International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 12 (2015) pp. 30635-30648

http://www.ripublication.com

# Nullifying The Channel Length and System Enhancement Using Different Channel Estimation Techniques For LTE Downlink Systems

**[1]Chandika Mohan Babu**
*IEEE Member, Assistant Professor, Wireless Communication Domain (D3)*
*School of Electronic and Communication Engineering,*
*Lovely Professional University, Punjab, India.*
*chandika.14736@lpu.co.in*
**[2]Isha**
*M. Tech Student, Wireless Communication Domain (D3)*
*School of Electronic and Communication Engineering,*
*Lovely Professional University, Punjab, India.*
*sharmaisha56@gmail.com*

## Abstract

The rising tides of data traffic, bandwidth and spectral efficiency are the main tradeoff for the high speed Broadband networks services which are under more pressure with QOS and channel variations. But the arrival of LTE and its standards has made complexity further improvement in achieving the user demands. LTE is based on two multicarrier modulation schemes OFDM and SCFDMA which are deployed in downlink and uplink respectively. A single subcarrier represents one OFDM symbol and at the beginning of each transmitted OFDM symbol with a cyclic prefix (CP) inserted in order to extenuate the effect of both inter-carrier interference (ICI) and inter-symbol interference (ISI) which arises due to multipath propagation. It is necessary for inserted CP length must be equal to or longer than the channel length. However, due to some unanticipated channel behavior, the cyclic prefix length becomes shorter than the channel length. In order to know the behavior of channel it is required to predict the nature of channel and its behavior on transmitted symbol. For this purpose different channel estimation techniques can be used. This paper presents channel estimation techniques which are LS, LMMSE, Hybrid LS-LMMSE and Hybrid LS-LMMSE channel estimation with ACPL. LS channel estimation technique is having less computational complexity but it is having less accuracy. LMMSE works for low SNR value and is complex. Hybrid LS-LMMSE refuse these problems but, it suffers from ISI effect. To resolve all the problems listed above a hybrid LS-LMMSE channel estimation technique with an ACPL can be used so that performance of the entire system can be enhanced. The performance of system can also be enhanced using proposed zero forcing method in terms of BER. The results are processed according to MATLAB Monte Carlo criteria to evaluate the performance of suggested estimation technique in terms of Bit Error Rate (BER) for 2x2 LTE downlink system.

**Keywords:** LTE; MIMO; OFDM; CP; LS; LMMSE; channel length, ZF.

## Introduction

Designing an efficient wireless communication system is always a challenge with tradeoff. With increase in demand for high data rate this task has become even more challenging. To achieve this challenging goal, 3rd Generation Partnership Project (3GPP) came in to existence. The long term evolution (LTE) is a standard introduced by 3GPP as one of the recent steps in cellular 3G services. LTE provides many benefits like high-speed data, bandwidth efficiency, latency, multimedia unicast and multimedia broadcast services to cellular networks. In order to achieve these benefits LTE employs new accessing technologies - Orthogonal Frequency Division Multiple Access (OFDM) for downlink transmission and Single Carrier Frequency Division Multiple Access (SC- FDMA) for uplink transmission. OFDM is used in the LTE downlink as a multiple access method due to its high data rate, high bandwidth efficiency, immunity to multi-path and frequency selective fading, and less complex equalization at the receiver. OFDM splits available spectrum into small units that allow signals to be sent in smaller pieces, making LTE much more flexible and simpler to work with than 3G. The smaller pieces also make communications less likely to be affected by interference, fading and other issues. SC-FDMA is introduced recently and it became handy candidate for uplink multiple access scheme in LTE system as it provides lower PAPR as compared to that of OFDM.

The performance of LTE downlink system is based on different parameters. But out of all those parameters channel estimation technique plays a key role. The channel estimation technique which is been analyzed is hybrid channel estimation technique which is based on Least Square (LS) and Linear Mean Minimum Square Error (LMMSE) algorithms. This technique may handle problem of channel length effect but suffers from presence of ISI. To extenuate this problem a new hybrid channel estimation technique is been analyzed with an adaptive cyclic prefix length (ACPL). It is been suggested that zero forcing technique reduces bit error rate than other analyzed techniques and thus enhance system performance.

