Performance Analysis of a Receiver with New Channel Estimation Technique Using HSPA⁺ Technology

M. Shashidhar, K. Kishan Rao, P. V. D. Somasekhar Rao
Department of ECE, Vaagdevi College of Engineering, Warangal-05, India
Department of ECE, Director, Vaagdevi Group of Colleges, Warangal-05, India
Department of ECE, JNTU College of Engineering, Hyderabad, India

Abstract: Rapid wireless subscriber growth coupled with the necessity to provide desired levels of user experience for broadband multimedia applications has led to the continuous evolution of HSPA technology. Some of the initially developed HSPA⁺ features, such as Higher Level Modulation and MIMO, focused on increasing spectral efficiency by taking advantage of favorable channel conditions when available. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability or diversity. The MIMO capacity theoretically increases linearly with the number of transmit antennas, provided that the number of receive antennas is equal to the number of transmit antennas. Estimating the MIMO channel for a high number of transmit and receive antennas becomes extremely challenging, since it is to estimate $N_T \cdot N_R$ channels, although in reality it is only interested in the data symbols, but not the channel. This paper aims at the investigation of the existing channel estimation techniques compared with proposed estimation technique i.e Advance Minimum Mean Square Estimation. After estimation research is done on receiver section based on MIMO-IDMA (Inter Division Multiple Access)technique.

Keywords: Multiple Input Multiple Output(MIMO), Interleave Division Multiple Access (IDMA), HSPA⁺

1. INTRODUCTION

The wireless communication environment is very hostile. The signal transmitted over a wireless communication link is susceptible to fading (severe fluctuations in signal level), co-channel interference, dispersion effects in time and frequency, path loss effect, etc[29]. The limited availability of bandwidth poses a significant challenge to a designer in designing a system that provides higher spectral efficiency and higher quality of link availability at low cost.

In communication systems are broadly categorized into four categories with respect to number of antennas in the transmitter and the receiver, as listed below.

1. SISO – Single Input Single Output system – 1 Tx antenna, 1 Rx antenna
2. SIMO – Single Input Multiple Output system – 1 Tx antenna, $N_R$ Rx antennas ($N_R>1$)
3. MISO – Multiple Input Single Output system – $N_T$ Tx antennas, 1 Rx antenna ($N_T>1$)
4. MIMO – Multiple Input Multiple Output system – $N_T$ Tx antennas, $N_R$ Rx antennas ($N_T,N_R>1$)

The research work is carried out on 3GPP HSPA⁺(High speed packet access +)-technology Release 7 of wireless communication over physical layer . To meet the demand for higher data rates and better coverage of wireless networks without increasing bandwidth or acquiring expensive frequency bands, an emerging technology called multiple input multiple output (MIMO) has appeared. MIMO is capable of significantly increasing wireless data throughput to achieve high data rates[28].The MIMO system block diagram is shown in the Figure 2.8 with an array of $N_T$ transmitting antennas.

![Figure 1. MIMO architecture](image)

The transmitted symbol matrix is Column matrix ‘X’ with the order of $N_T \times 1$, where $x_i$ is the $i^{th}$ symbol transmitted from antenna ‘i’. In general the relation between transmitted and received symbols is

$$Y =HX+V$$

Where $Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{N_R} \end{bmatrix}$ and $H = \begin{bmatrix} \end{bmatrix}$
Apart from the antenna configurations, there are two flavors of MIMO with respect to how data is transmitted across the given channel. Existence of multiple antennas in a system means existence of different propagation paths. Aiming at improving the reliability of the system, we may choose to send same data across the different propagation (spatial) paths. This is called spatial diversity. Aiming at improving the data rate of the system, we may choose to place different portions of the data on different propagation paths (spatial multiplexing). These two systems are listed below.

1. MIMO – implemented using diversity techniques – provides diversity gain – Aimed at improving the reliability
2. MIMO-implemented using spatial-multiplexing techniques – provides degrees of freedom or multiplexing gain – Aimed at improving the data rate of the system

Channel estimation is an imperative technique especially in wireless systems. In wireless communication channel changes over time, usually caused by transmitter and/or receiver being in motion. Due to this channel is adversely affected by the multipath interference resulting from reflections from surroundings, such as hills, buildings and other obstacles.

