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Implementation of FBMC - OQAM Systems in 5G Communication

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***Abstract*--Because of the versatility it gives through the choice of prototype filters, robustness against asynchronous transmissions, and the lack of a cyclic-prefix requirement, FBMC-OQAM is a promising multi-carrier technology being studied for future wireless communication systems. The performance of FBMC-OQAM is investigated, and generic preamble structures are proposed, followed by the design of mathematical optimization problems to improve the robustness of both estimation approaches against this inherent interference. In the proposed doubly selective channels are used for equalization at the receiver for reducing the noise and it is a time selective and frequency selective channel estimation technique. This method provides better results when compared to state of art methods.**

***Index Terms*-- FBMC-OQAM, prototype filters, generic preamble structures, noise suppression.**

I.INTRODUCTION

Because of its numerous advantages over single-carrier signal transmission, multi-carrier signal transmission has dominated the field of modern wireless communications. Due to the complete orthogonality between sub-carriers and effective transceiver implementation, Orthogonal Frequency Division Multiplexing (OFDM) has been by far the most popular among them, and is thus part of numerous communication protocols, including 4G LTE, WIFI, DVD, and so on.

However, the rectangular pulse shape's strong spectral side lobes, loss of orthogonality in the presence of rapid channel perturbations and carrier frequency offsets, and spectral efficiency loss owing to Cyclic Prefix (CP) limit OFDM's prospects as a modulation technique for next-generation systems.

As an alternative multi-carrier for next-generation systems, the Filter Bank Multi-Carrier (FBMC) [1] is being investigated. It uses a non-rectangular pulse shaping prototype filter with controlled spreading over time and frequency and does not require a CP, meaning that the symbol duration and physical layer delay can be significantly reduced as compared to a CP-based solution.

The most popular variation of FBMC, staggered multi-tone (SMT), also known as FBMC OQAM (Offset Quadratic Amplitude Modulation), sends real-valued symbols from the OQAM constellation at half symbol spacing. The prototype filter ambiguity function now has a more relaxed real-domain orthogonality condition.

FBMC (Filter Bank Multi Carrier) is a multi-carrier modulation technique that has its roots in OFDM.

It's a variation of OFDM that seeks to solve some of the problems, however at the cost of more signal processing.

FBMC makes substantially better use of existing channel capacity and can provide larger data rates within a given radio spectrum bandwidth, indicating that it has a higher level of spectrum efficiency.

Filter bank multicarrier tries to address some of the flaws of OFDM (orthogonal frequency division multiplexing).

OFDM necessitates the use of a cyclic prefix, which is one of its major drawbacks. The cyclic prefix in OFDM is essentially a replica of a transmitted symbol that is attached at the start of the next. This redundancy lowers transmission throughput and wastes electricity.

Another downside of OFDM is that the subcarriers' spectral localisation is poor, which leads to spectral leakage and interference with unsynchronized signals.

OFDM was developed into filter bank multicarrier. FBMC is a technique that employs banks of filters that are often implemented using digital signal processing techniques. Side lobes expanded out on either side when carriers in an OFDM system were modified. Filters are employed to remove them in a filter bank system, resulting in a much cleaner carrier. FBMC modulated systems are more complex than OFDM modulated systems. This occurs as a result of the filter banks exchanging FFT/IFFT modules.

II. RELATED WORKS

The performance of semi-blind, training, and data-aided channel estimate approaches for multiple-input multiple-output (MIMO) filter bank multicarrier (FBMC) systems with offset quadrature amplitude modulation was investigated in [2]. A semiblind MIMO-FBMC (SB-MF) channel estimator is created that takes advantage of both the training symbols and the data symbols' second-order statistical features, resulting in a considerable reduction in the mean squared error (MSE) as compared to its traditional training-based equivalent.

Its performance is compared to that of the least squares MIMO-FBMC (LS-MF) channel estimator based on the interference approximation approach, which estimates the channel solely using training symbols. The proposed and LS-MF estimators' MSEs are characterised using Cramér-Rao lower limits, which show that while the MSE per parameter of the proposed scheme declines with the number of received antennas, it remains constant for the training-based technique.

The suggested SB-MF and LS-MF channel estimators' bit error rates are calculated as a consequence. A data-aided MIMO-FBMC channel estimator based on expectation maximisation is also examined, which performs iterative maximum a posteriori channel estimation in the E-step followed by data detection in the M-step.

In filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) systems, an efficient preamble design based on comb-type pilots (CTP) is used for channel estimation.

Within a certain window, the proposed preamble is analogous to the CTP used in OFDM systems. Thus, for FBMC/OQAM channel estimation, it provides OFDM-like channel estimation with minimal complexity and eliminates inter-symbol interference/inter-carrier interference. Furthermore, the proposed preamble may easily be expanded to support additional antennas (MIMO). The proposed preamble length might be extremely close to that of traditional preamble designs, such as the interference cancellation approach, and the channel estimation with the proposed preamble could achieve good performance both in single antenna and MIMO systems, according to simulation results [3].

The work Multiple-input multiple-output filter bank multicarrier with offset quadrature amplitude modulation (MIMO-FBMC/OQAM) system described by the author in [4] makes use of multiple antennas and offers more benefits than a typical FBMC/OQAM system. However, because to the inherent imaginary interference, traditional preamble-based channel estimation (CE) approaches in MIMO-FBMC/OQAM systems are unable to achieve excellent CE performance and are prone to high peak to average power ratios (PAPR). We focus on efficient preamble design for CE in MIMO-FBMC/OQAM systems in this study, which is motivated by these issues.

The interference weights in the symmetric structure are taken into account in an extended preamble structure that uses the symmetry pattern to cancel interference. The additional interference effect from the centre of the preamble structure is also taken into account because the preamble length has been lengthened. In comparison to current preamble approaches, the simulation results show that the suggested preamble method has a lower PAPR, a better bit error ratio (BER), and a lower mean square error (MSE).

Preamble methods are used to estimate channel parameters in filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) systems. Preamble for channel estimation, on the other hand, reduces the spectrum efficiency of the system. A modified subspace blind channel estimation approach for FBMC/OQAM systems is proposed in this research. The suggested method differs from earlier preamble-based methods in that it uses geographical diversity to introduce data redundancy for blind channel estimation, resulting in good spectrum utilisation.

At high SNRs, the suggested method can significantly enhance root mean square error (RMSE) performance compared to traditional preamble-based methods. The proposed approach in FBMC/OQAM systems in the [5] is validated by simulation results.

III. METHODOLOGY

Based on the time and frequency correlation of distributed pilots, the suggested technique estimates doubly-selective channels. We use an interactive interference cancellation approach to eliminate interference at both the pilot and data positions.

Our method works with every linear modulation scheme, with the exceptions of Orthogonal Frequency Division Multiplexing (OFDM) and Filter Bank Multicarrier Modulation (FBMC). Many articles attempt to estimate the channel impulse response, H, while dealing with a doubly-selective channel.

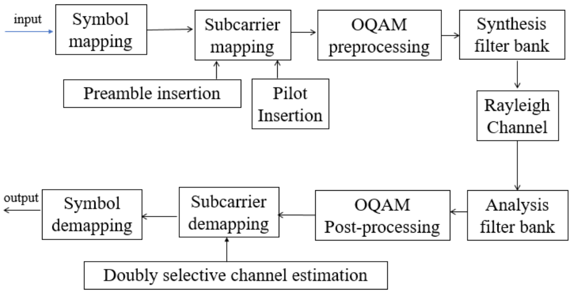

Figure 1: Block diagram of proposed method

However, predicting the impulse response is difficult since the number of active subcarriers in practical systems is always less than the size of the Fast Fourier Transform (FFT), L NFFT. This means that the channel transfer function at the zero subcarriers cannot be reliably measured, and hence the impulse response cannot be accurately estimated as well.

Only a pseudo impulse response may be obtained by applying an inverse Fourier transform to the Lactive subcarriers' channel transfer function, implying a rectangular filter. Even if the genuine impulse response may be, the pseudo impulse response's delay taps are no longer time bound (within the symbol period).

The discontinuity of the channel transfer function at the edge subcarriers causes this, which makes estimate approaches that rely on the assumption that delay taps are time limited problematic. The computational difficulty is another factor to consider. Even if the impulse response can be precisely estimated, the matrix multiplication in (5) must still be evaluated, posing a significant computational challenge.

By explicitly predicting the transmission matrix D, all of these flaws can be eliminated. Because the one-tap channel is frequently approximated using interpolation, this is already happening to some extent in practical systems. The diagonal elements of D correspond to the one-tap channel coefficients.

