An Effective 8×7.5 GBPS WDM Free Space Optical Communication System

K. Arivazhagi [1] and T. K. Shanthi[2]

[1]PG Student,

[2]Associate Professor,

[1][2]Department of ECE

A.C.Government College of Engineering and Technology,Karaikudi-630003.

***Abstract*:- This paper is created on free space optical communication system which contains eight users each of which has 7.5 Gbps bit rate. Most popular WDM method is integrated for data transmission. FSO communication has taken over the radio frequency communication and microwave systems due to its advantages like its high bandwidth, license free, high safety, efficient power transmission, less distortion and easily deployable as compared to all other wireless network. Results have been accomplished by the simulation which includes error free SNR and Q factor up to 1 km.**

Keywords — Free Space Optics, Wavelength Division Multiplexing, Q-Factor, SNR.

I.INTRODUCTION

The optical wireless communication system mainly includes of three parts: the transmitter, receiver and propagation channel. In the recent few years, tremendous growth and advancement has been observed in information and communication technologies. With the increase in usage of high speed internet, video-conferencing, live streaming etc., the bandwidth and capacity requirements are increasing drastically [12]. Unlike RF carrier, where spectrum usage is restricted, optical carrier does not require any spectrum licensing and therefore, is an attractive prospect for high bandwidth and capacity applications. “Wireless optical communication” (WOC) is the technology that uses optical carrier to transfer information from one point to another through an unguided channel which may be an atmosphere or free space. WOC is considered as a next frontier for high speed broadband connection as it offers extremely high bandwidth, ease of deployment, unlicensed spectrum allocation, reduced power consumption (1/2 of RF), reduced size (1/10 the diameter of RF antenna) and improved channel security [13]. It can be classified into two broad categories, namely indoor and outdoor wireless optical communications. Indoor WOC uses IR or visible light for communicating within a building where the possibility of setting up a physical wired connection is cumbersome [14]. Indoor WOC is classified into four generic system configurations i.e., directed line-of-sight (LOS), non-directed LOS, diffused and tracked. Outdoor WOC is also termed as free space optical (FSO) communication. The FSO communication systems are further classified into terrestrial and space optical links that include building-to-building, ground-to-satellite, satellite-to-ground, satellite-to-satellite, satellite-to-airborne platforms (unmanned aerial vehicles (UAVs) or balloons) [15]. OWC is also known as Visible Light Communication (VLC) or Free Space Optical (FSO) has been propagating signals through at a wavelength between 380nm to 740nm for VLC and 750nm to 1600nm for laser through free and open spaces [1].Nowadays, using of radio waves, Infra-red beam or laser for transmitting data is more familiar. Presently, There is an increasing demand for multimedia services with a very high quality of services. FSO system can be used as a better alternative, to optical fiber or to currently available access technologies for last mile access with multiGigabits rate network [2]. Free Space Optical communication is an optical communication technology that uses Line of Sight (LOS) path propagating in free space for Transmission of signal/data/information between two desired points for telecommunication or computer networking. The word “Free Space” in this context pertains to air, outer space, vacuum or wireless [4]. The high carrier frequency of FSO in the range of 20THz to 375THz, renders it to provide high data rates [5]. FSO is a technology that can provide high speed point to point communication when the location is difficult to communicate using optical fiber. FSO communication can be used in many optical links, such as building-to-building, ship-to-ship, aircraft-to-ground and satellite-to-ground [9]. Mainly an FSO system is adopted when a physical connection is not a practicable solution due to high costs or other considerations. It is also adopted to fulfill the requirement of higher bandwidth in order to handle the data transmission of the system [4]. FSO has evolved as a future technology for coming generation indoor and outdoor broadband wireless applications. Indoor wireless optical communication is also called wireless infrared communication; outdoor optical wireless communication is commonly called FSO [6].There are numerous benefits of free space optics: lower costs associated with the system, no fiber cable required, no rooftop installations requires and no license is required. Transmission rate of this system is very high around 10 GB per seconds hence can transmit a large amount of data. This speed is due to the fact that the signal can be transmitted through the air quicker than they can be transmitted through fiber optic cables. Interference between signal and radio frequencies is negligible [10]. Despite of its so many advantages, the link is highly susceptible to attenuation due to weather conditions and turbulence. The loss in the light beam is mainly caused by absorption due to molecular diffusion and scattering caused by rain, fog, snow and haze [11]. Out of which fog is a severe weather condition. Atmospheric turbulence [2] occurs due to the variation in refractive index profile. Visible Light Communication system using LEDs and laser are ideal source for future application (indoor and outdoor) for dual purpose of lighting and data communications [11]. By switching white LEDs on and off rapidly, higher data rate in excess of 100 Mbps can be achieved with RGB white LEDs [7].

