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Performance Evaluation of the Optical Wireless Communications System Using OFDM : with either Direct or Coherent Detection

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Abstract— Orthogonal Frequency Division Multiplexing (OFDM) is a promising modulation technique which is now used in most emerging broadband wired and wireless communication systems. This is due to the effective solutions to Inter Symbol Interference (ISI) caused by a dispersive channels .In the optical wireless communications, OFDM could offer high efficiency and good communications alternatives .A proposed an analytical model for performance evaluation of the Optical Wireless Communication (OWC) system using OFDM with either direct or coherent detection will be presented. Optisystem simulator is used for different number of sub carriers for OFDM (256, 512, 1024 subcarriers) with 4QAM and 16 QAM modulation technique. The system data rate is 10 Gb/s.

Keywords— OFDM, OOFDM, QAM, BER, Direct detection, Coherent detection.

I. INTRODUCTION

The OFDM technique is widely exploited today in broadband wired and wireless radio communication systems. Because of the inherent robustness of the OFDM to multi-path interference and frequency-selective fading as well as attractive functionalities such as dynamic bandwidth allocation and an adaptive bit rate, this multiple sub carrier modulation technique is very attractive in a broad perspective – extending beyond broadband radio communications. [1] Despite these important advantages of OFDM, it is only recently that it has been considered for optical communications. OFDM is considered a potential candidate for the next-generation mobile wireless systems. [2]Optical Wireless Communications employs Laser Diodes (LDs) as transmitters and Photodiodes (PDs) as receivers. With their inherent high efficiency, these semiconductor devices enable a secure communication in areas, where the RF transmission is physically impossible or prohibited. These include underwater communication, the aviation industry, hospitals, and hazardous environments such as oil and gas refineries. The continuously enhanced wireless communication standards will not be able to fully satisfy the future demand for mobile data throughput because the available Radio Frequency (RF) spectrum is very limited. Hence, an expansion of the wireless spectrum into a new and largely unexplored domain – the visible light spectrum – has the potential to change the face of future wireless communications. The advantages of an optical wireless system include among others: [3]

Vast amount of unused bandwidth.

No licensing fees.

Low-cost front end devices.

No interference with sensitive electronic systems.

II. LITERATURE REVIEW

To meet the accelerating demands in communication systems, the integration of optical network and wireless radio is a promising solution. ROF means the optical signal is being modulated at radio frequencies and transmitted via the optical fiber. The RoF technology is transport systems have the potential to serve both fixed and mobile customers with offer large transmission capacity, significant mobility, flexibility, large bandwidth and increased mobility in a cost-effective way. [4] The use of OFDM in optical access networks and combining the OFDM modulation in RoF system a very high efficient communication system can be created which effectively utilizes the bandwidth. Coherent system has high performance than direct detection system. [5] The systems with OFDM give better performance in comparison with the system without OFDM. The simulated results show that without OFDM, the maximum data rate and transmission distance for the systems is much less than that with OFDM. We can conclude that the acceptable BER performance can be achieved even up to 150 Km of the fiber length for the data rate of 10 Gb/s for optical communication systems with OFDM. This shows that the optical communication systems with OFDM are one of the powerful means to mitigate dispersion, whereby it can effectively compensate the dispersion in optical communication systems without employing any separate dispersion compensating module. [6]

III. OFDM FOR OPTICAL WIRELESS COMMUNICATIONS

There are two basic kinds of techniques allowing the demodulation of an optical signal into the originally transmitted electrical signal: those are direct and coherent detection. Both techniques have its pros and cons, and this subsection describes them.

A. OFDM FOR OPTICAL WIRELESS COMMUNICATIONS USING DIRECT DETECTION

a sequence of binary data from pseudo random bit sequence is mapped to frequency domain sub carriers by employing Quadrature Amplitude Modulation (QAM) .The MQAM symbols are modulated onto different frequency sub carriers using OFDM Modulator and low pass roll off filter. The quadrature modulator, which is used to up convert the signal at high RF frequency. the electrical wave signal from OFDM transmitter are combined with the continuous wave light from CW laser, this two waves are then modulated by Mach-Zehnder Modulator to form optical signal which would be sent through the optical wireless channel .

