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# Comparative Study of Pruned DFT Spread and PPN FBMC-OQAM System for 5G Communications Under Line of Sight Conditions

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***Abstract:***

*The 5G use cases belong to the Ultra-reliable and low latency category require very good spectral efficiency, ultra low latency, lower PAPR and very high throughput. A single technology can not satisfy all the 5G requirements, always a tradeoff between the requirements and the filtering technique used. The existing Cyclic Prefix based OFDM has certain inherent disadvantages such as larger PAPR, less spectral efficiency. Single Carrier FDM (SC-FDM) is used in the uplink of the LTE system which has an advantage of Lower PAPR, but it has all other the disadvantages exhibited by OFDM. An innovative method to overcome these disadvantages, that is Pruned DFT spread FBMC with one tap scaling which is proposed by Ronald Nissel et.al where it combines the benefits of FBMC-OQAM and SC-FDM systems. This technique provides the benefit of lower PAPR similar to SC-FDM, very low latency, and larger throughput. 5G applications like autonomous vehicle driving, smart city services like - traffic maintenance, smart energy, and smart utility services along with rural connectivity can be supported by using this Pruned DFT Spread FBMC-OQAM system. In this work, Pruned DFT Spread FBMC-OQAM (PDFTSFBMC) system is simulated and tested against Outdoor line of sight (LOS) fading profiles such as Rural Line of Sight (RLOS), Urban Approaching Line Of Sight (UALOS), and Highway Line of Sight (HLOS), which is a necessary component for a for fulfilling the key necessities for 5G communications.*

***Keywords—*** *Bite Error Rate, HLOS, Pruned DFT, RLOS , UALOS*

## I. Introduction

The future generation cellular network systems revolutionize our daily lives with ultra high speed data applications like UHD, 3D video streaming, ultra low latency ultra reliable applications like remote surgeries, Massive Machine-to-Machine(M2M) connectivity with high reliability for Industries, smart cities[1-4]. Currently the 5G standards working on not only high spectral efficiency and data rates but also accommodating different applications such as Industrial Internet of Things (IIoT), tactile internet, vehicle-to-vehicle communications(V2V), which needs the introduction of innovative technologies that are different from the existing ones, which is shown in figure 1.

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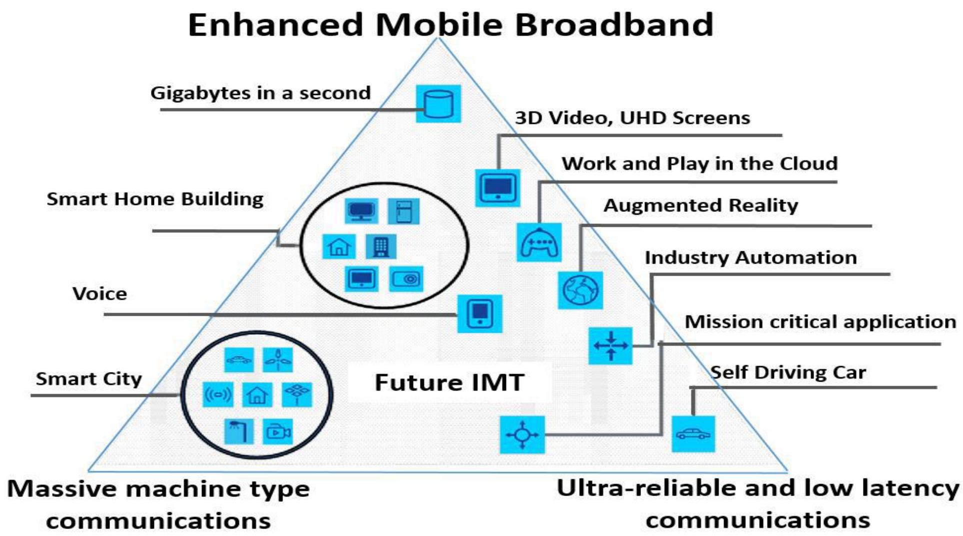


Figure 1. Application Areas and Requirements of 5G [5]

The orthogonal frequency division multiplexing (OFDM) modulation has been very quite extensively used in Long Term Evolution (LTE) and other wireless standards due to its low implementation complexity by the usage of fast Fourier transform (FFT). It also nullifies most of the multi path channel impairments by the introduction of redundant symbols known as the cyclic prefix (CP) at the transmitter [6]. However, the use of rectangular pulse shape filter causes a significant spectral leakage, in turn causes out-of-band emissions and results into large guard bands at the edges of the spectrum, which leads to spectral inefficiency.

