Performance Evaluation of Adaptive Algorithm with Linear Equalizer in MIMO OFDMA System

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***Abstract*—Orthogonal frequency division multiple access (OFDMA) is one of digital modulation technique that allow many user to access during the same time and provide high speed data rate transmission in wireless communication system. Due to multipath propagation in real environment, wireless performance is degrading due to Inter Symbol Interference (ISI). In order to overcome this problem, Recursive Least Square (RLS) algorithm with Linear Equalizer will be used in this research. By adding space time frequency block code (STFBC) and multiple input multiple output (MIMO) antenna, this combination will prove their ability to reduce ISI and enhance system performance. The objective of this paper is also to evaluate Pairwise Error Probability (PEP) performance using combination of adaptive algorithm and LE. The PEP simulation results show the improvement of performance after reducing ISI and also prove that STFBC was able to achieve maximum diversity order in the MIMO OFDMA system.**

***Index Terms*—Inter Symbol Interference (ISI); Linear Equalizer (LE); Recursive Least Square (RLS); Pairwise Error Probability (PEP).**

I. INTRODUCTION

Orthogonal Frequency Division Multiple Access (OFDMA) has been introduced in the IEEE 802.16 wireless for Metropolitan Area Network (MAN) standard to improve transmission rate in wireless communication system [1]. Nowadays, consumer aims at delivering high data rate applications and services. Due to that reason, as a one of modulation technique, OFDMA allow many users to access at the same time by assigning different groups of carriers to different user [2]. MIMO-OFDMA is a new wireless communication technology that has gained more attention for its capability of high rate transmission and its robustness against Multi-path fading.

OFDMA need to maintain the orthogonality between each other to avoid signal loss [2]. Signal distortion occur when ISI appear in the system due to multipath. It causes frequency-selective fading due to different echoes of transmitting symbols overlapping at the receiving end. Even though OFDMA can handle multipath well but still the system need other supporters to reduce interference. As stated by previous researchers [3], ISI occur when a symbol overlap with other symbol and attenuate the signal. Error correcting codes or adaptive equalization techniques are the technique used to overcome this problem [4]. For this research, RLS is used with LE to combat ISI. The difference between linear and nonlinear is when analog signal being processed at the receiver. It is linear when the signal did not used feedback path to adapt the equalizer [5].

Cyclic prefix (CP) will also be used to help equalizer remove interference as long as the CP at least equal or larger than channel delay spread. Transmitted symbol that is in linear convolution form will change to circular convolution form. CP is a tail symbol of frame or repetition of the first section of a symbol that appended to the end symbol [6].

Space time frequency (STF) code as a diversity technique had been used in this research by distributing both time and frequency. Space time (ST) code is the first technique that realize the advantage of diversity of multiple antennas but separating extra frequency of frequency selective fading [7]. After that, space frequency (SF) had been proposed by replacing time domain with frequency domain but system performance degrade in heavily selective channels and only spatial diversity can be achieved by SF [8]. Recently ST and SF were also applied in MIMO system with a few changes that need to be considered but the performance is still not as good as STF [9][10].

Based on the information above EW- RLS will be tested with linear equalizer for MIMO OFDMA system in order to overcome ISI. RLS is an algorithm in term of recursive form of Least Square algorithm. RLS require λ known as forgetting factor during simulation of the algorithm. It is believed that, with combination of STFBC in MIMO OFDMA, it will improve system performance. The simulation will be analysed in terms of PEP performance. This research will prove that RLS algorithm functions better when using equalizer and STF. It makes the differences with previous work [3][5] because so far there is no exact literature on the performance of adaptive algorithm with equalizer using space time frequency block coding technique for MIMO OFDMA. MATLAB code will be used for the simulation to obtain result. Table 1 shows simulation parameter based on IEEE 802.16.

Table 1
Simulation Parameter

Parameter	Values
System Bandwith (MHz)	10
FFT size	1024
Cyclic Prefix	128
Modulation	QPSK
Doppler Frequency	200Hz
Channel	COST 207 TU
Delay	0 0.2e-6 0.5e-6 1.6e-6 2.3e-6 5.0e-6
Path Gain	1.122 1.259 1.156 1.059 1.038 1.023
Sub channel	35

II. METHODOLOGY

A. System Description

Figure 1 is a MIMO OFDMA system with two transmits and two receives antenna. There are 3 main parts in this system; transmitter, channel and receiver. At the transmitter, data input is modulated by mapping to constellation and subdivided into parallel sub channel. Sub channel that form from a group of subcarriers will function as a data transmission [11]. Each symbol is serial to parallel (S/P) converted and generated using inverse fast Fourier transform (IFFT). Frequency domain is converted to time domain while maintaining orthogonality between subcarriers. Cyclic prefix is added to reduce ISI in the system and act as a guard interval that will copy data from the end of the symbol in order to fill guard period and can be calculated using;

$$Ts = T + Tg \quad (1)$$

which T_s is total symbol duration, T is original symbol time and T_g is guard extension that usually quarter of original symbol time. When the data go through the channel, it will face Rayleigh fading, noise and Doppler effects. Combination of all elements in the channel can be expressed as

$$R(t) = \sum h(t,\tau) * S(t) + Z(t) \quad (2)$$

which Z(t) is AWGN noise and h(t) is channel impulse response given by

$$Z(t) = A(t)e^{j\theta(t)} \quad (3)$$

where A(t) is attenuation and θ(t) is uniformly distributed random phase.

