Performance Analysis of Interleave Division Multiple Access System

Izz K. Abboud, Muaayed F. Al-Rawi, Nasir A. Al-Awad

Abstract— **This paper studies the performance of coded orthogonal frequency division multiplexing system using two modulation techniques, quadrature phase shift keying (QPSK) and M-ary quadrature amplitude modulation(M-QAM) with M=8, 16, 32, and 64. The convolutional code is used as error-correcting-code. The communication channel used is vehicular channel with Additive White Gaussian Noise (AWGN). Simulation results show that the performance of coded orthogonal frequency division multiplexing system is better than that with un-coded one for QPSK and M-QAM. Also, the performance of the system with QPSK is better than that with M-QAM. Furthermore, the performance degrades as M increases.**

Keywords: **IDMA design; performance analysis; QPSK; M-QAM; Interleavers.**

I. INTRODUCTION

As the interest for high data rate administrations develops in wireless networks, different testing issues emerge when the current multiple access advancements are utilized. The real issues for orthogonal multiple access (MA) technologies, for example, TDMA, FDMA and OFDMA, incorporate their affectability to between cell impedance and casing synchronization necessity for looking after As of late, another variation of Code orthogonality.

Division Multiple Access (CDMA) conspire known as Interleave Division Multiple Access (IDMA) scheme has advanced not too far off of wireless communication [1-9]. The IDMA conspire utilizes the interleavers as the main methods for user partition so as to guarantee security identified with data of users. The fundamental thought of IDMA is to isolate each layer by interleaving the spreaded coded data sequence with a special interleaver. In this way, it is conceivable to transmit the distinctive layers in the meantime in a similar recurrence and separate them on the receiver side.

IDMA is another technology that can expel the disservices of existing CDMA system for example multiple access interference (MAI) and inter-symbol interference (ISI) by utilizing chip-level interleavers for user partition and the receiver utilizes a basic chip-level iterative multiuser detector (MUD). In CDMA, interleavers are utilized for coding gain. The fundamental standard of IDMA is that any two users are isolated by an interleaver (and the interleavers ought to be diverse for various users). In IDMA scheme, the majority of the CDMA issues don't exist because of use of user explicit interleavers as interchange method for user detachment instead of unitary spreading PN-successions utilized in CDMA conspire. With IDMA scheme, user detachment is accomplished with the assistance of user explicit interleavers, having low cross-connection among them. As the spreaded user data is encouraged to the user explicit interleavers, it results in better orthogonality between resultant interleaved data in the channel. The state of orthogonality is kept up for expelling the danger of crash between the interleavers in the channel. Figure 1 demonstrates the block diagram of IDMA framework with K concurrent users. It comprises of IDMA transmitter, different access multipath channel, and IDMA receiver. The transmitter and receiver are explained in details in the next sections.

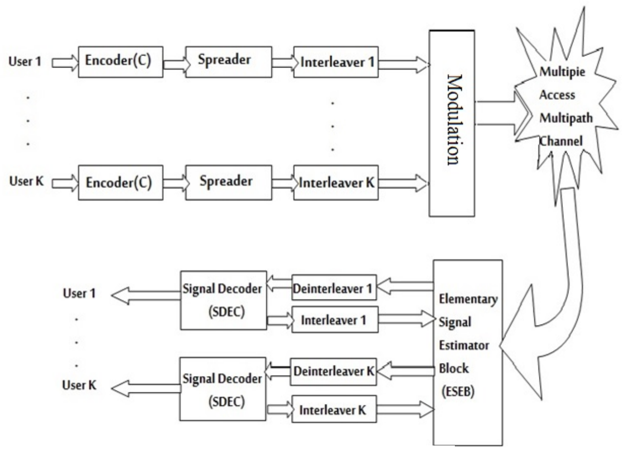

Figure 1 IDMA System

II. IDMA TRANSMITTER

A. Encoder

This block encodes the input data succession utilizing forward-error correcting (FEC) encoder, which empower a set number of error identification and redress at the receiver without retransmitting the data stream. The FEC code can be a block or a convolutional code. The encoder can be expelled from the IDMA transmitter bringing about uncoded IDMA framework. Be that as it may, on the off chance that the encoder is there, we have a coded IDMA framework.

