Effect of Prototype Filter Length on PAPR Reduction and Side Lobe Tail Attenuation on Autocorrelation in FBMC Cognitive Radio

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***Abstract*: FBMC is a multicarrier modulation technique that consists of transmitting simultaneously N elementary symbols via N parallel orthogonal subchannels.FBMC systems have taken special attention during last few years.FBMC provides higher spectral efficiency than OFDM as it does not require a guard interval or cyclic prefix extension.Orthogonality is required only for neighbouring sub channels due to special Nyquist filter used in FBMC systems which is characterized by its reduced out of band ripples and its high frequency selectivity.Unfortunately,since FBMC signal like in any other multicarrier system,is a sum of large number of independently modulated subcarriers,it suffers from high Peak to Average Power Ratio.As a result of introduction of this undesired high PAPR ,the system performance is affected by increase in spectral spread and in band distortion which is not good trend from Nyquist pulse shaping point of view.To overcome this problem ,it is necessary to reduce PAPR by adopting and implementing some suitable technique.Hence,here Prototype filter length has a significant role to play as a PAPR reduction technique.Also,quicker side lobe tail attenuation plays a significant role for efficient FBMC.**

***Index Terms*: Filter Length, PAPR, Side lobe tail attenuation, FBMC.**

1.INTRODUCTION

Filter Bank multicarrier communication systems provide adaptability towards time and frequency selectivity of propagation channels which allows for an adaptation to the frequency response of channel by using different modulation schemes and different power allocation for respective subcarriers.FBMC systems with complex moduations provide better spectral shaping of the subbands[1-2].But,the practical transmission systems are peak power limited and exhibit non linear behavior which tends to the spectral widening of the transmit signal.Earlier literature available in the context of Multicarrier communication shows that there are different PAPR reduction techniques available like amplitude clipping,partial transmit sequence,selected mapping,active constellation extension[3].The resulting PAPR distributions have a strong impact on the performance of Filter bank based multicarrier systems.

2.Filter Bank Multicarrier Systems

Primarily,Multicarrier system can be implemented using an IFFT as modulator at transmitter end and FFT as a demodulator at the receiver end.Hence,complex modulated envelope of transmitted multicarrier signal at IFFT output is represented by[3] as $p_n(m)=\sum d_i(m)e^{j2\pi in/N}$ for 0<n<N-1.N is the number of subcarriers and d_i represents the input signals corresponding to the modulation symbols.On receiver side,sampled data is recovered by $d_i(m)=1/N\sum s_n(m)e^{-j2\pi in/Im}$where 0<i<N-1.Unlike the OFDM systems,FBMC systems make use of Nyquist filter highlighted by its reduced out of band attenuation and more frequency selectivity.In prototype FBMC scheme,each basic symbol modulates 2K-1 subcarriers where K denotes the length of prototype filter frequency response.FBMC systems when implemented as Polyphase Networks downscale the complexity and put IFFT size to N.

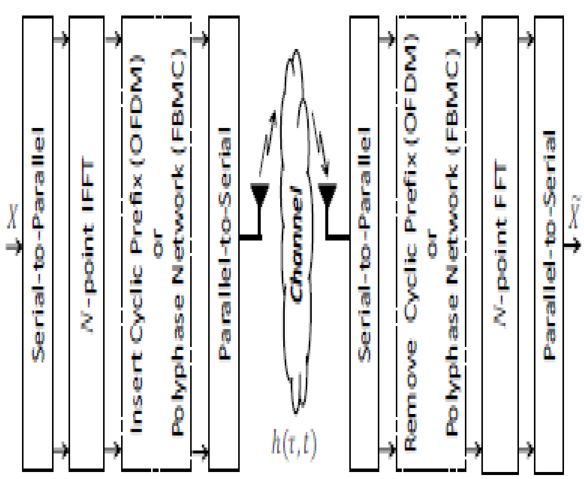

Figure.1.Transceiver Block Diagram of Basic OFDM and FBMC (Improved OFDM).PAPR Reduction in FBMC signals can be obtained by choosing suitable simulation parameters.

3.PAPR and CCDF

The Peak to Average Power Ratio of a given signal s(t) is defined as the ratio of peak power of s(t) to its average power.PAPR is the performance parameter to measure the sensitivity to the nonlinear devices of transmission schemes having non- constant envelope and particularly multicarrier modulations.The PAPR of the complex envelope s(t) of a continuous baseband signal transmitting complex symbols with duration can be written as

$$PAPR(s(t)) = \frac{\max_{[0,Ts]}[s(t)]^2}{1/T_0 \int s(t)^2 dt} \quad \text{where } T_0 = LM-1 \quad \text{Eq.1}$$

Equation no.1 defines PAPR after upsampling by a factor of L where PAPR output is a result of Pulse shaping.The value of L=4 gives sufficiently accurate results.If we consider a discrete time signal and particularly FBMC signal with N subcarriers,then PAPR is defined as[4]

$$PAPR(s(t)) = \frac{\max_{[0<n<N]}[s(n)]^2}{E[s(n)^2]}$$

For FBMC signals,the cumulative distribution function(CDF) of PAPR gives probability that PAPR is below some threshold level μ[5].Hence,$CDF(\mu)=Pr[PAPR(s(n))<\mu]=(1-e^{-\mu})^N$. Whereas Complementary CDF of PAPR indicates the probability that PAPR is above some finite threshold level μ defined by $CCDF(\mu)=Pr(PAPR(s[n]>\mu)=1-(1-e^{-\mu})^N$ The filter length directly affects the system performance and contributes to the filter bank group delay.Impulse Response of Prototype filter for Overlapping factor K=4 gives sufficiently accurate results.Various analytical results on the study of Power versus Sub carriers,IN Power versus Subcarriers,SINR versus Subcarriers,Capacity versus Subcarriers etc are available in literature.A better approximation for continuous signal PAPR can be obtained by using a pulse shaped oversampled output.For analysing PAPR as a random variable,CCDF is taken as a statistical distribution measure[5]The practical relevance of PAPR results without pulse shaping has not been taken seriously by earlier researchers as the curves obtained are used to show the impact of pulse shaping on PAPR output.Simulation results confirmed the accuracy of proposed technique.A comparison of results obtained through Intensive Monte Carlo Simulations,is presented[6].

4.Simulation Results

Basically,FBMC system can be implemented using IFFT as modulator and a FFT as a demodulator.FBMC system provides a noticeable improvement over conventional IFFT scheme.Only FBMC Polyphase network can reduce the increased computational complexity due to increase in size of IFFT/FFT.

