DESIGN OF OPTICAL OFDM IN WIRELESS COMMUNICATION

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***Abstract* - Orthogonal Frequency Division Multiplexing (OFDM) is a modulation technique using multiple carriers. It mainly provides high spectral efficiency and the multiple carriers share the data among themselves. Its resiliency to RF interference and lower multi-path distortion makes it unique compared to other modulation techniques. One of the most famous networking technologies viz., Wireless Local Area Network (WLAN) is operating under the concept of OFDM modulation technique. OFDM is also applied in WiMAX, Digital Television Broadcasting (DVB), 4G and many more. Recently, Visible Light Communication using OFDM is on the research path. Peak-to-Average-Power Ratio (PAPR) is the major negative aspect of OFDM due to non-linearities of the power amplifier, and can be alleviated by clipping the OFDM peak signal. On the other hand, this limitation can be used as an advantage in optical OFDM to intensity modulate the Light Emitting Diodes (LEDs). The main aim of this paper is to design an optical OFDM communication system with PAPR reduction so as to show its enhanced performance when compared with conventional OFDM and HF OFDM communication systems.**

Keywords - OFDM, IFFT/FFT, PAPR, BER

I. INTRODUCTION

Although Orthogonal Frequency Division Multiplexing (OFDM) was invented in 1966 and patented in 1970, recently it is widely used in broadband wired and wireless communication systems. The main peculiarity of OFDM is its superior flexibility due to dynamic bandwidth allocation and adaptive bit rate functionalities. The high spectral efficiency and high tolerance to frequency selective fading, channel dispersion, and multi-path interference makes it unique compared to other communication systems. In order to shape the signal in the transmitter as well as to recover the data from the signal at receiver site, discrete IFFT/FFT is utilized in modern high-speed DSP based OFDM systems. Nowadays, OFDM technique is attracting a lot of interest in optical wireless communications due to its resilience to multi-path propagation induced Inter Symbol Interference (ISI), high spectral efficiency and immunity to fluorescent-light noise near the DC region. Peak-to-Average-Power Ratio (PAPR) being the serious limitation in OFDM can be alleviated in optical OFDM by clipping method and pilot-assisted method. The rest of the paper is arranged as follows: Section II deals with the design of optical OFDM communication system followed by the simulation results and concluding remarks in section III.

II. DESIGN OF OPTICAL OFDM SYSTEM

Fig. 1 shows the block diagram of an OFDM based optical wireless communication system. In this system, the input data is first converted to parallel form using a serial-to-parallel converter module to perform symbol mapping in M-level Quadrature Amplitude Modulation (QAM). The output from the mapper is X(k), where k = 0, 1, ... N_{sub} - 1 and N_{sub} is the number of data carrying tones/sub carriers.

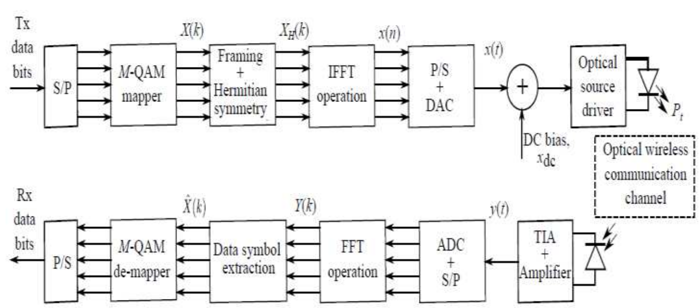

Fig. 1: Block diagram of optical OFDM communication system

In an optical OFDM communication system, the condition of satisfying only real values in time domain signal must be ensured, where the time-domain signal is used to modulate the intensity of the optical carrier. This condition is achieved by imposing Hermitian symmetry on X(k) prior to the IFFT operation as shown in fig. 1. The resulting signal $\boldsymbol{X}_H$ is represented as:

$$\boldsymbol{X}_H = 1, X(k), 0, 0, \ldots, 0, 0, 0, 0, \ldots\ldots, 0, X^*_{NL-k} \quad \ldots\ldots (1)$$

where N = 2(1 + N_{subc}) and X^* (.) denotes the complex conjugate of X(.) and zero padding is done to capture all the signal peaks. The frequency domain signal is given in equation (1) which contains N(L – 1) padding zeros to account for an L – times oversampling in the time domain signal. Using N L-point IFFT block, $\boldsymbol{X}_H$ is then modulated onto the subcarriers whose output is the L-times oversampled time domain signal x(n) and can be defined as:

$$x(n) = \frac{1}{\sqrt{NL}} \sum_{m=0}^{NL-1} X_H(m)\, exp\left[\frac{j2\pi nm}{NL}\right] ; \; 0 \le n \le NL - 1 \quad \text{.......(2)}$$

Cyclic prefix (CP) is generally added in OFDM signal to eliminate Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI), however, since it has a negligible effect on electrical signal-to-noise ratio (SNR) and spectral efficiency in optical OFDM, CP is not added in the proposed design. As continuous time domain signal x(t) is used to modulate the intensity of the optical source, the discrete signal x(n) is feeded to a digital-to-analogue converter (DAC).

