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Evaluating Li-Fi System Performance in the Presence of External While Light Interference

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Abstract

The development in optical communications has made the possibility of communication by lighting rooms possible through Li-Fi technology, which is a technology for transmitting data via light. Maintaining the performance of the network is one of its most important components in the shadow of external light, whether sunlight, industrial light, or any other light source, and this effects the efficiency of the system, data rate, and BER. In this research, the effect of a white light will be discussed on the Li-Fi system, using multiple modulation patterns and getting the good performance of the system design in Optisystem and Matlab for three types of modulation and power distribution.

Keywords- optical commutation, Li-Fi performance, Q Factor, light interference.

I. Introduction

Since the internet of things (IoT) connects electrical devices to the digital world and has become more necessary due to the growing requests and business across the internet, it makes the researchers interested in areas beyond wireless fidelity, which transmits signals using the electromagnetic spectrum's radio wave. For data transfer, the modern telecommunications industry mostly uses radio frequency-based networks.

Wi-fi employs the 2.4 GHz radio frequency and has a capacity limit of 50-100Mbps.Enhaned demand for Wi-Fi due to new technologies like 5G and as increase in subscribers has LED to higher traffic that compromises the dependability of the signal. Spectrum is scare due to growth in the number of uses, and this increases the cost of doing [1][2].In Wi-Fi, the radio wave can pass through walls and the signal can intercept by hacker. Speed and security rank highly.

As a result, researchers looked into a new technology called Li-Fi to address the problems with radio waves related to capacity, efficiency, security , and availability .Known by several names, including visible light commutation and more recently Li-Fi, optical wireless technologies offer a whole new paradigm in wireless technologies with respect to transmission , speed ,flexibility, and use. [3]–[5] , Because Li-Fi uses light rather than radio waves to transport data, it is also known as Wi-Fi that runs on light. The spectrum of visible light is 10,000 times larger than that of radio waves in a Li-Fi system.VLC has no capacity restrictions and correlates to electromagnetic spectrum frequencies between 380 and 750 nm. .It has the potential to transmit at speeds greater than 100 GB /s with a high-speed data rate transfer of more than 1GB/s[6].

LED light bulbs are used to transfer data through illumination. Because of their great efficiency, extended lifespan, and low energy consumption, the LEDs utilized in Li-Fi systems are perfect for widespread use in illumination and indicator applications. In this system, light is produced and information is sent and received via LED bulbs that are utilized in residences, workplaces, and cars. LEDs operate at such high speeds and with such quick on /off swatting that it is invisible to the unaided eye.

VLC is also useful as one of the way to connect wirelessly to the internet of thing [7][8][9]. light cannot pass through walls and doors in the Li-Fi system, which increases security and enables control of the access network. If we consider transparent materials, then the Li-Fi channel is bounded by room-limited devices[10][11].The economic value of this technology to its users lies in the use of a free band that doesn't require a certificate .This can be possible, for interface-free data transmission .Moreover, it can operate fibers ,which are impracticality possible, for interference-free data transmission. Moreover ,it can operate underwater since radio wave cannot pass through there. Li-Fi is safe to apply in aircrafts, hospitals ,military bases ,boats and nuclear power plants where are electromagnetic interaction [12].There is many types of noise in Li-Fi ambient light interference, sun light, or artificial sources. This interference is a critical problem if the ambient light are in similar wavelengths of the Li-Fi signal. modulation noise duo to presses of modulation in light signal and thermal noise this noise in photo detectors and amplifiers[13]

To make a simple on-off keying modulation ,a low-power system can be used. Different techniques and formulas have been invented in order to enhance the VLC system performance. In particular, there are new modulation algorithms that create reliable and high-speed optical wireless networks [14], [15], [16].

This research proposes a small range indoor Li-Fi network system technology and analyses the system with different modulation formats ,with external white light noise .Section 2 literature review , Section 3 Metrology, Section 4 results and dissection , and finally Section 5 the conclusion .

II. LITERATURES REVIEW

There are many researcher papers in Li-Fi noise .In[17], study the effect of different colors of LED light on Li-Fi transmission data performance in indoor and outdoor networks and observed that the white LED has the minimum noise levels compared to the other colors A one-way ANOVA program was used to do these cases. In[18] , design a Li-Fi network and calculate an energy loss in the light path and use Matlab to show the result of power .In[19], calculate the performance of LOS and NLOS of visible light commutation using an opti system and show the noise of the receiver signal NLOS is greater than LOS .In [20], observed the performance of the Li-Fi system using the different types of modulation, pulse amplitude modulation (PAM), pulse position modulation (PPM),and phase shift modulation (PSM), but in[21], show the indoor Li-Fi system that the effect of external white light is in the different modulation techniques employed when exposed to an ambient noise source. The study is carried out considering pulse position modulation (PPM), differential phase shift keying (DPSK), and quadrature phase shift keying (QPSK) modulation techniques, and the system is analyzed considering varying bit rates and shows the QPSK result is better than others, In[22], show the effect of Non-Return to Zero(NRZ), Return to Zero (RZ) and Compressed spectrum return to zero (CSRZ) modulation in the Li-Fi system with external white light sources and thermal noise .