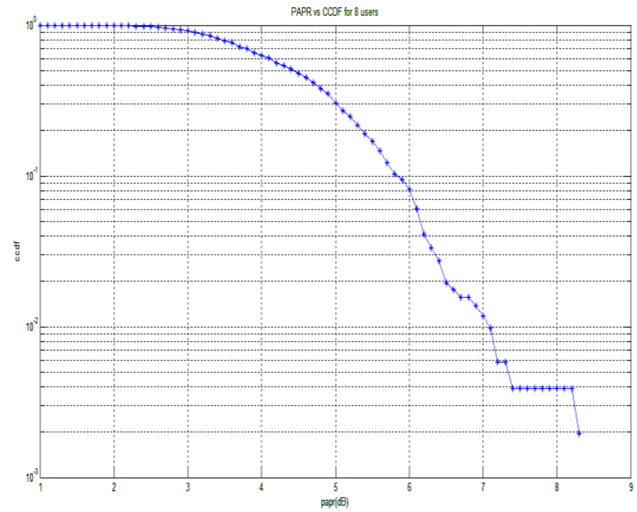

Figure.2 N=16 at Cyclic Prefix =4

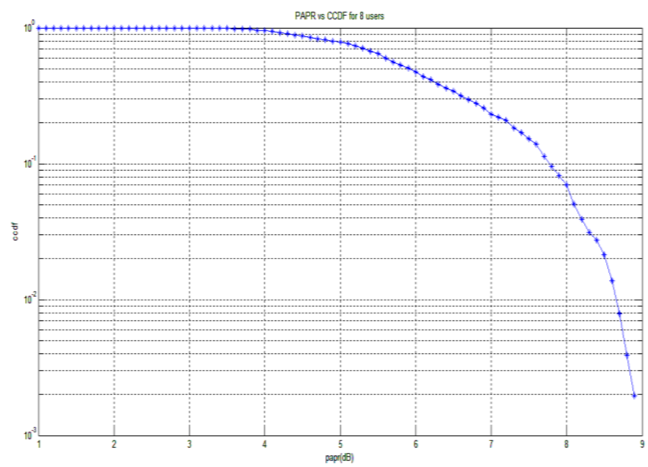

Figure.3 N=32 at CP=4

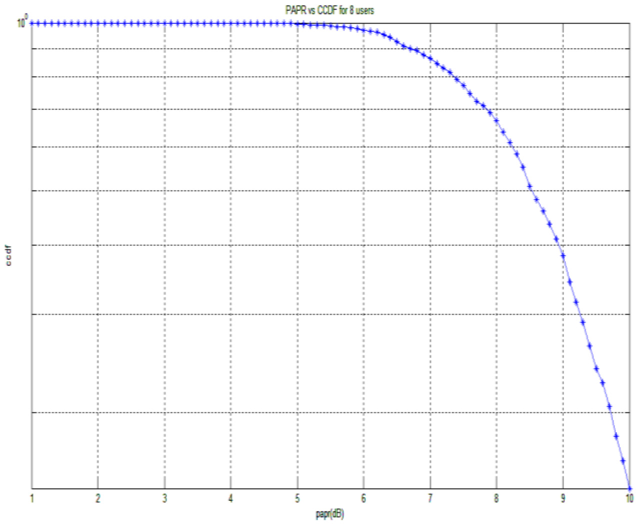

Figure.4 N=64 at CP=4

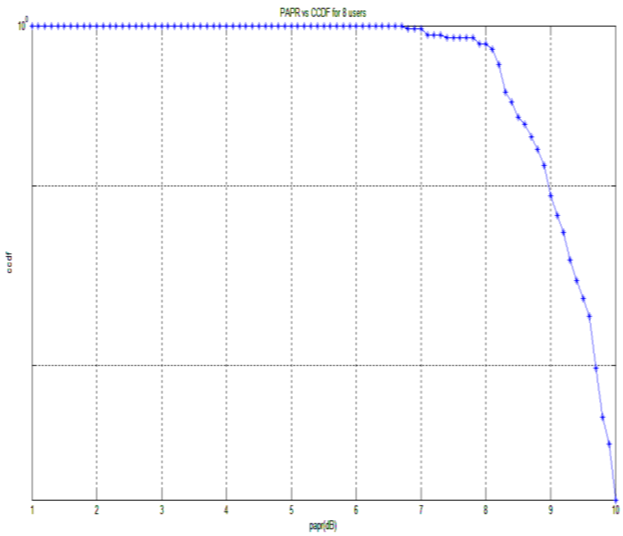

Figure.5. N=128 at CP=4

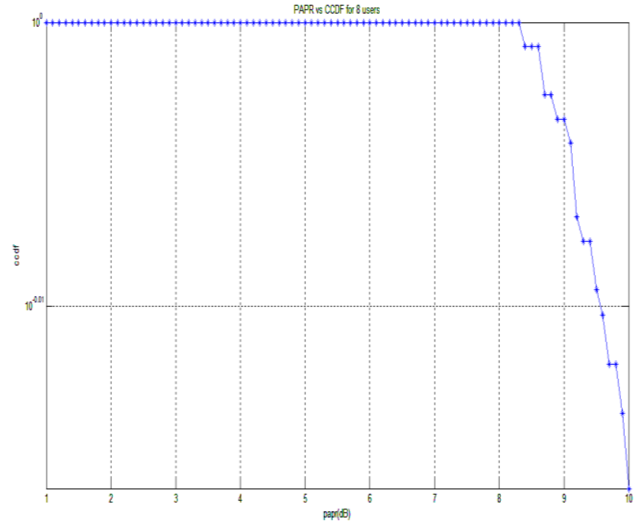

Figure .6 N=256 at CP=4

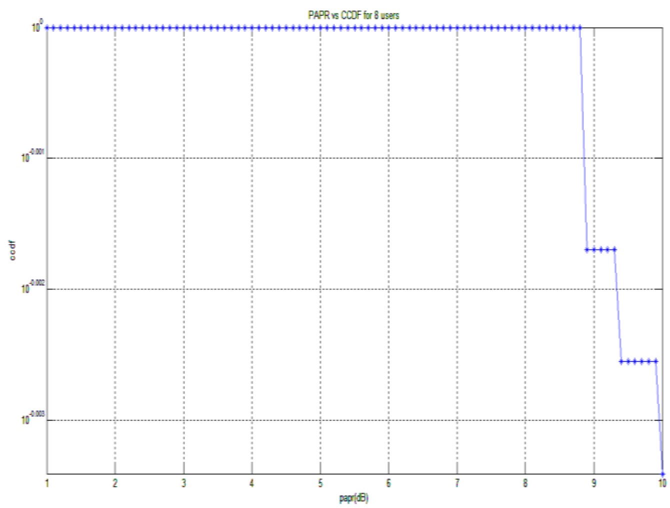

Figure .7 N=512 at CP=4

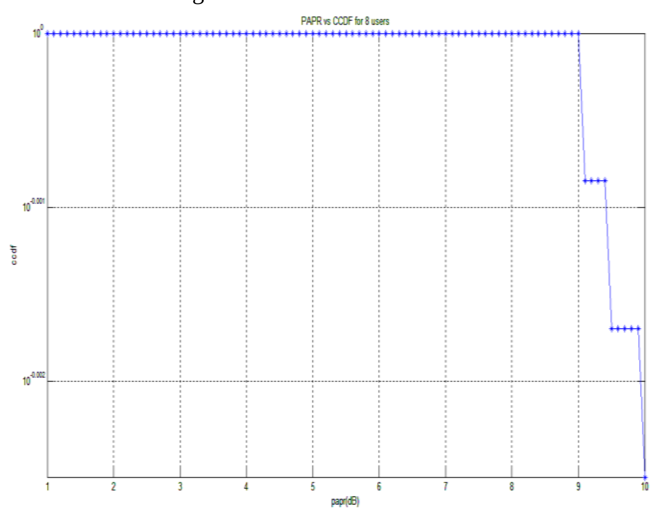

Figure.8 N=1024 at CP=4

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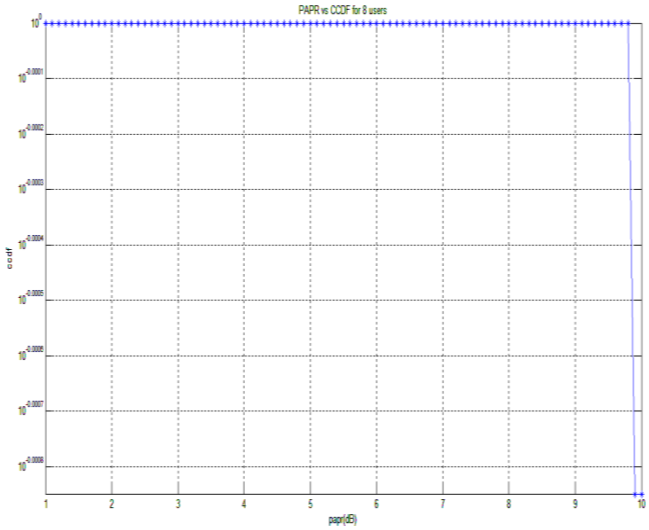

