Original Article

Performance analysis of CDMA Spreading codes for LTE/MIMO

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Abstract

The key technologies of 4G/LTE are OFDM and CDMA. Predefined precoding codebook defined by 3GPP for LTE is a promising technique with limited feedback from the receiver. Multipath problem and interference at the UE and eNB are the major problems of cellular communication. WHT, Kasami and gold sequences are CDMA code sets used to mitigate MAI and multipath problems. This paper combines mode 2Precoding transmission mode of LTE with CDMA code sets in frequency domain. WHT lowers interference in uplink transmission whereas Kasami and Gold sequences give good results in downlink transmission. In this paper BER of WHT, Kasami and Gold sequences with precoding are compared and graphs are plotted.

Keywords: CDMA, BER, WHT, Kasami Sequence, Gold Sequence, MIMO-OFDM, MAI

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Introduction

Advances in Mobile communication Technology is causing the Third Generation Partnership Project (3GPP) to add more features to 4G/Long Term Evolution (LTE). MIMO(Multiple Input Multiple Output) technology of 4G/LTE enhances throughput, coverage area and reliability of the link between eNB(Base Station) and User Equipment (UE). MIMO-OFDM systems combat the multipath effect of cellular technology. OFDM (Orthogonal frequency division multiplexing) mitigates ISI (Inter Symbol Interference) at the receiver. Multipath effect, carrier signal frequency offset, timing synchronization problem or Doppler spread effect results in Multiple access interference(MAI) in MU-OFDM(Multi user). Self-Interference (SI) is the interference caused by the transmitter antenna of the same transceiver [1]. SI is added to the signal of interest transmitted from the antenna of different transceivers.

Precoding techniques in LTE raises data transmission rate and minimizes multipath problem. In Precoding, the transmitter uses prior knowledge of the channel or it obtains channel information from the receiver. Using this information, the transmit signal is designed to mitigate ISI in the receiver. Precoding schemes are selected by considering full channel or partial channel state information at the transmitter. In LTE, spatial multiplexing techniques increases data rate whereas transmit diversity provides reliability.

In CDMA technology, spreading codes play an important role in distinguishing different users. Codes are classified into orthogonal codes like Walsh-Hadamard and non-orthogonal codes like PN-sequence, Kasami code and Gold code. These codes are selected based on Code length, Auto correlation and cross correlation functions [2]. The code with minimum cross correlation function is best suitable for CDMA systems. Usage of Spreading codes in wireless communication results in low BER, MAI and multipath effect.

Performance comparison in terms of BER is done for different spreading codes for CDMA in [5]. Synchronous communication model is used to test orthogonal and non-orthogonal codes for different code lengths and user scenarios. Increasing number of users resulted in poor performance of sequences due to rise in MAI. Better performance is observed in Orthogonal Hadamard code sequence. Large set of Kasami code has Poor performance.

Non orthogonal Gold and Kasami codes exhibit poor correlation properties for terrestrial networks. Terrestrial networks are characterized by multipath effect and interference. Advanced versions of Gold and Kasami codes suitable for terrestrial CDMA and WCDMA are described in [2]. These codes exhibit good correlation properties in both synchronous and asynchronous CDMA and W-CDMA environments.

In this paper, Precoding for transmit diversity is combined with CDMA spreading codes and BER is compared for different code sets. Organization of the paper is done as follows Section II briefs related work done in this area. Section III describes precoding used along with mathematical generation of CDMA code sets. Comparison results with system models are explained in Section IV. Conclusion is described in Section V.

Related Work

4G/LTE uses OFDM multi carrier technology to mitigate interference. The main problem is its High PAPR (Peak to Average Power Ratio). High peaks of the OFDM signal degrade the performance of the power amplifier. Among several techniques of reducing PAPR, Precoding gives better performance. Walsh-Hadamard Precoding to lower PAPR is described in [3]. For different IFFT points, PAPR is obtained and compared with no Precoding. Walsh Hadamard Transform is effective in reducing PAPR.

