Network Performance Analysis Using Optical-to-RJ11 Converters in Point-to-Point Communication

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Abstract— **Currently, fiber optic cable is the most sophisticated transmission medium and is starting to be widely used for data transmission. However, like any other transmission medium, fiber optic cables also produce attenuation or loss. This study analyzes network performance using 2 converters that will be connected to RJ11 telephones and single mode optical cables with predetermined specifications. Analysis on this network is carried out to determine the results of the attenuation value and sound quality on the fiber optic network. The data collection technique that was carried out began with designing the research materials. The materials used are single mode fiber optic cables, RJ11, converters, telephone servers, and telephones as information senders and receivers. Measuring tools used are Sound Spectrum analyzer and OPM. Conducted research by changing the bending of fiber optic cable in order to determine the performance of the communication system. The results are loss values as well as sound output on the fiber optic cable . The quality of network performance based on the measured bending loss values has different results. The smallest loss occurs at 5 cm bending which is -11.46 dBm and the largest at 0.5 cm bending is -50.00 dBm. The bending value used also affects the quality of the sound emitted on the telephone, where at the largest bending, which is 5 cm, the sound output power value is 77.475 dB. Meanwhile, when the smallest bending is 0.5 cm, the resulting value is only around 49.7 dB.**

Keywords— Bending, Converter, Fiber Optic, Loss, Point-toPoint, RJ11

I. INTRODUCTION

Based on data attached by the Ministry of Communication and Information, internet users in Indonesia in June 2022 will reach 82 million people. With this achievement, Indonesia is ranked 8th as the largest Internet user in the world. However, internet speed in Indonesia is still not as fast as other developed countries such as America or Japan. Another problem that is no less important is the inequality of distribution between regions so that data transmission is not balanced between locations. With the increase in internet service users, higher network quality and large bandwidth quantities are needed to meet consumer needs [1][2].

Currently, fiber optic cables are the most sophisticated transmission media and are starting to be widely used for sending data. Fiber optic cable is a data transmission technology using light. The light source that is widely used in the application of fiber optics is a laser, because the laser light is straight so it can easily penetrate the cable. However, it does not rule out the possibility of using LEDs as a light source in transmitting data using fiber optics [3][4]. Fiber optic cables can support voice, data, video, and other types of transmission, and offer many advantages over copper cables [5]-[7]. With the various advantages possessed by fiber optics, people prefer to use fiber optics rather than copper cables to transmit information [8]. Following the rapid development of technology and communications, the number of fiber optic cables to be installed for various technologies will increase rapidly in the future [9]-[11]. With the implementation of fiber optic cables, it is certain that data transmission via the internet will also be faster.

However, like other transmission media, fiber optic cables also produce attenuation. Attenuation or losses referred to are a decrease in the signal power emitted by an optical source caused by various factors, one of which is the scattering of light caused by uneven connections or bends in the optical fiber so that the power emitted becomes weak [12][13]. Attenuation can occur due to various things, one of which is bending, slicing, and the quality of the device itself [14]-[16]. To find out the attenuation you need a special tool to calculate it, so that the resulting attenuation complies with the standards set by each network service provider [17].

In designing this fiber optic communication network, researchers analyzed network performance using 2 converters which will be connected to an RJ11 telephone and a single mode optical cable with predetermined specifications. It is hoped that the analysis of this network will be able to produce a good optical communications network design seen through loss and sound quality parameters in decibel units [18].

II. METHOD

The research methods carried out in this journal are as follows:

A. Theoretical Study

The following is a series of definitions and concepts of tools and systems used in research:

1) Registered Jack (RJ)

Registered Jack (RJ) is a telecommunications network interface standard for connecting data and voice to services provided by local telephone operators or long distance

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operators. Available specifications include physical construction, cables, and signal semantics. Thus, Registered Jack is named with the letters RJ and followed by two digits to indicate its type. Examples are RJ11, RJ45, and RJ25. This type is the most commonly used type for one, two and three service connections respectively. The type of RJ used in this research is RJ11.

