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A Comparative Analysis of Pulse Shaping Filtering in FBMC - Waveform Technique for 5G Radio Access Network (RAN)

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ABSTRACT: The goal of the 5G wireless communication system is to combine the wide range of communication services.The huge demand of radio services has created a serious technical problem.One of the main challenge is to meet spectral requirement.Since most of the wireless communication protocol is assigned to specific spectrum and hence efficient spectrum utilization is required. This can be achieved by proper choice of pulse shaping filter. Pulse shaping is essential in spectral shaping to minimize the spectral bandwidth,.The pulse shaping filter are designed to generate a band limited signal,to reduce ISI,ICI and ACI are essentially corresponding to energy distribution.The main objective of this paper is to analyze the performance of various pulse shaping filters in terms of BER for FBMC system and also compares the BER performance of FBMC and OFDM system.

KEYWORDS: RAN, OFDM, FBMC, ISI, ICI, ACI, BER

I. INTRODUCTION

(OFDM) has enjoyed its dominance as the most popular signaling method in broadband wired and wireless channels. OFDM has been utilized in most wireless standards like IEEE 802.11 and IEEE802.16, 3GPP-LTE, and LTE-Advanced. It provides low complexity and achieves very high Spectral efficiency. However, it has been noted that OFDM has many challenges in more complex networks. When OFDM made an attempt to transmit over a set of non-contiguous frequency bands, the subcarrier filters in IFFT/FFT filter banks of OFDM introduces significant out-of-band noise to nearby users and also adds up significant ingress noise from them.

Various Methods of reducing OFDM spectral leakage were dealt with and which makes the transmitter more complex. To cope up with the drawbacks of OFDM, a new emerging method FBMC is introduced to reduce the out-of-band power leakage and increase the Spectral Efficiency. This paper is organized into the following sections-Section I, give the introduction of FBMC and Shortcomings of OFDM. Section II discusses the FBMC system with the help of block diagram, Section III describes the design of various pulse shaping filter, Section IV discusses the FBMC merits and demerits, Section V is about simulation performed in MATLAB for comparing the power spectral densities, Computational Complexity and prototype filter comparison of FBMC and OFDM techniques. Lastly, Section VI discusses the conclusion of the paper.

II. FBMC SYSTEM

FBMC transmission based on filter banks[2]. The transmitter contains OQAM a Synthesis Filter Bank (SFB) and the receiver contains an Analysis Filter bank (AFB) and OQAM Post Processing.In OQAM pre-processing the first operation is a simple complex-to-real conversion, where the real and imaginary parts of a complex-valued symbol are separated to form two new symbols i.e., Even and Odd symbols. (This operation can also be called as staggering). So the order of the symbols depends upon the index value of subchannel, i.e., the conversion is distinct for even and odd numbered subchannels. The complex-to-real conversion is upsampled by a factor of 2. After this, the second operation is the multiplication by the pattern of real and imaginary samples. For example {1, j, 1, j….} for even and {j,1,j,1…} for odd. The input signals may be either purely real or imaginary-valued after the OQAM pre-processing.
The SFB is fed with offset QAM symbols. SFB utilizes the polyphase structure, which consists of filter sectioncoefficients of the filter are determined by the prototype filter design.The transform block (IFFT block) in SFB essentially performs the modulation to the subcarrier frequencies and a set of output samples are generated. The number of subchannels (M) is basically arbitrary, but the choice is made as a power of 2 in order to use IFFT/FFT as efficient algorithms for the transform blocks. The output samples from the parallel branches go through a parallel-to-

serial conversion. The figure shows the structure of FBMC-based multicarrier systems. A Receiver performs similar processing blocks, but in reverse order. The FBMC, also called OQAM/OFDM.

