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Research Article

Performance of Walsh-HadamardPrecoding for open loop diversity mode in LTE

Anjana K [a*], Dr.SayedAbdulhayan [b]

[a*,b] PhD Scholar, Associate Professor,DayanandaSagar
College of Engineering,Bangalore
[a] k1anjana@gmail.com, [b] sabdulhayan@gmail.com

Abstract

LTE technology utilizes pre-coding technique at the transmitter to send channel based data preprocessinginformation to simplify the complexity of the receiver. Precoded data of downlink is transmitted using Orthogonal Frequency Division Multiplexing(OFDM) from base station to the Mobile Users. Precoding is done in frequency domain along with some transforms to reduce problems of OFDM. This paper investigates performance of precoding for TM3 mode of LTE with Walsh-Hadamard transform. The graphical results show the relation between SNR and BER for 16QAM modulation scheme with N=512..

Keywords: Bit Error Rate(BER),Signal to Noise Ratio(SNR),Peak Average Power Ratio(PAPR),Inter Channel Interference(ICI),Long Term Evolution(LTE),Multiple Access Interference(MAI)

1. Introduction

LTE uses Multiple Input Multiple Output (MIMO) technology to improve system performance. Transmit diversity, spatial multiplexing and beamformingare some of the MIMO techniques used in LTE[3].In case of spatial multiplexing,each antenna at the transmitter sends multiple streams of data to many receiving antennas at the same time.Transmit diversity is a technique in which delayed version of thesignal is sent by using multiple antennas at the transmitter. Proper equalizers are used at the receiver to increase diversity gain.

OFDM is a frequency division multiplexing technique, used in LTE increases symbol duration and reduces ISI caused due to multipath problem.Itconverts high rate data in to smaller data streams for transmittingin parallel over orthogonal subcarriers.Precoding in OFDM systems provide frequency diversity and improves bit error rate performance in frequency selective fading channels. The major issues of OFDM are its high PAPR and MAI. High PAPR results inperformance degradation ofpower amplifier at the transmitter.PAPR is reduced by using many techniques such as interleaving, clipping and several transforms.MAI problem can be overcome by increasing the transmission power at the transmitter.But the increasing transmission power for one user causes interference for other users. MAIsuppression requires superior multiuser detection and signal processing techniques. Hadamard Walsh transform is an effective method to reduce PAPR and MAI(Multiple Access Interference).

Hadamard-Walsh code is used for downlink transmission. In the uplink, MAI increases due to small timing mismatch among users even if the channel is perfect.

In this paper, performance of normal precoding is compared with Hadamard-Walsh precoding for TM3 mode of LTE downlink. Hadamard-Walsh precoding reduces PAPR and MAI at the cost of increasing BER.

Subsequent sections elaborate organization of this paper. Section 2 presentsOFDM transmitter model forTM3 model of LTE andPAPR. In Section 3, Precoding for TM3 mode of LTE is discussed. The Hadamard -Walsh transform is discussed in section 4. Simulation outcomes are discussed in section 5.