Figure.9 N=2048 at CP=4

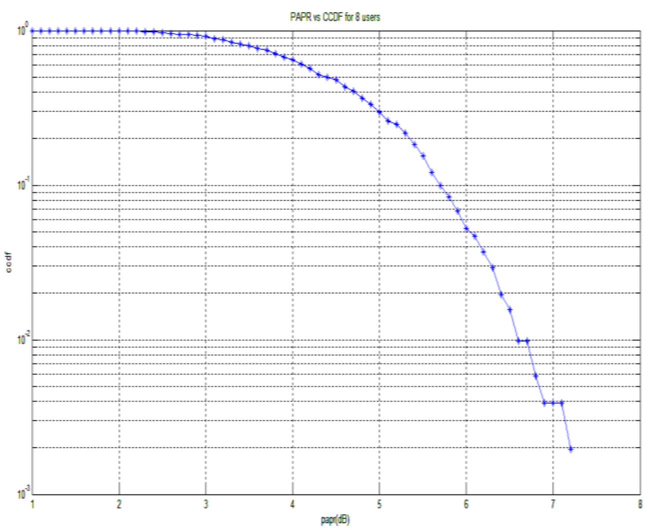

Figure.10 N=16;CP=8

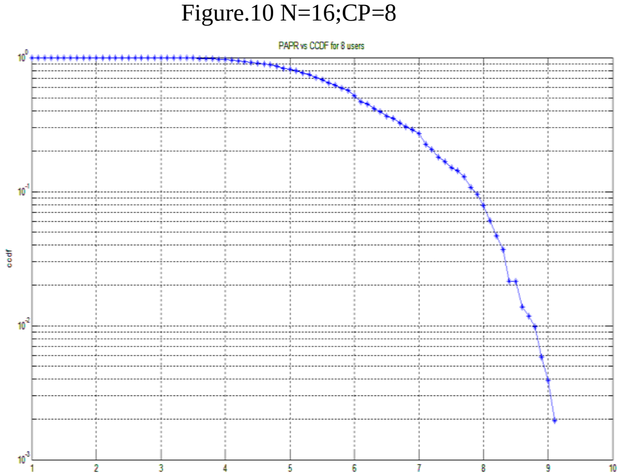

Figure.11.N=32;CP=8

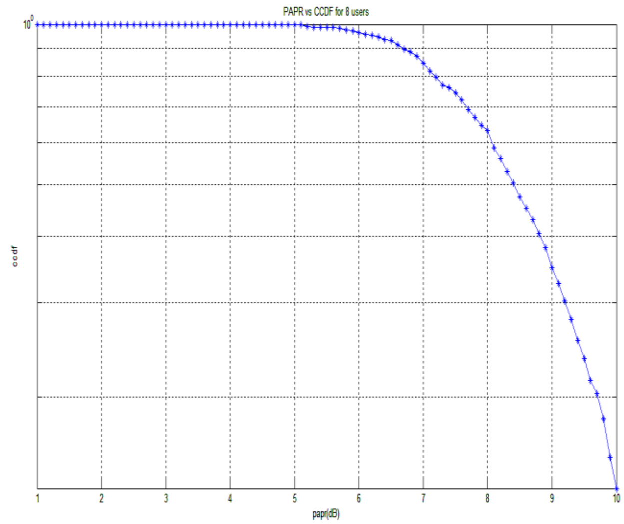

Figure .12 N=64;CP=8

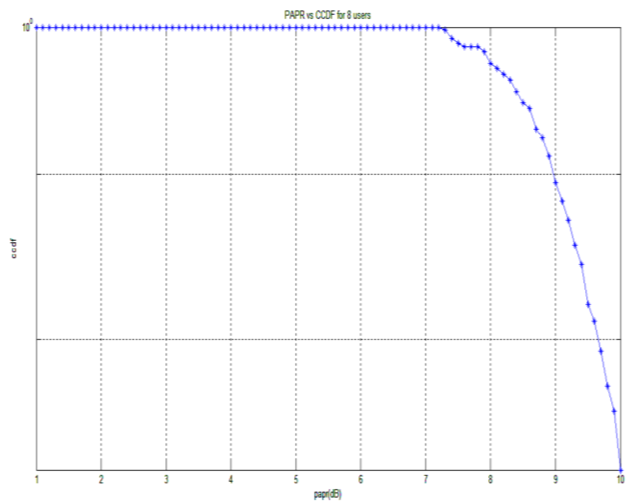

Figure.13 N=128;CP=8

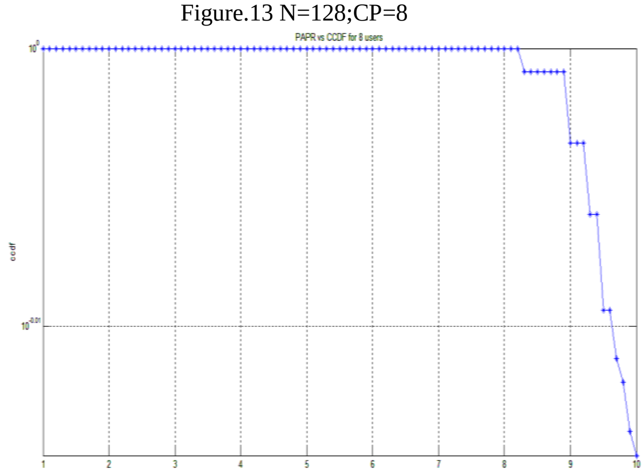

Figure.14 N=256;CP=8

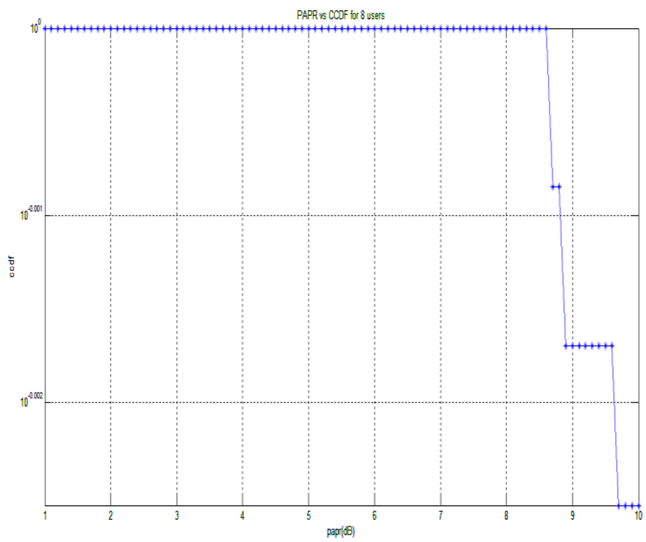

Figure.15 N=512;CP=8

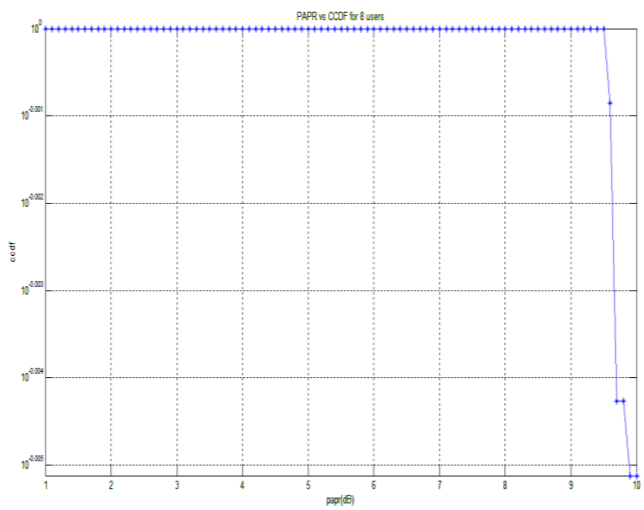

Figure.16 N=1024;CP=8

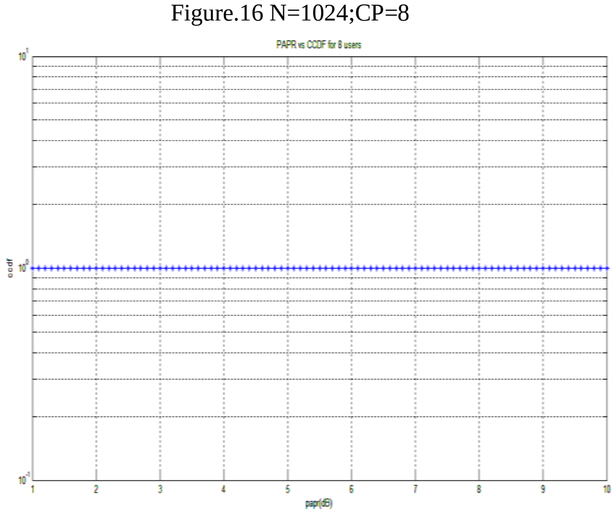

Figure.17 N=2048;CP=8

All the parameter values like FFT,number of symbols,data length and number of users are declared or initialized.Then for generation of Walsh code,the number of data subcarriers are defined.The cyclic prefix value is defined.Similarly the data bits are defined for other users with the application of either BPSK or QPSK modulation technique.Then data bits corresponding to the users are spreaded and IFFT taken for these users.Then Cyclic Prefix is appended for the user.The effect of awgn noise with multiple Eb/No values is studied on the faded data received at receiver.Thereafter,the cyclic prefix is removed and FFT taken for the user values.Then despreading of data subcarriers and demodulation and decoding of data is done.PAPR versus CCDF is evaluated for all the 8 users at the end.It is found that practical transmission systems are peak power limited. Fig.2 to Fig.9 show the graphic plots obtained between CCDF and PAPR(dB)for a Fix value of Cyclic Prefic=4 with number of users N varying as,16,32,64,128,256,512,1024 and 2048 respectively.Fig.10 to Fig.17 show the graphic plots obtained between CCDF and PAPR(dB) for a Cyclic Prefix =8 with number of users in the range 16<N<2048. The trend of CCDF versus PAPR variation has been clear from the Table.1.Table.2 shows the Comparison in PAPR values obtained in two different approaches.