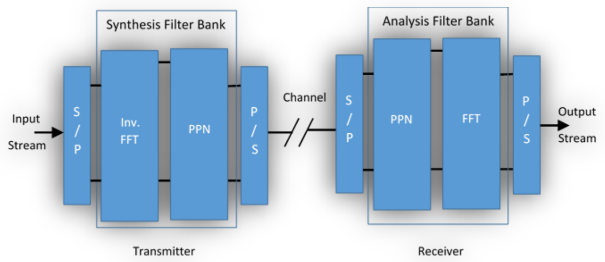

Fig.1. FBMC SYSTEM MODEL[9]

III. PULSE SHAPING FILTER

A.PHYDAS PROTOTYPE FILTER

It is essential to design a prototype filter and transmit data in such a manner, there is no ISI inspite of Overlapping. Prototype filters are characterized by overlapping factor K,which is the ratio of the filter impulse response duration and multicarrier symbol period T. Where K is an integer number. The filter associated with zero frequency is called a prototype filter and the filter bank is obtained by frequency shifts.i.e, other filters are deduced from it through frequency shift.

The impulse response of PHYDAS(Physical layer for Dynamic Spectrum Access) filter is given as

$$h(t) = 1 + 2\sum_{l=1}^{L-1}(-1)^l\, H_l\;\; Cos(2\pi \frac{lt}{LT}) \qquad (1)$$

Where L is the overlapping factor and H_l is the filter coefficient.T is signaling period.T=1/Δf subcarrier spacing

The frequency coefficients of filter obtained from K=2,3 and 4 are given in TABLE I.

TABLE I.Frequency DomainPHYDAS Filter Coefficients[9]

K	h1	h2	h3	h4
2	1	$\sqrt{2}/2$	-	-
3	1	0.911438	0.411438	-
4	1	0.971960	$\sqrt{2}/2$	0.235147

B.GAUSSIAN PULSE SHAPING FILTER:

Pulse shaping technique is used to reduce ISI. The impulse response of the function of this filter is a Gaussian function. The Gaussian filter has a narrow bandwidth and sharp cut off frequency. So it has low spectral side lobes.

Unlike RRC and PHYDAS filter, it does not implement zero crossing points.Gaussian filter can be chosen if there is no restriction on bandwidth and filter length. Gaussian pulse is having better Time- frequency localization property (ṗ=1). GSM and Bluetooth protocol uses Gaussian filter with α=0.3 and α=0.5 respectively.

The impulse response of Gaussian pulse is defined as

$$g(t) = e^{-\pi t^2} \qquad (2)$$

C.R0 RAISED COSINE FILTER(RRC)

RRC filter is bandwidth efficient compared to rectangular pulse shaping filter.RRC filter has an infinite attenuation in the stop band.But in practice its length should be reduced to a finite value. Reducing the number of samples reduces the stop band attenuation**.** The filter response of the Root Raised Cosine filter is mathematically defined by

$$h_{RRC}(t) = \frac{[\frac{4\alpha}{\pi}(\frac{\cos(1+\alpha)\pi n}{R})] + [(1-\alpha)sinc(\frac{1-\alpha)\pi n}{R})}{\sqrt{R}[1-\left(\frac{4\alpha n}{R}\right)^2]} \qquad (3)$$

Where α is called the roll off factor which tells us the sharpness of the frequency response and R is the samples per symbol.RRC leads to low spectral leakage in frequency domain if the roll off factor is large. It also offers a good balance between the time and frequency locality in FBMC system

IV. FMBC PROS and CONS

FBMC Merits:

- Provide a spectrum efficient and more selective system
- Perfect choice for filling spectrum holes in CR Network.
- CP(Cyclic Prefix) is not needed
- Provide robust to channel time and frequency spreading.
- Robustness against high mobility.
- The complexity of both the transmitter and receiver will be reduced with the help of smaller size IFFT/FFT blocks.
- The system latency will be reduced. This is because the length and, thus, the corresponding group delay of the underlying prototype filter are reduced.
- The effect of CFO will be reduced.
- The PeakAveragePowerRatio of the transmit signal will be reduced

FBMC Demerits:

- The development of MIMO based FBMC is very limited and is non-trivial.
- To design wider BW and the higher dynamic range system will have more challenges in achieving RF performance
- Inefficient for short bursts due to long filter tails

Complexity:

Computational complexity of the filter bank is evaluated by means of calculating a number of real addition and multiplication operation[9]. The Number of real multiplications used in SFB and AFB is given in equation (1) and (2)

$$\xi_{SFB}=2.(M.2+M(log_2\ (M)-3)+4)+KM.2) \quad (4)$$

$$\xi_{AFB}=2.(M.2+M(log_2\ (M)-3)+4)+KM.2) \quad (5)$$

$$\xi_{FBMC}=\xi_{SFB}+\xi_{AFB} \quad (6)$$

$$\xi_{FBMC}=4.[(M.2+M(log_2\ (M)-3)+4)+KM.2)] \quad (7)$$

$$\xi_{OFDM}=2.(M(log_2 M)-3)+4 \quad (8)$$

Where $L_P = KM - 1$ is a length of the prototype filter.

