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Design of FBMC System Using Firefly based DFT Spread for Lower PAPR

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Abstract

The filter bank multicarrier employing offset quadrature amplitude modulation (FBMC/OQAM) is a candidate transmission scheme for 5G wireless communication systems. In this project, in order to further enhance the amount of PAPR reduction, a novel pre-coding method based on a pruned Discrete Fourier Transform (DFT) in combination with one-tap scaling. The proposed technique is compared with FBMC-OQAM and SC-FBMC. The involvement of optimization techniques helps in obtaining the global best solutions. In this work, Firefly optimization algorithm (FA) is applied to pruned DFT spread. The swarm intelligence concept works on FBMC system. The results evaluate that the implemented technique i.e. FA-Pruned DFT spread having good PAPR and spectral efficiency with lower latency. The comparison of results is shown using simulated results performed in matlab.

Keywords: FBMC system, OQAM, DFT-Spread, Firefly optimization

1. Introduction

The advanced modulation scheme that provides the information about the different modulation techniques is to specify the benefits of FBMC, OQAM and SC-FDMA. The subclass of multicarrier system is Filter Bank Multicarrier, which is mainly implemented to filter the desired signal. The principle behind this technique is to divide the spectrum into narrow sub-channels in the frequency domain. Another modulation technique is Offset Quadrature Amplitude Modulation, in which the complex valued symbol is considered, which comprises of real as well as the imaginary. It has complex orthogonality without cyclic prefix.

The next generation of wireless systems (5G) should support a large range of possible use cases, for example, low latency communication or machine type communication [1]. This requires a more flexible assignment of the available time frequency resources, not possible in conventional Orthogonal Frequency Division Multiplexing (OFDM) due to its bad spectral behavior. We thus need new waveforms (or derivatives of OFDM), such as windowed OFDM or Universal Filtered Multi-Carrier (UFMC) [2]. Another method with even better spectral properties is Filter Bank Multi-Carrier (FBMC) with Offset Quadrature Amplitude Modulation (OQAM), in short just FBMC, which usually employs pulses that are localized in both, time and frequency, at the expense of replacing the complex orthogonality condition with the less strict real orthogonality condition [3]. Although FBMC behaves in many aspects similar to OFDM, some techniques become more challenging due to the imaginary interference, for example, channel estimation [4] or Multiple-Input and Multiple-Output (MIMO) [5]. There exist many works which combine MIMO and FBMC but most of them have serious drawbacks, such as [6] which relies on channel information at the transmitter or [7] which requires high computational complexity. A more elegant method to combine MIMO with FBMC is to spread symbols in the time (or frequency) domain, which allows us to cancel the imaginary interference. Authors in [5] use a Fast Fourier Transform (FFT) spreading which, however, has the disadvantage of residual interference and increased complexity due to the additional FFT. A better solution is to spread symbols with a reduced Hadamard matrix because it requires no multiplications so that the additional complexity becomes very low. Such approach was first suggested in [8] and later applied by the same authors in [9] to combine FBMC with Alamouti's space-time block coding. After the spreading and despreading process, we can straightforwardly apply all MIMO methods known in OFDM, resulting in the same MIMO complexity.

2. Related Work

The input signal separates the array of band-pass filter into multiple components. The components are attenuated differently and recombine the modified version of the original signal. In such a multi carrier system, symbols are mainly rectangular in shape then it is transmitted in the form of time frequency grid. It comprises of high subcarrier spacing which leads to low latency transmissions. The increase in subcarrier leads to effective bandwidth. The multipath delay spread provides the smaller subcarrier spacing. The Fifth Generation of mobile network systems leads to flexible subcarrier spacing. The channel delay spread is low in densely arranged heterogeneous networks it mainly uses the multiple-Input and Output beam-forming and high carrier frequency ranges. The Out-Of-Band emission is low, as the guard band arranged between different users is small.

Multicarrier Modulation: It is a technique which transmits the data along closely spaced system over multiple carriers. Its advantage includes interference, narrow band fading and multipath effects. The transmitting data stream is divided into various lower data rate streams.