In this work, effective white light source at different modulation to propose Li-Fi system are shown, considering different data rates to analysis the model and show the effects in results of BER ,Q Factor, and eye high.

III. METROLOGY

1-THE STRUCTURE OF SYSTEM

The transmission part of the system, as depicted in figure 1, comprises bit sequence generation elements represented by pseudo-random bits. The signal is then modulated by one of the formats, RZ,or,NRZ,Manchester coding, until a sequence is generated that enters the LED , which converts it into a light signal, and the light noise is adding. White on the transmitted signal to discuss its effect on receiver ,which consists of a PIN photodiode that converts the optical signal into electrical, then after that into a filter to purify the signal from noise [23], then into bit error rate analysis to measure BER, as well as Q factor

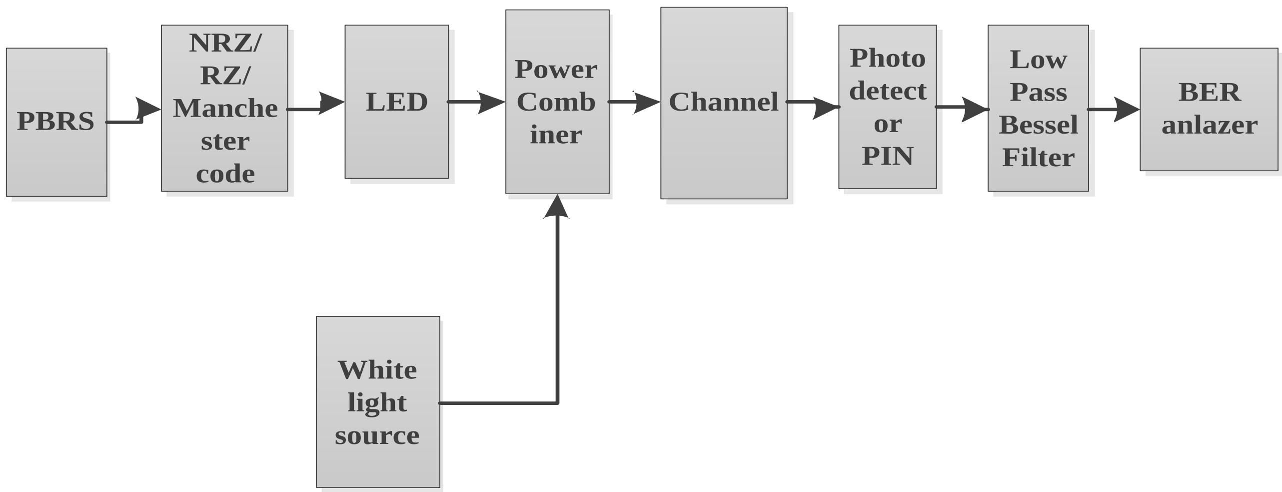


Figure 1, system architecture .

