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BER SIMULATION STUDY FOR A FEC ENCODED DS-CDMA WIRELESS COMMUNICATION SYSTEM WITH IMPLEMENTATION OF ALAMOUTI DIVERSITY SCHEME

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Abstract:-

Multipath fading encountered in time-varying channel renders wireless communications highly non-reliable. To obtain an average bit-error rate of 10^{-3} using BPSK modulation with coherent detection, performance degradation due to Rayleigh fading can account for a SNR of 10dB higher than that in AWGN. This paper evaluates the performance of a FEC encoded DS-CDMA based wireless communication system with varying the order of QAM and PSK modulations. Two transmit antennas and one receiving antenna mounted scheme over an AWGN and Rayleigh fading channels was used for this study. The simulation was done by our developed computer program written in MATLAB source code. The BER results show that the MISO scheme supported DS-CDMA system provides satisfactory performance in retrieving transmitted messages through hostile fading channel environment with the implementation of BPSK digital modulation technique. System performance degrades while increasing the order of digital modulations.

Keywords: - DS-CDMA, Alamouti, Fading channel, Convolutional code, FEC encoding.

1. INTRODUCTION

Theoretically, transmitter power control technique known as "water-filling" is the most effective way to mitigate multipath fading [1], [2]. However, the transmitted power adaptation requires knowledge of channel SNR to be estimated at receiver and sent back to transmitter that inevitably results in throughput reduction and higher complexity in both transmitter and receiver. Dynamic range of transmitter amplifier necessary to accommodate power back-off represents another disadvantage in using "water-filling" technique. Diversity is a powerful technique that is more practical and, therefore, widely used in combination with space-time coding to combat signal fading. Diversity is characterized by the number of independently fading sub-channels being created by multiple antennas at transmitter and/or at receiver. Depending on antenna configurations, space-time wireless systems can be categorized into SISO (single input single output) being the traditional channel, SIMO (single input multiple output) having one single transmit antenna and multiple receive antenna, MISO (multiple input single output) using multiple transmit antennas and a single receive antenna and MIMO (multiple input multiple output) having multiple transmit antennas and multiple receive antennas [3], [4]. Some reports are limited to the review of several study cases of MISO configuration where suitable coding or signal processing techniques are exploited to allow the extraction of transmit diversity without channel knowledge at the receiver. If the sub-channels associated to transmit antennas have independent fades, the order of diversity is proven to be equal to the number of transmit antennas. This approach is attractive in public broadcasting systems such as cellular (for voice) or broadband wireless access (for data communications) to keep the subscriber side equipment cost down with simpler hardware requirement and more compact form factor by avoiding the implementation of several receive antennas. Alamouti's simple but efficient transmit diversity technique [5] is introduced. This approach uses space-time coding to achieve diversity on one single receive antenna in flat-fading wireless channels. Extension to multiple receive antennas is also reviewed by Winters' approach using signal processing to create diversity from multiple transmit antennas has already been reported [6]. An extension to frequency selective fading for Alamouti's technique in the OFDM framework has been proposed by N. Ahmed *et al* [7]. A. Rahman *et al* [8] also did some work on STBC encoded MIMO-OFDM system. Arunarasi *et. al* [9] and H. Hena *et al* [10] already reported about DS-CDMA and Md. Matiqul *et. al* [11] already reported about MC-CDMA. Although several research papers come out every day but still this topic may be of an interest.

2. TWO BRANCH TRANSMIT DIVERSITY WITH ONE RECEIVER

The scheme is associated with the following three steps [Figure 2.1]:

2.1 The encoding and transmission sequence of information symbols at the transmitter

2.2 The combining scheme at the receiver

2.3 The decision rule for maximum likelihood detection

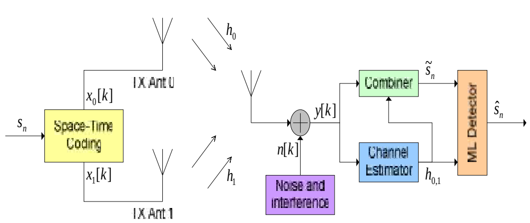

Figure 2.1: Alamouti's simple transmit diversity scheme [12].

2.1 Encoding and Transmission Sequence

The space-time coding scheme is based on pairs of symbols that are transmitted in two consecutive symbol intervals. During the first (even-numbered) interval, the two symbols are transmitted unaltered and simultaneously by two antennas. During the following (odd-numbered) interval, the complex conjugates are transmitted as shown in Figure 2.2.