RJ11 is a standard connector used to connect telephones, fax machines, and related products in the United States, Japan, and many other countries. The main application of this RJ on a computer is connecting the modem with telephone wall jacks for a dial-up internet connection.

The physical structure of the RJ11 connector is illustrated in Fig. 1. The RJ11 connector, which is usually made of transparent plastic, consists of a mating plug and receptacles. Each has four contacts (pins) and can accommodate twisted pair wire. Twisted pair wire is a thin diameter copper wire commonly used for telephone cables. Cables are twisted around each other to minimize crosstalk (e.g. Figure 1).

The RJ11 connector is also sometimes used to connect computers to simple networks. However, most networks, including Ethernet, use RJ45 which has a similar appearance but is larger and has eight contacts. Ethernet is by far the most commonly used LAN (Local Area Network). The characteristics of the RJ11 connector used in this research are summarized in Table I.

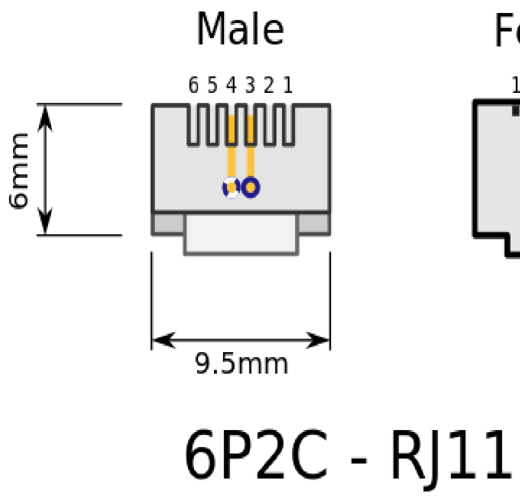

Figure 1. 6P2C-RJ11 Modular Cable

TABLE I
RJ11 CHARACTERISTICS

Configuration	6P2C or 6P4C
Utility	Telephone, ADSL line, cable modem. RJ11 is mostly used for voice applications
Bandwidth	The RJ11 connector can support around 24Mbps
Shape and Size	Square shaped with a width of 9.65 mm

2) Fiber Optic

Fiber optic cables are transmission lines used to transmit light signals from one place to another. This cable is made of glass or plastic and the light source used is a laser or LED.

The fiber optic used in this research is step index-singlemode optical fiber. The structure of a single-mode fiber optic is illustrated in Fig. 2. Single-mode fiber has low signal losses and high data rates. Single mode propagation mode can only allow one mode or one light beam for propagation, therefore single mode is generally used in applications with high bandwidth.

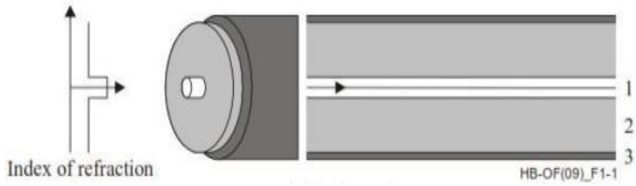

Figure 2. Single-Mode Fiber Optic

Single-mode fiber optic has a smaller bandwidth compared to multimode optical fiber because it has a smaller diameter so it is very efficient in light travel. This fiber optic also has better dispersion resistance because there is only one mode that propagates on the fiber and has a longer range. The fiber optic used is optical fiber that complies with the ITU-T G.652 standard. fiber optics. The type of cable used is the Aerial Self Supporting Loose Tube Optical Fiber Cable type and has fiber characteristic attenuation of 0.22 dB/km. devices with specifications that can be seen in the following Table II.

TABLE II
G.652 FIBER OPTICAL SPECIFICATIONS

Parameter	Specification	Unit
Attenuation (1310 nm)	≤ 0.35	dB/Km
Attenuation (1550 nm)	≤ 0.21	dB/Km
Attenuation (1490 nm)	≤ 0.28	dB/Km

3) LED

LED (Light Emitting Diode) is a diode that can emit light when it receives a forward bias current. LED can emit light because it uses gallium, arsenic and phosphorus doping. The different types of doping can produce light with different colors. LED (Light Emitting Diode) is a type of diode, so it will only flow electric current in one direction. The LED will emit light when an electric voltage is applied with a forward bias configuration.

