ARPN Journal of Engineering and Applied Sciences

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OPTIMIZATION OF BER PERFORMANCE IN THE MIMO-OFDMA SYSTEM FOR MOBILE WIMAX SYSTEM USING DIFFERENT EQUALIZATION ALGORITHM

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ABSTRACT

Combination of Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiple Access (OFDMA) is implemented to offer a simple and high performance system as to increase channel capacity and serve high data rate. Even though the OFDMA concept is simple in its basic principle, but it suffers one of the most challenging issues, which is synchronization error that introduces the inter-symbol interference (ISI), thus degrades the signal performance. The goal of this paper is to provide a method to mitigate this ISI by employing the equalizers at the receiver end and using Space Time Block Codes (STFBC) to improve the Bit error rate (BER) performance and to achieve a maximum diversity order in MIMO-OFDMA by using simulation based on the platforms of MATLAB software As a result, the BER performance is improved when implementing equalizers at the receiver with STFBC outperforms the conventional system without equalizer with a maximum diversity order and an efficient bandwidth in the Mobile WiMAX system.

Keywords: inter-symbol interference (ISI), multiple input multiple output (MIMO), orthogonal frequency division multiple access (OFDMA), bit error rate (BER), space time block codes (STFBC), worldwide interoperability for microwave access (WiMAX).

INTRODUCTION

Successful deployment of wireless voice communication systems promises a bright future for wireless high data rate services such as internet access or multimedia applications [1]. OFDM (Orthogonal Frequency Division Multiplexing) provides such high data rate services and considered as a good choice of this matter due to its ability to overcome multipath fading. Currently, there is a strong interest in extending the OFDM concept to multiuser communication scenarios. A prominent example of this trend is orthogonal frequency division multiple access (FDMA) protocol [2]. Many broadband wireless networks have now included the MIMO option in their protocols. In principle, OFDMA and MIMO can be combined to offer the benefits of simplicity, high performance system [3] and exploitation of the multipath diversity which increases the achievable rate and enhances link reliability [4]. The proposed method is to test the diversity performance of this system by using the Alamouti code technique which is the simplest compared to the others. Basically, in this OFDMA system, there are two basic diversity order systems which are the Space-Time Block Codes (STBC) and Space- Frequency Block Codes (SFBC), while the Space-Time-Frequency Block Codes (STFBC) is the combination of both. STFBC can offer spatial, temporal and frequency diversity MIMO channels. The coding distributes symbols along transmit antennas, time slots and at different frequencies. This STFBC may contain several OFDM symbols which can increase diversity order [5].

Even OFDMA has a lot of advantages, yet there are still some disadvantages exist in this system. For instance, different users share available subcarriers in OFDMA thus, synchronization becomes a difficult task. The receiver must estimate a number of parameters and need to compensate inter-symbol (ISI) interference [6]. The cyclic prefix (CP) can be added to overcome this matter but ISI may still exist if channel delay spread is larger than the CP and this will severely affect the system performance. Thus, by adapting the ideal equalizer at the receiver, performance degradation and ISI can be reduced. There were several work done previously for instance, in [5], the researcher investigated BER of system performance using STFBC with intercarrier interference self-cancellation scheme (ICI-SC) without equalizer to reduce ICI only but not ISI.

Besides, in [7], the author introduced a diversity technique, but it is applied for MIMO-OFDM system using a new ICI-SC technique subcarrier mapping scheme without equalizers. However, it is difficult to obtain frequency diversity gain and suffers ICI and ISI. In [8], the researcher studied the performance evaluation of BER using STFBC MIMO-OFDM using equalization algorithm. However, the system could not achieve the maximum diversity order and an efficient bandwidth. In [9], the researcher evaluates system performance using pair-wise error probability with specific subcarrier mapping and a linear equalizer for MIMO-OFDM system. So far, there is no literature on performance evaluation of BER using equalization and diversity order technique (STFBC) in MIMO-OFDMA system. Therefore, this research paper is proposed. The objectives of this paper are to simulate the BER performance of MIMO-OFDMA using MATLAB software, to mitigate the inter-symbol interference (ISI) in the OFDMA system, to implement the equalizers at the receiver and to evaluate the different type of diversity order in this system.

