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Efficient BER Performance using Unitary Differential Space-Time Frequency Code for MIMO OFDM Systems

R. KARUNASRI[1], M. RAJANI DEVI[2]

[1]PG Scholar, Dept of ECE, Vardhaman College of Engineering, Hyderabad, JNTUH, Telangana, India,
E-mail: rajojikarunasri6504@gmail.com

[2]Associate Professor, Dept of ECE, Vardhaman College of Engineering, Hyderabad, JNTUH, Telangana, India,
E-mail: rajimerigala@gmail.com.

Abstract: In ultra-wideband (UWB) communications spectral resources are potentially wasted in order to avoid narrowband interference in the case single carrier based multi band system. This paper proposes unitary differential space-time-frequency codes (DSTFCs) for MB-OFDM UWB communications, which increase the system bandwidth efficiency because no channel state information (CSI) is required. The proposed system would be useful when CSI is unavailable at the receiver. The paper also quantifies for the variable puncture rate Forward error correction scheme for significant improvement in the bit error performance of proposed MB-OFDM. Performance of proposed system is analyzed in deep fading environment (Raleigh fading channel) results are presented which show that the variable rate forward error correction (FEC) with MB-OFDM UWB communication is better than that with conventional system, and the BER performance is also be improved significantly by using 64 QAM as our modulation scheme.

Keywords: Orthogonal Frequency-Division Multiplexing (OFDM), Ultra Wideband (UWB), Forward Error Correction (FEC), Differential Space-Time-Frequency Codes (DSTFCs), Channel State Information (CSI), BER Performance, 64 QAM.

I. INTRODUCTION

In telecommunications, 4G is the fourth generation of cellular wireless standards. It is a successor to 3G and 2G families of standards. Multi-band orthogonal frequency-division multiplexing (MB-OFDM) is one of 4G ultra wideband (UWB) radio standards, which provides high-speed connectivity in a wireless personal area network (PAN) [1] with specification of the data rates from 53.3 to 480 Mbps [2]. Due to the high data rates, the MB-OFDM standard requires to process large amount of computations in very short time; its modem has to compute one symbol that consists of 165 complex numbers in every 312.5 ns. Even though its performance requirement results in large hardware complexity, a low power design with small chip size is absolutely essential for applying this technology to portable handheld devices. Also, an operating frequency of a circuit is one of the dominant factors that determine power consumption. MB-OFDM defines two constellation mapping schemes: QPSK and DCM modulations. The QPSK spreads data into several subcarriers and the DCM requires data reordering. The spreading and reordering processes involve non-trivial amount of buffer storages and also latency. Conventionally those processes are done as separate phases: interleaving first and then spreading or reordering. But, here can unify the spreading and the (inverse)-reordering with the (de)interleaving process. With the proposed interleaver architecture, here can perform the spreading before the interleaving process by fully utilizing array cells of our interleaver. The rest of this paper is organized as follows. In Section II, the related work is introduced. Section III formulates the proposed methodology for efficient BER performance DSTFCs. Section IV explains about simulated results are explained in Section V. conclusion is presented in Section VI.

II. RELATED WORK

Really, recurrence specific blurring diverts are frequently experienced in broadband remote correspondences. It is surely understood that orthogonal recurrence division multiplexing (OFDM) is a standout amongst the best systems to beat the recurrence selectivity issue. The consolidated arrangement of space-time coding and OFDM is proposed in [7]-[9], generally named MIMO-OFDM frameworks. In the interim, it is demonstrated in [8], [9] that, notwithstanding spatial assorted qualities, multipath differing qualities (recurrence differences) can likewise be given in MIMO-OFDM frameworks. To profit by the multipath assorted qualities, a lot of exploration has been done previously (allude to [10] and references in that). To the best of our insight, the issues of joining DUSTM with OFDM when connected to recurrence specific blurring channels have not adequately been examined. The space-time-recurrence coding proposed in [10] was received to perform DUSTM for OFDM-based MIMO correspondence frameworks. In any case, these methodologies oblige that the blurring channels keep pretty nearly steady up to 2M OFDM blocks, where M is the quantity of transmit reception apparatuses. Consequently, they are not well suitable for fast fading channels.

