OFDM 시스템에서 전송방법에 있어 Exponential Effective SINR Mapping 방법과 기존방법과의 성능비교

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Performance Comparison of Exponential Effective SINR Mapping with Traditional Actual Value Interface for Different Transmission Schemes in OFDM Systems.

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Abstract - In this paper we compare performance of exponential effective SINR mapping (EESM) with traditional actual value interface (AVI) approach for various modulation and coding schemes (MCS) in terms of coded bit error rate (BER) or block error rate (BLER) using different transmission schemes. This paper provides explanation and comparison of the two algorithms for single input single output (SISO), and single input multi-output (SIMO,1X2) in OFDM systems. We calibrate the value of beta (β) in EESM using large number of channel realizations, here β is a calibration constant. This paper also presents importance of beta value in EESM and how it improves the performance of OFDM wireless systems. We propose different modulation and coding schemes. Here we consider Standford university interim (SUI) channel models. Furthermore this paper also shows the detail observation of the two algorithms. Finally the conclusion review given for short summary.
Keywords: EESM, AVI, OFDM, SUI, BER, BLER, SISO, SIMO

1. INTRODUCTION

A demand high speed broadband data transmissions for mobile wireless access and for nomadic is the task of the future mobile communication systems. But for all these fastest systems it is needed a system which works well in different channel environment. So for all these goals different technique using OFDM, OFDMA, MIMO, TDMA etc are using.

In AWGN static channel the link performance of a coded digital communication is characterize by the block error rate versus the SNR, but it is sufficient in the case of when SNR value remains constant during each coded block. In wireless mobile communication system the SNR value doesn't hold constant during each block, and a large variation can happen during deep fades.

In wireless standard systems, for network performance system level simulation should be used, but due to high complexity and computation cost it takes long times to simulate all the links [1]. Basically link level simulation is used for physical level performance evaluation. Link level simulation modeled radio link involving different parameters of the channel condition i.e. channel estimation, synchronization, fading etc.

For evaluation of a new OFDM radio access system with various MCS a large number of parameters should be measured. Since multidimensional mapping on to BLER is often too complex, it is desirable to have a simple and generic link performance model to determine BLER using a limited number of quality parameters [2]. Performance gains achieve on a single communication link level do not necessarily translate into the same gains at system level, where multiple bas stations communicate with multiple users.

To directly map this time-dispersive channel to an accurate estimate of the block-error probability will need some efforts on link level. Channel coding and frequency-domain interleaving will reduce the negative effect of a frequency-selective channel on OFDM performance but will not eliminate it completely (the negative effect will be much higher at higher-rate coding i.e. (higher data rates). So for all these requirements it is needed to make an interface between link and system level environment, which properly handle all these challenges. Previously some other interface connection is also adapted i.e. AVI, dynamic value interface (DVI) etc but due to complexity and inaccuracy it's not efficient in OFDM system [4]. Traditional AVI is good for fixed channel but not efficient for dynamic channel environment.

In this paper first we will discuss about AVI, effective SINR and exponential effective SINR mapping for SISO as well as for SIMO. Then we will show the numerical coded BER values of AVI and EESM for SISO as well as SIMO. At the end observation of the two algorithms, and what are the challenges for both algorithms are explained. Finally we will overview about the paper.

2. ACTUAL VALUE INTERFACE

Here first we will discuss about SINR and how to derive it. After that we will show some information about AVI and their basic formula.

In communication systems with interference, we often use the received signal- to- interference ratio in place of SNR for calculating error probability [3]. Since the noise n(t) has uniform power spectral density (PSD) $N_0/2$ the total noise power within the bandwidth 2B is $N=(N_0/2)(2B)=N_0B$, hence the received SNR is given by $SNR=P_r/N_0B$ and if we include interference in communication systems then it is given in equation 1.

$$SINR=P_r/N_0B+P_I \tag{1}$$

where N_0B is total noise power and P_I is interference power.

For multi carrier OFDM system we have to simulate multi sub carriers and the effect of noise and interference of these sub carriers and also effect on the received forward error correction (FEC) blocks. Many ways are defined for combining the SINR's of multiple sub carriers in to an effective SINR. In fixed and mobile broadband wireless access networks the average SINR is stochastic processes, the random nature of this process is due to both fast fading and intra system interference [5]. Actual value interface is conventional link to system interface and still using in majority of systems. When applying the conventional link to system interface called AVI to OFDM, The average SINR sample is the average SINR overall sub-carriers given as in equation 2 [6].

$$SINR_{avg} = 1/N \sum_{N=1}^{N} SINR_N \quad (2)$$

This SINR average is then mapped on to BER or BLER. We can also estimate our BLER through other variable i-e normalized root mean square values of the SINR [7].

3. EFFECTIVE SINR MAPPING

In effective SINR category, there are different functions using different ways. So there are different forms of effective SINR calculation, like capacity effective SINR mapping, logarithmic effective SINR and exponential effective SINR mapping. The basic diagram of finding effective SINR and then mapped to BLER/PER are given in figure 1. So for finding effective SINR value we need some compression function to evaluate this scalar value.