SYSTEM MODEL

An OFDMA system is defined as one in which each terminal occupies a subset of subcarriers (termed an OFDMA traffic channel), and each traffic channel is assigned exclusively to one user at any time [10]. In OFDMA, users are not overlapped in frequency domain at any given time [11]. However, the frequency bands assigned to a particular user may change over the time.

In order to mitigate the presence of ISI, the implementation of equalization at the receiver can be made in frequency or time domain to diminish such interference. This paper will focus on implementing three different types of equalizers which are Zero-Forcing Equalizer (ZF), Minimum Mean Square Error (MMSE) Equalizer and Maximum Likelihood Sequence Estimation (MLSE) Equalizer. In this paper, the BER performance will be compared through with and without equalization at the receiver OFDMA system. Figure-1 shows an example of a baseband model of OFDMA system. The block diagram basically comprising of three major parts namely transmitter, channel and receiver.The data input at the transmitter side are random data which are being produced within the MATLAB command language. Then, the random data will be generated in serial format to perform serial to parallel conversion. The serial data stream represents the data information to be transmitted.

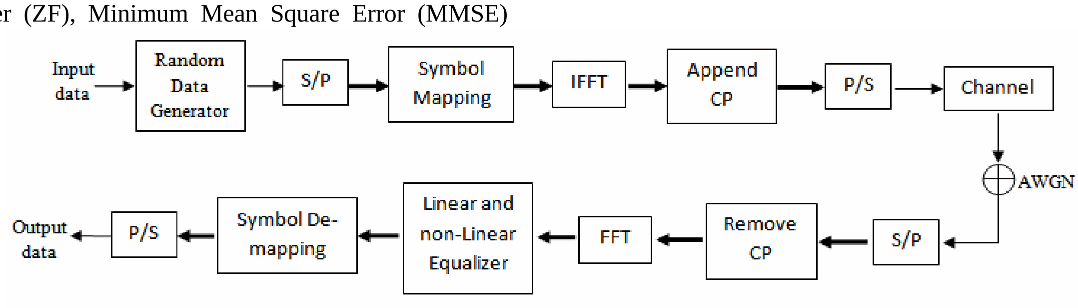

Figure-1. OFDMA system block diagram with equalizer.

The parameters such as number of subcarriers used and the FFT size are using Mobile WiMAX wireless communication standards in OFDMA technology system. Quadrature Amplitude Modulation (QAM) is being used to perform modulation on parallel stream. Each symbol is presented by complex number in phase and quadrature phase vector [12]. The selection of modulation scheme applied to each sub-channel depends solely on the compromise between the data rate requirement and transmission robustness [12]. The samples of the transmitted OFDM signal can be obtained by performing an IFFT operation on the group of data symbols to be sent on orthogonal sub-carriers [13]. The IFFT is used to convert the frequency domain data into time domain signal while maintaining the orthogonality of subcarriers [14]. Cyclic prefix consists of a block of redundant samples at the beginning of each transmitted frame and it is also a cyclic extension of the symbol to eliminate ISI effects on original symbols.

Additive white Gaussian noise (AWGN) channel is the most common channel model but it does not work well due to multipath propagation. It is static in real environment and applied in simulation in the MATLAB software. Practical channel that is being used is Rayleigh channel which may introduce a different phase, amplitude attenuation, delay and Doppler shift to the signal. At the receiver part, serial input data is converted to parallel form and the symbol transformation is performed by FFT [12]. The output from the FFT will contain interferences or distortions including ISI. Equalization is implemented to mitigate this ISI. The equalized output is demapped, deinterleaved and then convolutionaly decoded to get back original data words [12]. To get the original message information, the data words will then be multiplexed.