In order to provide reliability and high data rates at the receiver, the system needs an accurate estimate of the time-varying channel. Furthermore, wireless systems are one of the main technologies which used to provide services such as data communication, voice, and video with Quality of Service (QoS) for users. The knowledge of the impulse response of mobile wireless propagation channels in the estimator is an aid in acquiring important information for testing, designing or planning wireless communication systems.

The channel estimation is based on the training sequence of bits and which is unique for a certain transmitter and which is repeated in every transmitted burst. The channel estimator gives the knowledge on the channel impulse response (CIR) to the detector and it estimates separately the CIR for each burst by exploiting transmitted bits and corresponding received bits. Signal detectors must have knowledge concerning the channel impulse response (CIR) of the radio link with known transmitted sequences, which can be done by a separate channel estimator. The modulated corrupted signal from the channel has to be undergoing the channel estimation using Least Square (LS), Minimum Mean Square Error (MMSE) which are existing techniques to reduce the error to further extent new technique is proposed (i.e.) Advanced Minimum Mean Square Estimation (AMMSE) before the demodulation takes place at the receiver side this is in section I.

In section II different types of estimation techniques are compared with new proposed technique. In section III describes performance of receiver based IDMA technique implemented with 2x2 MIMO system.

II-DIFFERENT TYPES OF CHANNEL ESTIMATION TECHNIQUES

i) LEAST SQUARE ESTIMATION:
When the parameters appear linearly in these expressions then the least squares estimation problem can be solved in closed form. It is relatively straightforward to derive the statistical properties for the resulting parameter estimates. It is supposed that $x$ is an independent (or predictor) variable which is known exactly, while $y$ is a dependent (or response) variable.

Least square estimation technique is used for ideal channel conditions. If $H_{LS}$ is a channel vector with least square and noise is not considered in this estimation. If noise is dominant this technique will not be applicable.

Consider the equation

$$Y = HX + V$$  \hspace{1cm} (1)

Where $Y$ is Received Vector

$X$ is Transmitted Vector

$V$ is Noise Vector

$H_{LS}$ or $H$ channel vector with least square

Error vector is $Y - H_{LS}X$

By taking magnitude of error vector

$J(H_{LS}) = \| Y - H_{LS}X \|^2$

For reduction of complexity of matrix magnitude is calculated. To get $J(H_{LS})$ as minimum differentiate $J(H_{LS})$ with respect to $H_{LS}$ and equating to 0.

$$\frac{d(J(H_{LS}))}{d(H_{LS})} = 0$$

$$= (Y - XH_{LS})^H(Y - H_{LS}X)$$

$$= Y^HY - Y^HXH_{LS} - H_{LS}^HX^HY + H_{LS}^HX^HXH_{LS}$$

$$H_{LS} = (X^HX)^{-1}X^HY$$  \hspace{1cm} (2)
ii) **MINIMUM MEAN SQUARE ERROR ESTIMATION:**

In Minimum Mean Square Error Estimation noise is considered, if noise is dominant $H_{LS}$ will give poor performance.

To improve we are calculating error as follows. Choose a weight vector and multiply it with $H_{LS}$ assumes it as $H_{MMSE}$.

![Diagram](image)

To obtain error to be minimum i.e., we are choosing $\omega$ in such a way that error $e$ and $H_{LS}$ as orthogonal.

\[
E[e_{MMSE}^H]=0
\]

\[
E[(H-H_{MMSE})H_{LS}]=0
\]

\[
E[H_{LS}H_{LS}^H]=0
\]

\[
E[H_{LS}H_{LS}]=0
\]

\[
R_{HLS} = \omega R_{HLS}H_{LS}^H
\]

\[
R_{HLS} = \omega R_{HLS}H_{LS}^H
\]

\[
\omega = \frac{R_{HLS}H_{LS}^H}{R_{HLS}H_{LS}^H}
\]

\[
H_{MMSE} = H + ZX
\]

\[
R_{HLS}H_{LS}^H = E[H_{LS}H_{LS}^H]
\]

\[
E[H_{LS}H_{LS}^H] = E[(H+X^{-1}Y)(H+X^{-1}Y)^H]
\]

\[
= E[H^H+X^{-1}Z(H+X^{-1}Y)^H]
\]

\[
= E[H^H] + E[X^{-1}Z(H+X^{-1}Y)^H]
\]

\[
= R_{HLS} + \frac{\sigma_x^2}{\sigma_x^2}I
\]

\[
H_{MMSE} = \omega H_{LS}
\]

iii) **PROPOSED ADVANCED MINIMUM MEAN SQUARE ESTIMATION (AMMSE):**

A new Technique is proposed by name Advanced Minimum Mean Square Estimation to minimize the error still more in comparison with Minimum Mean Square Error estimation if noise is more dominating.

