Original Article

Analysis of Precoding with Kasami sequence for LTE-MIMO

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Abstract

In wireless communication, obtaining high SNR at the transceiver is challenging work. The uplink and downlink transmission of cellular communication technologies are affected by self-interference (SI), Multiple Access interference and Inter Carrier Interference (ICI). Good Auto and cross correlation function make spread sequences of CDMA ,suitable for reducing interference at eNB(Base station) and UE(User Equipment). In this paper, Kasami sequence is combined at the transmitter with TM2 transmission mode of LTE in frequency domain to mitigate MAI in Uplink transmission. BER and SNR plots for with and without Kasami sequence for TM2 mode and results are compared. Kasami sequence precoding is found to be good for reducing interference in Uplink transmission of MIMO-LTE.

Keywords: CDMA, BER, SNR, MIMO, SI, Kasami Sequence, MIMO-OFDM, MAI.

INTRODUCTION

Modern mobile communication network uses CDMA techniques and OFDM to increase spectral efficiency. CDMA technique allows multiple users to use same frequency band by assigning different code to each user. In Wireless communication, CDMA techniques are used to reject multipath interference at both transmitter and receiver OFDM is multi carrier transmission technique used in LTE-MIMO. In this whole bandwidth is divided in to number of narrow bands of low data rates [1]. In OFDM, maintaining orthogonality is difficult for all the subcarriers resulting in performance degradation of the system.

In LTE, is used to achieve Precoding transmit diversity by multiplying input with precoding matrix at the transmitter. Interference reduction and increase in BER is achieved by combining spread spectrum sequences with precoding. Spread spectrum technique spreads energy obtained at one frequency over a wide frequency band. In this transmission bandwidth is made much greater than minimum bandwidth required for transmission. The good correlation properties make these sequences suitable for air traffic.

Spreading sequences can be orthogonal or non-orthogonal sequences [2]. Orthogonal sequences have zero cross correlation value. M-sequence, Kasami and gold sequences are non-orthogonal whereas Walsh Hadamard transform is orthogonal sequence. The new set of orthogonal small set Kasami code gives same auto correlation, cross correlation and peak correlation functions as that of non-orthogonal Kasami code sets. The proposed set results in numbers of orthogonal code sequences in each code set less than that of the chip lengths.

In modern communication systems CDMA serves many users simultaneously and allows all the users to make use of entire channel bandwidth. In this system, each user is assigned with unique code. Along with serving many users, cross correlation need to be kept low to reduce MAI. This paper [11] explains small set of Kasami sequence, capable of providing more number codes compared to synchronous CDMA system. It compares BER of different orthogonal codes for various SNR values.

Full Duplex (FD) communication is the key technology of wireless communication in order to achieve high throughput. In FD, spectral efficiency is doubled by simultaneously using same equipment for both transmission and reception. For multi-user MIMO full duplex(FD) system, a downlink precoding scheme is discussed in[3]. It is designed to reduce SI in the uplink, multiple access interference in downlink. It lowers hardware complexity by using only one radio frequency amplifier at each Base station. Results are compared with conventional Zero forcing methods. This precoder gives better results over conventional methods with negligible reduction in performance of the system.

This paper focus on design of uplink precoding scheme for the base station(BS) by considering mitigation of multiple access interference in LTE-MIMO full duplex(FD) system. The MIMO precoding transmission mode of LTE is combined with Kasami sequence to improve performance. BER and SNR of the proposed scheme are compared with conventional precoding method of LTE. This paper is structured as follows: Introduction to the topic is given in section I, Work related to proposed system is covered in section II, PN sequence properties and mathematical expressions for Kasami code set is given section III, Results are discussed in section IV. Conclusion is given in section V.

RELATED WORK

LDPC Coding and decoding technique is useful for improving efficiency in multi user systems. BER at the receiver is improved by choosing LDPC techniques with appropriate spread spectrum sequence like Walsh Hadamard Transform, Kasami and Gold codes [4]. Combination of LDPC and Kasami code set resulted in high coding gain at a cost of low BER.