The description about all the concepts is been discussed in further sections.[1][3][8][9]

## LTE Downlink System

In order to go in depth lets first of all discuss the major parameter of LTE downlink system and that is OFDM system, upon which the entire LTE downlink system is wholly based.[4][5]

In OFDMA transmitter, the high speed serial data from each user is first converted in to low speed parallel data streams. This increases the symbol duration which reduce the Inter-symbol Interference (ISI) at the receiver. Then the parallel data streams are passed through modulator, where adaptive modulation schemes such as (BPSK, QPSK, 16-QAM, 64-QAM) is applied. These modulated data streams are then mapped to orthogonal subcarriers by dividing the available spectrum into number of orthogonal frequency subcarriers.

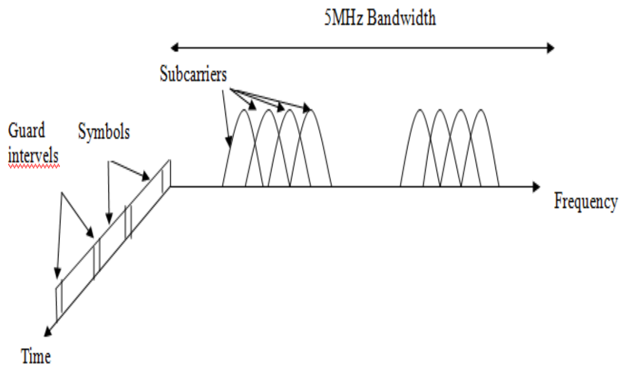


**Figure 1:** OFDM Signal Representation

This makes the time domain data stream from user into a frequency domain data stream or signal having different frequency with different low speed data streams. The IFFT stage converts these complex data streams into time domain and generates OFDM symbols. In practice, the IDFT is implemented very efficiently as an Inverse Fast Fourier Transform (IFFT) and the IFFT keeps the spacing of the subcarriers orthogonal and not requires intra-cell interference cancellation.

Subcarriers are basically of four types Data subcarriers, Pilot subcarriers, Null subcarriers and direct subcarriers.

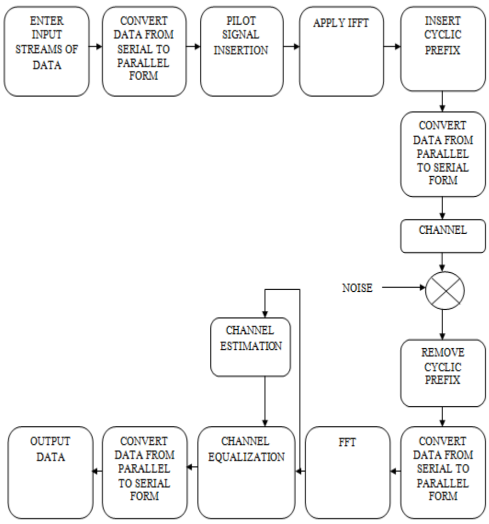


**Figure 2:** OFDM Block Diagram

A guard band or cyclic prefix (CP) is inserted between OFDMA symbols in order to cancel the ISI at the receiver. CP is a copy of the last part of the OFDM symbol which is pre-pended to the transmitted symbol as shown in fig3. This makes transmitted signal periodic, which plays main role in avoiding ISI and ICI. The duration of these CP should be greater than the channel impulse response or delay spread. After appending CP the data streams are converted to a serial data stream to be transmitted in the channel.

For LTE, the standard length of the cyclic prefix has been chosen to be 4.69μs. This enables the system to accommodate path variations of up to 1.4 km, the symbol length in LTE is set to be 66.7μs. The symbol length is defined by the fact that for OFDM systems the symbol length is equal to the reciprocal of the carrier spacing so that orthogonality is achieved. With a carrier spacing of 15 kHz, this gives the symbol length of 66.7μs. [3][2][10]