2. LTE OFDM Model

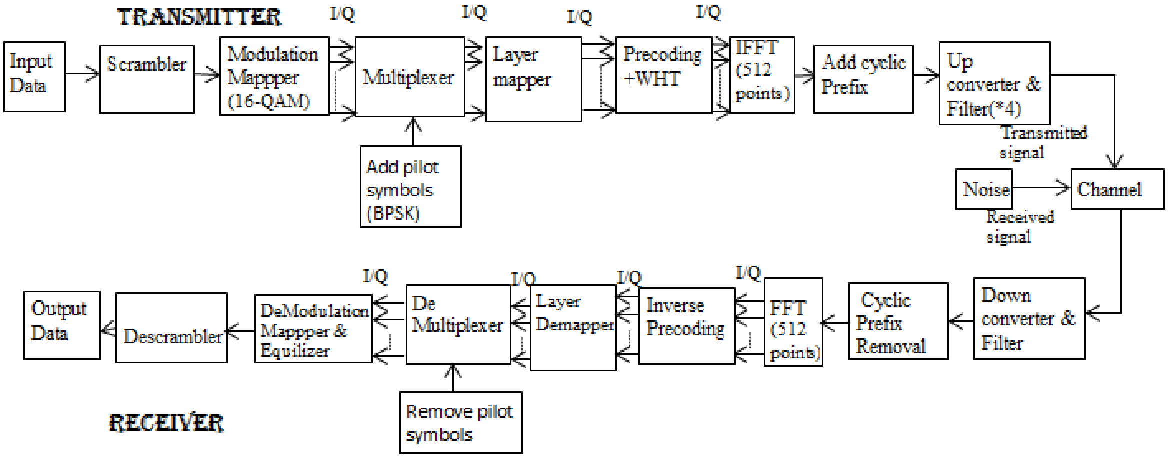

Figure1. Block diagram of OFDM model for TM3 mode of LTE with precoding and WHT

The simulation model used for TM3 mode of LTE is presented in figure.1.The model uses transmitter, a channel and a receiver. In this scheme, scrambler converts input random data into binary data. A16 QAM modulation mapper is used to convert stream of bits from higher layers in to symbols for subcarriers of OFDM system.BPSK pilot symbols are mixed with QAM symbols to achieve proper decoding of the received signal. Layer mapper generates signal for 2*2 MIMO in transmit diversity mode. Precoder is combined with Walsh Hadamard transform to generate signal for transmitter antennas. Computational load of both transmitter and receiver is reduced by using discrete Fourier transform.At transmitter, IFFT converts frequency domain symbols(phase and quadrature), into time domain symbols. Cyclic prefix is added as guard period between successive symbols to minimizeInter symbol Interference(ISI) and ICI.Then the signal is upconverted,filtered and transmitted through the channel.

OFDM signal reception is the reverse process of transmission which includes down converter,FFT, layer and modulation demapper. Assuming Minimum Mean square error(MMSE) receiver, pseudo inverse of precoding matrices are considered to obtain the received signal. After cyclic prefix removal, time domain signal is passedthrough FFT block to obtain frequency domain signal.

In OFDM systems, IFFT at the transmitter is used to correlate successive modulated input data samples (e.g, PSK or QAM). Orthogonal data subcarriers in time domain are generated using IFFT.. Let, input data isa vector of length M given by,

$X=[X^0, X^1\ldots\ldots X^{M-1}]^T$. Morthogonal sub-carriers are used to transmit the signal, then $f_n= n\Delta f$, where $n\Delta f = 1/MT$ and MT is the time duration of the data block X.

$$x(t)= \frac{1}{\sqrt{M}}\sum_{n=0}^{M-1} Xne^{-j2\Pi nf\Delta t}, \qquad 0\le t\le MT \quad (1)$$

$j=\sqrt{-1}, \Delta f$ is subcarrier spacing.

At the transmitter, high dynamic range of IFFT increases PAPR. This effect reduces linearity and surge the design complexity of power amplifier.Independentlymodulated OFDM subcarriers causes rise in peak power compared to the average power of the system. PAPR of the transmitted signal is the ratio of peak power to average power.

PAPR of the transmitted signal is given by [2]

$$PAPR=\frac{Peak\_power}{Average\_power} \qquad (2)$$

$$PAPR[x (t)]=\frac{max_{0\le t\le MT}|x(t)|^2}{P_{avg}}= \frac{max_{0\le t\le MT}|x(t)|^2}{\frac{1}{MT}\int_0^{MT}|x(t)|^2dt} \qquad (3)$$

Where, $P_{avg}$is the average power obtained in the frequency domain.

3. Precoding for TM3 mode of LTE

High UE speedor feedback overhead on the uplink makes difficult to obtain reliable PMI feedback at the transmitter.In that case, fixed set of precoding matrices are applied cyclically across all the OFDM subcarriers in the frequency domain.

Considering Mspatial layers and N transmit antennas,signal at the transmitter antenna due to precodingforopen loop transmit diversity is defined by

$$Y(i) = W(i)D(i)UX(i) \quad (4)$$

where $Y(i) = [y^0(i), \ldots , y^{N-1}(i)]^T$, $y^N(i)$ denotes the i^{th} complex symbol transmitted on the Nth antenna, W(i) of size N x M is the matrix used for precoding, $X(i) = [x^0(i), \ldots , x^{M-1}(i)]^T$, $x^M(i)$ denotes the i^{th} modulation symbol transmitted on the m^{th} layer, matrix U of size M × M is used for energy distribution on M layers and the matrix D(i) of size M × M isemployed to provide phase shift for large delay cyclic delay diversity (CDD).The matrices U(i) and D(i) are given in table 1 and 2.

