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Power Losses in Fiber Optic Communication Systems

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ABSTRACT

If a communication system is able to transmit a lot of information in one second and its signal can reach the receiver with high accuracy, the communication can be considered successful. One of the methods that can be used for this communication is through fiber optics. Fiber optics is a technology in the field of optics that is used to propagate data through light. The benefit of this technology is that it transforms electrical signals into light signals (fiber optic communication systems). Then, the light signal travels through the optical fiber and at the receiving end, this signal is converted back into an electrical signal. During transmission through optical fibers, several types of losses can occur, such as Rayleigh propagation loss, turning, mode coupling, and splicing. This loss of power has a significant impact on the performance of the optical fiber itself, which is the main reason for this study.

Keywords: *Communication, Communication System, Rayleigh, Bending Losses, Modde Coupling, Splice Losses.*

1 Introduction

Communication is basically used to meet everyone's needs. "," which means "together or with," is the origin of communication. Next, "unus", which means "one". The words communio and communicare are derived from both words, which means to share something with someone, give something to someone, tell someone.(R. T. Siregar et al., 2021)

According to KBBI, communication is the process of sending and receiving messages or news between two or more parties so that the message can be understood clearly. Electromagnetic waves are modulated to transmit information. As an information carrier wave, fiber optic communication systems use light. The sender converts the information signal into an electrical quantity. In this place, the light spreads through the attenuation dam due to the impure fiber material, which absorbs and diffuses the light.

By using an electronic repeater device placed at a certain distance, light can be restored after being widened and attenuated.. This tool works by converting the received light into an electrical signal, amplifying it, and then converting it back into light. However, this method is not very efficient because it can cause bigger errors, reduce transmission speed and bandwidth, and the cost can be very high.

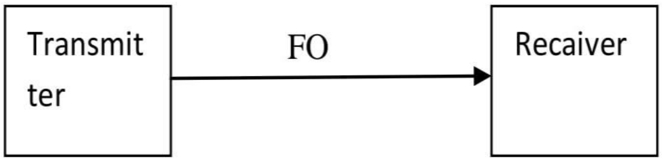

Figure 1. Basic Communication System on Optical Fiber

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There are 3 main components in a fiber optic communication system:

1. Diode Laser Transmitter (LD) and Light Emmiting Diode (LED)
2. Fiber optic transmission media
3. Receiver as receiver detector, using PIN and PPE

(Hariyadi, 2018)

2 Research Methodology

This study adopts a literature review method to collect and analyze related data. This study draws on previous research that is similar or related. Some of the similarities underlying this study were found after collecting literature. Fiber optics are now very commonly used, especially in the field of telecommunication signal transmission. The phenomenon, Total Internal Reflection (TIR) occurs when light passes through the medium through which it travels, so that optical fibers can transmit signals in the form of electromagnetic waves in the form of light. As in equation (1), the following:

$$Qc = sin^{-1} \frac{n2}{n1} \quad (1)$$

(Ilham Arif Firmansah, 2021)

In equation (1) The refractive index of the light-conducting medium n1 and the protective layer n2, respectively, have the following conditions in equation (2):

$$n2 \leq n1 \quad (2)$$

All of these phenomena allow light to spread throughout the medium, no matter which angle it passes through or its extreme tendencies.

3 Results and Discussion

The Various types of power losses are divided into four parts, including :

3.1 Spread Losses (Rayleigh)

The inconsistency of the refractive index in the fiber optic core led to Rayleigh dispersion. Scattering occurs when the refractive changes in a critical part of the optical fiber compared to the wavelength of the propagated beam (Huang et al., 2002)

Rayleigh scattering is the effect of ray splitting due to small shifts in the recritical index of the base material and the mantle. It is considered deep because the transition in the material only occurs in certain places (Pt & Access, 2023).

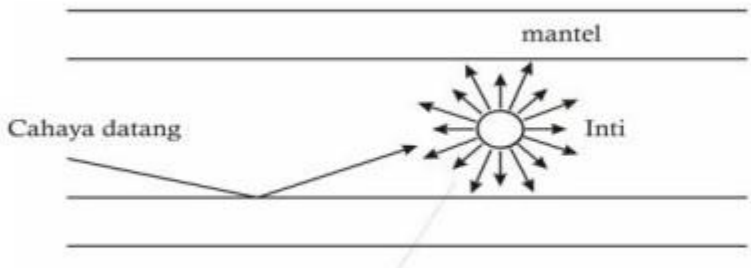

Figure 2. Rayleigh Spread (PARENRENG, 2021)

Figure 2 shows that the light is split and scattered throughout the space. If the light travels at an angle lower than the critical angle, any part of the beam can pass through the mantle and be lost as a loss of power. As a result, these rays will affect light with the smallest wavelength or frequency. (Adella Mahisa Putri, Anita Fauziah, 2023).
The formula used to find the losses of rayleigh power is:

$$\propto S = \frac{34.748\,\pi^3 (n^2 - 1)^2 k_B \mathrm{T}_f \beta_T}{\lambda^4} \text{ .... (3)}$$

