Magnetic Field Effect of Conductor loops on Free-Space Optical Communication

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Abstract

This paper work investigates the effect of magnetic field resulting from Conductor loops on the performance of the Free-space optical communication systems. This aim can be done by using a laboratory setup and simulation. The obtained results show serious variation (system stability decreases) of data transmission into FSO communication systems according to the effect magnetic field. Thus, the received power decreased when the magnetic field increased. It also affects the signal quality and system performance. As at weak magnetic field there is low influence on the Q-factor (≥ 6), whereas when it increases, it reflects serious effects on Q-factor (< 6).

Keywords: Laser system, magnetic field, free space optics, Q-factor.

1. Introduction

The Free Space Optical (FSO) systems were used to allow laser signals to be transmitted and received without significant loss. [1]. They have the ability to transfer huge energy quantities. Moreover, these systems are negatively affected by external turbulence and obstacle and thus reducing link reliability and availability [2]. Unlike radio frequency (RF) links, FSO links provide a license-free, high-speed and secure communication system. [3]. Therefore, several parameters of FSO systems can be changed depending on the conditions of the transmitted path, such using the spacing of transmission beams to better align FSO connections [4, 5]. The transmitter divergence angle was designed to "increase the availability of the link or decrease the transmitter power", while preserving the availability of the target link. The signal power attenuation through the atmospheric channel can be described by the Beers-Lambert Law [6]:

$$\tau_R = \frac{P_R}{P_O} = e^{-\sigma R} \quad \dots (1)$$

τ_R is the range (R) of transmitted laser signal,
P_R is the power of the received laser signal,
P_0 is the power of the transmitted laser signal, and
σ is the coefficient of attenuation.

Several papers have been conducted on analyzing the intensity variations produced via external magnetic field. For example, The magnetic field effect on the direction of propagation of optical signals [7, 8]. Biot-Savart's law for current distributed volume was utilized to find a magnetic field circulation formula [9]. The current I was produce in the conductor as a result of moving charges. Thus, the calculation of magnetic field can be done at point (P) by considering the contributions of the magnetic field, $d\,\vec{B}$, arising from small parts of the wire $d\,\vec{s}$ due to the current. The source of wire segments infinitesimal current can then be written as, according to Biot-Savart law ($Id\,\overrightarrow{s}$) [10, 11];

$$d\vec{B} = \frac{\mu_\circ}{4\pi}\frac{I d\vec{s}}{r^2} \times \frac{r}{r} \qquad \dots.(2)$$

As r is the "position vector" from the considered conductor part to the point of effect. $\mu_\circ$ is the "free space permeability":

$$\mu_\circ = 4\pi.10^{-7}\ \frac{Vs}{Am}$$

The aim of the work is to investigate the effect of magnetic field resulting from Conductor loops on the performance of the FSO communication systems. It is conducted via using laboratory setup and simulation software "Opti-System 7.0".

2. System design and simulation

In order to, study the real performance of "data transmission system" influenced by a weak magnetic field. Experimental setup is designed for testing laser output power stability used in free space communication with presence of weak 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, optical detector, an optical power meter, power supply and tesla-meter with axial B-probe". In a conductor loop, the current I (A) emerged as charges stat moving, the magnetic field B (mT) was 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 measure the magnetic field B amount and the output power P.