The 4G waveform OFDM [7] have the disadvantages of higher PAPR, higher latency, lower spectral efficiency and no support for asynchronous communications. To overcome some of the above mentioned OFDM limitations, Filter bank multi carrier with Offset-Quadrature Amplitude Modulation (FBMC-OQAM) system [8-16] are proposed and evaluated, even though it has a limitation of higher latency and implementation complexity. To Improve the PAPR performance of OFDM, in LTE uplink Single Carrier Frequency Division Multiplexing (SC-FDM) technique [17] is used. Conventional Poly Phase Network (PPN) based FBMC system, inherently introduces the latency due to its structural design with delay elements. An innovative technique of pruned DFT spread FBMC (PDFTSFBMC) is proposed in [18] to fulfill all essential requirements of 5G communications. In order to achieve the lower latency, and lower PAPR, Pruned DFT Spread FBMC OQAM system is proposed [18]. In this technique, pre-coding, spreading are used before the IFFT and one tap scaling method instead of PPN structure for improving the complex orthogonality as well as reducing the implementation complexity.

## II. Proposed Pruned DFT Spread FBMC OQAM System

The current PHYDYAS filter based in the FBMC systems are complex to implement due to the use of Poly Phase Network(PPN) method and in the proposed system it is replaced by pruned DFT spreading [18], where zeros are set for half of the DFT inputs and after that one tap scaling is used. This pruned DFT spreading method is thoroughly discussed illustratively and its operation is also explained in [18][19]. In this work, despite different kind of prototype filters [20] are available, due to the poor time localization issue of the PHYDYAS filter [21], Hermite filter [22-23] based prototype filters are used. The proposed pruned DFT Spread FBMC system block diagram is shown in Figure 2.

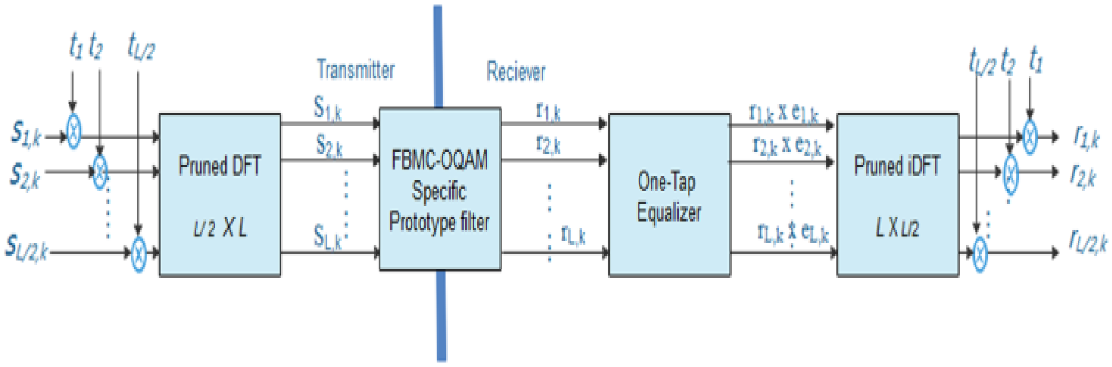


Fig 2: Block diagram of PDFTSFBMC system [24]

In Pruned DFT Spread system, pre-coding is carried out for shaping the transmitted signal and which resembles as a complete rectangular shape that can be translated in to reduction of the latency. The outcome of the pruned DFT block $s_{1,k}, s_{2,k}, \ldots s_{L/2,k}$ is similar to CP-OFDM based system [25]. This output is multiplied with a truncated Hermite prototype filter and thus the FBMC-OQAM system is developed. At the receiver, $r_{1,k}, r_{2,k}, \ldots r_{L/2,k}$ are passed through the one tap equalizer, which perfectly reconstructs the original DFT filtered signal and it is $r_{1,k} x\, e_{1,k}, r_{2,k} x\, e_{2,k} \ldots, r_{L/2,k}\, x\, e_{L/2,k}$.

