ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)

Vol. 2, Special Issue 10, March 2016

A LOW COMPLEXITY EASES APPROACH FOR Q-OFDMA SYSTEMS

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Abstract **— Quadrature Orthogonal Frequency Division multiple access (Q-OFDMA) has been renowned as a promising technique which provides a solution to the high PAPR (Peak to average power ratio), sensitivity to carrier frequency offset (CFO) problem and design complexity as introduced by the normal OFDMA systems. Exploiting this Q-OFDMA systems on the Multi-Input Multi-Output (MIMO) architecture, leads to a remarkable improvement in achievable rates. A critical part of this technology is to design the full-rate diversity codes for two transmit and two receive antennas. This paper endeavours to identify key factors and trade-offs issues associated with designing Q-OFDMA systems. We proposed an Space Time Block Codes and spatial multiplexing technique as well as low complexity detection methods for more than 2x2 antennas at the cost of low complexity. This performs well for different fading channel environments and improves the overall system performance such as diversity gain, SNR (Signal to Noise Ratio), Coding gain and BER (bit error rate. The proposed scheme can be easily applied in OFDMA and Single-Carrier Frequency Division Multiple Access (SC-FDMA) by adjusting the parameters of Q-OFDMA.**

Keywords* — *BER, CFO, diversity gain, LDPC Codes, MIMO, OFDMA, PAPR., Q-OFDMA, SC-FDMA.

I. INTRODUCTION

Wireless technology makes our life easy and comfortable. However, the demand on bandwidth and spectral availability are endless. Nowadays, designers have got difficult task of limited availability of radio spectrum, fading, multi-path, interference, to meet the demand for high data rate [1]. The 2G and 3G standards are not good enough to satisfy the demand of high capacity. Therefore, the new standard 4G which is the successor of 2G and 3G and Broadband Wireless Access (BWA) such as WiMAX, LTE have emerged as a promising solution for providing fully broadband internet for mobile and stationary users and able to offer new exciting multimedia services with superb quality [2] by adopting a new technique called MIMO (Multiple Input Multiple Output)..For instant, the system must provide a data rate near 20 Mbps with less than 10-6 BER. Today it is proved that OFDM have great potential to satisfy high data rate applications with more robustness to frequency selective channels. The MIMO based OFDM technique is an excellent choice providing the flexibility and opportunities to use advanced techniques, such as adaptive loading, transmit diversity, and receiver diversity, to improve transmission efficiency. However, this MIMO based OFDM waveform exhibits very pronounced envelope fluctuations resulting in a high peak-to-average power ratio (PAPR). Highly linear power amplifiers are required by signals with high PAPR to avoid excessive intermediation distortion. To achieve this linearity, the amplifiers have to operate with a large back off from their peak power. It results in less power efficiency (measured by the ratio of transmitted power to dc power dissipated), which places a significant burden on portable wireless terminals. Another problem with OFDMA in cellular uplink transmissions derives from the inevitable offset in frequency references among the different terminals that transmit simultaneously. Frequency offset destroys the orthogonality of the transmissions, thus introducing multiple access interference. To overcome these effects, Q-OFDMA systems are developed [3]-[5]. On the other hand, various diversity techniques and coding schemes are studied to enhance the overall system performance, among which spatial multiplexing [6] and the space time block code (STBC) [7] are two general schemes achieving diversity gain and multiplexing gain for more than two antennas respectively. Spatial multiplexing is the one where independent data streams can be sent among different multiple antennas. Hence spatial multiplexing doubles triples, or quadruples the data rate depending on the number of transmit antennas. The STBCs offer an excellent way to exploit the spatial diversity gain because of the implementation simplicity as well as their low decoding complexity [6], [7]. But this STBC works well only for 2x2 antennas. To achieve full rate transmission for more than two antennas, Quasi-Orthogonal space time block codes were introduced [8]. It does not have fully diversity but it can be achieved through complex constellation rotation. As Quasi-Orthogonal space time block codes and spatial multiplexing provides only a maximum diversity gain and no coding gain, researchers are fascinating an error correcting codes using low complexity decoding approach. By studying modern research, it has been found that Low density parity check (LDPC) codes are one of the best error correcting codes in today's coding world and are known to approach the Shannon limit. Because of their excellent forward error correction properties, LDPC codes are set to be used as a standard in Digital Video Broad-casting (DVBS2) and 4G mobile communications [9] and as a part of WIFI

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802.11 a standard. These codes can jointly improve the system performance at the low decoding complexity.