**STEP1:**

Consider

\[
Y = HX + V
\]

Where $Y$ is received signal

\[
H \text{ is Channel matrix} \\
X \text{ is Transmitted signal} \\
V \text{ is Noise signal}
\]

The conditional probability density of Y given H, X is

\[
f_Y(Y|H,X) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{1}{2\sigma^2}|Y - HX|^2\right)
\]

Where $\sigma$ is Variance

**STEP2:**

If the transmitted symbols $\{X_t\}_{t=1}^C$ with the probability of $1/C$ then conditional probability density function of Y given H is

\[
f_Y(Y|H) = \sum_{t=1}^C \frac{1}{C} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{1}{2\sigma^2}|Y - HX|^2\right)
\]

Let $Y = [y^1, y^2, ..., y^D]^T, X = [x^1, x^2, ..., x^D]^T$

D is number of symbols

Y is called incomplete data since the transmit data is hidden. Meanwhile $(Y, X)$ Is called complete data because in-out both are present. Since it is difficult to estimate with incomplete data.

The probability density function of incomplete data is converted into probability density function of complete data

**STEP3:**

The probability density function of incomplete data is

\[
f_Y(Y, H) = \prod_{d=1}^D f(Y_d|H, X_d)
\]

Applying log likely hood function as

\[
\log f(Y, H) = \sum_{d=1}^D \log f(Y_d|H, X_d)
\]

The probability density function of complete data is

\[
\log f((Y, X) = \sum_{d=1}^D \log f(Y_d|H, X_d))
\]

**STEP4:**

**MEAN IDENTIFICATION:**

Expected value of the log likelihood function of $H$ is computed by taking exception over $X$' condition on $Y$ using latest estimate of H as follows

Complete data

\[
Q(H|^{(p)}) = E_{X|Y,H^{(p)}}[\log f(Y|X,H)]
\]

= $\sum_{t=1}^C \log f(Y|X,H^{(p)}) . f(X_t|Y,H^{(p)})$

We know that

\[
\log f(Y|X,H) = \sum_{d=1}^D \log f(Y_d|H, X_d)
\]
\[ f(X_i | Y, H^{(p)}) = \frac{f(X_i, Y^d | H, H^{(p)})}{f(Y^d | H^{(p)})} \]  

(12)

Since \( P(A|B,C) = P(A,B|C)/(P(B|C)) \)

\[ \Rightarrow \sum_{l=1}^{C} \sum_{d=1}^{D} \log \left( \frac{1}{C} f(Y^d | H, X_l) \right) \cdot \frac{f(X_l, Y^d | H, H^{(p)})}{f(Y^d | H^{(p)})} \]

\[ \Rightarrow \sum_{l=1}^{C} \sum_{d=1}^{D} \log \left( \frac{1}{C} f(Y^d | H, X_l) \right) \cdot \frac{f(Y^d, H^{(p)}, X_l)}{f(Y^d | H^{(p)})} \]

\[ \log f(Y, X | H) = \sum_{l=1}^{C} \sum_{d=1}^{D} \log \left( \frac{1}{C} f(Y^d | H, X_l) \right) \cdot \frac{f(Y^d, H^{(p)}, X_l)}{f(Y^d | H^{(p)})} \]  

(13)

Where \( H^{(p)} \) denotes latest estimate of \( H \)

Step 5:

**DIFFERENTIATION IDENTIFICATION:**

\( H^{(p+1)} \) is determined taking the equation \( \log f(Y, X | H) = \sum_{l=1}^{C} \sum_{d=1}^{D} \log \left( \frac{1}{C} f(Y^d | H, X_l) \right) \cdot \frac{f(Y^d, H^{(p)}, X_l)}{f(Y^d | H^{(p)})} \) over all possible values of \( H \) and differentiating this equation with respect to \( H \) and setting its derivative to zero.

