Simulation of WDM-OFDM Modulation Techniques in High Speed Optical Communication Systems

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Abstract: ***Advancements in optical transmitters, detectors, high purity optoelectronic material components and optical sources have made fibre optic technology, the world's fastest growing communication technology, further highlighting the significance and importance of fibre optic communication. Bit error, Rate, Loss, Reliability and Security in communications have all been enhanced as a result of this revolution. Extremely low complexity, low cost, low power consumption, high data rate requirements have spurred great development of UWB Wired & Wireless communications in a variety of applications. An effort to employ a MATLB/SIMULINK based modulation technique OFDM, QAM and QPSK. Measurements were taken at various SMF distances and the BER and SNR values were recorded. When compared to other formats QPSK performs better on WDM PON systems. Using the graphical user interface of MATLAB, we want to conduct a study of the signal-to-noise ratio and the error probability. The error probability drops linearly from maximum to minimum as the signal-to-noise ratio increases, independent of the channel capacity. We can deduce that the QPSK format provides a significantly higher channel capacity in an OFDM communications systems. OFDM and coded OFDM optical communication networks make extensive use of the QPSK technique. When it comes to optical networks, QPSK provides more channel capacity than QAM. Different modulation systems like QAM and QPSK send signals across high-speed optical transport networks in different ways. The QPSK also helps shed light on the problem plaguing modem optical transmission systems.***

Keywords: Fibre optic Communication (FOC), Orthogonal Frequency Division Multiplexing (OFDM) Systems, Signal to Noise Ratio (SNR), Bit Error Rate (BER), Quadrature Phase Shift Keying (QPSK), QPSK performance, Optical Networks.

1. Introduction

1.1. Orthogonal Frequency Division Multiplexing (OFDM):

Multiplexing using Frequency Division Multiplexing (FDM) allows all users to a same channel simultaneously (full time) but at distinct frequencies, thus signal interferences. Consequently, consumer bandwidth is shared but their time is not. Not to mention that FDM still has the chance of cross talk. One digital multicarrier technology that is well suited for high-speed data transmission is Orthogonal Frequency Division Multiplexing (OFDM) [1]. OFDM finds application in both wireless and wired communication systems and also offers a number of practical advantages. The introduction of Orthogonal Frequency Division Multiplexing (OFDM) allows optical communication system to overcome both linear and non-linear limitations, allowing for high-speed data transmission. Due to OFDM's effective use of FFT techniques for the construction of various modulation and demodulation functions, high-rate processing is achievable in optical communication.

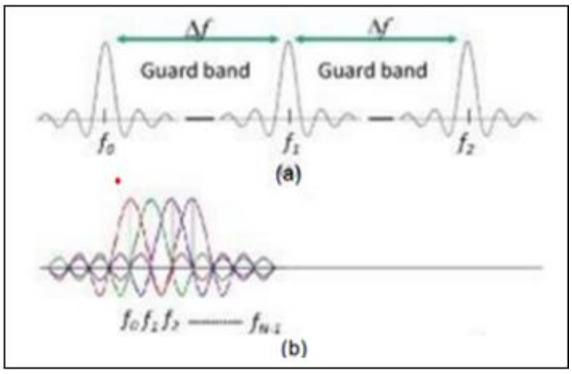

Figure 1: Difference between System Carriers FDM (a) and OFDM (b)

Difference between FDM and OFDM

The signal carriers in OFDM systems are orthogonal to one another and packed densely, in contrast to FDM systems where there are widely spaced. When two carriers are orthogonal it means that their peaks coincide with one other. Because OFDM signals can transport more data in a smaller bandwidth, there are more efficient then FDM systems in terms of bandwidth utilization. When comparing OFDM and FDM systems, the peak to average power ratio of the farmer is higher. [2] For the same amount of bandwidth, an OFDM system can deliver a higher data rate than FDM system. Radio and satellite communication use frequency division multiplexing systems, which necessitate a high number of guard bands between neighbouring frequency bands. LTE and other technologies that demand higher data rates employ OFDM systems. While advanced algorithms can mitigate some of the multipath interference that plagues OFDM systems, it remains significantly higher than that of FDM systems. While users in FDM systems make full use of the available bandwidth, those in OFDM have their own dedicated narrow band channel. This means that OFDM can accommodate more channels and subscribers than FDMFSM.