MAI is major drawback of MIMO-CDMA systems It degrades system performance by reducing their capacity and by increasing BER. It occurs when multiple users use same frequency band at the same time. MAI becomes significant when power level of the intended user is lower than interfering user [5].Statistical analysis is done by deriving expression for probability density function (PDF) of MAI and MAI plus noise. Resulting PDFs are found to be function of parameters such as the number of users, number of antennas, spreading code length, channel variance and noise variance. Simulation results are obtained to see the dependency of PDF of MAI on these parameters and close agreement with theoretical values.

TRANSMISSION MODE AND PROPERTIES, MATHEMATICAL GENERATION OF KASAMI CODE SEQUENCE

A. Transmission modes of LTE

LTE has 8 transmission modes defined by 3GPP standard of cellular communication. These modes are selected on the basis wireless channel traffic. Modes are based on spatial multiplexing or transmit diversity for open loop or closed loop scenario. In LTE base station called eNB communicates with User Equipment (UE).

Transmit diversity in mode2 is achieved by sending same data through various antennas of the transmitter. For 2 X 2 MIMO, this mode in selected as default mode. Each antenna uses different coding schemes and frequency elements for the transmission are used[6]. It provides reliability and spectral efficiency with low data rate. It is used for edge and heavy traffic areas of the cell.

The Precoding matrix for TM2 mode for M spatial layer X N transmit antennas is given by

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

Where, $x^M(i)$ is i^{th} modulation input symbol transmitted on the m^{th} layer and $y^N(i)$ is input to the transmitting antennas.

B. PN Sequence properties and mathematical generation of Kasami code

PN sequence properties

Pseudo Noise (PN) is a periodic binary sequence. It is generated by using feedback shift registers[7][8].

Balance property

The number of 1's in each period of maximum length PN sequence given by $2^m - 1$ is one more than number of zeros.

Autocorrelation property

For PN sequence of length N, autocorrelation function r (i) is given by

$$r(i) = \begin{cases} 1\ for\ i = 0 \\ -\frac{1}{N}\ for\ i \leq N-1 \end{cases} \quad (2)$$

Auto correlation value is maximum when there is perfect synchronization (zero time shifts) and zero for any time shift other than zero.

Cross Correlation property

Comparison between two sequences is done using cross correlation property. The cross correlation between two sequences X and Y is given by

$$R_{x,y}(\tau) = \frac{1}{N}\sum_{k=1}^{N} X_k Y_{k-\tau}\ where \tau = 0, N, 2N \dots \dots \quad (3)$$

Minimum Cross correlation value is preferred to avoid Self interference and MAI.

Merit Factor (MF)

It is the ratio of radiation energy of main lobe level to the energy of side lobe levels[9].

For binary sequence $B = (b_0, b_1 \dots \dots \dots b_{n-1})$ of length $n > 1$, where $b_i \in \{-1,1\}, 0 \leq i \leq n-1$, if $C_0(B)$ is energy of main lobe level and $C_u(B)$ for $u \in \{1 \dots \dots \dots \dots n-1\}$, the MF is given by

$$MF(B) = \frac{C_0(B)}{2\sum_{u=1}^{n-1}|C_u(B)|^2} \quad (4)$$

Kasami code

Kasami sequences are binary sequences of length

2^N-1 where N is a nonnegative, even integer. They have cross correlation properties close to ideal codes. Kasami sequences can be small set and large set sequence. The large set has all the sequences of small set. Small set matches with Welch's lower bound for correlation functions. Three valued cross correlation function of Kasami sequence of length N is given$\left\{-1, -\left(2^{\frac{n}{2}}+1\right), 2^{\frac{n}{2}}-1\right\}$.Wide flat spectrum is the result of high Merit Factor(MF) and good correlation values of these sequences. This Characteristic makes Kasami Large set suitable for WCDMA uplink transmission.

Small set Kasami sequence

Small Kasami set contains $M = 2^{n/2}$ binary sequences with period$N = 2^n - 1$, where N is even.