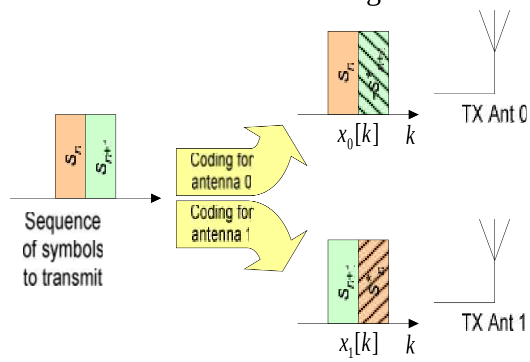

Figure 2.2: Alamouti's space-time coding for transmitting antennas [12].

Let s_n be the sequence of symbols to be transmitted. Let $x_0[k]$ and $x_1[k]$ be the signals transmitted by antennas zero and one respectively at time *k*. Please note that the symbol time *k* is introduced to highlight the sequential aspect in transmitted and received signals. However, the symbol index *n* is retained to avoid eventual confusion that apparent non-causality in the following equations may cause. Two consecutive symbols are transmitted simultaneously over two antennas during the symbol interval *k*, where *k* is even, as

Equation 2.1: $$\begin{cases} x_0[k] = s_n \\ x_1[k] = s_{n+1} \end{cases}$$

During the odd-numbered symbol interval, the same symbols are re-transmitted, in complex conjugate form and inverted polarity on antenna zero, as

Equation 2.2: $$\begin{cases} x_0[k+1] = -s_{n+1}^* \\ x_1[k+1] = s_n^* \end{cases}$$

While the fading is assumed to remain unchanged across two consecutive symbol intervals, the channel can be modeled by complex multiplicative distortions for transmit antenna zero and one as

Equation 2.3: $$\begin{cases} h_0[k+1]=h_0[k]=h_0=\alpha_0 e^{j\theta_0} \\ h_1[k+1]=h_1[k]=h_1=\alpha_1 e^{j\theta_1} \end{cases}$$

And since the time delay between receptions of $x_0[k]$ and $x_1[k]$ caused by spatial distance between transmit antenna locations (order of several wavelengths) is assumed negligible compared to the symbol interval, the received signal can be expressed as

Equation 2.4: $$y[k]=h_0x_0[k]+h_1x_1[k]+n[k]$$

2.2 Combining Scheme

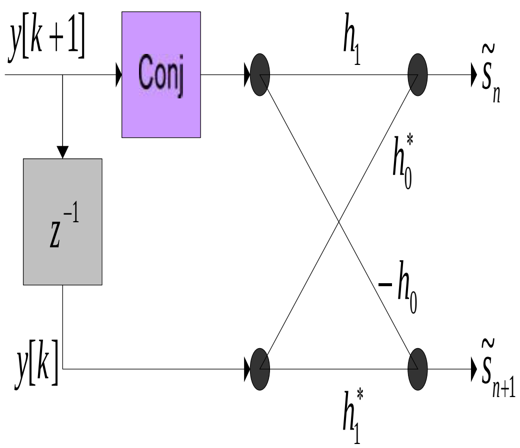

Figure 2.3: Alamouti's combining scheme at the Receiver [12].

The received signal is combined across two consecutive symbol intervals in the following manner

Equation 2.5: $$\begin{cases} \tilde{s}_n = h_0^* y[k] + h_1 y^*[k+1] \\ \tilde{s}_{n+1} = h_1^* y[k] - h_0 y^*[k+1] \end{cases}$$

Where, the channel complex multiplicative factors $h_{0,1}$ are estimated and made available by channel estimator. Substituting Equation 2.1 through Equation 2.4 into Equation 2.5 and after simplifying, it gives -

Equation 2.6: $$\begin{cases} \tilde{s}_n=(\alpha_0^2+\alpha_1^2)s_n+h_0^*n[k]+h_1n^*[k+1] \\ \tilde{s}_{n+1}=(\alpha_0^2+\alpha_1^2)s_{n+1}+h_1^*n[k]-h_0n^*[k+1] \end{cases}$$

shows the combined signals are in fact transmitted symbols being scaled and received in additive noise.

