



## MODIFIED DFT SPREAD FILTER BANK MULTI CARRIER ACCESS WITH POLY PHASE NETWORK

Kommabatla Mahender<sup>1</sup>, K.S Ramesh<sup>2</sup>, Tipparti Anil Kumar<sup>3</sup>

<sup>1</sup> Assistant Professor, Department of Electronics and Communication Engineering,  
Sumathi reddy institute of technology for women, Ananthasagar, Telangana, India

<sup>2</sup> Professor, Department of Electronics and Communication Engineering, KL  
University, Vaddeswaram, Andhra Pradesh, India

<sup>3</sup> Professor, Department of Electronics and Communication Engineering, CMR  
institute of Technology, Kandlakoya, Hyderabad, Telangana, India

<sup>1</sup>kmsharma2@yahoo.co.in, <sup>2</sup>dr.ramesh@kluniversity.com,  
<sup>3</sup>[tvakumar2000@yahoo.co.in](mailto:tvakumar2000@yahoo.co.in)

Corresponding author: <sup>1</sup> kmsharma2@yahoo.co.in,

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### Abstract

*This paper proposes a novel precoding method using the pruned DFT (pDFT) spread FBMC along with the Poly-phase network (PPN). This method outperforms the pruned DFT spread FBMC in many aspects and also avoids Inter symbol Interference. This technique has advantages of both FBMC-Offset Quadrature amplitude modulation (OQAM) and Single carrier Frequency division multiple access (SC-FDMA). Proposed technique has same PAPR as SC-FDMA and has very low out-of-band emissions and does not need cyclic-prefix. This method reduces latency, computational complexity and complex orthogonality is restored. A comparative performance is also evaluated between pDFT-FBMC PPN and other multicarrier schemes and we observe that pDFT-FBMC PPN is better than other schemes. Simulation is performed by using Matlab.*

**Keywords:** FBMC, Poly-phase network, FBMC-OQAM

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### I. Introduction

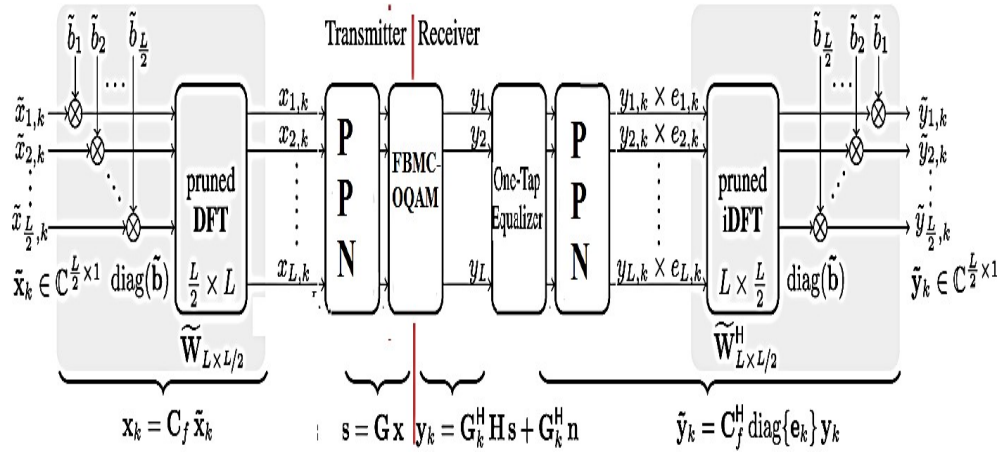
Pruned DFT (pDFT) spread FBMC proposed in [I,VIII] was able to provide a number of desirable advantages like low values of PAPR, OOB and latency and all these features were obtained by the expense of computational complexity and imaginary interference on complex data. The computational complexity of pruned DFT was two times larger than SC-FDMA. The proposed technology in this paper outperforms pruned DFT and also provides a comparative analysis with the pruned DFT in features like PAPR, OOB, BER analysis, Power spectral density,

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Throughput, and computational complexity. The structure of pruned DFT is employed with a modification of new block of Poly-phase-network (PPN). Similar block is also added at the receiver end. The functionalities of remaining blocks is same as proposed in [I]