Indoor WOC is classified into four generic system configurations i.e., directed line-of-sight (LOS), non-directed LOS, diffused and tracked. Outdoor WOC is also termed as free space optical (FSO) communication. The FSO communication systems are further classified into terrestrial and space optical links that include building-to-building, ground-to-satellite, satellite-to-ground, satellite-to-satellite, satellite-to-airborne platforms (unmanned aerial vehicles (UAVs) or balloons) [16].

Advantages of FSO Communication over RF Communication:

FSO communication system offers several advantages over RF system. The major difference between FSO and RF communication arises from the large difference in the wavelength. For FSO system, under clear weather conditions (visibility > 10 miles), the atmospheric transmission window lies in the near infrared wavelength range between 700 nm to 1600 nm. The transmission window for RF system lies between 30 mm to 3 m. Therefore, RF wavelength is thousands of times larger than optical wavelength.

This high ratio of wavelength leads to some interesting differences between the two systems as give below.

Huge modulation bandwidth:

It is a well known fact that increase in carrier frequency increases the information carrying capacity of a communication system. In RF and microwave communication systems, the allowable bandwidth can be up to 20% of the carrier frequency. In optical communication, even if the bandwidth is taken to be 1% of carrier frequency (_1016 Hz), the allowable bandwidth will be 100 THz. This makes the usable bandwidth at an optical frequency in the order of THz which is almost 105 times that of a typical RF carrier [17].

Narrow beam divergence:

The beam divergence is proportional to ג /DR, where ג is the carrier wavelength and DR the aperture diameter. Thus, the beam spread offered by the optical carrier is narrower than that of RF carrier. This leads to increase in the intensity of signal at the receiver for a given transmitted power. Fig. 2 shows the comparison of beam divergence for optical and RF signals when sent back from Mars towards Earth [18].

Unlicensed spectrum: In RF system, interference from adjacent carrier is the major problem due to spectrum congestion. This requires the need of spectrum licensing by regulatory authorities. But on the other hand, optical system is free from spectrum licensing till now. This reduces the initial set up cost and development time [19].

High Security:

FSO communication can not be detected by spectrum analyzers or RF meters as FSO laser beam is highly directional with very narrow beam divergence. Any kind of interception is therefore very difficult. Unlike RF signal, FSO signal cannot penetrate walls which can therefore prevent eavesdropping [20].

In addition to the above advantages, FSO communication offers secondary benefits as: (i) easily expandable and reduces the size of network segments, (ii) light weight and compact, (iii) easy and quick deployability, and (iv) can be used where fiber optic cables cannot be used. However, despite of many advantages, FSO communication system has its own drawbacks over RF system [12].

Choice of wavelength in FSO communication:

Wavelength selection in FSO communication is very important design parameter as it affects link performance and detector sensitivity of the system. Since antenna gain is inversely proportion to operating wavelength, therefore, it is more beneficial to operate at lower wavelengths. However, higher wavelengths provide better link quality and lower pointing induced signal fades [21].