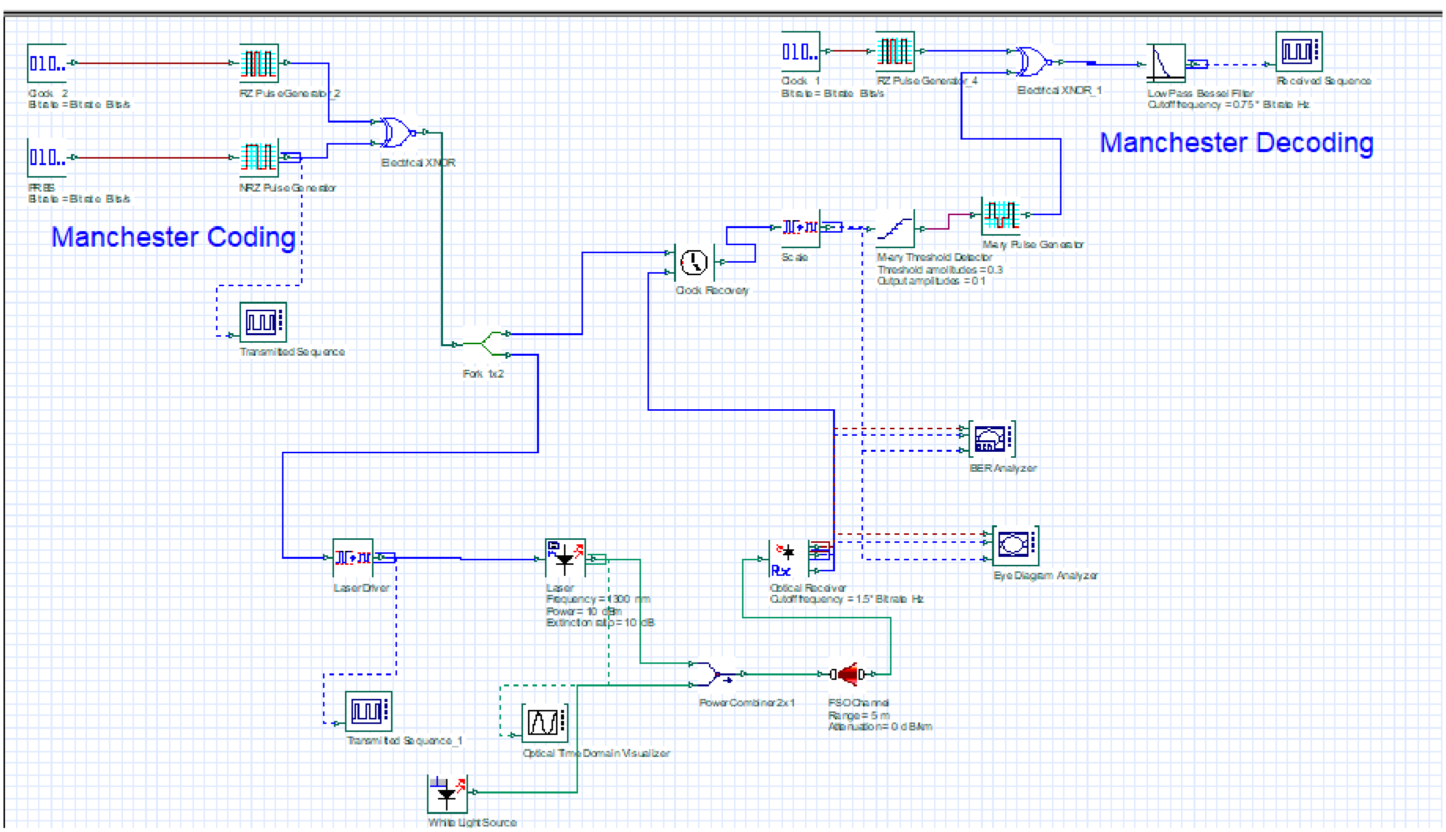
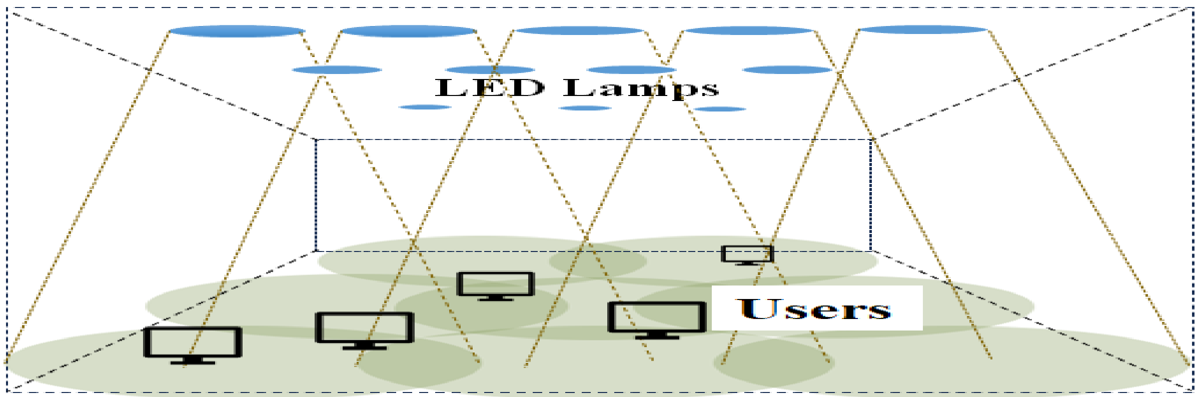


Figure 2 ,show the architecture of Manchester coding in opti system

Figure 2 shows the architecture of a Li-Fi system with Manchester coding ,it's like biphase coding technology that the switch occurs in the half clock cycle. To encoder and decoder signal without error the system contain encoder and decoder in transmitter and receiver[24].

Figure. 3 shows an indoor VLC system in this network. The signal is distributed like a Wi-Fi network from the LED to all users. the LED sent data, and the users received data by a PIN photodiode in this study, add the interference of other lights and show the effect on the receiver signal.