\[ H^{(p+1)} = \arg \max_{H} Q(H | H^P) \]

\[ H^{(p+1)} = \left[ \sum_{l=1}^{C} \sum_{d=1}^{D} |X_l|^2 \frac{f(Y^d, H^{(p)}, X_l)}{f(Y^d | H^{(p)})} \right]^{-1} \cdot \left[ \sum_{l=1}^{C} \sum_{d=1}^{D} |Y^d, X_l|^2 \frac{f(Y^d, H^{(p)}, X_l)}{f(Y^d | H^{(p)})} \right] \]  

(14)

By this error will be minimized

The following parameters are considered for simulation

**TABLE 1**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE transmitting power (4UE)</td>
<td>27 dBm</td>
</tr>
<tr>
<td>Number of Transmit antennas</td>
<td>02</td>
</tr>
<tr>
<td>Number Receive antennas</td>
<td>02</td>
</tr>
<tr>
<td>Transmission Time Interval</td>
<td>2ms</td>
</tr>
<tr>
<td>System BW</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Length of data stream</td>
<td>1024 bits per frame</td>
</tr>
<tr>
<td>Number of Training symbols in SBCE (Nz)</td>
<td>8 symbols per frame</td>
</tr>
<tr>
<td>Number of Training symbols in TBCE (Nz)</td>
<td>24 symbols per frame</td>
</tr>
<tr>
<td>Modulation scheme used</td>
<td>BPSK, QPSK and QAM</td>
</tr>
<tr>
<td>Channel model</td>
<td>Rayleigh fading and AWGN</td>
</tr>
<tr>
<td>Frequency</td>
<td>2100MHz</td>
</tr>
<tr>
<td>Bit rate</td>
<td>11500-21000 kbps</td>
</tr>
<tr>
<td>Thermal noise</td>
<td>-108.09 dbm</td>
</tr>
<tr>
<td>Noise figure</td>
<td>6 db</td>
</tr>
<tr>
<td>Noise power</td>
<td>-102.09 dbm</td>
</tr>
<tr>
<td>Interference margin</td>
<td>3.01 db</td>
</tr>
<tr>
<td>Total interference level</td>
<td>-99.05 dbm</td>
</tr>
<tr>
<td>Mobility</td>
<td>1 km</td>
</tr>
<tr>
<td>Transmitted power</td>
<td>27.8 dBm</td>
</tr>
</tbody>
</table>

In SISO-MMSE technique at SNR=18 dB, BER is \( 6 \times 10^{-3} \) and SISO-proposed AMMSE technique at SNR=18dB, BER is \( 2.5 \times 10^{-3} \). The performance of SISO proposed AMMSE efficiency is increased by 42% comparing with SISO-MMSE

In MIMO-MMSE technique at SNR=18dB, BER is \( 9 \times 10^{-4} \) and \( 5 \times 10^{-4} \) at SNR =18dB for MIMO-proposed AMMSE
The performance of MIMO-proposed AMMSE efficiency is increased by 55% comparing with MIMO-MMSE.

III. IDMA TRANSMITTER RECEIVER MIMO-STRUCTURE

![MIMO IDMA Transmitter Receiver Structure](image)

Figure 3 MIMO IDMA TRANSMITTER RECEIVER STRUCTURE

Figure 3 shows transmitter and (iterative) receiver structures based on these principles, interleaving is the only mechanism for user separation here, it is referred to as Interleave Division Multiple Access (IDMA). The upper part shows the transmitter structure of an IDMA system with K simultaneous users. The input data sequence $d_k$ of user-k is encoded based on a low-rate code $C[84]$. The coded sequence is then interleaved by a chip-level interleaver-k, producing $\{x_k, x_k(1), ..., x_k(j), ..., x_k(J)\}$. The key principle of IDMA is that the interleavers $\{\pi_k\}$ should be different for different users. It is assumed that the interleavers are generated independently and randomly. These interleavers disperse the coded sequences so that the adjacent chips are approximately which facilitates the simple chip-by-chip detection scheme. Assume quasi-static single-path channels. After chip matched filtering, the received signal from K users can be written as

$$r(j) = \sum_{k=1}^{K} x_k h_k(j) + n(j) \quad j=1,2,\ldots, (15)$$

where $h_k$ is the channel coefficient for user-k and $\{n(j)\}$ are samples of an AWGN with variance $\sigma^2 = N_0/2$. Here the channel coefficients $\{h_k\}$ are known a priori at the receiver side.