CP-OFDM: The cyclic prefix is the copy of the transmitted signal which is provided at the beginning of the each block and it continues in the cyclic manner, it leads to redundancy in the guard band.

Block Spread FBMC - OQAM: The drawbacks of the FBMC-OQAM are overcome as in-order to restore orthogonality the symbols are spread in both time and frequency. It mainly utilizes FFT spreading, as it uses the Walsh–Hadamard spreading. It is propagated by fast Walsh-Hadamard transform and has it is implemented without additional complexity. The simple one-tap equalizers is implemented, as the signal is filtered by the order one.

CDMA Transmission using Complex OQAM: The OQAMCDMA system consists of complex valued data symbols in which transmission allows the reduction of the multiple access control. Walsh-Hadamard spreading code is required for the transmission of complex symbols in OQAM-CDMA, in-order to guarantee the complex.

3. Pruned DFT Spread FBMC

The basic idea of pruned DFT spread FBMC can be best explained by the underlying basis pulses. Precoding by C transforms the basis pulses $g_{l,k}(t)$ into $\tilde{g}_i(t)$, described by. Note that the size of C and thus the number of new basis pulses $\tilde{g}_i(t)$ depends on the precoding method. Figure 2 shows the power of the basis pulses and illustrates a step by step construction of our method, starting from a conventional OFDM system. Figure 4.2 (a) shows OFDM [10] for N_{FFT} = 512, L = 16 and K = 1. The underlying basis pulses are frequency shifted rectangular functions. In terms of transmit power, however, a frequency shift has no influence so that only one basis pulse can be observed in Figure 1 (a). All the basis pulses are added together with some random weights (the data symbols), so that, according to the central limit theorem, the signal distribution at one time sample approaches a Gaussian distribution. This explains the poor PAPR of OFDM. In SC-FDMA , see Figure 1 (b), DFT precoding by WL transforms the basis pulses of a conventional OFDM system in such a way that a single carrier transmission is emulated. In particular, the basis pulses are more localized in time and even though they still overlap the signal at one time sample is mainly determined by 1-2 basis pulses. Thus, as long as the data symbols are not Gaussian distributed but chosen from a limited symbol alphabet such as a Quadrature Amplitude Modulation (QAM) signal constellation, the PAPR will be better than in OFDM.

Unfortunately, SC-FDMA has the same poor OOB emissions as OFDM. This can easily be deduced by considering the transmitted signal at the edge positions, that is, tF = 0 and tF = 1. Similar as in OFDM, the underlying rectangular pulse cuts through the signal so that, at the edges, the signal abruptly jumps to zero without a smooth transition. Only basis pulses close to the edge positions are affected by this cutting effect. Thus, setting the edge basis pulses to zero reduces the OOB emissions and is indeed the basic idea of zero-tail DFT-spread- OFDM [11]. However, authors in [12] remove only a few basis pulses to keep the overhead low. To remove L/2 basis pulses from the set that is, DFT spreading matrix $\mathrm{W_L}$ is replaced by a pruned DFT matrix $\mathrm{W}_{\mathrm{L}\times\mathrm{L}/_2}$. This step can also be interpreted as setting half the input samples of a conventional DFT to zero. In contrast to zero-tail DFT-spread-OFDM, our method does not impose any overhead because we also reduce the time spacing by a factor of two, as typically done in FBMC-OQAM. This also explains why we remove exactly L/2 basis pulses. The result of our approach is shown in Figure 1 (c). To combat multipath delays, zero-tail DFT-spread-OFDM utilizes the zero-tail overhead in a similar way as the CP in OFDM. This reduces the spectral efficiency. Again, we choose a different approach, namely, we transform the OFDM system into an FBMC system so that the channel induced interference becomes very low and can often be neglected [2]. As discussed above an OFDM system can easily be transformed into an FBMC system simply by multiplying the IFFT output with a prototype filter p(t), as shown in Figure 1.2 (d). In the last step, see Figure 1.2 (e), the individual basis pulses are scaled up so that the sum transmit power is approximately constant over the transmission time. This final step completes our novel pruned DFT spread FBMC transmission scheme. Figure 2 also explain why complex orthogonality is approximately restored. To be specific, DFT spreading reduces the time duration of the underlying basis pulses so that each basis pulse experiences an approximately flat prototype filter. Such system reflects a conventional SC-FDMA transmission and is clearly orthogonal. Orthogonality relies on the approximation that the prototype filter is flat over the duration of the basis pulse. This approximation becomes tight for L → ∞ because the time duration of each individual basis pulse approaches zero. However, in practical systems, this will not be the case.

