at 19.74 dB, the 5 m cable became 19.98 dB, and the 10 m cable reached 20.06 dB. These results show that cable length affects signal transmission performance, both in terms of receiving power and attenuation value. The receiving power tends to decrease as the length of the cable subjected to macrobending increases.

Table 3 shows the received power of twists and macrobending before activation using patch cord cables of length 3m, 5m, and 10 m. From the table, the attenuation value is obtained on patch cord cables with curvature diameters of 6 cm and 15 cm but with different numbers of twists, namely 3 coils and 5 coils. The PTx value obtained from calibration before reduction is -7.39 dBm. While the PRx value is obtained by taking measurements using OPM.

In this study, the attenuation of patch cord cables was tested with various numbers of twists and cable lengths. For a 3 m patch cord with 3 twists, the measured attenuation values were 19.98 dB at 6 cm diameter of curvature and 19.89 dB at 15 cm diameter. In a 5-meter patch cord cable with the same conditions, the recorded attenuation values were 20.54 dB for a diameter of 6 cm and 20.50 dB for a diameter of 15 cm. The 10 m patch cord cable showed attenuation values of 20.59 dB at a diameter of 6 cm and 20.57 dB at a diameter of 15 cm. For a 3 m patch cord with 5 coils, the measured attenuation values are 20.06 dB at a curvature diameter of 6 cm and 19.98 dB at a diameter of 15 cm. For the 5 m patch cord with the same conditions, the recorded attenuation values were 20.57 dB for a diameter of 6 cm and 20.52 dB for a diameter of 15 cm. The 10-meter indoor cable showed attenuation values of 20.62 dB at 6 cm diameter and 20.59 dB at 15 cm diameter.

From the data obtained, the number of coils, curvature diameter, and cable length have a significant influence on the attenuation value. The decrease in attenuation value as the curvature diameter increases indicates that the coiling and curvature of the patch cord affect the transmission efficiency of the optical signal. Larger curvature diameters tend to reduce the attenuation value and improve the quality of the received signal. Where, the curvature diameter of 15 cm and 6 cm on the patch cord cable has an influence on the attenuation value. The largest attenuation value is found at a curvature diameter of 6 cm with a number of turns of 5 with a cable length of 10 m.

Then, the cable was treated with macrobending with a diameter of 0.8 cm, the attenuation value increased. For a 3 m cable with 3 coils, the attenuation value was recorded as 21.07 dB at a curvature diameter of 6 cm and 20.95 dB at a diameter of 15 cm. The 5 m cable showed an attenuation value of 21.31 dB at 6 cm diameter and 21.20 dB at 15 cm diameter. Meanwhile, for the 10 m cable, the measured attenuation values were 21.85 dB for a diameter of 6 cm and 21.73 dB for a diameter of 15 cm. For the 3 m cable with 5 coils, the attenuation was recorded at 21.15 dB at a curvature diameter of 6 cm and 21.05 dB at a diameter of 15 cm. The 5 m cable showed attenuation values of 21.37 dB at 6 cm diameter and 21.28 dB at 15 cm diameter. Meanwhile, for the 10 m cable, the measured attenuation values were 21.93 dB for a diameter of 6 cm and 21.82 dB for a diameter of 15 cm. It can be observed that an increase in the number of turns in the cable results in an increase in the attenuation value. In addition, the macrobending treatment with a diameter of 0.8 cm in this study, involving patch cord cables with lengths of 3 m, 5 m, and 10 m, indicates a significant increase in the receiving power.

Based on the data results, the smaller the curvature diameter, the higher the attenuation value. An increase in the number of coils also correlates with an increase in the attenuation value. In addition, the greater length of the patch cord also leads to an increase in the attenuation value. Higher attenuation values indicate a decrease in transmission quality in optical signal delivery. Therefore, the presence of macro-bending in patch cord cables with a smaller diameter of curvature and a larger number of coils can reduce the quality of signal reception at the final stage.