## II. Block illustration of proposed structure

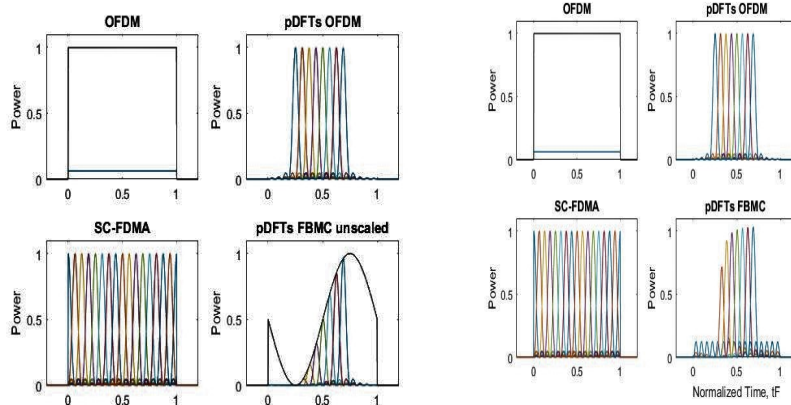
The proposed technology of pDFT spread FBMC with poly-phase network is as shown in figure



**Fig 1-Block diagram of pDFT FBMC with PPN**

### Pruned DFT/iDFT

As proposed in [V,VIII] we use a DFT spreading block to spread the symbols in frequency domain. We have seen that a kin to SCFDMA, frequency domain spreading of signs, PAPR of the system reduces to a large extent. But in SC-FDMA due to sharp transitions at the edges of pulses we observed that it produces a lot of OOB emissions. To reduce OOB emissions we have avoided sharp transitions at the end by considering only few basis pulses. In our pruned DFT method we have consider only  $L/2$  basis pulses.



**Fig 2-Representaton of basis pulse of various transmission schemes**

As shown in figure 2 we can observe the way how the basis pulse differ in OFDM [I] and how it can be converted to other multicarrier schemes as shown. From figure 2, OFDM underlying basis pulses are frequency shifted rectangular pulses. When OFDM is Precoded with DFT single carrier system is emulated, that is SC-FDMA. When OFDM is precoded with pruned DFT, it generates pruned DFT OFDM. When pDFT OFDM is filtered with a prototype filter it generates unscaled pDFT FBMC and unscaled pDFT FBMC is multiplied with scaling factor to generate pDFT FBMC.

The time domain, sign conveyed can remain articulated through [VII]

$$s(t) = \sum_{m=1}^M \sum_{l=1}^L g_{l,m}(t) x_{l,m} \quad (1)$$

Basis pulse  $g_{l,m}(t)$

$$g_{l,m}(t) = p(t - mT) e^{j2\pi lF(t-mT)} e^{j\pi/2(l+m)} \quad (2)$$

At time location  $m$ , conveyed symbols of FBMC are

$$x_m = C_f \tilde{x}_m \quad (3)$$

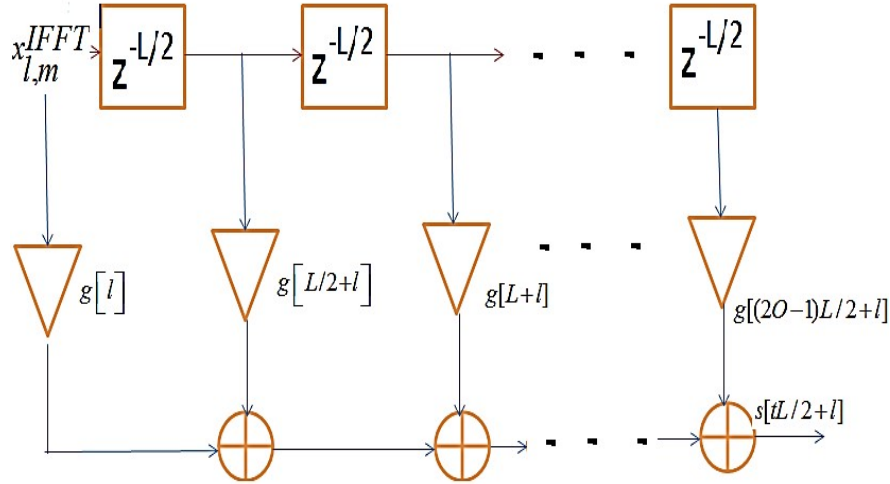
At the receiver reverse process of pruned DFT is implemented with pruned IDFT