No of Layers	M x M matrix U
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & e^{-j2\Pi/2}\end{bmatrix}$
3	$\frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\\1 & e^{-j2\Pi/3} & e^{-j4\Pi/3}\\1 & e^{-j4\Pi/3} & e^{-j8\Pi/3}\end{bmatrix}$
4	$\frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\\1 & e^{-j2\Pi/4} & e^{-j4\Pi/4} & e^{-j6\Pi/4}\\1 & e^{-j4\Pi/4} & e^{-j8\Pi/4} & e^{-j12\Pi/4}\\1 & e^{-j6\Pi/4} & e^{-j12\Pi/4} & e^{-j18\Pi/4}\end{bmatrix}$

Table 1.U matrix to distribute energy among each layers

No of Layers	D(i)
2	$\begin{bmatrix}1 & 0\\0 & e^{-j2\Pi i/2}\end{bmatrix}$
3	$\begin{bmatrix}1 & 0 & 0\\0 & e^{-j2\Pi i/3} & 0\\0 & 0 & e^{-j4\Pi i/3}\end{bmatrix}$
4	$\begin{bmatrix}1 & 0 & 0 & 0\\0 & e^{-j2\Pi i/4} & 0 & 0\\0 & 0 & e^{-j4\Pi i/4} & 0\\0 & 0 & 0 & e^{-j6\Pi i/4}\end{bmatrix}$

Table 2. Large delay CDD matrix D(i)

4. Hadamard –Walsh transform

The Hadamard-Walsh transform is a orthogonal transformation technique that decomposes input signal into a set of orthogonal rectangular functions called Walsh, ,Hadamrdor Walsh-Fourier transforms. Every element of hadamard matrix is either +1 or -1.The proposed Hadamard transform scheme reducesPAPR by reducing auto correlation of input sequence and lowers MAI.The Hadamard matrix of order 2 is defined by [6]

$$H_2=\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix} \quad (5)$$

The precoding with Hadamard transform is given by

$Y(i) = HW(i)D(i)UX(i)$,Where H is Hadamard matrix.(6)

5. Simulation Results

LTE OFDM MIMO system for mode TM3is simulated using MATLAB 2018version for 2X2 MIMO. Parameter values used for configuration are illustrated in table 3.

Parameters(dl-sch)	**VALUE**
Antenna system	2*2 MIMO
FFT Size	512
Number of subcarriers used	300
Bandwidth, B	5MHz
Sampling frequency, fs	5MHz
Subcarrier spacing	15KHz
Used Subcarrier index	-150 to -1,+1 to+150
Cyclic Prefix duration	4.74µs
Data Symbol duration	66.6 µs
Total Symbol duration	71.3 µs
Modulation	16QAM/BPSK
Subframe Length	1ms
Symbols per frame	1440
Channel model	AWGN/Raleigh channel

In the simulation MIMO channels are assumed to be AWGN channel.

