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CLOSED FORM EXPRESSIONS FOR BIT ERROR RATE IN INTERLEAVE DIVISION MULTIPLE ACCESS (IDMA) SYSTEM USING RAYLEIGH FADING CHANNEL

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Abstract:- *In this letter, a closed-form Bit error rate expression is derived for interleave-division multiple access systems with decode-and forward relaying subject to multipath Nakagami-m fading channels. The Bit error rate expression is obtained by using the BEP of the IDMA system is analysis. The perfect interleaving sequences of the BEP and derived expression are used to analyze system performance for different parameters, such as number of relays and Nakagami-m fading parameter. The accuracy of theoretical derivation is extensively validated through comprehensive computer simulations. It is shown that the results obtained by the proposed expression are in well agreement with the simulation results.*

Keywords: *- Nakagami-m Fading channel, Bit Error Rate (P_{BER})*

Introduction

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unit less performance measure, often expressed as a percentage. The bit error probability (p_e) is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

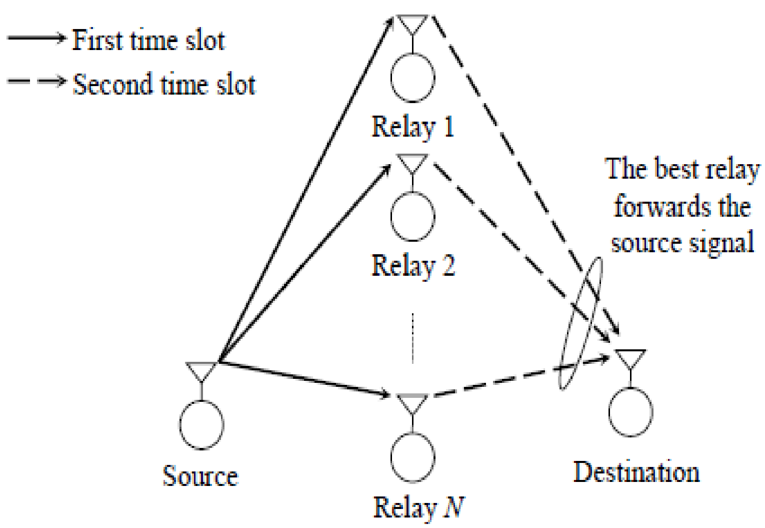

Fig.1 Illustration of IDMA for user k.

As shown in Fig.1, we take into account a relaying base on IDMA system over Weibull links. We assume that there are k cooperating users in the considered system and user is willing to cooperate the other users by using DF protocol. In addition, each user is equipped with one antenna. The channel coefficients between sources- relays or relays-destination are flat Weibull fading.

IDMA Transmitter and Receiver Principles

Transmitter Structure

The part of fig.2 the transmitter structure of IDMA with K users, The input data sequence d_k of user k is encoded using a low rate code C, generation a coded sequence c_k= [$c_k(1)$,…..$c_k(j)$,…..$c_k(J)$], where J is the frame length. The element in ck are then fed to an interleave producing x_k=[$x_k(1)$,…..$x_k(j)$,…..$x_k(J)$]. The element is c_k and x_k are called "chips". Users are solely distinguished by their unique interleaves. We assume that the interleaves are generated independently and randomly.

