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IJIEMR Transactions, online available on 22 Aug 2022. Link :http://www.ijiemr.org/downloads.php?vol=Volume-12&issue=Issue 08

10.48047/IJIEMR/V12/ISSUE 08/03

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Volume 12, ISSUE 08, Pages: 12-18

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PAPR Reduction in FBMC-OQAM System using Clipping and Window Techniques

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***Abstract*:** Multicarrier modulation has drawn a lot of interest in the field of contemporary communications in order to satisfy the demand for a higher data rate. OFDM prototype filters exhibit poor stopband behaviour as a result of the employment of cyclic prefix and IFFT, which results in spectral leakage between the sub channels. The most popular MCM technique is OFDM. Due to the shortcomings of OFDM, a multicarrier system using offset quadrature amplitude modulation (OQAM) and filter banks has been proposed. The prototype filter for the FBMC-OQAM system is made using the frequency sampling method of filter design, and the entire filter bank is made using exponential modulation. The main issue in every multi-carrier system is high PAPR. Simple PAPR reduction methods, including clipping, A-law companding, and U-law companding, are employed in the FBMC-OQAM system. Through the use of CCDF plots and BER plots, the system's performance is evaluated. According to simulation results, the proposed strategy performs better than the existing solutions in terms of PAPR reduction and BER.

Keywords: OFDM, FBMC, BER, OQAM, Clipping, SNR, Companding, PAPR.

1. INTRODUCTION

Wireless communication systems are expected to support higher bit rates in the present and future. The best choice for improving bit rate is multicarrier (MC) based systems, which divide the entire wideband frequency-selective communication channel into several sub bands, each with less frequency-selective fading [1]. Simple equalization methods can be used at the receiver because it can be assumed that each sub band will essentially experience flat fading as the number of sub bands increases [2-4].

The well-liked multicarrier modulation method known as orthogonal frequency division multiplexing (OFDM) is used in digital video broadcasting (DVB), digital audio broadcasting (DAB), and other applications. In addition to its advantages, OFDM has significant disadvantages, namely its high spectrum efficiency and use of the cyclic prefix (CP) to lower ISI. The main drawback of every multicarrier modulation technique is the high peak-to-average power ratio (PAPR) of the transmitted signal [5]. In other words, because numerous separate subcarriers are superimposed on one another, producing high peaks at the transmitter end, the broadcast signal will have a wide dynamic range. In order to magnify the multicarrier signals sent, practical HPAs do not show linearity over the whole dynamic range of the MC signal. As a result, the transmitted MC signal is distorted, which degrades the BER performance of the entire system. The prototype filter's stop band attenuation is only about 13 dB, which leads to frequency sub band leakage and ineffectiveness when CP is added to the OFDM system [6].

The drawbacks of OFDM led to the development of filter bank-based multicarrier (FBMC) technology, which enables a large prototype filter order and effective stop band attenuation in the sub channel filters. The sub channel filters' frequency leakage was lessened as a result. The FBMC system was influenced by the concept of a transmultiplexer. It is possible to simplify receiver equalization without the use of CP by employing subchannel filters with improved spectral shapes. The FBMC-OQAM technology uses offset quadrature amplitude modulation (OQAM). This modulation lessens interference from adjoining channels by attaining orthogonality across the nearby sub-channels [7].

Similar to OFDM, large dynamic range ADCs, DACs, and amplifiers are required because of the high PAPR problem that affects all multicarrier modulation systems. Therefore, decreasing PAPR is a crucial component of a successful high-data-rate communication system.

OFDM supports a wide range of PAPR reduction techniques, such as amplitude clipping [8], nonlinear companding [9], selective mapping, partial transmit sequence, tone reserve, etc. The inadequacies of OFDM led to the development of FBMC. Since the nearby symbols overlap, none of the PAPR reduction strategies utilized in OFDM can be used in the FBMC system. We go over methods for PAPR reduction for an FBMC system with PAM symbols. However, the BER performance is poor and only works with PAM symbols. Clipping is carried out with iterative adjustment for PAPR reduction for the FBMC-OQAM system [10]. The system has a sophisticated receiver design that is used to correct for clipping noise. The sliding window tone reservation (SWTR) and multi block joint optimization (MBJO) techniques are used by the FBMC-OQAM system to lower PAPR. The system complexity is noteworthy due to the use of the overlapping structure of the FBMC-OQAM symbol; however, BER performance is not evaluated there. Therefore, a system with an acceptable BER, high PAPR reduction capabilities, and a simpler system architecture is required. In this study, an FBMC-OQAM system is simulated. From a single prototype filter, a filter bank can be built using exponential modulation. In this work, an FBMC-OQAM system is simulated. The system is modeled using the frequency sampling approach to filter design. Data bits are sent from a source to the 64-subchannel FBMC-OQAM system. The transmitter sends multicarrier signals via the AWGN channel, the ITU vehicle A channel, and the pedestrian B channel. At the receiver, frequency domain MMSE one-tap equalization for the ISI channels is carried out using Block Type Pilot Arrangement (BPTA), which is used in the developed FBMC-OQAM system as the PAPR reduction method [11].