At the receiver, the incoming optical radiation is converted into an electrical signal by the PIN photodetector. The transimpedance amplifier (TIA) converts the resultant current signal into a voltage signal, followed by a post detection amplifier which boosts the signal for digital conversion using analogue-to-digital converter (ADC). The received signal is translated into its frequency domain equivalent by an FFT operation. The data symbol extraction block shown in fig. 1 removes the conjugate symbols and the padding zeros introduced at the transmitter. The estimates of the transmitted data are obtained by an M-QAM demapping operation and since the received data should be in serial form, it is converted to serial by parallel to serial converter module.

A. Peak-to-Average-Power Ratio (PAPR) Reduction

PAPR is caused due to large number of sub-carriers present at the IFFT output of transmitter section. By adding an FFT block prior to IFFT at the transmitter, both being reverse operations, get cancelled out thereby reduces the number of sub-carriers and hence PAPR. However, this is applicable only for single carrier (SC) OFDM. There are several methods to reduce PAPR in an optical OFDM such as distortion technique, coding technique and scrambling technique. The coding technique uses a special forward error correction code set that excludes OFDM symbols with a large PAPR. The third technique scrambles each OFDM symbol with different scrambling sequences and selecting the sequence that gives the smallest PAPR. The designed optical OFDM uses distortion technique for PAPR reduction, i.e., when PAPR is larger than a fixed threshold, the signal peak will be clipped.

A parameter termed as error vector magnitude (EVM) is used to express the caused distortion due to clipping method. That is,

$$EVM_i = \frac{\sqrt{\frac{1}{N}\sum_{k=0}^{N-1} |X'_{i,k} - X_{i,k}|^2}}{|X_{i,k}^{max}|} \quad \text{........(3)}$$

where $X'_{i,k}$ is the measured data constellation point relative to the reference constellation point $X_{i,k}$ and the maximum constellation amplitude is represented by $X_{max}^{i,k}$. The distribution of 8PSK constellation point after the clipping operation is shown in fig. 2 which tells us the fact that there is no obvious effects on the constellation by clipping the peak signal.

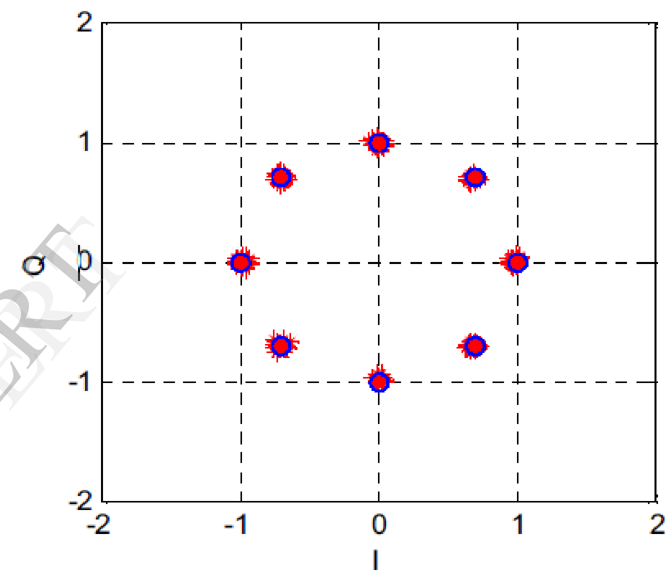

Fig. 2: 8PSK constellation distribution after the clipping operation

Although the above method alleviates PAPR, the clipping operation distorts the signal leading to a decreased error performance of the designed system. When we go for pilot-assisted PAPR reduction technique, bit error rate (BER) will be less compared to optical OFDM using clipping operation. The comparison of BER performance of clipped optical OFDM with pilot assisted optical OFDM is shown in figure 3.

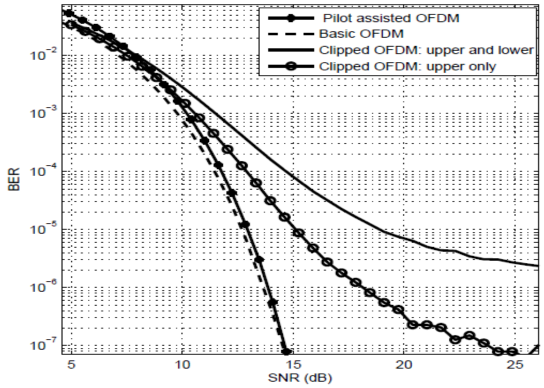

Fig. 3: Comparison of BER performance of clipped optical OFDM with pilot-assisted optical OFDM, showing enhanced performance in BER c

III. CONCLUSION

An optical OFDM communication system is designed with effective PAPR reduction. The simulation results show that PAPR reduction technique using pilot assisted method is more effective compared to clipping method for optical OFDM. This optical OFDM design leads to the major parameter for visible light communication which is on the research path.

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