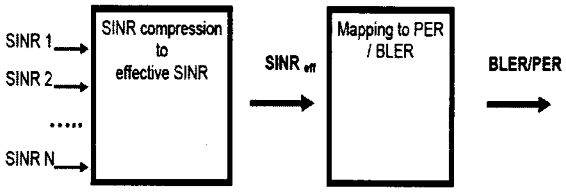


Figure 1. Effective SINR Representation

3.1 PRINCIPLE OF EESM

Here we show basic of EESM, and some important condition for its performance. We also shows calibration of beta in this topic. The new mapping algorithm which catches more attention from industry side is exponential effective SINR mapping now days. EESM is used to map the instantaneous values of SINR's to the corresponding BLER value. But for this mapping, link level simulator has to produce a specific mapping table for all channels realization. The mapping of the effective SINR to the corresponding BLER value will use either a look-up table or analytical expression. The basic idea of EESM is to find a compression function that maps the set of SINRs to a single scalar value that is a good predictor of the actual BLER. So it means EESM work both with SNR as well as SIR. The formula which calculate effective SINR mapping given is given in equation 3.

$$SINR_{effective} = -\beta\left[1/N \sum_{N=1}^{N} \exp(SINR_N/\beta)\right] \quad (3)$$

Here N shows total number of sub carriers. β is the important factor in this algorithm, which has to be adjusted for accurateness of the algorithm, and depends on the modulation and coding scheme (MCS). $SINR_N$ is the signal to interference and noise ratio on N_{th} sub carriers. Since this function use exponential so it is called exponential effective SINR mapping. For EESM to be accurate it has to follow the following rule in equation 4..

$$BLER(\{SINR_n\}) \approx BLER_{AWGN}(SINR_{effective}) \quad (4)$$

where $BLER(SINR_n)$ show block error rate for instantaneous channel realization and $BLER_{AWGN}(SINR_{effective})$ shows AWGN block error rate. The equation above is not just for average channel realizations, but at least for almost all channel realizations.

For MRC single input multiple outputs (SIMO) the received signal is

$$y = \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} s + \sum_j \begin{bmatrix} v_{1,j} \\ v_{2,j} \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (5)$$

where h_1 and h_2 are channel coefficients and v_1 and v_2 is the received interference, and the corresponding receiver $G = [h_1^* \ h_2^*]$ the received signal becomes in equation (6)

$$z = \| H \|_F^2 s + \sum_j G\begin{bmatrix} v_{1,j} \\ v_{2,j} \end{bmatrix} + G\begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (6)$$

and by taking powers, the SINR becomes in equation (7)

$$SINR = \| H \|_F^4 / \sum_j \left\| G\begin{bmatrix} v_{1,j} \\ v_{2,j} \end{bmatrix} \right\|^2 + \| H \|_F^2 \sigma^2 \quad (7)$$

and with case of no interference it is shown in equation (8).

$$SINR = \| H \|^2 / \sigma^2 \quad (8)$$

The effective SINR over N multiple antenna elements is given in equation (9), here N=2 because we consider 1X2 transmission scheme.

$$SINR_{effective} = -\beta \ln\left(1/N.M \sum_{N=1}^{N} \sum_{M=1}^{M} \exp^{\gamma_{NM}/\beta}\right) \quad (9)$$

3.1.1 β DERIVATION

To obtain Beta, several realization of the channel have to be conducted using a given channel model (e.g. SUI-3 channel model). The main steps which included in calibration of beta are given below.

1. First to generate an AWGN reference curve for a specific MCS level.
2. Next to measure the SINR per sub-carrier for the same MCS level using the desire channel model. And then SINRs values are converted to a scalar value using EESM formula.
3. Compare the two values gained from the previous steps $SINR_{EESM}$, and $SINR_{AWGN}$.
4. Then using the formula in equation (10). for beta selection, it will be our best value of beta.

$$\hat{\beta} = \arg\min |SINR_{AWGN} - SINR_{EESM}| \quad (10)$$

where equation (11). are vectors for 1 to n realizations of SINR of AWGN channel.

$$SINR_{AWGN} = [SINR_{(AWGN,1)}, SINR_{(AWGN,2)}, \ldots\ldots SINR_{(AWGN,n)}] \quad (11)$$

Equation (12) shows vectors of from 1 to n realizations of effective SINR.

$$SINR_{effective}(\beta) = [SINR_{(eff,1)}, SINR_{(eff,2)}, \ldots SINR_{(eff,n)}] \quad (12)$$

Here $SINR_{AWGN}$ is the required AWGN channel SINR which meet target BLER. $SINR_{effective}$ is the effective SINR model in different channel environments.

3 Simulation Results

The parameters, which we are suppose for comparison for these two methods given in table 1.

