COMPANDING AND CLIPPED FILTERING BASED HYBRID TECHNIQUE FOR PAPR REDUCTION OF FBMC-OQAM: A SURVEY

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Abstract—**For transmitting QAM signals, a filter-bank multicarrier - quadrature amplitude modulation (FBMC-QAM) system with two prototype filters is presented. Filtering for even-numbered sub-carrier symbols and odd-numbered sub-carrier symbols is done separately in the proposed transmitter. Multicarrier transmission, which sends data over the channel in several frequency subcarriers at a lower data rate, has become popular in this situation. Its main selling point is that it prevents frequency selective fading. Non-contiguous orthogonal frequency division multiplexing (NCOFDM) and filter bank multicarrier modulation are two ways for implementing multicarrier modulation (FBMC).**

Filter bank multicarrier system is an efficient multicarrier scheme and potential waveform for 5G, and this work reviews the FBMC-OQAM Filter employing A-Law and MU-Law Companding. FBMC has a high Peak-to-Average Power Ratio (PAPR), similar to OFDM and other multicarrier systems, which necessitates the use of high-power amplifiers with a wide dynamic range. Companding techniques are employed to reduce PAPR at the cost of BER performance loss. A unique application of A-law and Mu-law companding techniques for PAPR reduction of the FBMC-OQAM scheme is proposed in this work. Using A-law and Mu-law companding algorithms, the paper also analyses the tradeoff between PAPR reduction and FBMC-OQAM Bit error rate performance.

Index Terms—High Power Amplifier (HPA), Filter Bank Multicarrier (FBMC), Bit Error Rate (BER), Peak to Average Power Ratio (PAPR)

I. INTRODUCTION

Multicarrier modulation has become more important in the development of broadband communication networks during the last few decades. Multicarrier modulation has demonstrated its ability to transmit huge volumes of data across a channel while boosting the robustness of communication systems against various impairments by providing concurrent streams of information in the frequency domain on distinct centre frequencies.

Despite the fact that wireless transmission and related technologies are thought to be nearing the end of their life cycles, the need for new technologies and better throughputs continues to grow. They are now extensively connected to the majority of infrastructural facilities and are inextricably linked to daily operations. Many interdisciplinary applications and cross-functionalities have been added to services and operations. Despite the fact that the last enormous boom has passed, researchers and developers are still looking for new technologies to better the present systems that have evolved through generations.

Mobile phones are no longer just devices for personal communication. They've evolved into portable intelligent computers that can run multimedia apps and perform functions that can be controlled remotely. Communication capability is one of its features, albeit it is a required infrastructural resource.

Through the wireless interface, several stationary and mobile devices are connected to networks in concurrently. These will be even more efficient, user-friendly, complex, and intelligent than they are now.

They will be able to meet these demands by acquiring and/or utilising remote resources with the help of wireless communication. These resources are in high demand, and may include cloud-based processing and intelligence, as well as storage. In remote centralised or distributed systems, certain jobs can be processed much more quickly and intelligently.

Orthogonal Frequency Division Multiplexing (OFDM) [2] is a prominent multicarrier system that is utilised in Digital Audio Broadcast (DAB), Digital Video Broadcast (DVB), and other applications. OFDM is a spectrally efficient method that reduces ISI by using a cyclic prefix (CP). At the same time, depending on its length, this CP reduces spectral efficiency. Filter bank multicarrier, a new multicarrier scheme, successfully overcomes this flaw (FBMC). The system can have strong stopband attenuation in an FBMC system because of subchannel filters, which limit frequency leaking between the subchannels and allow the prototype filter order to be large. Sub channel filters can simplify equalisation at the receiver and eliminate the need for CP [3].

Because OFDM suffers from a high peak to average power ratio (PAPR) due to the non-linearity of practical HPAs used to amplify the transmitted signal, FBMC suffers from the same problem, hence lowering the PAPR is the major requirement for achieving large data rates. Because of the high PAPR, high dynamic range amplifiers and ADC/DACs are used [1]. High PAPR is the main issue in all multicarrier systems since it distorts the signal, resulting in poor BER performance.

Partially transmit sequence (PTS) [4], coding schemes, selective mapping (SLM) [4], phase optimization, tone injection (TI), companding [5], tone reservation (TR), clipping and filtering, and active constellation extension are some of the PAPR reduction strategies utilised in OFDM (ACE).