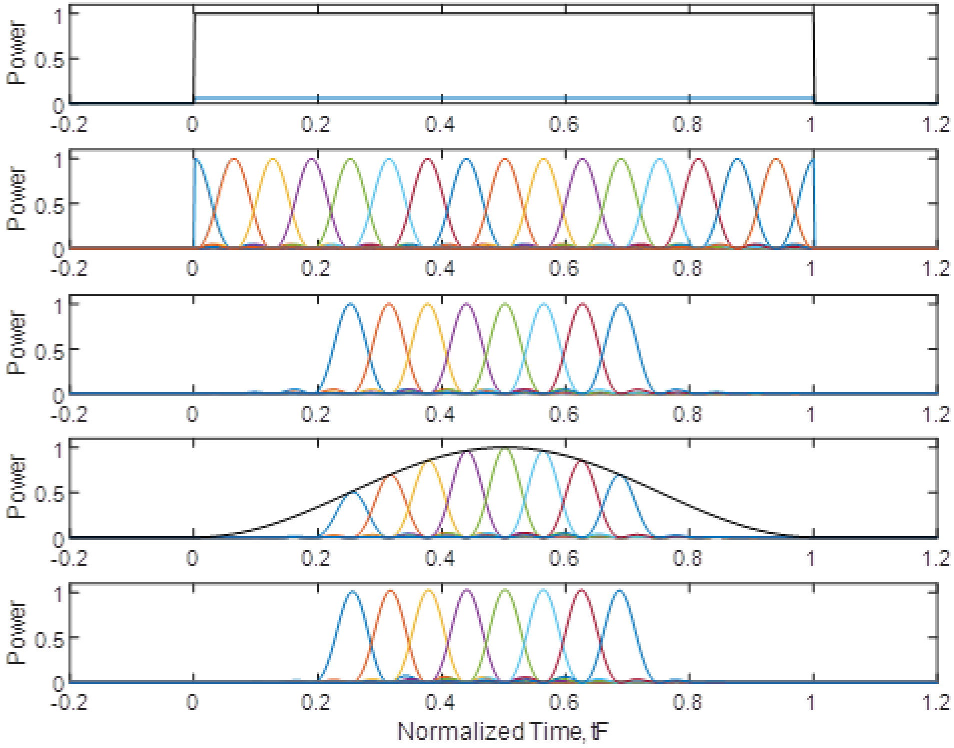

Fig.1. Power of the underlying basis pulses in time, that is, $\left|g_{l,k}(t)\right|^2$ and $|\tilde{g}_i(t)|^2$ for NFFT = 512, L = 16 and K = 1; (a) conventional OFDM; (b) conventional SC-FDMA, that is, precoding by DFT matrix W_L; (c) only L/2 = 8 basis pulses, close to the center, are utilized, that is, W_L is replaced by a pruned DFT matrix, $W_{L\times L/2}$; (d) multiplication by a window/prototype filter p(t) so that OFDM transforms into FBMC; (e) one-tap scaling of the basis pulses so that the transmit power is approximately constant over time.

A. Latency

In conventional FBMC there exists a large overlapping of symbols in time and the transmission requires a long ramp-up and ramp-down period. In pruned DFT spread FBMC, on the other hand, pre-coding by C_f shapes the transmitted signal in such a way that the overlapping in time is very low and the ramp-up and ramp-down period dramatically reduced. In pruned DFT spread FBMC, on the other hand, the main energy is concentrated within overlapping factor O = 0.5. Thus, reducing the overlapping factor to O = 0.8 has only a minor influence on the SIR.

