Enhanced Algorithm for MMIB in Distributed MIMO System

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Abstract. Link abstraction model based on MMIB (Mean Mutual Information per Bit) has already been applied to 802.16m-based systems. MMIB performs well in SISO system. However, it will make an inaccurate prediction of BLER if directly applied to Distributed MIMO system. In this paper we propose an enhanced algorithm. Simulations show great improvements compared to the original MMIB algorithms.

Keywords: MIMO, MMIB, AMC, ESINR, Link abstraction model.

1 Introduction

The next generation wireless communication system (4G) requires a data rate of above 1Gbps. Wide bandwidth and high spectral efficiency are applied to achieve such a high rate. As low frequency spectrum resource is valuable, the high frequency band above 6GHz is alternative. However, as frequency increases, coverage ability reduces. To maintain good coverage when users are in any position, distributed base stations can be used. To achieve high spectral efficiency, high order modulations as well as multi-antenna technology are required. Therefore, distributed MIMO technology will be widely used in 4G wireless communication system.

AMC can increase the average throughput, in which modulation order and coding rate adapt to changes of channel capacity. AMC technology needs instantaneous link performance prediction. In recent years, some models have been brought out.

Reference [1] proposed EESM (Exponential Effective SINR Mapping) algorithm. SNR values on all modulation symbols within a coded block are mapped to a value ESINR by an exponential function, and this value corresponds to the only BLER on AWGN channel. One drawback of the algorithm is that the AWGN reference curves are different for different modulation modes. So EESM is not suitable to be used when coded bits are mapped onto multi-modulation types in a coded block.

MIESM (Mutual Information Effect SINR Mapping) algorithm [2] uses the mutual information per received symbol to map BLER. AWGN reference curves with MIESM are independent of modulation types, but only dependent of coding rate. Simulation results show that MIESM algorithm outperforms EESM algorithm.

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MIESM calculates mutual information on an equivalent "symbol channel", which is constrained by the symbol constellation. However, the channel between encoder and decoder contains modulation and demodulation except the "symbol channel". The non-ideal demodulation algorithm may affect the channel mutual information. An improvement is MMIB (Mean Mutual Information per Bit) algorithm [3]. MMIB calculates MIB on the channel between coding output bits and LLR (Log-Likelihood Ratio) output after demodulation. MMIB which is the average of all MIB values in a coded block is used to correspond to BLER.

MMIB algorithm is accurate in SISO systems. However, in distributed MIMO systems, different data streams may differ in average SNR. As a result, SNR values in a code block will vary much if stream interleaving is used. BLER curves may not coincide with AWGN reference curves. So it is not accurate that predicting BLER according to AWGN reference curves. This paper proposes a modified method based on power function, which makes great improvements compared to the original MMIB algorithm.

This paper is organized as follows. The second section explains the distributed MIMO system model and the link abstract model. The third explains the modified MMIB model. Simulation results are present for verification in the fourth part and a conclusion follows.

2 Distributed MIMO System Model and Link Abstract Model

2.1 Distributed MIMO System Mode

A simulation scenario for distributed MIMO system is presented as follows.

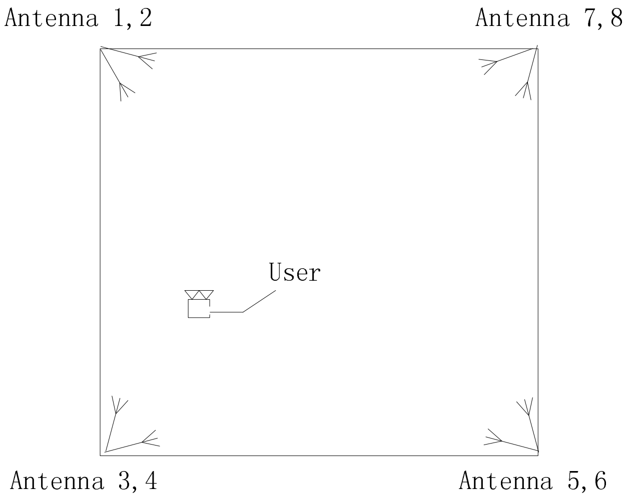


Fig. 1. A simulation scenario distributed MIMO system

Four base stations distribute at the corners of a rectangular channel. Every base station has two antennas. One is vertically polarized, the other is horizontally polarized. So a total of eight antennas achieve the coverage of the whole channel. The user side also has eight antennas, with half wavelength distance between each other. Horizontally polarized antennas and vertically polarized ones are alternately placed.

The whole process in physical layer is shown in Figure 2.