II. SYSTEM MODEL

At the transmitter section, each user's data stream is first encoded, interleaved and mapped to a certain constellation. Instead of defining the sub channel in one-dimension frequency domain as like conventional OFDMA systems Q-OFDMA systems are defined over an array of two dimensions in the intermediate domain [11]. The block diagram is shown in Fig. 1.

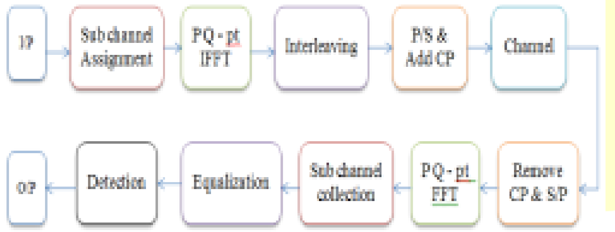


Fig. 1. Block diagram of Q-OFDMA systems.

This array is P Q, where both P and Q are powers of 2, and N = P Q is the equivalent to the total number of subcarriers in ordinary OFDMA systems. Assume that at a specific frame, user k occupies M sub channels. After all users' data is assigned, the symbols of user k's at sub channel q can be extracted from the symbol matrix, then the transmitter transforms the signals from intermediate domain to time domain. Based on the layered FFT/IFFT concept [10], the transform process includes the weighting operator, the per-row IFFT, and the column-wise read-out (i.e. interleaving). After adding cyclic prefix (CP) whose length is longer than the delay spread of a channel, the time domain samples are transmitted over a multipath fading channel. At kth user's receiver, after removing the CP, the time domain samples are then serial-to-parallel converted to a P Q array. Compute Q-point FFT for each row, then collect the data at subcarrier q from each FFT output and arrange them into a vector. After weighting, the received symbol in intermediate domain nq contains AWGN samples, each having zero mean and variance, which are same as that of noise samples introduced in the received time domain signals. Before performing channel estimation and signal detection at the receiver of Q-OFDM systems, a Fourier transform is implemented to the received intermediate-domain symbol. This scheme recovers the orthogonality (avoids interference) between subcarriers in the frequency domain to allow for a simple one-tap equalization, similar to that for conventional OFDMA system. Thus frequency diversity can be achieved without introducing any additional complexity for precoders at the transmitter [11].

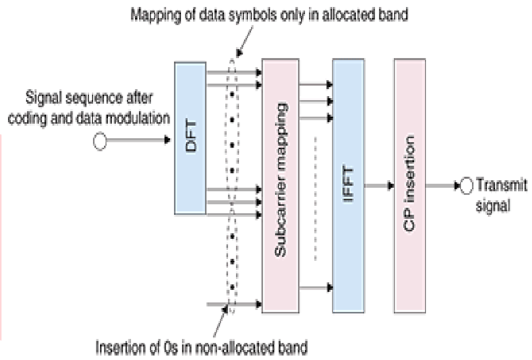


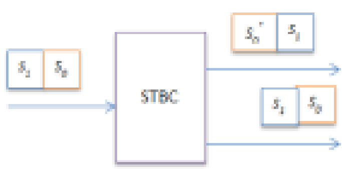
Fig. 2. Subcarrier Mapping

Q-OFDMA is designed by dynamically allocating different subcarriers to different users. Orthogonalization of sub channels is performed with low complexity by using the fast Fourier transform (FFT).The subcarrier mapping is shown in Fig. 2. The aim of subcarrier allocation is to maximize the system throughput and minimize the overall transmit power, while satisfying some constraints, such as bit error rate (BER), data rates, and fairness [12]-[15]. The serial high-rate data stream is converted into multiple parallel low-rate data streams, each modulated on a different subcarrier. A cyclic prefix (CP) or guard interval is critical for OFDM to avoid interblock interference caused by delay spread of wireless channels. They are usually inserted between adjacent OFDM blocks. In addition, this enables broadcast services on a synchronized single frequency network (SFN) with appropriately cyclic prefix design. This allows broadcast signals from different cells to combine over the air, thus significantly increasing the received signal power and supportable data rates for broadcast services [15]. Furthermore, Q-OFDMA provides flexibility and high spectrum efficiency using pilot channel insertion and the provision of guard band.