Binary sequence u of length N is used to obtain sequence w 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,

$$K_S(u,n,m) = \begin{cases} u & m = -1 \\ u \oplus \mathrm{T}^m w & m = 0, \ldots, 2^{\frac{n}{2}} - 2 \end{cases} \quad (5)$$

Large set Kasami Sequence

Large set of Kasami sequence generates $2^{\frac{n}{2}}(2^n + 1)$ sequences. Binary sequence v is formed by decimating the sequence u by,$2^{\frac{n}{2}+1} + 1$,K and m are uses as shifting parameters forv and w. For mod(n, 4) = 2, the large set of Kasami sequences are given below.

$$K_L(u,n,k,m) = \begin{cases} u & k = -2; m = -1 \\ v & k = -2; m = -1 \\ u \oplus T^k v & k = 0 \ldots\ldots 2^n - 2; m = -1 \\ u \oplus T^m w & k = -2; m = 0 \ldots\ldots\ldots 2^{n/2} - 2 \\ v \oplus T^m w & k = -1; m = 0 \ldots\ldots\ldots 2^{n/2} - 2 \\ u \oplus T^k v \oplus T^m w & k = 0..2^{\frac{n}{2}} - 2; m = 0..2^{n/2} - 2 \end{cases} \quad (6)$$

RESULTS

The proposed system uses TM2 mode of precoding with Kasami sequence. The system designed uses spread sequences to weight ith symbol Y (i) from the conventional precoder given by

$$Y(i)' = Q\,Y(i) \quad (7)$$

Where Q is 8 bit Kasami sequence.

BER and SNR are checked for conventional TM2 precoder and the proposed precoder. Performance is checked for 2 X 2 MIMO scenario for both uplink transmission between eNB and UE. GNU Radio interface connects eNB to RF frontend(Lime SDR) GNU radio allows exchange of traffic between the eNB and UE.

Figure 1. BER Vs Time plot for conventional precoding:uplink transmission

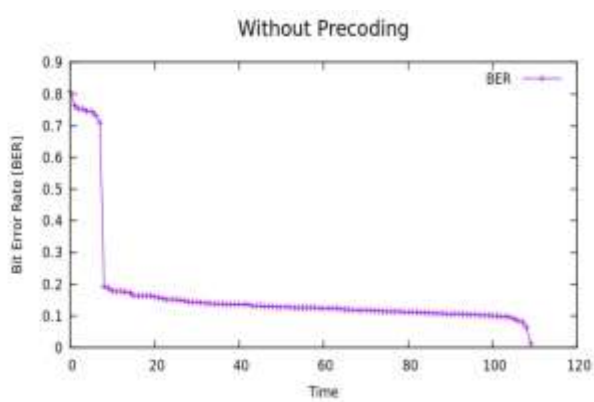
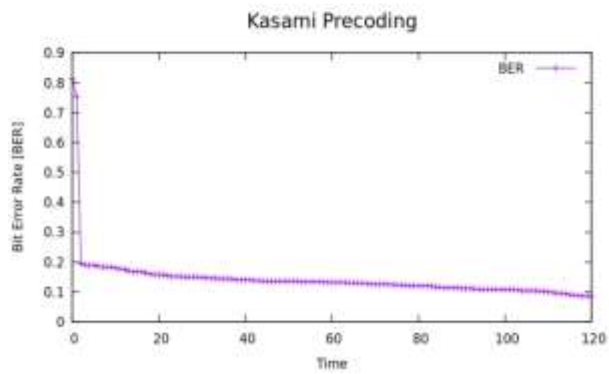


Figure 2. BER Vs Time plot for Kasami precoding: uplink transmission



From the BER plot it is clear that initially Kasami code BER drops rapidly to 0.2db and then levels are lower than conventional TM2 precoding.