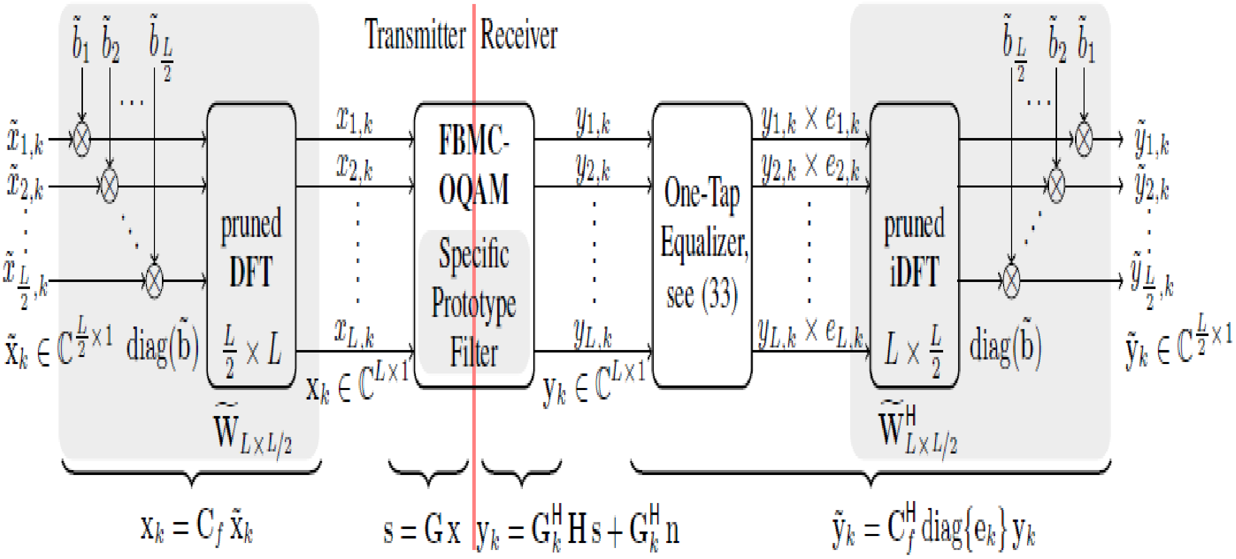

Fig2. Block Diagram of Proposed Model

B. Computational Complexity

The computational complexity of our transmission scheme is approximately two times higher than in conventional SC-FDMA. DFT spreading in SC-FDMA has a complexity of $L\log L$, while one-tap scaling in combination with a pruned DFT requires approximately $\frac{L}{2} + L\ \log\frac{L}{2}$ multiplications. Finally, the reduced time spacing in FBMC implies that all the calculations have to be applied two times as often as in SC-FDMA (no Cyclic Prefix)

4. FA in DFT Spread FBMC

Fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex. Firefly's attractiveness is proportional to the light intensity, and their attractiveness decreases as their distance increases. Thus for any two flashing fireflies, the less bright one will move towards the brighter one. If there is no brighter one than a particular firefly, it will move randomly.

Algorithm

The implementation procedure of the proposed firefly algorithm (FA) can be stated below:

Step 1: Generate the initial population of fireflies $\{x_1, x_2, \dots \dots . x_n\}$

Step 2: Calculate brightness value for each firefly

Step 3: Update the step of each firefly.

Step 4: Fireflies intensity are given as $\{I_1, I_2, \dots \dots . I_n\}$.

Step 5: Rank the fireflies and find the current best

Step 6: Move each firefly I towards other brighter fireflies.