K – Overlapping Factor

M-Number of the subchannel.

The complexity of FBMC and OFDM systems are given in equation(4) and (5) and from the equation, it is apparent that FBMC is more complex than OFDM.SinceFBMC utilize separate filter for each carrier.

Localization:

The localization of prototype filter characterizes the distribution of energy in time and frequency. Localization in time is defined as $\|\gamma p(\gamma)\|^2$ .Localization in frequency is defined as $\|fP(f)\|^2$

Where $\|L\|^2$ norm and p(γ) and P(f) are said to be transformed pairs.

V. SIMULATION RESULT

Simulation result shows the FBMC attractive features.

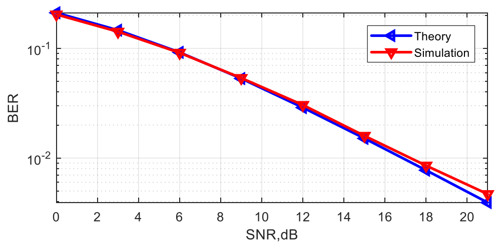

Fig.2. BER Comparison of FBMC in AWGN channel.

Figure 2. Shows the simulation results of FBMC under the AWGN channel and it is compared with theoretical BER expressions and it validates the analytical expression too.

TABLE II. Simulation Parameters

FBMC-OQAM	
Number of Subchannel(M)	256
Overlapping Factor(K)	2,4
FFT Size	1024
Filter	PHYDAS,Gaussian Filter,RRC
Length of filter	K*M-1
Cyclic Prefix	Not Used

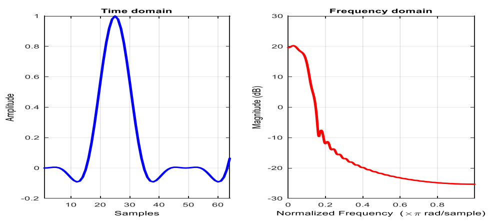

Fig.3 Impulse and Magnitude response of PHYDAS filter.

Fig.3. Shows the impulse response and magnitude response of the PHYDAS filter in FBMC system.Filter frequency coefficients are shown in Table I.It can be observed that OOB(Out Of Band) ripples are negligible and shows higher selectivity.

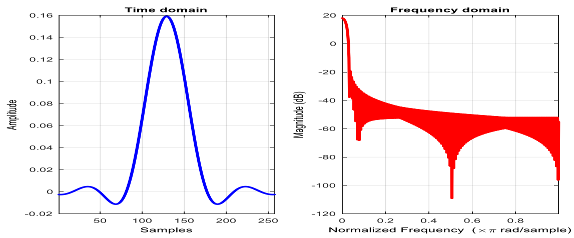

Fig.4. Impulse and Magnitude response of RRC filter.

Fig.4. Shows the impulse and magnitude response of RRC filter. Roll off factor α=0.5 is chosen, and which determines the sharpness of the filter.

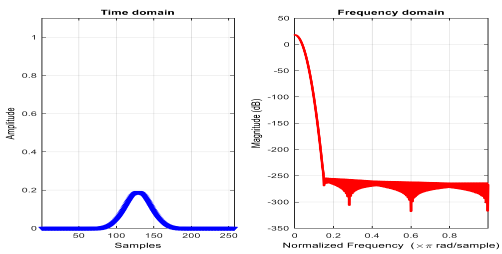

Fig.5. Impulse and Magnitude response of Gaussian filter

Fig.5. Shows the impulse and magnitude response of Gaussian filter.Unlike PHYDAS and RRC,it does not implement zero crossing. Impulse Response of the filter shows no zero crossings.Gaussian filter can be chosen if there is no restriction in bandwidth and filter length.Gaussian filter has good localization in time and frequency.