1.2 Optical OFDM System

Orthogonal Frequency Division Multiplexing (OFDM) divides data into blocks before transmission over a high-speed data channel. Different types of fibre, network ranges (from short to long-haul), and detection methods (direct or coherent) could be accommodated by modifying an optical OFDM transmitter. The system's designs would allow for bit rate flexibility through the use of multiple modulation depths. The figure is a schematic of an optical OFDM transmitter. With the use of Fourier transform algorithms, the system encrypts data before sending I over a network of lower rate sub-carriers. Data modulated by OFDM is transmitted across an optical channel by the system. The transmitter, the channel and the receiver are the three primary components of a transmission system. There are a number of digital modulation schemes accessible for use in the transmitter sector, including as Quadrature Amplification Modulation (QAM), Quadrature Phase Shift Keying (QPSK) and 16 QPSK (M-ary). The data is presented in N-parallel paths. A dense comb of OFDM sub carrier frequencies can be generated using an inverse-FFT (IFFT), which satisfies a basic need of the OFDM technology for numerous microwave mixers producing different sub carrier frequencies. Converting data from high-rate, randomly generated stream into a low-rate, randomly generated stream and vice-versa is the job of serial to parallel and parallel to serial converters, respectively. [3].

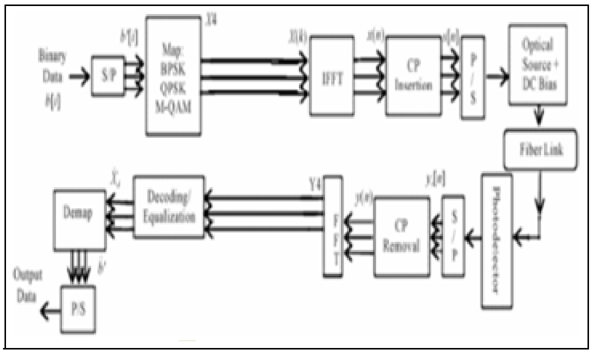

Figure 1.2: Optical OFDM system blog diagram

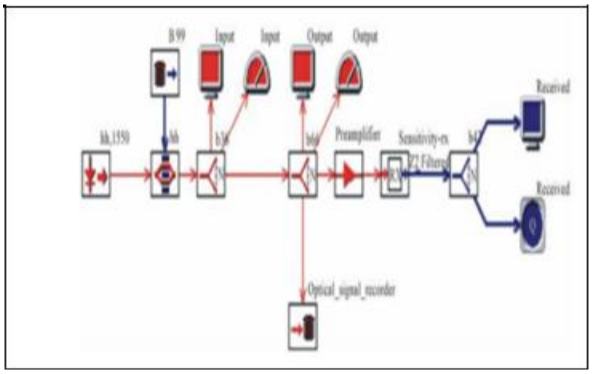

Figure 1.3: System model for optical transmission

The average beat length of the fibre is 5 meters and is dispersion is zero at a wave length of 1391.53354633 nm. The CW an optical source with the following key futures was utilized: CW power of 1mW, FWHM line width of 10 MHz and a centre emission wave length of 1550 nm. The laser had a Lorentzian design. The optical signal is modulated using an amplitude dual-arm Mach Zehnder Modulator [3] with the parameters: 0dB excess loss, 0.5 V offset voltage 20dB extinction ratio, O chirp factor and 3 dB average power reduction due to modulation. Performing serial-to-parallel conversion and eliminating the cyclic prefix are examples of reversing operations used in the receiver section. Sub-carrier recovery is the last step before de-mapping QPSK and M-ary QAM to binary values.