To reduce PAPR, Complex BIFORE Transform (CBT) Precoding scheme is compared with Walsh Hadamard transform (WHT) in [5]. Binary Fourier Transform (BIFORE) is an advanced linear orthogonal Hadamard transform with non-real complex values. CBT method provides better BER performance compared to conventional OFDM and WHT in fading multipath channels.

Precoding And Mathematical Generation Of CDMA Code Sequences

Tm2 Transmission Mode Of Lte For Mimo

3GPP standard of cellular communication has defined 8 transmission modes for LTE. Selection of these modes depends on wireless channel condition. TM2 or Transmit diversity mode is default transmission mode for 2 X 2 MIMO used for control and broadcast channels.In this mode, same information is sent through different antennas of transmitter. For each antenna transmission, different coding schemes and frequency elements are used. This mode used when the channel is varying rapidly or information of the channel is missing [8].It provides high throughput and spectral efficiency for noisy wireless channel.

Generation Of Spreading Codes Of CDMA

Walsh Hadamard Transform (WHT)

WHT performs linear orthogonal operation in order to convert input signal into set of basic functions [3]. Codeword rows of Hadamard square matrix are used to generate Walsh functions [4]. The matrix length n of rows (or columns) is 2n. Recursive procedure is used to generate Walsh functions. It lowers PAPR by reducing autocorrelation of the input sequence.

$$W_1 = [0], \quad W_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \quad W_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

In general,

$$W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

Kasami code

Kasami codeexhibits good auto correlation cross correlation properties close to ideal codes. Two sets of Kasami sequences are small set and large set. The large set contains all the sequences of small set and some Gold sequences. It generates small set $M = 2^{n/2}$ binary sequences with period$N = 2^n - 1$, where N is even. Kasami sequences of length N provides three valued cross correlation function given by$\left\{-1, -\left(2^{\frac{n}{2}} + 1\right), 2^{\frac{n}{2}} - 1\right\}$.

For binary sequence u of length N, sequence w is obtained by decimating u with $2^{n/2} + 1$. m is the shift parameter for w, T is left shift parameter and modulo 2 addition is denoted by $\oplus$.The small set of Kasami sequences is given by the following formula,

$$K_S(u, n, m) = \begin{cases} u & m = -1 \\ u \oplus \mathrm{T}^m w & m = 0, \ldots, 2^{\frac{n}{2}} - 2 \end{cases}$$

(1)

Gold code

Gold code is special set of PN (pseudo random) binary sequences with good correlation functions. Due to this characteristic, it is used as scrambling code in wireless communication. Gold code is generated by multiplying 2 PN sequences. Gold sequences generate more sequences by using a pair of m-sequences. More number of users can be supported by using different gold sequences.

Preferred pair of gold code sequence is obtained by time shifting one of specified pair of sequences u and v of period N. The code G (u, v) of Gold code [6][7] is given by

$G(u,v) = \{u, v, u \oplus v, u \oplus Tv, u \oplus T^2 v, \ldots, u \oplus T^N v\}$ (2)

Where $\oplus$ specifies modulo 2 additionand T is shifting operator.

Results

The System defined for LTE integrates mode 2 transmission mode of Precoding with spread spectrum sequences. In the conventional method, predefined Precoding matrices are applied to all OFDM subcarriers in the frequency domain.

