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A Novel PAPR Reduction in Filter Bank Multi-Carrier (FBMC) with Offset Quadrature Amplitude Modulation (OQAM) Based VLC Systems

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Abstract— The peak to average power ratio (PAPR) is one of the major problem with multicarrier-based systems. Due to its improved spectral efficiency and decreased PAPR, Filter Bank Multicarrier (FBMC) has recently become an effective alternative to the orthogonal multiplexing division (OFDM). For filter bank multicarrier communication/offset quadrature amplitude modulation-Visible light communication (FBMC/OQAM-VLC) systems is proposed a PAPR reduction technique. The suggested approach overlaps the proposed FBMC/OQAM-based VLC data signal with the existing signals. Non-redundant signals and data signals do not overlap in the frequency domain because data signals are scattered on odd subcarriers whereas built signals use even subcarriers. To reduce the effects of large-amplitude signal reduction, the suggested technique converts negative signals into positive signals rather than clipping them off as in conventional FBMC-based VLC systems. The PAPR reduction and bit error rate (BER) are realized using a scaling factor in the transformed signals. Complementary cumulative distribution function(CCDF) and BER are used to calculate the performance of the proposed approach. The presented study found that FBMC/OQAM-VLC systems to achieve a good trade-off between PAPR reduction and BER.

Keywords- FMBC; OQAM; PAPR; CCDF; BER; VLC, spectral efficiency.

I. INTRODUCTION

The subcarriers in a multicarrier transmission are not dependent on time domain, because the subcarriers can align to produce either a positive or negative combination, their combined output has a high range. Peak to average power ratios(PAPRs) are used to quantify the significant variation in signal power [1]. For the upcoming wireless communication system (5G), Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation System (FBMC/OQAM) is one of many new waveforms that have been proposed. The FBMC system is a multicarrier modulation scheme that takes advantage of the low out-of-band(OoB) interference, improved shape, increased frequency efficiency, and relaxed orthogonal properties of FBMC/OQAM techniques. In accordance with real-world channel environments, it can use a variety of filters with various characters [2]. Therefore, the FBMC/OQAM systems have improved side-lobe qualities by design and can operate more effectively in settings with wider frequency dispersion. Like all multicarrier systems, FBMC has a high PAPR. A high PAPR drastically affects the High Power Amplifiers efficiency if it is forced towards saturation, which might result in signal clipping. OoB interference and in-band interference both have a detrimental effect on the system's bit error rate (BER). There are well-known OQAM-PAPR reduction techniques that can significantly reduce PAPR at almost no BER deterioration [3]. However, due to the inherent denoted overlap in FBMC systems, these techniques must be extended to FBMC schemes.

Visible Light Communication(VLC) has gained a lot of interest in contrast to conventional wireless radio communications are supported. Due to their minimal influence on electrical devices, VLC systems can also be employed in medical institutions, aviation, and spacecraft [4]. Multicarrier systems have received a lot of interest recently because of their capacity to address frequency-selective fading issues at high data rates. A cyclic prefix (CP) and the right amount of space between subcarriers are needed for the multicarrier modulation technique known as OQAM, which guarantees the offset of waveforms modulated by different data symbols. Moreover, VLC systems lack a spectrum mask in opposed to radio communication systems. OQAM is employed in VLC systems to speed up transmission and the radio signal/VLC signal as a result differ greatly [5].

II. RELATED WORKS

An Active Constellation Extension (ACE) clipping technique was presented by Sandeep Kumar et al. [6] as a lossless, straightforward, and appealing PAPR reduction method. Therefore, that the minimal PAPR cannot be attained whenever the desired clipping value is applied under an unknown parameter. To overcome the minimal a cutting factor issue, a new ACE method with dynamic cutting reduction is suggested. The size of clipping level "A" is first controlled using an adaptive strategy. In order to speed up convergence, iterative computations are completed using a novel step factor that takes potential overlap into account. According to the simulation results, the updated technique greatly speed up convergence and reduced PAPR without requiring any more processing or side information at the receiver end.

In order to generate the peak canceling signal, Sundru et al. The regression significance of the regression model is used in the Overlapping Scaling Tone Reservation (OSTR) approach while taking into consideration the possibility of subsequent term differences. Controlled Clipping Tone Reservation (CTR) and the Multi Block-Tone Reservation (MBTR) technique, which are already being employed in the system directly, can perform even worse than the suggested method for the OFDM/OQAM system, according to simulation data [7]. To improve the Several portable Intermediate-Frequency over Fiber (IoF) front hauls for PAPR reduction, Da Chen et al. proposed an approach called Peak Shrinking and Interpolating. It essential to identify the signal are increases rapidly and reduce them, after which the interpolated peak values from the reduced signal are used to lower the PAPR. In relation of the PAPR reduction and simulation time, it relates the PSI method to the earlier TR and PPD techniques. With a PAPR reduction of more than 4.3 dB at 0.1% CCDF, the experiments demonstrate that the PSI scheme performs better than the two preceding systems with reduced computational complexity [8].

For the purpose of reducing PAPR in ACO OFDM systems, Ling Cheng et al. Low complexity hybrid selective mapping (LCHSLM), a novel hybrid technique that combines companding and modified selective mapping (SLM) is proposed. Computer models demonstrate to the conventional SLM or compounding alone, the proposed approach dramatically lowers the PAPR. Additionally, compared to conventional SLM and without BER degradation, LCHSLM significantly reduces complexity [9]. H Merah et al. offer a unique partial transmit sequence-based technique (N-PTS). It is necessary to overcome the main challenge of a high PAPR as well as the issue of overlapping structure that affects FBMC/OQAM. The complexity of computation is also decreased in that regard. Use of a frequency-domain FBMC/OQAM signal is the proposed method. To accomplish this, the data from a storage device is used to find the lowest PAPR value. Last but not least, it is significant to remember that SI asserts that its BER performance is still excellent even when utilizing the phase offset with Minimum Euclidian Distance (MED) requirement, necessitating no more bits to be communicated [10].

