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Performance Investigation in Optical OFDM

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ABSTRACT

Optical Orthogonal frequency division multiplexing (OOFDM) has been one of emergent and competent technique to be used with future generation communication networks, due to less inter symbol interference caused by a dispersive channel. In view of it this paper presents investigated transmission performance with novel designed OOFDM system for different transmission parameters with fixed communication length. To achieve good transmission performance in optical OFDM system it must be optimized in various ways. Higher bit rate transmission is favored with low baud rate, BPSK modulation scheme, booster power in the range of zero to 14dB constellation patterns are very good. Further it is also noticed that transmission is affected with variation of cyclic prefix and QAM size and number of subcarriers.

I INTRODUCTION

Present era of information world relies on higher data rate communication for huge number of applications and more bandwidth is always essential for higher data rate transmission. Lots of schemes have been investigated from time to time. Orthogonal frequency Division Multiplexing (OFDM) scheme is one of a spectrally competent transmission alternative for broadband communication. It exhibit excellent performance in wireless as well as in wired environments because of its robustness to frequency dependent impairments.OFDM [1] is widely accepted in RF-wireless systems cell-networks, digital-audio broadcasting and digital-video broadcasting due to it is pliant to multipath propagation. It is beneficial due to application of advanced digital signal processing of fast-Fourier transforms (FFTs) and IFFT and efficient amplitude and phase equalization employing only one complex multiplication per OFDM subcarrier, OFDM signals applied in optical domain is termed as Optical OFDM (OOFDM) [2].OOFDM transmission system is followed by wireless channel (fiber-wireless systems) or copper wire (few DSL or fiber-coaxial systems) [3].Presently OFDM is used as a new transmission scheme to attain high-speed transmission at gigabit data rates and to compensate optical fiber dispersion [4-6]. Although OFDM offers excellent advantages but large peak to average power ratio (PAPR) is one of a main problem in OFDM schemes which require large linear range for transmission network. Also OpticalOFDM links undergoes from limited linear dynamic range due to nonlinear distortion of optical transmitter, moreover Mach-Zehnder modulator (MZM) or laser diode. Nonlinear distortion due to MZM/Laser/optical channel can be a key limiting factor in high speed wired/wireless OFDM systems with huge number of subcarriers; OFDM is also illustrated with multimode and free-space optical links [8-10].But OFDM entails receiver sensitivity penalty since it needs large mean optical powers for conversion of bipolar OFDM(BOFDM) to unipolar optical signals [11].A lot of study is ongoing in this area as channel of optical systems are nonlinear and OFDM signals are generated with Quadrature Amplitude Modulation (QAM) on each subcarrier so lots of parameter optimization are needed while designing OpticalOFDM communication system since there is no right way of deciding these parameters. In this view it presents designing and parameter optimization on an OOFDM transmission system.

II. Theoretical considerations

OFDM termed as Orthogonal Frequency Division Multiplex system since multicarrier communication system with orthogonal subcarriers. It divides high data rate streams into lower data rate streams, which were transmitted concurrently over numerous sub-carriers. Since symbol duration is augmented for lower rate parallel subcarriers, the comparative amount of dispersion in time caused by multi-path delay spread is diminished. With an OFDM system, the carrier spacing Δf is 1/NT, where N is the number of carriers and 1/T is overall symbol rate. With this carrier spacing, the sub channels can maintain orthogonality, although the sub channels overlap. So there is no inter-subcarrier interference with ideal OFDM systems and number of subcarriers N is chosen so that sub channel bandwidth is less than channel coherence bandwidth. In this state, each sub channel does not experience significant inter-symbol interference (ISI) and to generate an OFDM signal with a large number of subcarriers extremely complex architecture involving several oscillators and filters at both transmit and receive ends is necessary. For an OFDM transmissions this complexity is diminished by transferring it from analogue to the digital domain mathematically, if the temporal expression of an OFDM signal is taken, Expression

$$X(t) = \sum_{i=0}^{\mathrm{NOFDM}} \sum_{K=0}^{N-1} e^{j2\pi k \Delta f t}\, p(t - iT_{OFDM}) \qquad (1)$$