A. Problem Outline

For differential transmission as a rule OFDM frameworks connected with a MIMO model. Be that as it may, differential transmission in MBOFDM frameworks connected with MIMO has not been considered yet. There are two principle contrasts between direct qualities in customary OFDM frameworks and in MBOFDM UWB ones. In the first place, diverts in the recent are considerably more dispersive than those in the previous, with the normal number of multipaths potentially coming to a few thousands. Second, divert coefficients in the previous are typically thought to be Rayleigh conveyed, while those in the last are log-regularly circulated. In this way, the frameworks joining MBOFDM UWB, MIMO and differential transmission must be all the more particularly examined, however there exist a few likenesses between those frameworks and the frameworks fusing customary OFDM, MIMO and differential transmission. The N-point FFT is formulated as

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{nk}, k = 0,1,\ldots N-1 \quad \textbf{(1)}$$

Where the twiddle factor is defined as $W_N^{nk} = e^{-\frac{2\pi nk}{N}}$.The n denotes the time index and the k denotes the frequency index. The radix 2k algorithm can be derived by integrating twiddle factor decomposition through a divide and conquer approach.

B. UWB specifications

This standard specifies an ultra-wideband (UWB) physical layer (PHY) for a wireless personal area network (PAN), utilizing the unlicensed 3100 - 10600 MHz frequency band, supporting data rates of 53.3, 80, 106.7, 160, 200, 320, 400, 480, 640, 800, 960 and 1024 Mb/s. Support for transmitting and receiving data rates of 53.3, 106.7, and 200 Mb/s using the convolutional code shall be mandatory. For each of the rates 160, 200, 320, 400 and 480, if LDPC coding is provided then convolution coding should also be provided. The UWB spectrum is divided into 14 bands, each with a bandwidth of 528 MHz the first 12 bands are then grouped into 4 band groups consisting of 3 bands. The last two bands are grouped into a fifth band group. A sixth band group is also defined within the spectrum of the first four, consistent with usage within worldwide spectrum regulations. At least one of the band groups (BG1 - BG6) shall be implemented.

UWB Features:

- Provide high data rates.
- Have very good time domain resolution allowing for ranging and communication at the same time.
- Have immunity to multipath and interference.
- Have potentially low complexity and low equipment cost.

C. Existing Schemes

1. Space-Time Block Codes: Space-Time Coding First of all discuss different diversity techniques that can be applied in wireless systems. The idea behind space-time coding is to apply one or more of these diversity techniques to combat fading. Then discuss briefly the space-time coding model and derive the pairwise error probability which leads the design criteria for ST block codes. Diversity techniques are effective ways of combating channel fading and improve reliable system performance in wireless communications. Diversity techniques include time, frequency, antenna and multipath diversity. Due to space limitation of the report, limit on the diversities that applicable to STBC. Time diversity is provided by channel coding in combination with limited interleaving. Multiple replicas of the transmitted signal are spaced in time and the time spacing between transmission exceeds the coherence time of the channel. It essentially provides a form of redundancy in time domain to the receiver. In frequency diversity, the replicas of the signals are transmitted over different frequency band. The frequency spacing between channels has to exceed the coherence bandwidth of the channel. It provide a form of redundancy in the frequency domain. Note that time and frequency diversity normal induce loss in bandwidth efficiency. Antenna diversity which is also known an space diversity, the transmitter and/or the receiver employs multiple antennas that are spatially separated or differentially polarized to create independent fading channels. It provides a form of redundancy in space domain and the performance gain can be provided without any penalty to system's bandwidth efficiency.

