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Performance analysis of iPR-FBMC with Maximal Ratio Combining

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Abstract-: Diversity combining techniques are an efficient way to reduce the effect of multipath fading and co-channel interference. In this paper we establish the use of diversity combining techniques to enhance the performance of imperfect reconstruction Filter Bank Multi-Carrier (iPR-FBMC), which doesn't require the use of orthogonality and Cyclic Prefix, this leads to increase in the spectral efficiency. We propose iPR-FBMC with Maximal Ratio Combining (MRC) to enhance its performance in terms of achievable rate and BER. Also, the performance of iPR-FBMC in multiuser communication with different subband allocation schemes is compared. Our simulation result shows that employing the diversity combining technique enhances the performance of iPR-FBMC

Keywords: Diversity combining, iPR-FBMC, Achievable Rate, cyclic prefix.

I.INTRODUCTION

By employing the use of diversity techniques, the effect of multi path fading and co-channel interference can be reduced. The basic idea of diversity is to provide two or more inputs at the receiver. If one signal experiences deep fade another independent path may have a strong signal. The fundamental principle of a diversity combining technique is to combine the multiple received signals of a diversity reception device into a single improved signal [1]. Amongst different diversity combining techniques available, Maximal Ratio Combining technique provides most acceptable results contrasted with remaining techniques [2, 3]. The performance of MIMO (Multiple Input Multiple Output) system under different channels with different diversity techniques provides that the Maximal Ratio Combining (MRC) is a good choice for MIMO and BPSK modulation scheme most suitable modulation for MRC equalizers [4]. [5] Proposed a method of utilizing channel diversity to increase the secrecy capacity in the wireless communication system. The Maximal Ratio Combining of channel diversity can enhance the security of the wireless communication system in normal operating scenarios. Based on these facts, we presume that the Maximal Ratio Combining is an efficient way to improve the performance of a wireless communication channel. The comparative analysis between FBMC and OFDM in [6] states that FBMC offers a number of advantages that may make it a more viable technology for many upcoming and future communication systems and FBMC outperforms the OFDM in many areas like uplink transmission, Cognitive Radio, PLC and DSL Communication systems etc. There is no necessity of Cyclic Prefix in iPR-FBMC compared to OFDM prompts more spectral efficiency for long data packets [7].[8] Proposed to combine OFDM with FBMC which does drops the orthogonality, but the symbol rate is halved as only half of the subbands are active for each data block thus it actually stores the orthogonality in time domain. In [9] took a further step and proposed iPR-FBMC without CP at all and concluded that iPR-FBMC is to be more competitive waveform for future generation cellular communication. In this work, we extended the existing work by including maximal ratio combining to enhance the performance of iPR-FBMC.

This paper organized as follows, existing and proposed methods described in section 2. Section 3, 4 of this paper presents the achievable rate and multiuser communication of iPR-FBMC. The simulation results are provided in section 5. Conclusions are drawn in section 6.

II.SYSTEM MODEL

A. Existing PR-FBMC System:

In the existing system, a non-orthogonal FBMC system without PR constraint is proposed by challenging the necessity of perfect reconstruction in both OFDM/OQAM (OFDM with offset QAM) [10] and EMFB (Exponential modulated filter bank). In the iPR-FBMC constraints on the prototype filter is relaxed. Now the filter could focus on improving the detection performance instead of having to meet the PR constraint. The existing iPR-FBMC system model derived from PR-FBMC (EMFB) system model [11]. The block diagram of the existing system is same as that of the proposed system with the exception of maximal ratio combiner as Diversity combining technique shown in fig (1).