Receiver Structure:

This received signal is passed to a multi-user detection (MUD) receiver that consists of an elementary signal estimator (ESE) and K a posteriori probability (APP) decoders (DECs), one for each user. The ESE performs chip-by-chip detection to roughly remove the interference among users[85]. The outputs of the ESE and DECs are extrinsic log-likelihood ratios (LLRs) about $\{x_k\}$ defined as

$$e(x_k(j)) = \log \left[ \frac{p(y | x_k(j) = +1)}{p(y | x_k(j) = -1)} \right]$$

(16)

Those LLRs are further distinguished by $e_{ESE}(x_k(j))$ and $e_{DEC}(x_k(j))$ depending on whether they are generated by the ESE or DECs. In the ESE section, $y$ in (26) denotes the received channel output while for the DECs, $y$ in (26) is formed by the deinterleaved version of the output of the ESE block.

$$e_{ESE}(x_k(j)) = \log \left( \frac{p(r(j) | x_k(j) = +1, h_k)}{p(r(j) | x_k(j) = -1, h_k)} \right)$$

(17)

Where $e_{ESE}(x_k(j))$ of each user is estimated depending on channel coefficients $\{h_k\}$ of each user

$$e_{DEC}(x_k(j)) = \log \left[ \frac{p(e | ESBX_k(j) = +1, c)}{p(e | ESBX_k(j) = -1, c)} \right]$$

(18)

Where $e_{ESE}$ is de repeater data of the de interleaved version of the output from the ESE block and $c$ is the code constraint by convolution code. These results are then combined using a turbo-type iterative process for a pre-defined number of iterations. Finally the DECs produce hard decisions on information bits for each user, received channel output while for the DECs, $y$ in (28) is formed by the de interleaved version of the outputs of the ESE block.

EXISTING ALGORITHM

- Step 1: First of all set $e_{DEC}(x_k(j)) = 0$ for all k, j It is a initial guess
- Step 2: Estimation of Mean and Variance of the transmitted signal $x_k$
- Step 3: Estimation of Mean and Variance of the received signal

PROPOSED ALGORITHM

- Step 1, First of all set $e_{DEC}(x_k(j)) = 0$ for all k, j It is a initial guess
- Step 2: Estimation of Mean and Variance of the transmitted signal through log likelihood based on proposed Advanced Minimum Mean Square Estimation (AMMSE):
  \[ E[x_k(j)] = \text{tanh} \left( e_{DEC}(x_k(j))/2 \right) \] for all k, j
  \[ \text{Variance} = 1 - E[x_k(j)]^2 \] for all k, j
- Step 3: Estimation of Mean and Variance of the received signal
  \[ E[r(j)] = \sum h_k E[x_k(j)] \] for j

510
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Variance = \sum|h_k|^2 \text{Var}(x_k(j)) + \sigma^2 \quad \text{for all } k, j

Step 4: Generation of LLR(Log Likelihood Ratio)
\( E_{BSE}(x_k(j)) = 2h_k r(j) - E[r(j)] + h_k E[x_k(j)] / [\text{Var}(r(j)) - |h_k|^2 \text{Var}(x_k(j))] \)

Figure 4 Comparison of Existed IDMA and Proposed MIMO-IDMA

From the Figure 4 Proposed MIMO-IDMA technique the is BER = 7x10^{-9} at SNR=18dB, whereas Existed MIMO-IDMA technique the is BER=8x10^{-9}. The efficiency of proposed MIMO-IDMA is 87% much better than existed MIMO-IDMA.

the efficiency is increased by 77% which is better. In MIMO-IDMA receiver at SNR=18dB the BER is 4x10^{-9} when it is compared with MIMO-QR-OSIC receiver based on proposed method the BER is 7x10^{-9}. So the efficiency is increased by 57%.

Conclusions:
A new estimation technique is proposed by name Advance Minimum Mean Square Error(AMMSE) its performance is better than LS & MMSE. MIMO receiver is implemented with IDMA technology compared with existing and proposed algorithm which is implemented by using log likelihood method and AMMSE technique. The proposed method performance of MIMO-IDMA is much better than existing.

REFERENCES