B. Spreader

The spreader receives a bit and spreads it to $S - bits$, where s is the spreader length. This spreading procedure is utilized for transfer speed development and the choice of spreading successions does not influence the execution of an IDMA framework. A real gain of spreading concerning the range of data transmission can be accomplished in a frequency selective fading environment. The expanded transmission bandwidth of a spread signal furnishes us with expanded frequency diversity. Such frequency diversity must be misused if the signal data transmission essentially surpasses the correlation frequency (for example the coherency transmission bandwidth) of the channel. Accordingly the spreader in an IDMA framework can be set the equivalent for all users or just it very well may be supplanted by a repetition encoder. The yield of the spreader for user k is C_k.

$$C_k = [c_k(1), c_k(2), \dots \dots \dots .., c_k(j), \dots \dots .., c_k(J)]^T \quad (1)$$

Where J is the frame length. The spreading sequences generated for IDMA should contain balanced number of $\{ 1 , -1 , 1 , -1 , \dots \}$.

C. Interleaver

The interleavers {πk}, which are decided on user partition, ought to be orthogonal for all users. The produced interleavers scatter the coded sequences with the goal that the neighboring chips are around uncorrelated, encouraging the basic chip-by-chip recognition in the receiver. The coded and spreaded sequence C_k is permutated by an interleaver π_k delivering the following sequence.

$$X_k = [x_k(1), x_k(2), \dots \dots \dots .., x_k(j), \dots \dots .., x_k(J)]^T \quad (2)$$

Where the element in x_k is denoted as "chips". The fundamental interleavers which are utilized in IDMA incorporate Random Interleaver (RI), Master Random Interleaver (MRI) [or power interleaver], Tree Based Interleaver (TBI), and Prime Interleaver (PI). In RI , a lot of memory space is required at the transmitter and receiver finishes. Additionally, impressive measure of data transfer bandwidth is devoured for transmission of all these interleavers just as the computational intricacy increments at the receiver end. The MRI reduces worries of additional transmission bandwidth utilization and memory necessity at transmitter and receiver closes. Nonetheless, this interleaver raises an extra issue of computational multifaceted nature happening because of iterative calculation of user explicit interleavers. The TBI is essentially expected to limit the computational intricacy and memory necessity that happen in RI and MRI. The PI is produced to diminish the transmission bandwidth and memory prerequisites contrasted with the pervious interleavers however its multifaceted nature is smidgen higher than the unpredictability of TBI. Table1 gives comparison among these interleavers considering memory requirement, bandwidth requirement, and complexity.

Table1 Comparison among interleavers

Parameters	RI	MRI (Power)	TBI	PI
Memory requirement	High	Low	Low	Lowest
Bandwidth requirement of Interleaver (30 users)	1.5×10^6	0.01×10^6	0.02×10^6	0.0001×10^6
Complexity	High	Very high	Low	Little high than TBI

In the following, the interleaving processes for each interleaver type are discussed.

- Interleaving Process

This procedure permutes the input data dependent on an interleaver pattern which relies upon the interleaver type as talked about underneath.

✓ Random Interleaver

This interleaver permutes the input data randomly. All interleaver patterns are put away in the receiver (base station) to be utilized in the deinterleaving procedure later.

✓ Master Random Interleaver

As per the user-*k*, client explicit interleaver π_k can be created dependent on specific mix of master interleaver with the end goal that $\pi_k \equiv \pi^k$. Just the master interleaver will be put away in the receiver (base station), and the quantity of users are transmitted to be utilized for deinterleaving process.

✓ Tree based Interleaver

Tree based interleaver needs two master interleavers, master interleaver π_1 and master interleaver π_2 that are randomly created. These interleavers will undoubtedly have orthogonality between one another to guarantee the insignificant cross relationship between's other created user explicit interleavers that utilization this interleaving algorithm. The distributions of the interleaving veils pursue the tree organize as appeared in figure 2. User explicit interleavers are structured utilizing a mix of randomly chosen master interleavers. The interleaver π_1 is decided on upper branch, while, π_2 is saved for commencement for lower branch. Upper branch is chosen for the instance of odd user tally while bring down branch is chosen for even user tally.

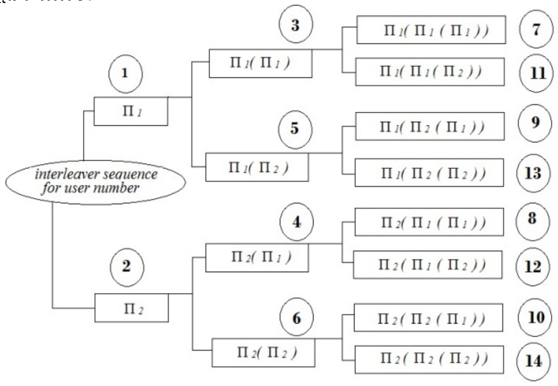

Figure 2 Interleaving strategy for Tree Based Interleaving scheme

✓ Prime Interleaver

Prime interleaver decides initial a prime number among 1 and C (where C is interleaver length), then erases the prime numbers that are components of C. From this computation, seed (number of users) is gotten. The seed must be transmitted to the receiver to produce the deintereleaver pattern utilizing a similar formula in the interleaving procedure. Note that all the interleaving mechanisms require memory to store the interleaver designs for every user with the exception of the prime interleaver.