FBMC Data Subcarriers N_c	**CCDF at CP=4**	**PAPR(dB)variation**	**CCDF at CP=8**	**PAPR(dB)variation**
16	$10^{-2.7}$	8.2	$10^{-2.7}$	7.3
	10^{-2}	7.3	10^{-2}	6.6-6.7
	10^{-1}	5.8	10^{-1}	5.7
	10^{0}	1-2.7	10^{0}	1-2.7
32	$10^{-2.7}$	8.8	$10^{-2.7}$	9.2
	10^{-2}	8.7	10^{-2}	8.8
	10^{-1}	7.8	10^{-1}	7.85
	10^{0}	1-4	10^{0}	1-4
64	10^{0}	1-5.6	10^{0}	1-5.75
128	10^{0}	1-6.8	10^{0}	1-7.3
256	10^{0}	1-8.3	10^{0}	1-8.2
	$10^{-0.31}$	9.65	$10^{-0.01}$	9.7
512	10^{0}	1-8.7	10^{0}	1-8.7
	$10^{-0.001}$	8.8	$10^{-0.001}$	8.85
	$10^{-0.002}$	9.3	$10^{-0.002}$	9.65
	$10^{-0.003}$	9.9	$10^{-0.003}$	-
1024	10^{0}	1-9	10^{0}	1-9.6
	$10^{-0.001}$	9.35	$10^{-0.001}$	9.72
	$10^{-0.002}$	9.8	$10^{-0.002}$	9.72
2048	10^{0}	1-9.7	10^{0}	1-10
	$10^{-0.001}$_ $10^{-0.004}$	9.8-9.9		

Table.1CCDF versus PAPR(dB) Variation

5.Performance Evaluation of Simulated PAPR Reduction technique

PAPR Reduction Technique	**Prototype Filter Length K**	**PAPR value in dB**
Proposed Technique(Walsh Code Transform)	1,2,4,8	7.5,8.7,9.6,10
Hadamard Transform Technique proposed by Brahim Elmaroud et al	1,2,4,8	7.2,8.6,9.2,9.5

Table.2 PAPR values Comparison between two approaches

PAPR increases as Prototype filter length K is changed from 4 to 8.This trend matches with simulation results presented in previous section**.**Lower the Cyclic prefix used,lower is the PAPR variation obtainable.Moreover,Shorter Prototype filter length is more beneficial as lower PAPR leads to lower computational complexity i.e lower hardware requirements and achievable cost efficient FBMC system.Hence,optimisation is to be done between PAPR reduction on one side and FBMC on other end because performance increases as overlapping factor increases.The present work can be extended to Polyphase Implementation of FBMC system with other transform techniques like Exponential companding transform,Exponential companding and Hadamard Transform combined,and selected mapping method[7].Infact,shorter Phydyas Prototype filter also shows similar trend with decrease in PAPR value at lower K factor.It means K=4 provides optimum results as compared to K=8 for the sake of comparison between proposed technique and that suggested/used by Brahim Elmaroud et al.Table.3 below illustrates the Simulation parameters taken for PAPR reduction in FBMC signals.

Simulation Parameter for Proposed FBMC with PAPR Reduction	**Value**
Bandwidth	1Mhz.The same can be extended to 5,6,7 and 8 Mhz
Number of Subchannels	16-2048
Overlapping Factor K	4,8
Number of Subcarriers	nFFT=K*N(K=4 optimum)in compliance with Phydyas FBMC(validated)
Mapping	BPSK/QPSK

Table.3 Simulation Parameters of FBMC system under consideration

Section B describes the Comparatative Analysis of the Effect of variable Doppler fD*Ts on Calculation of Autocorrelation Function through Filter Method and Spectrum Method as done in the *PHYDAS*,the underlying basis of which is FBMC.The Code for generating channels with filter method and spectrum method has been given in Matlab to evaluate autocorrelation function from FBMC system as well. Firstly,the product fd*Ts is set equal to 0.01 with fd=100.Then sampling time is calculated and spectrum is obtained using command flat_spec(Ns,fD,fdTs).Hence,autocorrelation is computed corresponding to these input parameters.Thereafter,truncation is done and w=ceil(4/fd*Ts) is made use of to correlate the theoretically calculated value of autocorrelation with that found from spectrum method.Then with filter method approach,again the value of autocorrelation is found and compared analytically with theoretical value.The same steps are repeated for other values of Fd*Ts=0.09,0.16,0.25,0.39,0.48,0.69,0.85 for Fd=100 and Fd=200.

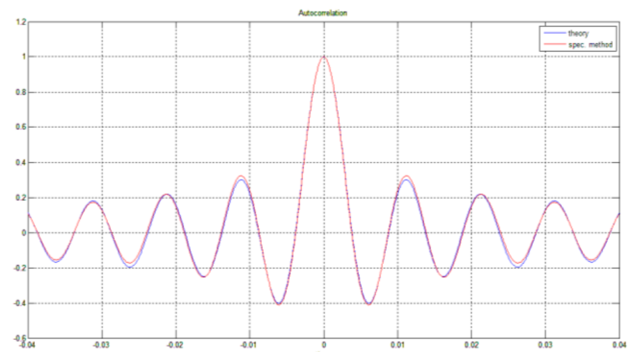

Figure 18. at Fd*Ts=0.01,Lp=K*M,Side lobe tail decay…(Spectrum Method**)**

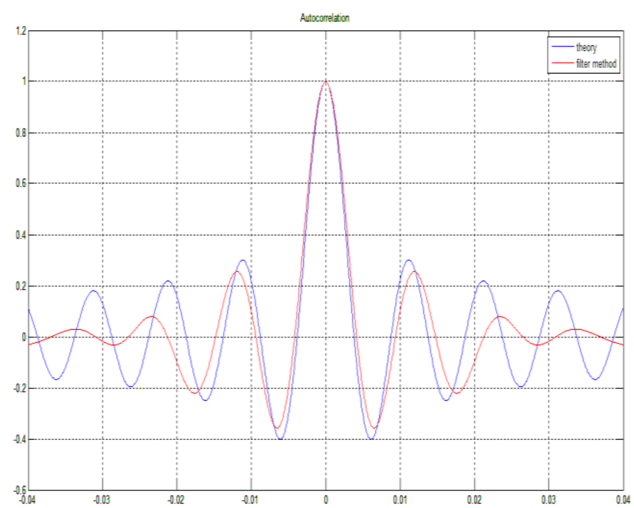

Figure 18(a)at Fd*Ts=0.01,Lp=K*M,Side lobe tail decay….(Filter Method)