2. FBMC-OQAM SYSTEM

2.1 OQAM pre/post processing

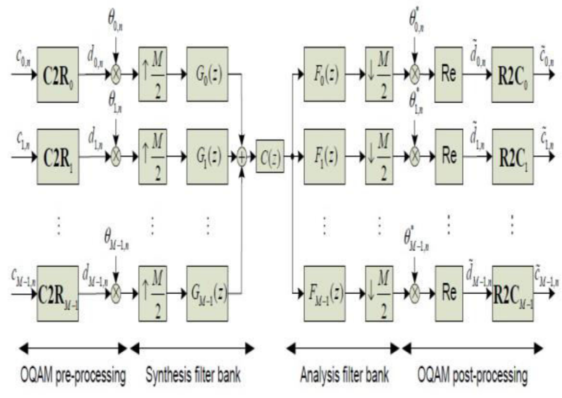

Figure1. FBMC-OQAM system

Figure1 shows the FBMC-OQAM system. In this simple explanation of the FBMC-OQAM system, the synthesis filter bank, analysis filter bank, and OQAM post-processing are the main processing units. Simple complex-to-real conversion is the first step in the OQAM preprocessing, where a fictitious complex is converted to a real complex parts of the QAM With k = 0, 1,..., M1, complex-valued symbols k and l are separated and time stretched by half the symbol period [12-13]. Due to the conversion from complex to real, the sample rate is multiplied by two. Since they are multiplied by powers of j (by $\Theta_{k,n} = j^{k+n}$), the adjacent values in a single subchannel and in the adjacent subchannels will be orthogonal to one another. In the OQAM post processing, the action of separating the two sections follows after the multiplication by the $\Theta_{k,n}$ sequence. These second operation is real to complex conversion. The sampling rate is reduced by two after the complex conversion.

2.2 Synthesis and Analysis Filter Banks

All the subchannel filters in the synthesis filter bank $G_k(Z)$ are derived from a single real-valued linear phase FIR prototype filter $G_0(Z)$ with impulse response p(m). The requirements for the k^{th} synthesis filter are

$$g_k(m) = p(m)exp\left(j\frac{2\pi k}{M}\left(m - \frac{L_p - 1}{2}\right)\right)$$

Where m=0, 1, ..., Lp−1 and Lp is the filter length. The k^{th} analysis filter can be created using the perfect reconstruction (PR) condition and has the formula $f_k(m) = g_k(Lp-1-m)$.

2.3 Prototype Filter Design

To assure perfect reconstruction (PR) or nearly perfect reconstruction (NPR), the technique can be incorporated into a prototype filter. The frequency sampling technique is used in this paper to develop the prototype filter. In the frequency sampling technique of filter design, where K is the overall number of required subchannels, the impulse response coefficients can be determined using the inverse Fourier transform of KM samples from the intended frequency response of the filter [14]. The closed-form p(m) representation of a Lp length prototype filter is provided by

$$p(m) = \frac{1}{N}\left(k_0 + 2\sum_{i=1}^{L_p-1}(-1)^i k_i \cos\left(\frac{2\pi i m}{KM}\right)\right)$$

where m = 0, 1, ..., Lp-1; Lp = KM-1, which then becomes the total length of the filter. A prototype filter with advantageous stopband performance is produced by using the criteria for selecting the values of k_i.

3. PEAK TO AVERAGE POWER RATIO (PAPR)

The term PAPR indicates that a signal has a high peak value that is much larger than its average value. The PAPR is the ratio of the maximum power of a sample of a certain transmitted signal to the average power of the signal (the square of the peak value). For a sent signal, $\mathbf{x}_n$, the following is how the PAPR is described:

$$PAPR = \frac{\max_{0\le n\le N-1}|x_n|^2}{\frac{1}{N}\sum_{n=0}^{N-1}|x_n|^2}$$

where N is the transmitted signal length.