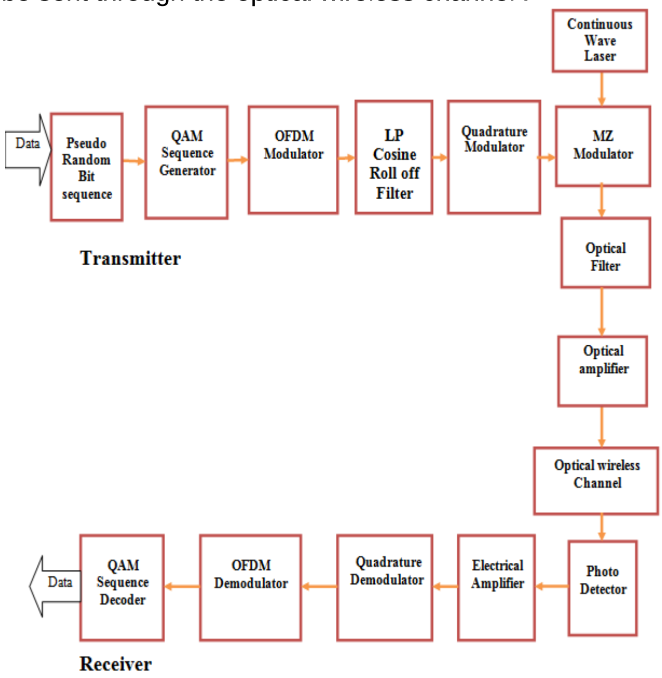

Fig. 1. *Block Diagram of Optical OFDM Using direct detection.*

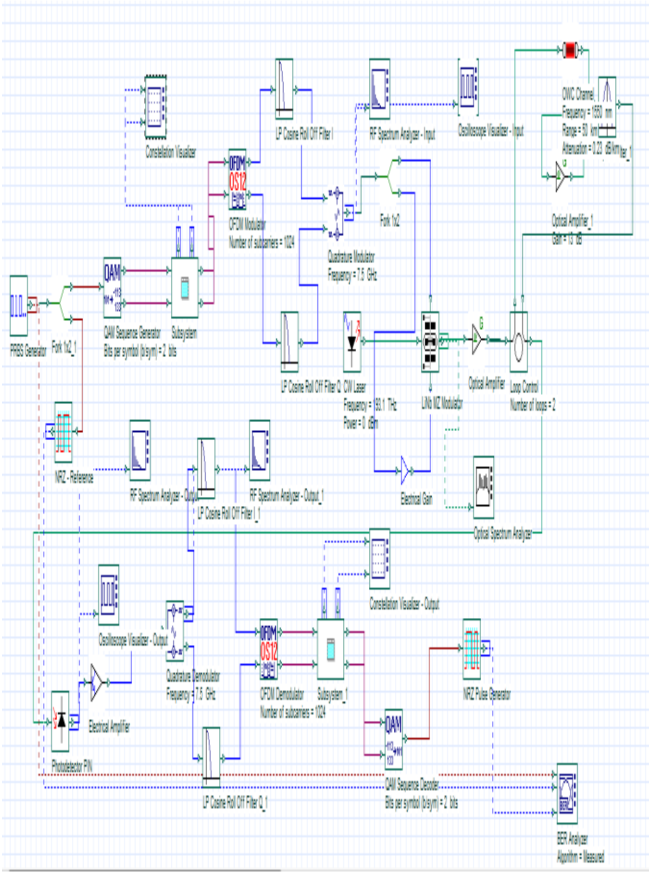

Fig. 2. *Optical OFDM using direct detection.*

Before sending through the optical wireless channel, the optical modulated signal is filtered by optical filter and amplified by optical amplifier .then the data would be received first by photo detector (receiver). This photo detector converts the incoming photonic stream back into a stream of electrons, so the optical signals are converted back into electrical signals. The signal then would recombine again in the OFDM receiver to get the original data back.

B. OFDM FOR OPTICAL WIRELESS COMMUNICATIONS USING COHERENT DETECTION

Coherent optical OFDM (CO-OFDM) represents the best performance in receiver sensitivity, spectral efficiency and robustness against polarization dispersion, but it requires the highest complexity in the transmitter design. The optical bandwidth requirements for CO-OFDM are much lower compared to DD optical OFDM because there is no need to transmit an optical carrier with the required gap to the OFDM band in addition to the modulated subcarriers. This leads to a spectral efficiency of nearly twice the one in DD-OFDM for any type of subcarrier modulation.[4]