2. Space-Time-Frequency Code Implementation in MB-OFDM UWB Communications: Intuitively, the combination of the emerging technologies MB-OFDM UWB, MIMO, and STCs will provide a significant improvement in the maximum achievable communications range, bit error performance, system capacity, and data rate. While the combination of OFDM, MIMO and STCs in the form of Space-Time-Frequency Codes (STFCs) in MIMOOFDM systems (usually referred to as STFC-MIMO-OFDM systems) has been well examined in the literature, such as [6], [7], the combination of MB-OFDM UWB, MIMO, and STCs has been almost unexplored with few papers examining this issue. There are two main differences between channels' characteristics in conventional OFDM systems and in MB-OFDM UWB ones. First, channels in the conventional OFDM system are less dispersive than those in the MB-OFDM UWB system, due to the fact that the latter has much larger bandwidth. Second, channel coefficients in the conventional OFDM system are usually considered to be Rayleigh distributed, while those in the MB-OFDM UWB system are log-normally distributed. Therefore, the systems incorporating MB-OFDM UWB, MIMO, and STCs must be more specifically analyzed, though there exist some similarities between them and the conventional STFC-MIMOOFDM systems.

Base on the literature survey, the perfect codes could be used directly in UWB systems depending on the multiple access techniques. The time hopping pattern can avoid interference (ICI) at the expense of data rate. In the direct sequence multiple access scheme, it is not possible to use the perfect codes directly because of interchip interference. When OFDM modulation is employed in UWB systems, each frequency band is a flat fading channel, and then apply directly the perfect codes. However, in this fading channel not taking advantages of frequency diversity.

III. PROPOSED METHODOLOGY

In this brief, Space-time frequency encoder which encodes a single stream through space using all the transmit antennas and through frequency by sending each symbol at different frequencies.

A. Functional Units

In a MB-OFDM system, a guard interval (9.5 nanoseconds) is appended to each OFDM symbol and a zero-padded prefix (60.6 nanoseconds) is inserted at the beginning of each OFDM symbol. The guard interval ensures that there is sufficient time for the transmitter and receiver to switch to the next carrier frequency. A zero- padded prefix provides both robustness against multi-path and eliminates the need for power back-off at the transmitter. More details about the zero padded prefix will be described in a later section. The structure of the MB-OFDM solution is very similar to that of a conventional wireless OFDM physical layer, except that the carrier frequency is changed based on the time-frequency code. In addition, other modifications have been made to reduce the area and size. MULTI-BAND orthogonal frequency-division multiplexing (MB-OFDM) is one of ultra-wideband (UWB) radio standards, which provides high-speed connectivity in a wireless personal area network (PAN) [1] with specification of the data rates from 53.3 to 480 Mbps [2]. Due to the high data rates, the MB-OFDM standard requires to process large amount of computations in very short time; its modem has to compute one symbol that consists of 165 complex numbers in every 312.5 ns. Even though its performance requirement results in large hardware complexity, a low power design with small chip size is absolutely essential for applying this technology to portable handheld devices.

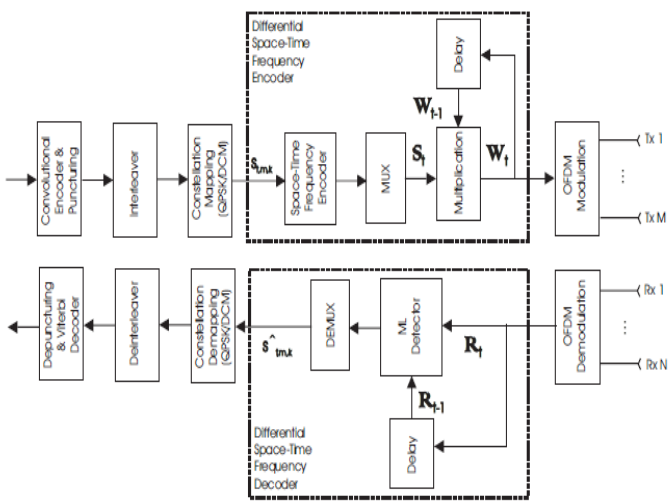

Fig. 1. Structural diagram of the proposed DSTFCMB-OFDM UWB system.