Yue Zhang et al. using a new discrete Fourier transform(DFT) technique to lower the PAPR for FBMC/OQAM frameworks. The connection between DFT and the concept of frame recurrence is the crucial concept. In contrast to the conventional DFT in PAPR analysis technique, the suggested DFT in PAPR suggested technique does not separate or transmit the real and imaginary components of the output. Instead, it sends the DFT module's output complex-valued signal. Without sacrificing time cost, transmission loss or lateral signals, the offered method can tackle the low PAPR problem. Outcome are presented to the respect for CCDF and BER to demonstrate the effectiveness of the suggested approach [11].

Djamel Abed et al. proposed a discrete sliding norm transform depending on the L2-metric as well as the average of samples at every moving action after an inverse discrete Fourier transform. In suggested L2-by-5 DSNT formulation, the FBMC-overlapping OQAM's structure is taken into account. In FBMC/OQAM systems, it can significantly lower the PAPR, preventing signal distortion and ensuring progressive enhancement at the HPA. This technique's main benefits are that it has a lower computational complexity than other techniques and doesn't require Side Information at the receiver [12]. The PAPR reduction strategy proposed by Fathi Tarik et al. combines TR & compounding law approaches for FBMC/OQAM-VLC. The experimental outcomes show that the new suggested methodology beats the TR and μ-law preceding approaches when taken independently in respect of PAPR reduction[13].

The FBMC/OQAM system, Jeong-Ho Kim et al. provide a two-step approach to addressing the problem of high PAPR. Depending on the outcome of the previous step, every input structure PAPR is reduced and every segment is improved. The unique process includes less permutations of stage parameters than conventional sequence model strategies, which reduces algorithm complexity while maintaining PAPR reduction. Additionally, BERs were evaluated dependent on the degree of density and compressed sensing is employed to recover sparse clipping signals. Additionally, numerical simulations were used to evaluate the PAPR reductions. The simulation outcomes support the claim that the suggested method successfully lowers the FBMC/OQAM system has large extremes [14] G. Gonzalez et al. The FBMC SGP-ACE technique and an advancement of the smart-gradient project active constellation extension (SGP-ACE) PAPR reduction method used in OFDM systems, it suggested as a novel approach. By applying it to a collection of nearby FBMC symbols, the suggested technique corrects to FBMC modulation's repetitive structure. The suggested technique greatly decreases complexity compared to existing FBMC PAPR reduction strategies which usually need the addition of complex signal processing and converges to a lower PAPR with fewer changes as a projection onto-convex-sets ACE method. The proposed FBMC SGP-ACE approach surpasses the established FBMC POCS-ACE method in terms of PAPR reduction by 2.6dB [15].

A hybrid scheme is investigated by FatmaNewagy et al. to reduce PAPR in FBMC systems by combining the preceding transform technique and μ-Law Companding technique. Additionally, the best Preceding technique that can be used with μ-law commanding is determined by examining the four preceding techniques. The discrete Hartley transform was evaluated (DHT). The Walsh Hadamard transform (WHT), discrete cosine transform (DCT) and discrete sine transform (DST) is used μ-law. The numerical results show that the FBMC systems with μ-law commanding and all preceding techniques combined can significantly improve the PAPR performance it includes DST Preceding and μ- law for both PAPR and BER performance [16].

HongbingQiu et al. presented in order to prevent inter-symbol interference (ISI) and inter-carrier interference (ICI), FBMC technology uses orthogonal frequency division multiplexing/offset quadrature amplitude modulation (OFDM/OQAM). Since positive signals are required for light-emitting diode (LED) modulation, current bias to the OFDM/OQAM signal to make it positive. The simulated study found that compared to DC biased CP optical OFDM, DC biased optical OFDM/OQAM has a greater power to overcome the optical transmission dispersion path underground (DCO-CP-OFDM). Even though, the M-OSLM algorithm significantly enhances the performance of PAPR reduction. At the same BER and SNR is 3 dB better than DCO-CP-OFDM [17]. Pretreated PTS, proposed by Zhang Peng et al., an effective P-PTS. The phase rotation sequences for the current symbol are determined and optimized in accordance with previous overlapped symbols in the first step, which employs a multiple overlapping symbols joint optimization scheme. Additionally, it uses a novel segment PAPR reduction scheme based on PTS technique in the second step. According to simulation results, The suggested P-PTS approach requires less cost and can reduce PAPR more effectively than methodologies, it also allows for more flexible trade-offs between complexity and PAPR reduction performance [18].

Nakamura et al. compressed double-sided signals there at receiver front-end. Two systems' time domain signals are pre-clipped at various bottom levels. The signal is pre-clipped at zero or a positive bottom level because ACO-OFDM only allows for non-negative values when calculating clipping levels. On the other hand, because DCO-OFDM allows for either positive or negative clipping levels. The receiver's must be estimated using the conventional method due to the bias value. Additionally, it has a lower power efficiency and a lower range between each OFDM symbol [19–20].

In order to reduce PAPR without transmitting side information, Ahmed K. Abed et al. suggested inserting dummy sub-carriers based on Particle Swarm Optimization (PSO) into the data. When the combined signal strength of this time series and the fake PAPR component is less than a fixed value, the PSO fake process determines to transmit the data. According to the simulation results, the PSO-based dummy sequence reduces PAPR to 3 dB when compared to the clipping technique and when relative to an ordinary Modulation scheme at 4 dB for the same BER performance [21]. YonghongHou et al. propose a novel superimposed O-OFDM scheme that lowers the PAPR by combining the superposition modulation and the μ-law mapping. Additionally, at the transmitter, the combination O-OFDM elements are placed in an influence manner, this eliminates the requirement for interference cancellation at the receiver and enables the demodulation of the symbols for each branch separately. The PAPR can be significantly reduced by the proposed scheme, according to simulation results. Although the nonlinearity and confined dynamic range of LEDs place some restrictions on the proposed approach, it nevertheless outperforms other competing schemes overall [22].