The simplest way to use is clipping and filtering [5]. Peaks that surpass the threshold value are clipped and then filtered to keep the peak value low. PTS and SLM are probabilistic algorithms that weight signal subcarriers with phase factors before transmitting signals with low PAPR [6][12]. Both of these strategies require the transmission of side information in addition to the signal, lowering the spectral efficiency. Because of their simplicity and flexibility, companding techniques are commonly utilised for PAPR reduction [7].

In this paper, we look at how FBMC-OQAM (Offset Quadrature Amplitude Modulation) performs in terms of PAPR and BER, and then use A-law and Mu-law companding approaches to reduce PAPR.

It is worth noting that the authors of [1] have also given a PAPR reduction analysis using the same approaches, but there is no detailed comparison based on the number of subcarriers and compression parameter values. In this paper, we show and discuss a complete PAPR reduction and BER analysis for various numbers of subcarriers (16, 32, 64, and 128) and varied compression parameter values for both compression approaches. The choice of compression parameter results in a trade-off between PAPR reduction and BER performance, as demonstrated.

II. LITERATURE REVIEW

In the mid-1960s, FBMC communication mechanisms were initially established. Chang [15] described the criteria for signalling a parallel set of PAM symbol sequences across a bank of overlapping filters with a minimum bandwidth using a bank of overlapping filters. Chang suggested vestigial sideband (VSB) signalling for subcarrier sequences to send PAM symbols in a bandwidth-efficient manner. Saltzberg [14] developed the concept and demonstrated how Chang's approach could be adjusted to transmit QAM symbols in a DSB-modulated manner. Saltzberg suggested that the in-phase and quadrature components of each QAM symbol be time staggered by half a symbol interval to retain the bandwidth efficiency of this method identical to Chang's signalling. Bellanger and Daguet [12] originally proposed an efficient digital version of Saltzberg's multicarrier system using polyphase structures, which was further examined by Hirosaki [17]. Another important advance was reported in [15], which stated that Chang's/approach Saltzberg's could be used to match channel variations in doubly dispersed channels and thereby eliminate inter symbol and inter carrier interference (ICI). Saltzberg's method has gotten a lot of attention in the literature, and it's been given various titles. To highlight the fact that the in-phase and quadrature components are transmitted with a time offset with respect to each other, most writers have used the designation offset QAM (OQAM). The suffix OFDM has also been added to underline the method's multicarrier functionality, leading to the term OQAM-OFDM. Others have coined the term staggered QAM (SQAM), or SQAM-OFDM. [18] was the first time we used the term staggered multitone (SMT). On the other hand, Chang's approach [02] has received very little attention. Those who have cited [16], for example, have just recognised its existence without providing much detail. Hirosaki, who has extensively studied and developed digital structures for the implementation of Saltzberg's method [24,28], has made a brief reference to Chang's method, noting that it is more complex to implement than Saltzberg's method because it uses VSB modulation and thus requires a Hilbert transformation. This assertion is incorrect, because, as we demonstrated in [18], Chang's and Saltzberg's approaches are comparable, and so an implementation for one may be transferred to the other with aminor adjustment.

The most often used multicarrier technology is OFDM. It is used in a wide range of communication goods. Alternative approaches for OFDM systems are FBMC. Guard interval is used in OFDM systems to mitigate channel distortion. FBMC, on the other hand, uses filtering techniques to reduce the problem of channel distortion. When using proper Filter design, only adjacent subcarriers overlap, resulting in nearly little interference from nonadjacent subcarriers. As a result, FBMC approaches are more suited for systems with high mobility and large doppler effect, when subcarrier orthogonality may be lost and ICI causes significant distortion in OFDM signals. Large sidelobes of OFDM subcarriers cause interference and, as a result, performance loss in asynchronous multicarrier communications in multiuser systems and cognitive radio networks. To suppress the sidelobes, bandwidth efficiency would be reduced by up to 50% [9]. It's also worth noting that scholars who have investigated Filter banks have created a new category of Filterbanks known as modified DFT (MDFT) Filterbanks [10].