Where $\Delta f = 1/T_{OFDM} = 1/(NT_S)$ and considering it is sampled every Ts it leads to:

$$X(nT_S) = \sum_{i-0}^{NOFDM} \sum_{k=0}^{N-1} Cik\, e^{j2\pi \cdot \frac{1}{NTs}\, n.T_s}$$
$$= \sum_{i=0}^{NOFDM} \sum_{k-0}^{N-1} aik\, e^{j2\pi Kn/N} \qquad (2)$$

The above expression (2) exhibit inverse fast Fourier transform (IFFT) of an OFDM symbol, IFFT operation is performed in OFDM system in transmitter module after the QAM mapping process. Therefore the modulation stage involves the IFFT application [14].For parallel demodulation of all subcarriers on receiver side, the procedure involves subcarrier detection in the digital domain using the Fast Fourier Transform (FFT) [13].Significant benefit in digital systems is that they are able to avoid the hardware complexity and allow cost-effective implementations and the drawback is that DAC and ADC are needed[12].In the DAC convolving each of temporal sample by a sinc function and this ideal pulse shaping is translated into a perfectly rectangular filter which removes the aliasing in the frequency domain, The following scheme (figure 1) depict the OFDM transmitter in the where IFFT block is used in order to modulate the OFDM signal.

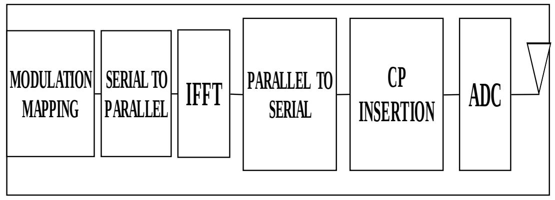


Fig.1 Block diagram of Optical OFDM Transmitter section

In the OOFDM design role of FFT/IFFT are very significant and FFT is almost same to IFFT and IFFT can be made using an FFT by conjugating input and output of the FFT and dividing the output by the FFT size so it make it's possible to use same hardware for both transmitter and receiver. Also the frequencies of an OFDM signal are represented in each branch of an IFFT operation(figure2), where input sequence symbols from subcarrier1 to the total number of subcarriers N are x_1, x_2 . . x_n and the corresponding output sequence are y_1. .. y_n.

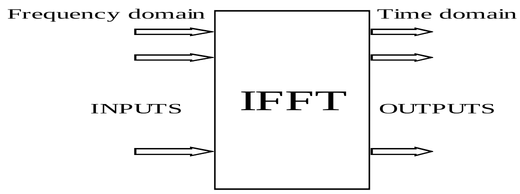


Fig.2 IFFT block section used in OFDM

Figure2 illustrates IFFT blocks and the frequency domain OFDM symbol at its output [13]. On the receiver side FFT is applied to extract the original data, FFT allows an efficient implementation of modulation of data onto multiple carriers. the subcarriers forming the received signal are demodulated by an FFT operation after being analogue to digital (A/D) converted and parallelized to form FFT block inputs. The output of the FFT contains N de-modulated values, which are mapped onto binary values and decoded to produce the binary output data. To successful map the de-modulated values onto the binary values, first the reference phase and amplitudes of all the sub-carriers have to be acquired. Alternatively different differential techniques can be applied.

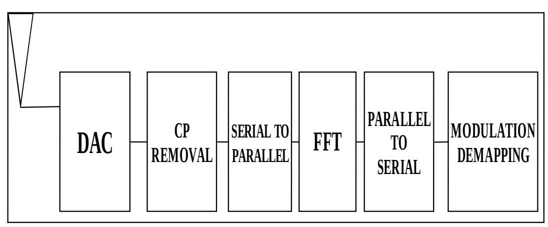


Fig.3 Block diagram of OFDM receiver section

Further in order to evade intersymbol interference and to sustain orthogonality between the sub channels in a time dispersive channel cyclic prefix is used. ISI is evaded if the length of the cyclic prefix, Tcp, is selected sufficient to surpass utmost surplus delay of the channel. Total symbol time Tsub is extended when cyclic prefix is used but sub-channel bandwidth is equivalent to inverse of the symbol time excluding the cyclic prefix Ts. Insertion of cyclic prefix means that sub channel bandwidth has to be augmented to maintain the bit rate constant and bit rate establishes symbol time T_{sub} and if a fraction of this is employed for cyclic prefix then time Ts is to be reduced which in turn directs to enhanced sub-channel bandwidth.