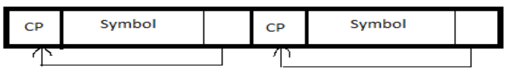


**Figure 3:** Inserting Cyclic prefix (CP)

At the receiver, the inverse processes of the transmitter occur. As we know if data rate increases more bandwidth will be required then due to this multipath fading which will increase ISI effect. This effect can be removed by using adaptive equalizers. These equalizers are implemented by FIR filters with adaptive tap coefficients. So, the multipath channel with L-taps for each channel path is given by

$$h(t,\tau) = \sum_{t=0}^{L-1} h_l(t)\delta(t-\tau_l) \tag{1}$$

Let $\overline{X} = [\overline{X_0}\,\overline{X_1}...\overline{X}_{N-1}]$ and $\overline{Y} = [\overline{Y_0}\,\overline{Y_1}...\overline{Y}_{N-1}]$ are the input and output data blocks of DFT block at receiver. $h_l$ is impulse response and $\tau_l$ is the multipath delays of channel. The serial data is converted to parallel data streams, CP is removed from each symbol and FFT stage converts the OFDM symbols in to frequency domain followed by subcarrier de-mapping and demodulation. Finally parallel data streams are converted to high speed serial data stream. OFDM symbol is represented as:

$$\overline{Y} = H\overline{X} + \overline{W} \tag{2}$$

$\overline{Y}$ is received OFDM symbol. $\overline{X}$ is diagonal matrix. H is a channel frequency response matrix. $\overline{W}$ is AWGN noise having zero mean and variance $\sigma_W^2$ .[13] [12]

**Table 1:** LTE Downlink Modulation Parameters

| | | | | | | |
|---|---|---|---|---|---|---|
| Transmission Bandwidth (MHz) | 1.25 | 2.5 | 5 | 10 | 15 | 20 |
| Sub-frame duration (ms) | 0.5 | | | | | |
| Sub-carrier spacing (KHz) | 15 | | | | | |
| FFT size | 128 | 256 | 512 | 1024 | 1536 | 2048 |
| Physical Resource Block (PRB) BW (KHz) | 180 | | | | | |
| Number of available PRB | 6 | 15 | 25 | 50 | 75 | 100 |

## LTE Frame Structure

The duration of one frame of LTE signal is of 10ms, each frame consists of 10 sub-frames having duration of 1ms, and each sub-frame is then divided into two time slots of 0.5ms each. Each time slot in the time domain consists of either 7 OFDM symbols for the normal CP or 6 OFDM symbols for the long CP. Each OFDM symbol in the frequency domain consists of 12 consecutive subcarriers. The smallest unit in the LTE transmission frame is one symbol by one subcarrier, which is called a Resource Element (RE) as shown in fig4. 12 adjacent subcarriers of one slot are grouped into a so-called resource block (RB) as shown in fig6. The pilot sub-carriers are equally spaced in frequency domain as pilots symbols are placed on every 6 subcarriers. In the time domain, the pilot symbols are transmitted in first, fourth and fifth OFDM symbol with different pilot subcarrier positions within the slot based on antenna ports configuration. [5]

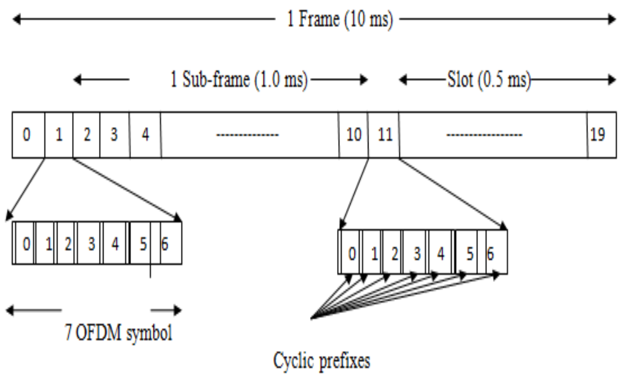


**Figure 4:** LTE Frame Structure

## Channel Estimation

Channel Estimation is basically a process of characterizing the effect of the physical medium on the input sequence. The channel estimate is essential for removing inter symbol interference, noise rejection techniques etc. In the wireless communication systems, excellent channel estimation technology has a directly impact on the decoding performance of the receiver. Therefore, in order to enhance the quality of communication, a channel estimation algorithm is necessary to implement with high performance to mark the QOS standards.

The Channel estimation process is difficult to achieve in LTE due to effects of ISI and ICI. ISI (Inter-symbol interference) means when one symbol interferes with subsequent symbols. ISI is caused due to multipath propagation or due to inherent non-linear frequency response of channel. Multipath propagation means signal from transmitter reaches receiver via many different paths having different path loss components. The cause of it may be reflection, refraction and atmospheric effects. Inter-Carrier Interference (ICI) is due to Doppler shift in OFDM modulator. ICI cause power leakage among subcarriers thus degrades system performance. So, to mitigate ICI and ISI effects, cyclic prefix (CP) is inserted at the beginning of each transmitted OFDM symbol.