Table 1. Parameters used in simulation

Remarks	Parameters
Number of sub-carriers	512
Number of sub-carriers in each channel	16
Doppler frequency	
Channel Models	5 Hz
No. of channel realizations	SUI
Total number of frames to be simulated	1000
Over Sampling Rate	
System Bandwidth	100
No. of symbols in each frame	8/7
	5e^6 Hz
	6

The calibration of beta values for different modulation and coding schemes for SISO and SIMO given in table 2, which is nearly equal to previous papers values. In simulation results we show deviation in coded BER of EESM and AVI in tabulated form given in table 3 and the coded BER give in order of table 2. The result clearly shows the difference between the two algorithms for different modulation and coding schemes. For lower order modulation and coding EESM performance is clearly high, but in higher order it's not a big difference but still give good performance than AVI. As EESM performance is going down for higher order modulation and coding, we must adapt some parameters in EESM to be more efficient and good performer in higher order modulation and coding schemes.

Table 2. Beta calibration values for SISI and SIMO

Modulation	Code Rate	Beta value for SISO	Beta Value for SIMO (1X2)
QPSK	1/3	1.5	1.45
	1/2	1.59	1.5
	2/3	1.68	1.59
	3/4	1.8	1.65
	4/5	1.75	1.72
16-QAM	1/3	3.1	2.82
	1/2	4.2	3.45
	2/3	5.4	4.3
	3/4	6.2	5.1
	4/5	6.8	5.6

Table 3. Deviation of coded BER for AVI and EESM

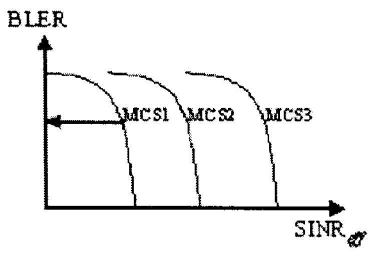
MC	AVI (SISO) Coded BER	EESM (SISO) Coded BER	AVI (SIMO) Coded BER	EESM (SIMO) Coded BER
QPSK (Code order in table2)	6.82x10-3	1.28x10-3	5.81x10-3	1.20x10-3
	7.87x10-3	1.42x10-3	6.45x10-3	1.35x10-3
	7.91x10-3	2.57x10-3	6.58x10-3	2.19x10-3
	8.12x10-3	3.10x10-3	6.91x10-3	2.86x10-3
	8.57x10-3	3.83x10-3	7.19x10-3	3.21x10-3
16.QAM (Code order in table2)	8.85x10-3	4.76x10-3	8.13x10-3	4.51x10-3
	8.9x10-3	5.78x10-3	8.53x10-3	4.57x10-3
	9.21x10-3	6.83x10-3	9.01x10-3	5.8x10-3
	9.53x10-3	6.86x10-3	9.21x10-3	6.15x10-3
	9.82x10-3	7.89x10-3	9.53x10-3	6.65x10-3

These tables show clearly that EESM is not just efficient for ½ coding but also efficient for different modulations and coding schemes. Also EESM is not just better for SISO, but as well for SIMO transmission schemes.

3.1.1 Observations

Based on the simulation and comparing of two algorithms, the following observation are given below.

1. As AVI is just simple direct average method, so it gives equal weight to all sub-carriers or symbols, even in high channel environment.
2. For every channel model AVI needs a new mapping table, so if there a lot of channel models, there will be a lot mapping tables, which is more complex to achieve.
3. Since it is simple, traditional and simple average value method, the execution time of the AVI is small compare to EESM.
4. Conventionally AVI of SNR is used together with BLER to characterize the performance. But in reality because different statistical distributions of SNR variations could lead to different orders of diversity, large deviation in BLER may appear at the same long-term linear average SNR value for different fading channels [8].
5. As in SISO EESM one beta value unifies all channels diversification for a single MCS and needs one link to system mapping curve under AWGN per MCS is needed, the same is for SIMO i.e.



Link Level Look Tables for AWGN

6. Since EESM has beta value for calibration, it gives more flexibility link to system mapping in terms of adapting with channel environment.
7. As calibration of beta is also a process involve in adjusting effective SINR values, it increase CPU time.
8. As from the tables it clearly shows that EESM is not perfect for higher order modulation, but compare to AVI, still its throughput is good.
9. As the throughput of EESM is not better for higher order modulation, we must increase value of beta according to our requirements, but we have to look our power resources. For higher order modulation we still have to adapt some parameters to not use higher values of beta.
10. The EESM mapping is less sensitive in the range of low SINR so we still need improvement in EESM.

4. CONCLUSIONS

In this paper we discuss some general concepts about wireless communication challenges. We discuss about AVI and effective SINR mapping for SISO and SIMO schemes, and compare both in terms of numerical values of Coded BER for different modulation and coding schemes. We also discussed about beta calibration in exponential effective SINR mapping and found best fit values for different modulation and coding schemes. We also explain observations of the two algorithms, and also mention some additional drawbacks in EESM. So we still need further improvement in this algorithm.

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