The intensity modulated passive optical networks with direct detection and both direct and external modulation techniques by Liam P. Barry et al. Here, data rates range from 8.4 to 14.8 GB/s and propagation lengths range from 0 to 75 km. According to the results, utilizing FBMC, it is possible to transmit SSMF up to 75 km over passive connections using affordable intensity modulation and detection techniques [23] Farabi M. Iqbal et al. For the UFMC and FBMC-OQAM system, a wavelength translation method utilizing a transistor light accelerator is proposed. Additionally, for a wavelength conversion application, it evaluate and contrast their BER and error vector magnitude (EVM) performance. According to the study results, BER and EVM are at their best when the injection current (IC) is between 0.7A and 0.9A. The PAPR is also utilized by the frequency relay using the FBMC and UFMC techniques[24].

Jingting Xiao et al. to determine the optimal pitch rotational parameters, it provide a Continuous-Unconstrained PSO-PTS method. The optimal solutions aspect parameter can be found using a constant PTS technique and the theoretical bounds are contained in the continuous-unconstrained searching space. The similar uncontrolled PTS algorithm can significantly speed up resolution and lower overall computation costs, once the aspect values obtained are in the linear system [25]. GhislaineMaury et al. suggested an optical wireless communication (OWC) systems. Because of its high PAPR, conventional O-OFDM has a high power consumption problem. By avoiding thresholding loss, the suggested linear decision approaches perform at transmitter and recover deleted data. Clipping can significantly lower the high PAPR of O-OFDM's, and the suggested methods can effectively avoid clipping distortions [26].

Problem Statement:

A lot of interest has been given to multi-carrier modulations because of increased transmission range. Even, the major issue of large PAPR is caused by the combination from every subcarrier output. Most typical PAPR reduction strategies are ineffective for the FBMC system because simultaneous IF channel multiplexing will cause maximum amplification and a greater PAPR. The asymmetric compression that is caused by optical devices and optical transmission cables is much susceptible to affect input signal. In order to solve this issue, significant efforts have been made. The FBMC-OQAM signal is influenced in the high amplifier's nonlinear region. Additionally, this results in BER degradation, which considers for an expensive with a broad dynamic range.

Contribution of the Paper:

- In general, it used normalized analysis together with FBMC-VLC and IM/DD broadcast.
- It found for using OQAM significantly increased BER performance in FBMC system. The method of the proposed FBMC/OQAM-VLC in PAPR reduction.
- When completely review the transceiver design concepts and compare to given VLC-OQAM schemes. The outcomes are validated through simulations.

The organization of this paper is presented. Section 2 discusses the relevant literature. Section 3 includes a description of the proposed scheme as well as a computational complexity analysis. The simulation results are presented in Section 4, and conclusions are presented in Section 5.

III. PROPOSED PAPR REDUCTION FOR FBMC/OQAM BASED VLC SYSTEM

A. *QAM-VLC Framework Model*

The IFFT was taken after the QAM-VLC are reference signal phase. It was common practice to require on the IFFT signal after QAM modulation that produced the desired result and required for twice as many IFFT/FFT in the transceiver (see Fig.1). Hermitian symmetry's (HS's) computational complexity requires a larger chip with a greater power requirement.

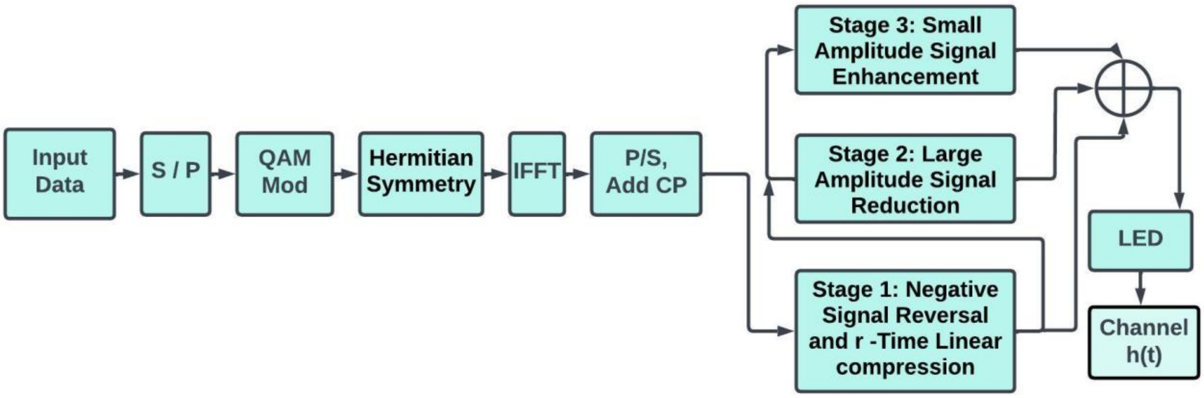

Figure 1(a). Block diagram of QAM-VLC Transmitter

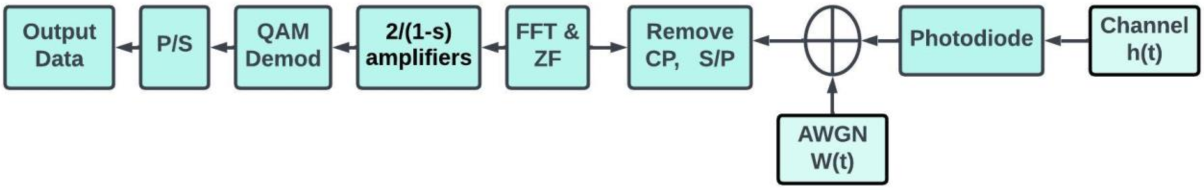

Figure 1(b). Block diagram of QAM-VLC Receiver

A scaling factor is used to compress the translated signals and lowers the high PAPR. Due to the use of odd subcarriers in the useable data transfers, interference between transmit of frequency domain is avoided. The suggested non-redundant three stage PAPR minimization approach has a good performance in PAPR, in order to lessen the effects of upper and lower LEDs clipping, superimposed three stage signals will relax the limited range of LED linearity. The suggested method is also spectrum-efficient since no pilot or side information is required. A CP is introduced following IFFT to reduce the impact of ISI. The produced QAM can be represented as follows in the discrete-time domain:

$$x(n)=\sum_{l=0}^{M-1} X(k)e^{\frac{j2\Pi \ln}{M}} \tag{1}$$

Here X(k) is the term of QAM data symbol, the length of IFFT is M and sub-carrier index is *l*.