III. IDMA Receiver

The IDMA receiver embraces an iterative problematic receiver structure. This receiver comprises of an elementary signal estimator (ESE), aposteriori likelihood (APP) decoders (DECs), and deinterleaver. The data is iterated for pre-chosen number of emphasess before at long last taking hard choice on it. Expect single way proliferation, the multiple access and coding requirements are considered independently in the ESE and DECs. The yields of the ESE and DECs are extrinsic log-likelihood ratios (LLRs) about $\{X_k(j)\}$ characterized as:

$$e\big(x_k(j)\big) = \log\left(\frac{P(y/(x_k(j)))=+1}{P(y/(x_k(j)))=-1}\right) \quad , \quad \forall k, j \qquad (3)$$

For the ESE, y in equation 3 signifies the received channel yield while for the DECs, y in equation 3 is framed by the deinterleaved rendition of the yields of the elementary signal estimator (ESE) block. A worldwide turbo type iterative process is then connected to process the LLRs created by the ESE and DECs blocks.

A. Basic Elementary Signal Estimator (ESE)

Assuming memoryless channel. After chip matched filtering, the received signal from K users for single path propagation can be written as:

$$r(j) = \sum_{k=1}^{K} h_k x_k(j) + n(j) \ , \quad j = 1,2, \ldots J \qquad (4)$$

where $x_k(j) \in \{+1, -1\}$ is the *jth* chip transmitted by user-*k*, the coefficient h_k for user-*k* represents the combined effect of power control and channel loss, $\{n(j)\}$ are samples of an AWGN process with zero-mean and variance $\sigma^2 = N_0/2$. Accepting that the channel coefficients $\{h_k\}$ are known apriori at the receiver. Because of the utilization of random interleaver $\{\pi_k\}$, the ESE task can be completed in a chip-by-chip way, with just a single example $r(j)$ utilized at once.

$$r(j) = h_k x_k(j) + \xi_k(j) \qquad (5)$$

$$\xi_k(j) = r(j) - h_k x_k(j) = \sum_{k' \neq k} h_{k'} x_{k'}(j) + n(j) \qquad (6)$$

Where, $\xi_k(j)$ is the distortion (including interference-plus-noise) in $r(j)$ with respect to user-*k*. From the central limit theorem, $\xi_k(j)$ can be approximated as a Gaussian variable, and $r(j)$ can be characterized by a conditional Gaussian probability density function:

$$P\Big(\frac{r(j)}{x_k(j)=\pm 1}\Big) = \frac{1}{\sqrt{2\pi Var\big(\xi_k(j)\big)}} \exp\left(-\frac{\Big(r(j)-\big(\pm h_k + E\big(\xi_k(j)\big)\big)\Big)^2}{2Var\big(\xi_k(j)\big)}\right) \qquad (7)$$

Where $E(.)$ and $Var(.)$ are the mean and variance functions, respectively. The following is the ESE detection algorithm based on Eqs.5&7, assuming that the apriori statistics $\{E\big(\xi_k(j)\big)\}$ and $\{Var\,(x_k(j))\}$ are available.

Algorithm 1: Chip by chip (CBC) detection

Step (i): Estimation of Interference Mean and Variance

$$E\big(r(j)\big) = \sum_k h_k E(x_k(j)) \qquad (8)$$

$$Var\big(r(j)\big) = \sum_k |h_k|^2 Var(x_k(j)) + \sigma^2 \qquad (9)$$

$$E\big(\xi_k(j)\big) = E\big(r(j)\big) - h_k E(x_k(j)) \qquad (10)$$

$$Var\big(\xi_k(j)\big) = Var\Big(r(j) - |h_k|^2\, Var\big(x_k(j)\big)\Big) \qquad (11)$$

Step (ii): LLR Generation

$$e_{ESE}\big(x_k(j)\big) = 2h_k \frac{r(j)-E(\xi_k(j))}{Var(\xi_k(j))} \qquad (12)$$

B. Iterative Interleaving / Deinterleaving Operation

This task is utilized inside the procedure of iterative decoding prompting increment the computational intricacy of the receiver end. The computational multifaceted nature is expanded definitely if there should arise an occurrence of substantial user tally. The ESE produces measurements that are deinterleaved before contribution to the soft-in/soft-out (SISO) decoder. The decoder delicate yield is interleaved and afterward utilized by the ESE on the following emphasis as apriori data, this enhances the yield measurements and the procedure proceeds. At last, hard yield choice is made by the decoder on the last emphasis. The interleaving/deinterleaving is utilized between the ESE and the decoder to evacuate relationships between's the receiver / decode operations.