*Line of Sight Fading Profiles*

Data transmissions over wireless channels undergo different kinds of multipath fading conditions and different channel models are used to assess the quality of transmission. This work is an extension of the previous work [24] which is done for Non-line of sight conditions to make it complete analysis for both LOS and NLOS conditions. To test the reliability of data transmission through the environment, three fading profiles namely Rural Line of Sight (RLOS), Highway Line of Sight (HLOS), and Urban Approaching Line of Sight (UALOS) [26-27], this maps to low, medium, high delay spreading factors respectively.

## III. Simulation Results

The proposed Pruned DFT spread FBMC-OQAM system with various channel models are simulated using MATLAB software (MATLAB 19b). Table 1 captures various input simulation parameters used for the pruned DFT Spread FBMC System.

Table 1: Input Parameters for the Simulations

| **Parameter Name** | **Value** |
|---|---|
| Number of subcarriers (L) | 256 |
| Size of FFT | 512 |
| QAM modulation order | 64 |
| Order of MIMO | 2X2 |
| Velocity in RLOS profile | 30Kmph |
| Velocity in ULOS profile | 60Kmph |
| Velocity in HLOS profile | 120Kmph |

### A. BER Analysis

For any wireless communication system, BER performance analysis is critical to find out the quality of the system. It provides the measure of error rate happened during the transmission of the data bits through the communication system. In this work, comparative Bit Error Rate (BER) analysis is done for three fading conditions RLOS, HLOS, and UALOS with 64QAM modulation. Thus

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simulated BER performance for various fading conditions such as RLOS, HLOS, and UALOS is shown in the figures 3, 4 and 5 respectively.