B. FBMC Based VLC System Model

Fig.2 shows the FBMC-VLC method. Each QAM symbol has to be divided into real and imaginary parts, after being modulated with QAM and loaded with an IFFT subcarrier. For each OQAM-FBMC symbol, an up-sampling of K times should be carried out, where K is the FBMC overlapping factor. A pulse-shaping filter was used to filter each OQAM-FBMC symbol. OQAM-FBMC time domain symbols were overlapped and added together at N/2 intervals. The PAPR minimization transmitted signal of the FBMC/OQAM based VLC system can be established using a non-redundant three stage approach.

The first step is to evaluate the performance of a synthesis filter bank (SFB), which may be accomplished by applying HS before to the SFB. Odd subcarrier signals satisfy X(k)= X*(M-k) property and even subcarrier transmitter achieve HS in X(0)=X(2)=X(3)=...=0. The FBMC-VLC are spectrum confinement performance is significantly greater than the OQAM-VLC and rises with K value. The time-domain FBMC-based VLC signal can be defined as:

$$x(n)=\sum_{l=-\infty}^{\infty}\sum_{k=0}^{M-1} A(l,k)\,h\left(n-\frac{lM}{2}\right).e^{\frac{j2\Pi l\left(n-\frac{f_p-1}{2}\right)}{M}}e^{j\varphi_{l,k}} \tag{2}$$

Where n = 0 to f_p-1and length of prototype filter is $f_p=lk-1$.

OQAM-VLC methods is equivalent to the traditional equivalents while the symbol rates are doubled. In addition, when K is given as the FBMC characteristics, the FBMC-VLC methods are performance of spectral reduction is significantly higher than OQAM-based VLC with increasing K values. The synthesis filter bank $f_K(n)$ can be obtained from

$$f_k(n)=h_p(n)\operatorname{Cos}\left[\frac{\Pi\left(k-\frac{1}{2}\right)\left(n+\frac{K+1}{2}\right)}{K}\right] \tag{3}$$

$$H(0)=1,\quad H\left(\frac{1}{f_p}\right)=0.98170,$$
$$H\left(\frac{2}{f_p}\right)=0.7072,\quad H\left(\frac{3}{f_p}\right)=0.2452,$$
$$H\left(\frac{i}{f_p}\right)=0;\ 4\le i\le f_p \tag{4}$$

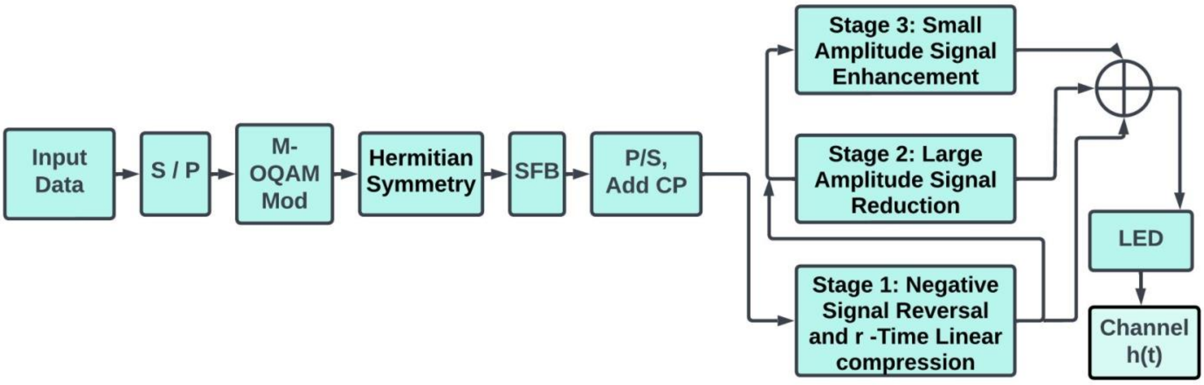

Figure 2(a): Block diagram of FBMC-VLC Transmitter in PAPR reduction method

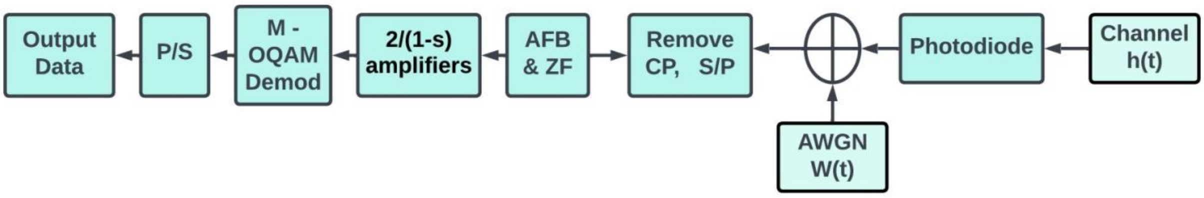

Figure 2(b): Block diagram of FBMC-VLC Receiver in PAPR reduction method

At the receiver, a signal was used to measure the intensity of light using photodiode and the bipolar signal is transferred to an analysis filter bank(AFB). The transmitted signal fits the LED's flexible area as follows:

$$x(n)=\begin{cases} A_{upper}; & A_{upper}<x(n) \\ x(n); & A_{lower}\le x(n)\le A_{upper} \\ A_{lower}; & A_{bottom}\ge x(n) \end{cases} \tag{5}$$

In comparison to a typical standard deviation, the normalized upper and lower ratios are A_{upper} and A_{lower}, respectively.