4) LASER

Light Amplification by Stimulated Emission of Radiation or abbreviated as LASER is a device or component that can emit electromagnetic radiation in the form of visible light through a stimulated emission process. This component in the form of a laser can take a small or weak light beam and make it into a large or strong light beam.

Lasers have an important role in various fields of life, from health, military, hobbies, technology in electronic devices to telecommunications systems. In laser communication technology, fiber optics are used as the backbone of long-distance communication networks. The visible light spectrum provides thousands of THz of bandwidth, and the infrastructure has the potential to support the availability of data communications networks and lighting at the same time.

5) Point-to-Point

In telecommunications science, Point To Point is a direct connection condition where there are two nodes connected to each other without an intermediary or without involving other nodes. Point To Point networks can connect two LAN lines via bridge mode without going through the routing process. The directional antenna is an antenna that is suitable for point to point installation because it has a straight beam and does not spread. It can provide connection authentication, transmission encryption and compression. Point To Point is used in many types of physical networks including serial cables, telephone lines, trunk lines, cellular telephones, dedicated radio networks, and fiber optics such as SONET.

The simplest transmission link is a Point To Point link which has a transmitter at one end and a receiver at the other end. This type of link accommodates the lowest requirements of fiber optic technology which is then the basis for analyzing more complex architectures.

Point-to-point communication using fiber optics has three main components: Transmitter, Receiver and One channel (two connectors, fiber, and splice)

The following are Process and Block Diagrams in Point-to-point communication. The point-to-point communication process is illustrated in Fig. 3, while the block diagram of point-to-point communication using optical fiber is shown in Fig. 4.

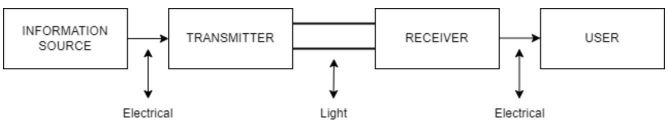

Figure 3. Point-To-Point Communication Process

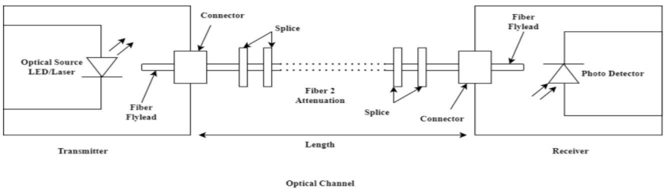

Figure 4. Block Diagram of point-to-point communication with Optical Fiber

6) Spectrum Analyzer

A spectrum analyzer is a measuring tool for measuring signals in the frequency domain. An analyzer can be used to make measurements on a transmitter that requires measuring parameters such as frequency, power, distortion, gain, and noise. Spectrum analyzers are also used to investigate the distribution of energy along the frequency spectrum of a known electrical signal.

Spectrum analyzers have a special function to measure several signal quantities in a limited frequency spectrum.

7) Optical Power Meter

Used to measure the wavelength and power of optical signals. From the power information received, an engineer can find out whether the power quality is still within the specifications of the device used or not, and can be used to segment the problem to trace whether the source of the problem is from an SFP whose power is weak, problematic patch cords and cores. which is on the ODF / OTB or from the optical path that stretches out there.

8) Optical Modulation

Optical modulation or light modulation is a modulation technique that uses light beams in the form of light pulses as information carrier signals. The light beam used is a light beam produced by a light source such as a laser or LED. Compared with conventional modulation, light modulation has the advantage of very high noise resistance, because the signal is not influenced by electromagnetic fields. In addition, this system allows data rates of up to hundreds of gigabits per second.

Apart from internal modulation such as OOK, in its development the modulation technique that is widely used today is external modulation. The external modulator used is electro-optical which utilizes the connection of electrical and optical signals with an interaction medium.

9) Fiber Media Converter

Fiber media converter is a network device that can connect two different types of networks via media such as twisted pair with fiber optic cable.