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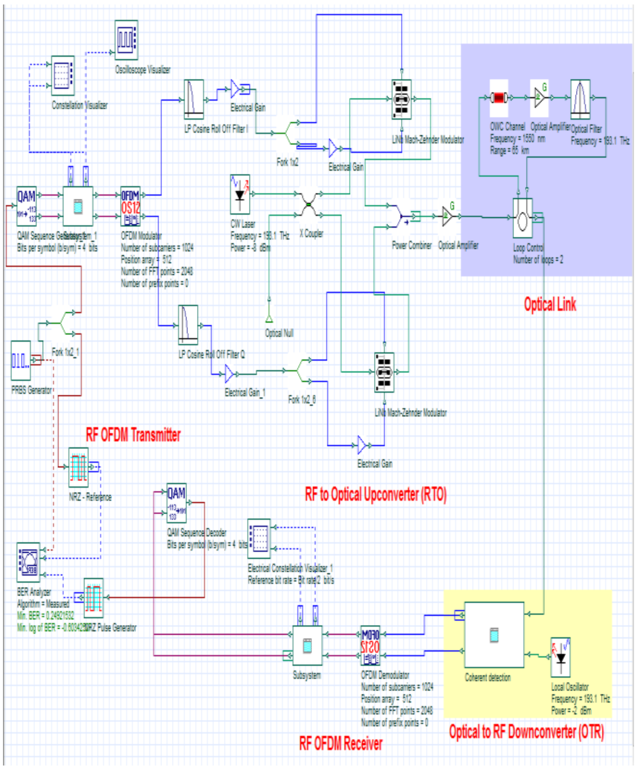


Fig. 3. *Optical Wireless Communications using coherent detection.*

The role of the optical transmitter is to convert the electrical signal into optical form using 2 MZM, and launch the resulting optical signal into the optical wireless channel after amplifying the signal. The optical receiver is consisted of two blocks as show in Figure above and also called Optical to RF down converter (OTR). The first block is local oscillator as in coherent OFDM systems, the optical carrier is not transmitted with the optical OFDM signal, but generated locally by a laser. This makes this kind of system to require less transmitted optical power than DD-OOFDM, though it is more sensitive to phase noise. The second part is coherent detection block which consist of 4 photo detector.

IV. Simulation Results and Performance Analysis

This chapter presents the simulation results of wireless Optical - OFDM system. The Optical - OFDM system designed in OptiSystem software. In this system the Quadrature Amplitude Modulation (QAM) and OFDM modulation technique is incorporated into Optical – OFDM system. This system can be used for both short distance as well as long-haul transmission at very high data rate. This improves the system flexibility and provides a very large coverage. The 4QAM and 16 QAM OFDM system will be explained and described by all simulation results for all parts of system using direct detection and Coherent detection using different number of subcarriers (256,512 and 1024 subcarrier).

TABLE1. GLOBAL PARAMETER SETUP

Parameter	Value
Bit rate	10Gbps
Time window	1.6384 e^{-006} s
Sample rate	40 GHz
Sequence length	16384 bits
Sample per bit	4
Number of sample	65536
optical wireless channel range	50 km
continuous wave laser power	0 dbm

A. 4QAM-OFDM optical system using direct etection with attenuation of the channel =0.2dB/km using 256,512and 1024 subcarriers.

In this project the OFDM Signal generation and decoding using 4 QAM as the modulation technique which will use 2 bit per symbol, the bit generator will generate a sequence of 0 and 1 of NRZ form signal with 16384 bits. The results for the system were shown in the figures below.

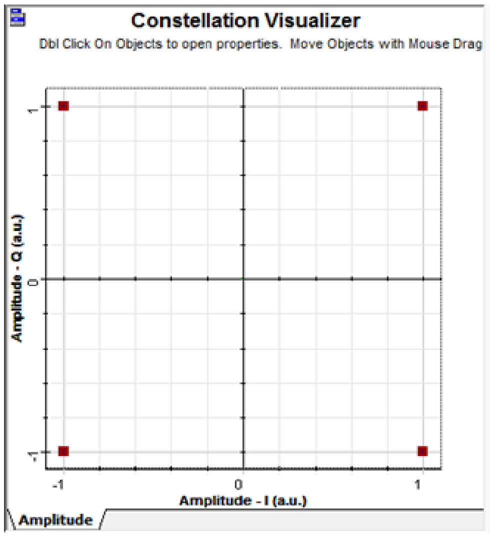
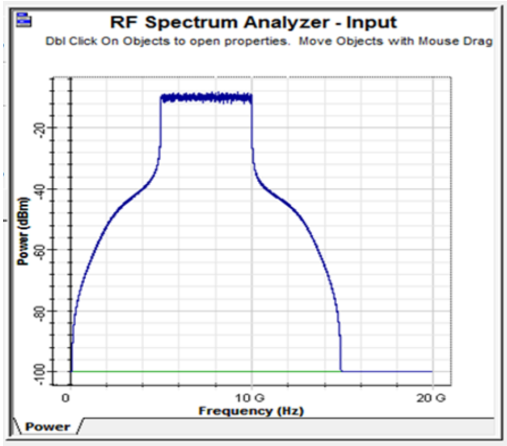
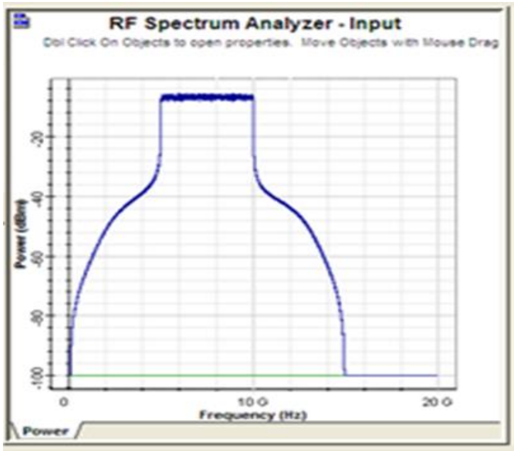


Fig. 4. 4QAM Encoder Constellation Diagram.