The Channel estimation in OFDM based systems is typically done using pilot signals called reference signals (RS) placed intermittently along with data in the time frequency grid. These methods give good performance at the cost of reducing the bandwidth efficiency of the system. There are two main problems in designing channel estimators for wireless OFDM systems. The first problem is how pilot information (data/signal known at the receiver) should be transmitted. This pilot information is needed as a reference for channel estimation. The second problem is the design of an estimator with both low complexity and good channel tracking ability. [5][6]

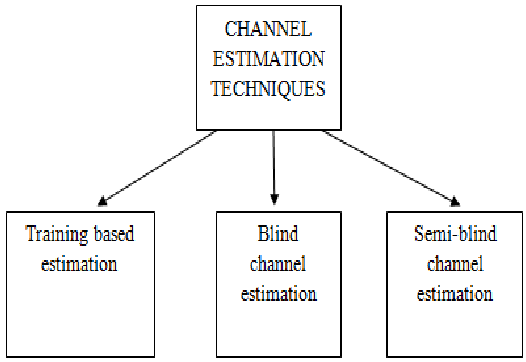


**Figure 5:** Types of Channel Estimation

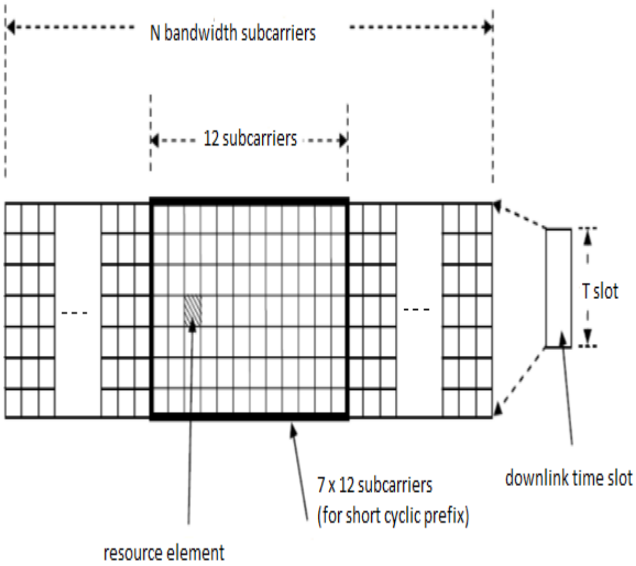


**Figure 6:** LTE downlink Resource Block

The received pilot signals form resource block which can be represented as mathematical expression for computing

$$\overline{Y}_P = \overline{X}_P H_p + \overline{W}_P \tag{3}$$

$(.)_p$ denotes position where reference signal are transmitted.
Pilot signals are of two types:

1. ***Reference signals****:* Reference signals are generated ass a combination of Pseudo Random Numerical (PRN) sequence and orthogonal sequence. These signals are basically used for channel impulse response.
2. ***Synchronization signals****:* These are the signals that are not used for channel estimation. They preferred for cell identification purpose.

Different channel estimation techniques are categorized in fig5.Major description is given with mathematical computations and implemented in Matlab.

### *A. Least square (LS) channel estimation technique*

Least square (LS) is simple and is having low complexity, which does not need relevant channel information. It minimizes square distance between received signal and original signal. It also works very well for high SNR values.

Least square (LS) is given by following equation:

$$\hat{H}_P^{LS} = (\overline{X_P})^{-1}\overline{Y_P} \tag{4}$$

It has large MSE (mean square error) and is easily affected by noise.

***B. Linear mean minimum square error (LMMSE) channel estimation technique***

In LMMSE channel response is estimated with the help of channel statistic information and relevance between subcarriers.

$$H_P^{LMMSE} = R_{HH_P}(R_{H_P H_P} + \sigma_\mu^2(\overline{X_P}\,\overline{X_P^H})^{-1})^{-1}\hat{H}_P^{LS} \quad (5)$$

$R_{HHP}$ is crosscorrelation matrix between all subcarriers and subcarriers with reference signal. $R_{HPHP}$is autocorrelation matrix with reference signal.LMMSE requires knowledge of channel frequency correlation and is complex due to inversion matrix lemma. Every time data changes, inversion are needed. By averaging transmitted data, the simplified LMMSE channel estimator can be written as:

$$\hat{H}_P^{LMMSE} = R_{HH_P}(R_{H_P H_P} + (\beta / SNR)I_P)^{-1}\hat{H}_P^{LS} \quad (6)$$

$\beta$ is scaling factor and $I_P$ is identity matrix. $\beta$ =1 for QPSK and $\beta$ =17/9 for 16 QAM.