Figure,3 indoor VLC network

2-MATHMITACAL ANALYSIS OF OPTICAL CHANNEL:-

The average transmission power distribution light source given in(1), [25]

$$p_{tr} = p_{dc}(1 + m\cos\omega \quad t) \qquad (1)$$

Where p_{tr} transmission power and m is modulation index in(2),[26]

$$m = \frac{I_{LED}}{(Ib - Ith)} \qquad (2)$$

Where $I_{LED}$is current of LED and Ith is threshold current

$$p_{re} = \frac{\pi D_{ap}}{8} i(0, l) \qquad (3)$$

p_{re} receiver power in(3), and D_{ap} aperture diameter

The BER calculator derive different metrics form the eye diagram such as Q-factor, eye opening , eye closure etc., the mathematical formulation of BER is given in(4):

$$\mathrm{BER} = \mathrm{P}_1(1)\mathrm{P}_1(0) + \mathrm{P}_0(0)\mathrm{P}_0(1) \qquad (4)$$

where$\mathrm{P}_1(0)$is the probability conditional of deciding 0 when is 1 sent and $\mathrm{P}_0(1)$ the probability conditional of deciding 1 when is 0 sent. $\mathrm{P}_1(1)$is possibility of receiving a 1bit , $\mathrm{P}_0(0)$is the possibility of receiving a 0 bit ;

From the BER can calculation the Q Factor mathematically in(5):

$$\mathrm{BER} = \frac{1}{2}\mathrm{erf}\frac{\mathrm{Q}}{\sqrt{2}} \qquad (5)$$

Where Q factor can calculator in(6),[27]

$$\mathrm{Q} = \frac{\mathrm{I}_1 - \mathrm{I}_0}{\sigma_1 + \sigma_0} \qquad (6)$$

I_1, $I_0$is current of 1 bit and 0 bit, σ_1, $\sigma_0$is stander deviation of current 1 and 0 in (7),[28].

$$\sigma = \sqrt{\frac{S_0 E_p}{2}} \qquad (7)$$

E_p average power

S_0 power spectrum density .

The eye amplitude ,eye closure, and eye height calculated together equaled m in (8),(9),(10).

$$E_{hi} = (I_1 - 3\sigma_1) - (I_0 - 3\sigma_0) \qquad (8)$$

$$E_{am} = (I_1 - I_0) \qquad (9)$$

$$E_{cl} = (V_1 \min - V_0 \max) \qquad (10)$$

And the opening eye factor in (11),

$$E_{op} = \frac{(I_1 - \sigma_1) - (I_0 - \sigma_0)}{I_1 - I_0} \qquad (11)$$

The LOS channel gain can calculate in indoor in(12) , multipath reflection in expiration below in (13),[20][29]that can see in fig.4 :

$$H_{LOS} = \begin{cases} \frac{A_r(m_1 + 1)}{2\pi d^2} \cos^{m1}(\emptyset) T_S(\psi)\, g(\psi) \cos(\psi), & 0 \le \psi \le \varphi \end{cases} \qquad (12)$$

$$m1 = \frac{-\ln(2)}{\ln(\cos\phi_{\frac{1}{2}})} \qquad (13)$$

m1 is the Lambertian emission order.

Φ1/2 – is the radiation angle at which the intensity is half of the intensity at the main-beam direction.

Ar – physical area of PD.

g – is the gain of the filter in (14),[18];

$$g(\psi) = \begin{cases} \frac{n^2}{\sin^2(\psi_{max})}, & \psi < \psi_{max} \\ 0, & \psi > \psi_{max} \end{cases} \qquad (14)$$

where: n – is a refractive index,
Ψmax - is the semiangle of the field of view (FOV) of the PD.

Finally SNR can be given in (16), where power recive in (15),

Pr Los = H. Los (0) Pt (15)

$$SNR = \frac{P_S}{P_{nois}} = \frac{(RP_R)^2}{\sigma^2 tot} \qquad (16)$$

Ps is recever signle power ,pnois is noise power at recevier, r is the detector respanceblaty and σ^2totis total noise

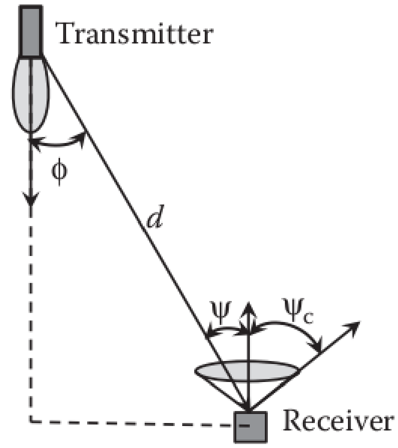


Figure. 4.LOS propagation signal

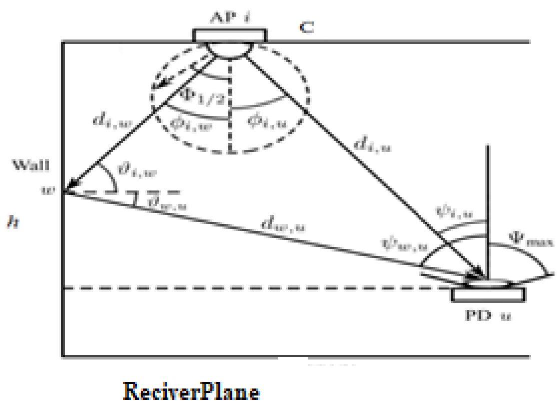


Figure 5 LOS and NLOS propagation

Figure 4,5 show the distribution of LED signal in indoor Li-Fi system they are two types line of side(LOS) and non line of side(NLOS).