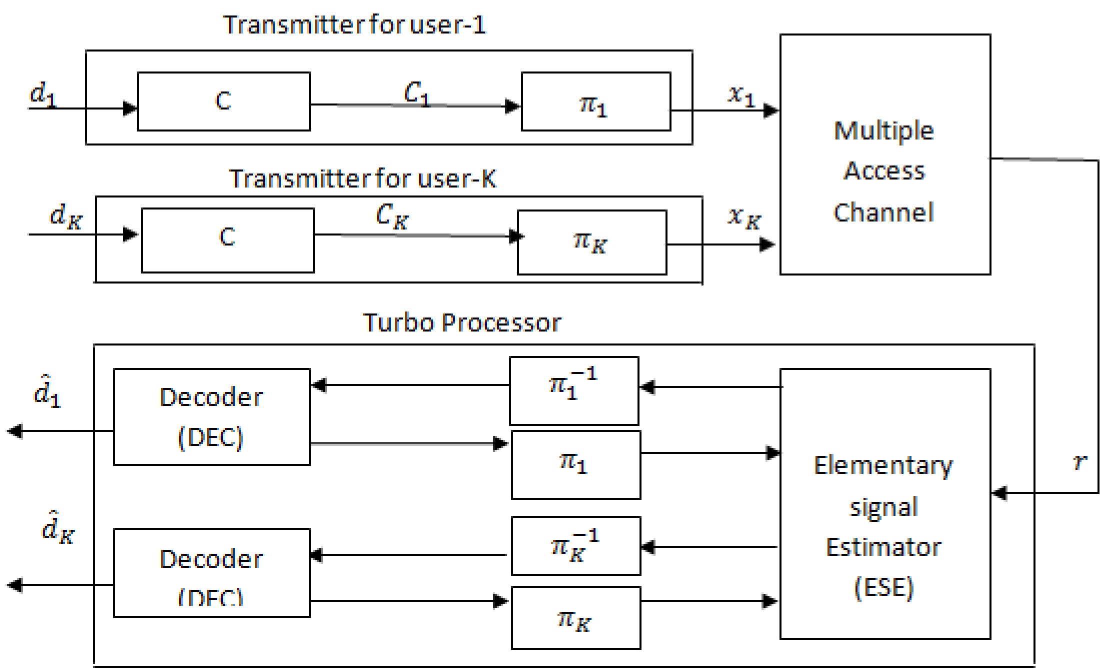

Fig.2 Transmitter and receiver structures of IDMA

Receiver Structure

The receiver structure consists of an elementary signal estimator (ESE) and K single-user a posteriori probability (APP) decoders (DECs). The multiple access and coding constraints are considered separately in the ESE and DECs. The ratio (LLRs) about {xk(j)}defined below.

$$e\big(x_k(j)\big) = \log\left(\frac{P_r\,(x_k(j))= +1}{P_r(x_k(j))= -1}\right)_{\forall\, k,j} \quad (1)$$

These LLRs are further distinguished by subscripts, i.e., eESE $\big(x_k(j)\big)$ and eDEC $\big(x_k(j)\big)$, depending on whether they are generated by the ESE or DECs. A global turbo-type iterative process is then applied to process the LLRs generated by the ESE and DECs.

Optimal Coding Technique

In [1], Mehmet Bilim, Nuri Kapucu and Ibrahim Develi have worked a close from approximate BEP expression for cooperative IDMA system over multipath Nakagami-m fading channels. With simple convolution/repetition codes, overall throughputs of 3 bits/chip with one receive antenna and 6 bits/chip with two receive antennas are observed for systems with as many as about 100 users. More sophisticated low-rate codes can also be used for further performance enhancement, as illustrated by comparison between low-rate and high-rate coded IDMA systems. With space time coding, the detection complexity is very moderate, and grows only linearly with the number of transmit antennas. Thus, systems with a large number of transmit antennas can be processed. The basic principle of the scheme in Fig. is the use of repetition coding together with random interleaving and iterative detection. The repetition coding is a simple way to achieve diversity, since each bit has N replicas transmitted from N antennas with different fading coefficients. At the receiver side, the information about a bit is collected from N samples. Such a technique has been studied before, e.g., the delay diversity. The work in this paper shows that such a simple scheme can achieve performance close to the theoretical limit (as a result of the iterative detection strategy). This scheme is applicable to any number of transmit antennas and is simpler and more flexible than other the schemes.