III. PROPOSED SYSTEM

To increase the quality of the signal at both transmitter and receiver, coding has done. We present various coding techniques to improve the SNR and BER using low complexity approach.

1) Space Time Block Codes (STBC): To address the issue of decoding complexity in space time trellis codes, Space–time block coding was developed. It transmits multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability over frequency selective and Rayleigh channels. It combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible. The STBC encoder is shown in Fig. 3.



ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)

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Fig. 3. STBC encoder

A space time block code is represented by a matrix. Each row represents a time slot and each column represents one antenna

transmission per time. In this matrix, Sij is the modulated signal to be transmitted in time slot I from antenna j. In this coding, data stream is encoded in blocks and pre-multiplying with DFT matrix prior to transmission. The data from user are transmitted as real component of first symbol and the complex conjugate of second symbol over the transmit antenna 1 and real component of second symbol with the complex conjugate of first symbol over the transmit antenna 2. Here space time coding over two OFDM frames occur in the intermediate domain. This does not have direct access to encode in the frequency domain. For finding the encoding and transmitting sequence scheme in the intermediate domain, [11] proposed an alamouti like STBC rule. The Alamouti like STBC rule for encoding in intermediate domain and decoding in frequency domain is shown in table 1. Similarly, decoding is done in the frequency domain, then transfer back to the intermediate domain to retrieve the data. The Alamouti STBC scheme provides full transmit diversity and the advantage of a simple decoder for systems with two transmit antennas. It was originally formulated for single carrier flat-fading channels.

TABLE I: TRANSMITTED SEQUENCE FOR TWO BRANCH TRANSMITTER DIVERSITY

		Time slot $2l$	Time slot $2l+1$
Intermediate Domain	Tx antenna 1	$x_q\hat{}(2l)$	$-(x_q\hat{}(2l+1))^*$
	Tx antenna 2	$x_q\hat{}(2l+1)$	$x_q\hat{}(2l)^*$

		Time slot $2l$	Time slot $2l+1$
Frequency Domain	Tx antenna 1	$x_q\hat{}(2l)$	$-(x_q\hat{}(2l+1))^*$
	Tx antenna 2	$x_q\hat{}(2l+1)$	$x_q\hat{}(2l)^*$

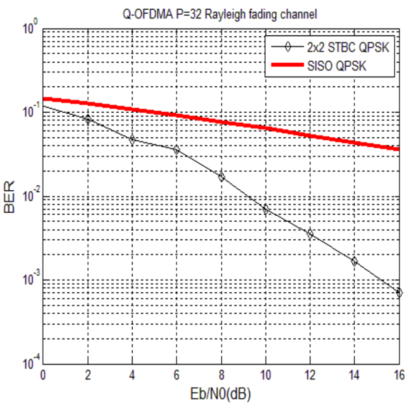
By employing block transmission and the pre- multiple access schemes allow many mobile users to share simultaneously a finite amount of radio spectrum. The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users. It has been proved as an effective technique to combat fading and enhancing data rates The encoding and decoding of these codes have very little complexity and significant gains can be achieved by increasing the number of transmit chains with very little decoding complexity. Quasi orthogonal STBC provides full rate coding gain and it also supports more number of antennas.

2) Spatial Multiplexing: The spatial multiplexing (SM) in the Q-OFDMA systems, which speeds the communication by transmitting multiple data symbols from multiple antennas, and the received signal from all receive antenna are detected and equalized simultaneously by the equalizer in one step [11].