***C. Hybrid LS-LMMSE channel estimation technique***

In the case where the cyclic prefix is longer than the channel, the LMMSE estimation technique is better than the LS estimator. The LMMSE estimator offers better performance than the LS estimator for LTE Downlink systems but at the cost of high complexity due to the inversion lemma.

However, in other case; even the cyclic prefix is shorter than the channel length; LMMSE shows also better performances than LS for LTE Downlink systems but only for low SNR values. For high SNR values, LMMSE loses its performance in terms of MSE and in other hand; LS estimator seems to perform better than LMMSE for this range of SNR values.

Therefore, a hybrid LS-LMMSE estimation technique robust to the channel effect is studied. It will act depending on the channel length. In the case where the cyclic prefix is equal to or longer than the channel length, the hybrid LS-LMMSE algorithm will apply directly the LMMSE channel estimation technique.

On other hand, the case where the inserted cyclic prefix is shorter than the channel length, it will act now depending on the received SNR value: when the SNR value is low, the hybrid LS-LMMSE algorithm will choose to apply the LMMSE estimator. However, when the received SNR value is considered high, it will switch to the LS estimator. It is clear that in this case where the channel length exceeds the cyclic prefix length, the hybrid LS-LMMSE channel estimator shows its true efficiency.[13]

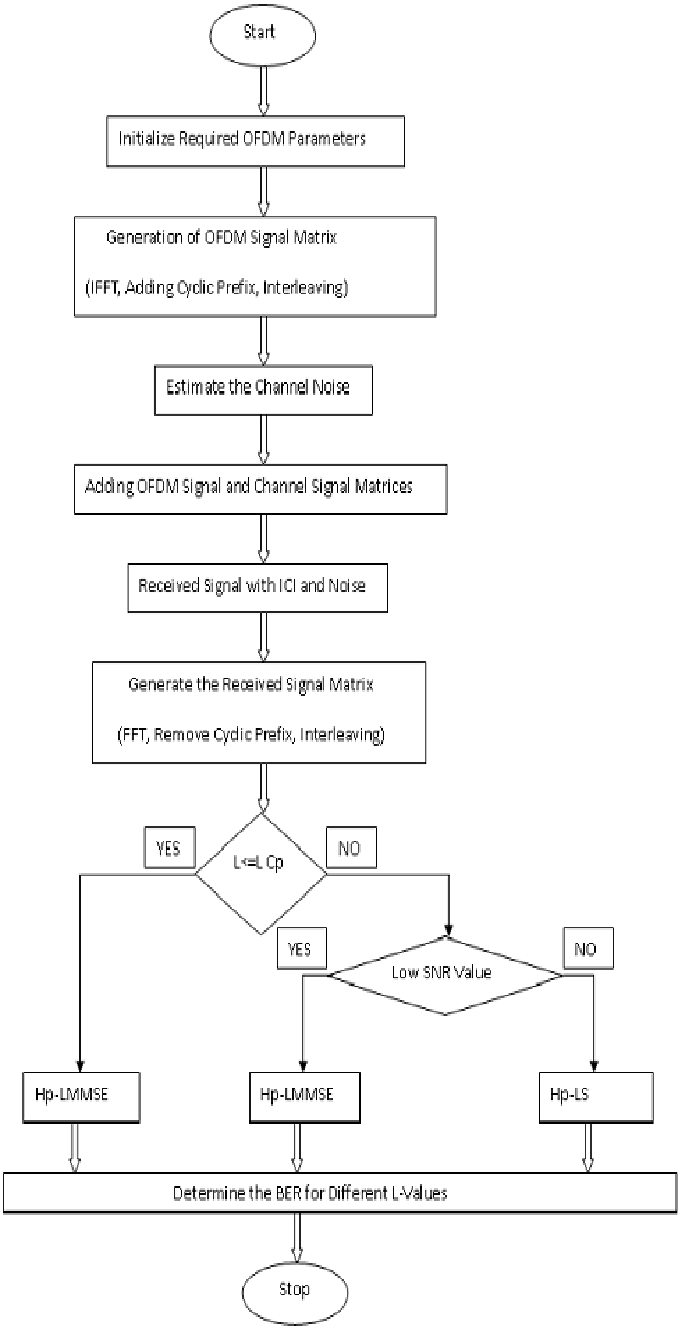


**Figure 7:** Hybrid LS-LMMSE Channel Estimation Algorithm

***D. Hybrid channel estimation technique with ACPL***

This technique enhances performance of LTE downlink system. Because in hybrid channel estimation technique ISI affect still exist. The ACPL algorithm allows transmitter to make CP length to channel length to completely suppress ISI and ICI effect. Thus CP length becomes $L_{CP}$=L+1.

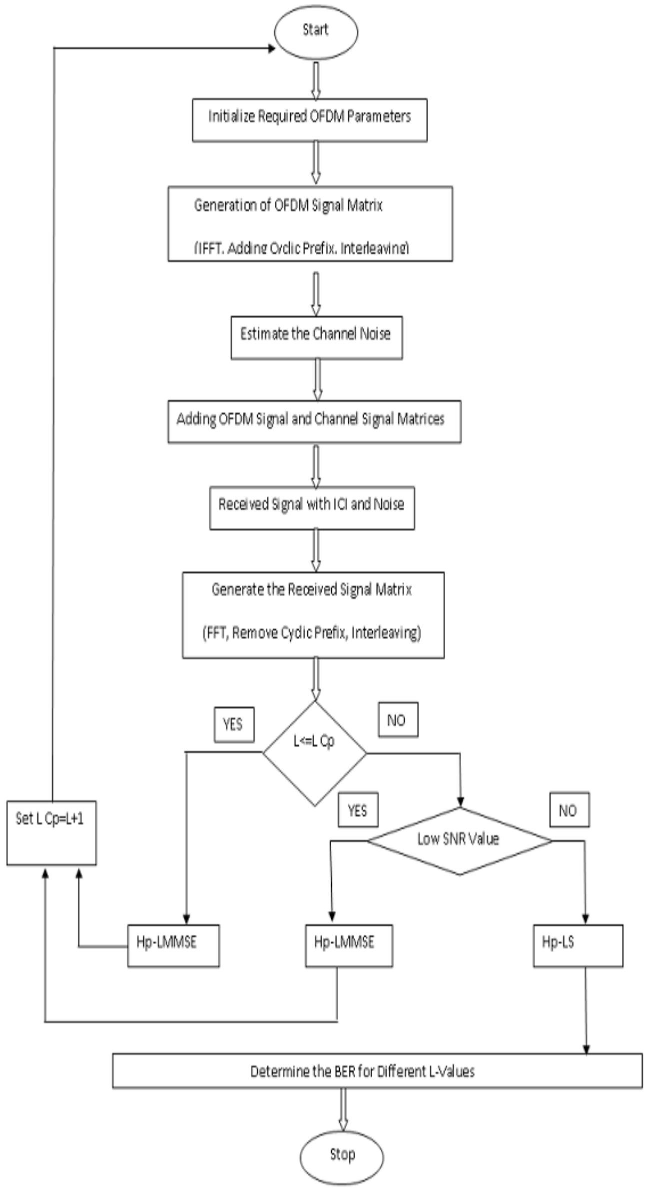


**Figure 8:** Hybrid Estimation Technique with ACPL

### *E. Zero forcing technique*

*Zero Forcing Equalizer* refers to a form of linear equalization algorithm or a technique which is used in communication systems and it applies the inverse of the frequency response of the channel. The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel. It has many useful applications. For example, it is studied heavily for IEEE 802.11n (MIMO) where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero Forcing corresponds to bringing down the intersymbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. Thus, Zero forcing algorithm aims to eliminate the inter symbol interference (ISI) at decision time instants i.e. at the centre of the bit/symbol interval. For 2 x 2 system it's equations will be like following:

The received signal on first receive antenna can be represented as:

$$y_1 = h_{11}x_1 + h_{12}x_2 + n_1 \tag{7}$$

$$y_1 = [h_{11} \quad h_{12}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1$$