Step 7: Stop when criterion is fulfilled; otherwise go to Step 2

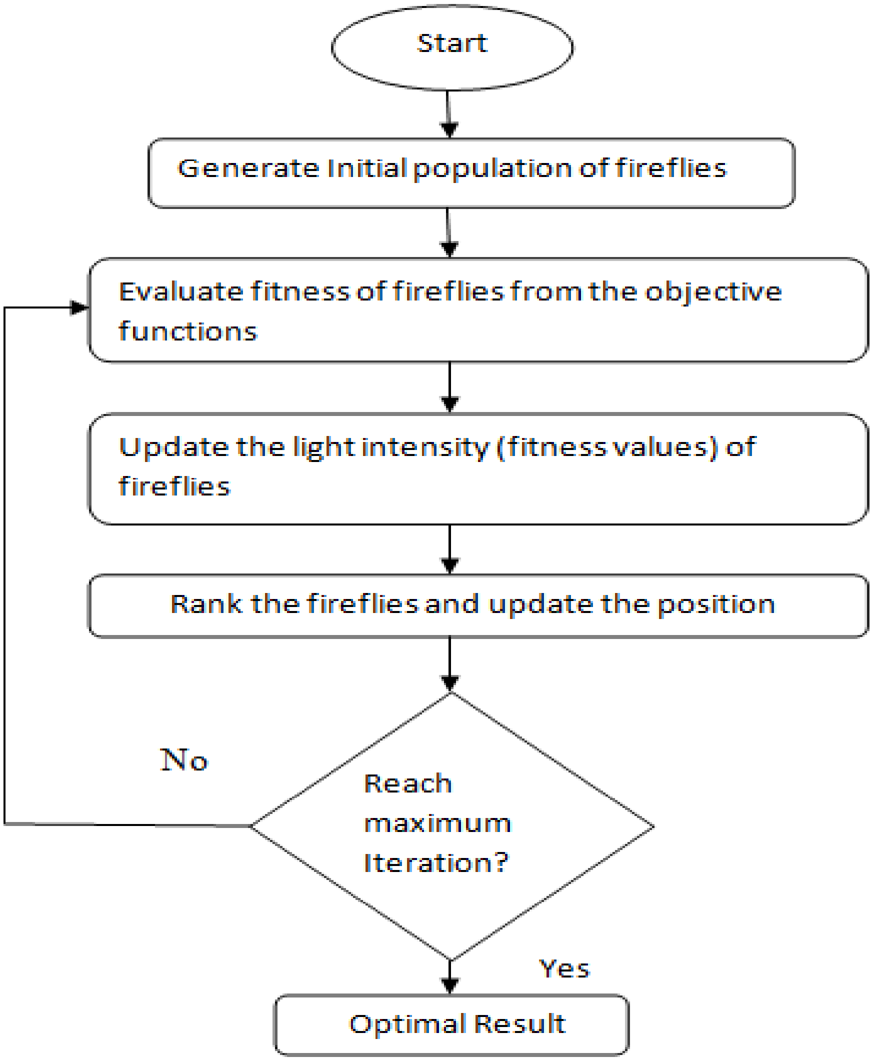

Fig3. Flowchart of Firefly Algorithm

The Firefly optimization technique is used to evaluate and identify the best subcarriers that need to be given for transmission of data. This help in identifying the source of low power consumption way of transmitting the signal. Hence the optimized DFT spread FBMC has lower PAPR compared to the DFT Spread FBMC.

4. Results and Discussion

The performance of proposed optimized purned dft spread FBMC is evaluated using matlab tool. In which the parameters evaluated are peak average power ration, bit error rate, throughput, power spectral density. The parameters evaluated are compared with other system and other techniques like using cyclic prefix and not using cyclic prefix. The firefly optimization algorithm that is used to identify the best subcarriers is having better performance in terms of parameters which are evaluated.