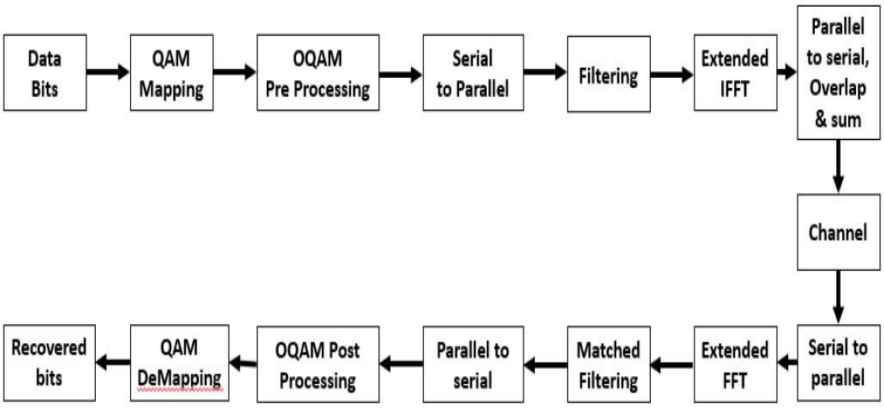


Figure 1: FBMC-OQAM System

For future remote correspondence frameworks, channel bank multi-transporter (FBMC) regulations, notably FBMC-Offset quadrature amplitude modulation (OQAM), are considered as an attractive alternative to OFDM. The waveforms' time/recurrence determination is broadened and can be traded off, resulting in better utilisation of physical assets and possibly improved strength to time-variation channel qualities as well as bearer recurrence balances. FBMC-OQAM, like OFDM, breaks down the communication channel into a series of lower-transmission-capacity sub channels that can be compensated at low variance with a single-tap equaliser. Unlike OFDM, FBMC-OQAM does not require a cyclic prefix to be expanded, and the created sub channels are roughly level and orthogonal. When the channel recurrence selectivity increases, the FBMC-OQAM framework encounters both sub channel obstruction and picture impedance on each sub channel, necessitating the use of advanced equalisation structures.

III. ORTHOGONAL RECURRENCE DIVISION MULTIPLEXING (OFDM)

A. OFDM

Bits are mapped to constellation symbols in an OFDM system, and modulation and demodulation are ensured by the inverse fast Fourier transform (IFFT) and the fast Fourier transform, respectively (FFT). The time domain of an OFDM symbol calculated using N IFFT points is calculated as follows:

$$i(t) = \sum_{n=-\infty}^{+\infty} \sum_{m=0}^{N-1} c_{m,n} f(t-nT) e^{j2\pi/Tmt} \tag{1}$$

Where,

- N is the number of subcarriers,
- T is the OFDM symbol period,
- Cm,nis a complex-valued symbol transmitted on the mth subcarrier and at the instant nT, and
- f (t) is a rectangular time window, defined by

$$f(t) = \begin{cases} 1/\sqrt{T} & t \in [0,T] \\ 0 & \text{Elsewhere} \end{cases} \tag{2}$$

Considering high values of *N* and according to the central limit theorem, the IFFT block transforms a set of independent complex random variables to a set of complex Gaussian random ones. In a distortion-free noiseless channel, the received symbol is given by the following equation-

$$y_{m0,n0} = c_{m,n} = i(t), f(t-n_0T)e^{j2\pi/Tm_0t} = \int_{-\infty}^{+\infty} i(t) f(t-n_0T) e^{-j2\pi/Tm_0t} dt \tag{3}$$

$$\sum_{n=-\infty}^{+\infty} \sum_{m=0}^{N-1} \int_{-\infty}^{+\infty} c_{m,n} f(t-nT) f(t-n_0T) e^{j2\pi/T(m-m_0)t} dt \tag{4}$$