Fiber optic media converters are small devices and PC card converters with chassis systems that offer advanced features for network management. The way a Fiber Optic Media Converter works is with an SNMP system (Simple Network Management Protocol) and then connecting to a LAN (local area) by modifying different media. The Fiber Optic Media Converter used in this research is shown in Fig. 5.

Figure 5. Fiber Media Converter

10) Bending

Bending, especially in optical fibers, is a condition where the optical fiber bends or bends at a certain angle. This causes signal loss or losses so that the light signal is reflected towards the outside of the optical fiber core.

Losses due to bending occur when rays pass through curved optical fibers, where the angle of incidence of the rays is smaller than the critical angle so that the rays are not reflected perfectly but are refracted. The illustration of signal loss caused by fiber bending is shown in Fig. 6.

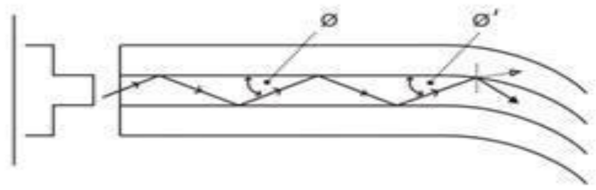

Figure 6. Bending Loss

Another thing that happens in bending is Microbending Loss. Microbending Losses are included as a result of an uneven surface (in the micro order) as a result of an imperfect material repair process. Losses caused by microbending conditions are illustrated in Fig. 7.

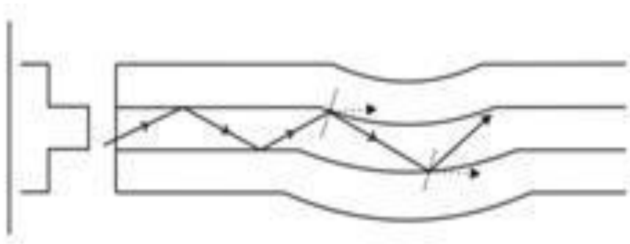

Figure 7. Losses due to Microbending

Apart from the two incidents, bending also causes losses when optical fibers are connected to connectors or couplers. Coupling losses arise because when optical fibers are coupled/connected to a light source or photo detector. This can happen because the energy radiated by the optical source can be incorporated into the optical fiber.

Losses also occur when connecting 2 optical fibers or slicing loss. These losses arise due to the gap between the two optical fibers being connected. This happens because the dimensions of the optical fiber are so small that the connection is not correct so that the rays from the optical fiber material to other optical fibers cannot be propagated completely. Several errors in splicing can cause splicing losses. The connection between the two optical fibers forms an angle, the two axes coincide but there is still a gap between them, there is a difference in size between the two optical fibers being connected.

B. Block Diagram of the System

The design that will be carried out in this research is shown in Figure 8.

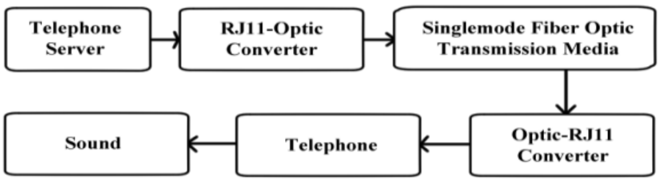

Figure 8. System Block Diagram

The diagram block explains the research design created.

The telephone server uses a PBX server from the Malang State Polytechnic campus which is connected to the AH Building. As data storage, the server will send or receive data according to client requests. Data transmission begins when the caller makes a call to the server.

Then the network that reaches the AH Building via the RJ-11 cable is converted using the RJ11-OPTIC Converter. The converter will convert electrical signals or data into light waves so that they can be passed to fiber optic media which is the research of this research.

On Fiber Optic Media, testing and measurements will be carried out by bending the optical cable with the diameter determined in this research.

Then the fiber optic cable is inserted into the OPTIC-RJ11 Converter which will convert the light waves back into electrical or data signals. From this Converter it will be connected to the Telephone.

Data or electrical signals received by the telephone will be converted into sound waves through the telephone speaker.

The resulting sound waves will be measured using a Spectrum Analyzer.