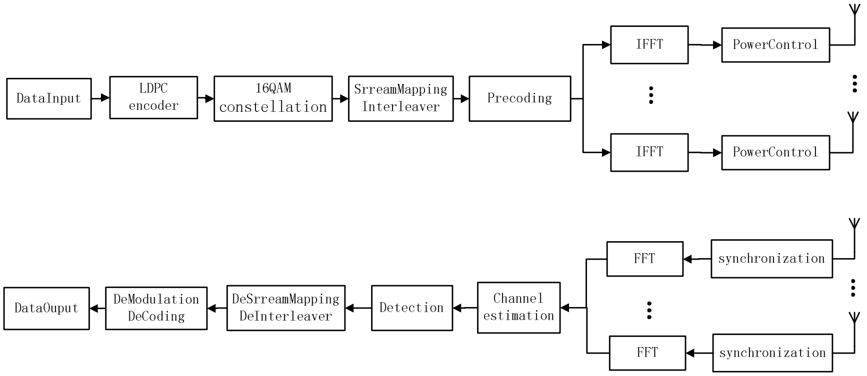


Fig. 2. Physical layer architecture

2.2 Link Abstract Model

The link abstract model is used to predict BLER by detection SNR. The link abstract model based on MMIB is described as follows (Figure 3).

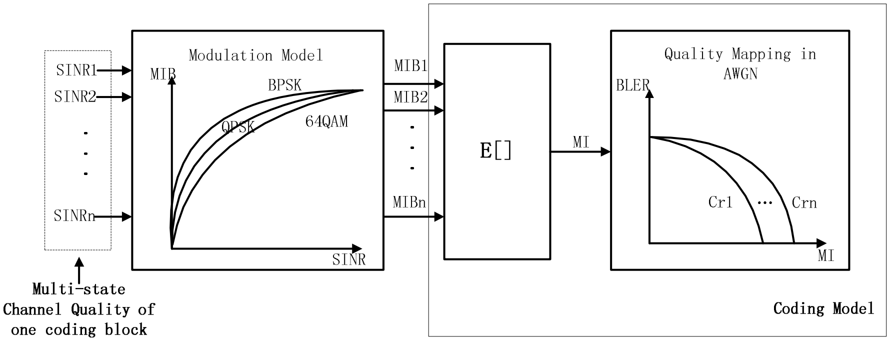


Fig. 3. MMIB based link abstract model

SNRi represents the SINR of the i^{th} modulation symbol in a coded block. The Mutual information per bit (MIB) will be received from SINR-BLER mapping curve which is dependent of modulation order, demodulation algorithm and SINR. The mean mutual information MI will be got by averaging MIB, which can be regarded as the upper capacity bound of the channel between encoder output port and decoder input port. At last, refer to the AWGN link performance curves to obtain the BLER, which is only relevant with code rate.

The differences among link abstract models mainly rest on Modulation models in which mutual information is calculated on different equivalent channel. MIESM uses the “symbol channel”. However, a “bit channel” between encoder and decoder is closer to the actual system (Figure 4).

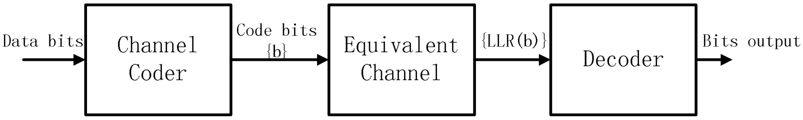


Fig. 4. Bit channel model

Bit channel, composed of three parts of modulation, AWGN channel, demodulation, is an abstract to the actual physical channel. Precise approximation of the actual channel capacity can be got by introducing MIB.

In modulator, every m bits ($b_{i1},\dots,b_{im}$, i=1,…,n, n represents the symbol number in a coded block, m={2,4,6} is the modulation order) are mapped to a modulation symbol . Due to the asymmetry of the modulation map, the mutual information between every bit b_{ij} in a modulation symbol and demodulator output LLR (b_{ij}) may be not equal. So we average the bit mutual information.

$$I_i = \frac{1}{m}\sum_{j=1}^{m} I(b_{ij}, LLR(b_{ij})) \tag{1}$$

The mean mutual information of all symbols over a coded block is

$$MI = \frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m} I(b_{ij}, LLR(b_{ij})) \tag{2}$$

Mutual information is only dependant on SINR if modulation order is specified. So the formula (2) can be described as

$$MI = \frac{1}{n}\sum_{i=1}^{n} I_i(SINR_i) \tag{3}$$

The mutual information of every bit in a symbol under different SINR can be computed numerically. Then the mean bit mutual information will be got, which can be stored in a table for use. Tables should be built for every modulation order.