In general, For M spatial layers X, N transmit antennas; signal transmitted to Nthantenna is given by,

$$\begin{bmatrix} y^{(0)}(2i) \\ y^{(1)}(2i) \\ y^{(0)}(2i+1) \\ y^{(1)}(2i+1) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & j & 0 \\ 0 & -1 & 0 & j \\ 0 & 1 & 0 & j \\ 1 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} Re(x^{(0)}(i)) \\ Re(x^{(1)}(i)) \\ Im(x^{(0)}(i)) \\ Im(x^{(1)}(i)) \end{bmatrix}$$

(3)

Where, $x^M(i)$ is ith modulation input symbol transmitted on the mth layer and $y^N(i)$ is output of Precoding block

The system designed uses spread sequences to weight ith symbol Y (i) given by

$$Y(i)' = Q\,Y(i) \quad (4)$$

Where Q can be orthogonal WHT, non-orthogonal Kasami or gold sequence. Code length of 8 bits is considered for both Kasami and Gold set.

BER performance is checked for 2 X 2 MIMO scenario for both uplink and downlink transmission between BS and UE. The Base Station connects to the RF Frontend (Lime SDR) via a GNU Radio interface. GNU radio enables exchange of traffic between the BS and UE.

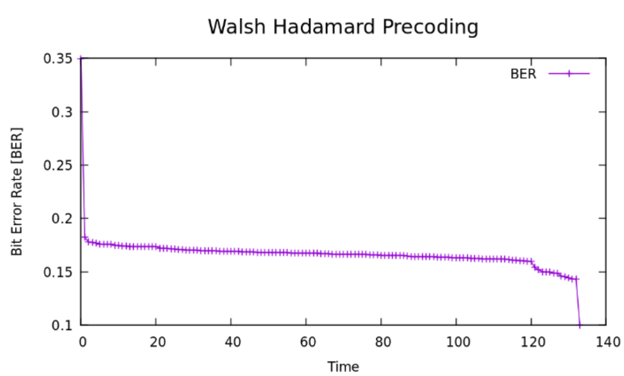

Fig. 1: BER vs Time plot for WHT: Downlink transmission

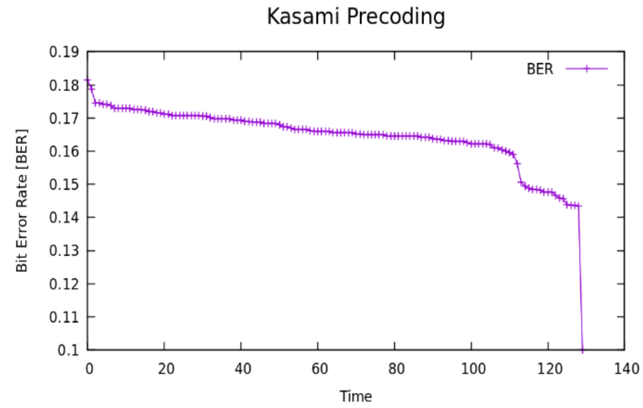

Fig.2: BER vs Time plot for Kasami code: Downlink transmission

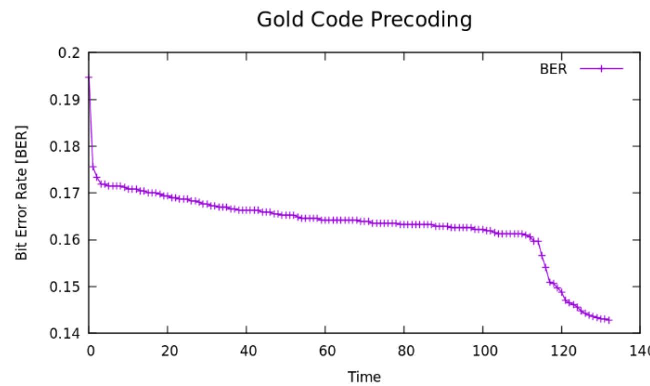

Fig.3: BER vs Time plot for Gold code: Downlink transmission

At eNB, MAI becomes significant during Downlink transmission. If multiple cellular users use same frequency band at the same time, MAI occurs. Performance of WHT, Kasami and Gold sequences are evaluated at eNB by considering BER.Kasami and Gold sequences have very low auto and cross correlation function when compared to WHT. It is clear that non orthogonal Kasami and gold sequences BER is low when compared to WHT. For Downlink, Kasami code gives better performance compared to WHT and Gold set.