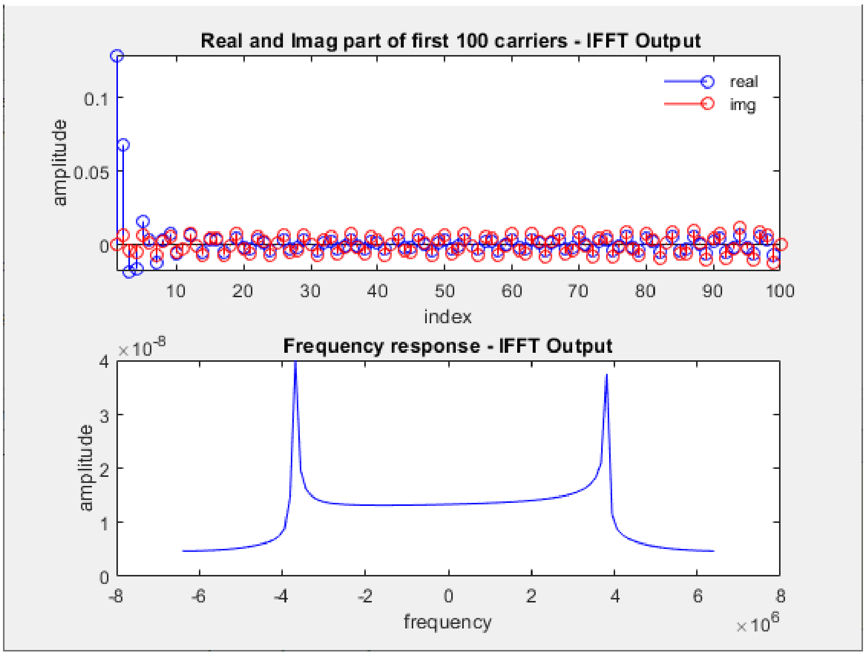

Figure 2.aTime domain response of IFFT,2.b. Frequency domain response of IFFT

The plot(a) shows time domain response of IFFT in terms of amplitude for walshhadamard encoding along with precoding.The plot(b) shows that Frequency domain response of 512 point IFFT for walshhadamard encoding along with precoding.

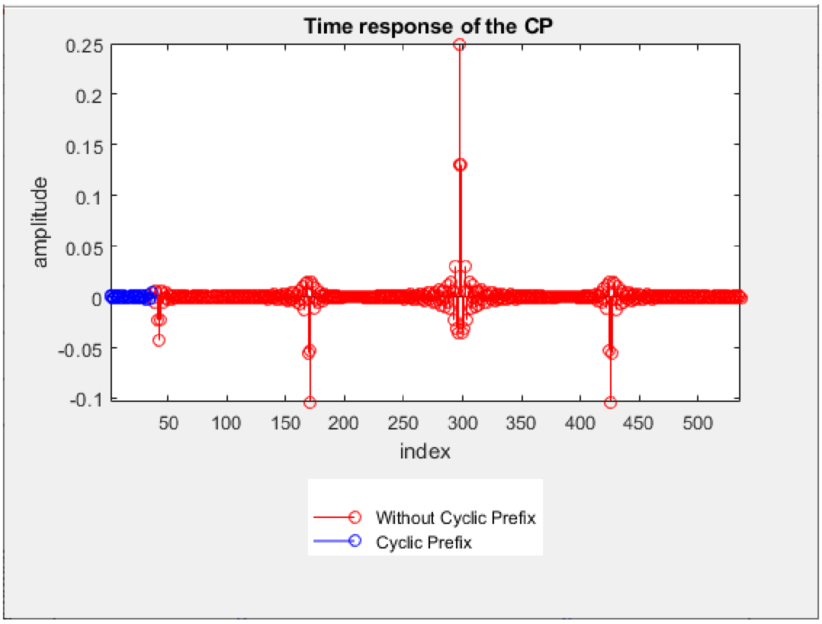

Figure.3 Time domain response after adding cyclic prefix

Figure 3 shows time domain response after adding cyclic prefix. Cyclic Prefix is used to detect start and end of symbol. Use of Precoding with Walsh Hadamarddevelops strongautocorrelation. Hence by considering with and without cyclic prefix area from the plot,we can identify start and end of symbols.

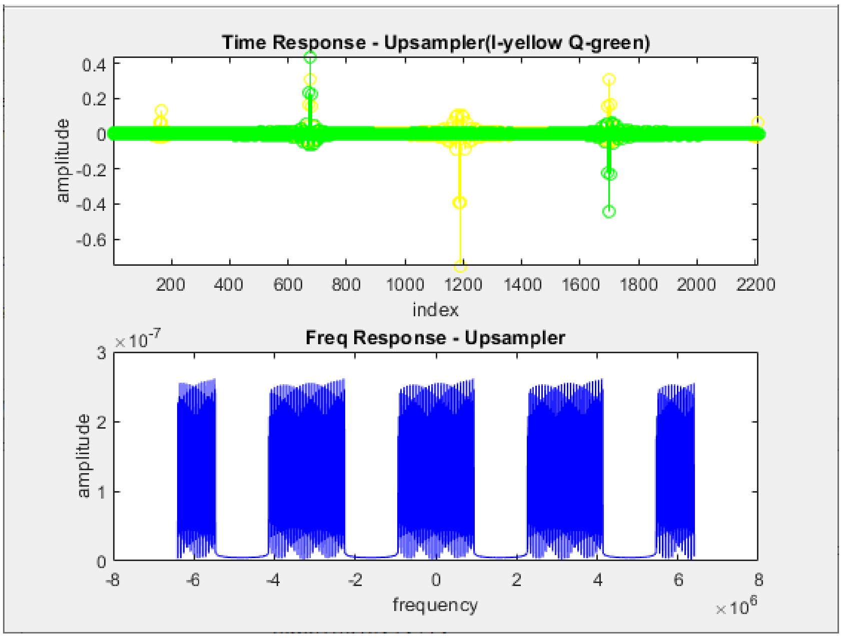

Figure.4.a.Time domain response of upsampler, 4.b. Frequency response of upsampler

