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BER Performance Analysis of QAM Modulation Techniques in MIMO Rayleigh Channel for WCDMA System

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ABSTRACT

Wideband Code Division Multiple Access (WCDMA) technology has emerged as the most widely adopted third generation (3G) air interface. 3GPP Release 7 (HSPA+) WCDMA systems introduced two features Higher Order Modulation (HOM) and Multiple Input Multiple Output (MIMO). MIMO improve the throughput in wireless medium. It achieves a higher spectral efficiency. This paper focuses on the performance analysis of 16 QAM and 64 QAM in multiple input multiple output (MIMO) Transmission in the Rayleigh channel by considering two encoding REED SOLOMON Encoding and BCH Encoding in WCDMA system. The analysis has been performed by using MATLAB for simulation and evaluation of Bit Error Rate (BER) for W-CDMA system.

Keywords : WCDMA, MIMO, QAM, Rayleigh Channel, BCH Encoding, REED SOLOMON Encoding.

1 INTRODUCTION

Wideband Code Division multiple Access (WCDMA) system is one of the most widely deployed 3G wireless cellular networks. WCDMA is being used by Universal Mobile Telecommunication System (UMTS). WCDMA is an approved 3G technology which increases data transmission rates via the Code Division Multiplexing air interface, rather than the Time Division Multiplexing air interface of GSM systems. It supports very high-speed multimedia services such as full-motion video, Internet access and video conferencing. It can also easily handle bandwidth-intensive applications such as data and image transmission via the Internet. WCDMA is a direct spreading technology, it spreads its transmissions over a wide, 5 MHz radio channel, carrier and can carry both voice and data simultaneously. Each channel will be able to support between 100 and 350 simultaneously voice calls at once, depending on sectoring, propagation condition, user velocity and antenna polarization. WCDMA will provide at least a six times increase in spectral efficiency over GSM. It features a peak data rate of 384 kbps, a peak network downlink speed of 2 Mbps and average user throughputs of 220-320 kbps. In addition, WCDMA boasts increased capacity over EDGE for high-bandwidth applications and features which include, among other things, enhanced security, QoS, multimedia support, and reduced latency. So there is a need the performance analysis of suitable new modulation, error correction coding and technology to be used in WCDMA system to improve the system performance in a multipath fading channel. Release 7 of 3 GPP (HSPA+) provide new features are higher order modulation and multiple input and multiple output (MIMO) both on downlink and uplink that enable improved data rate and number of simultaneous user supported, both feature improve the spectrum efficiency, especially for the users in good channel condition [1]. Multiple-input multiple-output (MIMO) communication techniques have received great attention and gained significant development in recent years. This is due to the fact that a MIMO channel can offer a significant capacity gain over a traditional single-input single-output (SISO) channel [2]-[5].

This paper evaluates the performance of 16 QAM & 64 QAM in MIMO channel when the channel is subjected to Rayleigh Fading, by using two different encoding REED Solomon encoding and BCH encoding in WCDMA system. The analysis has been performed by using MATLAB for simulation and evaluation of Bit Error Rate (BER) for both modulation technique and analysis which modulation gives better result in Reed Solomon encoding and BCH encoding. This paper is organized as follows: Section 2 describes the stimulation model. The Multiple input and multiple output (MIMO) is given in Section 3 Reed Solomon encoding and BCH encoding describe in Section 4. Section 5 discusses about the results. Section 6 gives concluding remarks.

2 STIMULATION MODEL

Small-scale fading are of two types, time-spreading of the signal and time-variant behaviour of the channel. For mobile radio applications, the channel is time-variant because motion between the transmitter and receiver results in propagation path changes. The rate of change of these propagation condi-

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tions accounts for the fading rapidity. Small-scale fading is also called Rayleigh fading because if the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by a Rayleigh pdf [6]. In mobile radio channel, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal or the enveloped of an individual multipath component. It is well known that is the envelope of the sum of two quadrature Gaussian noise signal obeys a Rayleigh distribution [7].

$$p(r) = \begin{cases} \frac{r}{\sigma^2} \exp\left(\frac{r^2}{2\sigma^2}\right) & 0 \le r \le \infty \\ 0 & r < 0 \end{cases} \quad (1)$$

Stimulated model for this work is shown in Fig-1 .this model is stimulated by MATLAB. A DSSS WCDMA system spreads the baseband data by directly multiplying the baseband data pulses with a pseudo-noise (PN) sequence that is produced by a pseudo-noise (PN) code generator [8]. A single pulse of the PN waveform is called chip .The user data is multiplied with PN code. After that on the multiplied signal implement error correction coding such as Reed Solomon encoding and BCH encoding particularly with 16 QAM or 64 QAM modulation techniques in W-CDMA system. The Modulated signal is transmitted by MIMO Transmission over the Rayleigh channel. At the receiver, the Spread spectrum signals are demodulated by cross-correlation with locally generated version of the pseudo random carrier. After that demodulation, signal is decoded. The Cross-correlation with the correct PN sequence dispreads the spread spectrum signal and restores the modulated message in the same narrow band as the original data [9]. Finally calculate BER at the received signal.