C. PAPR Reduction for Proposed FBMC/OQAM-VLC System

The negative signals in the initial stage are deleted before transmission, so which lowers the BER performance. Large amplitude next stage signals, which are meant to reduce the proposed FBMC/OQAM-VLC signal and produce the initial state of the signals. Due to the second stage signal are symmetrical qualities, the large-amplitude signals are symmetrical location is reduced by an equal amount. The result of BER is decreased by selecting the corresponding negative signals again and before to transmission. The negative regions of proposed FBMC/OQAM-VLC transmissions are transformed into positive regions instead of getting cut off with 0 as in traditional proposed method signals to reduce the effects of significant signal reductions from the 2nd stage signals. The transmission signal intensity on odd subcarriers must be reduced for negative signals and linear compression is necessary to lessen the effect.

$$x_1(n)=\begin{cases} x(n); & x(n)\ge 0 \\ s\left|x(n)\right|; & x(n)<0 \end{cases} \tag{6}$$

Where scaling component is s ($0 \le s \le s_{max}$); s_{max} given as max. value of s.

In the second stage, we design a signal to lower high amplitude on the proposed signal. The second stage to avoid interfering with the initial stage are relevant data. In the second stage, the developed signal has the symmetry condition, is given by

$$x_2(n)=x_2(n^*) \tag{7}$$

In the second stage $x_2(n)$ and $x_2(n^*)$ have the same value; let n* be the symmetry in time index. When a high transmission is turned off at the cutoff using Eq. 6, which takes into consideration two examples relating to the large and low regions of LED, the symmetric output need not be decreased to be negative. The clipping cutoff point is expressed as:

$$C_2=(1-s)\,x_1\left(n_p\right) \tag{8}$$

Here n_p is peak signal in time index. The composition of first and second stage signal is given by

$$x_1(n)+x_2(n)=\begin{cases} C_2; & x(n)>C_2 \\ (1-s)\left[x_1\left(n_p\right)-x_1(n^*)\right]; & x_1(n^*)<C_2 \\ x_1(n); & otherwise \end{cases} \qquad (9)$$

The last-stage signals are null on odd subcarriers $x_3(1)=x_3(3)=x_3(5)=....=0$, whereas the initial-stage amplitude of proposed FBMC/OQAM-VLC signals is increased on even subcarriers, which satisfies the Hermitian symmetry. Let $x_3(k)$ is the k^th^ subcarrier's last-stage signal. As a result, the symmetric signal's superposition to the enhancement is smaller than C_3 as

$$\left(C_3-x_1(n)\right)+x_1(n^*)<C_3 \qquad (10)$$

The design of last-stage signal is given by

$$x_3(n)=x_3(n^*)=\begin{cases} C_3-x_1(n); & 0<x(n)<C_3 \\ 0; & otherwise \end{cases} \qquad (11)$$

The composition of first and third stage signals is given by

$$x_1(n)+x_3(n)=\begin{cases} C_3; & 0<x(n)<C_3 \\ C_3-x_1(n^*)+x_1(n); & 0<x(n^*)<C_3 \\ x_1(n); & otherwise \end{cases} \qquad (12)$$