The bits encoded with 4QAM decoder which will use 2 bit per symbol.



(a)



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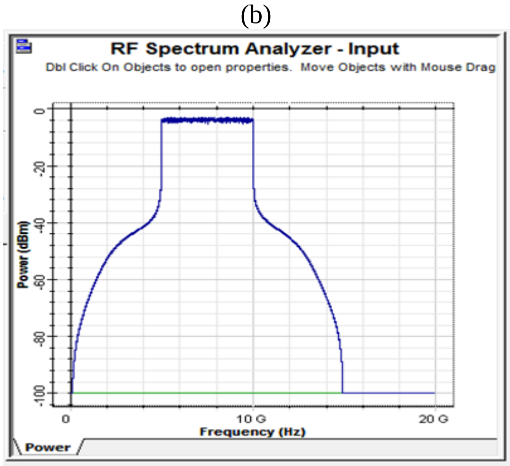
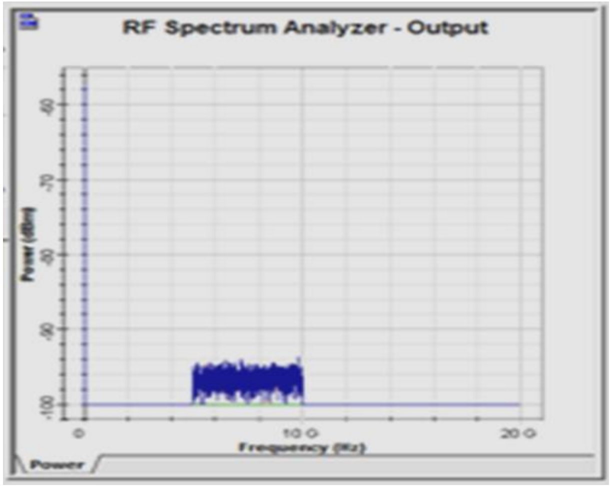


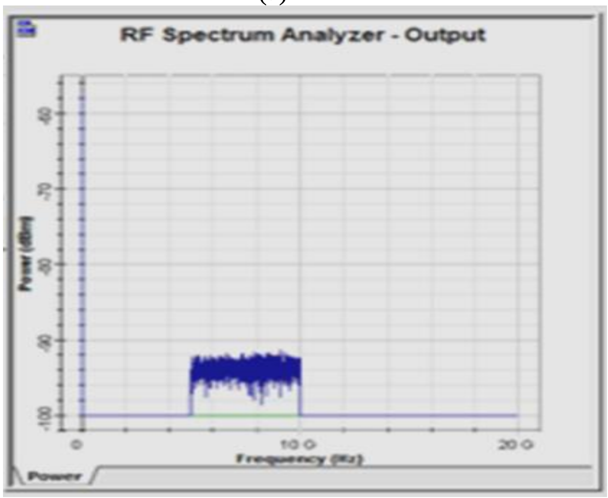
(c)

Fig. 5. *Modulated OFDM Signal in Frequency Domain using 256,512,1024 subcarriers (a)256 subcarriers,(b)512 subcarriers,(c)1024 subcarriers .*

this figure shows the electrical wave signal from OFDM transmitter which will be combined with the continuous wave laser light, this two waves are then modulated by Mach-Zehnder Modulator to form optical signal which would be sent through the optical wireless channel .Modulated OFDM Signal using 256, 512, 1024 subcarriers power=-10 dbm,-6 dbm and -4 dbm respectively and bandwidth of 15Ghz. We notice that the power increased as we increase subcarriers. The result for the receiver part was shown in the figures below.