3) Convolutional codes with Viterbi coding: These codes are often implemented in concatenation with a hard-decision code, particularly Reed Solomon. Viterbi-decoded codes, concatenated with large Reed-Solomon error correction codes that steepen the overall bit-error-rate curve and produce extremely low residual undetected error rates. Longer constraint lengths produce more powerful codes, but the decoding complexity of the Viterbi algorithm increases exponentially. Today, the Viterbi algorithm is usually applied to codes with a constraint length no greater than nine. [16].*Turbo coding:* Turbo coding is an iterated soft- decoding scheme that combines two or more relatively simple convolutional codes and an interleaver to produce a block code that can perform to within a fraction of a decibel of the Shannon limit. [17] Shown that an iterative (turbo) equalization in conjunction with channel estimation for Q-OFDMA systems to mitigate the noise enhancement effect while using Zero forcing equalizer. In this coding, turbo equalization eliminates the ISI introduced when a precoding DFT matrix breaks a orthogonal character of a block D.It provides the MMSE (minimum mean square error) based on the received signal x and priori information of x. i.e., mean E(X) and covariance COV(X, X). For the initial equalization stage, priori information is not available and hence the extrinsic information is independent of priori information. At the decoder, the extrinsic information is fed as a priori information. Based on this hard decision is made. Here Interleaver/Deinterleaver module shuffles the coded bits to decorrelate the error and make the error correct as possible. For channel estimation, the training symbols and soft decoded data are utilized to track the channel frequency response and suppress the ISI caused by channel estimation errors in Q-OFDMA systems. Estimation, equalization and decoding algorithms according to the performance /complexity trade-off shown that, the iterative receiver approach can improve the Q-OFDMA systems BER performance with acceptable complexity [18].

IV. RESULTS & DISCUSSION

We have conducted numerical simulations to evaluate the performance of the STBC codes. The Q-OFDMA systems are exploited in MIMO (Multiple Input Multiple Output) architecture and have compared with the SISO (Single Input Single Output). As Q-OFDMA can have the ability to cope with various multipath channel fading environments, the 2x2 STBC Q-OFDMA systems and SISO systems for different number of subcarriers are shown in the simulation results.



ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)

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Fig. 4. BER of SISO and 2 × 2 STBC for the Q-OFDMA system with $P = 32$ on a Rayleigh fading channel.

Fig. 4 shows the BER for SISO and 2 × 2 STBC Q-OFDMA systems with QPSK modulation. We set the parameters N =256 and P = 32, which means the supported number of users is Q = N/P = 4. The simulation result is less than 1dB from the analytical BER curve for the STBC Q-OFDMA system using QPSK modulation.

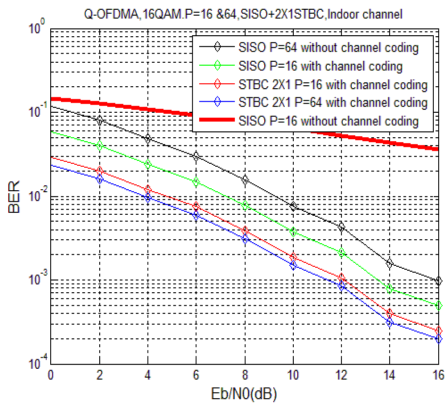

Fig. 5. BER performance comparison between Q-OFDMA systems without channel coding, with 1/2 convolutional channel coding, with STBC, in CM2 channel model, with 16QAM modulation and ZF equalizer.

Fig. 5 shows that BER performance of SISO and 2x2 STBC Q-OFDMA systems with and without convolutional coding. While employing channel coding, the BER significantly reduces with increase in gain. Increasing the number of subcarriers increase data transmission .Hence more number of data is transmitted through large subcarriers. The 2x1 STBC with increase in subcarrier p=16, p=64 reduces the BER for the values of SNR plotted similar to the SISO p=16, p=64 with and without channel coding. Convolutional coding is employed across the channels.

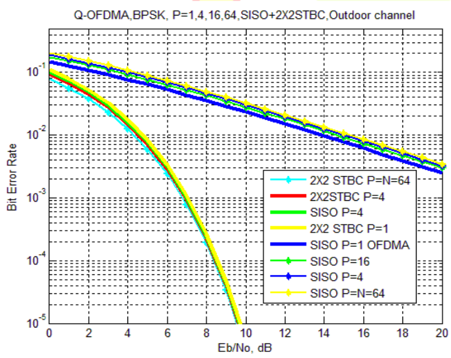

Fig. 6. BER of SISO and 2 × 2 MIMO for the Q-OFDMA system on a frequency-selective outdoor channel for *P* = 1 (OFDMA), *P* = 4, *P* = 16, and *P* = *N* = 64 (Single-Carrier).