2. Results

This study develops an optical OFDM system that makes use of several modulation methods including Quadrature Amplitude Modulation (QAM) and Quadrature Phase Shift Keying (QPSK). This study reports on a number of signals conditioning metrics including OSNR, BER, Chromatic dispersion and electrical signal to noise ratio (SNR). It may be possible to locate the problem using these settings. The system may dynamically adjust and reorganise itself to improve transmission based on the conclusions made for these parameter values. Simulation tools OPSIM and MATLAB were utilized in this investigation. The outcomes of the simulations for the different parameters of the optical OFDM system are detailed in this section. Table contains the values of several critical parameters that are used in the simulation.

Optical OFDM System:

Table 1: Optical OFDM Simulation Parameters

Parameter	Value
Data Rate	10 Gbps
Wave Length	1550 nm
Fibre Length	100 km
CW Laser Frequency	193.1 THz
Gain	35 dB
Cyclic prefix	16 bit
FFT	64 bits

Analogue methods for tracking optical spectrum analysis performance. It is normal practice to measure OSNR. An Optical signal to noise ratio of 11dB/0.1 nm is necessary for achieving a minimal BER of e-03.

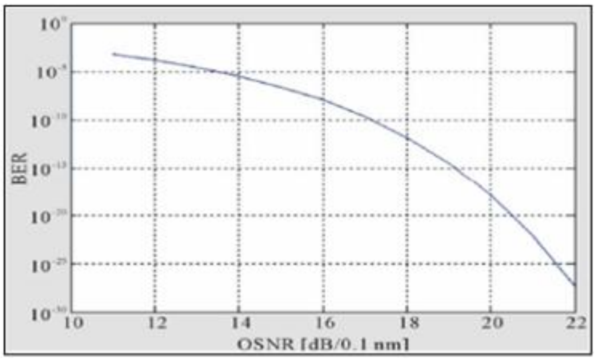

Figure 1.4: BER Performance vs OSNR of optical OFDM system

The image depicts the Bit Error Rate (BER) metrics for optical OFDM transmission across a 100-kilometer distance. With an OSNR [1] value of 17.7 dB/0.1 nm, BER of e-012 effectively a bit error rate.The OSNR [4] value needed for BER of e-03 is 11.9 dB/0.1 nm can be seen in figure 1.4.

QPSK Modulation System

Table 2: Simulation results for QPSK Modulated System

Parameter	Value
BER	7.06425e-012
Eye Opening	0.0723e-006
Jitter	0.0201543
Q-Facor	19.98dB

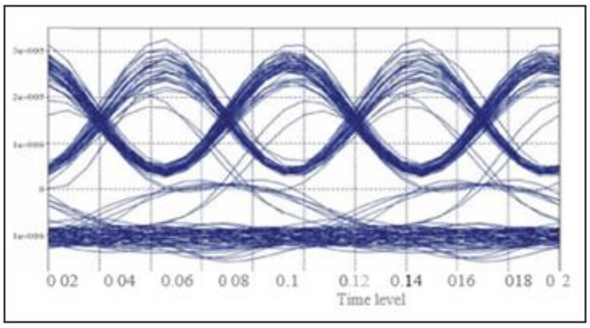

Figure 1.5: Eye Diagram for QPSK transmission

QAM Modulation System:

Table 3: Simulation results for QAM Modulation System

Parameter	Value
BER	6.5624e-013
Eye Opening	0.158919e-06
Jitter	22.24 dB
Q factor	18.99 dB

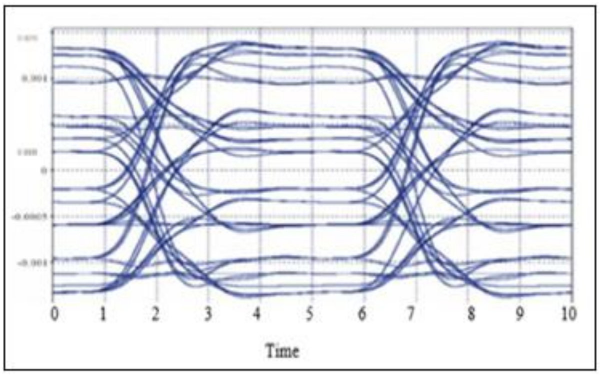

Figure 1.6: Eye Diagram for QAM transmission

Chromatic dispersion:

Table 4: Chromatic dispersion Vs Wavelength

Wavelength in nm	Chromatic dispersion in ps/km-nm
1.3	7
1.5	17
1.7	21
1.8	25

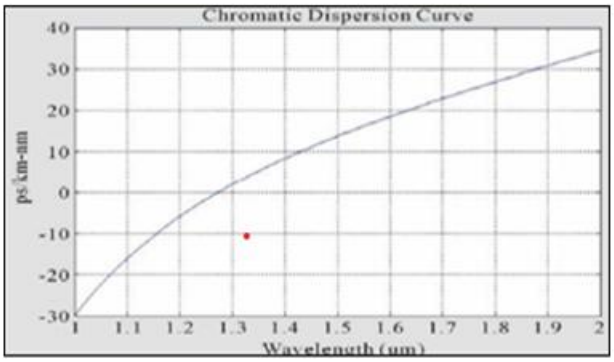

Figure 1.7: Chromatic Dispersion Vs. Wavelength

Among the several performance monitoring metrics, chromatic dispersion is useful for channel estimate. Chromatic dispersion occurs because the various spectral components have varying group velocities. Chromatic dispersion has been examined in this study in relation to wavelength. The graph in Figure 1.7 demonstrates the variation in chromatic dispersion as a function of frequency.

According to previous reports, the chromatic dispersion is typically between 15 and 18ps/(km-nm) about 1.5µm and near 1.55µm, there is minimal fiber loss, making this area of great importance. In the current simulated system, the dispersion ranges from 12 to 17ps/(km-nm) 1.5µm to 1.55µm as can seen clearly in the above figure.1.7. The current model's simulation results show a much reduced dispersion in the 1.5µm - 1.55 µm range.

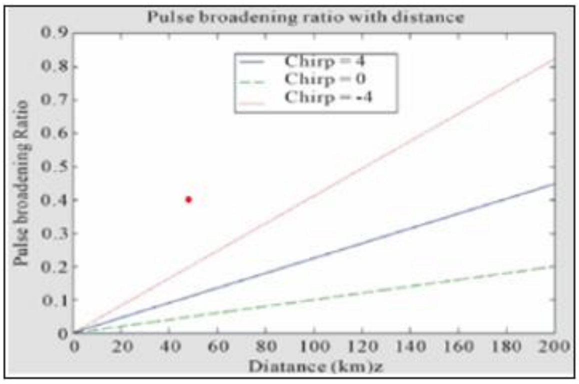

Figure 1.8: Pulse Broadening ratio with distance

When evaluating the efficiency of transmission quality, SNR is yet another crucial metric to consider. In Figure1.9, we can see a comparison curve of the QAM, optical OFDM system's performance with respect to BER and SNR. The optical OFDM system's current performance is compared to its theoretical counterpart on this curve. A QAM modulated OFDM system is simulated and compared with theoretical results obtained from the analytical formulation of following equation.

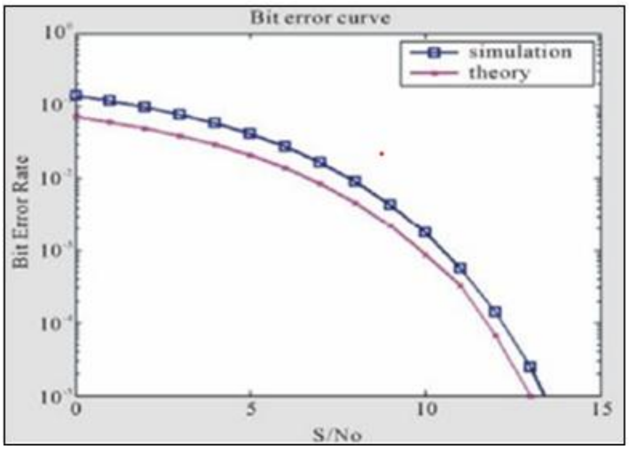

Figure 1.9: BER performance of QAM system both the results of numerical simulation and analytical calculation