(a)



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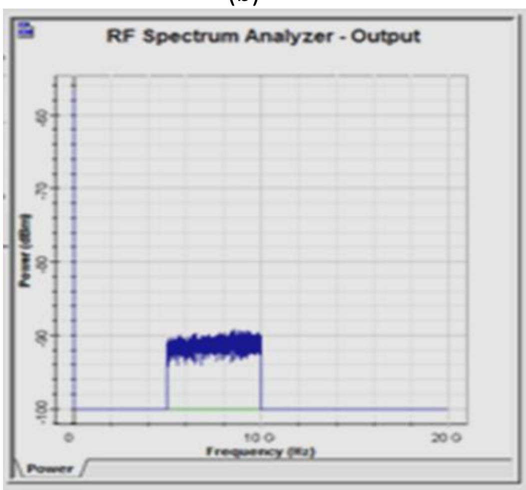

(c)

Fig. 6. *Signal after photo detector using 256,512,1024 subcarriers,(a)256 subcarriers,(b)512 subcarriers,(c)1024 subcarriers .*

This figure shows the Signal after photo detector as the signal is converted from optical to electrical. using 256,512 ,1024 subcarriers The Signal power =-94 dbm,-92 dbm and -90 dbm respectively.

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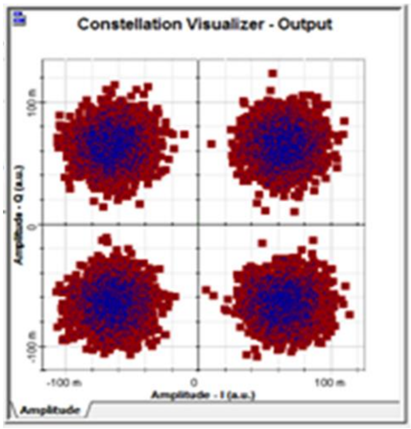
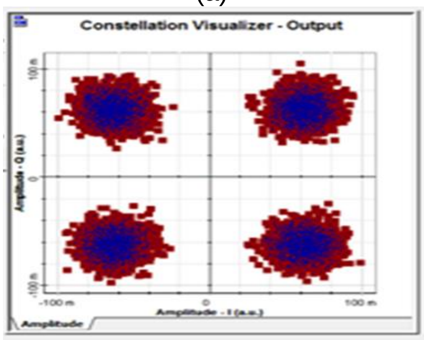
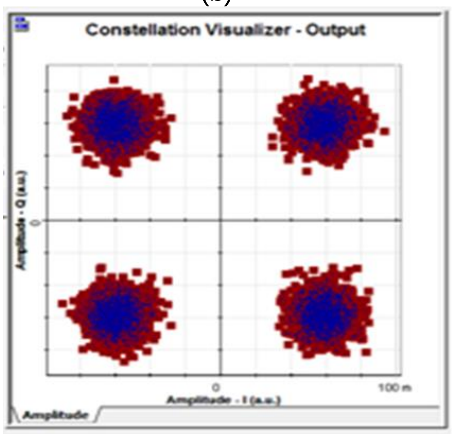


(a)



(b)



(c)

Fig. 7. Final Constellation Diagram for 4QAM, 256,512,1024 OFDM subcarriers(a)256 subcarriers,(b)512subcarriers,(c)1024 subcarriers.

In figure7 the final Constellation Diagram at receiver side is shown ,the best constellation diagram is for 4QAM 1024 subcarrier. If we use different attenuations of the channel with different number of the subcarriers we obtain the following results shown in table 2 and the relation between Min. BER ,attenuation and continuous wave laser power is shown in figure 8,9.

TABLE2. MIN. BER AND Q FACTOR FOR 4 QAM, 256,512 AND 1024 OFDM SUBCARRIERS USING DIRECT DETECTION WITH ATTENUATION OF THE CHANNEL =0.24,0.25,0.26,0.27,0.28 DB/KM.

Attenuation					
0.28	***0.27***	***0.26***	***0.25***	***0.24***	**no. of subcarrier =256**
1.406	1.596	1.812	2.080	2.399	***Q Factor***
0.157	0.110	0.068	0.036	0.016	***Min. BER***
					no. of subcarrier =512
1.717	1.950	2.261	2.658	3.107	***Q Factor***
0.084	0.050	0.023	0.007	0.001	***Min. BER***
					no. of subcarrier =1024
2.088	2.425	2.762	3.150	3.4440	***Q Factor***
0.035	0.014	0.005	0.001	0.0005	***Min. BER***

we obtain the best results at no. of subcarrier=1024 and attenuation =0.24 db/km as when attenuation increased Min.BER increase and Q factor decrease. when we increase no. of subcarriers Min. BER decrease and Q factor increase