III. Simulation design Modeling

Designed OpticalOFDM Simulation block consists of following major sections OFDM transmitter, optical modulator, Mach-Zehnder interferometric modulator (MZM), laser source and PIN detector, OFDM receiver. MZM optical modulator is constructed such that phase difference between the two optical waveguides that propagate the split beams is 0 when voltage is not being applied, the serial to parallel (S/P) converter branches high data rate stream into several low data rate streams. For each of streams the binary data is selected block wise, and mapped to QAM symbols. QAM is a method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. A QAM signal there are two carriers each having same frequency but differing in phase by 90 degrees, one signal is called I signal, and other is called the Q signal. QAM symbols modulate each of the data-subcarriers of the OFDM symbol. The generation and modulation of all the subcarriers is done simultaneously by IFFT block and output of IFFT block is the time samples, describing the OFDM symbol. At this stage, cyclic prefix is inserted to the OFDM symbol in order to increase the tolerance towards multi path delays, or in fiber optics, dispersion. This is done by the CP block by copying the first segment of the time samples and adding it to the end of the time series, thus increasing the time window. The parallel output from the CP block, describing the OFDM symbol, in the time domain, is now converted to a serial stream via the parallel to serial (P/S) converter. The time data is still in the digital domain. At this stage the stream is converted to an analog signal for transmission, or modulation of a carrier.

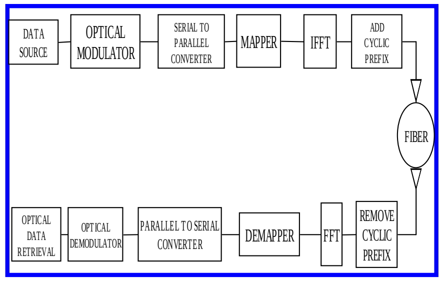


Figure4: General Simulink model used for optical OFDM

IV. RESULTS AND DISCUSSION

This paper successfully demonstrated design and performance analysis for OpticalOFDM transmission system. Transmission performance has been investigated for number of transmission parameters. In the results shown in figure 5plot for Q vs. booster power it is noticed that performance is better for booster power of zero to 14dB and after it performance degrades since fiber is highly nonlinear medium.

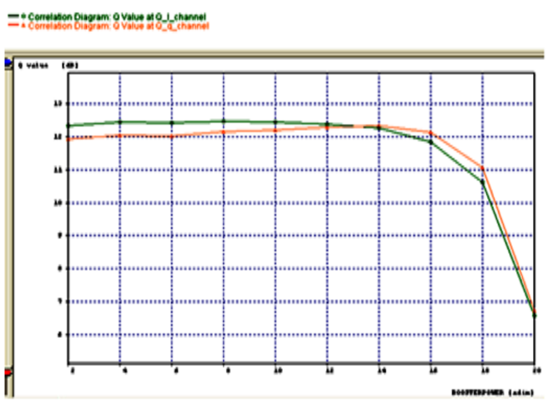


Fig 5.Q vs. Booster power transmission performance

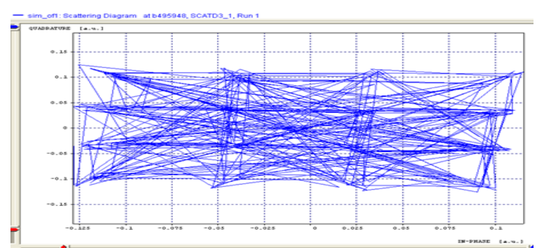


Fig.6At bit rate 10Gbps.Q vs. Length simulated OOFDM (baud rate2.5Gbaud/s, subcarrier16, CP0.990)

From the transmission results shown in figure 6 as constellation pattern for 10Gbps transmission with selected baud length of 2.5Gbaud/s it is noticed that constellation pattern is very denser means an erroneous transmission pattern.