### **Poly-Phase Transmitter and receiver**

The IFFT data output obtained by input  $x_{l,m}$  is given by  $x_{l,m}^{IFFT}$  and this data is passed into poly-phase network as shown in figure. PPN block is used for the purpose of

overlapping and then filtering .When data is processed in PPN then the output of PPN is given as,

$$x_{l,m}^{PPN} = \sum_{O=0}^{2O-1} g[On/2+l]x_{l,m-o}^{IFFT} \quad (4)$$



**Fig 3- Representation of poly-phase network system**

In the above equation  $O$  remains the overlying feature used for sample filter  $g[i]$  and the transmitted data is expressed in vector notation and is given by

$$x_l^{PPN} = G_l x_l^{IFFT} = G_l X^{even} w_l \quad (5)$$

$x_l^{PPN} = [x_{l,o}^{PPN}, \dots, x_{l,M-1}^{PPN}]^T$  is a vector representation of transmitted data

In the above equation PPN processed data is expressed in matrix form and is given as  $G_l$ .

$$[G_l]_{ij} = g[(i-j)L/2+l], 0 \leq i-j < 2O \quad (6)$$

$= 0$  elsewhere

At the receiver a PPN received filter is used which performs filtering by down sampling and matched filter is maintained at it. FBMC received data along with the matched filter can be given as

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$$y_{l,m}^{PPN} = \sum_{O=0}^{2O-1} g^* [oL/2 + l] x_{l,m+O}^{PPN} \quad (7)$$

When ideal channel is considered, that is zero noise channel, then received symbols at PPN receiver can be given in vector form as explained in next part.

### FBMC-OQAM transmitter/receiver

The data processed in PPN is transferred through the channel by using FBMC-OQAM transmitter and this block performs the processing of basis pulse matrix  $G_l$  on the data. At the receiver matrix  $(G_l)^H$  is used for demodulation and then signal received is given by

$$\begin{aligned} y_m &= G^H (Hs + n) = G_l^H (HG_l x_l^{PPN} + n) = G_l^H HG_l x_l^{PPN} + G_l^H n \\ &\approx \text{diag}\{h\} G_l^H G_l x + G_l^H n \end{aligned} \quad (8)$$

Where the one tap channel is expressed by  $h$  and it achieves only real orthogonality of OQAM as  $\Re\{G^H G\} = I_{LM}$

### One-tap equalization

One tap equalization [XI] is accomplished at the receiver with  $e_m C^{LXI}$  on received data symbols and at that time despreading is thru to give

$$\tilde{y}_m = C_f^H \text{diag}\{e_m\}^{-1} y_m \quad (9)$$

Spreading matrix is resultant of supposing AWGN channel which doesn't need equalization. Complex orthogonality is reestablished to facilitate

$$C_f^H G_m^H G_m C_f \approx I_{L/2} \quad (10)$$

The approximation used in above equation specifies the existence of minor intrinsic interference and hence system becomes quasi stable orthogonal.

Still, in several conditions this has null effect on the performance.

Spreading and despreading matrix of  $D_L$  is assumed by vector 'a' and is given as

$$a = \text{diag}\{D_L^H G_m^H G_m D_L\} \quad (11)$$

$[a]$  relates to  $i^{th}$  column of  $D_L$ . Half of  $L$  largest elements of vector ' $a$ ' of  $D_L$  matrix are used for transmission.