3.2 Appeal Losses

Head losses in piping systems are usually categorized into two main types. Major head loss occurs due to fluid viscosity and turbulence caused by the roughness of the pipe surface. Minor head losses occur due to changes in cross-sections and other components in the piping system. This phenomenon results in a loss of energy along a pipe with a constant diameter at the laminar flow (Mujahid, 2021).
Bending occurs due to the variation of the contour in an area, which causes a difference in the position. When optical fibers pass through the area and light is transmitted, a loss of power occurs. The data obtained from this phenomenon can be analyzed for use in the design of sensor systems (A. C. P. Siregar, 2022).
The minor losses caused by doing can be calculated using the following equation:

$$\Delta p = k \times \rho \times \frac{v2}{2}$$

The overall pressure drop in the distribution system can be calculated by:

$$\Delta \mathrm{p\ total\ penyalur} = \Delta \mathrm{p\ mayor} + \Delta \mathrm{p\ minor}$$

The total amount of loss in the system can be expressed as:

$$\Delta \mathrm{p\ total} = \Delta \mathrm{p\ mayor} + \Delta \mathrm{p\ minor} + \Delta \mathrm{p\ komponen}$$

(Simatupang et al., 2022)

Link power budget analysis (Power Link Budget) and evaluation of the increase time budget (Rise Time Budget) are two common methods that ensure the desired fiber optic communication system meets the specified specifications. The process of evaluating the link's power budget begins by establishing the power range between the optical transmitter output and the receiver's minimum sensitivity. If the results of this evaluation meet the set requirements, the next stage is to conduct an analysis of the time budget for the increase. During this stage, the limitations that arise due to dispersion on the transmission line can be calculated to ensure that the system is operating as intended. (Tamimah & Siregar, 2023).
The use of optical fibers in transmission lines can be affected by conditions that alter the physical state of the fiber. These physical changes are known as bendings and can be divided into two types: small curvatures and large curvatures. Minor bends occur due to cable imperfections caused by various external factors. In contrast, large bending occurs when optical cables are bent at a certain angle, which can cause significant attenuation in the signals propagating within the fiber core (Pahri, 2022).

3.3 Disadvantages of Varieety Partnerships

In optical fibers, power that has been successfully coupled into a propagating variety can be disrupted and transferred into a leakage or radiation variety (Putri, 2022). This coupling effect can be minimized by placing the lens in front of a light source such as a superichal surface, on a light source or the tip of an optical fiber (Habib et al., 2019).
The general combinations of losses are as follows:

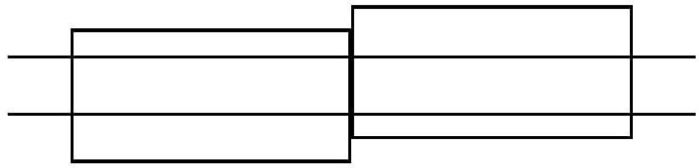

Figure 3. Coupling

μP_{in}/P_{out} = / .... (4)
So

L = $-\ 10\ \log\mu$................ (5)

With : is the input power of optical fiber (Watts)P_{in}
is the power of the light source (Watts)P_{out}
and μ is Splicing Efficiency (Watts)

Alternative

L = ... (6)$-\ 10\ \log\eta$

Where : d is the width of the connection (μm)
A is the width of the fiber cable (cm)
η is efficiency (Al-Azzawi, 2006)

OTDR (Optical Time Domain Reflector) is used to simulate losses on optical fiber. Power drops to the connector at the point where the first and second wires connect and ends of the wires, while power increases at the junction point. The closure of the fiber optic cable transmission line causes a steep drop. OTDR was chosen because it has the ability to detect any point of pressure on silica optical fibers (Tamimah & Siregar, 2023).

3.4 Material Losses

Material losses are an important parameter in understanding its nature and behavior. Here are the key points about absorption in optical materials. In glass fibers, absorption losses are caused by three mechanisms: resonant ion absorption, infrared, and ultraviolet. (Simatupang et al., 2022):

a. The coefficient of material losses (α) is a material-specific exponential coefficient that determines the transmission or absorption of a material for a given sample thickness. The absorption coefficient is independent of the thickness of the sample, meaning that two thicknesses of the same material will produce the same absorption coefficient, although different absorption values can be observed (Bock, n.d.)

b. The coefficient is usually measured by determining the transmittance of a homogeneous sample under collimated lighting. For non-homogeneous or randomly distributed samples, such as granules, powders, or fibers, alternative methods such as integrating cavity spectroscopy may be used (Martinez Anton et al., 2021)
c. The absorption coefficient can be calculated using the relationship between the transmissivity (T) and the refractive index (n) of the material. This method is particularly useful for optical materials with a high refractive index, as it provides accurate results with fewer measurement steps than traditional methods such as the integral sphere method and calorimetry techniques (Paramarta & Wendri, 2019)
d. The three main effects on the interaction of light with matter are reflection (R), absorption (A), and transmission (T). Absorption occurs when light is captured and scattered as heat in a material as it passes through it. The absorption coefficient is used to describe the absorption properties of materials, and is an important parameter in understanding the behavior of optical materials (Waspodo, 2017)

Accurate measurement and calculation of absorption coefficients are essential in a variety of applications, such as the characterization of non-homogeneous samples, the development of optical devices, and the analysis of light absorption by water particles. (Kailas, 2019)

4 Conclusion

Communication is basically used to meet everyone's needs. Electromagnetic waves are modulated to transmit information. As an information carrier wave, the optical fiber information system uses light. Fiber optics are now very commonly used, especially in the field of telecommunication signal transmission. However, in fiber optic systems, there are power losses which include propagation losses (Rayleigh), bending losses (bending losses), mode coupling losses, and material losses. These losses have an impact on the performance of the optical fiber.

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