Zero forcing equalizer

Zero Forcing Equalizer is a form of linear equalization algorithm which applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel in communication system [10]. This form of equalizer was first proposed by Robert Lucky. It has many useful applications. For example, it is applied for IEEE 802.16e (Mobile WiMAX) in MIMO, where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero-Forcing corresponds to bringing down the intersymbol interference (ISI) to zero and will be useful when ISI is significant compared to noise [11].

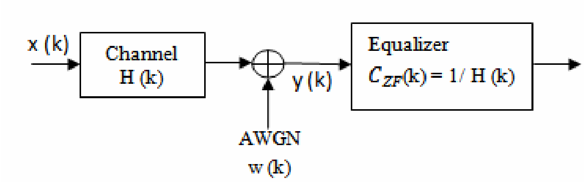

Figure-2. Block diagram of Zero-Forcing equalizer.

Figure-2 above shows an example to show that there are different parameters used in Zero-Forcing equalization. Let C_{ZF} (k) be the equalizing circuit filter. The LTI filter with transfer function, C_{ZF} (k) is considered to be the ZF equalizer, that can be realized by multiplying the OFDMA received signal as an Equation (1) with the vector 1/H (k) which produces the Equation (2). In this case, the equalizer filter compensates for the channel induced ISI as well as the ISI, but this is not eliminating all ISI because the filter is of finite length.

$$y(k) = x(k)H(k) + w(k) + I(k) \quad (1)$$

$$c_{zf}(k) = \frac{1}{H(k)} \quad (2)$$

Where $y(k)$ is complex coefficient envelope of FFT, $x(k)$, $H(k)$ and $w(k)$ are frequency domain equivalents of input data, channel impulse response and AWGN noise respectively.

Minimum means square error equalizer

A more balanced linear equalizer in this case is the minimum mean-square error equalizer, which does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output. Since this scheme can minimize the mean square error (MSE) between the desired equalizer output and the actual equalizer output, it is found that adaptive MMSE equalizer is an effective and feasible method to mitigate the serious effects of multipath dispersion.

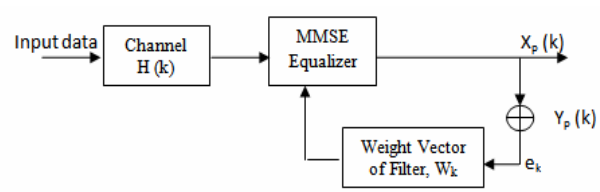

Figure-3. Block diagram of MMSE equalizer.

Figure-3 above shows a block diagram whereby a few parameters involved which are, $H(k)$ is the channel impulse response, $X_p(k)$ is the actual output while the $Y_p(k)$ is the desired output. The e_k is the error between these two output of the system. In this type of equalizer, the tap weights are chosen as they minimize the mean-square-error (MSE) of all the ISI terms and the noise power at the output of the equalizer. MMSE is the expected value of the squared difference between the desired data symbol and the estimated data symbol. Error between desired and actual output is given by [12].

$$e_k = x_p(k) - Y_p(k)^T W_k \quad (3)$$

where W_k is the weight vector of filter. Mean square error is the square of Equation (3) which produces equation as followed,

$$MSE = E\left[X_p(k)\right]^2 + W_k R W_k - 2P^T W_k \quad (4)$$

R and P are the correlation and auto-correlation matrices. To minimize ISI we have to find filter weights which minimized when $R = P\ W_k$. The vector W_k corresponds to the number of taps in the equalizing filter. The equalizer correction term which is the inverse of channel response multiplying with the Equation (1) produces the equalizer output as below,

$$C_{MMSE} = {}^{1}\!/\!_{\left[H(k)+N_o\right]} \frac{1}{H(k)+N_o} \quad (5)$$

where the $H(k)$ is the channel impulse response, while the N_o is the noise in the system.