Analysis After Activation

The measurements carried out are the same as before activation, namely measurements taken at the final termination device on the FTTB network using patch cord cables of different lengths, namely 3m, 5m and 10m. Each cable length is given various treatments, namely without coiling, with coiling, macrobending without coiling, and macrobending with coiling. In the measurement, what distinguishes it from before activation is the input source used, which after activation comes from the OLT that has been installed with the SFP. The SFP used in this study is an 8 dB SFP. The input power used is in accordance with Table 4 which is the average result of the calibration of the OPM measuring instrument with OLT PON1 which has an 8 dB SFP installed, which is 7.60 dBm.

Table 5 shows the results of the receiving power without coiling and with macrobending conditions after activation using patch cords with lengths of 3 m, 5 m, and 10 m. From the table, it can be seen that the receiving power increases at all three cable lengths. This indicates that the length of the cable affects the signal transmission performance, both in terms of receiving power and attenuation. The receiving power tends to decrease as the length of the cable subjected to macrobending increases.

Table 6 presents the results of the receiving power with the first condition, which is a coil with a curvature diameter of 5 cm and 15cm of patch cord as many as 3 coils and 5 coils with lengths of 3 m, 5 m and 10m. The second condition is a coil with a curvature diameter of 5 cm and 15 cm with an additional treatment of macrobending of 0.8 cm. The PTx value recorded from calibration before reduction is 7.60 dBm, while the PRx value is obtained through measurement using OPM. To determine the total attenuation value, the calculation is done by subtracting the PTx value from the PRx value as follows:

$A_{total} = P_{Tx} - P_{Rx}$

Total attenuation condition 3 coil, curvature diameter 15 cm and length 3 m
$A_{total} = 7{,}60\text{ dBm} - (-12{,}28\text{ dBm})$
$A_{total} = 19{,}88\text{ dB}$
Total attenuation condition 5 coil, curvature diameter 6 cm and length 10 m
$A_{total} = 7{,}60\text{ dBm} - (-12{,}71\text{ dBm})$
$A_{total} = 20{,}31\text{ dB}$
Total attenuation condition 3 coil, curvature diameter 15 cm, macrobending 0.8 cm and length 3 m
$A_{total} = 7{,}60\text{ dBm} - (-15{,}06\text{ dBm})$
$A_{total} = 22{,}66\text{ dB}$
Total attenuation condition 5 coil, curvature diameter 6 cm, macrobending 0.8 cm and length 10 m
$A_{total} = 7{,}60\text{ dBm} - (-16{,}32\text{ dBm})$
$A_{total} = 23{,}92\text{ dB}$

From the above calculations, the author can analyze that the total attenuation of macrobending 0.8 cm with 3 coiling and 5 coiling still meets the ITU-T G984 calculation standards. Where 19.88 dB (total attenuation of 3 coil, curvature diameter 15 cm and length 3 m) < 20.31 dB (total attenuation of 5 coil, curvature diameter 6 cm and length 10 m) < 22.66 dB (total attenuation of 3 coil, curvature diameter 15 cm, macrobending 0.8 cm and length 3 m) < 23.92 dB (total attenuation of 5 coil, curvature diameter 6 cm, macrobending 0.8 cm and length 10 m) < 28 dB (ITU-T G984,6). This means that the total attenuation of 3 coil < total attenuation of 5 coil < ITU-T G984.6.

Therefore, the number of turns, curvature diameter, and cable length have a significant effect on the attenuation value. The influence of macrobending and the number of cable turns also affect the attenuation value. The decrease in attenuation that occurs with increasing curvature diameter indicates that the cable coil and curvature affect the transmission efficiency of the optical signal.

CONCLUSION

This study aims to measure and analyze the effect of coiling, no coiling, macrobending without coiling, and macrobending with fiber optic cable coiling on Fiber To The Building (FTTB) network activation. Based on the results of research and analysis, the following conclusions can be drawn :

1. The attenuation value of Fiber To The Building architecture to the effect of the number of coils and without coils with a Patch Core cable length of 3 m, 5 m and 10 m has increased.
2. The smaller the coil diameter, the greater the attenuation of the optical cable, the attenuation of the optical cable increases as the length of the Patch Core cable increases and the macrobending treatment with a diameter of 0.8 cm significantly affects the data transmission performance and increases the attenuation.

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