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Efficient SINR Computation Using LMMSE Approach in MIMO-OFDM System

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Abstract:
In this paper, we design a communication system with transmitted symbols under flat fading channel and estimate the channel by Least Square (LS) approach and Linear Minimum mean Square Error (LMMSE) approach for channel coefficients. We analyze the link-to-system interface for MIMO-OFDM system level simulations and propose an efficient method for calculation of the effective SINR. The accuracy of the proposed effective SINR is evaluated by simulated BLER performance comparison. In this paper, Efficient SINR computation using LMMSE approach, reduction in the BLER is obtained with reduced computational complexity.
Keywords: BLER, LMMSE, LS, MIMO-OFDM, SINR.

I. INTRODUCTION

In future communication systems, high-speed data transmission with low latency is a key characteristic under different UE movement situations. Orthogonal Frequency Division Multiplexing (OFDM) is being considered as a modulation and multiple access method for 4^{th} generation wireless networks due to its good spectrum efficiency and tolerance of inter-symbol interference (ISI).

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation scheme in which the wide transmission spectrum is divided into narrower bands and data is transmitted in parallel on these narrow bands. With the possible data rates, the transmission bandwidth of OFDM systems is also large. With the latest OFDM applications it is necessary to utilize Multi Input Multi Output (MIMO) technology in order to achieve a significant increase in spectral efficiency. MIMO OFDM based cellular systems are currently standardized by 3GPP for UTRAN LTE and by IEEE for WiMAX.

In order to understand multi-cell MIMO-OFDM system deployments the system level simulator should be used in evaluating the network performance. Due to the complexity reasons, a single simulator that would model entire wireless communication system with all functionality is not feasible. Thus, a two level architecture consisting of a link level simulator and a system level simulator has been adopted for analyzing, testing and evaluating future wireless network behavior. The link level simulator estimates the quality of a specific link between transmitter and receiver under different channel propagation conditions. The system level simulator is used to evaluate the performance of the whole network in terms of capacity and coverage. The mapping method to interconnect the two simulators is essential and has to be defined carefully. Previously, Average Value Interface and Actual Value Interface [1] have usually been used. Due to both inaccuracy and complexity, probably they are not effective in OFDM evaluation. Furthermore, the traditional L2S methods assume fixed channel in order to provide a simple but accurate link performance prediction model. The target of such prediction model is to transfer the receiver performance accurately from the link level to the system level.

The Signal to Interference plus Noise Ratio (SINR) is broadly defined as the ratio of the desired Signal power to the Interference plus Noise power and has been accepted as a standard measure of signal quality for communication systems. In recent 3GPP contributions and standardization, several link to system (L2S) mapping methods have been proposed, which can be effectively used to OFDM systems by using effective SINR concept.

In this paper we estimate the channel by LS and LMMSE methods for channel quality. We consider the method with least Symbol Error Rate (SER) and compute Effective SINR with reduced computational complexity and mapped to the BLER performance in System level simulator.

II. CHANNEL ESTIMATION

2.1 Least Square Channel Estimation

In order to estimate the channel, LTE systems use pilot signals called reference signals.
The received pilot signals can be written as:

$$Y_P = X_P H_P + N_P \tag{1}$$

The goal of the channel least square estimation is to minimize the square distance between the received signal and the original signal.

The Least Square (LS) estimates of the channel at the pilot subcarriers given in (1) can be obtained by the following equation

$$\hat{H}_P^{LS} = (X_P)^{-1} Y_P \quad (2)$$

$\hat{H}_P^{LS}$ represents the LS estimate obtained over the pilot subcarriers

2.2 LMMSE Channel Estimation

The Channel estimation [2] can be done by combination of frequency domain channel response and time domain channel response.

We can write the channel estimation $H_{tr}(k)$ problem mathematically by the equation given below.

$$H_{tr}(k) = \sum_{t=0}^{T} \sum_{r=0}^{R} \sum_{p}^{P-1} h_{tr}(p) e^{-j\left(\frac{2\pi kp}{K}\right)} \quad (3)$$

Where
K - Total number of users
N - Total number of subcarriers
T - Total number of transmitting antennas
R - Total number of receiving antennas
P - Total number of paths in the channel
$h_{tr}(p)$ - Time domain channel response

Frequency domain channel response $H_{tr}(k)$ can be obtained for k^{th} user of t^{th} transmitting antenna and r^{th} receiving antenna by evaluating time domain channel response $h_{tr}(p)$

The steps involved in LMMSE channel estimation algorithm is given below.

1: Input bits in the time domain is given to the OFDM transceiver.

2: Modulation mode is defined & serial data is converted into parallel data.

3: Pilot mode is defined i.e. Block type pilot.