The proposed model of a DSTFC MB-OFDM UWB system requiring no transmission of channel estimation symbols is depicted in Fig. 1. In this figure, refer the two novel blocks to as the multiplexing (MUX) and demultiplexing (DEMUX) blocks. These two blocks are transparent, i.e. having no effect to the system, if constant envelop modulation schemes (e.g. PSK and 64QAM) are used, but non-transparent in the case of DCM scheme.

Consider the application of the Alamouti STFC.

$$\mathbf{S_t} = 1/\sqrt{2}\begin{bmatrix} \bar{\mathrm{s}}_{t,1} & \bar{\mathrm{s}}_{t,2} \\ -\bar{\mathrm{s}}^*_{t,2} & \bar{\mathrm{s}}^*_{t,1} \end{bmatrix} \quad \textbf{(2)}$$

where the MB-OFDM symbol $\bar{\mathbf{s}}_{t,m}$, for m = 1, 2, is a column vector of Nfft complex symbols corresponding to Nfft sub-carriers, i.e. $\bar{\mathbf{s}}_{t,m} = [s_{t,m,1}\ s_{t,m,2} \ldots s_{t,m}$, Nfft]T . Channels in the DSTFC MB-OFDM system are assumed to be constant during a time window of K consecutive transmitted DSTFC code blocks, i.e. during 2KTSYM (ns), where K is an integer number and TSYM is the MB-OFDM symbol interval TSYM = 312.5 ns [3]. The STFC in (2) can be rewritten in the following form

$$\mathbb{S}_t = 1/\sqrt{2}\begin{bmatrix} \mathrm{diag}(\bar{\mathrm{s}}_{t,1}) & \mathrm{diag}(\bar{\mathrm{s}}_{t,2}) \\ -\mathrm{diag}(\bar{\mathrm{s}}^*_{t,2}) & \mathrm{diag}(\bar{\mathrm{s}}^*_{t,1}) \end{bmatrix} \quad \textbf{(3)}$$

The proposed DSTFC MB-OFDM system initializes the transmission with an identity matrix W_0 = I2Nfft. The subsequent code matrices will be generated and transmitted according to the following principle

$$\mathbb{W}_t = \mathbb{S}_t\mathbb{W}_{t-1}. \quad \textbf{(4)}$$

The transmission model can be expressed as follows

$$\mathbb{R}_t = \mathbb{W}_t\mathbb{H}_t + \mathbb{N}_t \quad \textbf{(5)}$$

Since channels are assumed to be constant during the transmission of K consecutive Alamouti STFC blocks, i.e. within a time window 2KTSYM (ns), the encoding principle (10) should be applied for t = 1, . . ., (K − 1) and the whole transmission protocol is reset for a new time window. As mentioned detailed in Section IV, the proposed DSTFC MB-OFDM concept would work well if the channel coefficients are assumed to be constant during at least two consecutive DSTFC blocks (i.e. K ≥ 2). This assumption is in fact normally the case. In practice, the UWB channel is typically unchanged during several tens of Alamouti DSTFC blocks to several thousands of DSTFC blocks. Therefore, the case where the channel changes after every two consecutive Alamouti DSTFC blocks is merely the fastest fading case where the proposed DSTFC concept still works accurately. If the channel matrix changes in every block, the difference of channels during different code blocks results in interference in the differential decoding process, thus the system performance would be degraded. Let us consider the following two scenarios, illustrating when coherent and differential STFC MB-OFDM systems should be deployed.

Taking bits as input and the randomize the bits and then encoding them, then that apply interleaver then apply IFFT and FFT algorithms in tx and rx sections for processing of data through channel i.e y = ifft(X) returns the inverse discrete Fourier transform (DFT) of vector X, computed with a fast Fourier transform (FFT) algorithm. If X is a matrix, ifft returns the inverse DFT of each column of the matrix. ifft tests X to see whether vectors in X along the active dimension are conjugate symmetric. If so, the computation is faster and the output is real. An N-element vector x is conjugate symmetric if x(i) = conj(x(mod(N-i+1,N)+1)) for each element of x. then apply Gaussian noise as y = awgn(x,snr) adds white Gaussian noise to the vector signal x.