3- Material and Tools: The programs used to analysis the data are Matlab, which refers to the equations of the Li-Fi and the light and simulates the systems in opti system 7 that give the results close to reality. The boundary conditions in this study show in table.1

TABLE.1 Some Simulation parameters

Room dimintions(m)	6*6*3
FOV of a reciver(deg)	70
Center frequancy(nm)	1300
Bandwaith(nm)	50
Link(m)	5

IV. RESULTS AND DISCUSSION

The MATLAB program was used to observe the effect of power distribution in the case of the presence of LEDs in separate areas of the ceiling of a room with dimensions of 6*6*3. It was noted that the best result is in the case of the presence of the LED in the middle of the ceiling, where the power distribution is observed as in figure 6.

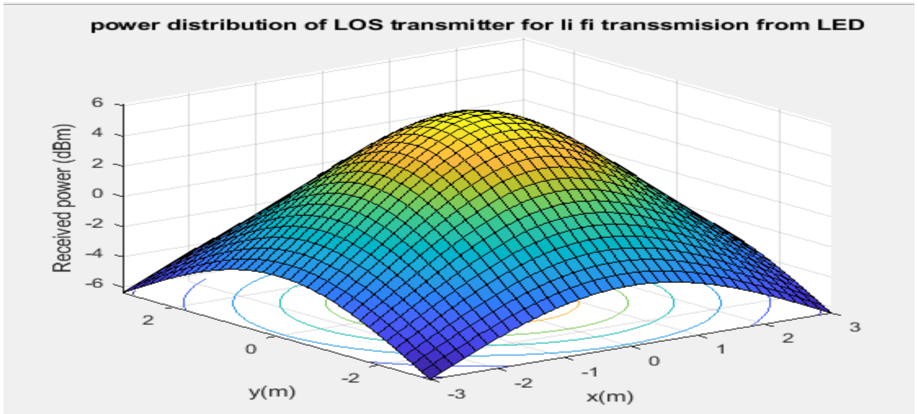
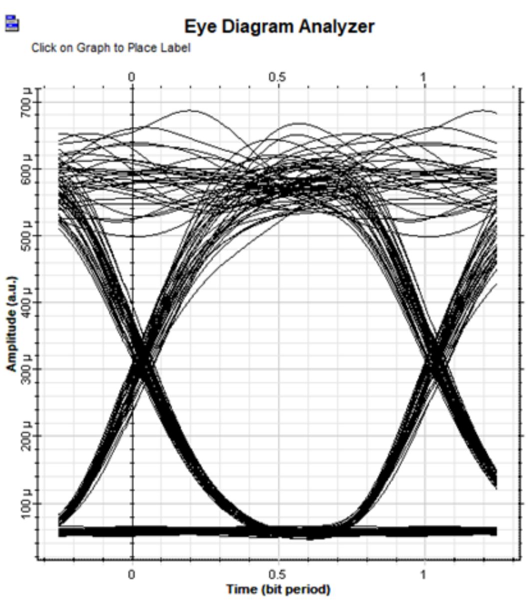
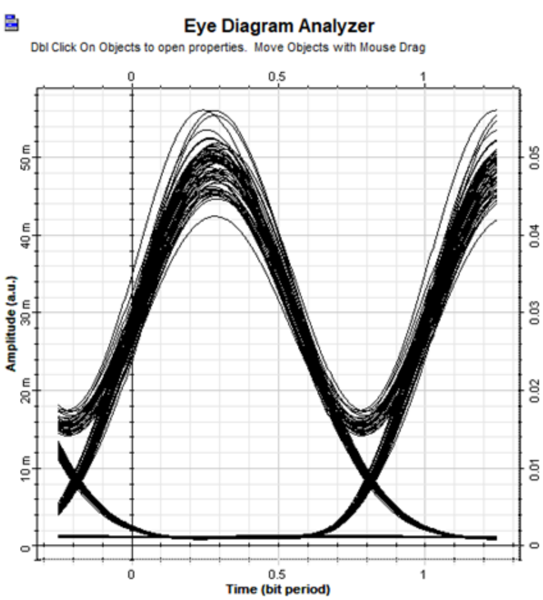