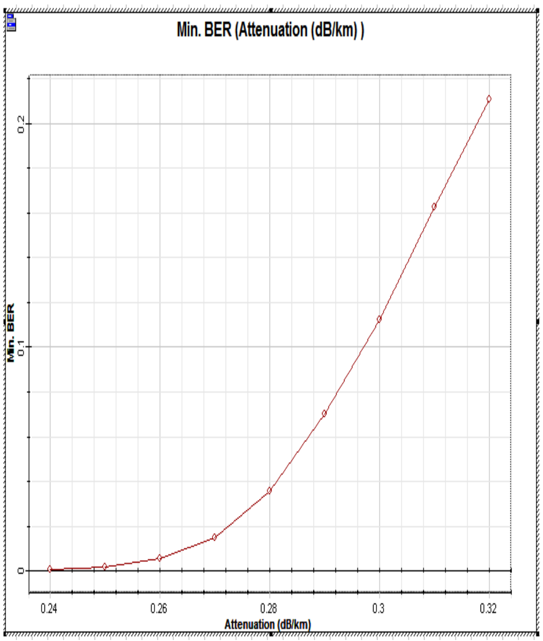


Fig. 8. *Relation between Min. BER and attenuation Using direct detection 4 QAM-OFDM,1024 subcarriers ,attenuation of the channel= 0.24,0.25,0.26,0.27,0.28,0.29,0.3,0.31,0.32 db/km.*

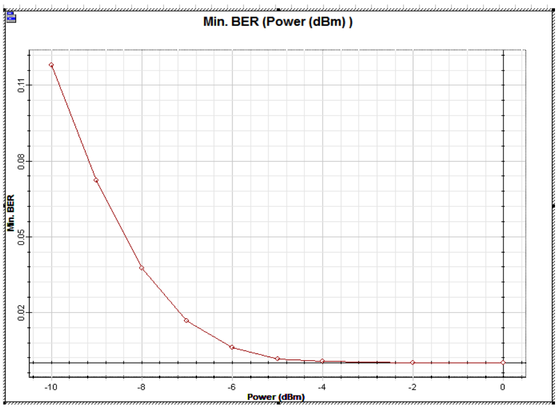


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Fig. 9. *Relation between Min. BER and Laser power Using direct detection 4 QAM-OFDM, no. of subcarrier =1024, attenuation of the channel =0.2db/km and laser power =-10,-9,-8,-7,-6,-5,-4,-2, 0 dbm.*

if we change 4 QAM to 16 QAM with different attenuations of the channel we obtain the following results shown in table 3

Table3. Min. BER and Q factor for 16 QAM, 256,512 and 1024 OFDM Subcarriers using direct detection with attenuation of the channel =0.01,0.02,0.03,0.05,0.1,0.2 db/km.

Attenuation						
0.2	***0.1***	***0.05***	***0.03***	***0.02***	***0.01***	**no. of subcarrier=256**
1.14	1.14	1.14	1.14	1.25	2.1	***Q Factor***
0.25	0.25	0.25	0.25	0.20	0.03	***Min.BER***
						no. of subcarrier=512
1.13	1.13	1.13	1.13	1.15	1.43	***Q Factor***
0.25	0.25	0.25	0.25	0.24	0.15	***Min.BER***
						no. of subcarrier=1024
1.07	1.07	1.07	1.07	1.07	1.11	***Q Factor***
0.28	0.28	0.28	0.28	0.28	0.26	***Min.BER***

we obtain the best results at no. of subcarrier=256 and attenuation =0.01 db/km as when attenuation increase Min.BER increase and Q factor decrease .when we increase no. of subcarriers Min. BER increase and Q factor decrease. the relation between Min. BER , attenuation and continuous wave laser power is shown in figure 10,11.

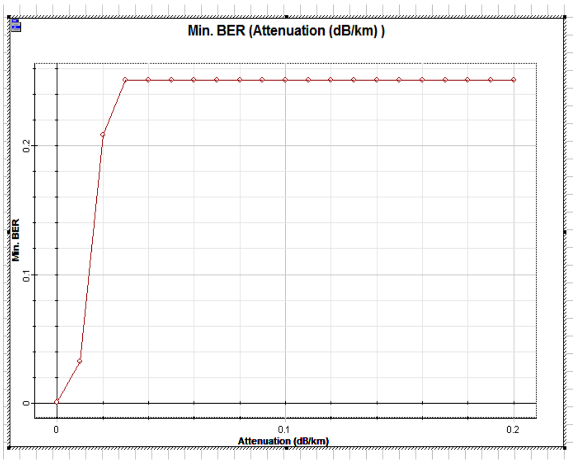

Fig. 10. Relation between Min. BER and attenuation Using direct detection 16 QAM-OFDM,256 subcarriers ,attenuation of the channel= 0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09,0.1,0.11,0.12,0.13,0.14,0.15,0.16,0.17,0.18,0.19,0.2 db/km.