The SFB (Synthesis Filter Bank) and AFB (analysis Filter Bank) are adopted at the transmitter side and the receiver side in order to process the message symbols. The upsampling and downsampling factor P is chosen as smaller than or equal to the number of subbands M. Due to the critical sampling at the receiver perfect symbol detection is only possible with the use of signal detection algorithms. The comparative analysis between PR-FBMC, OFDM and iPR-FBMC concludes that the performance of iPR-FBMC surpasses PR-FBMC and indeed outperforms OFDM. The existing framework also concludes that performance of iPR-FBMC in interleaved subband allocation scheme is more efficient than localized. In this work, we extend this work by proposing the use of MRC to achieve better performance of imperfect reconstruction Filter Bank Multi-Carrier (iPR-FBMC)

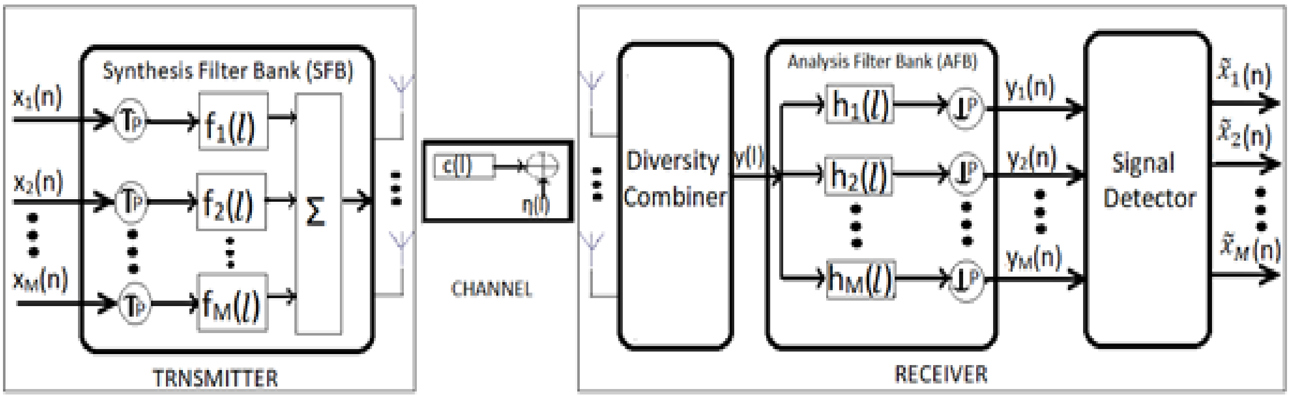

Fig.1. Transceiver diagram of proposed iPR-FBMC system ($x_m(n)$ is QAM modulated and P=M)

B. Proposed system model:

The proposed iPR-FBMC modulating scheme shares the same properties with that of the existing system except the Maximum Ratio Combiner is implemented to maximize the performance of the proposed system. At the transmitter side, In SFB section the upsampling factor P smaller than or equal to the number of subbands M. when P<M, this case is said to be oversampling. All the synthesis filters can be exactly same as that in PR-FBMC. Since input symbols are complex ones, so the real orthogonality between subbands doesn't hold anymore even using the same filters. When P=M, the complex valued filters bank is critically sampled. The prototype filter can now be selected promptly, as long as the spectrum restricted within a predefined mask which incredibly simplifies the design task of FBMC exclusively in non-uniform time-varying spectrum splitting scenario. The system model is depicted in the above fig (1).

At the transmitter side, the complex input QAM symbols $\{x_m(n)\}_{n=0}^{\infty}$ are directly applied to the SFB (synthesis filter bank). The filters $f_m(l)$ of SFB are developed from a common low pass prototype filter $\{h_p(l)\}_{l=0}^{N_f-1}$ of length N_f over frequency shifting [12].

$$f_m(l) = h_p(l) \exp\left(j\frac{2\pi}{M}\left(m-\frac{1}{2}\right)\left(l+\frac{(\frac{m}{2}+1)}{2}\right)\right) \quad (1)$$

For subband indices m= 1… M, and filter tap indices l = 0, 1,...N_f-1. $\{h_p(l)\}_{l=0}^{N_f-1}$ Must be arranged to meet the PR constraint. For fairly good performance $\{h_p(l)\}_{l=0}^{N_f-1}$ designed according to [13].

The output of the SFB transmitted through a multipath channel $\{c(l)\}_{l=0}^{L_c-1}$ of length L_c and corrupted by Additive White Gaussian Noise $\eta(l)$ that is distributed according to $\mathcal{CN}(0, N_o)$ denotes a circular Gaussian random vector with zero mean and covariance N_o.