Finally, the resultant output x_R of the three stage signals is

$$x_R(n)=x_1(n)+x_2(n)+x_3(n) \qquad (13)$$

Algorithm for the proposed three stage PAPR minimization for FBMC-OQAM based VLC system

```
Data is being input at this first stage.
Stage 1: Linear reduction and negative signal reversal.
    • Time-domain signal in the proposed FBMC/OQAM - VLC after IFFT: $x(n)$
    • Linear reduction and negative signal reversal:
    • If $x(n) < 0$
        then $x_1(n) = s|x(n)|$
        else $x_1(n) = x(n)$;
        Stop
Stage 2: Reducing signal amplitude transmission in second stage
    • There are two requirements for 2nd stage:
        $x_2(n) = x_2(n^*)$, and $x_2(n) < 0$, $x_2(n^*) < 0$.
    • The initial stages are choosing of the peak signal as:
        $\left[x_1(n_p), n_p\right] = \arg\max_{0\le n^*\le M-1}\left(x_1(n^*)\right)$
    • The clipping cutoff point is $C_2=(1-s)\,x_1\left(n_p\right)$
    • The design of 2nd stage signal is
    • When $x_1(n) > C_2$
        then $x_2(n)$ equals $C_2 - x_1(n)$ and $x_2(n^*)$ equals $x_2(n)$;
        else $x_2(n) = 0$ and $x_2(n^*) = 0$;
        stop.
Stage 3: Final stage for improving small-amplitude signals.
    • There are two requirements for 3rd stage:
        $x_3(n)$ equals $x_3(n^*)$, and $x_3(n) > 0$, $x_3(n^*) > 0$.
    • Two constraints are: $0<C_3<A_{upper}$ and $C_3<C_2$
    • The design of 3rd stage signal is
    • when $x_1(n) > 0$ and $x_1(n) < C_3$,
        then $x_3(n)$ equals $C_3 - x_1(n)$ and $x_3(n) = x_3(n)$;
        else $x_3(n) = 0$ and $x_3(n^*) = 0$
        stop .

Result: $x_R(n) = x_1(n) + x_2(n) + x_3(n)$.
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The PAPR reduction of the final signal is

$$PAPR_{dB}=10\log_{10}\left(\frac{\max\limits_{0\le n\le N-1}\left|x_R(n)\right|^2}{E\left[\left|x_R(n)\right|^2\right]}\right) \qquad (14)$$

It has been demonstrated that a large scaling factor value significantly lowers the PAPR. In order to eliminate interference with the usable data on odd subcarriers, it is demonstrated that the second and final stage signals are symmetrical. It was determined that the greatest tradeoff between efficiency and computational complexity should be oversampling factor is 4.

The spectral efficiency (SE) of FBMC/OQAM-VLC is given by

$$SE=\frac{Usable\ Bandwidth}{Total\ Bandwidth} \qquad (15)$$

$$SE=rb\left(1-BER\right)\eta_T\eta_F \qquad (16)$$

Where the channel coding rate is *r*, the number of bits/subcarrier are $b = log_2(M)$ and the time and frequency efficiency is $\eta_T\eta_F$.

$$\eta_T=\frac{\text{length of transmitted information}}{\text{length of }\left(\text{transmitted tail+transmitted information}\right)}$$

$$\eta_F=\frac{\text{subcarriers carrying data}}{\text{total no. of subcarriers in the bandwidth}}$$

IV. EXPERIMENTAL RESULTS

To evaluate the effectiveness of the CCDF and BER, the experimental results are explained in this section. For OQAM, a CP of length lcp = 16 was used to accomplish the overlapping factor K = 4. Scaling factor values fall between 0 and 0.5. Implementing FBMC will reduce complexity and high PAPR issues while increasing spectrum efficiency. Table 1 is used to determine the simulation parameters.

Table 1: System Simulation Parameter

Parameters	**Values**
FFT Length	1024
No.of subcarriers	128
Modulation scheme	4,16,64,64,256-QAM, OQAM
Filter function	IOTA
Channel	AWGN
Scaling factor S	0.3
Boundary limit C3	0.6
No. of data block	10^{-3}
CP of length lcp	64