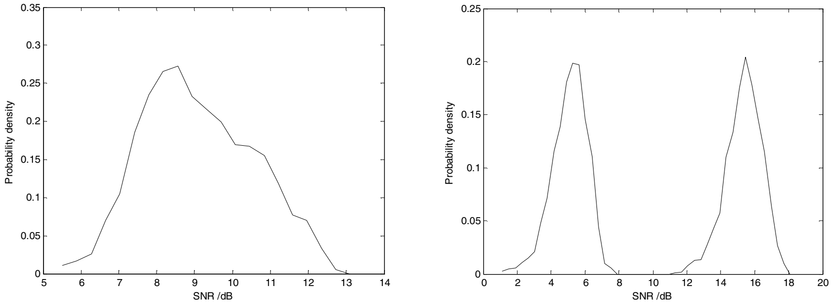
3 The Modified MMIB Model in Distributed MIMO System

Reference [3] gives the MMIB model in MIMO system with linear receiver.

$$\begin{aligned} MI &= \frac{1}{nN_t}\sum_{i=1}^{n}\sum_{k=1}^{N_t} I_i^k(SNR_i^k) \\ BLER &= B_{AWGN}(MI) \end{aligned} \tag{4}$$

Where N_t refers to the number of transmitting antennas and n the number of modulation symbols. B_{AWGN} is the mapping function between MI and BLER on AWGN channel.

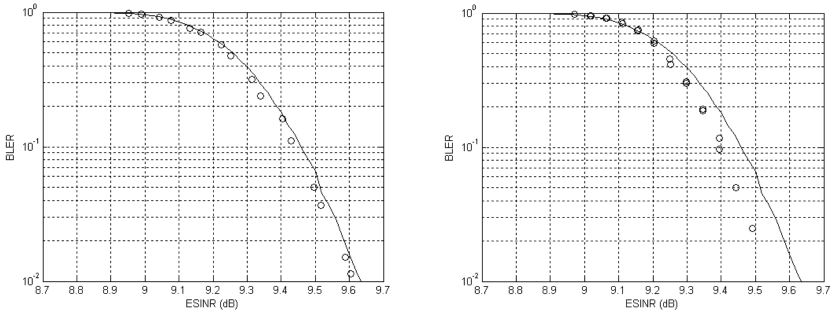
In distributed MIMO systems, post-detection SINR values may vary much in a coded block due to two factors. One is that user have different distances from different base stations. Since power control may non-ideal, received power of each transmitting antenna may differ. The other is the potential correlation among some base station antennas in the case of numerous data streams. As a result, post-detection SINR may vary among different data streams. For example, SINR distribution in a code block with user in two positions may be as follows.



(a) (b)

Fig. 5. SINR distribution with user in two positions

The left shows the SINR distribution when user is in the center of the channel. We can see that the mapping between MI and BLER coincides with the AWGN reference curve (Fig.6(a) dots represent mapping in actual channel and solid line is AWGN reference curve). The right shows the SINR distribution when user is close to two base stations and far from the other two stations. SINR values of data streams mapping to close stations are high and SINR values of other streams are low. The mapping curve between MI and BLER differ widely from that on AWGN channel (Fig. 6(b)).



(a) (b)

Fig. 6. MI and BLER mapping in different positions

The deviation between two curves in Fig. 6(b) results from the great difference between SINR values in a coded block. So we can add a modified function on SINR to make dispersive SINR values intensive. Meanwhile, curves that fit AWGN reference curves well (Fig. 6(a)) might be insensitive to this modification. We choose a power function here.

$$g(x) = \alpha_2 * x^{\alpha_1} \tag{5}$$

Where $0 < \alpha_1 < 1$, $\alpha_2 > 0$. The function makes SINR values more intensive by increasing lower SINR values and decreasing higher SINR values. The modified MMIB model is as follows.

$$\begin{aligned} ESINR &= g^{-1} I\left(\frac{1}{N}\sum_{i=1}^{N} I(g(SINR_i))\right) \\ BLER &= B_{AWGN}(ESINR) \end{aligned} \tag{6}$$

Where I(.) is the mean mutual information per bit in one symbol. The parameters α_1, α_2 in function g(.) are searched in the link level simulation under the criterion for minimizing the logarithm mean square error [6]

$$\alpha = \arg_{\min}\{\sum_{i=1}^{P} \log_{10}(BLER_i) - \log_{10}(BLER_{AWGN}(ESINR_i(\alpha)))\} \tag{7}$$

Where P is the number of simulated channel snapshots. $BLER_i$ is derived from link level simulation on the set of snapshots. $BLER_{AWGN}$ is the block error rate on AWGN channel. By using the logarithm mean square error the algorithm tries to get low error at high SINR, which is the region of interest [6].