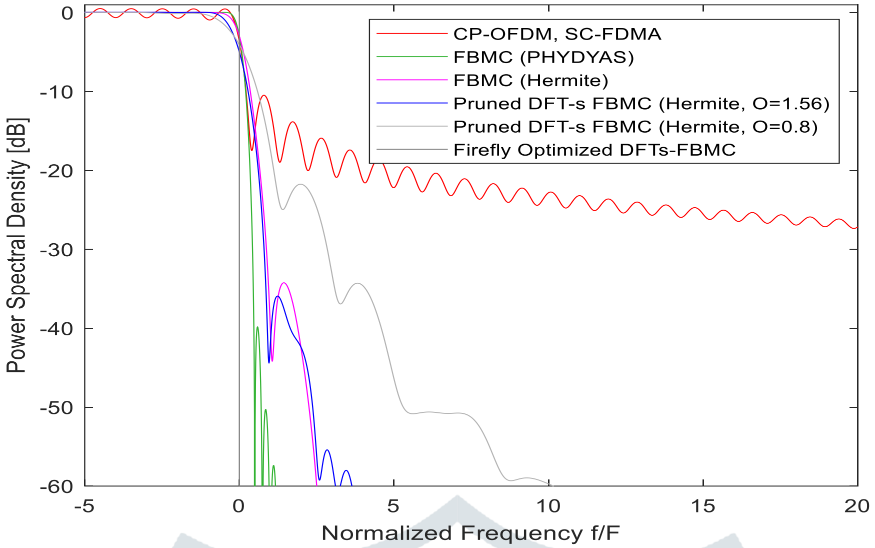

Fig4. Frequency w.r.t Power Spectral Density

In fig4 the normalized frequency is shown at different power spectral density is shown. For PSD -60dB the Normalized frequency is around 3.5Hz to 4Hz for firefly optimized DFT FBMC, whereas the normalized frequency for CP-OFDM and SC-OFDM is 20H at -28dB.

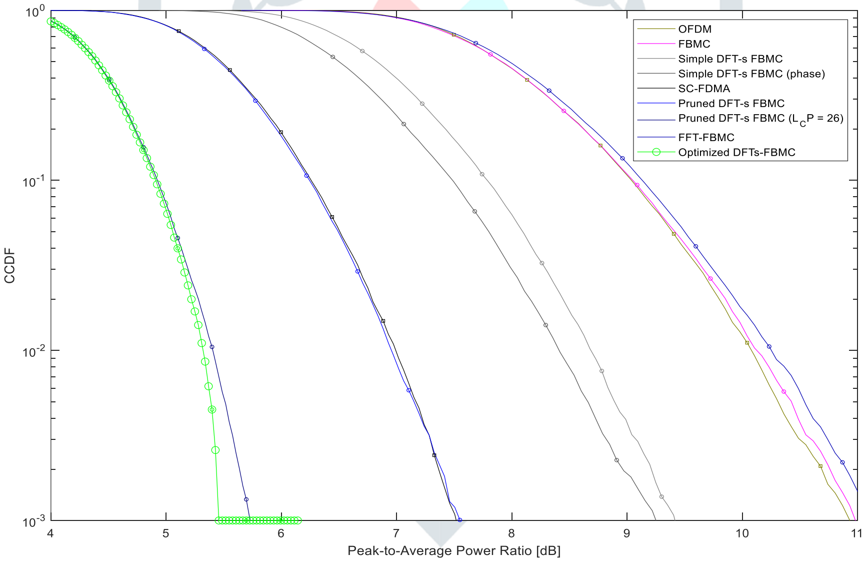

Fig5. PAPR using different methods

The PAPR value is been reduced to 5.5dB for optimized DFT FBMC and it is 6db lesser when compared with FFT FBMC and FBMC systems. The PAPR value obtained for Pruned DFT-FBMC with a cyclic prefix of 26 is 5.8dB, in the absence of CP the PAPR obtained is 7.5dB. Due the presence of optimization technique the PAPR value is reduced to some extent.

Table1. PAPR for different methods

Technique	OFDM	FBMC	Simple DFT FBMC	SC-FBMC	FFT FBMC	Pruned DFT FBMC/CP=26	**Optimized pruned DFT Spread FBMC**
PAPR (dB)	10.9	11	9.5	9.3	11.7	7.5/5.8	**5.5**

The bit error rate obtained for various signal to noise ratio using different techniques is shown in fig6. Let us consider a SNR of 20dB and tabulate the values of BER.