Theoretical BER predictions indicate a gain of nearly 11.5 dB at a BER of 10^{-4}. Be aware that the theoretical predication and the experimental findings are quite close, with the latter suggesting a gain of approximately 13 dB at the same BER; nevertheless, this could be due to extra disturbances and losses in the fibre channel during transmission. Compared to the theoretical formula, the simulated optical OFDM system performs 1.5 – 2 dB poorer. Formulas based on theory fail to account for to account for the performance-degrading effects of synchronization problems and quantization of received samples.

$$BER = 1-\left(1-\frac{1}{\log_2 M}\left(1-\frac{1}{\sqrt{M}}\right)Q\left(\sqrt{\frac{3}{M-1}\frac{S}{N_0}}\right)\right)$$

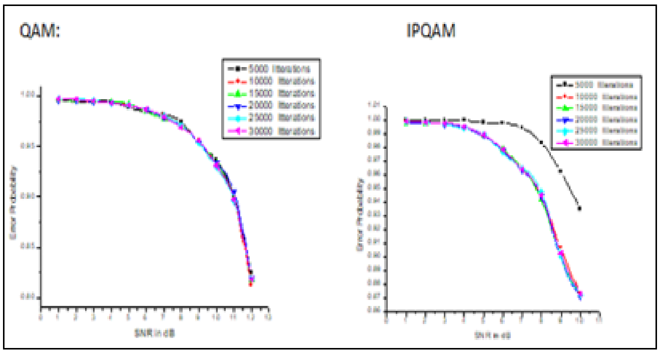

Figure 10: BER performance (Error Probability) of QAM, IPQAM systems results of numerical simulation [7]

Validation of Simulated Results (Discussions)

The OFDM employs parallel processing for data block transmission, it has been suggested that this is optimal for high-speed applications. Digital signal processors allow for the efficient implementation of fast Fourier transform (FFT), which is used in this method. A BER value of 10e-12 is associated with a Q factor of 16.9 dB, whereas a BER value of 10e-15 is associated with a Q factor of 18.06dB. For the QAM modulated system, the simulation test bed reports a Q factor of 18.99dB and a BER value of 6.5624e— 013 at an eye opening of 0.1S8919e— 06, whereas for the QPSK modulated system, the Q factor figures are 19.98dB and a BER value of 7.06425e—012 at an eye opening 0f0.0723e—006. The BER value e—05 at an OSNR of 13dB given in the simulation results for the optical OFDM system's performance. At an OSNR of 13.9dB/0.1 nm, the current simulated system is reporting a BER of e—0S. The usual dispersion values are between 15 and 18ps(km—nm) close to 1.5 pm and 1.55 um. This region is of great importance since the fiber loss is least near 1.55 um. Reportedly, for positive values of the chirp factor, the broadening grows linearly. The chirp factor must be zero in order to get minimum broadening.

The design of the OFDM, QAM. QPSK and IPQAM modulation system in the MATLAB Simulink is performed and the results are plotted. The Simulink involve linear effect; these results will be close to real system [7]. In WDM PON system IPQAM gives better performance as compared to other format. We are analysed the error probability and SNR using MATLAB graphical user interface.

3. Conclusions

These modulation schemes are useful to improve channel capacity of OFDM and Coded-OFDM and in figure designed Multiplexing optical networks. The above modulation techniques such as QAM, QPSK and IPQAM modulations propagates the signal in different optical transport network. OFDM modulation is useful to improve spectral efficiency of optical channel in future designed Multiplexing optical networks of multipath fading and higher order implementation for further research 1.e. 4^{th} and 5^{th} Generation Mobile Communications.

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