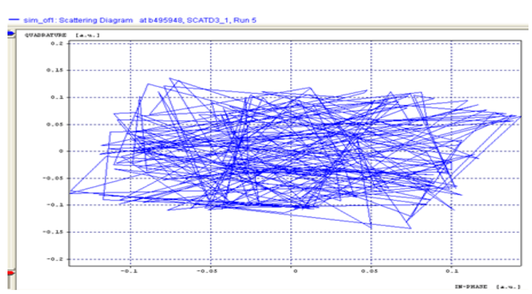
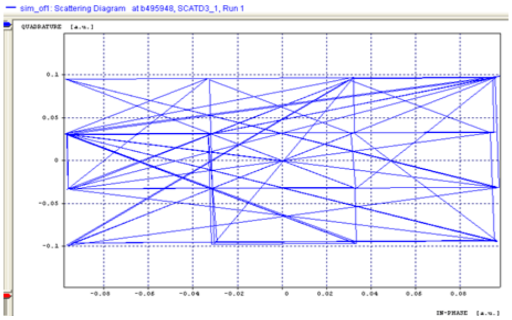


Fig.7At bit rate 40Gbps.Q vs. Length simulated OOFDM (baud rate2.5Gbaud/s, subcarrier16, CP0.990)

From the transmission results shown in figure 7 as constellation pattern for 40Gbps transmission with selected baud length of 2.5Gbaud/s it is noticed that constellation pattern is very denser means an erroneous transmission pattern. It can be concluded that constellation pattern is very poor means erroneous transmission performance and dependent upon baud rate selection.



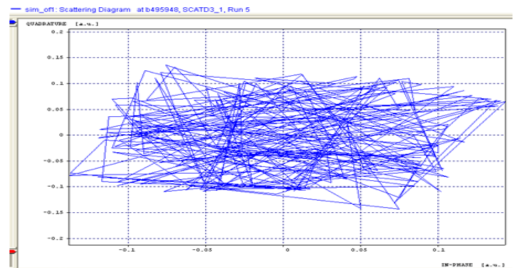


Fig.8At bit rate 40Gbps.Q vs. Length simulated **Fig.9 constellation pattern at bit rate 40Gbps.MQAM-OOFDM**

OOFDM (baud rate1Gbaud/s, subcarrier16, CP0.990)

From the transmission results shown in figure 5 as constellation pattern for 40Gbps transmission with selected baud length of 1Gbaud/s it is noticed that constellation pattern is very denser means an erroneous transmission pattern. It can be concluded that constellation pattern is better means transmission performance is very good.