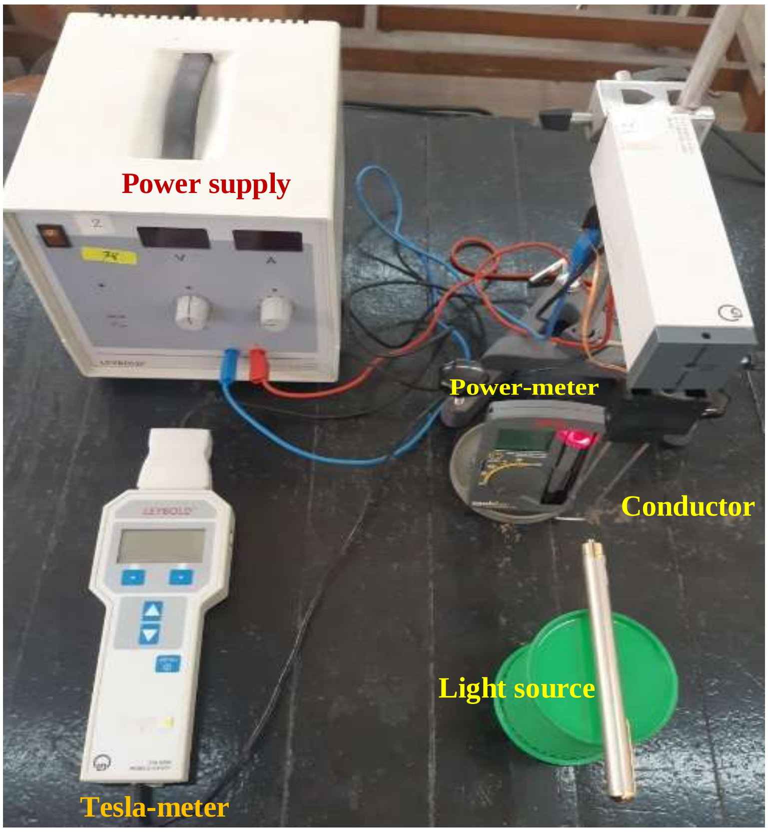


Figure 1. The laboratory experimental setup.

The main design of a proposed optical fiber system can be shown in Figure 2. It consists of NRZ Pulse Generator, Pseudo-Random Bit Generator, laser source, Mach-Zehnder Modulator, optical fiber channel and avalanche photo-diode. Moreover, the received data can be visualized by optical power meter, electrical analyzer and bit error rate (BER) analyzer.

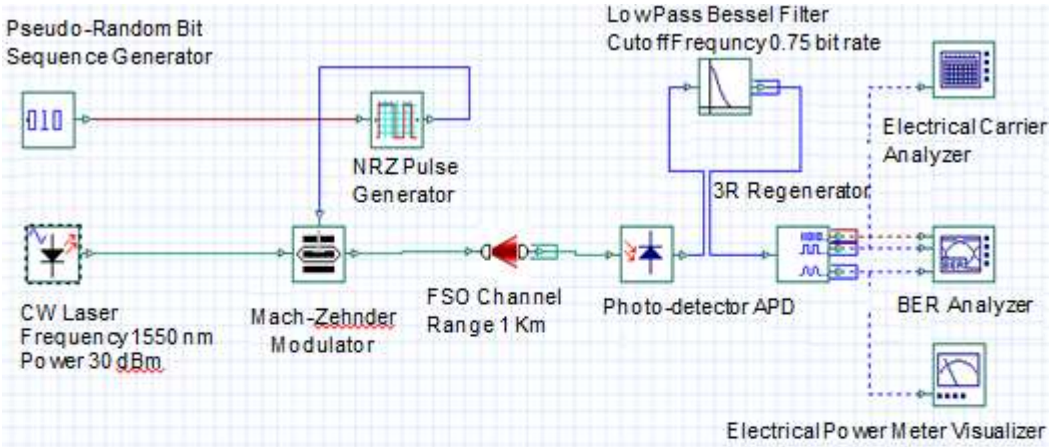


Figure 2. Simulation layout of a FSO system.

Table (1) shows the parameters of the numerical simulation.

Table (1) simulation parameters of the system.

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

3. 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 (2) illustrates the magnetic field values, output optical power and optical power fluctuation percentages

Table (2) experimental measurements

Magnetic Field (mT)	Power fluctuation percentage (%)	Recieved Power (dBm)	Q-Factor
0.12	106	22	6.5
0.19	109.5	23.5	6.3
0.25	109.9	23.8	6.1
0.29	110	24	5.6
0.37	110.2	24.6	5.3
0.46	110.4	24.8	5.09
0.55	110.4	24.9	4.7
0.63	110.5	25.1	4.4
0.71	110.8	25.4	4.1
0.80	110.8	25.7	4.1