Therefore scaling vector, for  $i$  equal to  $1, 2 \dots L/2$  and pruned DFT matrix is presumed by (12) and it persuades diagonal elements are one.

$$[\tilde{b}]_i = \sqrt{2/[a]_i} \quad (12)$$

$$\tilde{D} = D \begin{bmatrix} I_{L/2} \\ O_{L/2} \end{bmatrix} \quad (13)$$

### III. Performance evaluation

#### Transmit Power

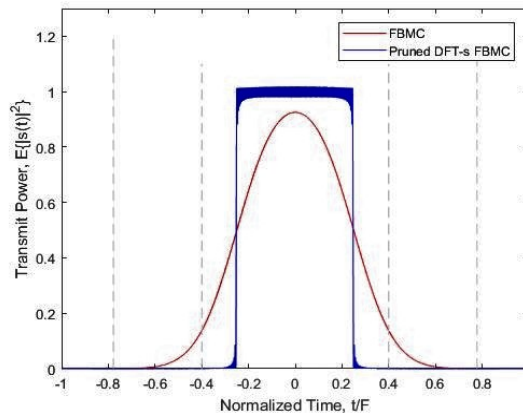
From figure 4, [VII] I conclude that, in usual FBMC the transmission entails a long rise and incline down period since there subsists a huge overlapping of signs in time. In pDFT-FBMC discussed in previous chapter, the overlying in time is truncated and the increase and incline downcast period drastically contracted, since pre programming by  $C_f$  contours the transmitted sign in such a genre. The power transmitted at time position  $m$  can be calculated as

$$p_m^{(t)} = \text{diag}\{G_m C_f C_f^H G_m^H\} \quad (14)$$

Where  $G_m$  is basis pulse matrix

$C_f$  is the precoding matrix

$(G_m)^H, (C_f)^H$  are Hermitian of matrices  $G_m$  and  $C_f$



**Fig 4-TRANSMIT POWER of one subcarrier**

## **Power Spectral Density**

From figure 6, Comparative study of PSD depicts that pruned DFT FBMC with PPN performs better when compared with other schemes [1] and it produces minimum side lobes thereby reducing Out-of band emission (OOBE)

Comparative study of power spectral density depicts that pruned DFT FBMC with PPN performs better when compared with other schemes and it produces minimum side lobes thereby reducing OOBE, PSD can be calculated by

$$p_k^{(f)} = \text{diag}\{D_N G_k C_f C_f^H G_k^H D_N^H\} \quad (15)$$

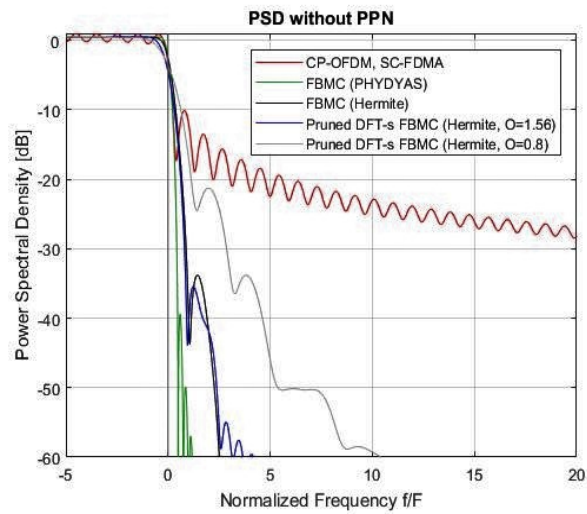
As shown in figure if we observe PSD without PPN, we compared different multicarrier schemes like CP-OFDM, SC-FDMA, FBMC with PHYDYAS and Hermite prototype filter and pruned DFT-FBMC with Hermite filter with different overlapping factors.

From the results we observe that compared to CP-OFDM and SC-FDMA, FBMC based system produces lower OOBE.