At the receiver side, all received signals are combined in a co-phased and weighted aspect to achieve the highest signal to Noise Ratio at the receiver all the time. In MRC diversity combining all individual signals from diversity branches (channels) are first weighted according to their signal voltage to noise power ratios and then summed orderly. The gain of that channel is inversely proportional to the mean square noise level and directly proportional to the RMS value of the signal. Assuming perfect knowledge branch amplitudes and phases MRC provides the maximum performance improvement. The BER for MRC in AWGN channel using BPSK modulation is given by [4].

$$P_b = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (2)$$

Where P_b is bit error rate and E_B/N_O is signal to noise ratio. The SNR with MRC is denoted as Υ, where bit error rate total is the integral of the conditional BER integrated over all feasible values of Υ [14]. Now the above equation (2) can be shortened to equation (3).

$$P = \frac{1}{2} - \frac{1}{2}\left[1+\frac{1}{E_b/N_o}\right]^{1/2} \quad (3)$$

The output of the maximal ratio combiner is given to the AFB (Analysis Filter Bank). The main aim of the AFB is to break down the full band signal is $\{y(l)\}_{l=0}^{\infty}$ into M subband signals $\{y_m(n)\}_{n=0}^{\infty}$ for m=1,2,…M. the analysis filters $h_m(l)$ of the AFB are derived from a common low pass proto type filter $\{h_p(l\}$ of length N_f through frequency shifting [12].

$$h_m(l) = f_m^*(N_f-1-l) \quad (4)$$

for m=all sub band indices m=1,2,…M , filter tap indices l=0,1,….N_f-1.The value of downsampling factor P identical to the number of subbands M. [15] has confirmed that such a straightforward filter bank structure can never achieve the PR property.

The successful data decoding is now possible for this iPR-FBMC system with the help of signal processing algorithms. The main aim of these algorithms is to develop a specific linear MMSE equalizer of finite length for each subband. The Same equalizer could be used for all iterations. After every iteration, the interference will be assessed and subtracted before equalization. Here the final decision could be made after several iterations. This procedure is stated in the below algorithm 1[9].

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Algorithm 1
Input: ${g_m,j(n)}_{n=0}^{N_o-1}$, m, j = 1, 2…M, $N_o$ and T, the total number of iterations.

Initialization:
i) Generate a set of M linear MMSE equalizers, denoted by ${w_m(n)}_{n=0}^{L_w-1}$ for each m=1, 2,…M respectively;
ii) Set hard decisions $\tilde{x}_m(n) = 0, \forall m, n$;
iii) Set $t \leftarrow 1$.

Iterative processing:
While $t \leq T$ do
    1) Interference estimation:
    $\tilde{I}_m(n) + g_{m,m-1}(n) * \tilde{x}_{m-1}(n) + g_{m,m+1}(n) * \tilde{x}_{m+1}(n)$;
    2) Interference cancellation:
    $\check{y}_m(n) = y_m(n) - \tilde{I}_m(n)$
    3) Equalization;
    $\hat{x}_m(n) = w_m(n) * \check{y}_m(n)$;
    4) Hard decision;
    $\tilde{x}_m(n) = Q[\hat{x}_m(n)]$.
    end for
    $t \leftarrow t+1$.
end while
Output: ${\tilde{x}_m(n)}, \forall m, n$.
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III. ACHIEVABLE RATE OF iPR-FBMC

In this subsection we compute the achievable rate of iPR-FBMC. The achievable rate computed by observing the aggregate signal $\{y(l)\}_{l=0}^{\infty}$ before Analysis Filter Bank instead of inspecting the subband signals $\{\{y_m(n)\}_{n=0}^{\infty}\}_{m=1}^{M}$. In information theory the mutual information of source symbols and processed symbols is not much greater than that of source symbols and immediate received symbols, so observing the $\{y(l)\}_{l=0}^{\infty}$ is equivalent to observing $\{\{y_m(n)\}_{n=0}^{\infty}\}_{m=1}^{M}$ If the analysis filters $h_m(l)$ are chosen as delay chains of length M.

$$h_m(l) = \delta[l - m + 1],\ l = 0, 1..M-1,\ \forall m. \qquad (5)$$

The maximum Achievable Rate for iPR-FBMC is derived from [9, section 3], by considering the transmission in AWGN channel using poly phase Identity the received signal given by

$$y_m(n) = \sum_{j=1}^{M} g_{m},j(n) * x_j(n) + z_m(n). \qquad (6)$$

Where $z_m(n)$ is the m-th poly phase component of the original noise n(l) and is unfiltered and i.i.d Gaussian with zero mean and variance N_o. The filter $g_m,j(n)$ of length N_g is the poly phase component of the cascaded filter.