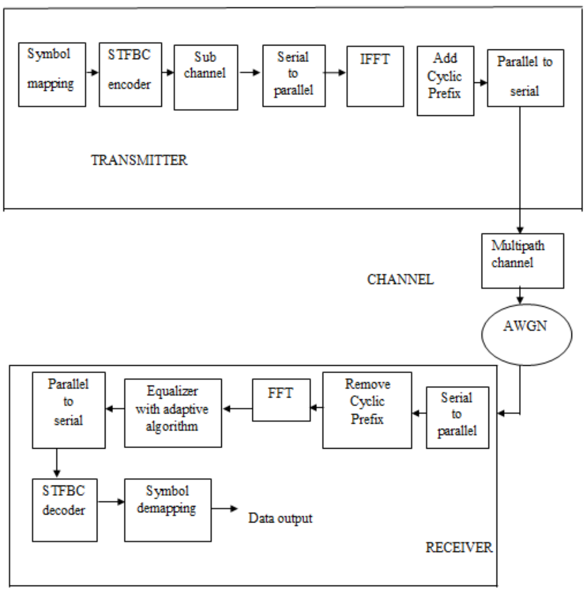

Figure 1: OFDMA Transceiver System

All of that indicating the system is simulated under real environment. In all wireless system, multipath fading channel model is concerned in the most situations. At the receiver, serial to parallel (S/P) will convert the data to parallel and CP will be removed from received signal. FFT will modulate the signal and changing time domain back to frequency domain. After that, equalizer is added to enhance system performance by removing ISI. P/S converter will convert parallel data into serial to recover original input data. STF code will occupy several symbols and increase the diversity order. This research will prove that by using combination of equalizer and adaptive algorithm with STF coding scheme will boost up wireless system performance.

B. Linear Equalizer

In the wireless transmission environment, an equalizer is implemented at the receiver. There are two types of equalizer; linear and non-linear. This research is focusing on general linear equalizer that applied to reduce ISI in linear channel. Equalizer can help to recover distorted original data that occur due to the interference during transmission [12].

C. Recursive Least Square Algorithm

Recursive Least Square is implemented with linear equalizer in order to enhance system performance. RLS is known as an algorithm that have better convergence speed compare to other adaptive algorithm. It will estimate autocorrelation matrix of input vector by using information from all past input samples. To decrease impact from past sample, cost function is used as a weighting factor. Based on the Figure 2, error can be calculated from:

$$e(t) = d(t) - D(t) \quad (4)$$

which d(t) is desired output of the system while D(t) is estimated output. λ as a forgetting factor is use for the algorithm to determine tracking ability. Basic equation of RLS can be described as:

$$w(t+1) = w(t) + e(t)G(t) \quad (5)$$

which w(t) defined as a filter coefficient vector while G(t) is a gain vector. G(t) can be calculated from:

$$G(t) = \frac{P(t)R(t)}{\lambda + R^T P(t)R(t)} \quad (6)$$

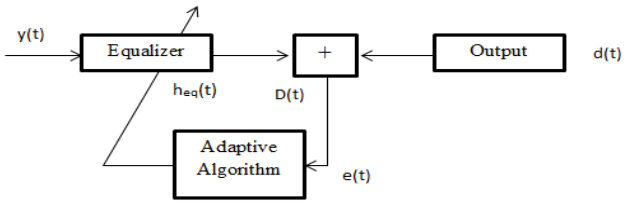

Figure 2: Equalizer with algorithm

D. Space Time Frequency

Diversity is also implemented in this research in order to enhance system performance. STF is well known among researcher because STF can spread the element of orthogonal design both in time and frequency. Table 2 show Space Time Frequency Block Code using 2 transmit and 2 receive antennas[13]. Based on the Table 2, first symbol Xn from antenna 1 will be transmitted during time slot 1 and frequency slot 1 followed by Xn+1 as a second symbol.