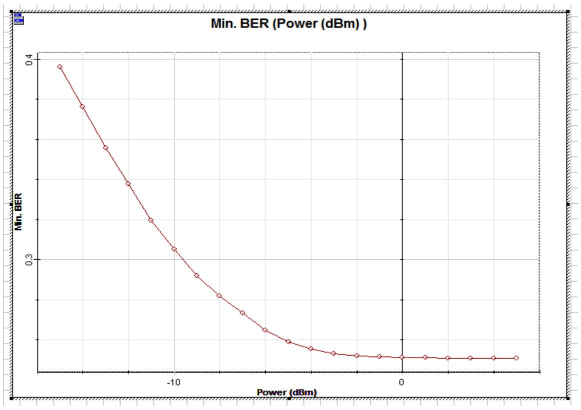

Fig. 11. Relation between Min. BER and Laser power Using direct detection 16 QAM-OFDM, no. of subcarrier =1024, attenuation of the channel =0.2db/km and laser power =-15,-14,-13,-12,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3, 4,5 dbm.

B. 4QAM-OFDM optical system using coherent detection with different attenuation of the channel using 256,512and 1024 subcarriers.

Coherent detection with 256,512 and 1024 OFDM Subcarriers using 4 QAM and different attenuation of the channel. we obtain the following results shown in table 4 .we obtain the best results at no. of subcarrier=1024 and attenuation =0.26 db/km as when attenuation increased Min.BER increase and Q factor decrease. when we increase no. of subcarriers Min. BER decrease and Q factor increase. coherent detection gives better performance than direct detection. and the relation between Min. BER ,attenuation and continuous wave laser power is shown in figure 12,13.

Table4. Min. BER and Q factor for 4 QAM, 256,512 and 1024 OFDM Subcarriers using coherent detection with attenuation of the channel =0.26,0.27,0.28,0.29,0.3 db/km.

Attenuation					
0.3	***0.29***	***0.28***	***0.27***	***0.26***	**no. of subcarrier=256**
1.450	1.596	1.700	1.85	2.01	***Q Factor***
0.146	0.108	0.088	0.06	0.04	***Min. BER***
					no. of subcarrier=512
1.855	2.028	2.235	2.35	2.62	***Q Factor***
0.063	0.042	0.025	0.01	0.0085	***Min. BER***
					no. of subcarrier=1024
2.373	2.606	2.831	3.27	3.57	***Q Factor***
0.017	0.008	0.004	0.001	0.0003	***Min. BER***

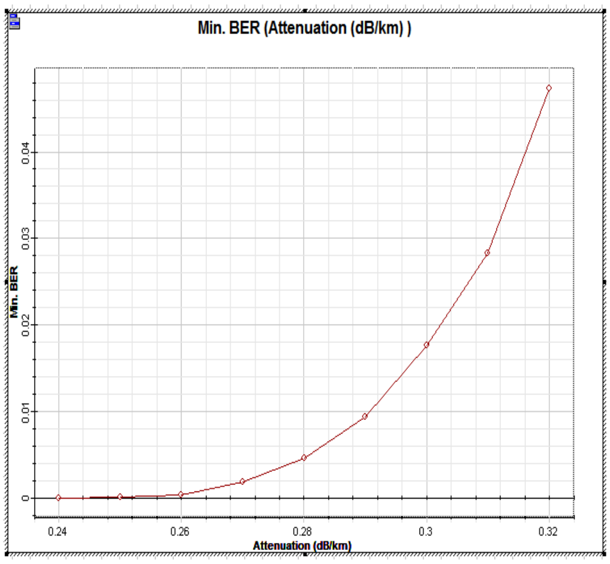

Fig. 12. *Relation between Min. BER and attenuation Using coherent detection 4 QAM-OFDM,1024 subcarriers ,attenuation of the channel= 0.24,0.25,0.26,0.27,0.28,0.29,0.3,0.31,0.32 db/km.*

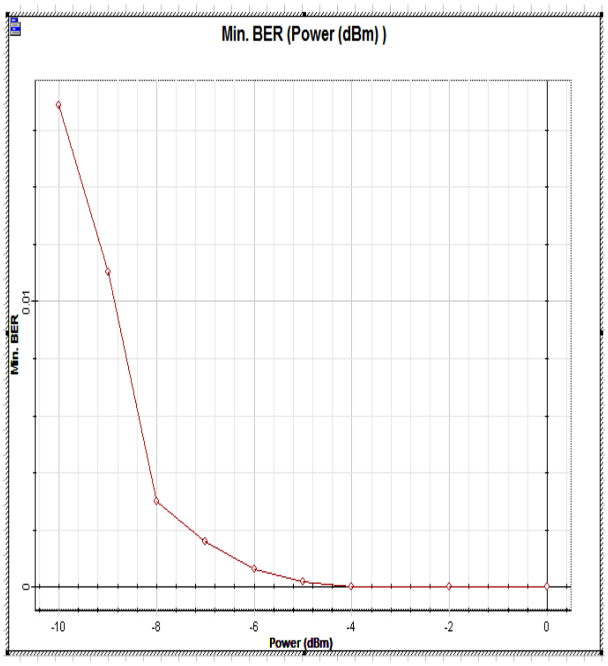

Fig. 13. *Relation between Min. BER and Laser power Using coherent detection 4 QAM-OFDM, no. of subcarrier =1024, attenuation of the channel =0.2db/km and laser power =-10,-9,-8,-7,-6,-5,-4,-2,0 dbm.*

if we change 4 QAM to 16 QAM with different attenuations of the channel we obtain the following results shown in table 5

Table5. Min. BER and Q factor for 16 QAM, 256,512 and 1024 OFDM Subcarriers using coherent detection with attenuation of the channel =0.06,0.07,0.08 db/km.