Figure 3. BER VsSNR plot for Conventional precoder; Uplink transmission

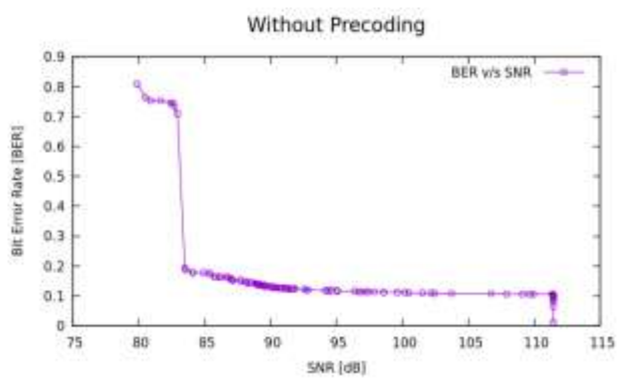
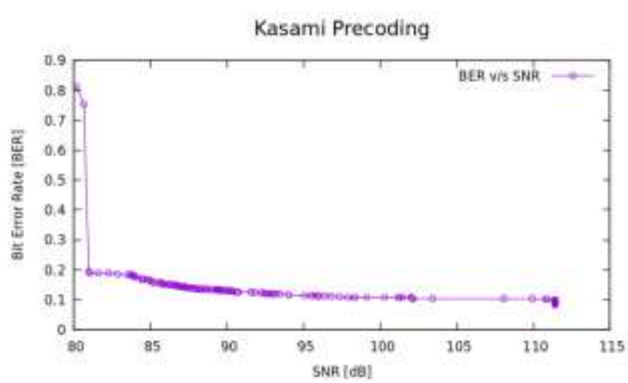


Figure 4. BER Vs SNR plot for Kasami precoding: Uplink transmission



SNR Vs BER graph of Kasami code shows sharp reduction at 82db. For higher values of SNR, BER is low when compared to conventional Precoder.

Figure 5. SNR VsBER for conventional precoding: Uplink transmission

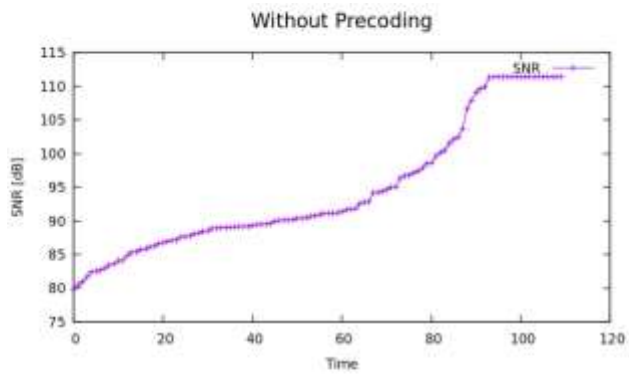
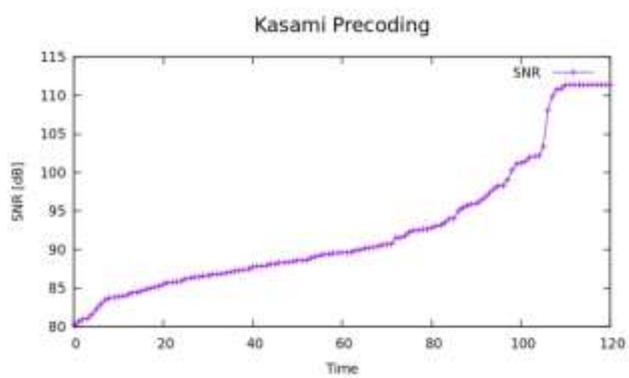


Figure 6. SNR VsTime for Kasami code: Uplink transmission



From figure 5 and 6 it is clear that SNR increment rate with respect to time is low for Kasami when compared to conventional precoding. If performance is evaluated with respect to BER, Kasami code is good option for precoding. The proposed method can be used to lower MAI.

CONCLUSION

In this paper, comparative analysis of spread code sequence like Kasami code precoding is done with TM2 transmission mode of LTE for 2x2 MIMO. BER and SNR plots of these coding methods are evaluated for LTE-MIMO Scenario. MAI causes performance degradation of the system. Good cross correlation property of Kasami set is used to reduce interference in uplink. The better BER response makes Kasami Precoding suitable for mitigating MAI. The performance can be observed for different code length and number of users.

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