Figure 6. show the power distribution of the room at 6 *6

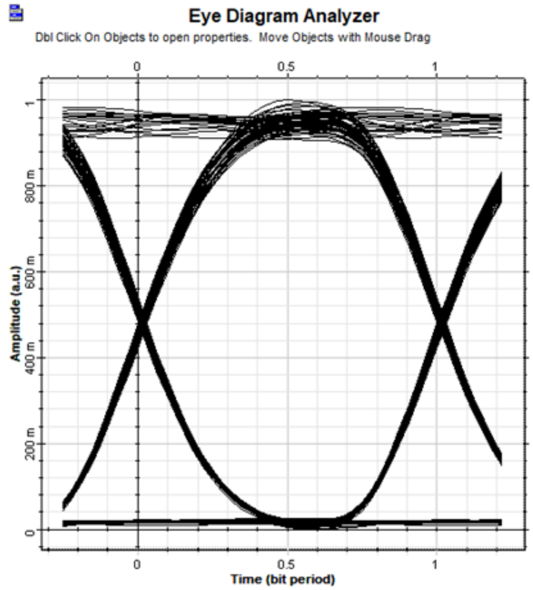
Use the Opti System program to design the system and observe the effect of each type of modulation on the system in the event of adding white light noise. The eye diagram of the simulation models (NRZ,RZ, Manchester code) is shown figure.7 at white light noise (-100 dBm) and data rate 10 Mbps show the less effect of noise in Manchester coding but other types effective more.



(a)

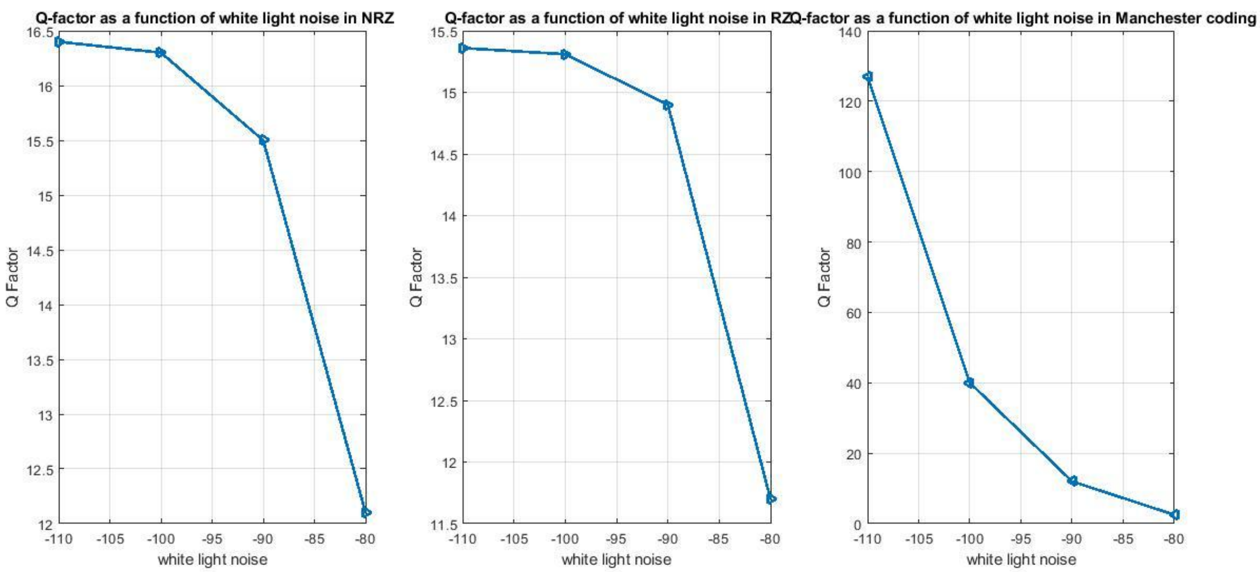


(b)



(c)

Figure 7. Eye diagram for distance 5m and data rate 10 Mbps (a) NRZ (b)RZ (c) Manchester coding



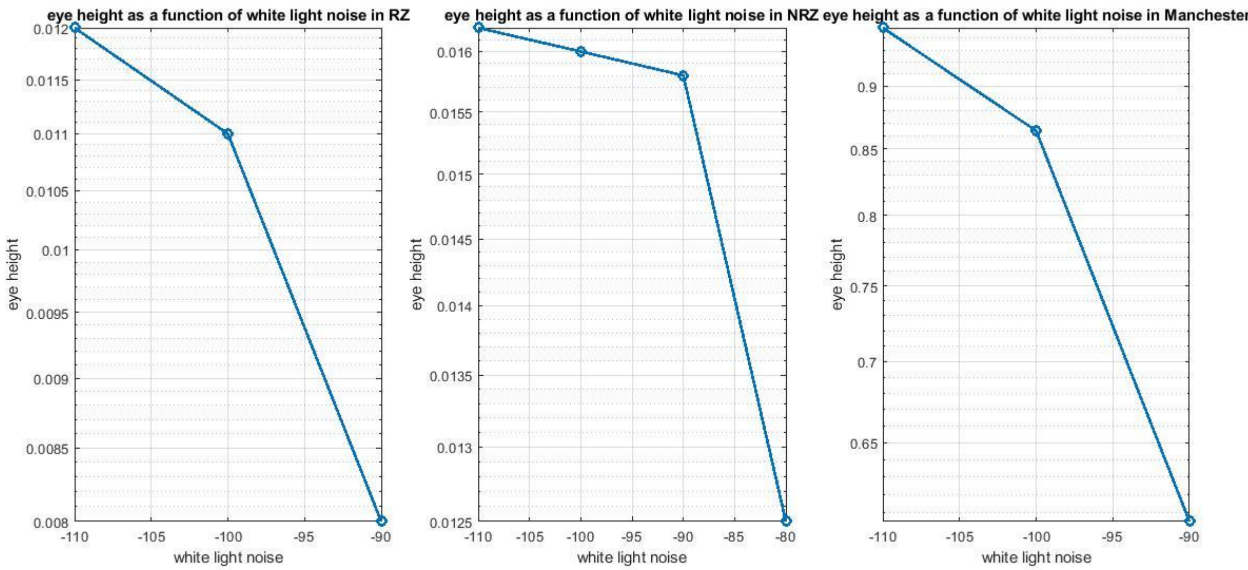
Figuer.8 show the Q Factor as a function of light noise (a) RZ,(B) NRZ,(c) Manchester