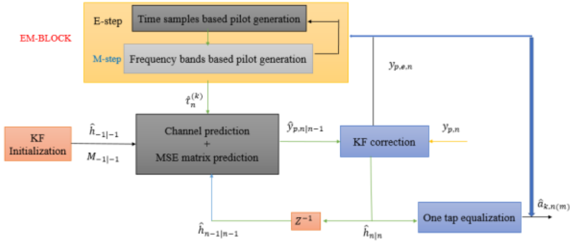

Figure 2: Block diagram for Doubly Selective Channel

Algorithm for Doubly selective channel

1. Transmission matrix D MMSE channel estimation (0).
2. Equalization and quantization with a single button press.
3. Set I = 0 as the initial value.
4. By creating the diagonal of the matrix, interference cancellation, y is obtained.

$$y = diag(transmission\ mat^D(0)$$

5. Improved transmission matrix estimate thanks to less interference at pilot points.
6. Quantization and equalisation have been improved with a single tap.
7. Repeat Step 4 to step 7.

Specifications:

- Input symbols = 16000
- Modulation technology = Quadrature Amplitude Modulation
- QAM modulation order = 16, 64;
- Overlapping Factor = 4
- Number of sub channels =256
- Sub carrier Spacing = 15KHz
- SNR = 70 dB
- Number users = 5
- Number of frames = 10
- Number of symbol per frame = 20

Procedure:

- The main parameters are initialized as per the stated specifications.
- Then the symbols are created based signal generated.

- Then the noisy environment is created and added to symbols.
- Next, these signals are modulated and filtered using filter bank multicarrier technique.
- Then again quadrature amplitude modulation is applied on the filtered signal for increasing the strength of the input signal.
- As a reference with the base method, pilots are added to the signal using IAM method and POP methods.
- For increasing the robustness at the receiver doubly selective channel is applied for equalization of the signals at receiver.
- Then quality metrics is calculated and plotted.

Equations for Proposed Method:
Transmitting Signal to Channel: Algorithm: Channel Estimation using doubly selective channel estimation techniques.
Input: A sequence of 16000 symbols forming a signal obtained from spectrum.
Output: Throughput, MSE, PAPR, BER.
1: Division of signal into packets and calculating power:
1.1: Let us consider the symbols as X_1, X_2 …$X_{16000.}$ Among these each 16000 bits are considered as one packet which are indicated as T_1, T_2….$T_{10.}$
1.2: This symbols are modulated using filter bank multi carrier techniques

$$X_k = fbmc(X)$$

Then this modulated signal is applied to the quadrature amplitude modulation,

$$S_n(t) = I\ cos(2\pi fcX_k) - \ Q\ sin(2\pi fcX_k)$$

Then pilots are added to the modulated signals

$$IAM_n(t) = IAM(S_n(t))$$

$POP_n(t) = POP(S_n(t))$
1.4: Then apply channel on the pilot inserted signals
$Ych\ =\ Rayleigh\ (IAM_n(t)\ ||POP_n(t))$

2: Apply doubly selective channel at receiver:
2.1: Calculation of Interference cancellation, y is given by constructing diagonal of the matrix
$Ydch\ =\ diag\ (diag(Ych))$
2.2: One tap equalization based $Ydch$
2.3: Finally calculating the throughput, MSE, PAPR and BER Values

VI. RESULTS & DISCUSSIONS

BER:

• The Bit error rate (BER) is the number of bit errors per unit time.
The Bit error rate (also BER) is the numbers of bit errors divided by the total number of transferred bits during a studied time interval.
Bit error ratio is a unit less performance measure often expressed as a percentage.

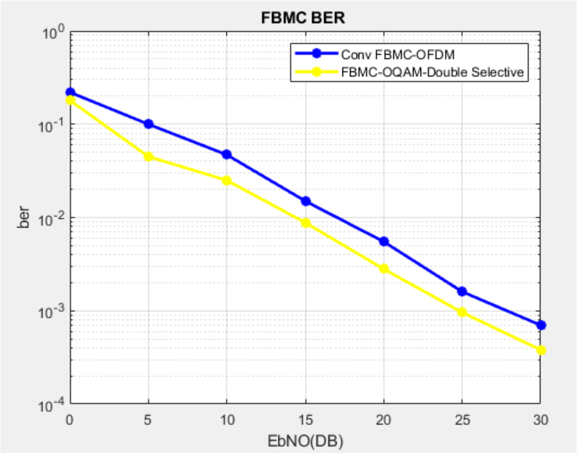

Figure 1: BER Comparison

MSE:
• To calculate Mean Squared Error (MSE) between the two signals, first you have to calculate the difference between the two signals i.e. error signal. Then, calculate the element wise square of this error signal to get Squared Error.