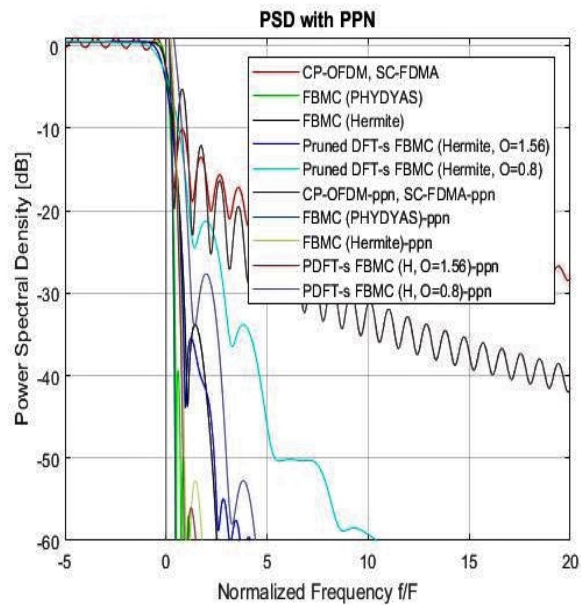
In FBMC system we compared with two different prototype filters PHYDYAS and Hermite and we observed that Hermite prototype filter performs superior over PHYDYAS.

We also observed that pruned DFT FBMC is optimized in OOBE compared with FBMC system. Finally we also compared pruned DFT FBMC using Hermite filter with different overlapping factors of 1.56 and 0.8 and we observe that when overlapping factor is decreased system generates minimum OOBE and in all the observed results of different systems we conclude that pruned DFT FBMC employed with a Hermite filter and Overlapping factor of 0.8 generates very low OOBE.

From the figure we observe the PSD of different multicarrier systems by using PPN. Just similar to the previous results we compared different systems without PPN and observed that pruned DFT FBMC with Hermite filter and an overlapping factor of 0.8 performs superiorly. All these systems are again studied by using PPN, we observe that PPN based systems perform good over Non-PPN system. Overall OOBE performance can be graded best for pruned DFT FBMC –PPN with Hermite prototype filter and an overlapping factor of 0.8



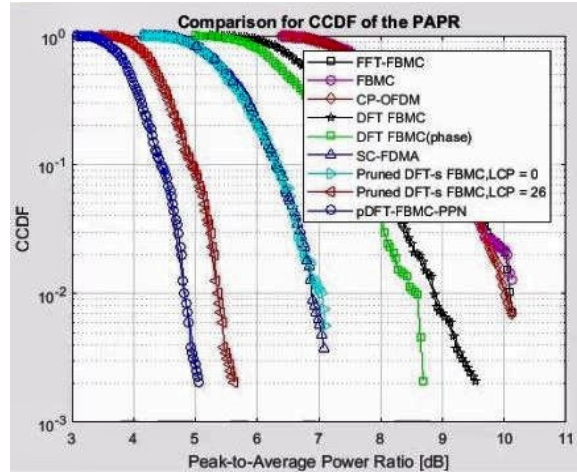
**Fig 5-Comparison of power spectral density without PPN**



**Fig 6-Comparison of power spectral density with PPN**



### Comparison of CCDF of PAPR



**Fig 7-PAPR COMPARISION**

PAPR is one of the fore most disadvantages of OFDM [VIII,IX]which makes it unsuitable for following group communication methods. As shown in figure 6.8, I measured PAPR [X, XI] for different schemes and made a comparative study. From the analysis we observe that pDFT-FBMC-PPN performs the best with low PAPR. We can also observe that PAPR can be optimized based on the frequency cyclic prefix (LCP).PDFT -FBMC with frequency cyclic prefix performs better when compared to the pDFT-FBMC without cyclic prefix.CCDF is used to calculate the power using a time domain signal. These curves give the information about probability of signal power > Average Power.

The above simulation results are generated by using the following design parameters

Number of Monte Carlo repetitions = 40

FBMC and OFDM Parameters

Number of subcarriers= 128;

QAM Modulation Order = 4

Subcarrier Spacing = 15 kHz (same as LTE)

Carrier Frequency = 2500 MHz

FBMC symbols in time = 30

OFDM symbols in time (no CP) = 15

Nu OFDM symbols in time (same as in LTE) = 14

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LTE CP Length in seconds = 1/Subcarrier Spacing/14;

Frequency domain CP for pDFT spread FBMC = 0

CP Length FBMC\_DFT = 26

Time domain" CP for the FFT-FBMC scheme = 0;.