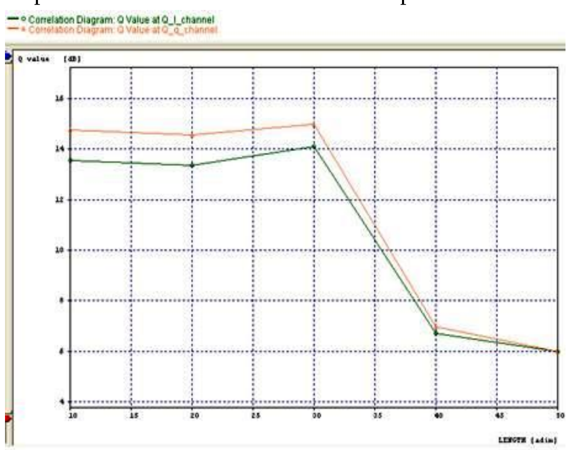


Figure10: Q vs length for OOFDM transmission

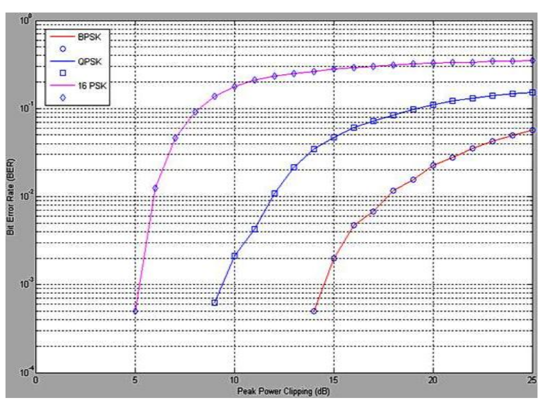


Figure10: BER vs. peak power clipping

Simulated results figure11 a comparative BER pattern with BPSK,QPSK,16BPSK for bit error rate vs. peak power clipping for OOFDM wave has been illustrated for different modulation schemes, it is noticed BER is lowest for BPSK.

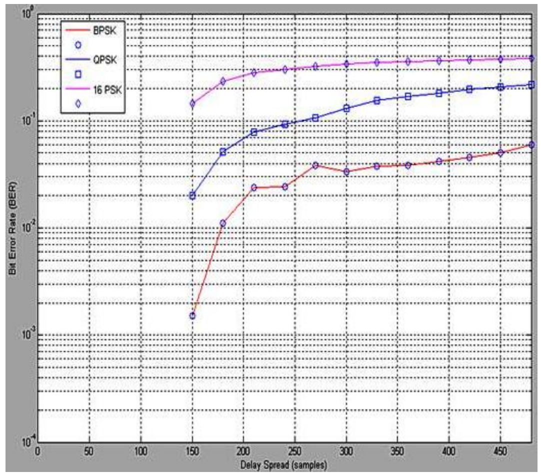


Figure11: BER vs. delay spread

Simulated results figure12 a comparative BER pattern with BPSK,QPSK,16BPSK for bit error rate vs. delay spread for OOFDM wave has been illustrated for different modulation schemes, it is noticed BER is lowest for BPSK.

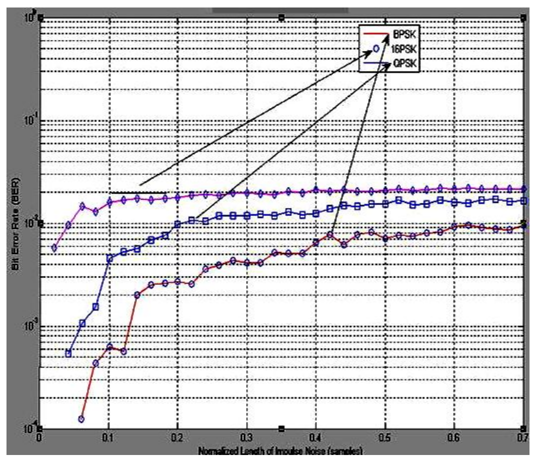


Figure12: BER vs. Impulse noise

Simulated results figure13 a comparative BER pattern with BPSK, QPSK, 16BPSK for bit error rate vs. impulse noise for OOFDM wave has been illustrated for different modulation schemes, it is noticed BER is lowest for BPSK. Consequently it can be concluded that transmission performance of OOFDM system is dependent upon number of transmission parameters like baud rate, booster power and modulation schemes used and peak power clipping. It is also concluded that better transmission performance achieved for BPSK modulation scheme, low baud rate. Results (figure10) plotted for Q vs. length plot illustrate that Quality factor which is one of significant transmission performance parameter degrades with increase in transmission length. The transmission performance with low baud rate transmission optical performance is good have shown better performance that is good constellation pattern but as the baud rate increases it has shown degrading effect on the constellation pattern of the OOFDM system at different bit rates. Transmission performance is affected with variation of baud rate, cyclic prefix and QAM size. For the performance analysis QAM size is also one of important parameter, usually determined by the noise tolerance of the transmission. By selecting a higher order format of QAM, the data rate of a link can be increased, QAM achieves greater distance between adjacent points in the I-Q plane by distributing the points more evenly and in this way the points on the constellation are more distinct and data errors are reduced. When noise becomes a problem lower QAM constellation can be selected order to reduce BER. The QAM size is selected by analyzing the transmission channel by the use of OOFDM training symbols. For fiber optic applications, usually low QAM constellations are selected due to several reasons one of them being noise tolerance. Simulated results show that the cyclic prefix determines the amount of tolerable multi path delay, or in fiber optic applications dispersion. The number of samples usually is determined by using OOFDM training symbols. The cyclic prefix increases the reliability of the OOFDM transmission however it is at the cost of data throughput. Cyclic prefix samples determine the amount of tolerable dispersion, or time delay in an OOFDM transmission. In it sidebands will be created due to the IM, and when chromatic dispersion is strong they will not be recombined properly at the receiver sideband thus they will cause nonlinear distortion. This modulation technique is therefore limited to low fiber distances and/or low data rates.