Overlapping factor K	4

A. Performance of PAPR Minimization

The CCDF performance of M-IFoF-VLC, OFDM-VLC, FBMC-VLC, SLM-MFOA and Proposed FBMC/OQAM-VLC are shown in Table 2.

Table 2: CCDF in PAPR reduction scheme

Scheme	**PAPR dB**
M-IFoF based VLC	9.8
OFDM in VLC	8
FBMC in VLC	6.4
DCT based VLC	5.9
SLM-MFOA	5.1
Proposed FBMC/OQAM in VLC	4.1

The PAPR reduction in CCDF performance for Proposed FBMC/OQAM-VLC systems are shown in Fig.3. The Proposed FBMC/OQAM-VLC system was obtained by 4.1 dB. It is demonstrated that the suggested PAPR reduction technique offers CCDF performance has M-IFoF based VLC technique achieved by 9.8 dB. For OFDM-VLC, FBMC-VLC, DCT-VLC, SLM-MFOA and Proposed FBMC/OQAM-VLC was obtained by 8, 6.4, 5.9, 5.1 and 4.2 dB respectively.

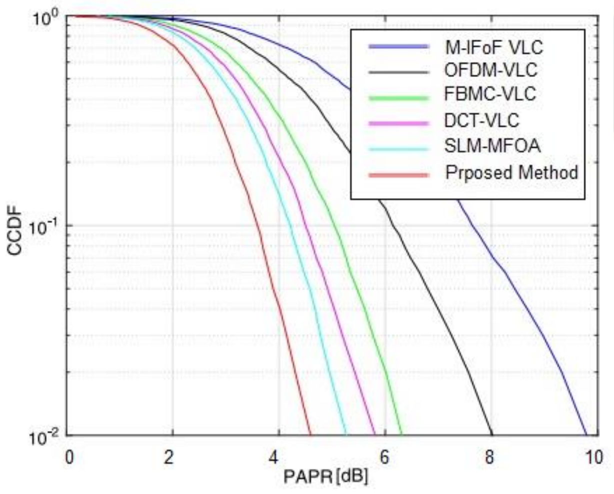

Figure 3: CCDF - PAPR Performance

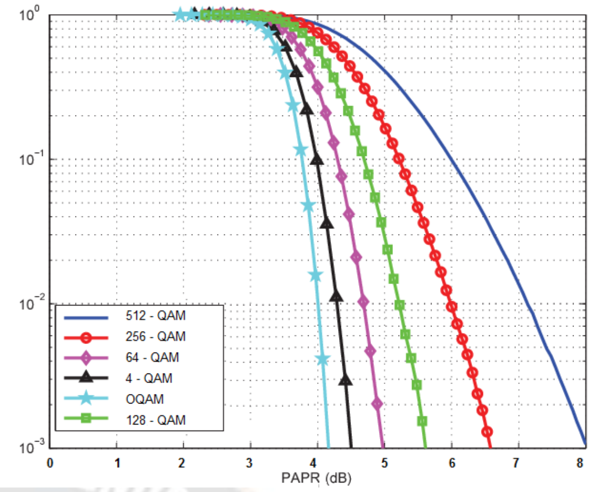

Figure 4: PAPR analysis at different QAM orders

Table 3: PAPR at different QAM orders

QAM order		At CCDF =		
		10^{-1}	10^{-2}	10^{-3}
OQAM	PAPR (dB)	3.8	4	4.1
4 - QAM		4	4.2	4.5
16 - QAM		4.3	4.7	5
64 - QAM		4.8	5.3	5.7
256 - QAM		5.2	6	6.8
512 - QAM		6	7.1	8.1

B. Performance of BER

The BER performance for FBMC/OQAM-VLC system is shown in Figure 5. When compared to traditional FBMC-based VLC, the suggested PAPR reduction technique offers higher BER performance. The proposed FBMC/OQAM-VLC transmissions without PAPR reduction approach, causing signal distortion. Signals that are outside the linearity of an LED are clipped and cannot be transmitted via an LED. The proposed method provides better BER performance, in comparison to traditional M-IFoF based VLC, OFDM-VLC, traditional FBMC-VLC, DCT-VLC and SLM-MFOA respectively.

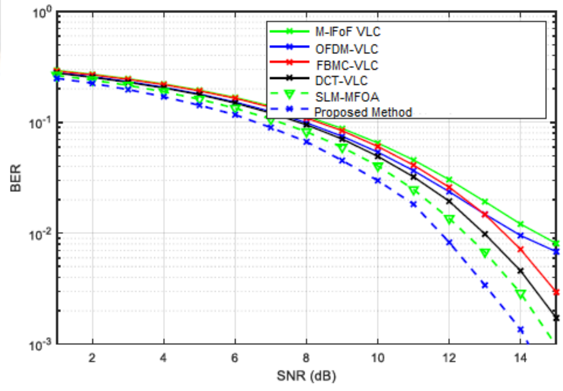

Figure 5: BER Performance

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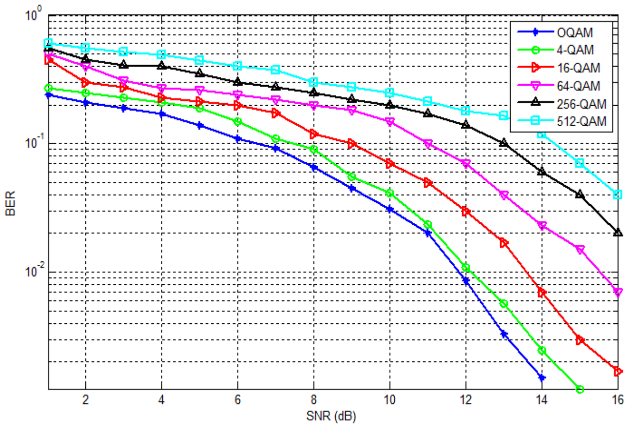

Figure 6 : BER vs SNR at different QAM orders

Table 4. BER performance at different QAM orders

QAM order		At Signal to Noise Ratio =		
		5dB	10dB	15dB
OQAM	BER	1.15×10^{-1}	3×10^{-2}	
4 - QAM		1.18×10^{-1}	4.1×10^{-2}	1×10^{-3}
16 - QAM		2.16×10^{-1}	6.9×10^{-2}	3×10^{-3}
64 - QAM		2.56×10^{-1}	1.16×10^{-1}	1.14×10^{-2}
256 - QAM		3.5×10^{-1}	2×10^{-1}	4×10^{-2}
512 - QAM		4.6×10^{-1}	2.45×10^{-1}	7.1×10^{-2}

C. Effect of Scaling Factors

The effect of scaling factor for the PAPR analysis of the M-IFoF-VLC, OFDM-VLC, FBMC-VLC, DCT-VLC, SLM-MFOA and Proposed FBMC/OQAM-VLC are shown in Table 5. The PAPR reduction examined as 9.4, 7.8, 6.2, 5.8, 5.1 and 4.1, respectively.

The PAPR reduction techniques are consistent CCDF performance of changing value of scaling factor. In FBMC/OQAM-VLC, confirming the performance measurement of the scaling factor as given in Fig.7. Consequently, there is a good trade-off between BER performance and PAPR reduction.

Table 5: Effect of scaling factor for proposed Method

Scheme	PAPR dB
M-IFoF based VLC	9.4
OFDM in VLC	7.8
FBMC in VLC	6.2
DCT based VLC	5.8
SLM-MFOA	5.1
Proposed FBMC/OQAM in VLC	4.2

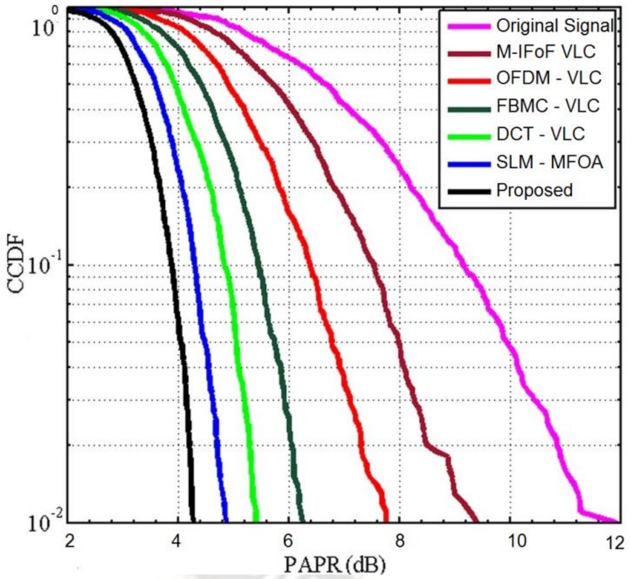

Figure 7: Effect of scaling factor for Proposed System

The analysis of PAPR is examined based on s. In the small range of LED's linearity, the PAPR is minimized for high values of s and in the large range of LED's linearity, the proposed PAPR minimization is independent of s. When the s value increases, transmitted signal power decreases, leading to get poor BER performance. In order to get good PAPR minimization and good BER performance, the proper selection of s is mandatory.