4: Inverse Fast Fourier Transform (IFFT) takes place.

$$X(n) = IFFT\{X(K)\} \quad n=0,1\ldots K-1 \quad (4)$$

5: Guard intervals are introduced to eliminate Inter Symbol Interference (ISI).

$$X_f(n) = \begin{cases} X(N+n), n=N_g \, to N_g+1 \\ X(n), n=0,1,\ldots N-1 \end{cases} \quad (5)$$

Where N_g is the number of guard intervals and Parallel data is converted into serial data.

6: Multipath flat fading channel is chosen where all frequency components of the signal will experience the same magnitude of fading.

$$y_f = x_f(n) \otimes h(n) + w(n) \quad (6)$$

7: Guard intervals are removed.

$$y(n) = y_f(n) \quad n=0,1,\ldots,N-1 \quad (7)$$

8: Fast Fourier Transformation (FFT) takes place.

$$Y(K) = FFT\{y(n)\} \quad k=0,1,\ldots,K-1 \quad (8)$$

The output Y(K) can be expressed as

$$Y(K) = X(K)H(K) + I(K) + W(K) \quad (9)$$

Where *H(K)* refers to channel, *I(K)* refers to ICI (Inter Carrier Interference) and *W(K)* refers to AWGN (Additive White Gaussian Noise).

9: Channel estimation is done using Linear Minimum Mean Square Error (LMMSE) estimator.

$$X_e(K) = \frac{Y(K)}{H_e(K)} k = 0,1,\ldots, K-1 \quad (10)$$

Where $X_e(K)$ refers to the estimated output and $H_e(K)$ refers to the estimated channel.

III. LINK-TO-SYSTEM INTERFACE MODEL

The concept of Link-to-System Interface model used for system level performance evaluation is presented in Fig 1. The effective SINR mapping approach maps the instantaneous channel state characterized by K quality measures of time, frequency and/or space resource elements into an instantaneous effective channel quality measure. Afterwards, effective channel quality measure is mapped to the performance metric, such as Block Error Rate (BLER), via AWGN performance curves obtained from the link level simulations.

In every Transmission Time Interval (TTI) packet transmission depending on the radio conditions is evaluated whether UE receives packet successfully or not. Evaluation process is executed through the following steps. First, each time instance post-processed SINR value γ_k is calculated for each sub-carrier C.

$$\gamma_k = \frac{P_{Signal}}{P_{Self\_Interference} + P_{noise+outofcell\_interference}} \quad (11)$$

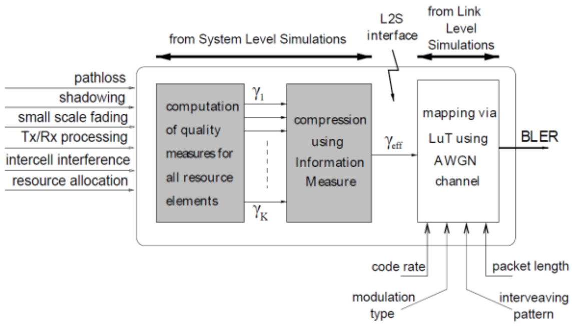

Figure 1: Link-to-System Interface model

According to the number of available transmit antennas and the selected receiver type, the SINR value after post processing γ_k is calculated for each sub-carrier based on *K* (*K=10C*) SINR values and used MCS. The specified L2S mapping method is applied to provide the effective SINR value:

$$\gamma_{eff} = f_{L2S}(\gamma_1, \ldots \gamma_K, MCS) \quad (12)$$

Afterwards the BLER is obtained for this transmission via mapping table *f* constructed for AWGN channel on the link level [3].

$$BLER = f(\gamma_{eff}, MCS) \quad (13)$$

The effective SINR value in (12) is calculated as a compression from a set of quality measures of resource elements (in OFDMA transmission quality measures are instantaneous sub-carrier SINR samples) as,

$$\gamma_{eff} = \alpha_1 I^{-1}\left(\frac{1}{K}\sum_{k=1}^{K} I\left(\frac{\gamma_k}{\alpha_2}\right)\right) \quad (14)$$

Where function $I(.)$ is referred to "Information measure" or compression function, and $I^{-1}(.)$ is its inverse. The scaling parameters α_1 and α_2 are needed to match the model to related MCS and channel bandwidth.

Each L2S interface mapping method uses own specific compression function: MIESM uses mutual information and EESM uses exponential function. The exponential "information measure" function with single scaling parameter $\beta = \alpha_1 = \alpha_2$ is defined as

$$I(\gamma) = A - Be^{-\frac{\gamma}{\beta}} \quad (15)$$

Providing Effective SINR as,

$$\gamma_{eff} = -\beta \ln\left(\frac{1}{K}\sum_{k=1}^{K} e^{-\frac{\gamma_k}{\beta}}\right) \quad (16)$$

The general principle of mapping is defined using information measure function I as follows

$$\gamma_{eff} = \alpha_1 I^{-1}\left(\frac{1}{K}\sum_{i=1}^{K} I\left(\frac{\gamma_i}{\alpha_2}\right)\right) \quad (17)$$

For a given instantaneous channel state $\{\gamma_1, \ldots \gamma_K\}$ and effective quality measure γ_{eff} . Here, $\{\gamma_1, \ldots \gamma_K\}$ are the post-processed SINR values received within a coded transport block. The scalars α_1 and α_2 are adjusted using least square fitting between the estimated BLER, BLER ($\gamma_{eff}, \alpha_1, \alpha_2$), and simulated BLER on the link level for each modulation and coding scheme (MCS).