The scalar snr specifies the signal-to-noise ratio per sample, in dB. If x is complex, awgn adds complex noise. This syntax assumes that the power of x is 0 dBW. As the name implies, a bit error rate is defined as the rate at which errors occur in a transmission system as shown in Fig.2. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be translated into a simple formula:

BER= Number of errors/ total number of bits.

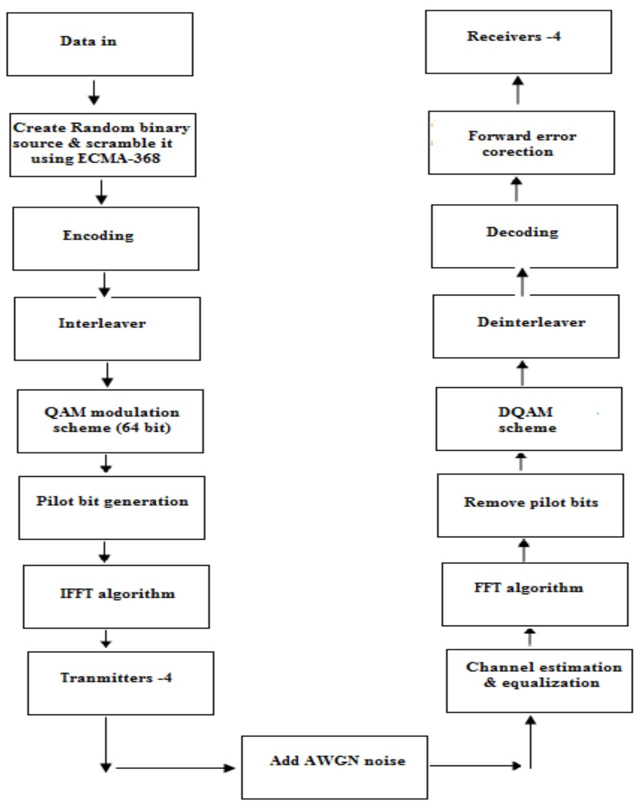

Fig.2. Simulation flow model for proposed system.

B. Extension Method (64QAM)

Fast algorithm is the method used to improve the power and capacity of the mobile communication system. Considering 64 total sub carriers with five of users based system. Considering channel parameters for defining the power constraints. In the implementation of first algorithm then calculate the effective capacity with pre defined conditions. (Maximum data point condition).

C. QAM Modulation

Quadrature Amplitude Modulation is a signal, in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. Both amplitude and phase variations are available it might likewise be considered as a mixture of amplitude and phase modulation. Inspiration to the utilization of Quadrature Amplitude Modulation (QAM) originates from the way that a straight amplitude modulated signal. QAM may exist either in analogue or digital formats. The analogue renditions of QAM are normally used to allow multiple analogue signals to be carried on a single carrier. Digital configurations of QAM are regularly referred as "Quantized QAM" and they are progressively utilized for information interchanges frequently inside of radio correspondences frameworks. In radio communication systems, when higher order modulation rates are able to offer much faster data rates and higher levels of spectral efficiency for the radio communications system. The higher order modulation schemes are considerably less resilient to noise and interference. They sense the channel conditions and adapt the modulation scheme to obtain the highest data rate for the given conditions. As signal to noise ratios decrease errors will increase along with re-sends of the data, thereby slowing throughput. While using lower order modulation scheme, the link can be made more reliable with fewer data errors and re-sends it.