The quality of the received signal decreases when light noise increases ,Figure 8 note the effect of variable white light noise from -110 to -80 dBm and data rate 10 Mbps, distance 5m,show the Q factor had a max value in Manchester code 127 at -110 dBm ,but have min value at -80 dBm,at RZ max value 15.3 at -110 dBm and min value at -80 dBm is 11.7,at NRZ show the max value at 16.4 dBm ,min at -80 dBm 12.1

In Table 2, it was observed that the Q factor and BER change with noise for each type of modulation. The max value of BER is 0.05 at -80dBm in Manchester, and the min value is 0 at -110 dBm in Manchester . It was noted that the most suitable type is Manchester, but at high noise the signal almost disappears and the BER increases, showing that the result of NRZ is good at all ranges of noise .

TABLE .2 Q Factor and BER at the different value of white light noise

White Light Noise(dBm)	Q FactorNRZ	Q Factor Rz	Q Factor Manchester	BER NRZ	BER RZ	BER MAN
-110	16.4	15.36	127	2.2 e-61	7.5 e-54	0
-100	16.3	15.31	40	2.6 e-60	1.5 e -53	3.8 e-37
-90	15.5	14.9	12	2.6 e-55	6.1 e-51	1.1 e-33
-80	12.1	11.7	2.5	3.5 e-34	3 e-32	0.005

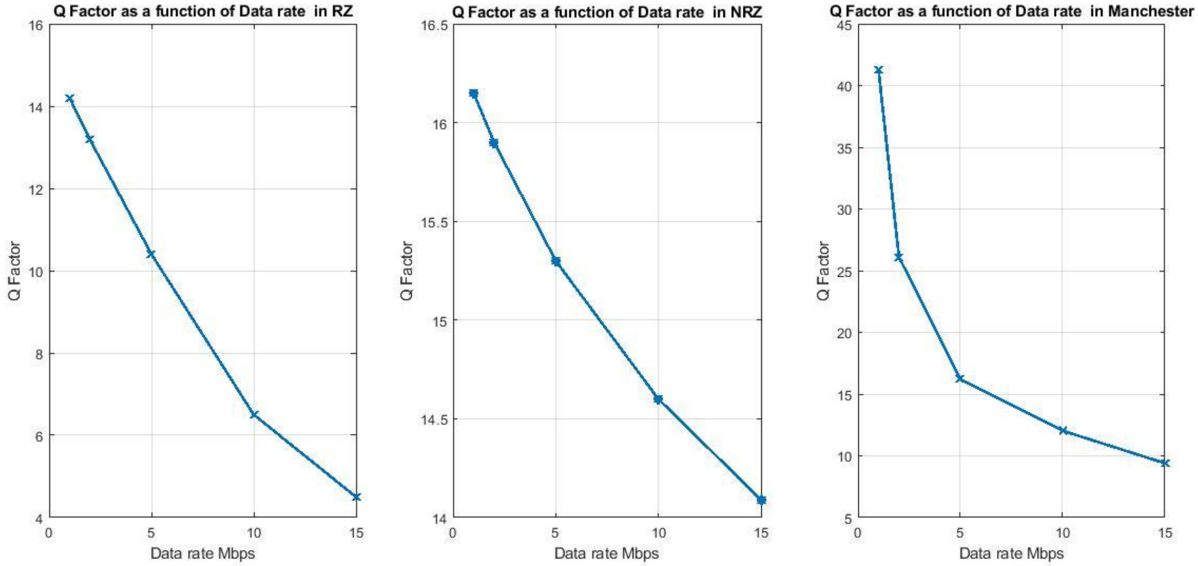


(a) (b) (c)

Figuer.9 show the Eye height as a function of light noise (a) RZ,(B) NRZ,(c) Manchester

Eye diagrams are used to examine the quality of signals in digital systems .It shows a series of bit signals superimposed on one another, forming a shape that resembles an eye. The eye diagram is primarily used to evaluate the performance of channels and circuits in commutation systems [30].Figure 9 show white light noise impacts the quality of the eye height . max height eye in Manchester is 0.989 and min value is -0.083, max height in NRZ 0.016, min 0.012, max height in RZ 0.012 min 0, The distortions caused by white light noise reduces the eye height.