Table 2
Space Time Frequency

Space Time Frequency	Time 1 Antenna 1	Time 2 Antenna 2
Frequency 1	Xn	Xn+1
Frequency 2	- Xn+1*	Xn*

E. Pairwise Error Probability

PEP can be described as probability on distinguish one symbol when other symbol is transmitted. In the simplest way to interpret is if there are two signal vector at transmitter but when the signal arrive at the receiver, only one signal exist. From that, we can determine the probability of decision error. The equation can be defined as [14]

$$P(C-\bar{C}) \leq l\binom{2\Gamma N-1}{\Gamma N}\left(\prod_{i=1}^{\Gamma}\lambda_1\right)^{-N}\xi^{\Gamma N} \quad (7)$$

C is a transmitted codeword while $\bar{C}$ as a decoded codeword containing faulty. Probability received signal vector can be described as $P(C-\bar{C})$. N is number of subcarrier and λ point out non zero Eigen value of $(\Delta C \cdot R)$. For ΔC that imply from equation $(C-\bar{C})(C-\bar{C})^H$, H function as a complex conjugate and transpose matrix. Γ can be obtained from $(\Delta C \cdot R)$ which is R indicate correlation matrix of H that accommodate both frequency and time correlation matrix. ξ is the average of Eb/No. l is a performance loss of the system due to frequency offset and can be represented from [15].

$$\ell = \left(\frac{S_0{}^2}{\xi(1-S_0)+1}\right)^{-\Gamma N} \quad (8)$$

which S_o is received signal power factor.

III. Simulation Result

Value parameters for RLS and LE to simulate are decided in Table 3 [16].

Table 3
Parameter for Algorithm

	Parameter	Value
RLS	Forget Factor	0.99
LE	Weight system	7

Based on the Figure 3, different diversity is use to simulate the best system performance. As stated previously, STF perform better compare to ST and SF. This is because STF spread symbol along both time and frequency. STF at Eb/No = 25dB which the value is PEP = 1.6 x 10^{-5}. SF yields in PEP at 2 x 10^{-4} and ST has worst performance with PEP = 5 x 10^{-4}. To differentiate the performance in better way, with PEP =9 x 10^{-3}, STF acquire the best percentage of improvement with 57% compare to ST and 47% compare to SF. Because of changes in symbol duration channel during transmission, ST performance is degrading in fast time varying and this explains why ST has worst performance of PEP.

Based on the Figure 4, the system is tested with and without using equalizer. At Eb/No = 25dB, for RLS-LE the value is PEP=6.5 x 10^{-6} which is indicate the best performance while without using any equalizer and adaptive algorithm, PEP = 9 x 10^{-6}. The performance is slightly bad. At PEP = 2 x 10^{-5}, with RLS-LE added to the MIMO OFDMA system, it is improving by 9.5%. Based on the Equation (7), forgetting factor play an important role for RLS gain. Smaller value of forgetting factor will make smaller contribution of previous sample. More fluctuation in filter coefficients can happen because filter is more sensitive to recent samples. Usually, value of forgetting factor is chosen between 0.98 and 1[17].

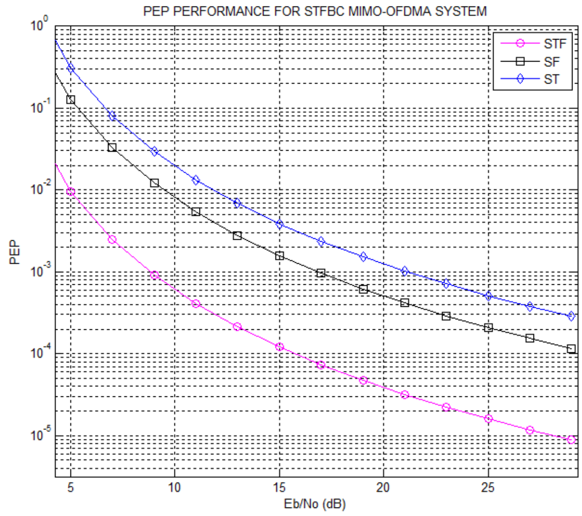

Figure 3: Comparison of PEP for different diversity

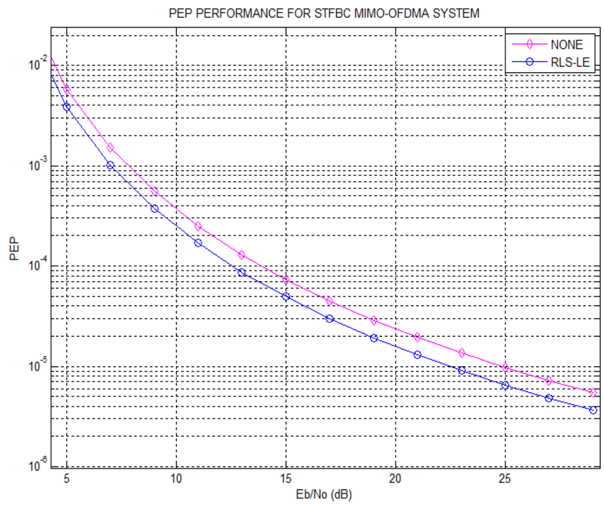

Figure 4: PEP comparison with algorithm and equalizer

IV. Conclusion

This paper is proving that when applying RLS-LE in the MIMO OFDMA system, performance of PEP become much better with 9.5% improvement by reducing ISI as well as to obtain maximum diversity order. RLS is well known as an algorithm that have better convergence speed compare to other algorithm. Besides that, LE is also one of the simplest equalizer that can be applied to the system because LE is mainly consist linear filter and threshold device. Low value of PEP will point out that system become more efficient. For the future recommendation, other type of equalizer or adaptive algorithm can be used to evaluate system performance.

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