The maximal achievable rate has derived as follows

$$R = \frac{M_p}{M\,N_d} \log_2 \left(1 + \frac{M\,N_d}{M_p}\frac{P_x}{N_o}\right) \qquad (7)$$

The assumption is that N_d modulated symbols per subband are transmitted using N_d independent subcarriers. Mp is the number of singular values of block diagonal matrix G (6), Number of subcarriers M and P_x is the average transmitted power.

IV. MULTIPLE ACCESS USING iPR-FBMC

In multi-user scenario, every user is designated to a subband. There exist three subband allocation schemes namely Interleaved, Localized and Random as shown in below figure

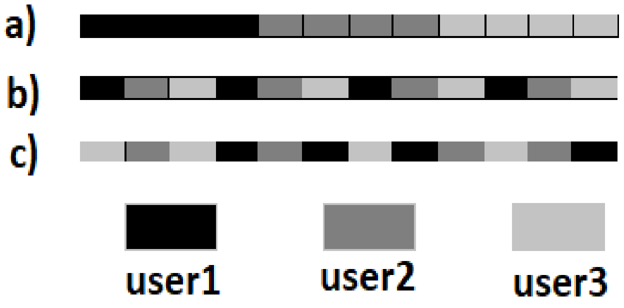

Fig.2. Representation of different subband allocation schemes for multiuser iPR-FBMC with 3 users and 12 subbands: (a) localized (b) interleaved (c) random.

In downlink, all the three subband allocation schemes can be used, as each user notices a single channel from the base station. Whereas in uplink, for PR-FBMC, it is crucial to separate all available users by using null subbands for isolation due to overlapping of subband's signal with another channel responses. As a conclusion only interleaved and random subband allocation schemes could be used for PR-FBMC. In uplink for iPR-FBMC there is no need to use null subbands for isolation thus all three subband allocation schemes could be employed. This leads to increase in the spectral efficiency for iPR-FBMC as compared to PR-FBMC.

V. SIMULATION AND RESULTS

BER comparative analysis for PR-FBMC, OFDM, iPR-FBMC and proposed system is carried out in this subsection. The table 1 given below shows some key parameters to frame this comparison more clear and fair. Channel coding is not included in the simulation. The reduction in power and spectral efficiency due to CP in OFDM and tailing of filters of FBMC is not considered in the simulation. The legend iPR-FBMC with MRC denotes our proposed system. The abbreviation PCS and RM in the legend refers to optimized filter design using poly phase component selection and rate maximization.

Simulation parameters of PRFBMC, iPR-FBMC and OFDM:

System Parameters	Possible Values
Modulation Formats	iPR-FBMC/OFDM: QPSK; PR-FBMC: BPSK
Data block length N_d	iPR-FBMC/OFDM: 100; PR-FBMC: 200
Number of subband/subcarriers (M)	8, 128
Length of subband filters for FBMC	$N_f = 6M$
Maximum passband /stopband deviations	0.001
Error ratio [13, Eq. (12)]	k = 1
Length of equalizers for iPR-FBMC	$N_e = 2N_g$
Number of iterations for iPR-FBMC	Q = 6
Length of multipath channels L_c	3, 12

A). Achievable Rate Comparison:

The achievable rate for single user iPR-FBMC, OFDM, PR-FBMC and iPR-FBMC with MRC is compared in this subsection. The achievable rates also contrasted with channel capacity in AWGN channel demonstrated as L_c- tap complex random Gaussian channel with equal power gains among the taps and total power is normalized to unity. In Fig. 3, For M=128 our proposed system accomplishing higher achievable rate than existing iPR-FBMC system and also OFDM in AWGN channel.