Sampling Rate = Subcarrier Spacing\*14\*12\*2;( Sampling rate, should approximately match the power-delay profile of the channel. "14", so that the CP fits the sampling rate)

Pseudo Overlapping Factor = 4; (Pseudo overlapping factor to keep the implementation simple. The true overlapping factor is 1.56

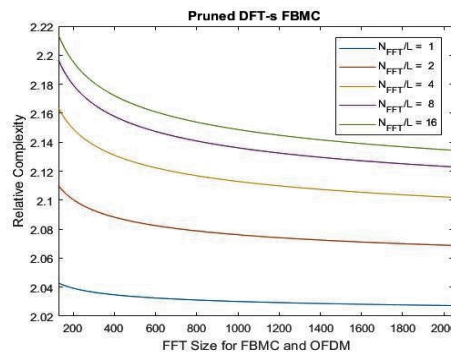
### Computational complexity

From equation 16 we perceive that computational intricacy of pDFT-FBMC is increased by two times when related with SC-FDMA and it can be computed assuming number of subcarriers =s as in equation 17

$$\frac{2\left(\frac{s}{2} + s \log \frac{s}{2} + Q_{FFT} \log Q_{FFT} + OQ_{FFT}\right)}{s \log s + Q_{FFT} \log Q_{FFT}} \quad (16)$$

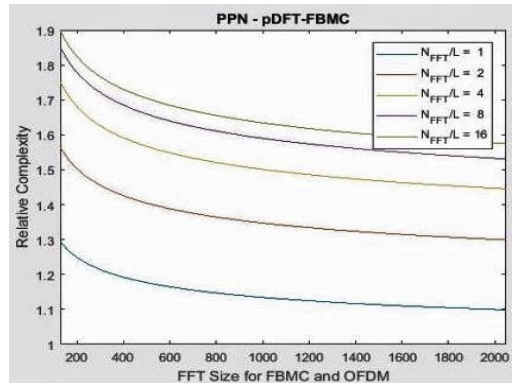
The term  $Q_{FFT} \log Q_{FFT}$  tallies to IFFT, mandatory for together, OFDM&FBMC. The computational intricacy at the receiver is same as above if we don't ruminant channel equalization. Moreover, FBMC involves a component wise multiplication of prototype filter, leading to an superfluous intricacy of  $ON_{FFT}$ . The computational intricacy is reduced to lower value in pDFT-FBMC with PPN and from the analysis we observe that complexity is reduced in proposed system

$$\frac{s \log s + 2N_{FFT} \log N_{FFT} + 16N_{FFT}}{s \log s + N_{FFT} \log N_{FFT}} \quad (17)$$



**Fig 8-Relative Computational complexity of pDFT-FBMC**

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**Fig 9-Relative Computational complexity of pDFT-FBMC**

#### **IV. Conclusions**

Upcoming wireless schemes will have to up keep a large assortment of diverse use cases within the same band. This is problematic in legacy CP-OFDM because of the poor OOB emissions. There subsists procedures to diminish the OOB emissions in OFDM, such as windowing and filtering, but they are only effective if the number of subcarriers is high. Not all possible use cases proposed for future wireless systems will employ such a high number of subcarriers, so that FBMC becomes an efficient substitute to OFDM, since it has considerable fine spectral properties. While FBMC has many benefits, it also requires some special handling because of the intrinsic imaginary interference. One-tap equalizers are in most practical cases sufficient for FBMC once the subcarrier spacing is matched to the channel. By spreading data symbols in time or frequency, complex orthogonality can be restored in FBMC-OQAM, allowing to straightforwardly employ all methods known in OFDM. I have derived the optimal spreading matrix and proposed two different interpretations of such spreading, either in the code dimension, or by transforming the basis pulses. Although the optimal spreading matrix provides analytical insights, a more practical solution is based on Walsh-Hadamard spreading because it requires almost no additional complexity and performs close to the optimum. One of the most important contributions of this thesis is pruned DFT spread FBMC, which has the remarkable properties of a low PAPR, low latency transmissions and a high spectral efficiency. Pruned DFT spread FBMC outperforms SC-FDMA in almost all aspects. It is more robust in doubly-selective channels, requires no CP and has much lower OOB emissions. If the channel is approximately flat within the transmission bandwidth, pruned DFT spread FBMC even outperforms conventional FBMC-OQAM in terms of throughput

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