IV. SIMULATION RESULTS

Simulation was done on MATLAB R2010a, the results was shown that the BER performance is good compared to conventional methods. To examine the performance advantage of the proposed DSTFC MB-OFDM system, several Monte-Carlo simulations were run in Matlab for four systems, namely the baseband, conventional differential MB-OFDM system (without MIMO) with QPSK modulation, the baseband, conventional coherent MB-OFDM system (without MIMO) with QPSK modulation, and the two baseband Alamouti DSTFC MB-OFDM systems with QPSK and DCM schemes.

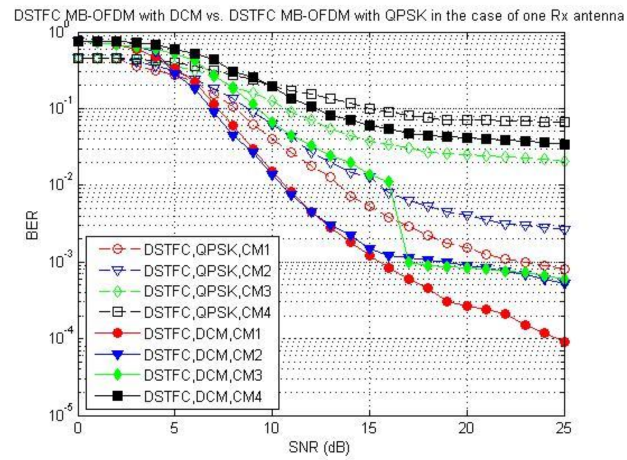

Fig. 3. DSTFC MB-OFDM with DCM vs. DSTFC MB-OFDM with QPSK in the case of one Rx antenna.

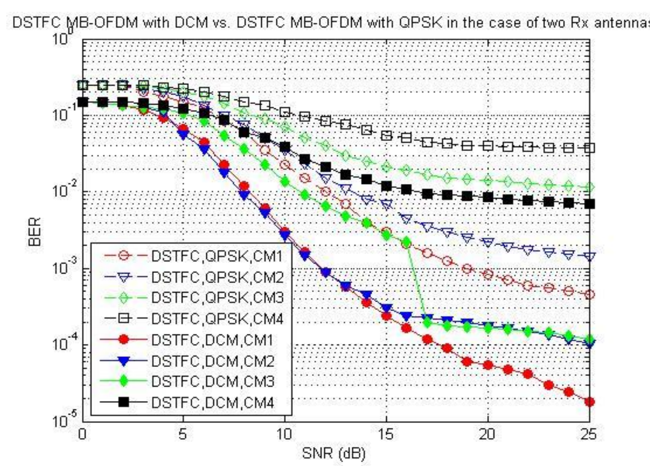

Fig. 4. DSTFC MB-OFDM with DCM vs. DSTFC MB-OFDM with QPSK in the case of two Rx antennas.

Fig. 3 compares the bit error performance of the three systems, namely the conventional differential MB-OFDM (dashed curves), the conventional coherent MB-OFDM (shaded curves), and the Alamouti DSTFC MB-OFDM (solid curves), in the case where the receiver is equipped with only one Rx antenna. From this figure, the proposed DSTFC MB-OFDM system brings about a significant improvement in the bit error performance, compared to the other two MBOFDM systems. For instance, the Alamouti DSTFC provides approximately a 3.5 dB gain in CM1 at the bit error rate BER = 10−2, compared to the conventional differential MBOFDM. The more dispersive the channel is (CM1 is the least dispersive channel model while CM4 is the most dispersive one), the higher gain the DSTFC provides. Furthermore, the proposed DSTFC system can even provide much better bit error performance over the conventional coherent MB-OFDM system at high SNRs. For example, the former is better than the latter at SNR being higher than 10 dB in CM1 and the gain can be as large as 2.5 dB at BER = 10−3. This improvement is due to the fact that the former deploys the MIMO system (more accurately, the 2 × 1 MIMO model).