C. System Planning

Figure 9 is a research design to measure the sound quality produced by telephones. The cable from the PBX server is connected to the media converter Node A. The Tx port on fiber media converter A is connected to the Rx port on fiber media converter B using a fiber optic cable. Vice versa, the Tx port on fiber media converter B is connected to the Rx port on fiber media converter A. After that, the converter B cable is connected to the telephone. To start the measurement, bend it to a predetermined diameter and measure the sound quality of the ringtone from the telephone using the Spectrum Analyzer application. Do this repeatedly with different diameter lengths.

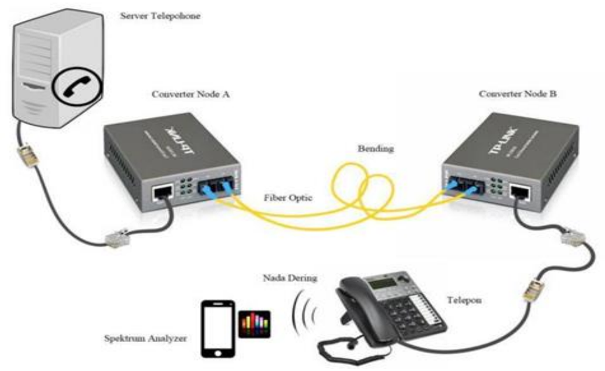

Figure 9. Research Design

III. RESULTS AND DISCUSSION

The following are the results of testing and analysis from the research that has been carried out.

A. Media Converter Output Power

Before testing the quality of service, we first measure the output power of the fiber media converter. The results of testing the output power of the fiber media converter without bending are shown in Figure 10 and Table III.

Figure 10. Media Converter Output Power Measurement

TABLE III
MEDIA CONVERTER OUTPUT POWER MEASUREMENT

Node A Output Power	Node B Output Power
-11.43 dBm	-12.26 dBm

B. Measurement of Media Converter Sound Output

Using the research design in Figure 9, carry out design measurements using the Sound Spectrum Analyzer software application to measure the strength or intensity of sound in decibels and frequency in Hertz. Test results for the sound output of the media converter without bending are shown in Figure 11 and Table IV.

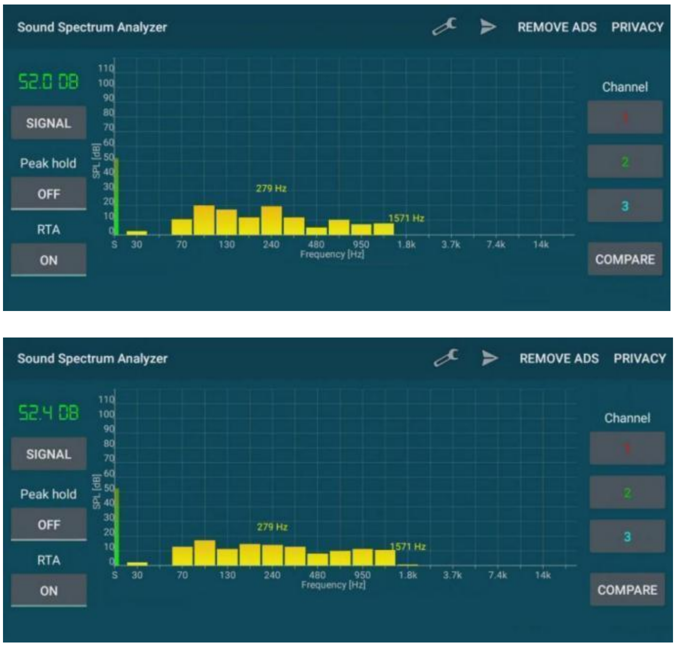

Figure 11. Sound Output Measurement Results

C. Measurement of Media Converter Sound Output

Based on the measurement results in Figure 11, by taking the average of the highest and lowest frequency values as well as the dB value obtained from 4 samples, the frequency and sound output values can be shown in Table IV.