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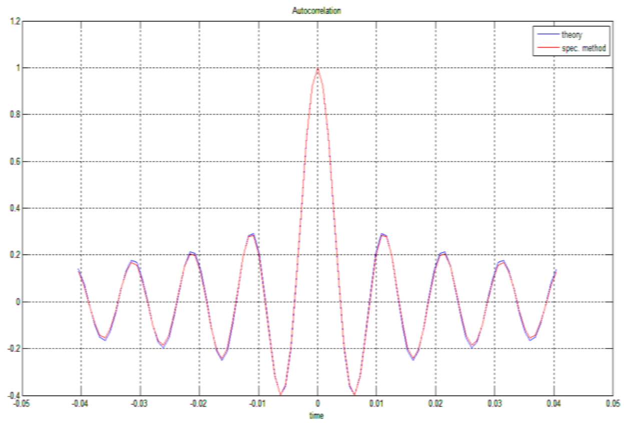

Figure 19. fd*Ts=0.09;Effect of Truncation…(Filter Method)

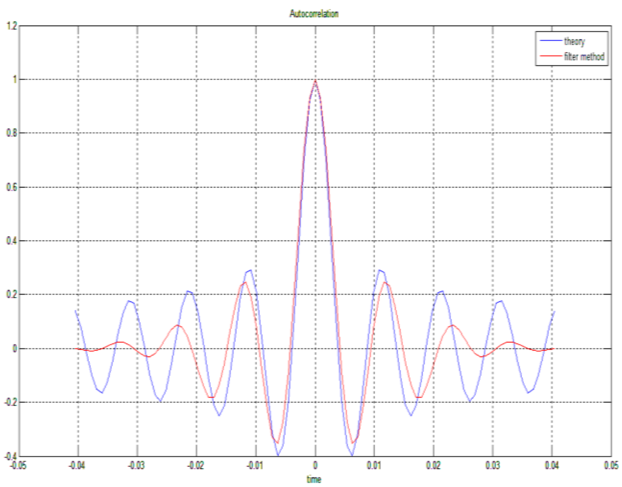

Figure.19(a)fd*Ts=0.09;Effect of Truncation….(Spectrum Method)

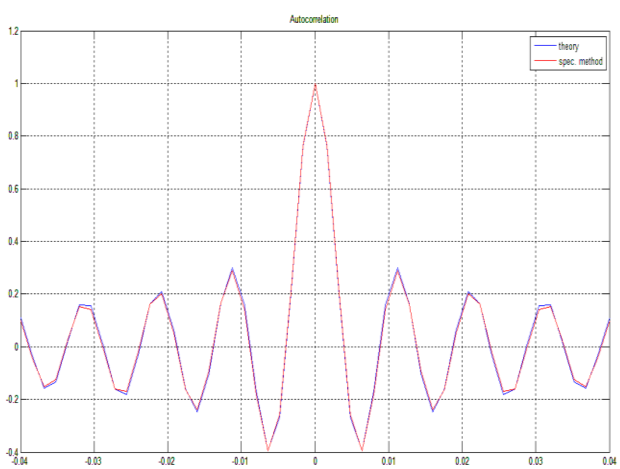

Figure. 20 FdTs=0.16;Effect of Truncation…..(Spectrum Method**)**

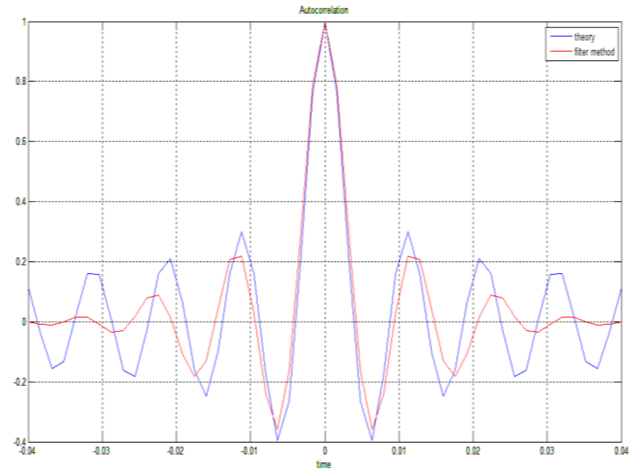

Figure 20(a)Fd*Ts=0.16;Effect of Truncation…….(Filter Method)

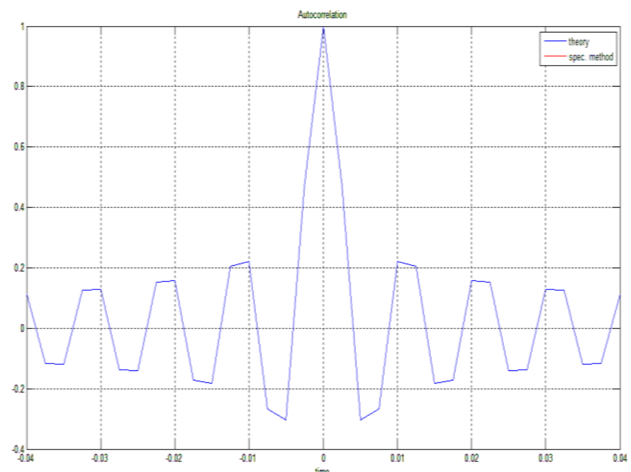

Figure.21.Fd*Ts=0.25;Effect of Truncation……..(Spectrum Method)

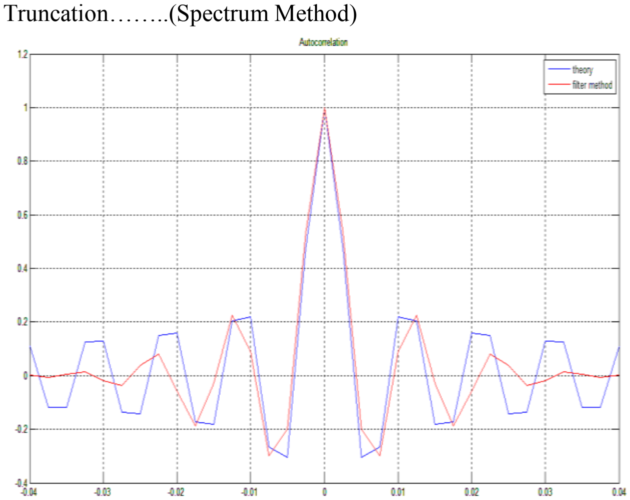

Figure 21(a) Fd*Ts=0.25;Effect of Truncation……(Filter Method)