The result shows the effect of white light noise in the proposed system, now show the effect of data rate in the system performance
For figure 10 the maximum Q factor in data rate 1Mbps is 41.3 in Manchester ,16.1 NRZ,14.1 RZ minimum in 15Mbps,9.4 Manchester ,14.09 NRZ,6.5 RZ. The higher data rates increase the possibility of error that reduce the Q factor .
Table 3 shows the relationship between the data rate and BER, show that when the data rate increases the BER increases because of the error increase .



(a) (b) (c)

Figuer.10 show the Q factor as a function of data rate (a) RZ,(B) NRZ,(c) Manchester

TABLE .3 BER at The Different Value of Data Rate

Data rate (Mbps)	BER RZ	BER NRZ	BER MAN
1	1.8 e-46	3.5 e-59	0
2	3.8 e-40	1.72e-57	2.4e-151
5	4.8 e-26	1.6 e-51	8.9 e-60
10	2.14e-11	3.4 e-49	1.1 e-33
15	2.7 e-6	1.6 e-41	1.9 e-21

In Figure.10 the LED with noise signal transmit and the signal was send and receives at PIN photo detector IN 10 Mbps and distance 5m between sender and receiver .

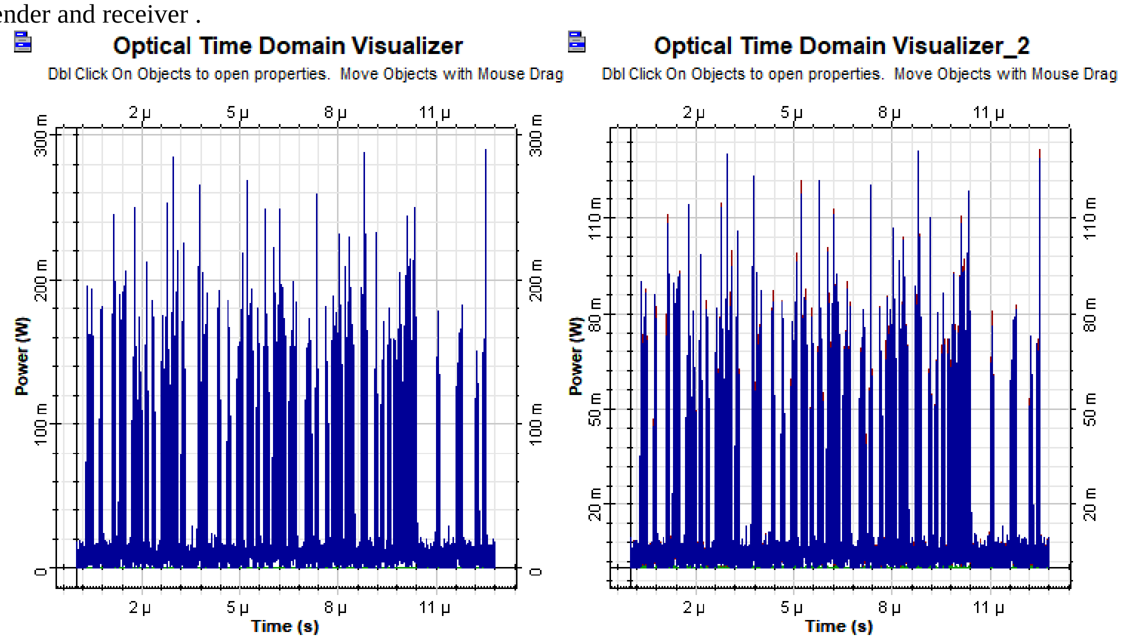


Figure 10. transmitter and receiver signal in NRZ

V. CONCLUSION

After seeing the results, the idea of the research was to find a type of modulation that is suitable for high speeds , has good efficiency, and has a low error to be used in practical fields in schools and universities. In the beginning, it was determined that the power sent to all sides of the room is that the best place to place the LED is in the middle. A model for the network was proposed, and the effect of external light was added to it. This effect was increased, and had observed the efficiency of the system at each value of the noise and for each type of modulation (RZ,NRZ,Manchester), so had noticed the better modulation in the simulation of the NRZ through several points: 1. In the event of increased noise, the quality of the signal is not affected, so the signal will not disappear. 2. The speed of the data is good in this modulation. The future work is to show the different color interferences with advance modulation.

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