TABLE IV
FREQUENCY AND SOUND VALUE

Test	Highest Frequency (Hz)	Lowest Frequency (Hz)	Sound Output (dB)
1	279	1571	52
2	279	1571	52.4
3	279	1571	53.6
4	193	1593	54.3
Average	257.5	1576.5	53.075

D. Measurement of Media Converter Sound Output

The following are the results of research tests and measurements using bending from a diameter value of 5 cm to 0.5 cm. The media converter output power test results and the average frequency and sound output results are shown in Table V and Table VI.

TABLE V
OVERALL RESULTS OF MEDIA CONVERTER OUTPUT POWER

Bending Diameter (cm)	Output Power (dBm)	
	Node A	Node B
5	-11.46	-12.27
4.5	-11.54	-12.35
4	-11.63	-12.50
3.5	-11.66	-12.51
3	-11.69	-13.03
2.5	-11.75	-13.14
2	-11.98	-13.26

Bending Diameter (cm)	Output Power (dBm)	
	Node A	Node B
1.5	-13.70	-14.98
1	-14.83	-15.79
0.5	-46.34	-50.00

TABLE VI
RESULTS AVERAGE FREQUENCY AND SOUND OUTPUT

Bending Diameter (cm)	Highest Frequency (Hz)	Lowest Frequency (Hz)	Sound Output (dB)
5	467.75	1593	77.475
4.5	467.75	1609	77.275
4	467.75	1630.75	77.225
3.5	446.5	1614.25	71.374
3	441	1609	67.425
2.5	467.75	1641.5	66.475
2	446.5	1652	60.4
1.5	462.5	1673.75	59.05
1	451.75	1641.25	57.4
0.5	435.5	1636	49.7

Based on Table V and Table VI, it can be seen that the smaller the bending diameter, the output power transmitted by the fiber media converter decreases, both the output power of media converter node A and the output power of media converter node B. When the cable is bent with a diameter 5 cm, 4.5 cm, 4 cm, 3.5 cm, 3 cm, 2.5 cm, 2 cm, 1.5 cm, and 1 cm, the output power transmitted by the fiber media converter only decreases slightly and does not decrease drastically. Furthermore, when the cable is bent to a diameter of 0.5 cm, the output power transmitted by the fiber media converter is reduced drastically, even to the point of power loss. This causes fiber media converter node A to not be able to connect to fiber media converter node B. So the communication line is cut off and communication using voice or text cannot be carried out.

Then the quality of network performance is based on sound output with decibel values. When the cable is bent with a diameter of 5 cm, 4.5 cm, 4 cm, 3.5 cm, 3 cm, 2.5 cm, 2 cm, 1.5 cm, and 1 cm, the average sound output obtained tends to be better even though there are changes due to The sound output power value is greater than the condition without using fiber optic cable, namely 53,075 dB. Meanwhile, at a bend of 0.5 cm, the sound power obtained is reduced that of conditions without using fiber optic cables. This can happen because the losses in the fiber optic network are close to -50.00 dBm. Because the results of the highest and lowest frequencies in the design are almost unaffected by changes in bending diameter, these frequency values are not involved in the research.

IV. CONCLUSION

Based on the research, it can be concluded that: A point to point voice communication system using fiber optic media can be implemented on an RJ-11 telephone device. Fiber media converters are used to convert electrical signals into optical signals and convert optical signals back into electrical signals. The Tx port on fiber media converter A is connected to the Rx port on fiber media converter B using a fiber optic cable. Vice versa, the Tx port on fiber media converter B is connected to the Rx port on fiber media converter A. The quality of network performance based on the measured bending loss values has different results. The smallest loss value results occur at 5 cm bending, namely -11.46 dBm and the largest loss value results occur at 0.5 cm bending, namely -50.00 dBm. The bending value used also influences the quality of the sound produced on the RJ-11 telephone, where the largest bending time, namely 5 cm, has a sound output power value of 77,475 dB. Meanwhile, at the smallest bend, the resulting sound output power value is only around 49.7 dB.

REFERENCES

[1] Sejati, Guntur Wahyu. 2018. “Design Of A Two-Way Digital Audio Communication System Using Arduino At 2.4 Ghz Frequency”. Department Of Electrical Engineering, State Polytechnic Of Malang.