4 Simulations for Verification

4.1 Simulation Condition

Simulation scenario is described in Section 2(A). LDPC encoder is chosen with code rate of 13/25 and 17/25. Modulation type is 16QAM. Four data streams are used. We take choosing antennas by transmitting power as our precoding scheme, which maps four data streams to eight transmitting antennas. Power control is not used. Ideal channel estimation is assumed and MMSE detector is used. SINR after detection is defined as [4]

$$SINR_k^i = \frac{\sigma_s^2 \| (R(k)H(k))_{ii} \|^2}{\sigma_s^2(((R(k)H(k))^H (R(k)H(k)))_{ii} - \| (R(k)H(k))_{ii} \|^2) + \sigma_n^2 (R(k)^H R(k))_{ii}} \tag{8}$$

Where $SINR_k^i$ refers to SINR on k^{th} symbol and i^{th} data stream in a coded block. H is channel matrix. σ_s^2 is signal power. σ_n^2 is Gauss noise power. R is MMSE detection matrix. The noise on the denominator composes of interference from other data streams and Gauss noise.

The channel model uses six paths and each path contains twenty sub-paths. The power rate between direct path and sum of all other non-direct paths is 13.3721. The carrier frequency is 6GHz. The bandwidth is 100MHz. User speed is 2m/s. We build the model by modifying the SCME model [5].

We choose channel snapshots randomly at different positions and different moments. 10000 code blocks are simulated to get BLER on each channel snapshot.

4.2 Simulation Results

Fig. 7 shows results that code rate is 13/25. Fig. 8 shows results that rate is 17/25. Dots refer to mapping between ESINR and BLER in actual channel and solid line refer to AWGN reference curve. We can see that the deviations become large as ESINR is high (Fig. 7(a), Fig. 8(a)) , which is the region that is important to system level simulation and adaptive transmission. The modified MMIB algorithm is more close to AWGN reference curve at high ESINR (Fig 7(b), Fig 8(b)). The deviations are less than 0.1dB in most cases.

Table 1 shows the values of α_1, α_2 and MSE (mean square error) under different conditions. Results also show that the modified algorithm outperforms the original algorithm.

Table 1. Accuracies of the two models

Code rate	MMIB model	α_1	α_2	MSE
13/25	Original			0.0515
	Modified	1.000	0.910	0.0096
17/25	Original			0.0517
	Modified	0.999	0.940	0.0071

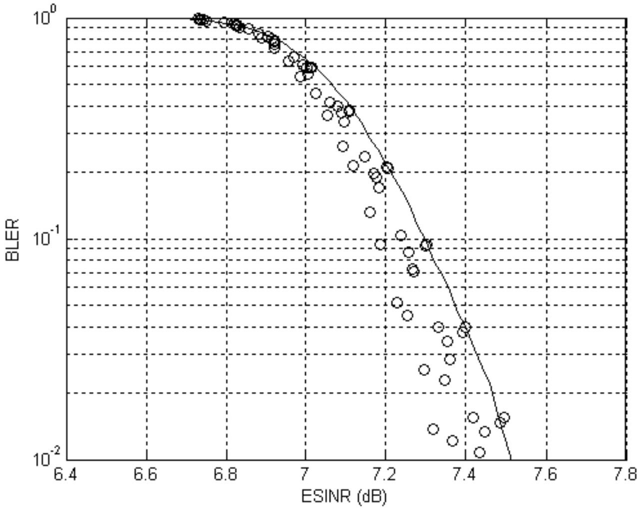


Fig. 7 (a). ESINR-BLER mapping curve for code rate-13/25 (original MMIB)

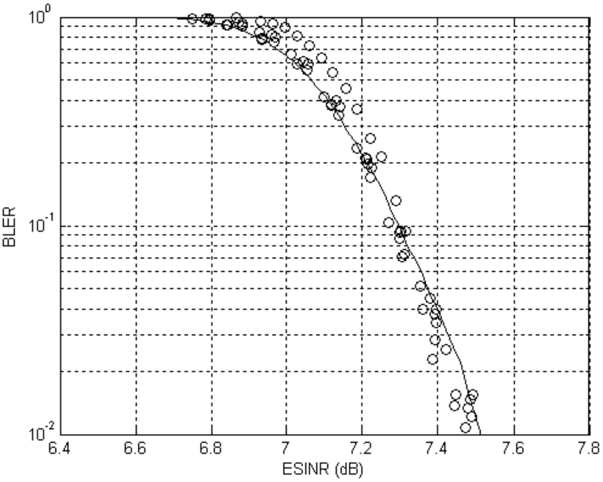


Fig. 7 (b). ESINR-BLER mapping curve for code rate-13/25 (modified MMIB)