The International Commission on Illumination [33] has classified optical radiations into three categories: IR-A (700 nm to 1400 nm), IR-B (1400 nm to 3000 nm) and IR-C (3000 nm to 1 mm). It can sub-classified into (i) near-infrared (NIR) ranging from 750 nm to 1450 nm is a low attenuation window and mainly used for fiber optics, (ii) short-infrared (SIR) ranging from 1400 nm to 3000 nm out of which 1530 nm to 1560 nm is a dominant spectral range for long distance communication, (iii) mid-infrared (MIR) ranging from 3000 nm to 8000 nm is used in military applications for guiding missiles, (iv) long infrared (LIR) ranging from 8000 nm to 15 μm is used in thermal imaging, and (v) far-infrared (FIR) is ranging from 15 μm to 1 mm. Almost all commercially available FSO system are using NIR and SIR wavelength range since these wavelengths are also used in fiber optic communication and their components are readily available in market [12].

The wavelength selection for FSO communication has to be eye and skin safe as certain wavelengths between 400 nm to 1500 nm can cause potential eye hazards or damage to retina [22].

In this paper 8×7.5 Gbps WDM FSO system has been designed which has transmitter and receiver section both are separated by FSO channel. At the receiver Signal Power, Noise Power, SNR, Q factor is calculated here for the 1550 nm to 1557 nm wavelength. By using FSO System distance of several kilometers can be achieved.

II. SYSTEM DESIGN:

A 8×7.5 Gbps WDM FSO system consists of eight users. Here the FSO system model consists of 8 user each user transmits the data rate of 7.5 Gbps at 1 km. The transmitter block of FSO system consists of 8 CW laser, 8 PRBS, 8 NRZ pulse generator, 8 MZM and 8×1 multiplexer. The receiver block of FSO system consists of 8 EDFA, 8 Photodiode, 8 Low Pass Bessel Filter, 8 3R Regenerator and 8 BER Analyzer. At the transmitter side there is bit sequence generator, which generates the data bit sequence of 9 Gbps bit rate. This bit sequence is followed by NRZ pulse generator which converts bit sequence into pulses. LASER sources are used to generate the beam light which have wavelength of 1550nm, 1551nm, 1552nm, 1553nm, 1554nm, 1555nm, 1556nm, and 1557nm respectively and have a 15mw power, Output of NRZ pulse generator and LASER is followed by Modulator. To transmit all these eight wavelengths, 8×1 WDM multiplexer is used to generate many to one combination. Then signal is ready to travel through FSO. It is assumed that all the turbulence effect such as scintillation, absorption, scattering, rain, fog, by which FSO system may be affected, is around 3dB/Km. So the total attenuation of FSO channel fixed at around 3dB/km. FSO is followed by another EDFA amplifier to amplify the signal strength before reaching to the receiver. At the receiver side signal is demultiplexed by 1×8 WDM demultiplexer in order to generate one to many combinations. All separate eight signals are detect by photodiode. PIN Photo detector is used to demodulate the signal. To calculate the Signal and Noise Power, Electrical Power Meter is used at the receiving end. To boost the ability of optical systems, bit rate may be increased and other is to use the WDM technique. It is found that at higher bit rates, the modulation format, and channel power are become main consideration for system design. A non-return-to-zero (NRZ) is a line binary code technique in which 1s and 0s are represented by one significant condition such as positive and negative voltage respectively with no other break condition [23].

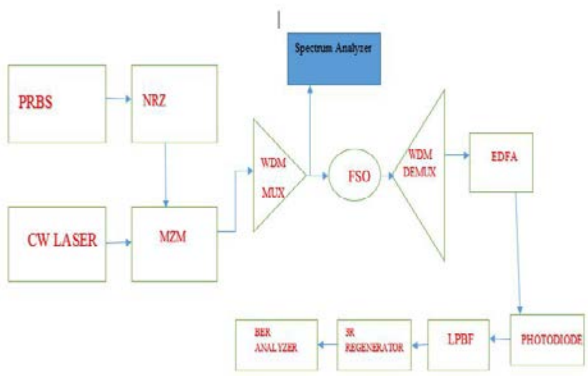

Fig 1: FSO SYSTEM MODEL

Table 1: FSO link parameters:-

Parameters	Value
Transmission Bit Rate	7.5 Gbps
Link Distance	1 km
Optical Transmitter Power	15 mW
Modulation Type	NRZ
Transmitter aperture diameter	0.16 cm
Receiver aperture diameter	0.51 cm
Beam divergence	0.35 cm
Transmitter wavelength	1550nm to 1557nm(8 channel)
Signal attenuation	0.2 dB/km
Photo detector type	PIN
Dark current	10 nA
Responsivity of receiver	1 A/W