VI. CONCLUSION

Optical OFDM has been designed and its performance has been investigated for parameter optimization. Results exhibited that transmission performance is entirely dependent upon a proper optimized selection of booster power, baud rate, cyclic prefix, QAM size, and FFT size and modulation schemes. Further it has been noticed that booster power in the range of zero to 14 dB and BPSK modulation scheme show better transmission performance as compared to other modulation schemes (BPSK/QPSK/16BPSK) employed.

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REFERENCES

1. J.G. Proakis,M. Salehi.2005.Essentials of Communications Systems Engineering. Prentice Hall, New Jersey, 2005, Chapter 11.
2. T. Kurt, A. Yongacoglu, J. Y. Chouinard.2006.OFDM and externally modulated multi-mode fibers in radio over fiber systems.IEEEWC.5 (10):2669–2774.
3. X. Fernando.2006.Radio over fiber in multimedia access networks. International Conference on Access Networks, Athens,Greece, Sep.4-6.2006.
4. Djordjevic, I. B., Vasic, B.2006.Orthogonal frequency division multiplexing for high speed optical transmission.Optics Express.14 (9):3767–3775.
5. Lowery, A. J., Armstrong.2005.10 Gbit/s multimode fiber link using power efficient orthogonal frequency division multiplexing. Optics Express.3 (25):10003–10009.
6. Tang, J. M., Lane, P. M., Shore, K. A.2006.High speed transmission of adaptively modulated optical OFDM signals over multimode fibers using directly modulated DFB.Journal of Lightwave Technology. 24 (1):429–441.
7. G. P. Agrawal, Nonlinear Fiber Optics , San Diego : Academic Press, 2001,3rd ed.
8. B.J. Dixon, R.D. Pollard,S. Iezekeil.2001.Orthogonal frequency-division multiplexing in wireless communication systems with multimode fiber feeds.IEEE Trans. Microwave Theory and Techniques.49**:**1404-1409.
9. N.E. Jolley, H. Kee, R. Rickard, J. Tang, K. Cordina.2005.Generation and propagation of a 1550-nm 10Gbit/s optical orthogonal frequency division multiplexed signal over 1000 m of multimode fiber using a directly modulated DFB.In Tech. Digest of the Conference on Optical Fiber Communication (OSA).5:319-321.
10. O. González, R. Pérez-Jiménez, S. Rodríguez, J. Rabadán, A. Ayala.2005.OFDM over indoor wireless optical channel.IEE Proc. Optoelectron.152:199-204.
11. D. Chanda, A.B. Sesay,Bob Davis.2004.Performance of clipped OFDM signal in fiber. In Proceedings of the Canadian Conference on Electrical and Computer Engineering, IEEE.4:2401-2404.
12. Jean Armstrong.2009.OFDM for Optical Communications, Journal of Light wave Technology.27 (3):189-204.
13. Sander L. Jansen. Short Course OFC, 2010.SC341 OFDM for Optical Communications (Short Course OFC, 2010).
14. Jean Armstrong.2009.OFDM for Optical Communications. Journal of Light wave Technology.27.