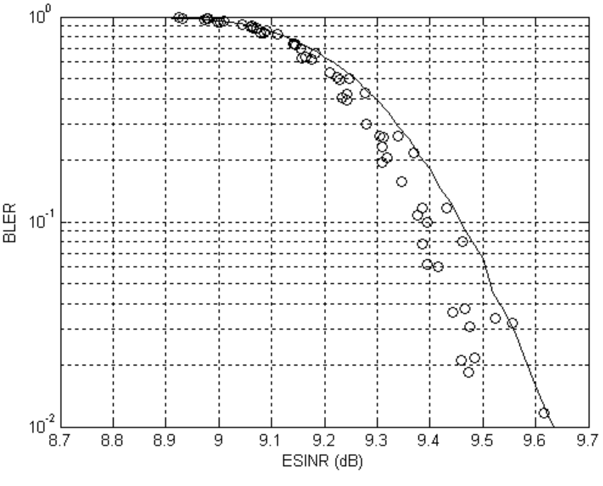


Fig. 8 (a). ESINR-BLER mapping curve for code rate-17/25 (original MMIB)

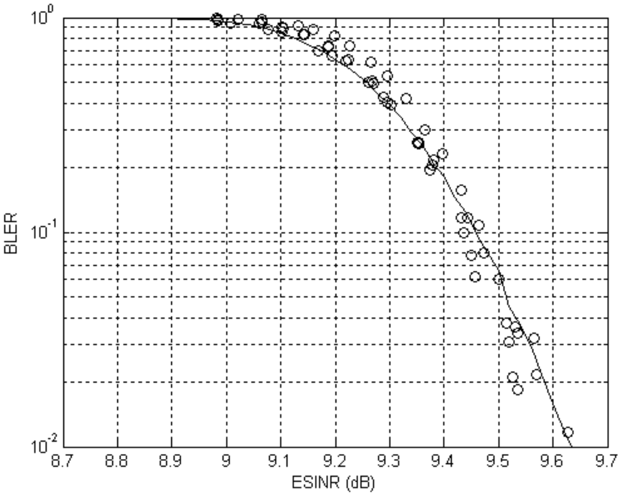


Fig. 8 (b). ESINR-BLER mapping curve for code rate-17/25 (modified MMIB)

5 Conclusion

MMIB algorithm is of high accuracy in SISO systems, but with considerable deviations in distributed MIMO systems. This paper proposes a modified method based on power function. The simulation shows that when applied to distributed MIMO systems, the modification can greatly improve the performance of MMIB algorithm. The enhanced algorithm can be applied to system level simulation and the adaptive transmission in practical systems.

References

1. Wachsmann, U., Pauli, M., Tsai, S.: Quality Determination for a Communications Link. U.S. Patent Office publication No. US 2004/02119883 A1 (2004)
2. Wan, L., Tsai, S., Almgren, M.: A Fading-Insensitive Performance Metric for a Unified Link Quality model. In: WCNC 2006, pp. 2110—2114 (2006)
3. IEEE 802.16 Broadband Wireless Access Working Group, Sayana, K., Zhuang, J., Stewart, K., Motorola Inc.: Link Performance Abstraction on Mean Mutual Information per Bit (MMIB) of the LLR Channel (2006)
4. IEEE 802.16 Broadband Wireless Access Working Group, Zhuang, J., Jalloul, L., Novak, R., Park, J.: IEEE 802.16m Evaluation Methodology Document (EMD) (2009)
5. Baum, D.S., Salo, J., Del Galdo, G., Milojevic, M., Kyösti, P., Hansen, J.: An Interim Channel Model for Beyond-3G System. In: Porc. IEEE VTC 2005, Stockholm, Sweden (2005)
6. Olmos, J., Ruiz, S., García-Lozano, M., Martín-Sacristán, D.: Link Abstraction Models Based on Mutual Information for LTE Downlink. COST 2100 TD(10)11052 (2010)
7. He, X., Niu, K., He, Z., Lin, J.: Layer Abstraction in MIMO-OFDM System. In: IEEE International Workshop on Gross Layer Design (2007)