Table2. Comparison of the proposed work with previous work

Work	source	Modulation Techniques	Attenuation	BER	Q-Factor (dB)	Bit Rate
Shaina et al	Laser	NRZ-OOK	70 dB/km	0.00153508	2.59	2.5 Gbps
Saru arora et al	Laser	NRZ-OOK	20 dB/km	$10e^{-11}$	6	2.5 Gbps
Manivannan et al	LED	RZ-OOK	-	-8.399	8.73	100 Mbps
Deeksha Jain et al	Laser	NRZ-OOK	70 dB/km	0.00160863	2.93428	10 Gbps
Ankita Shivhare et al	Laser(4 Channel)	NRZ-OOK	25 dB/km	-	6.21	50 Gbps
Proposed work	Laser(8 channel)	NRZ-OOK	3 dB/km	1.4167 e-^{018}	8.68	7.5 Gbps

III. SIMULATION RESULT AND DISCUSSION:

FSO system consists of 8 channels. Each channels transmits the data rates of 2.5 Gbps, 5 Gbps, 7.5 Gbps and 9 Gbps at different distances.

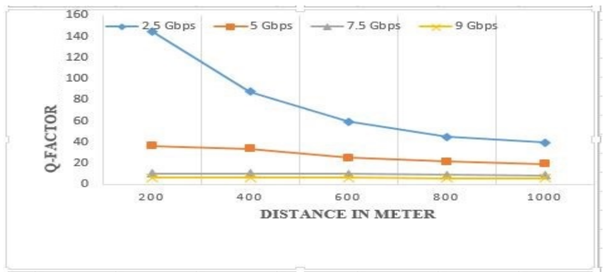

Fig 2: NRZ MODULATION GRAPH

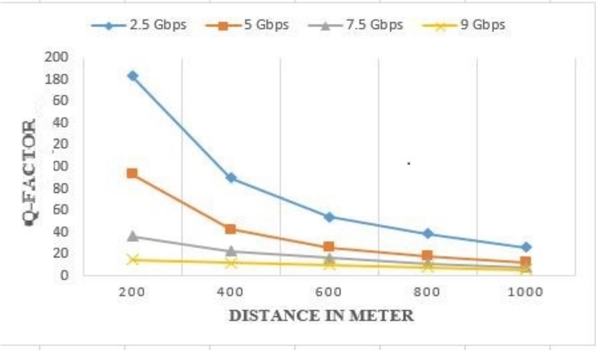

Fig3: RZ MODULATION GRAPH

Fig 2 and Fig 3 describe the different data rates are transmitted at different distance. Fig 2 show the different data rate are transmitted at different distance by using NRZ pulse generator. Here 2.5 Gbps, 5 Gbps, 7Gbps and 9 Gbps are transmitted up to 1km the achieved quality factor 39.5057 for 2.5 Gbps, 19.1924 for 5 Gbps, 8.6 Gbps for 7.5 Gbps and 5.708 for 9Gbps data rates.

Fig 3 show the different data rates are transmitted at different distance by using RZ pulse generator. Here 2.5 Gbps, 5Gbps, 7.5 Gbps and 9 Gbps are transmitted up to 1km the achieved quality factor 25.9517 for 2.5 Gbps, 12.2721 for 5Gbps, 7.95053 for 7.5 Gbps and 4.719 for 9 Gbps data rates.

After analyzing fig 2 and fig 3 the NRZ pulse generator give the excellent quality than the RZ pulse generator. So the NRZ modulation techniques is best for free space optics communication.