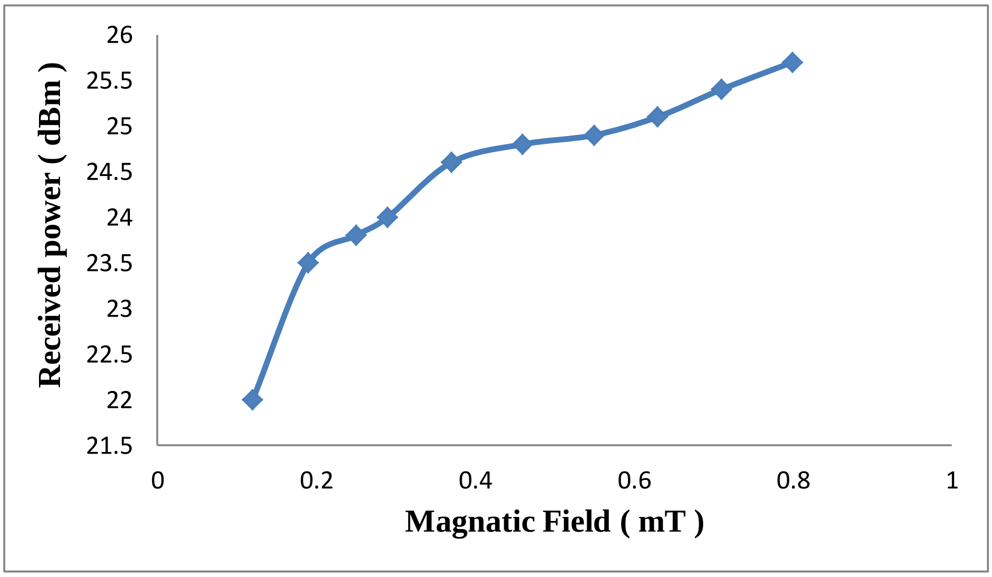


Figure 3. Magnetic field vs received power.