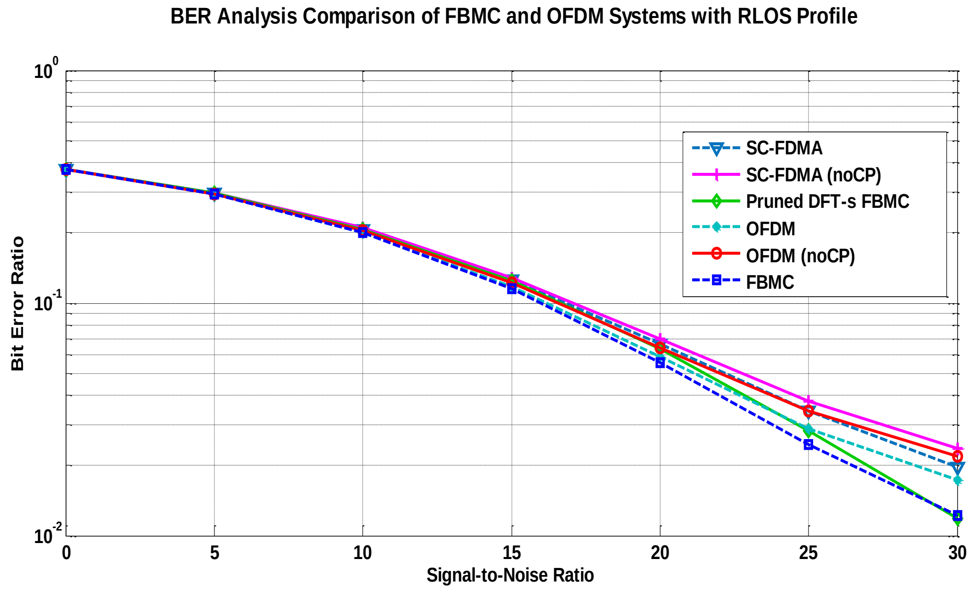


Fig 3: Comparative BER analysis of the RLOS fading condition with 64 QAM

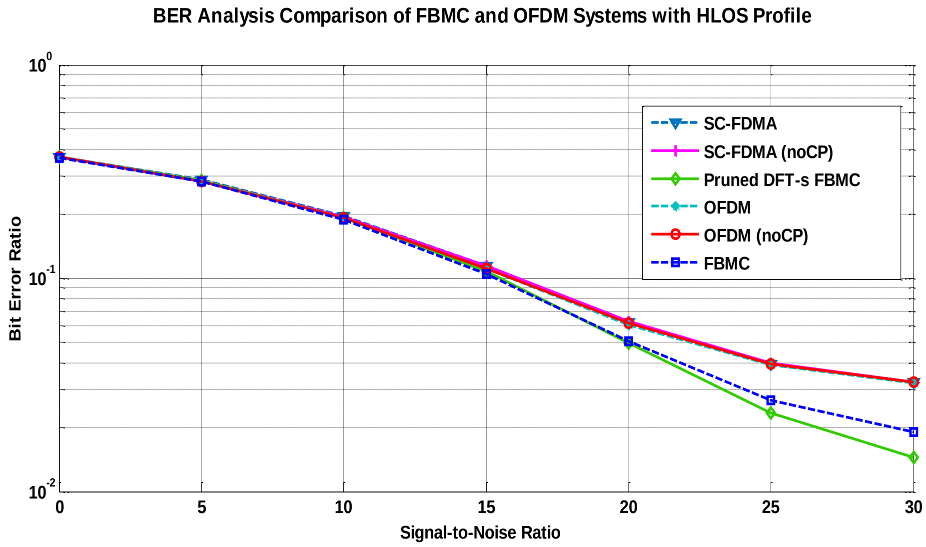


Fig 4: Comparative BER analysis of HLOS fading conditions with 64 QAM

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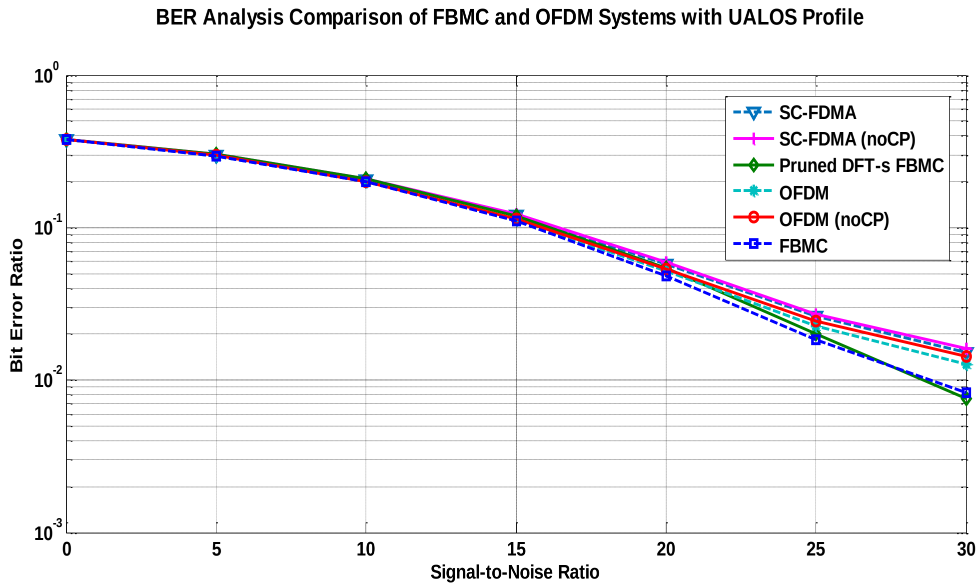


Fig 5: Comparative BER analysis of UALOS fading condition with 64 QAM

From figures 3, 4 and 5, the lower BER can be observed for the FBMC and pruned DFT-S FBMC systems when compared to OFDM (CP) and SCFDM (with and without CP) systems under rural, highway and urban fading conditions. On highways with speed of 120 Kmph pruned DFT Spread FBMC is much better than OFDM, FBMC and SCFDM systems. The results indicate that the pruned DFT spread FBMC OQAM systems are having lower BER values under HLOS profile compared to other systems and more suitable for vehicular communications mentioned in [28-30].