IV. SIMULATION METHODOLOGY

Table 1. Simulation parameters

Parameter description	Parameter value
Scenario/Network	57 cells(500 m ISD), sync. DL, FDD, Reuse 1
Simulation time	3M steps(about 214sec), 1ms step
Total number of UEs	210
UE velocity	3 km/h
Channel model	Modified ITU Vehicular A, 20 dB Ploss
Receivers (N_{tx} = 2, N_{rx} = 2)	LMMSE(dual stream transmission) IRC (single stream transmission)
MCSs(β) CQIs	16QAM 4/5 (6.9977) 5ms measurement period, 2ms report delay, 1dB error variance, 1dB quantization step, 2 resource blocks per CQI
Packet scheduling	Maximum Throughput TD Maximum Throughput FD max 5 scheduled users
Hybrid ARQ	Async. Chase Comb., max 1 retransmission

The performance of the proposed L2S interface model is evaluated by means of system level simulator based on the 3GPP LTE downlink technology described in [4]. All the simulations are performed in a three tier diamond-pattern macro cell scenario with 19 sites of 3 sectors. Uniformly distributed within 21 cells in the middle (inside tiers 1-2) with a constant speed but can make random turns. The 36 cells at the edge of the scenario produce the interference at the same level as the average load in the center cells. The exact macro cell mobility model is described in [5]. The simulations were run using 3GPP Case 1 parameters [4]. The simulation parameters in this study are summarized in detail in Table 1.

The Simulation results from Fig 3 show that LMMSE approach for channel estimation reduces symbol error rate when compared to the LS approach. From Fig 4, the BLER performance curves for 16QAM modulation with different β values (coding scheme) from the effective SINR obtained from Link level simulation, it can be observed that as the β value Increases from B=4.78, 6.38, 6.99, the BLER performance becomes better.

V. SIMULATION RESULTS

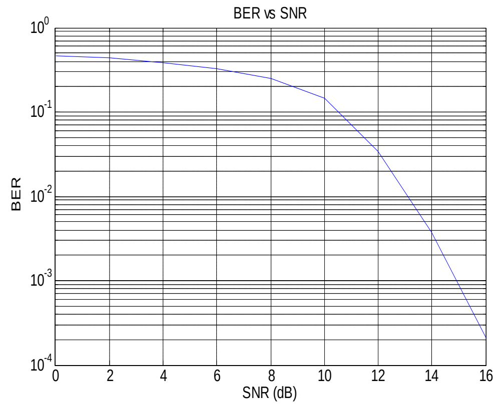

Figure 2: BER performance for 16QAM modulation

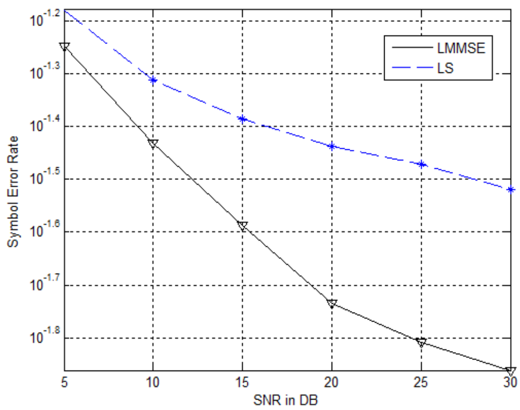

Figure 3: SER for LS and LMMSE approach

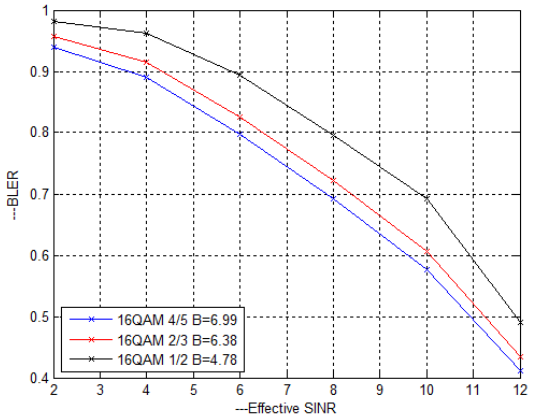

Figure 4: BLER performance curves for 16QAM modulation.

VI. CONCLUSION

In this paper the channel estimation is done by using LS and LMMSE approach. From the simulation results it could be concluded that LMMSE channel estimation provides better Symbol Error Rate compared to LS channel estimation. The performance of L2S interface model is evaluated using both analytical tools and system level simulations. Reduced BLER is obtained from System level simulations for 16QAM modulation with better β value with reduced computational complexity.

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