From Fig. 6, it has been shown for single antenna system that the BER depends on the value of P. In high SNR regime, the BER is lower the higher P, and in low SNR regime, the BER is lower the lower P. we observe that due to the spatial diversity this crossing point has been shifted significantly to low SNR regime. It is located somewhere around 5dB of SNR. Above 5dB, higher P always outperforms lower P, and the best system is the single carrier system, e.g. SC-FDMA, for which P = N = 64, given system perfection. We can conclude that when the SNR is below 28dB, in terms of BER on the frequency-selective GSCM channel for single antenna systems

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it is convenient to choose P as low as possible, and OFDMA performs best. But for 2x2 STBC Q-OFDMA systems it is convenient to choose P as big as possible, when the SNR is above 5 dB and the single carrier system performs best.

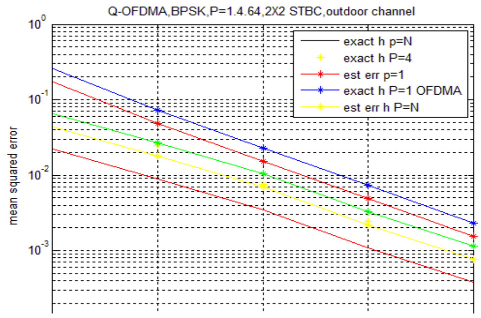

Fig. 7. Comparing the BER with exact channel knowledge with the situation where the channel estimation has 1% error for 2x2 STBC Q-OFDMA systems with $P = 1, 4, N$.

Fig. 7 shows the impact of the channel estimation on the receiver. When the estimated channel information has 1% error, and if also having the subcarrier P= total subcarrier, N for the 2x2 STBC can exhibit the similar performance compared to the OFDMA with N subcarriers having exact channel information.

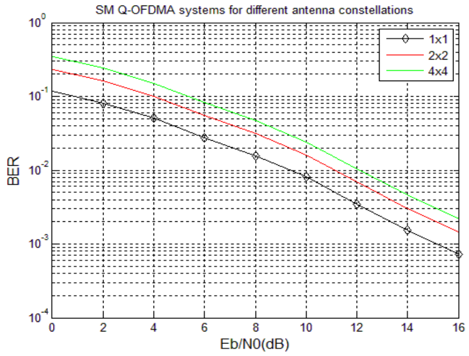

Fig. 8. BER performance of SM Q-OFDMA systems for different antenna constellations, in CM2 channel model, with 16QAM modulation and MMSE equalizer.

Fig. 8 shows the BER performance comparison of SM Q-OFDMA systems between different antenna constellations, using 16-QAM modulation and MMSE equalizer, simulated in a dense multi- path indoor channel environment (CM2 channel model). It can be seen that SM Q-OFDMA with different antenna pairs have similar BER trend, and the 4 × 4 SM Q-OFDMA has better performance than SISO Q-OFDMA using channel gain by 3 dB (at 10–4 BER). But for increasing number of antennas the BER slightly reduces than compared to previous antenna configurations.

V. CONCLUSION

In this paper, we have addressed the coding schemes which enhance the performance of Quadrature-OFDMA systems. We had extended spatial diversity and multiplexing for Q-

OFDMA systems in the MIMO architecture. Based on the relationship between frequency-domain signal and intermediate-domain, the proposed STBC takes advantages of inherent frequency diversity in Q-OFDMA and achieves full diversity introduced by STBC. Further data rate can be enhanced by sending multiple data streams through multiple antennas using spatial multiplexing. Hence the space time block codes in addition with spatial multiplexing provide an excellence for further improvement of system performance significantly in terms of BER.

VI. FUTURE WORK

The Existing space time block codes provides better performance for only up to two transmit and receive antennas. If antenna number increases, this does not achieve full rate and full diversity gain. There is a natural trade-off between diversity gain and multiplexing gain, increase in number of antennas improves diversity gain but multiplexing gain decreases. Even though these 4x4 SM Q-OFDMA systems achieve better performance than SISO systems, BER increases than compared to 2x2 STBC Q-OFDMA systems. The idea is to deploy Quasi Orthogonal STBC codes [19] with the LDPC codes [9] can be able to support four transmit and receive antennas and attaining the Shannon limit with a low BER. This can furthermore increases the system capacity with a maximum possible gain. Also ML decoding reduces the complexity of decoding without sacrificing the performance [21]. We hope that this hybrid scheme increases the quality of the signal at the level of lowest complexity.

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