Error = t1-t2; %Error between two signal

$$Sqrd\_err\ =\ error.\hat{}2;$$

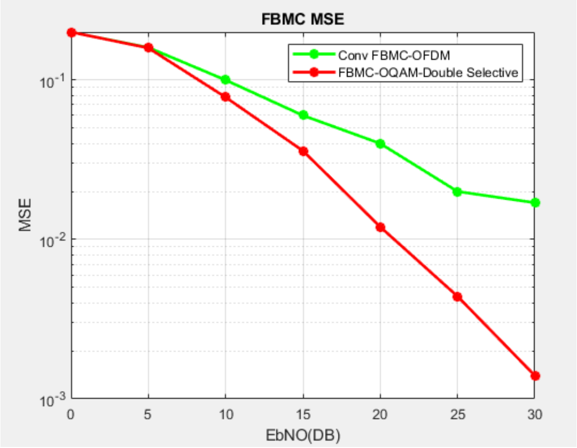

Figure 2: MSE comparison

PAPR:

- The PAPR is the ratio of a sample's maximum power to its average power in an OFDM transmit symbol.
- In simple terms, PAPR is the ratio of peak power to the average power of a signal.

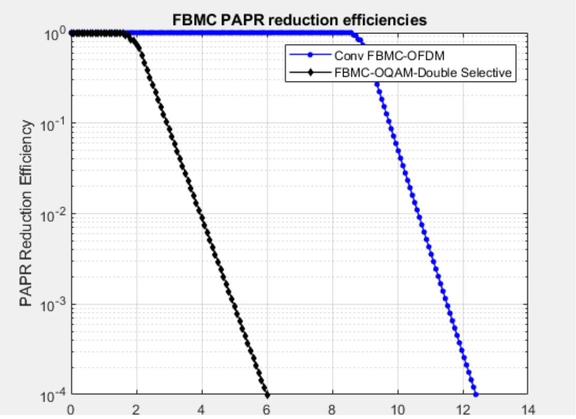

Figure 3: PAPR Comparison

Through Put:

- In general terms, throughput is the rate of production or the rate at which something is processed.
- When used in the context of communication networks, such as Ethernet or packet radio, throughput or The pace at which a message is delivered successfully via a communication link is referred to as network throughput.

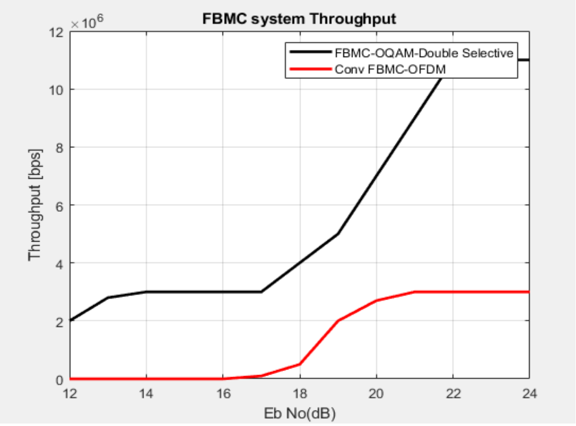

Figure 4: Throughput Comparison

Parameters	Existing Method (dB)	Proposed Method (dB)
BER at 15dB	10.^-1	10.^-2
Throughput at 18dB	0.5	4
MSE at 15dB	10.^-1	Below 10.^-1
PAPR at 4 probability	10.^0	10.^-2

By comparing the existing methods – FBMC OQAM and proposed methods-using doubly selective channels, we came to know that doubly channel estimation provides better results when compared to all the other methods like traditional FBMC, OQAM, and GFDM etc. These results are practically proven and shown in the above comparison table.

CONCLUSION

The design of channel estimation preambles for FMBC-OQAM systems was discussed in this study. Because of the inherent interference encountered during channel estimation, FBMC-performance OQAM's is fundamentally limited. We propose that the available degrees of freedom in preamble design be used to mathematically optimise the preamble for improved noise suppression in IAM and POP channel estimation methodologies, as well as doubly selective channel estimations for PAPR increase.

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