4. PAPRREDUCTIONTECHNIQUES

4.1 Amplitude Clipping

One of the easiest methods to lower PAPR is amplitude clipping, in which the broadcast signal's oscillating envelope is clipped at the transmitter at a predetermined threshold, $y_c(n)$ as follows:

$$y_c(n) = \begin{cases} Ae^{j\phi(y(n))} & \text{if } |y(n)| > A \\ y(n) & \text{if } |y(n)| \le A \end{cases}$$

where A is the specified clipping threshold and y(n) is the phase of y(n). Clipping is finished at the transmitter end. As a result, estimating at the receiver is difficult since once the signal is clipped, the data is actually lost. As a result, clipping causes signal distortions that degrade the system's efficiency [15].

4.2 Nonlinear Companding Transforms

Using a nonlinear transform function at the transmitter end, the higher amplitudes of the transmitted signal are compressed, and the lower amplitudes are increased in this manner. As a result, it increases the noise resistance of tiny signals. It is possible to swiftly recover a coupled signal from the received signal by using the inverse of the nonlinear transform carried out at the transmitter [15]. The nonlinear transform function of the computation shows that there are mainly;

A-law Companding: For a given input *y*, the companding function can be given as,

$$F(y) = sgn(y)\begin{cases} \frac{A|y|}{1+ln(A)} & \text{if } |y| < \frac{|y|_{max}}{A} \\ \frac{1+ln(A|y|)}{1+ln(A)} & \text{if } |y| \ge \frac{|y|_{max}}{A} \end{cases}$$

Where A is the compression parameter. The selection of this parameter should increase BER performance and PAPR reduction.

μ-law Companding: For a given input *y*, the *μ*-law companding transform is given by,

$$F(y) = sgn(y)\frac{ln(1+\mu|y|)}{ln(1+\mu)};\ -1 \le |y| \le 1$$

Where μ=25 is used. μ-law companding at the transmitter increases the dynamic range of the signal and therefore has less of an effect on small-amplitude designs.

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5. FREQUENCY DOMAIN MMSE ONE-TAPE EQUALIZER

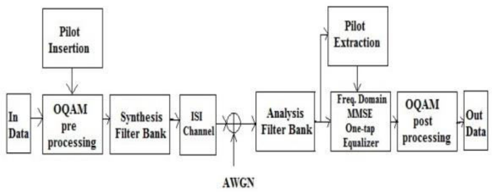

Figure 2. FBMC-OQAM system model with equalizer in ISI channel

The FBMC-OQAM system block diagram with frequency domain MMSE one-tap equalization is shown in Figure 2. Two fading channels vehicular A and pedestrian B are considered in this situation. Channel state information can be estimated using Block Type Pilot Arrangement (BTPA), which communicates pilots for all subcarriers at a single instant for a certain block of transmitted data [16-17]. In each block, an estimate of the channel transfer function is computed and used until the arrival of the subsequent pilot symbol.

Given that FBMC-OQAM is a multicarrier modulation method, channel fading in each subchannel may be referred to as frequency-flat fading. The channel frequency response for each subchannel must therefore be assessed. MMSE equalization minimizes the mean square error between the transmitted signal and the predicted output for each subcarrier [18]. This promotes more harmony between ISI and noise augmentation.

For the n^{th} subcarrier, the MMSE equalization weight is given by

$$p(n) = \frac{H^{\star}(n)}{|H(n)|^2 + (SNR)^{-1}};\ 0 \leq n \leq M-1$$

where H(n) is the channel transfer function at subchannel n and M is is the number of subchannels. Applying MMSE frequency domain one-tap equalization to the received signal Y(n) yields the estimation of the sent signal X (n), where X(n) = p (n) Y(n) as the outcome.

6. RESULTS

An FBMC-OQAM system can have up to 64 subchannels and 64000 bits from a source is transmitted to OQAM. Before processing, block OQAM-modulated signals are routed into the synthesis filter bank. The prototype filter has been designed using the frequency sampling method. Synthesis filter banks are produced by exponentially modifying the single prototype filter. The synthesis filter bank's overall output is sent to the channel. The AWGN channel is considered. The received signal is equalized at the receiver using a frequency-domain MMSE one-tap equalizer. In the BTPA transmission, pilots are employed to estimate channel state data. The equalized signals are received by the analysis filter for transmission. M was demodulated in order to recreate the transmitted symbols. The performance of PAPR is evaluated using a CCDF plot for the three PAPR reduction procedures. The BER performance of the FBMC-OQAM system for three channel scenarios is investigated both with and without PAPR reduction methods.

Figure 3 shows the CCDF plot for the FBMC-OQAM system using clipping method with various clipping levels. The lower clipping value gives the better PAPR performance. Figure 4 represents BER performance of the system.