Maximum Likelihood Sequence Estimator

Among of all those equalizers, MLSE exhibits the strongest capability in compensating ISI. However, its main problem is the complexity that increases exponentially with the memory length of the channel. The MLSE Equalizer block uses the Viterbi algorithm to equalize a linearly modulated signal through a dispersive channel. The block processes input frames and outputs the maximum likelihood sequence estimate (MLSE) of the signal, using an estimate of the channel modeled as a finite input response (FIR) filter.

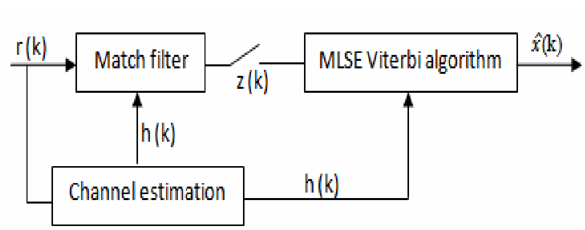

Figure-4. Block diagram of MMSE Equalizer.

Figure-4 above shows the architecture of the MLSE equalizer. The receiver compares the time response with the actual received signal and determines the most likely signals. The problem to be solved is to use the observations $\{r(k)\}$ to create a good estimation of $\{x(k)\}$. In this system, the $r(k)$ is received signal, $h(k)$ denotes the overall channel response of the system, whereas $z(k)$ is the output of the received signal passed to the match filter, and the Viterbi algorithm is obtained by computing the recursive relation iteratively and produce

VOL. 9, NO. 8, AUGUST 2014 ISSN 1819-6608
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the estimated sequence, $\hat{x}(k)$ which is defined to be sequence of values which maximize the functional [12].

$$C_{MLSE} = p(r|x) \qquad (6)$$

Where $p(r|x)$ denotes the conditional joint probability density function of the observed series $r(k)$ given that the underlying series has the values $x(k)$.

SIMULATION RESULTS

One of the important parameter in wireless communication for quality measurement of recovered data is the performance of BER. It is observed that different equalization techniques can give low BER performance under multipath fading environment, but with slight changes in BER the quality changes many folds [13]. Simulation results are plotted for bit error rate (BER) performance of MIMO-OFDMA system and being compared with and without the implementation of three different equalizers. Besides, BER performance also can be observed when the three different diversity methods used in the system. Table-1 shows the system parameters for MIMO-OFDMA for Mobile WiMAX system that has been used in this project [14].

Table-1. MIMO-OFDMA parameter [14].

System bandwidth (MHz)	**1.25**	**2.5**	**5**	**10**	**20**
Sampling frequency (MHz)	1.4	2.8	5.6	11.2	22.4
FFT size	128	256	512	1024	2048
Subcarrier spacing (kHz)	10.94				
OFDM symbol duration(μs)	102.86				
Useful symbol time(μs)	91.43				
Cyclic prefix(μs)	11.43				

Zero-Forcing, MMSE, MLSE equalizer

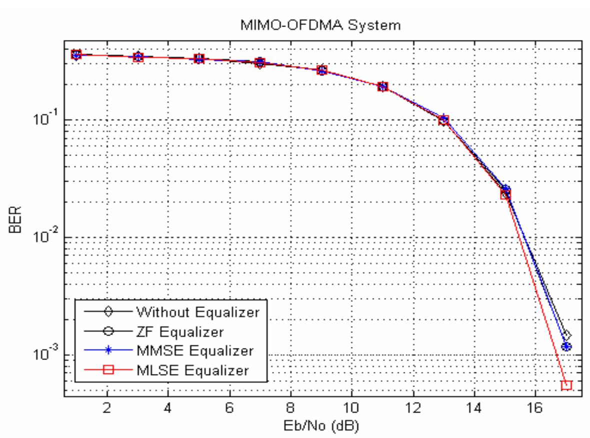

Figure-5. BER comparison using ZF equalizer, MMSE equalizer, MLSE equalizer and without equalizer.