### B. *Throughput Analysis*

The throughput of a system is depends on the channel characteristics as well as the channel immunity towards noise and typically defined as number of successfully transmitted bits and its measurement unit is bits per second. The throughput performance of FBMC and OFDM systems are analyzed with 64QAM modulation and 256 sub carriers. For these input parameters, the theoretical maximum that can be achieved is 21.8 Mbps. In this work, as shown in the figures 6, 7 and 8, three realistic fading condition profiles, namely RLOS, HLOS, and UALOS were considered for the throughput comparisons of various systems.

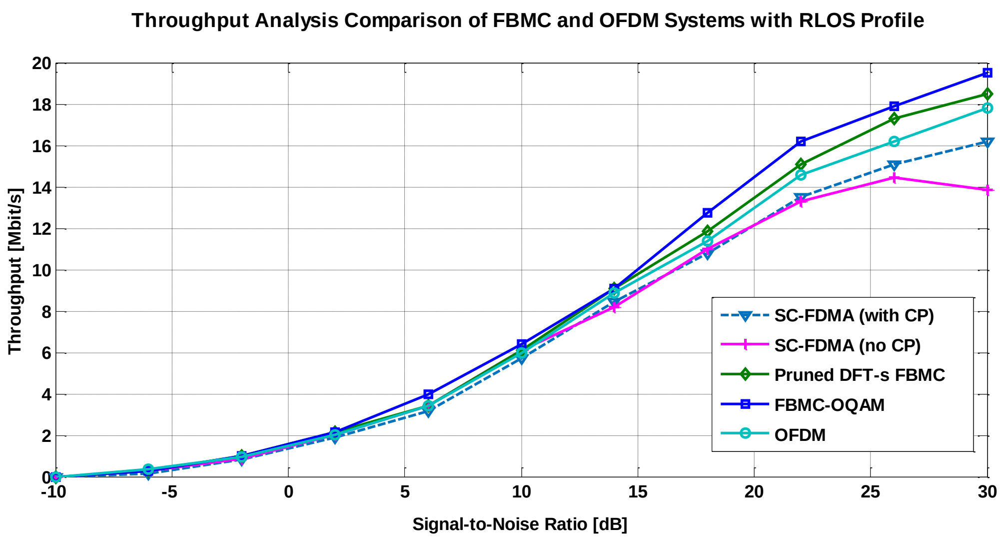


Fig 6: Throughput analysis under RLOS fading conditions

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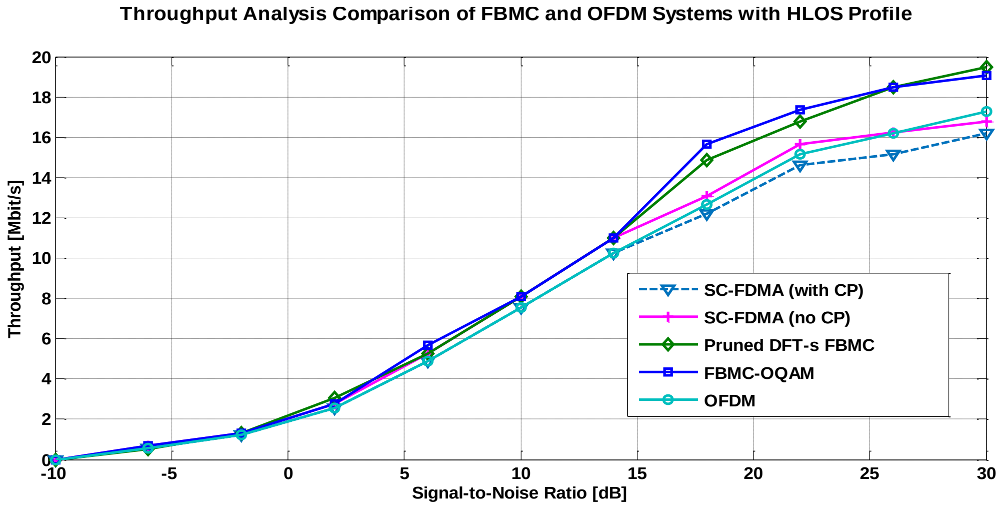