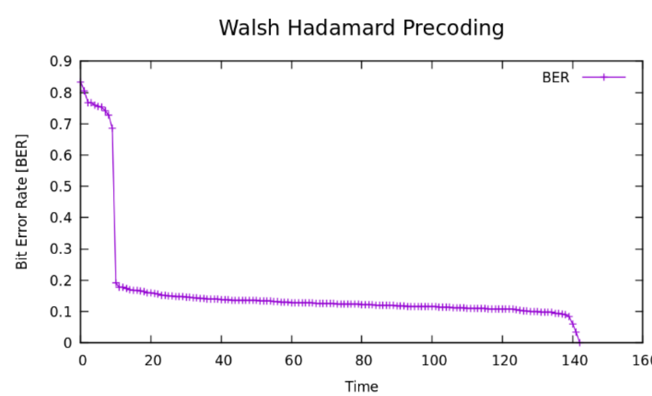

Fig.4: BER vs Time plot for WHT: Uplink transmission

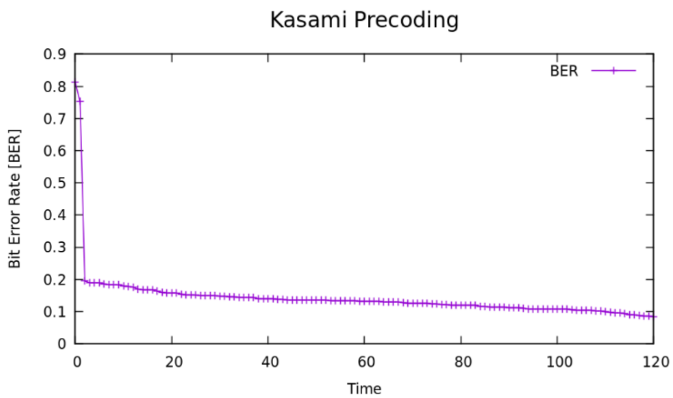

Fig.5: BER vs Time plot for Kasami code: Uplink transmission

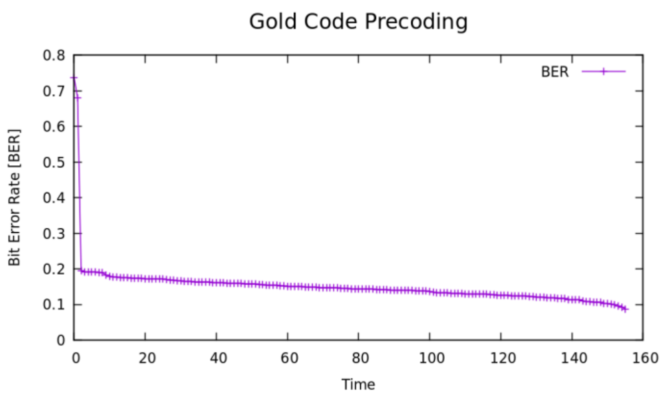

Fig.6: BER vs Time plot for Gold code: Uplink transmission

During Uplink transmission, self-interference plays major role at eNB. Self-interference or transmitter leakage results when signal leaks from the device transmitter to its own receiver. Comparison of Performance of WHT, Kasami and Gold sequences at eNB is done in terms of BER.For WHT, BER is less than 0.2 db. It is clearly seen that non orthogonal Kasami and gold sequences BER is more compared to WHT. WHT performance is better compared to Kasami and Gold code.

Conclusion

In this paper, comparative analysis of spread codes is done for 2x2 MIMO. The transmit diversity or TM2 transmission mode of LTE is used when getting feedback from UE is difficult. BER of these codes are evaluated for 2X2 MIMO scenario. Good correlation property of Kasami set makes it proper candidate for Downlink transmission. WHT provided low BER for Uplink transmission. The performance can be observed for different code length and number of users.

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