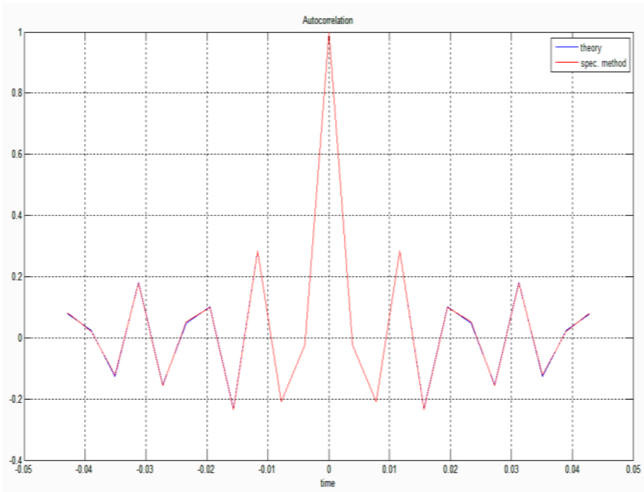

Figure 22 FdTs=0.39;Effect of Truncation..(Spectrum Method)

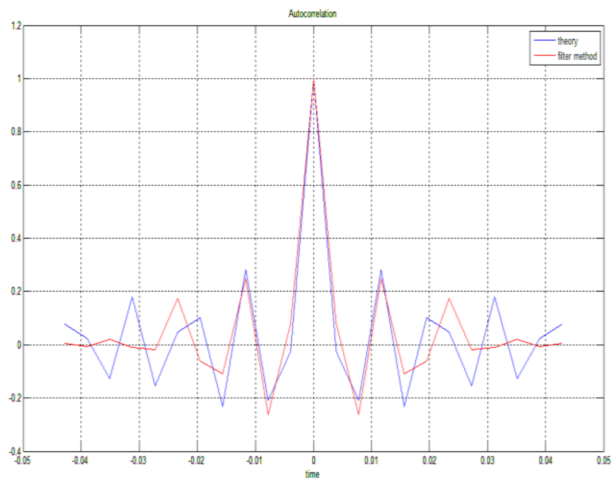

Figure 22(a)Fd*Ts=0.39;Effect of Truncation..(Filter Method)

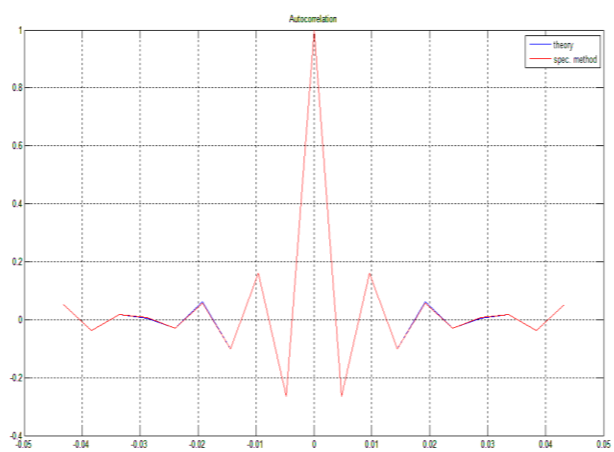

Figure 23.FdTs=0.48;Effect of Truncation..(Spectrum Method)

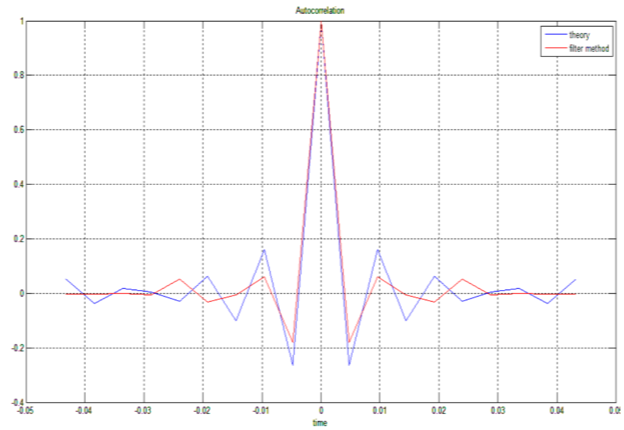

Figure 23(a)Fd*Ts=0.48;Effect of Truncation…(Filter Method)

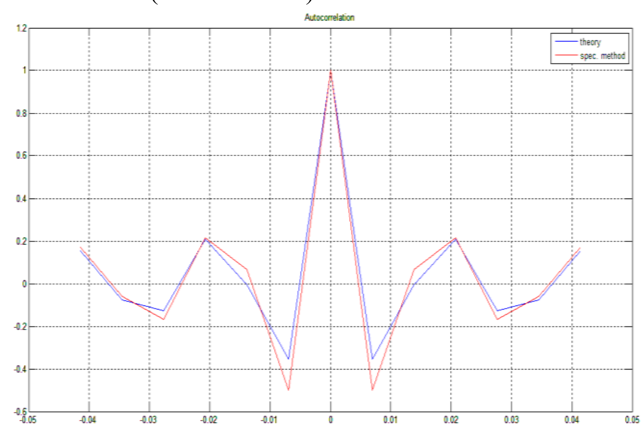

Figure.24 Fd*Ts=0.69;Effect of Truncation….(Spectrum Method)

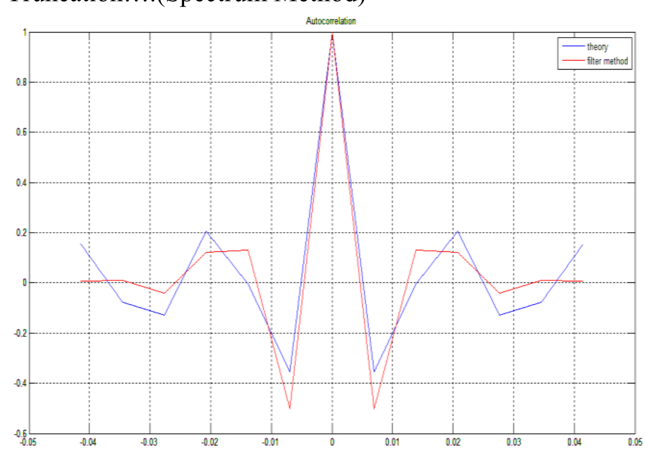

Figure 24(a)Fd*Ts=0.69;Effect of Truncation…(Filter Method)