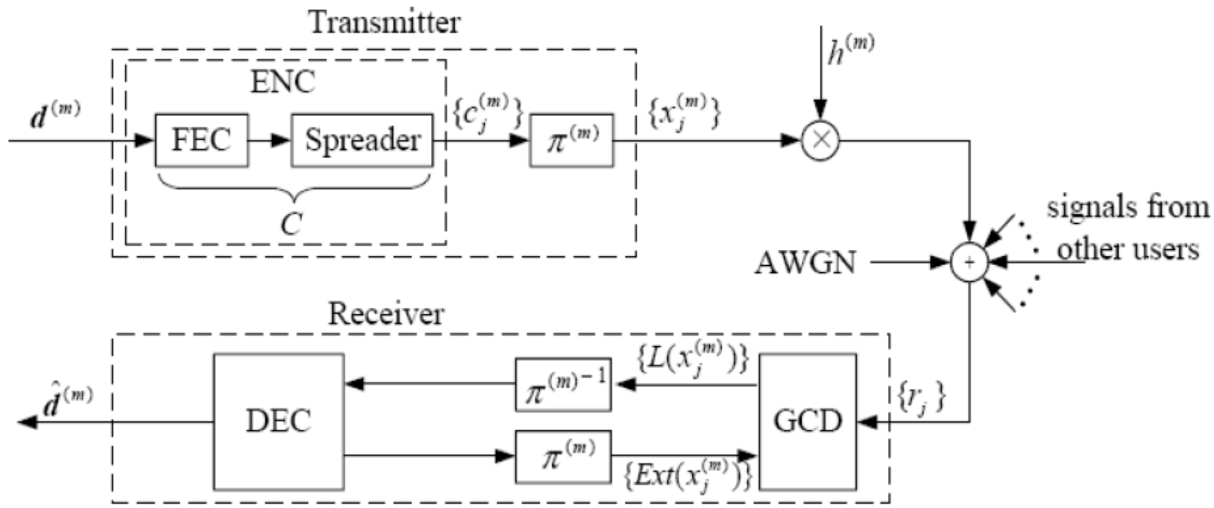

Fig.3 Transmitter and receiver structures of IDMA

It also appears that a codeword difference matrix in an interleave-based code has a large probability of being full rank after random interleaving. The theoretical analysis of this problem remains open and is a subject of current investigations. It will also be interesting to discover if careful design can lead to better performance for the interleave-based code, and how much improvement can be achieved. We are currently working on this issue.

Error Probability Analysis for IDMA System

Here, the BEP of the cooperative IDMA scheme is analyzed. We assume perfect channel estimates and perfect interleaving sequences. The BEP of the considered system can be given by

$$P_e = \sum_a P_{e/a}\, p(a) \qquad (2)$$

Where a is the set of relays which correctly decoded and $P_{e/a}$ is the conditional error probability at D node.
p(a) is the error probability for the transmission between S-D node and is given by

$$p(a) = \prod_{n\in a}\left(1 - P_{e,R_n}\right)\prod_{J\in a} P_{e,R_j} \qquad (3)$$

Where $P_{e,R_n} = \int_0^\infty AQ\left(\sqrt{B\gamma}\right) P_{\gamma SR_n}(\gamma) d\gamma$ is the average BEP at nth relay, A and B are constants that depend on the modulation type (for example, A=1, B=2 for binary phase shift keying (BPSK) and A=1, B=1 for quadrature phase shift keying, (QPSK)). Q(x) is Gaussian Q-function defined by $Q(x) = \frac{1}{\sqrt{2\pi}}\int_0^\infty \exp\left(\frac{-t^2}{2}\mathrm{dt}\right)$. the probability density function (PDF) of the instantaneous SNR at nth relay node. P_{e,R_j} Is the same as P_{e,R_n}after replacing the subscript n with j. for a given decoding set a the BEP at D node can be defined as.

$$P_{e/a} = \int_0^\infty AQ(\sqrt{B\gamma}\,)P_{\gamma tot}(\gamma)d\gamma \qquad (4)$$

Where $P_{\gamma tot}(\gamma)$ is the PDF of the total instantaneous SNR at D node, When the multipath Nakagami-m fading channels are assumed, the PDF of the instantaneous SNR, $P_{\gamma ij}(\gamma)$, is given as

$$P_{\gamma ij}(\gamma) = \sum_{P=1}^{P_{ij}} \frac{\left(m_{ij}^{P}\right)^{m_{ij}^{P}}}{\left(\bar{\gamma}_{ij}^{P}\right)^{m_{ij}^{P}}} \frac{\gamma^{m_{ij}^{P}-1}}{\Gamma\left(m_{ij}^{P}\right)} \, exp\left(-\frac{\gamma\, m_{ij}^{P}}{\bar{\gamma}_{ij}^{P}}\right) \qquad (5)$$

Where $\Gamma(.)$ is gamma function, γ_{ij}^{-p} is the average SNR of the p-path. We obtain the moment generating function (MGF) of the instantaneous SNR as

$$M_{\gamma ij}(s) = E(e^{-s\gamma ij}) = \prod_{P=1}^{P_{ij}} \left(1 + \frac{s\gamma_{ij}^{-P}}{m_{ij}^{P}}\right)^{-m_{ij}^{P}} \qquad (6)$$