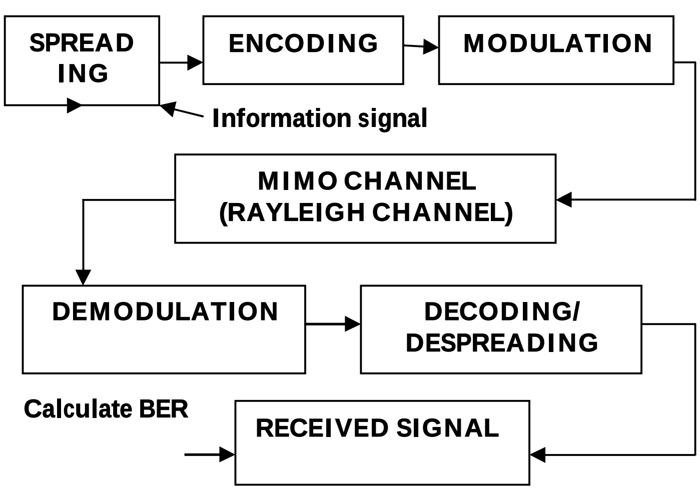

Fig. 1. WCDMA Stimulation model

3 Multiple Input and Multiple Output (MIMO)

In wireless communications, when multiple antennas are employed at both the transmitter and the receiver, such a system is commonly known as a multiple-input multiple-output (MIMO) system. MIMO techniques can be effectively used to increase system throughput over hostile wireless channels. It is well known fact that with the number of transmit antennas N_T and number of receive antennas N_R, the capacity of MIMO systems increases linearly with $N_T N_R$. MIMO increase the channel link range and data throughput without increase in transmit power & no additional bandwidth providing. MIMO systems can improve the spectrum efficiency over single antenna transmission systems, this can be achieves by spreading the same total transmit power over the antenna array that improve the array gain. A Release 7 MIMO capable UE can receive data rates up to 28.8 Mbps in a 5 MHz carrier. Release 7 HSPA+ standardizes the scheme of downlink MIMO called D-TxAA (Dual-Transmitter Adaptive Array). D-TxAA is restricted to dual transmit and receive antennas. For dual stream MIMO, received chips can be modeled as [1].

$$\vec{y}[n] = [H^1 \;\; H^2]. \begin{bmatrix} \vec{x}^1[n] \\ \vec{x}^2[n] \end{bmatrix} + \vec{z} \quad (2)$$

Where $H^i = \left[\vec{h}_1^i, \dots, \vec{h}_{d-1}^i, \vec{h}_d^i, \vec{h}_{d+1}^i, \dots, \vec{h}_k^i\right], i = 1,2$ is the channel convolution matrix from the ith transmit antenna to the receiver. $\vec{y}[n]$ denotes the received chip and $\vec{x}^i[n] = \left[[x_{n+1}^i, \dots, x_{n+d-1}^i, x_{n+d}^i, x_{n+d+1}^i, , x_{n+k}^i]^T\right], i = 1,2$ represents the transmitted chip from ith transmit antenna. $\vec{z}$ denotes the channel fading.

4 Encoding

Error control coding is a method to detect and possibly correct errors by introducing redundancy to the stream of bits to be sent to the channel. The Channel Encoder will add bits to the message bits to be transmitted systematically. After passing through the channel, the Channel decoder will detect and correct the errors.

4.1 Reed Solomon Encoding

Reed-Solomon codes are block-based error correcting codes with a wide range of applications in digital communications and storage. It is vulnerable to the random errors but strong to burst errors. Hence, it has good performance in fading channel which have more burst errors. In coding theory Reed–Solomon (RS) codes are cyclic error correcting codes invented by Irving S.Reed and Gustave Solomon.

Reed-Solomon codes are subclass of nonbinary *cyclic* codes. It operates on multiple bits rather than individual bits. A RS codes with symbols made up of *m*-bit sequences, where *m* is any positive integer having a value greater than 2. R-S (*n*, *k*) codes on *m*-bit symbols exist for all *n* and *k* for which. [10].

$$0 < k < n < 2^m + 2 \quad (3)$$

Where n is the total number of code symbols in the encoded block and k is the number of data symbols being encoded. The conventional R-S (*n*, *k*) codes are,

$$(n, k) = (2^m - 1, 2^m - 1 - 2t) \quad (4)$$

Where t is the symbol-error correcting capability of the RS code, and the number of parity symbols are $n - k = 2t$. An extended R-S code can be made up with $n = 2^m$ or $n = 2^m + 1$, but not any further. Reed-Solomon codes achieve the largest possible minimum code distance for any linear code with the same encoder input and output block lengths. For nonbinary codes, the distance between two codeword is defined as the number of symbols in which the sequences differ (Hamming distance).