Where, $C_{mn}$is the received symbol,

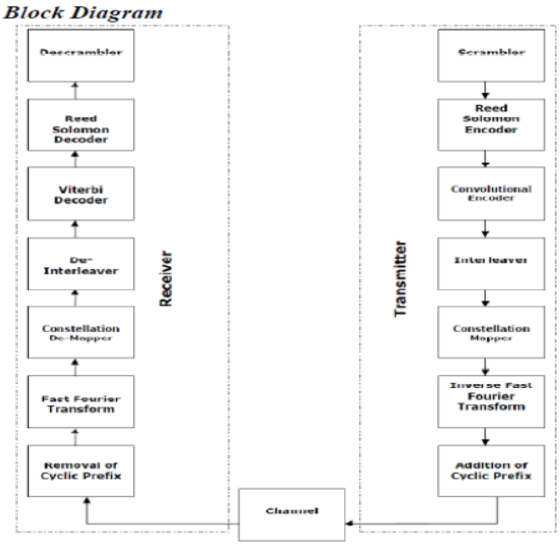


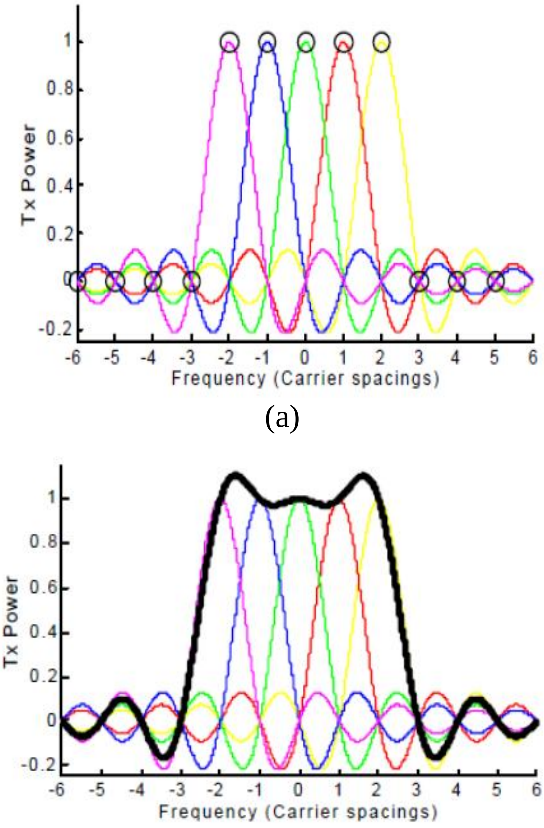
Figure 2 complete OFDM systems

B. ORTHOGONALITY

The key to OFDM is maintaining orthogonality of the carriers. If the integral of the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. Two sinusoids with frequencies that are integer multiples of a common frequency can satisfy this criterion. Therefore, orthogonality is defined by:

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)dt = 0(n \neq m) \tag{5}$$

where n and m are two unequal integers; f0 is the fundamental frequency; T is the period over which the integration is taken. For OFDM, T is one symbol period and f0 set to 1/T. for optimal effectiveness.



(a)

(b)

Figure 3 (a) Shows the spectrum of each carrier(b) Shows the overlap combine response

*C.*SCRAMBLR/DESCRAMBLE

Information bits are given to the transmitter as inputs. These bits go through a scrambler that randomizes the bit arrangement. This is done with a specific end goal to make the info arrangement more scatter so that the reliance of information sign's energy range on the genuine transmitted information can be dispensed with. At the collector end descrambling is the last step. Descrambler just recuperates unique information bits from the mixed bits.

D. ENCODER/DECODER

The mixed bits are then encouraged to the Reed Solomon Encoder which is a part of Forward Error Correction (FEC). Reed Solomon coding is a blunder revision coding method. Info information is over-inspected and equality images are figured which are then attached with unique information .long these lines repetitive bits are added to the genuine message which gives resistance against serious channel conditions. A Reed Solomon code is spoken to in the structure
RS (n, k), where,

$$n=2^{m}-1 \quad (6)$$

$$k=2^{m}-1-2t \quad (7)$$

Here m is the number of bits per symbol, k is the number of input data symbols (to be encoded), n is the total number of symbols (data + parity) in the RS codeword and t is the maximum number of data symbols that can be corrected. At the receiver Reed Solomon coded symbols are decoded by removing parity symbols.

E.CONVOLUTION ENCODER/DECODER

Error-coded bits are further coded by Convolutional encoder. This coder adds redundant bits as well. In this type of coding technique each m bit symbol is transformed into an n bit symbol; m/n is known as the code rate. This transformation of m bit symbol into n bit symbol depends upon the last k data symbols, therefore k is known as the constraint length of the Convolutional code.

F. INTERLEAVER / DE-INTERLEAVER

Interleaving is done to shield the information from burst mistakes amid transmission. Reasonably, the in-coming piece stream is re-masterminded so that neighboring bits are not any more adjoining each other. The information is broken into pieces and the bits inside of a piece are improved. Talking as far as OFDM, the bits inside of an OFDM image are modified in such a design so that adjoining bits are set on non-nearby subcarriers. To the extent De-Interleaving is concerned, it again revises the bits into unique structure amid gathering.

G. CONSTELLATION MAPPER/DEMAPPER

The Constellation Mapper basically maps the incoming (interleaved) bits onto different sub-carriers. Different modulation techniques can be employed (such as QPSK,BPSK, QAM etc.) for different sub-carriers. The De-Mapper simply extracts bits from the modulated symbols at the receiver.

H. INVERSE FFT/FFT

This is the most important block in the OFDM communication system. It is IFFT that basically gives OFDM its orthogonality. The IFFT transform a spectrum (amplitude and phase of each component) into a time domain signal. It converts a number of complex data points into the same number of points in time domain. Similarly,FFT at the receiver side performs the reverse task i.e. conversion from time domain back to frequency domain.