Using the fraction decomposition for $M_{\gamma ij}(s)$

$$M_{\gamma ij}(s) = \sum_{P=1}^{P_{ij}} \omega_{ij}^{P} \left(1 + \frac{s\,\bar{\gamma}_{ij}^{P}}{m_{ij}^{P}}\right)^{-m_{ij}^{P}} \qquad (7)$$

We can observe the PDF of the instantaneous SNR as given in equ.(4) by evaluating the inverse Laplace transform of equ.(7) now, if we return to obtain the PDF of the total instantaneous SNR, $P_{\gamma tot}(\gamma)$ at D node.

$$P_{\gamma tot}(\gamma) \approx P_{\gamma SD}(\gamma) + \sum_{n=1}^{N} P_{\gamma R_n D}(\gamma) \qquad (8)$$

Inserting equ.(5) into equ. (8) and using equ.(4), we get

$$P_{\frac{e}{a}} \approx \int_{0}^{\infty} AQ\left(\sqrt{B\gamma}\right) \left(\begin{array}{c} \sum_{P=1}^{P_{SD}} \frac{(m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \frac{\gamma^{m_{SD}^{P}-1}}{\Gamma(m_{SD}^{P})} \times \exp\left(-\frac{\gamma^{m_{SD}^{P}}}{\bar{\gamma}_{SD}^{P}}\right) + \sum_{n=1}^{N} \sum_{P=1}^{P_{R_nD}} \frac{(m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \\ \times \frac{\gamma^{m_{SD}^{P}-1}}{\Gamma(m_{SD}^{P})} \, exp\left(-\frac{\gamma^{m_{SD}^{P}}}{\bar{\gamma}_{SD}^{P}}\right) \end{array} \right) d\gamma \qquad (9)$$

The integral in equ.(9) which is not easy to evaluate, this equation (9) is take by [1] contains Gaussian Q-function and the exponential terms that are dependent on integral variable. The Q-function in terms of the exponential function which is suitable for the general problem of analyzing the error probability over fading channel as

$$Q(x) \approx \frac{1}{12} \exp\left(-\frac{x^2}{2}\right) + \frac{1}{4} \exp\left(-\frac{2x^2}{3}\right) \qquad (10)$$

The approximation in equ.(10) make the derivation of BEP expression easier due to the fact that exponential terms provide a simple form of Gaussian Q-function with a certain level of accuracy. Therefore, the integral expression in equ.(9) can be rewritten as

$$P_{\frac{e}{a}} \approx \int_{0}^{\infty} A \left(\frac{1}{12}\, exp\left(-\frac{B\gamma}{2}\right) + \frac{1}{4} exp\left(-\frac{2B\gamma}{3}\right)\right) \times \left(\begin{array}{c} \sum_{P=1}^{P_{SD}} \frac{(m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \frac{\gamma^{m_{SD}^{P}-1}}{\Gamma(m_{SD}^{P})} \, exp\left(-\frac{\gamma^{m_{SD}^{P}}}{\bar{\gamma}_{SD}^{P}}\right) \\ + \sum_{n=1}^{N} \sum_{P=1}^{P_{R_nD}} \frac{(m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \frac{\gamma^{m_{SD}^{P}-1}}{\Gamma(m_{SD}^{P})} \times exp\left(-\frac{\gamma^{m_{SD}^{P}}}{\bar{\gamma}_{SD}^{P}}\right) \end{array} \right) d\gamma$$

(11)

After some mathematical manipulations, an approximate $P_{e/a} \approx P_e$ as

$$P_e \approx \sum_{P=1}^{P_{SD}} \frac{A\, \omega_{SD}^{P} (m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \left(-\frac{(K_1 + K_2)^{-m_{SD}^{P}}}{12} - \frac{(D_1 + K_2)^{-m_{SD}^{P}}}{4}\right)$$
$$+ \sum_{n=1}^{N} \sum_{P=1}^{P_{R_nD}} \frac{A\omega_{SD}^{P}(m_{SD}^{P})^{m_{SD}^{P}}}{(\bar{\gamma}_{SD}^{P})^{m_{SD}^{P}}} \times \left(-\frac{(K_1+D_2)^{-m_{R_nD}^{P}}}{12} - \frac{(D_1+D_2)^{-m_{R_nD}^{P}}}{4}\right) \qquad (12)$$