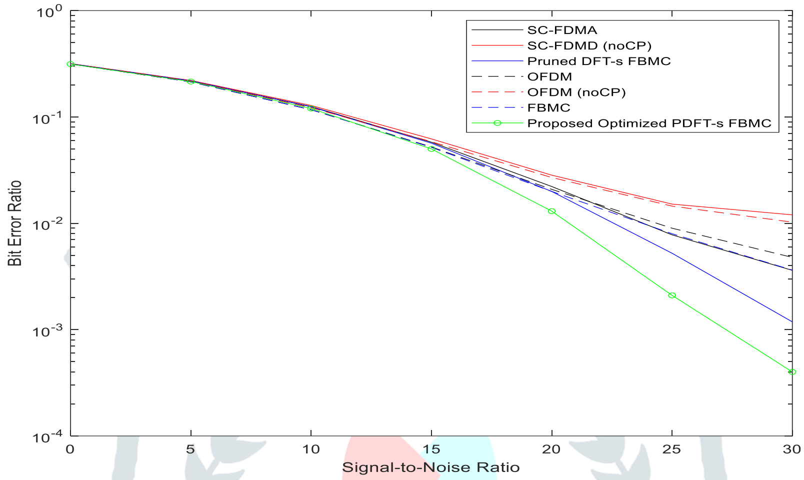

Fig6. Bit error rate using different approaches

Table2 presents the evaluated values of BER for a particular SNR value to compare the proposed optimized pruned DFT and simple Pruned DFT FBMC.

Table2. BER for SNR 20dB

Technique	SC-FDMA	SC FDMA no CP	OFDM	OFDM no CP	FBMC	Pruned DFT FBMC	**Optimized pruned DFT Spread FBMC**
BER	$10^{-1.7}$	$10^{-1.72}$	$10^{-1.74}$	$10^{-1.76}$	$10^{-1.79}$	$10^{-1.85}$	$10^{-2.0}$

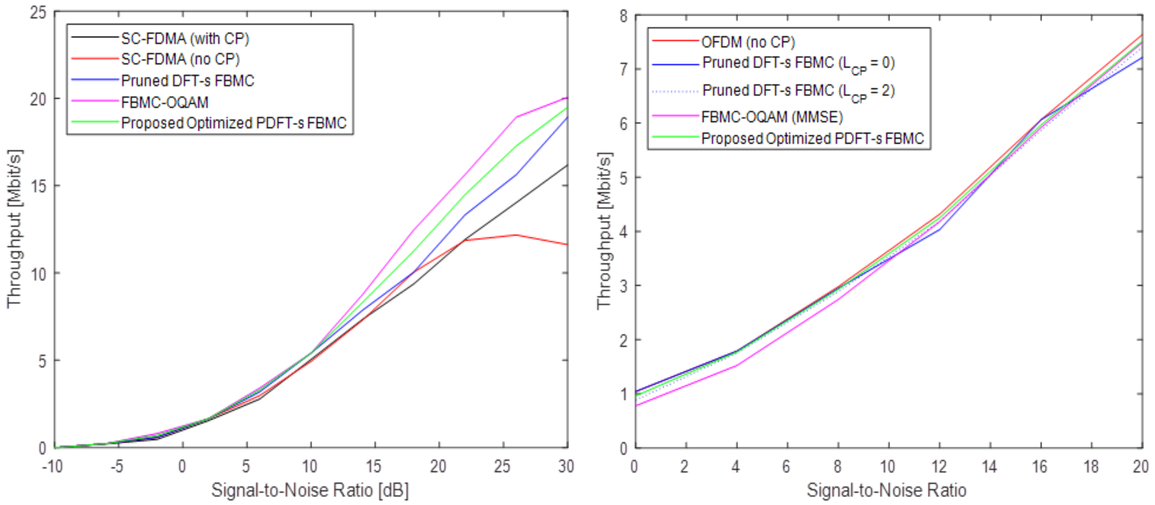

Fig7. Throughput w.r.t SNR

The throughput i.e. number of bits transmitted are evaluated based on the signal to noise ratio. The proposed optimized pruned DFT S-FBMC having good transmission rate and is shown in fig7.

5. Conclusion

Proposed Firefly optimized pruned DFT spread FBMC transmission scheme outperforms SC-FDMA in many aspects. It is more robust in doubly-selective channels, requires no CP and has much lower OOB emissions. Furthermore, if the channel is approximately frequency-flat, our method even outperforms conventional FBMC because MIMO can be straightforwardly employed. Potential applications of pruned DFT spread FBMC include uplink transmissions in wireless communications as well as M2M communications, where the good time-frequency localization guarantees that no sophisticated synchronization between users is necessary.

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