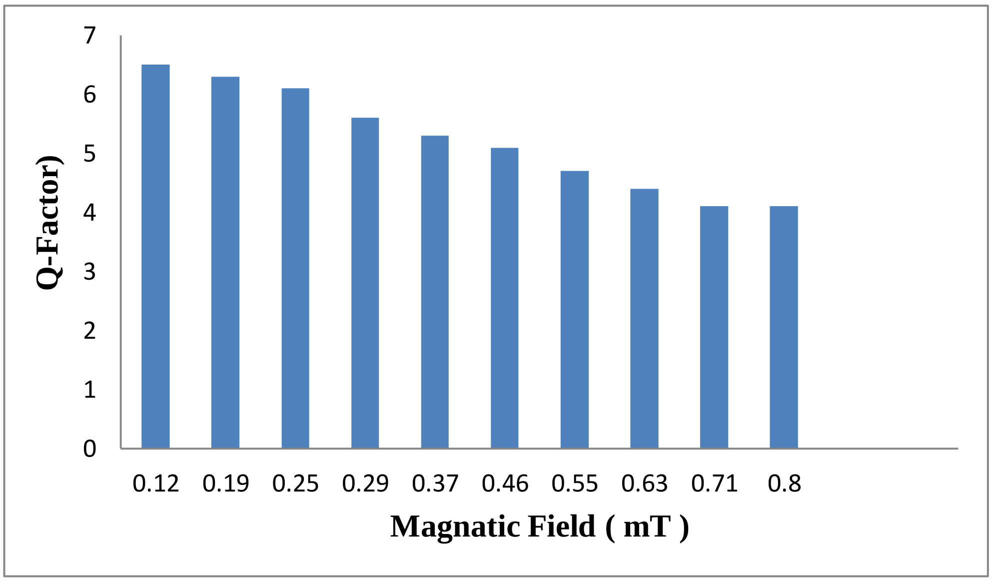
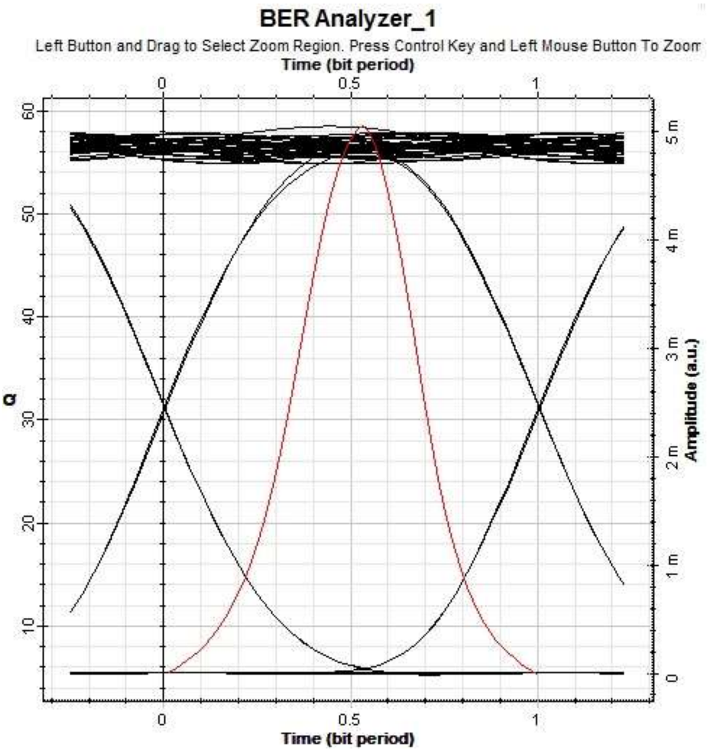
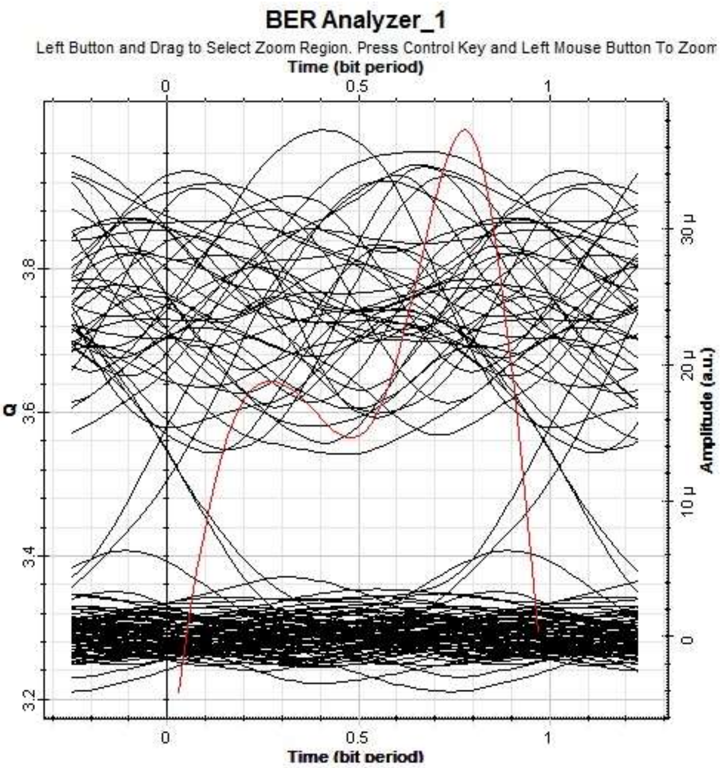


Figure 4. Magnetic field vs Q-factor.

As shown in the tables 2 and figures 2, 3, the losses in the received power increase when the magnetic field increases, (power in (dBm) refer to the losses in the optical power). Also the Q-factor decrease when the magnetic field increases. Moreover, for better reception of signal the Q-factor (≥6) [12]. In terms of signal to noise ratio (SNR), the Q-factor measures the transmitted signal quality factor. (SNR) is known as "the signal power to noise power ratio that damages the signal". To determine the consistency of the received data, the eye diagram is used. An eye is opened clearly at 1.2 (mT) Then, the eye is closed partially at 0.8 (mT).



(a)



(b)

Fig. 5. Eye diagram at: a- 1.2 (mT), and b-0.8 (mT).

Conclusions

In this paper, the results demonstrate that variation (system stability decreases) of data transmission into FSO communication systems according to the effect magnetic field. Thus, the received power decreased when the magnetic field increased. It also affects the signal quality and system performance. At weak magnetic field there is low influence on the Q-factor (≥ 6), whereas when it increases, it reflects serious effects on Q-factor (< 6).

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