[2] Hafidhotunnis, Ummi. 2018. “Implementation Of Voice Transmission Via Optical Fiber Using Different Leds”. Department Of Electrical Engineering, State Polytechnic Of Malang.

[3] Saputra, Bambang Eka. 2019. “Design And Build A Video Chat Server With Raspberry Pi As An Access Point For Worker Communication In Areas Without Signal”. Department Of Electrical Engineering, State Polytechnic Of Malang.

[4] Selamet, Rachmat. 2017. Socket Programming In Java. Bandung: Likmi College Of Information And Computer Management

[5] Tua Lesmana, Indra, 2017, Data Transfer Analysis Using Socket Programming (Case Study: Moving Vehicles). Bandung: Bandung State Polytechnic.

[6] Fajar, Ahmad Nurul. 2006. Socket Programming With Java In Developing Software With Client Server Architecture. Jakarta: Uieu.

[7] Ummi Hafidhotunnisa, Yoyok Heru.P.I, Waluyo (2016). Implementation Of Voice Transmission Via Optical Fiber Using Different Leds. Department Of Electrical Engineering, State Polytechnic Of Malang.

[8] Adiati, Rima Fitria Kusumawardhani,Apriani Setijono, Heru. Analysis Of Signal To Noise Ratio And Bit Error Rate Parameters In The Lamongan-Kebalen Segment Fiber Optic Communication Backbone.

[9] Rusdi Wartapane, Nur Aminah. Testing, Measuring And Analyzing Attenuation Values Due To Coupling Of Optical Fibers In Optical Transmission Lines. Ujung Pandang State Polytechnic Electrical Engineering

[10] Lestari, V. A., T, T. N. D. S., Stat, B. U. S., Terapan, F. I., Bandung, K., Budget,

[11] L. P., & Budget, R. T. (2018). Fiber Optical Network Design For Bumi Adipura Cluster Solutions Optical Fiber Network Design For Bumi Adipura Cluster Solutions The Following Are The Devices Used For The Fiber Optic Network In Fiber To The Home. Optical Line Terminal (Olt. 4(3), 2421–2429.

[12] Pamungkas, N. S., Hambali, I. A., & Saputri, D. M. (2017). Performance Analysis Of Xg-Pon Technology Using Splitter Performance Analysis Of Xg-Pon Technology With Splitter. 4(3), 3595–3602.
[13] Prayudha, B. R., Wahyudi, E., & Zulherman, D. (2018). Fiber To The Home (Ftth) Network Performance Using Splitters 1: 64. 321–325.
[14] T. Lee, K. J. Runta And E. 8. Hara, A Digital Multiplexed Fiber Optic Transmission System For Analog Audio Signals, Faculty Of Engineering University Of Regina Regina, Saskatchewan Canada,
[15] Aratake, Atsushii. High Reliability Of Silica-Based 1 × 8 Optical Splitter Modules For Outside Plant.
[16] Asada, Hideyuki Yamada, Takashi Rabou, Nabil Abd Ikeda, Hiroaki Shimodaira, Yoshifumi, Optical Fiber Digital Transmission Of Multiplexed Video And Audio Signals Suitable For Multimedia Applications. Shizuoka University 3-5-1 Johoku, Hamamatsu 432 Japan
[17] Jinzhu Li: Hiroaki Ikeda: Singenobu Shinohara:Kazuaki Wakai: Hirofumi Yoshida: And Etsuo Tsuchiya, Optical Audio And Video Signal Transmission System For Home Appliances. Shizuoka University, 3-5-1 Johoku, Hamamatsu 432 Japan Palcom Electronics Corporation, 157-2 I- Ida-Cho, Hamamatsu 435 Japan.
[18] Daniyati, Rizqa. 2011. "The Effect Of Curvature (Bending Loss) On The Influence Of Intensity Arising In Optical Fibers" Faculty Of Mathematics And Natural Sciences, Sepuluh November Institute Of Technology, Surabaya.