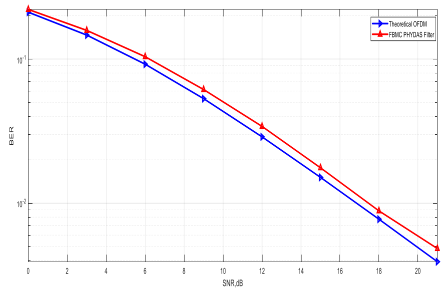

Fig. 6. BER Comparison of FBMC PHYDAS filter with OFDM

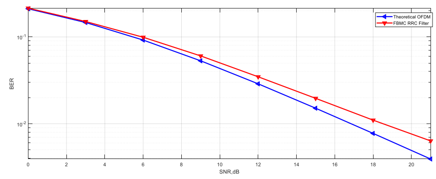

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Fig. 7 .BER Comparison of FBMC RRC filter with OFDM

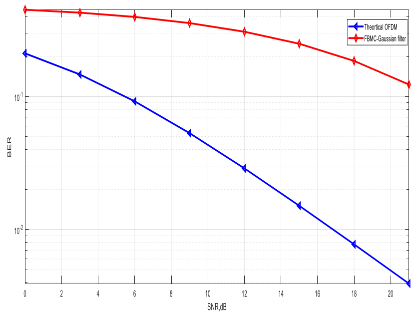

Fig. 8 .BER Comparison of FBMC Gaussian filter with OFDM

Fig.6,7 and 8 Shows the BER comparison of PHYDAS ,RRC and Gaussian Filter with OFDM system.From the BER response it has been observed that PHYDAS filter outperforms comparable to RRC and Gaussian filter.Since Gaussian filter is not having zero crossings in a symbol period which results in ISI and degrades the performance.RRC can give the same result as that of PHYDAS filter. But we need to keep rolling off factor as large. But narrow filter must have smaller roll off factor which leads to ISI. Hence the optimum choice is a PHYDAS filter for multi carrier communication. BER comparison of these three filters is shown in Table III.

TABLE III. BER Comparison of Pulse shaping filters.

SNR (dB)	0	3	6	9	12	15	18	21
BER-PHYDAS FILTER	0.21132	0.14666	0.092705	0.053105	0.028845	0.01509	0.0077409	0.0039249
BER-RRCFILTER	0.21469	0.150	0.09219	0.060469	0.03475	0.019625	0.011	0.0006348
BER-GAUSSIAN FILTER	0.44994	0.42775	0.39738	0.3753	0.30741	0.24975	0.18547	0.12325

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VI. CONCLUSION

This paper investigates various pulses shaping filter in terms of BER and their performances are tabulated in TABLE III. From this we come to know that PHYDAS outperforms RRC and Gaussian filter. Since PHYDAS have better localization and simple equalization. RRC can also be used for the same purpose, but it needs very long filter length. So PHYDAS filter is apt choice for multicarrier communication.

As we know OFDM uses a rectangular filter for all subcarriers whereas FBMC utilizes individual filters for each subcarrier. Excellent filtering of subcarriers makes it a good choice for 5G Radio Access Network.FBMC is an elegant method that resolves most of the problems by taking a PHYDAS filtering approach to multicarrier communication.

VII. FUTURE ENHANCEMENT

The RF spectrum is the most wanted resource for future wireless communication. The scarcity of spectrum is a challenging factor to design a wireless communication system with enhanced spectral efficiency. To achieve better spectral efficiency Cognitive Radio environment is introduced. In CR environment unlicensed users are allowed to transmit and receive data over a portion of the spectrum when licensed users are not in use. Even though OFDM offers the number of advantages, but it is not suitable for CR environment, because of large sidelobes of the frequency response of subcarriers in a licensed band leads to interference. Hence FBMC is a good choice for CR environment where filter bank technique is used to suppress the sidelobes.

FBMC will eventually arise as an effective replacement of OFDM and makes it an ideal choice for cognitive radio network.

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