Figure 4.a shows plot of time domain response ofupsampler with upsampling rate=4. Plot b shows frequency response of upsampler.

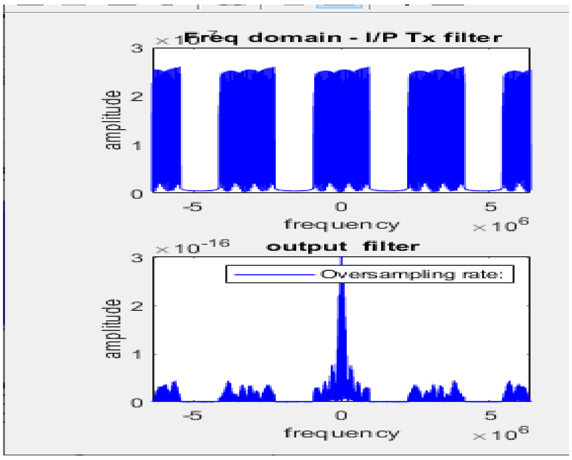

Figure 5. a. Frequency response of duplex filter at the input of filter,b. Frequency response of duplex filter at the output of filter.

Plot 5.a shows Frequency response for Duplex Filter at Input for Bandwidth of 5MHz .Plot b shows frequency response of duplex filter output at the transmitter.

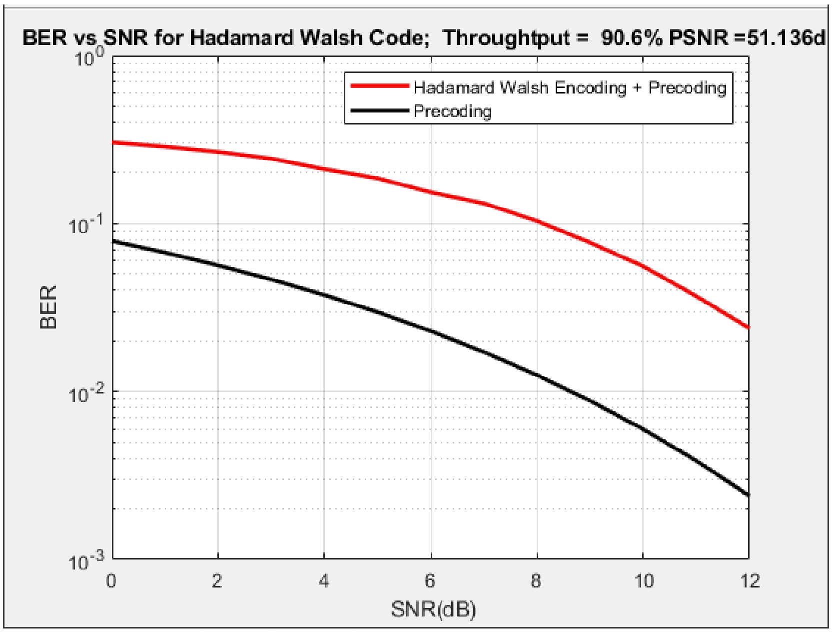

Figure.6.BER Vs SNR graph

Figure 6 gives comparison between precoding with Walsh Hadamard encoding and normal Precoding. It is found that BER is more for same SNR as with Normal Precoding. This is disadvantage of extra encoding with Walsh Hadamard code.

6. Conclusion

This paper has proposed a novel precoded OFDM based LTE system for TM3 mode. The performance of MIMO system with this method is better than normal open loop precoding. This method reduces PAPR and ICI at the cost of increasing BER.At first phase, simulation is done for conventional precoding with 16QAM and number of subcarrier (N=512) and then simulated proposed method for same parameters. It is observed that BER increases for the same SNR as that of normalprecoding,

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