The received signal on second receive antenna can be represented as:

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_2 \tag{8}$$

$$y_2 = [h_{21} \quad h_{22}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2$$

Where $y_1$, $y_2$ are received symbol and $n_1$ ,$n_2$ are noise on first and second antenna respectively

$h_{11}$ is channel from first transmitting antenna to first receiving antenna

$h_{12}$ is channel from second transmitting antenna to first receiving antenna

$h_{21}$ is channel from first transmitting antenna to second receiving antenna

$h_{22}$ is channel from second transmitting antenna to first receiving antenna

$x_1$, $x_2$ are transmitted symbol

Thus in matrix notation equation can be represented as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{9}$$

It is equivalent to

y=Hx+n (10)

to solve for x matrix W must be satisfied WH=I

$$W = (H^H H)^{-1} H^H \tag{11}$$

Where, W is equalization matrix and H is channel response

$$H^H H = \begin{bmatrix} h_{11}^* & h_{21}^* \\ h_{12}^* & h_{22}^* \end{bmatrix}\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \tag{12}$$

$$H^H H = \begin{bmatrix} |h_{11}|^2 + |h_{21}|^2 & h_{11}^* h_{12} + h_{21}^* h_{22} \\ h_{12}^* h_{11} + h_{22}^* h_{21} & |h_{12}|^2 + |h_{22}|^2 \end{bmatrix} \tag{13}$$

Thus, ZF nulls out interfering terms. Hence removed Inter symbol Interference.

## Simulation Results

In order to investigate the performance of the proposed hybrid LS-LMMSE estimation technique with ACPL for LTE Downlink systems under the effect of the channel length, simulation studies are conducted. Here, we have considered a LTE-5 MHz Downlink systems having 2 transmit and 2 receive antennas. The number of used subcarriers is set to be 300. The length of cyclic prefix is 16. The transmitted signals are quadrature phase-shift keying (QPSK) modulated.100 LTE radio frames are sent through a frequency-selective channel. The summary of the simulation parameters are shown in Table I. With zero forcing BER get reduced.

**Table 2:** Simulation Parameters

| | |
|---|---|
| LTE Bandwidth | 5 MHz |
| Channel Model | Rayleigh |
| Cyclic prefix length | 16 |
| Number of used subcarriers | 300 |
| Number of transmit antenna | 2 |
| Number of Receive antenna | 2 |
| Modulation scheme | QPSK |
| Number of transmitted Frames | 100 |
| FFT size | 512 |

If channel length is L=20 and L=40 then according to proposed algorithm it will choose either LS or LMMSE technique based on received SNR value. Then it will allow transmitter to adopt CP length; $L_{CP}$= L+1, i.e. for L=20 and L=40, $L_{CP}$ will be 21 and 41 respectively. With proposed zero forcing technique BER performance is enhanced which is been depicted in Fig 9 and Fig 10.