Fig. 4 presents the bit error performance of the three systems in the case of two Rx antennas, i.e. in a 2 × 2 MIMO model. Once again, see that DSTFCs improve significantly the bit error performance of MB-OFDM systems. For illustration, a gain of at least 4.5 dB (over the conventional differential MB-OFDM system) can be achieved at BER = 10−4 when the Alamouti DSTFC is utilized. Similarly, the DSTFC system might even perform much better than the conventional coherent MB-OFDM system at the high SNR range. It is noted that the aforementioned improvements were gained without any increase of total transmission power, but thanks to the introduced space, time and frequency diversities in the proposed DSTFC MB-OFDM system.

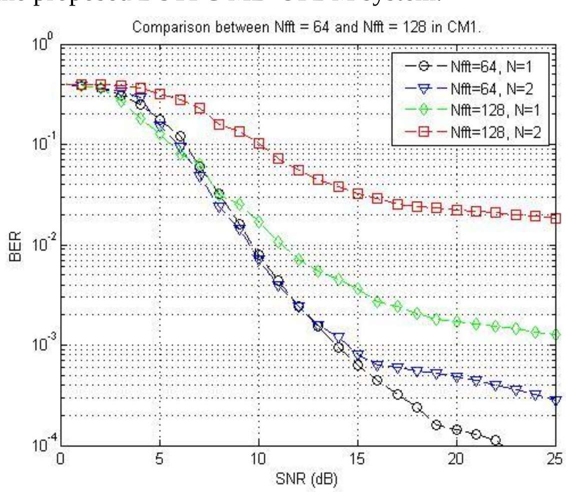

Fig. 5. Comparison between Nfft = 64 and Nfft = 128 in CM1.

From the above two figures, one can observe the error performance enhancement in the Alamouti DSTFC system, compared to the conventional differential MB-OFDM system, in all channel models thanks to the higher diversity order introduced by the proposed DSTFC MB-OFDM system. For illustration, BER slopes are measured by the SNR difference (dB), denoted as _SNR, per BER decade within the range from BER = 10−1 to BER = 10−2 and measured based on Fig. 4.

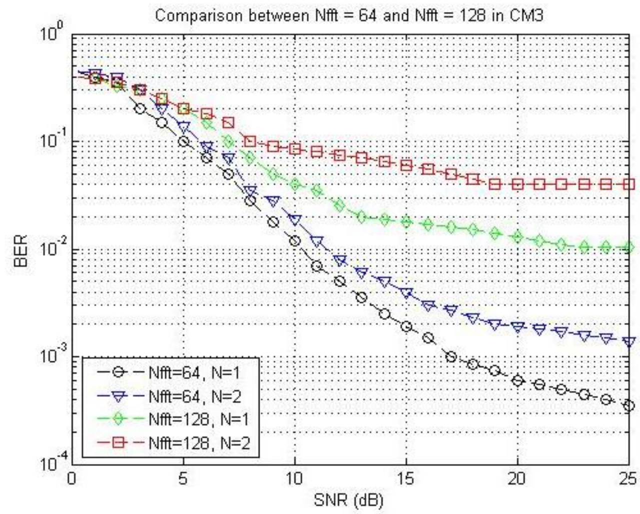

Fig. 6. Comparison between Nfft = 64 and Nfft = 128 in CM3.

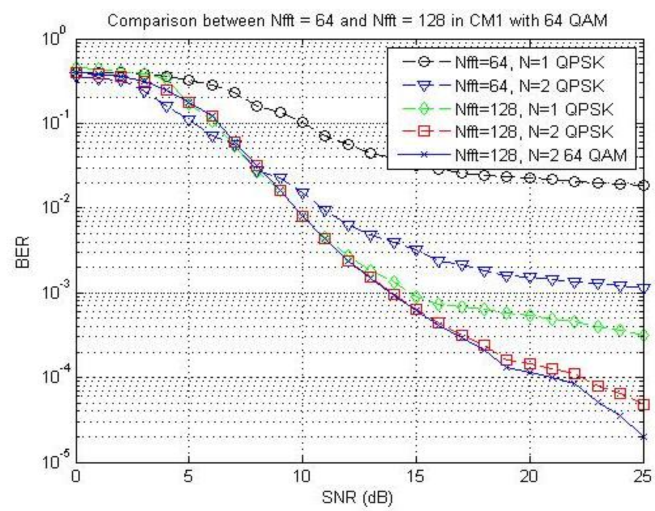

Fig. 7. Comparison between Nfft = 64 and Nfft = 128 in CM1 with 64 QAM.