For Reed- Solomon codes, minimum distance is given by

$$d\text{min} = n - k + 1 \quad (5)$$

The RS code is capable of correcting any combination of t or fewer errors, where *t* can be expressed as

$$t = \left\lfloor \frac{d_{min}-1}{2} \right\rfloor = \left\lfloor \frac{n-k}{2} \right\rfloor \quad (6)$$

4.2 BCH Encoding

They were first developed by A. Hocquenghem in 1959 and R.C.Bose and D.K. Ray-Chaudhuri in 1960 . BCH codes were first applied to binary codes with symbols defined in Galois field GF(2m). BCH codes are used to correct errors in many systems including: storage devices, Wireless or mobile communications, satellite communications, Digital television, high-speed modems such as ADSL, etc. Bose –Chaudhuri – Hocquenghem (BCH) Codes are important classes of linear block code. These codes are multiple error correcting and detecting codes and a generalization of the Hamming code. BCH Codes are characterized for any positive integers m ($m \geq 3$) and t error ($k \leq 2^{m-1}$) by the following parameters.

Block length: $n = 2^m - 1$
Parity check bits: $n - k \leq mt$
Minimum distance: $d \geq 2t + 1$

Each BCH codes can detect and correct up to t random errors per code word. The BCH codes offer flexibility in the choice of code parameter mainly block length and code rate.

In BCH codes, α is a primitive element of GF(2^m). The generator polynomial is the lowest degree polynomial over GF(2) which has $\alpha, \alpha^2, \alpha^3, \ldots\ldots, \alpha^{2t}$. The codeword length is $2^m - 1$ and t is the number of correctable error. The generator of the binary BCH codes is found to be least common multiple of the minimal polynomial of each α^i term($0 < i < 2t$). For the generator polynomial simplification considering every even power of a primitive element has the same minimal polynomial as some odd power of the element.

The generator polynomial $g(x)$ of BCH codes for t-correctable error and length of codeword $2^m - 1$ is given by

$$g(x) = LCM\{\phi_1(x), \phi_3(x), \ldots\ldots.\phi_{2t-1}(x)\} \quad (7)$$

5 RESULTS

The WCDMA model is simulated by MATLAB for performance analysis of 16QAM and 64 QAM modulations in the Rayleigh channel by using two error control encoding such as BCH encoding and REED SOLOMON encoding in the MIMO Transmission. The simulation parameters used in the simulation are given in Table 1. Then the BER performance of WCDMA is calculated and compared by varying the SNR of the various channel by using two encoding one by one.

The simulation is done in this project by using M-files. A script can be written in MATLAB editor or another text editor to create a file containing the same statements that can be typed at the MATLAB command line. The file is saved under a name that ends in .m. BER is a performance measurement that specifies the number of bit corrupted or destroyed as they are transmitted from its source to its destination. Several factors that affect BER include bandwidth, SNR, transmission speed and transmission medium.

TABLE 1
STIMULATION PARAMETER

Parameter	**Value**
System	WCDMA
No. of users	2
Modulation technique	16 QAM / 64 QAM
MIMO Tx and Rx Antenna	2×2
Type of Fading Channel	Rayleigh channel
Encoding	BCH Encoding / Reed Solomon Encoding

Figure 2, The graph compare the Bit error rate (BER) and Signal to Noise ratio (SNR) for 16QAM and 64QAM modulation in WCDMA system by BCH encoding over the Rayleigh channel by MIMO transmission , the result show that 64QAM has low BER than the 16 QAM .If the SNR varied from 0 to 9 dB, The 64 QAM give better result than the 16 QAM over the Ri-

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cian channel by using BCH encoding .Each symbol of 16QAM conveys 4 bits per symbol but that of 64-QAM is 6 bits/symbol. SNR is defined as the ratio between signal power to noise power and it is normally expressed in decibel (dB).

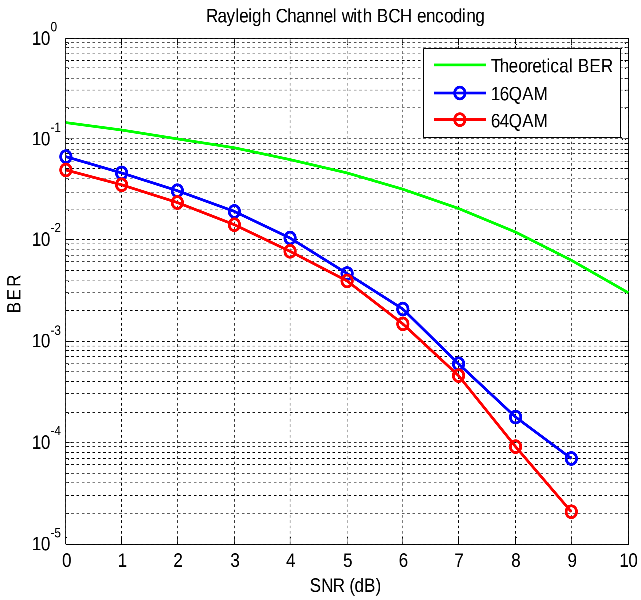

Fig. 2 Comparison of 16QAM / 64 QAM in Rayleigh channel by using BCH encoding.