Where $K_1 = -\frac{B}{2}, K_2 = -\frac{m_{SD}^{P}}{\gamma_{SD}^{-P}}, D_1 = -\frac{2B}{3}$ and $D_2 = -\frac{m_{R_nD}^{P}}{\gamma_{R_nD}^{-P}}$

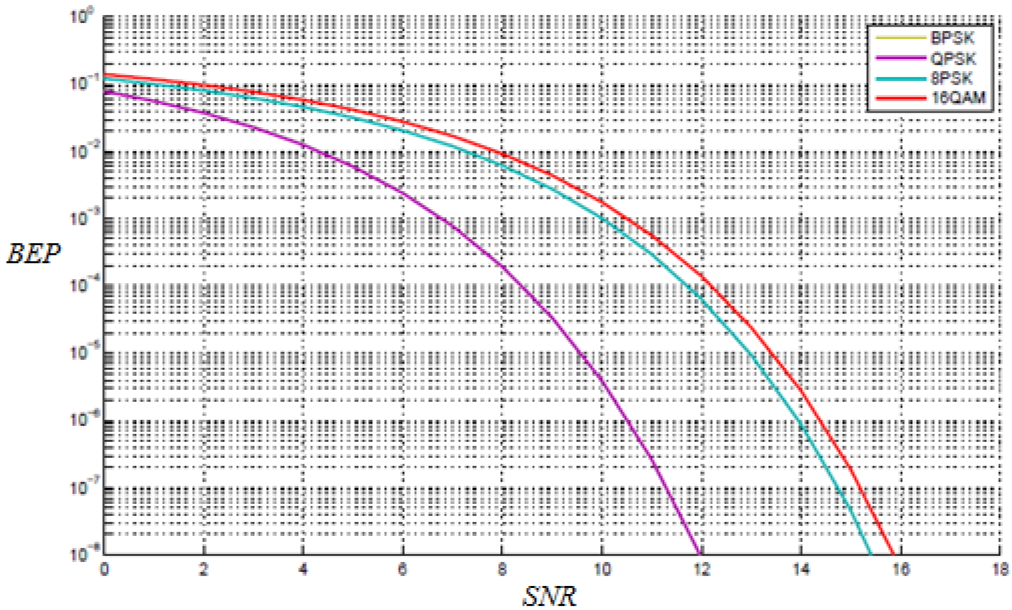

Fig.4 Comparative BEP Graph of BPSK and QPSK

Numerical Examples and Discussions

In this section, we present computer simulations to confirm the validity of the derived BEP expression for the Interleave Division Multiple Access system. We assume that PSK signaling is used in the consider system. The error probability of the IDMA system by taking very important parameters into a relays, number of different path and Nakagami-m fading parameters, we plotted the analytical curves in fig. (4) With respect to our expression presented in equation (4).
Fig. (4) Shows the BEP of the IDMA system versus average SNR for both various Nakagami-m fading with BPSK and QPSK modulations. We can observe that our derived BEP expression results match well with simulation results, especially when the SNR is greater than 5dB. The BEP performance improves with increasing the number of relays in the medium and high SNR region. Fig. (4) The analytical BEP curves obtained for IDMA system with different number if relays and number of paths. It can be seen that the results obtains by the proposed expression coincide with the computer simulations. The major effect of the number of relays and the number of path on the BEF performance of IDMA network,

Conclusion

The common advantage of conventional CDMA is maintained, since IDMA is just a special form of CDMA. As a consequence, existing CDMA system may be enhanced by IDMA as well. And the testing of IDMA system such as in interleaving scheme for memory optimization, improvement in coding schemes, automatic repeat request, synchronization issues and peak to averages power reduction and in modulation schemes. The BEP performance of IDMA network is presented over multipath Nakagami-m fading channels by using the rake receiver at relays and destination node. A new approximate BEP expression is derived for the proposed system using the exponential approximation of Gaussian Q-function. The accuracy and validity of the derived closed-form expression is verified by simulations.

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