2.3 Decision Rule of the Maximum Likelihood Detector

The detector makes decision of which symbol being transmitted based on the Euclidean distance to all possible symbols

Equation 2.7: $$\hat{s}_n = s_j;\ j=\underset{i}{\text{argmin}}\,|\tilde{s}_n - s_i|$$

2.4 Comparison between Alamouti Diversity and Maximal Ratio Combining Diversity

To illustrate the comparable performance between Alamouti diversity scheme which presented in previous sections and maximal ratio combining diversity scheme, let us consider the one transmit antenna and two receive antennas diversity system as shown in Figure 2.4.

The received signals are expressed by -

Equation 2.8: $$\begin{cases} y_0[k]=h_0x[k]+n_0[k] \\ y_1[k]=h_1x[k]+n_1[k] \end{cases}$$

Where, $x[k]=s_n$ is the transmitted signal during symbol interval k, $h_{0,1}=\alpha_{0,1}e^{j\theta_{0,1}}$ channel response assumed to remain unchanged across consecutive symbol intervals and $n_{0,1}[k]$ additive noise terms. The MRC produces

Equation 2.9: $$\begin{aligned}\tilde{s}_n&=h_0^*y_0[k]+h_1^*y_1[k]\\&=(\alpha_0^2+\alpha_1^2)s_n+h_0^*n_0[k]+h_1^*n_1[k]\end{aligned}$$

That is indeed very similar to the expressions in Equation

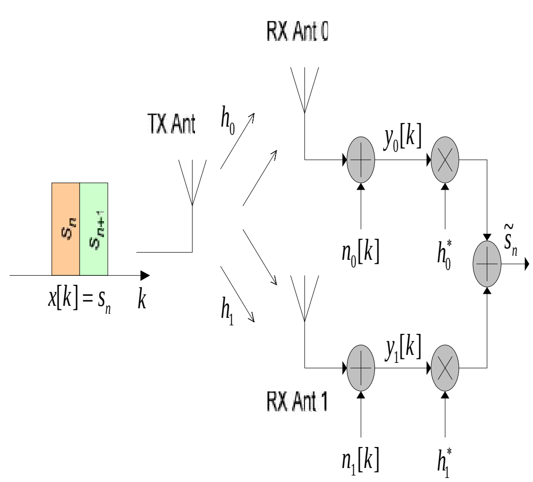

Figure 2.4: Maximal Ratio Combining Diversity [12].

However, while Alamouti's, and MRC in general, provides an array gain due to different noise sources, the matched filter bound doesn't and suffers a gain reduction proportional to diversity order *M*. Besides, Alamouti's approach appears to be more popular thanks to its simple formulation, efficiency and flexible adaptability to other configurations (MISO and MIMO) and coding scheme (space-time vs. space-frequency).

Alamouti's proposed technique is based on narrowband fading assumption where the channel is determined by a set of complex scalars that remains unchanged across several symbols interval. As per Alamouti's paper, the simulated cases (2-by-1 or 2-by-2 antennas) report 3dB performance degradation from the equivalent MRC (1-by-2 or 1-by-4 antennas). This performance loss is due to the fact only half of total power is radiated from each transmitting antenna. It can also be seen as one receive antenna can pick up only half the equivalent power compared to the MRC cases. Of course, MRC comparable performance can be achieved whenever total power is not a constraint and, hence, can be doubled to accommodate both transmit antennas.

3. THE PROPOSED COMMUNICATION SYSTEM MODEL

In the presented simulated communication system model (Figure 3.1), the synthetically generated binary random data and text messages for multi-users have been considered. The individually generated random data and messages are then encoded with ½ and ⅔-rated convolution encoder. The encoder output are converted into bipolar NRZ format and subsequently fed into BPSK, QPSK, 8PSK, 16PSK, 2QAM, 4QAM, 8QAM and 16QAM digital modulator. The digitally modulated signal is then multiplied with generated pseudo random noise for each user.

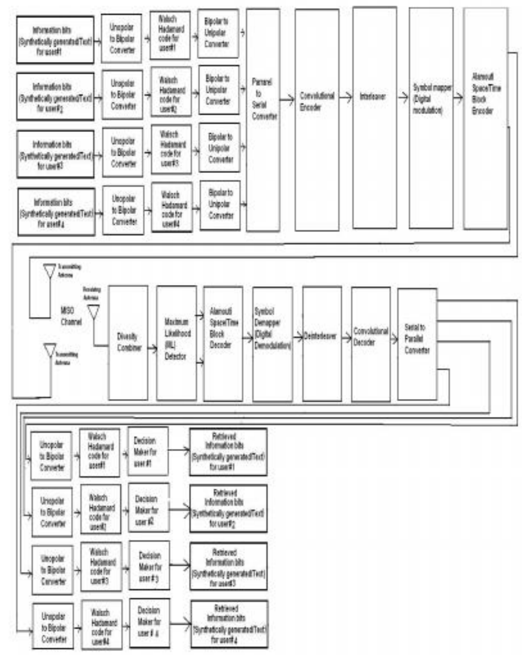

Figure 3.1: Block diagram of Alamouti encoded model for multi-user DS-CDMA system