Figs.5 and 6 illustrate the effect of the different FFT/IFFT sizes to the performance of the proposed DSTFC MB-OFDM system, with the number of Tx antennas M = 2 (the Alamouti DSTFC is simulated) and the number of Rx antennas N = 1 and N = 2. Specifically, Fig. 6 compares the system performance between two FFT sizes, namely Nfft = 64 and Nfft = 128, in the same channel model CM1, while Fig. 6 compares the system performance in the channel model CM3. From the two figures, two important observations can be drawn. First, the larger the FFT size is, the better the system error performance is. In each figure, the two curves corresponding to the pairs (Nfft = 64, N = 2) and (Nfft = 128, N = 1) are in parallel, i.e. the two curves have the same slopes. In other words, the DSTFC MB-OFDM UWB system has the same diversity orders in these cases. Figs. 7 and 8 illustrate the effect of the different FFT/IFFT sizes to the performance of the proposed DSTFC MB-OFDM system. Here using 64 QAM as modulation scheme to get the better performance of BER along with SNR.

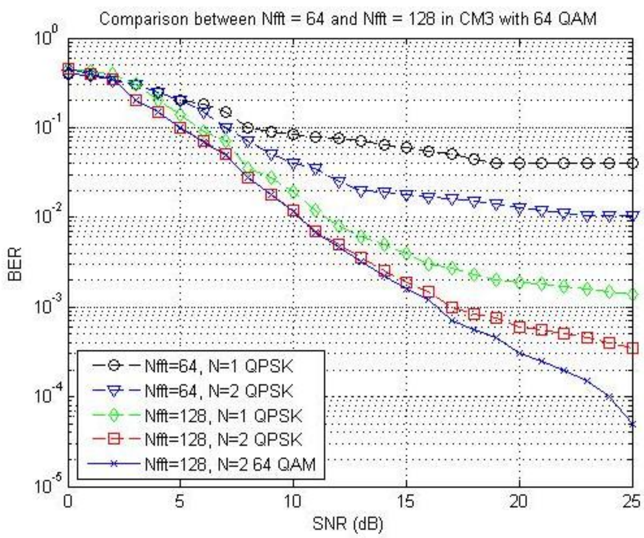

Fig.8. Comparison between Nfft = 64 and Nfft = 128 in CM3 with 64 QAM.

V. CONCLUSION

The paper has also derived the novel coding and decoding algorithms for the proposed DSTFC MB-OFDM system and the in-depth analyses of the diversity order and the factors affecting the performance of a realistic MB-OFDM UWB system. Furthermore, beside the case study of MB-OFDM UWB systems, it is the conjecture that the proposed DSTFC principle might be applied to various other wireless systems, such as WiMax MIMO, providing better BER than the respective WiMax without MIMO. Here to improve the BER performance proposed scheme used 64 QAM as our modulation scheme. Examination of the application of DSTFCs in WiMax MIMO might be our future work.

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Author's Profile:

R. Karunasri has received her **B.Tech.** degree in Electronics and Communication engineering from the Hasvita college of Engineering and Technology, JNTU University, Hyderabad, India, in 2013. Currently doing **M.Tech** in electronics and communication engineering (Wireless and mobile communication system) in Vardhaman College of Engineering, Shamshabad, India.

M. Rajani Devi received her **B.Tech** degree in Electronics and Communication Engineering from Bapatla Engineering College, Bapatla, Nagarjuna University, Andhra Pradesh, India, in 2004. Received her **M.Tech** in Digital Communications from Kakatiya University, Warangal, India. Her research interest includes wireless communication (**WiFi, WiMax**), Communication networks.