Attenuation			
0.08	***0.07***	***0.06***	**no. of subcarrier=256**
1.148	1.148	1.924	***Q Factor***
0.250	0.250	0.053	***Min.BER***
			no. of subcarrier=512
1.148	1.148	1.424	***Q Factor***
0.250	0.250	0.152	***Min.BER***
			no. of subcarrier=1024
1.1480	1.148	1.217	***Q Factor***
0.250	0.250	0.221	***Min.BER***

we obtain the best results at no. of subcarrier=256 and attenuation =0.06 db/km as when attenuation increase Min.BER increase and Q factor decrease .when we increase no. of subcarriers Min. BER increase and Q factor decrease. coherent detection gives better performance than direct detection. and the relation between Min. BER ,attenuation and continuous wave laser power is shown in figure 14,15.

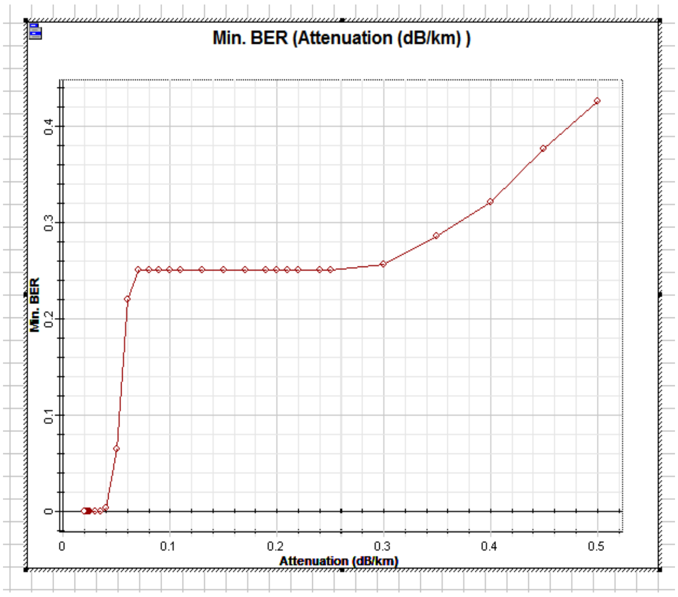

Fig. 14. *Relation between Min. BER and attenuation Using direct detection 16 QAM-OFDM,256 subcarriers ,attenuation of the channel= 0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09,0.1,0.11,0.13,0.15, 0.17,0.19,0.2,0.21,0.22,0.24,0.25,0.3,0.35,0.4,0.45.0.5 db/km.*

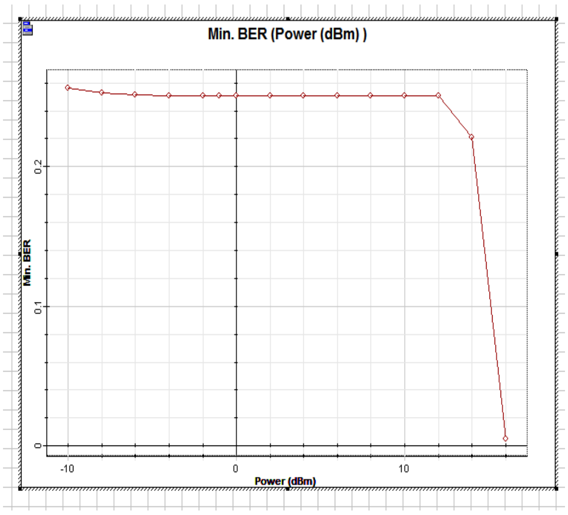

Fig. 15. *Relation between Min. BER and Laser power Using coherent detection 16 QAM-OFDM, no. of subcarrier =1024, attenuation of the channel =0.2db/km and laser power =-10,-8,-6,-4,-2,-1,0,2,4,6,8,10,12,14,16 dbm.*

Conclusions

OFDM is a very promising technology for optical communications. We notice that when we use coherent detection the system performance is better than direct detection .We notice that when attenuation increases Min. BER increases and when we increase Power of CW laser Min. BER decreases.

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