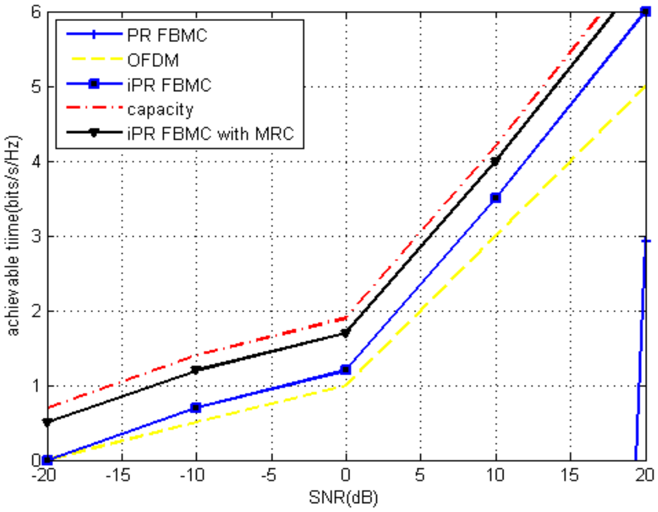

Fig.3. Achievable rate comparison of OFDM, PR-FBMC, iPR-FBMC, iPR-FBMC with MRC and channel capacity.

B). BER Performance:

The BER performance of point to point communicate on in a single user case for M=128 and L_c= 12 in AWGN channel is simulated in this subsection. For iPR-FBMC with no utilization of PCS, BER is slightly poor because of error in iterative interference estimation and cancellation procedure. It can be seen that our proposed method could improve the BER performance significantly better than iPR-FBMC with PCS as appeared in fig 4.

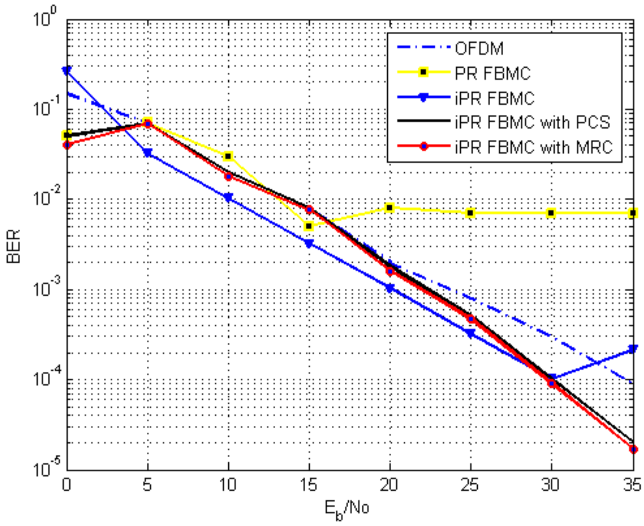

Fig. 4. BER comparison between OFDM, PR-FBMC, iPR-FBMC and iPR-FBMC with MRC in both AWGN channel for M = 128 and L_c = 12.

Fig. 5 demonstrates the BER performance of all the systems with L_c= 3 and M=128. The performance of iPR-FBMC is getting worse as compared to iPR-FBMC with PCS and iPR-FBMC with MRC for a small length of the channel. It can be seen that iPR-FBMC with PCS and iPR-FBMC with MRC gives a similar performance for this case.

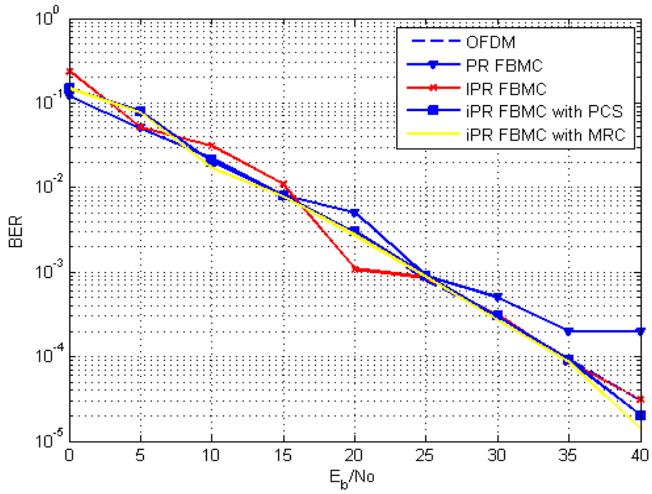

Fig.5. BER comparison between OFDM, PR-FBMC, iPR-FBMC and iPR-FBMC with MRC for M=128 and L_c = 3.