The pseudo randomly noise contaminated modulated signals for users are then added up and Alamouti encoded and transmitted through two transmitters and passed through AWGN and Reyleigh fading channel. The channel output is then received by single antenna and multiplied with the generated pseudo random noise and demodulated. The demodulated signal for each user is processed. The processed output is sent up to the decision making device and eventually, the information bits and messages transmitted for each user is recovered.

4. RESULTS AND DISCUSSIONS

Simulation parameters are given in the Table 4.1. This section presents and discusses all the results obtained by the computer simulation programs written in MATLAB. The bit error rates (BER) at different SNRs ranging from 0 to 10 dB under different modulation techniques for the present multi transmit antenna supported multi user DS-CDMA system have been estimated.

Parameters	Types
Data bits	1000
Msg. Length	Variable
SNR in dB	0-10
Channel	AWGN, Rayleigh
bit/sample	10
Detector	ML Detector
Diversity scheme	Alamouti scheme (2-by-1)
Channel coding	½- rated Convolution coding
Modulation	BPSK,QPSK,8PSK,16PSK,2QAM,4QAM,8QAM and 16QAM

Table 4.1: Summary of the simulated model parameter

Figure 4.1, shows the effect of different modulation techniques for the FEC encoded DS-CDMA communication system in case of single user direct data transmission. It is seen from the Figure 4.1 that the lowest bit error rate (BER) is achieved in 4QAM as compared to QPSK and 16PSK digital modulations. In the case of 4QAM, the phase and amplitude of RF carrier corresponding to digitally modulated symbols are changed as compared to merely change in phase of RF carrier in case of PSK (QPSK/16PSK) digital modulation.

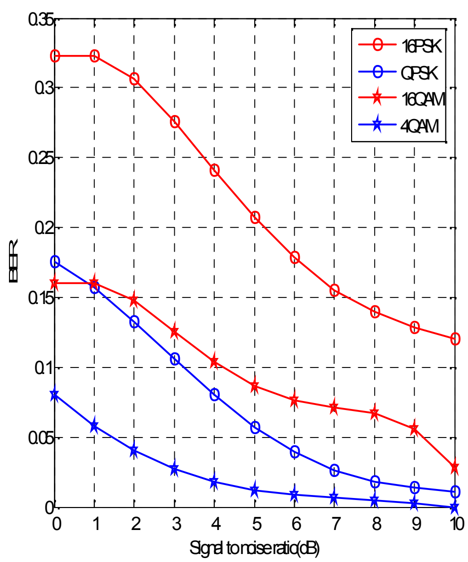

Figure 4.1: Comparison of PSK and QAM digital modulation schemes for single-user DS-CDMA system without implementation of Alamouti diversity scheme.

With increase in modulation order in QAM from 4 to 16, the RF carrier phase fluctuation is comparatively greater. For a typical SNR value 7dB, the BERs for QPSK and 4QAM are 0.0210 and 0.0012, respectively, suggesting that the system performance is improved by 12.43dB.

Similarly, for the same assumed SNR value 7dB, the BERs for 16PSK and 16QAM are found to have values of 0.1292 and 0.0758, respectively. In this case, the system performance is also improved by 4.23dB.

Figure 4.2, shows the bit error rate performance for different modulation level of QAM without Alamouti diversity scheme. It is seen from this Figure that the BER increases with increasing modulation level. As the modulation order is increased, the amplitude and phase of the RF carrier spacing between adjacent digitally modulated symbols are decreased with the increase in probability of noise insertion. it is seen that for a typical SNR value 7 dB, the BER for 2QAM and 16QAM are 0.0004 and 0.0958, respectively .It implies that the system performance is improved by 23.79 dB.