Fig 7: Throughput analysis under HLOS fading conditions

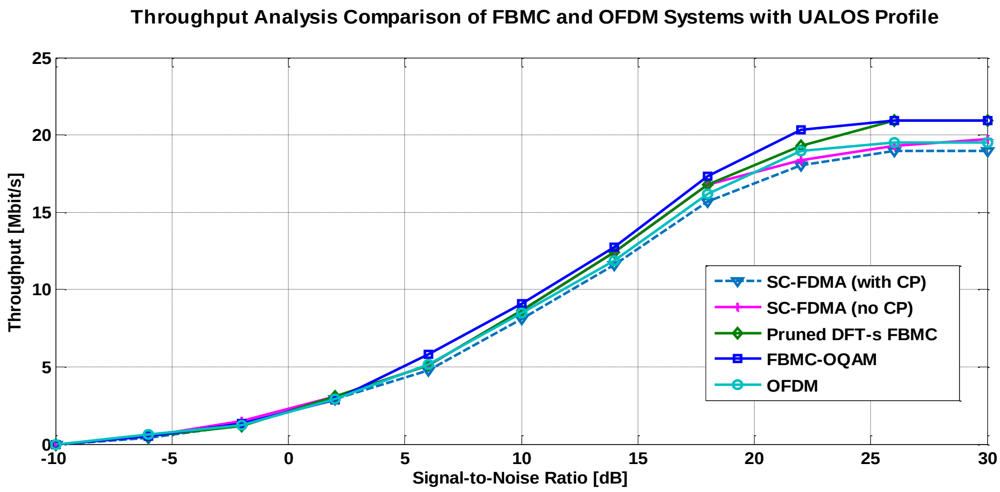


Fig 8: Throughput analysis under UALOS fading conditions

From figure 6, it can be concluded that for the rural line of sight conditions FBMC-OQAM system attains a maximum throughput value of 19.8 Mbps, pruned DFT spread FBMC system achieves 18.5 Mbps throughput, where as the OFDM reaches a maximum throughput values of 17.8 Mbps. This shows a clear edge for FBMC based systems. Figure 7 indicates, under a typical Highway line of sight fading conditions , pruned DFT spread FBMC based systems outperform other systems by reaching a maximum throughput value of 19.7 Mbps, where as the maximum throughput values of FBMC and OFDM system reaches 19.2 Mbps and 17 Mbps respectively. Another observation is that OFDM and SCFDM systems throughput performance drops at higher SNR values. In the other typical case of urban approaching line of sight conditions, both pruned DFT spread FBMC and FBMC-OQAM systems reaches throughput values of 21.6 Mbps, which is nearing the theoretical maximum and the same is observed in figure 8. In this case, OFDM and SCFDM systems reach throughput values of 19 Mbps. It can be safely come to conclusion that the proposed pruned DFT spread FBMC systems are capable of bettering the BER and throughput performance compared to OFDM systems and similar to traditional FBMC systems.

## IV. CONCLUSION

In this work, both FBMC and OFDM based systems are simulated and performance is comparatively analyzed in terms of BER and throughput. The results indicate that the performance of

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Pruned DFT Spread FBMC system is better-quality than the OFDM and SCFDM systems under various LOS fading conditions. It is noteworthy to talk about the reduced implementation complexity in the Pruned DFT case, in contrast to the conventional FBMC-OQAM, which uses PPN. So, the results show the superiority of the Pruned DFT Spread FBMC systems over other systems for the highly reliable and low latency applications of 5G and IoT, where LoS conditions are prevailing in the vehicular communications.

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