The BER performance of different systems with a small subcarrier M=8 is depicted in the figure 6. It can be seen that iPR-FBMC with MRC provides preferable performance over the existing iPR-FBMC with prototype filter optimized using PCS and Ratio maximization yet regardless it experiences the error floor at high SNR values. This simulation results conclude that our proposed method significantly improves the BER performance of the existing iPR-FBMC system.

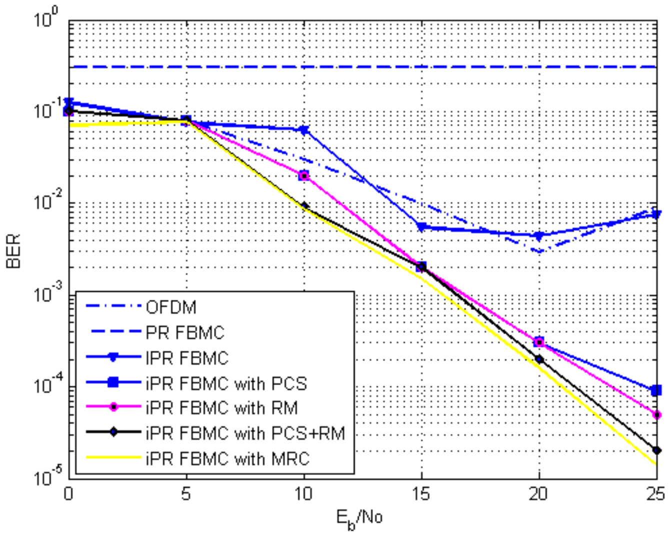

Fig.6. BER comparison between OFDM, PR-FBMC iPR-FBMC and iPR-FBMC with MRC in AWGN channel with L_c= 12 and M = 8.

C) Multiuser communication with different subband allocation schemes:

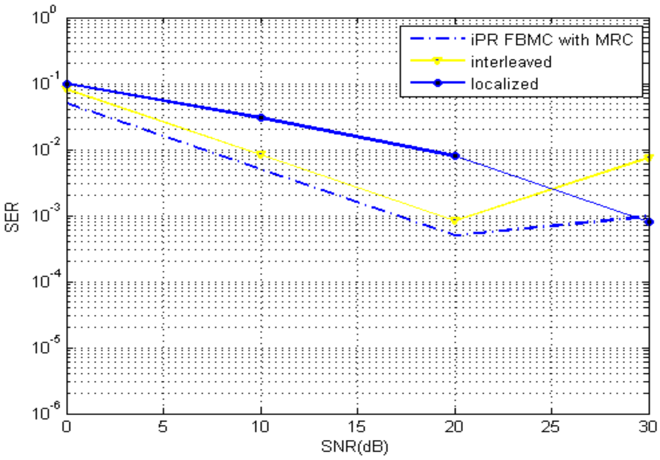

Fig.7: SER of iPR-FBMC using localized and interleaved subband allocation schemes and iPR-FBMC with MRC using interleaved subband allocation with M = 128 subbands in total.

In this subsection, we compare localized and interleaved subband allocation schemes for multi user iPR-FBMC with polyp hase component selection. The localized subband allocation scheme is acknowledged to be the previous simulation. We assume that there are K=64 users and simulate SER (symbol error rate) performance in AWGN channel with channel length L=12.As shown in the fig.7 the performance of iPR-FBMC with MRC in interleaved subband allocation outperforms existing iPR-FBMCsystem. We conclude that interleaved subband allocation scheme provides more preferable results than the localized scheme for iPR-FBMC.