EYE DIAGRAMS FOR DIFFERENT DATA RATES TRANSMITTED UPTO 1KM

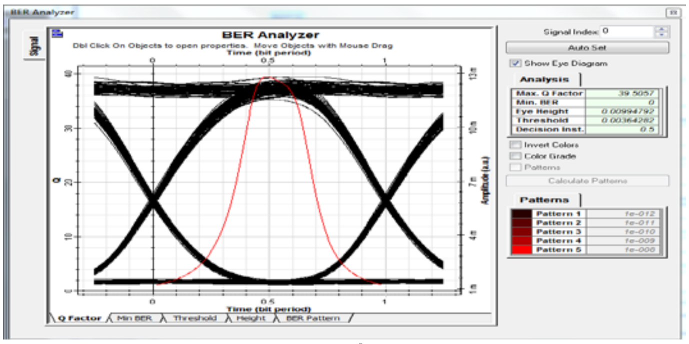

Fig 4: 2.5 Gbps

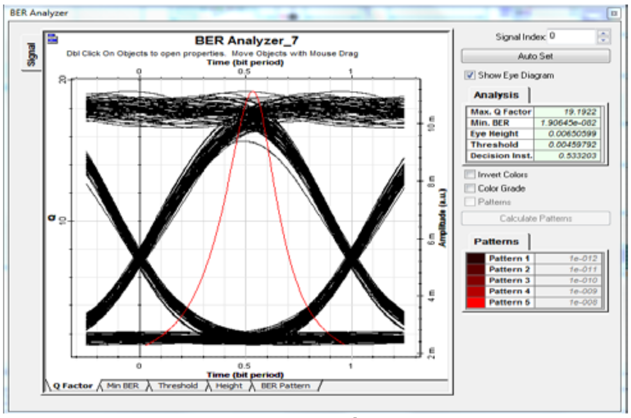

Fig 5: 5 Gbps

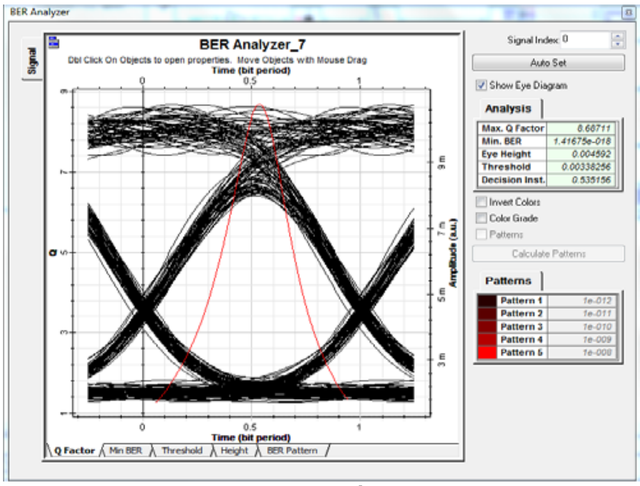

Fig 6: 7.5 Gbps

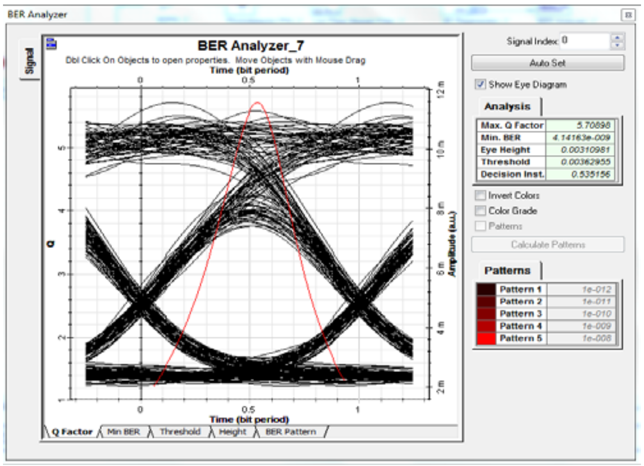

Fig 7: 9 Gbps

CONCLUSION

In this study a 8× 7.5 Gbps WDM system has been observed. In previous work 4× 12.5 Gbps system is designed using optisystem simulation tool. From the study it has been observed that up to 1km the Q factor is 8.68 dB. As long as the length is increased beyond 1km Q factor may be decreased.

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