D. Effect of Limit Boundary C_3

Fig.8 shows the impact of limit boundary C_3 on the proposed FBMC/OQAM-VLC scheme. The proposed PAPR reduction methods CCDF performance is demonstrated with $C_3 = 0.6$. The PAPR analysis for Boundary C_3 of the M-IFoF-VLC, OFDM-VLC, FBMC-VLC, SLM-MFOA and Proposed FBMC/OQAM-VLC shown in Table 6. The PAPR reduction examined as 13.9, 9, 6.2, 5.1 and 4.2 dB respectively.

Table 6: Boundary C_3 for Proposed FBMC/OQAM -VLC

Scheme	PAPR dB
M-IFoF based VLC	13.9
OFDM in VLC	9
FBMC in VLC	6.2
SLM-MFOA	5.1
Proposed FBMC/OQAM in VLC	4.2

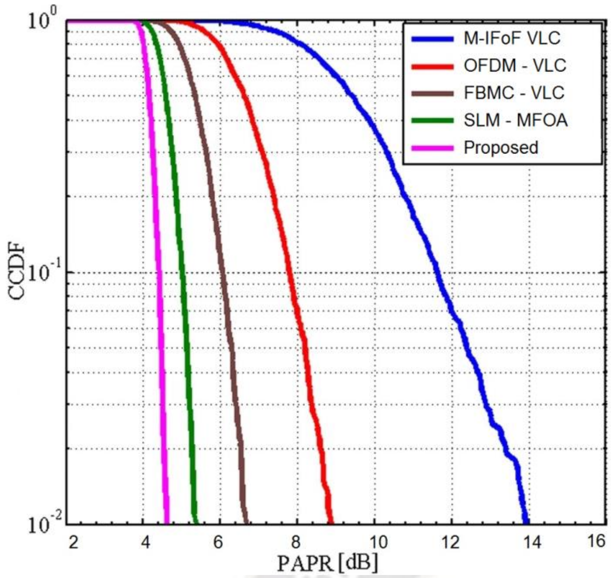

Figure 8: Effect of C_3 for FBMC/OQAM in VLC

E. Spectral Efficiency (SE)

As shown in Figure 9, the spectral efficiency of FBMC/OQAM based VLC techniques shows improvement when compared with M-IFoF-VLC, OFDM-VLC, FBMC-VLC, SLM-MFOA schemes. The SE analysis for different methods are given Table 7.

Table 7. Spectral Efficiency performance of different techniques

Scheme		**At SNR =**	
		10 dB	20 dB
M-IFoF based VLC	Spectral Efficiency (bits/s/Hz)	0.72	0.75
OFDM in VLC		0.76	0.76
FBMC in VLC		0.89	0.9
SLM-MFOA		1.36	1.39
Proposed FBMC/OQAM-VLC		1.75	1.81

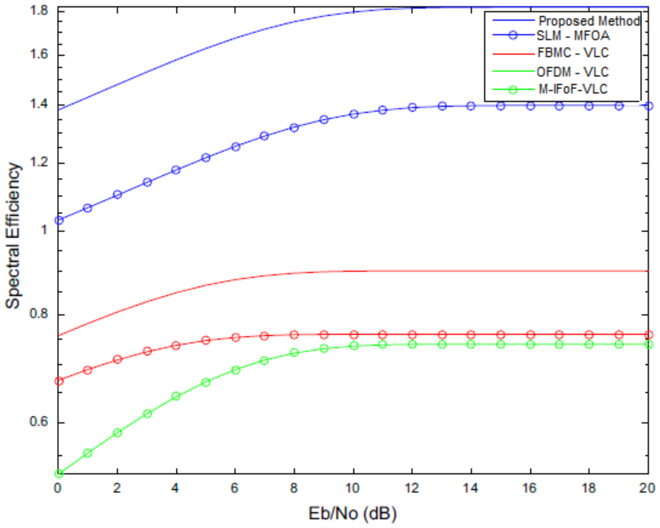

Figure 9: Spectral Efficiency of FBMC/OQAM-VLC

Figure 10 shows the real FBMC signal fluctuations and reduced PAPR reduction signal. The original signal without PAPR reduction is compared to the PAPR reduced signal. In all instances, the entire amplifier range was used for the measurements. The resulting signal samples were scaled to match the same amplifier range as in the case with no PAPR reduction when employing the proposed FBMC/OQAM-VLC.

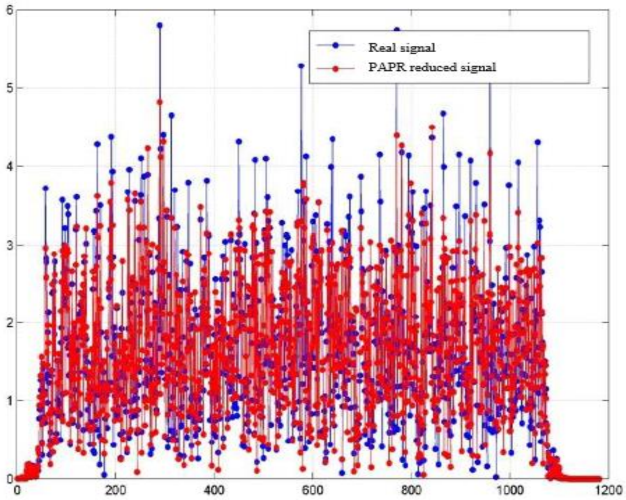

Figure 10: Real signal and PAPR reduced signal

Table 8 show the compare the performance study in PAPR for FBMC/OQAM in VLC schemes. The PAPR comparison for the methods outlined above is summarized in Figure 11 using the proposed FBMC/OQAM-VLC approach. Comparing the proposed method to M-IFoF based Mobile Fronthaul, OFDM-VLC, FBMC-VLC and SLM-MFOA and it is observed that the proposed method significantly lowers PAPR.

Table 8: Proposed PAPR reduction for FBMC/OQAM in VLC system in performance study

Scheme	**PAPR dB**
M-IFoF based VLC	9.8
OFDM in VLC	8
FBMC in VLC	6.4
DCT based VLC	5.9
SLM-MFOA	5.1
Proposed FBMC/OQAM in VLC	4.1

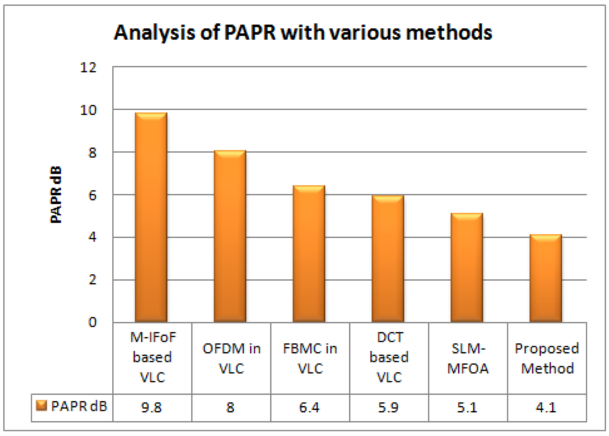

Figure 11: Analysis of PAPR using Different Schemes

V. CONCLUSIONS

This paper presents an FBMC/OQAM-VLC approach for PAPR reduction. To enhance the small-amplitude signals generated by FBMC modulation, while the other is used to reduce the large amplitude signals. The outcomes demonstrate that the suggested method can produce good CCDF performance, particularly when using $C_3 = 0.6$. By utilizing the step size, it is feasible to establish a reasonable trade among PAPR reduction and BER. The PAPR reduction result of the analysis shows the FBMC/OQAM-VLC system for a variety of S and C_3 values. The computational complexity of proposed system is higher because of the larger size of FFT and the various filtering techniques. The system performance is evaluated in terms of BER, spectral efficiency, PAPR, and SNR. It was shown that, when compared to other approaches, the suggested approach has the lowest PAPR, high spectral efficiency, and good BER performance.

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