VI. CONCLUSION

We have presented a way to improve the performance of existing iPR-FBMCsystem by employing the Maximal Ratio Combining as a diversity combining technique. At first, we calculated and compared Achievable Rate of the existing system and the proposed method. Our method provides a better achievable rate performance with number of subcarriers M=128 in AWGN channel superior to both PR-FBMC and OFDM. As expected our method essentially enhances the BER performance as compared to the existing iPR-FBMCsystem. In multi user communication interleaved subband allocation scheme is a superior alternative for iPR-FBMCsystem. There are different challenges to complete this work like employing advanced signal processing and detection techniques and universally optimal prototype filter design will be left for future study.

VII. REFERENCES

[1].T.S. Rappaport, Wireless Communications: Principles and Practice. Upper Saddle River, NJ: Prentice Hall, 2nd Ed. 2000.

[2].A.J. Goldsmith, Wireless Communications, Cambridge University Press. 2005.

[3].M.K Simon, M.-S Alouini, Digital Communications over Generalized Fading Channels: A Unified Approach to Performance Analysis. New York: Wiley 2000.

[4].M. Anitha, R. Siva Priya, M. Raja Lakshmi, S. Vijayalakshmi "MIMO System Performance using Various Modulations under Different Channels with STBC, ZF and MRC" IEEE international conference on electrical, computer and communication technologies (ICECCT), 2015.

[5].Fangming He, Hong Man and Wei Wang "Maximal Diversity Combining Enhanced Security" IEEE COMMUNICATIONS LETTERS, VOL. 15, NO. 5, MAY 2011

[6].B. F. Boroujeny, "OFDM versus filter bank multicarrier," IEEE Signal Processing Magazine, vol. 28, no. 3, pp. 92-112, May 2011.

[7].F. Schaich, T. Wild, and Y. Chen, "Waveform contenders for 5G: suitability for short packet and low latency transmissions," in Proc. of IEEE Vehicular

Technology Conference (VTC Spring), Seoul, South Korea, May 18-21, 2014, pp. 1–5.

[8].R. Zakaria and D. Le Ruyet, “A novel filter-bank multicarrier scheme to mitigate the intrinsic interference: application to MIMO systems,” IEEE Transactions on Wireless Communications, vol. 11, no. 3, pp. 1112-1123, Mar. 2012.

[9].Jian Dang, Zaichen Zhang, Liang Wu, andYongpeng Wu, “A New Framework of Filter Bank Multi-Carrier: Getting Rid of Subband Orthogonality” IEEE TRANSACTIONS ON COMMUNICATIONS volume 65, issue 9, pp. 3922-3932, Sept 2017.

[10].P. Siohan, C. Siclet and N. Lacaille, “Analysis and design of OFDM/OQAM systems based on filterbank theory,” IEEE Transactions on Signal Processing, vol. 50, no. 5, pp. 1170-1183, May 2002.

[11].J. Alhava and M. Renfors, “Exponentially-modulated filter bank-based transmultiplexer,” in Proc. of IEEE International Symposium on Circuits and Systems, Bangkok, Thailand, May 25-28, 2003, vol. IV, pp. 233-236

[12].J. Alhava and M. Renfors, “Recursive algorithms for modulated and extended lapped transforms,” IEEE Transactions on Circuits and Systems – I: Regular Papers, vol. 61, no. 1, pp. 191-201, Jan. 2014.

[13].S. W. A. Bergen, “A design method for cosine-modulated filter banks using weighted constrained-least-squares filter,” Digital Signal Processing, vol. 18, no. 3, pp. 282-290, May 2008.

[14].NishaAchral, GarimaMathur, Prof. R.P. Yadav, "Performance Analysis of Wireless MIMO System by Using Alamouti's Scheme and Maximum Ratio Combining Technique" Dept. of Electrical and Electronic Engineering, 20 II.

[15]. A. Viholainen, T. H. Stitz, J. Alhava, T. Ihalainen and M. Renfors, “Complex modulated critically sampled filter banks based on cosine and sine modulation,” in Proc. of IEEE International Symposium on Circuits and Systems, Phoenix-Scottsdale, Arizona, USA, May 26-29, 2002, vol. I, pp. 833-836.