	SNR	BER16QAM	BER64QAM
1	0	0.0662	0.0495
2	1	0.0464	0.0352
3	2	0.0309	0.0237
4	3	0.0195	0.0144
5	4	0.0103	0.0077
6	5	0.0046	0.0039
7	6	0.0020	0.0015
8	7	6.0104e-04	4.6103e-04
9	8	1.7758e-04	9.2206e-05
10	9	6.8300e-05	2.0490e-05
11	10	0	0

Table. 2 Simulation result for 16QAM / 64 QAM in Rayleigh channel by using BCH encoding.

Figure 3 shows the BER comparison of 16 QAM and 64 QAM by using Reed Solomon encoding over the Rayleigh channel in MIMO WCDMA system. It is observed that a similar trend is found when the encoding is done by Reed Solomon encoding again bit error rate of 64 QAM is low in comparison to 16 QAM .It shows that 64 QAM modulation gives better performance in MIMO Rician fading. If compare the bit error rate of 16QAM and 64QAM in both encoding, the result shows that bch encoding gives low BER in comparison to Reed Solomon encoding for both 16 QAM and 64 QAM modulation. The result verified that BCH encoding is better than the Reed Solomon encoding.Higher order QAM modulation schemes are vulnerable to error and error correction Coding gives higher chances of signal survivability in multipath fading Channel and thus enhances the system performance

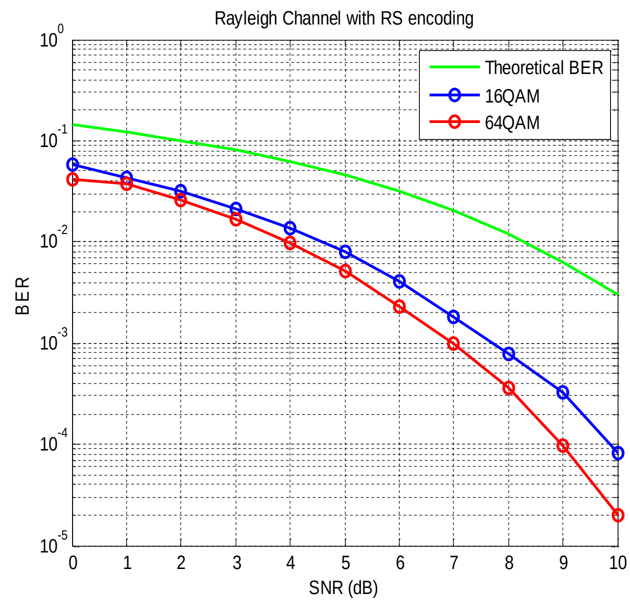

Fig. 3 Comparison of 16QAM / 64 QAM in Rayleigh channel by using RS encoding.

	SNR	BER16QAM	BER64QAM
1	0	0.0578	0.0415
2	1	0.0429	0.0372
3	2	0.0315	0.0259
4	3	0.0212	0.0168
5	4	0.0139	0.0096
6	5	0.0080	0.0052
7	6	0.0041	0.0023
8	7	0.0018	0.0010
9	8	7.7381e-04	3.5714e-04
10	9	3.2738e-04	9.6726e-05
11	10	8.1845e-05	1.9841e-05

Table. 3 Simulation result for 16QAM / 64 QAM in Rayleigh channel by using RS encoding.

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6 CONCLUSION

In this paper, we have analyzed and compared the performance of WCDMA system in MIMO Rayleigh channel for two modulation techniques 16QAM and 64QAM by considering the Reed Solomon encoding and BCH encoding , to reduce the error performance of the signal and compare which modulation and encoding gives better result through MIMO Channel in the presence of Rayleigh fading. The performance of W-CDMA system in MIMO Rayleigh channel shows that 64QAM modulation technique has a better performance compared to that of 16-QAM. From the stimulated result shows that BER of 64 QAM is lesser in comparison to 16 QAM in both encoding (Reed Solomon encoding and BCH encoding) .we compare BER by varying SNR from 0 to 9 dB. But if compare the BER performance of BCH encoding and reed Solomon encoding the result shows that the BCH encoding gives better BER performance in comparison to Reed Solomon encoding in MIMO Rayleigh channel.

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