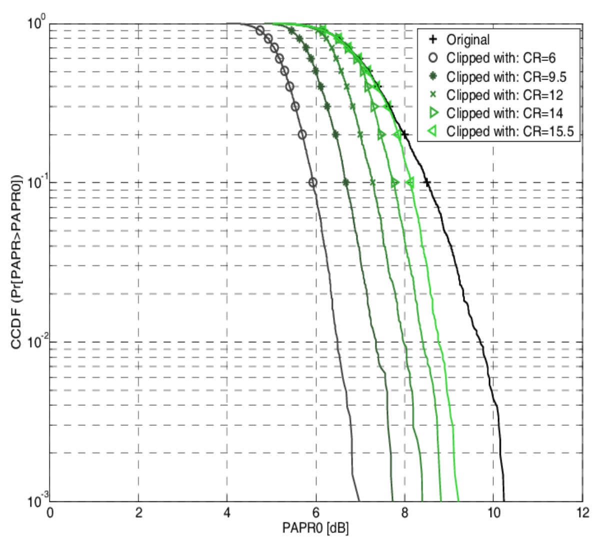

Figure 3. PAPR analysis with various clipping values

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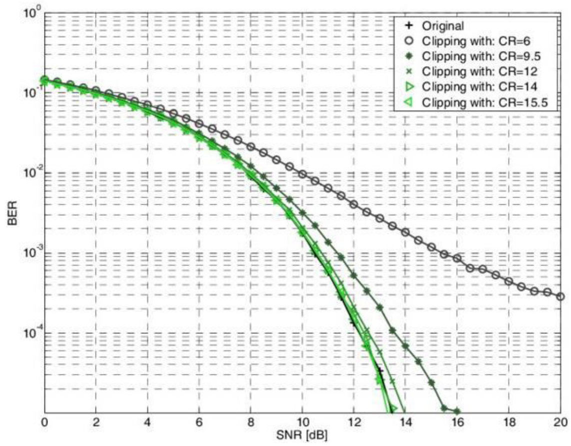

Figure 4. BER performance with various clipping values

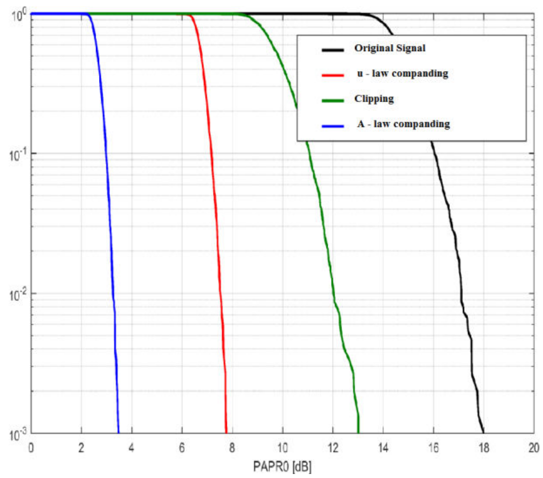

Figure 5. PAPR Performance

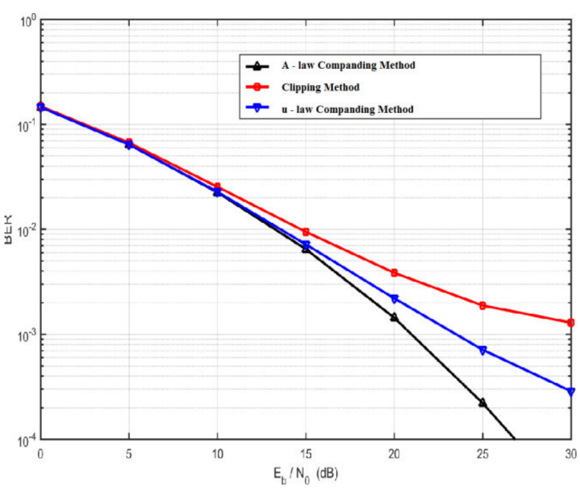

Figure 6. BER performance

7. CONCLUSION

Modern communication systems need a larger data rate, hence multicarrier modulation (MCM) approaches have gained a lot of popularity. In this paper, an FBMC-OQAM system is implemented using the exponential modulation of a single prototype filter. The main drawback of any MCM system is the significant PAPR for multicarrier-modulated transmitted data. Here, three simple methods for lowering PAPR; clipping, A-law companding, and u-law companding were covered. The CCDF graphic demonstrates that these three solutions significantly reduce PAPR compared to the ideal state. The BER performance of the ideal FBMC-OQAM system and the modified systems with PAPR reduction were examined in three different channel circumstances. u- law companding will be a better alternative for reducing PAPR in the FBMC-OQAM system than A-law companding and clipping.

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