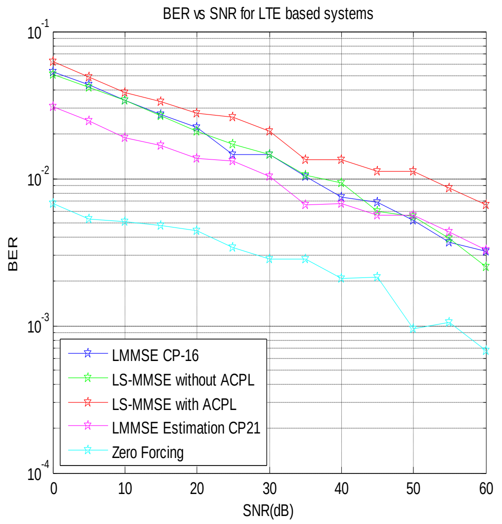


**Figure 9:** BER versus SNR for *L*=20

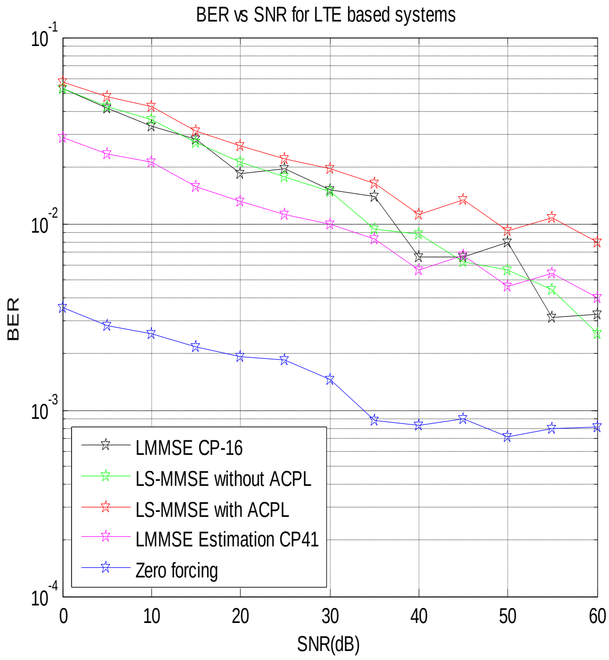


**Figure 10:** BER versus SNR for *L*=40

## Conclusion

In this paper Zero forcing technique is proposed and a hybrid LS-LMMSE channel estimation technique with ACPL for LTE downlink system is analysed. In order to suppress ICI and ISI, cyclic prefix (CP) is inserted at the beginning of each transmitted OFDM symbol. CP length must be equal to or longer than the channel length. However, there may be the case where the CP length can be shorter than the channel length because of some unforeseen behavior of the channel. So, various channel estimation techniques are verified and it is found that LMMSE performs better for low SNR value than LS estimator for insufficient CP but at the cost of the complexity due to its dependence to the channel and noise statistics. In the other case, LS shows better performance for high SNR values. However, hybrid LS-LMMSE estimation resolves all these problems except ISI. Simulations results have shown the efficiency of hybrid LS-LMMSE technique with ACPL which completely suppresses ICI and ISI effect. But for further improvement zero forcing technique is used in this paper which shows that the interfering signals are nulled out completely.

## References

[1] Y. Li, N. Seshadri, and S. Ariyavisitakul, "Channel estimation for OFDM systems with transmitter diversity in mobile wireless channels," IEEE J. Sel. Areas Commun., vol.17, no.3, pp.461–471, March 1999.

[2] D. Wan, B. Han, J. Zhao, X. Gao, and X. You, “Channel estimation algorithms for broadband MIMO OFDM sparse channel,” Proc.14th IEEE Int. Symp. on Personal, Indoor and Mobile Radio Communications, pp.1929–1933, Beijing, China, Sept. 2003.

[3] S. D. Ma and T. S. Ng, “Time domain signal detection based on second-order statistics for MIMOOFDM systems,” IEEE Trans.Signal Process. vol. 55, no. 3, pp. 1150–1158, Mar. 2007.

[4] M. Simko, D. Wu, C. Mehlführer, J. Eilert, D. Liu “Implementation Aspects of Channel Estimation for 3GPP LTE Terminals” in Proc. Proc. European Wireless 2011, Vienna, April, 2011.

[5] A. Khlifi and R. Bouallegue, “Performance Analysis of LS and LMMSE channel estimation techniques for LTE Downlink Systems” International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 5, October 2011.

[6] A. Khlifi and R. Bouallegue, “Hybrid LS-LMMSE channel estimation technique for LTE Downlink Systems” International Journal of Next Generation Networks (IJNGN) Vol. 3, No. 4, December 2011.

[7] Ahmed Hesham Mehana and Aria NosratinialIt, “Performance of MIMO Single-Carrier Frequency Domain Zero-Forcing Equalizer,” IEEE International Symposium on Information Theory Proceedings, pp. 3023-3027, 2012.

[8] SubinWang, Chunjing Hu, Tao Peng and Wenbo Wang ,“ A Low Complexity MMSE Based Channel Estimation Technique for LTE OFDMA Systems,” IEEE 14th International Conference on Communication Technology , pp. 143 – 147, 2012.

[9] A. Omari, R. Bouallegue, R. Hamila, M. Hasna, “Channel Estimation for LTE Uplink System by Perceptron Neural Network” International Journal Of Wireless & Mobile Networks (IJWMN), Vol.2, No.3, August 2014

[10] Earle Shankar, Guruebella, “Adaptive Channel Estimation for SCFDMA System” International Journal of Research and Applications (IJRA), Vol 1 No 3, 2014.