I. ADDITION/REMOVAL OF CYCLIC PREFIX

Interleaving is done to shield the information from burst mistakes amid transmission. Reasonably, the in-coming piece stream is re-masterminded so that neighboring bits are not any more adjoining each other. The information is broken into pieces and the bits inside of a piece are improved. Talking as far as OFDM,the bits inside of an OFDM image are modified in such a design so that adjoining bits are set on non-nearby subcarriers. To the extent De-Interleaving is concerned, it again revises the bits into unique structure amid gathering.

IV. FILTER BANK MULTICARRIER (FBMC)

Channel bank multi-transporter (FBMC) regulations, and all the more particularly FBMC-Offset quadrature amplitude modulation (OQAM), are seen as an intriguing option to OFDM for future remote correspondence frameworks . The time/recurrence determination of the waveforms is expanded and can be exchanged off bringing about a superior use of the physical assets and possibly in an enhanced strength to time-variation channel attributes also, bearer recurrence balances. Like OFDM, FBMC-OQAM disintegrates the correspondence channel in an arrangement of lower-transmission capacity sub channels that can hence additionally be remunerated at a low unpredictability with a single-tap equalizer. As opposed to OFDM, FBMC-OQAM does not require the expansion of a cyclic prefix and the made subchannels are just roughly level and orthogonal. At the point when the channel recurrence selectivity expands, the FBMC-OQAM framework experiences both between subchannel obstruction and between image impedance on each subchannel, making it important to utilize propelled equalizer structures . Moreover the blend of FBMC-OQAM with SIMO techniques results in an unmanageable impedance term showing up between the reception apparatus streams on neighboring subchannels, that makes the outline of the framework testing. The configuration of SIMO FBMC-OQAM frameworks has set off a great deal of exploration as of late.

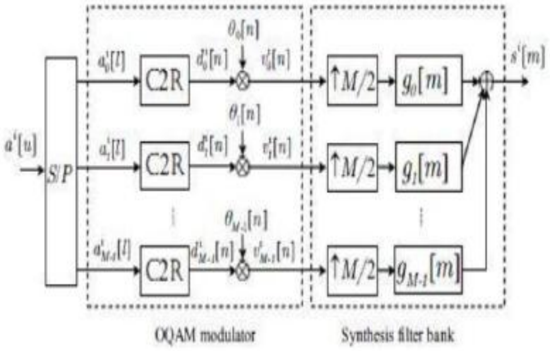


Figure 4:OQAM modulation and synthesis filter bank.

A. Mu-law Companding

Mu-law companding for the given input *x*is stated as:

$$F(x) = sgn(x)\frac{\ln(1+\mu|x|)}{\ln(1+\mu)} \quad (8)$$

The value used here is μ= 25 and μ= 255.This technique does has greater effect on small amplitudes but dynamic range is increased of the transmitted signal [1]. The de-companding formula is given as:

$$F^{-1}(x) = sgn(x)\frac{1}{\mu}((1+\mu)^x - 1) \quad (9)$$

B. A-law Companding

A-law companding for the given input *x*is stated as:

$$F(x) = sgn(x)\begin{cases} \frac{A|x|}{1+\log(A)}, & |x| < \frac{1}{A} \\ \frac{1+\log(A|x|)}{1+\log(A)}, & \frac{1}{A} \leq |x| \leq 1 \end{cases} \quad (10)$$

Where Ais the compression parameter and value used is A=13 and A=87.6. This value must be chosen in such a way that it gives a good PAPR reduction and better BER performance. The de-companding formula is given as

$$F^{-1}(x) = \begin{cases} \frac{|x|(1+\ln(A))}{A}, & |x| < \frac{1}{1+\ln(A)} \\ \frac{\exp(|x|(1+\ln(A))-1)}{A}, & \frac{1}{1+\ln(A)} \leq |x| < 1 \end{cases} \quad (11)$$

The above expression show as A-law companding Techniques for PAPR Reduction.

V. CONCLUSION

We present a novel application of the Mu-law and A-law companding strategies to reduce PAPR in the FBMCOQAM scheme in this work. Companding strategies are effective at lowering PAPR, but they have a negative impact on overall system performance. The simulation findings show that when companding is used, the PAPR decreases significantly, albeit at the cost of a high BER.

FBMC is a multicarrier modulation technique that emerged from OFDM, the most extensively used multicarrier communication technique. At the penalty of higher complexity, FBMC outperforms OFDM in terms of spectral efficiency, resilience, and spectral protection. Because of these advantages, FBMC is an excellent solution for CR communications, multiple access networks, TVWS, and PLC.

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