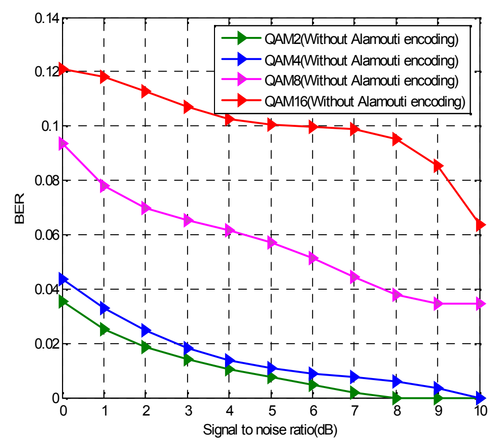

Figure 4.2: BER performance for different modulation level of QAM without implementation of Alamouti diversity scheme.

Figure 4.3, shows the Bit Error Rate performance for different modulation levels of QAM under implementation of Alamouti diversity scheme. Same trend is observed here also in Figure 4.3. In this case,, for a typical SNR value of 2dB, the BER for 2QAM and 16QAM are 0.0002 and 0.1083, respectively, which is suggestive of the system performance improvement by 27.37 dB.

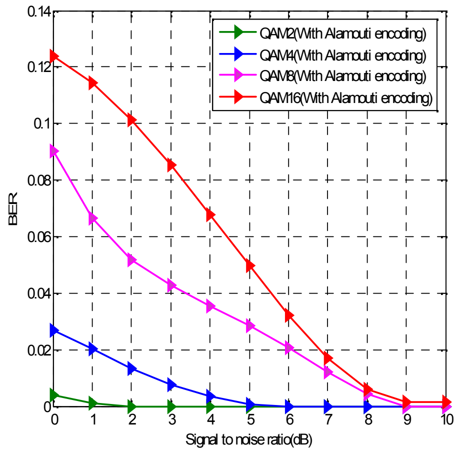

Figure 4.3: BER performance for different modulation level of QAM in Alamouti diversity encoded single user DS-CDMA system.

From Figure 4.4, it is seen that for a typical SNR value 6 dB, the BER for QPSK and 16PSK are 0.00042 and 0.1292 respectively and the system performance is improved by 14.88 dB.

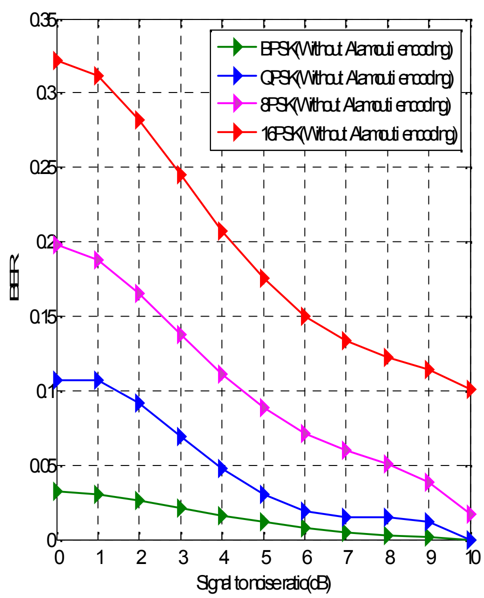

Figure 4.4: BER performance for different modulation level of PSK without implementation of Alamouti diversity scheme.

It is observed from Figure 4.5 that for a typical SNR value of 2 dB the bit error rate for BPSK and 16PSK are 0.0004 and 0.2292, respectively, which indicates that the system performance is improved by 27.59 dB.

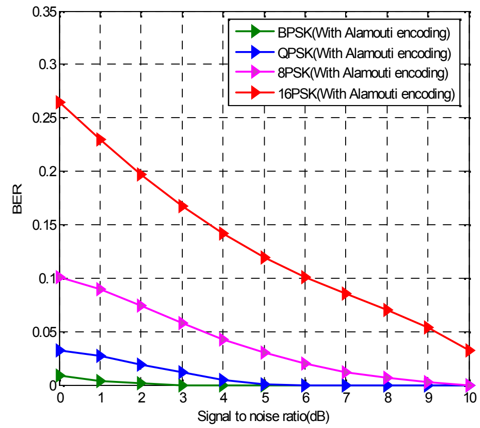

Figure 4.5: BER performance for different modulation levels of PSK with implementation of Alamouti diversity scheme.

CONCLUSION

From our study it can be concluded that using BPSK digital modulation technique in FEC encoded multiuser DS-CDMA wireless communication system with implementation of Alamouti diversity provides satisfactory performance in retrieving transmitted messages through hostile fading channel environment. It also suggests that the system performance is gradually improving by implementing FEC encoded Alamouti Diversity with decreasing modulation order. BPSK and 2QAM shows almost the same performance followed by the same criteria.

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