Figure-5 above shows that BER performance can be compared between different equalizers. From the simulation, it can be observed that the MLSE equalizer gives the best performance which produces the less interference (ISI) in the system compared to MMSE and Zero-Forcing equalizer. So, as the interference is decreased, the BER is decreased as well but SNR is increased. This is because of MLSE evaluates a sequence of received data samples to determine the most likely correct transmitted sequence. This is proven in the Equation (6), as the most likely transmitted signal, $x(k)$ is increased, the equalizer output, C_{MLSE} is also increased. So, it can successfully minimize the interference in the signal. That is why changes in BER can be seen clearly at high SNR=17dB.On the other hand, the MMSE equalizer gives better performance compared to ZF equalizer because it is not only equalizing the channel but also suppressing the noise as in Equation (5) which proves that when the channel impulse response, $H(k)$ and noise, N_o is decreased, the output equalizer, C_{MMSE} will increased. Besides, by applying the ZF equalizer in the system, the performance is improved too as in Equation (2) whereby the channel impulse response, $H(k)$ is decreased, the output equalizer C_{ZF} will increased which tends to produce an increment of SNR, as the interference and BER is reduced. But it does not perform as well as the MLSE and MMSE equalizer since this equalizer forces the ISI to zero when only the ISI is significant but does not consider the noise.

STF, ST, SF diversity

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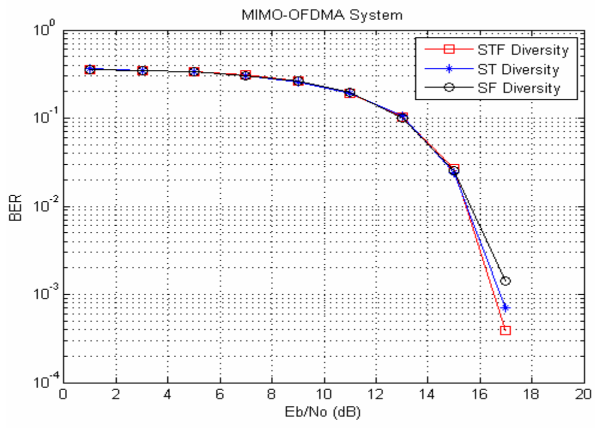

Figure-6. BER performance with three different diversity methods.

In Figure-6 above shows the BER performance comparison when using different diversity order system when implementing the MLSE equalizer since this is the best equalizer among the others. It can be seen that by using space, time, frequency diversity (STF), it offers the maximum diversity order compared to space, time (ST) diversity and space, frequency (SF) diversity because it can transmit data in different time and frequency slot which improved the performance of the system as the SNR is increased while BER and ISI is decreased. It means that, there is least amount of ISI when STF diversity order is applied in the system. At higher SNR=17dB, BER value is at 7x10-3, which gives the least amount of ISI. This is because in the Equation (6), as the most likely transmitted signal, $x(k)$ is increased, the equalizer output, C_{MLSE} is also increased. So, it can successfully minimize the interference in the signal.

CONCLUSIONS

The multipath propagation causes fading of received signal power which leads to ISI. The equalizers are used to improve the distorted received signal caused by ISI. This paper compares the performance of equalized system with the unequalized system to observe which equalizer is the best among three different equalizers that can generate the least ISI in the system and at the same time, it will improve the BER performance within the OFDMA system. From the simulation results, it can be proved that with the equalization system, the ISI can be mitigated, the maximum diversity order can be achieved and the BER performance also can be improved.

FUTURE WORK

This project applies the basic concept in Mobile WiMAX system. In future works, QPSK (Quadrature Phase Shift Keying) as the modulation scheme can be used instead of using QAM. Moreover, the BER system performance also can be investigated for other types of equalizer such as Decision Feedback Equalizer, Blind Equalizer, and Linear Equalizer.

ACKNOWLEDGEMENT

This work was supported in part by the Research Management Institute University Teknologi MARA under Excellent fund (Research Intensive Faculty) grant number 600-RMI/DANA 5/3/RIF(86/2012) .

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