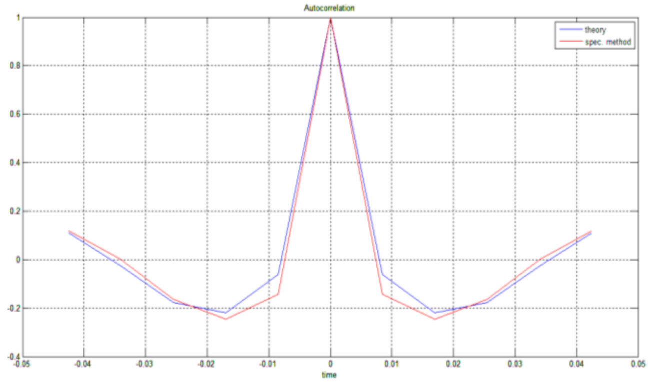

Figure.25 Fd*Ts=0.85;Effect of Truncation….(Spectrum Method)

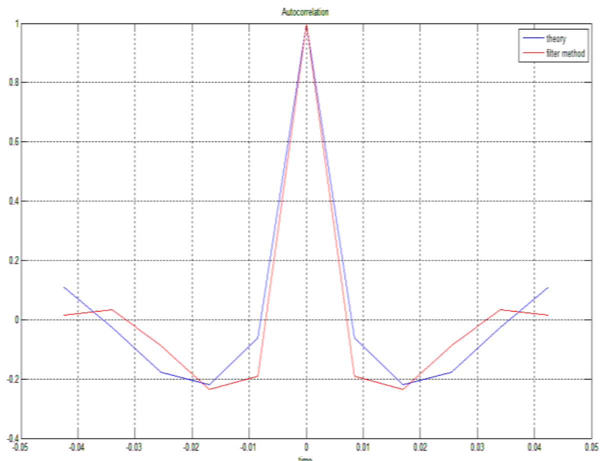

Figure 25(a) FdTs=0.85;Effect of Truncation………….(Filter Method)

We can analyze the effect of Prototype Filter Length on Side Lobe Tail Attenuation at Different values of Fd*Ts(Doppler Factor) for Efficient Pulse Shaping in PHYDAS/FBMC Structure in Table.4&5 as below.

Fd*Ts	Fd	w=4/Fd*Ts	Ts(Sampling Time)=Fd*Ts/Fd
0.01	100	400	0.0001
0.09	100	44.44	0.0009
0.16	100	25	0.0016
0.25	100	16	0.0025
0.39	100	10.256	0.0039
0.48	100	8.333	0.0048
0.69	100	5.797	0.0069
0.85	100	4.705	0.0085

Table.4 Calculation of w and Ts at different Fd*Ts values with Fd=100

Fd*Ts	Fd	w=4/fD*Ts	Ts(Sampling Time)=Fd*Ts/Fd
0.01	200	400	0.00005
0.09	200	44.44	0.00045
0.16	200	25	0.0008
0.25	200	16	0.00125
0.39	200	10.256	0.00195
0.48	200	8.333	0.0024
0.69	200	5.797	0.00345
0.85	200	4.705	0.00425

Table.5 Calculation of w and Ts at different Fd*Ts values with Fd=200

The Performance Evaluation of Effect of variable Doppler Fd*Ts on Computational Complexity(i.e Prototype FilterLength) and Calculation of Autocorrelation Function through Filter Method and Spectrum Method on the basis of comparatative analysis (as shown in Figures from Fig.18 to Fig.25) has been done[8].The present study has its deep impact on the Performance Enhancement of Filter Bank Multicarrier based Cognitive Radio Under the Constraints of Multipath fading environment[9-12].

Conclusion: A good comparatative analysis of Effect of FBMC Prototype Filter Length on PAPR reduction in signals along with the effect on side lobe tail attenuation or pulse truncation in FBMC system with consideration of pulse width,K factor and roll off response under filter -spectrum approach has been done at various values of sampling frequency.It is seen that as per the the nyquist criteria of efficient pulse shaping ,quicker or earlier side lobe tail decay happens with increase in value of Doppler factor Fd*Ts and sampling time or sampling frequency gets affected accordingly.It means more the Fd*Ts factor,more the sampling time,means lesser the sampling frequency which implies faster side lobe tail decay possible due to involvement of FBMC system which has become more efficient as compared to its earlier OFDM version with cyclic prefix. FBMC system provides a noticeable improvement over conventional IFFT scheme.A Flowchart for PAPR versus CCDF for FBMC is shown in Appendix A.

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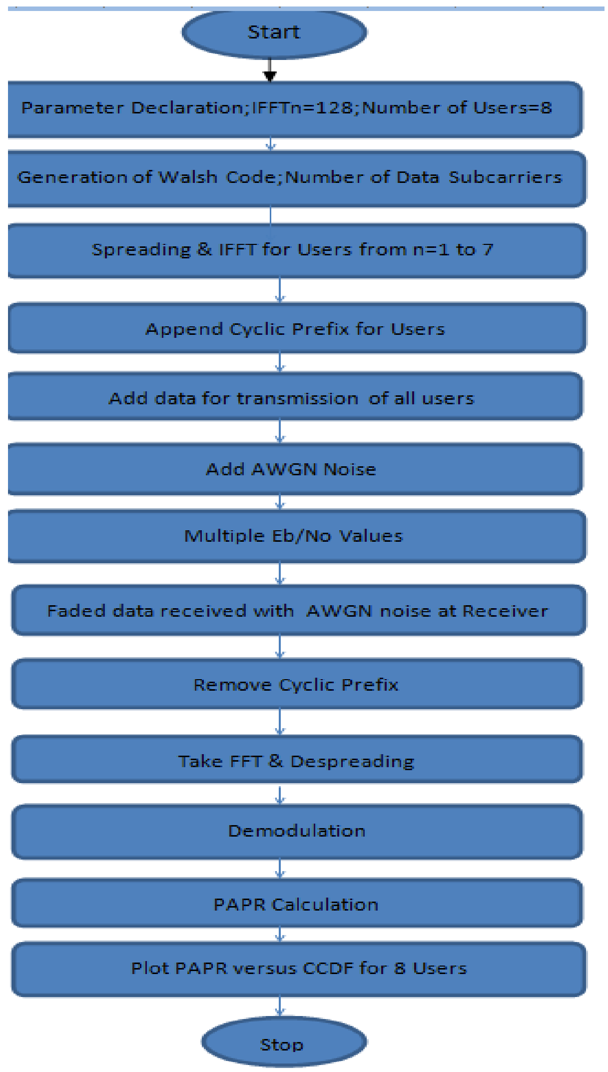
Appendix A



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