Optical Fiber Communication Affected by Magnetic Field of a Straight Conductor

Muntadher J. Khudhair¹, Khalid Ghalib Mohammed², Firas S. Mohammed³*
¹,³ College of sciences, department of physics, Mustansiriya University, Baghdad, Iraq
² College of education, department of physics, Mustansiriya University, Iraq
Email*: fsphd@uomustansiriya.edu.iq

Abstract. This paper deals with the effect of magnetic field of a straight Conductor on data transmission in optical fiber communication systems. A proposed method utilized to measure the stability of system performance. The experimental and simulation results demonstrated that the system instability increases effectively under the effect of external Magnetic Field. The experimental results show linear dependence of the output power fluctuation with the low magnetic field. Furthermore, for higher magnetic field values the maximum probability values of the output power close to 110%. Moreover, high values of Q-factor (≥ 6) indicate a lower rate of received signal loss and the effect of the external magnetic field can be neglected in common applications.

Keywords: Fiber optics, magnetic field, Q- Factor, bit error rate.

1. Introduction

For long-distance and high-bit-rate communication systems, optical fibers were used. Optical fibers have the following advantages over copper cable; to transmit more bits of information in a given time period, the loss of a silica optical fiber is much lower than that of copper cable and the optical fibers are purely dielectric waveguides [1]. Since all spatial modes in one fiber are orthogonal to each other, it is possible to transmit them over the same fiber and to recover the signal after transmission without any loss of information [2]. The light propagating in an optical fiber faces different challenges such as (temperature, polarization, strain, humidity, etc.) [3, 4, 5]. In this paper, we explore the disturbance effect of the magnetic field of a straight Conductor on data transmission in optical fiber communication systems. Biot-Savart’s law for a current distribution in conductor is used to obtain a physical formula for the magnetic field [6]. Several studies attempt to measure the magnetic field influence on; the optical signals propagation direction [7-9], tunable refractive index
and field dependent transmission [10]. The attenuation constant $\alpha$ is a measure of total losses can be calculated using [11]:

$$\alpha_{dB} = 10 \log \frac{P_{out}}{P_{in}} \quad \ldots \quad (1)$$

Where $P_{in}$ is the input power to the fiber and $P_{out}$ is the power at the output of the fiber. A proposed method utilized to measure the stability of the output signal of the optical fiber when a magnetic field is applied. It would be more reasonable to combine the experimental and simulation measurements for more accurate conclusions.

2. Experimental setup

Experimental setup was designed for testing laser output power stability used in fiber-optic communication with presence of a low magnetic field. The experimental setup for this investigation is illustrated in Figure (1). The proposed system consists of laser diode (LD) used as an optical source, Single mode fiber (3 m length) as a dielectric waveguide, optical detector, an optical power meter, high current power supply and tesla-meter with axial B-probe. When charges move in a straight conductor and produce a current $I$ (A), the magnetic field $B$ (mT) can be calculated as a function of the current. It can be done by increase the current $I$ from 0 to 20 (A) in steps of 2 (A), and take the measured values of magnetic field $B$ and optical output power $P$.

![Figure 1. The experimental setup.](image-url)
3. Simulations of the propagation system

In order to explore the performance of data transmission system under the effect of a magnetic field of straight conductor numerical simulation is the common choice. The main design of a proposed optical fiber system can be shown in Figure 2. It consists of Pseudo-Random Bit Generator, NRZ Pulse Generator, Mach-Zehnder Modulator, laser source, optical fiber channel and avalanche photo-diode. Moreover, the received data can be visualized by optical power meter, electrical carrier analyzer and bit error rate (BER) analyzer. Table (1) shows the parameters that used in the numerical simulation.

![Figure 2. Simulation layout of the proposed optical fiber system.](image)

| Parameter                  | Value    |
|----------------------------|----------|
| Laser wavelength           | 1550 (nm) |
| Transmitter optical power  | 30 (dBm) |
| Receiver sensitivity       | -20 (dBm) |

4. Results and discussion

The main result can be presented as follows: Table (1) and Figure 3, show experimentally the change in the output power of the transmitted signal due to the change in an external magnetic field. Also, Table (1) illustrates the percentage of the output power fluctuation.

| Table (2) Experimental measurements. |
|---------------------------------------|
| Conductor current (A) | Magnetic field (mT) | Optical output power (mW) | Power fluctuation (%) | Output power (dBm) |
|------------------------|---------------------|---------------------------|----------------------|--------------------|
| 2                      | 0.14                | 1.06                      | 106                  | 31.8               |
In order to observe the change in the efficiency of the output signal, Q-Factor is obtained from the simulation of propagation system. Therefore, the result is presented in Fig. 4 shows the relation between the Magnetic Field and Q-Factor.

**Figure 3.** Magnetic Field vs Optical output power

**Figure 4.** Magnetic Field vs Q-factor.
The experimental results show linear dependence of the output power fluctuation with the low magnetic field. Furthermore, for higher magnetic field values the maximum probability values of the output power close to (1.1 to 1.8 mW) equivalent to (110%). From Combining All results one immediately obtains that the system instability increases effectively under the effect of external Magnetic Field. Moreover, high values of Q-factor (≥ 6) indicate a lower rate of received signal loss [12]. Therefore, it demonstrated that the system performance based on Q-Factor work properly (doesn't exceed the limitation) and the effect of the straight conductor magnetic field can be neglected in common applications such as communication.

5. Conclusion

The variation in data transmission in optical fiber communication systems according to the effect of the straight conductor magnetic field has been investigated. The experimental results reflect serious instability in the output power. system instability increases effectively under the effect of external Magnetic Field. The experimental results show linear dependence of the output power fluctuation with the low magnetic field. Furthermore, for higher magnetic field values the maximum probability values of the output power close to 110%. Despite that the simulation measurements demonstrated that high values of Q-factor (≥ 6), it can be neglecting the influence of the external magnetic field in common applications.

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