- Deinterleaving Process

After demodulation process, the deinterleaver successions are created. The method for creating the deinterleaver successions relies upon the sort of interleaver as talked about underneath.

✓ Random Interleaver

The random interleaver produces the deinterleaver patterns utilizing the as of now put away interleaver patterns. It contrasts the estimation of vector $\boldsymbol{e}$ and the area of their appearance in the interleaver patterns. The vector $\boldsymbol{e}$ is a row vector characterized as $[1,2,3,\ldots,\mathrm{C}]$,where C is interleaver length. The deinterleaver succession permutes the got arrangements to get the spreaded sequences which equivalents to the chip sequences at the transmitter.

✓ Random Master Interleaver

Contingent upon the quantity of users we create the deinterleaver pattern from the as of now put away mester interleaver patterns by contrasting the estimation of e vector and master interleaver areas of their appearance in itself. The deinterleaver pattern permutes the received sequences to get the spreaded sequences which equivalents to the chip successions at the transmitter.

✓ Tree Based Interleaver

Contingent upon the two master interleaver patterns that are as of now put away at receiver, we produce the comparing deinterleaver patterns relying upon the quantity of users. The received signal is permuted by the deinterleaved patterns

✓ Prime Interleaver

Contingent upon the seed number (the quantity of user), the deinterleaver patterns are produced by utilizing a similar formula for the interleaving procedure. In the wake of deinterleaving process the spreaded successions are apply to the interpreting procedure, coming about the original data.

C. Signal Decoder (SDEC)

The SDEC in Fig.1 does a posteriori likelihood (APP) decoding utilizing the yield of the ESE as the input. With binary phase shift keying (BPSK) signaling, its yield is the extrinsic log-likelihood ratios (LLRs) $\{e_{DEC}(x_k(j))\}$ of $x_k(j)$ characterized in equation 3, which is utilized to create the accompanying measurements. In the iterative procedure, ESE and SDEC trade the extrinsic information about $x_k(j)$. The chip by chip (CBC) detection for IDMA scheme can be concluded as follows:

$$e_{DEC}\left(x_k(\pi(j))\right) = \sum_{j=2}^{S} e_{ESE}\left(x_k(\pi(j))\right) \quad (13)$$

$$E(x_k(j)) = \tanh\left(e_{DEC}\left(\frac{x_k(j)}{2}\right)\right) \quad (14)$$

$$Var(x_k(j)) = 1 - (E(x_k(j)))^2 \quad (15)$$

1. Elementary signal estimator generates $e_{ESE}(x_k(j))$ by Eq.12 for decoder DEC-*k*.
2. DEC-*k* generates $e_{DEC}\left(x_k(\pi(j))\right)$, which are used to update mean and variance of $x_k(j)$.

Under the suspicion that $\{x_k(j)\}$ are autonomous, equations .8 &11 are a clear result of equations 5 & 6. The Step (ii), appeared in algorithm 1, is acquired by assessing equation 3 dependent on equation 7. The activities in equations 8 & 9, i.e., creating $E(r(j))$ and $Var(r(j))$, are shared by all users, costing just three increases and two augmentations for each coded bit per user. In general, the ESE activities appeared in step (i) and step (ii), cost just seven multiplications and five additions for every coded bit per user, which is extremely humble. Strangely, the expense per information bit per user is free of the quantity of users *K*. This is impressively lower than that of different choices.

IV. SIMULATION RESULTS

PC reenactment tests have been completed on the framework appeared in figure 1 with K=30 and data length of 512 bits, utilizing BPSK modulation, and AWGN channel with single path. The four interleavers are associated with the reenactments. Figure 3 demonstrates the exhibitions [bit error rate] (BER) versus signal-to-noise-ratio (Eb/No) of the IDMA framework. It appears that the exhibitions of the four interleavers are roughly the same (even however TBI and PI perform smidgen better) which is valid since all interleavers were intended to keep up around a similar bit error rate. The main contrasts among the interleavers are identified with memory necessity, transmission bandwidth prerequisite, and computational unpredictability as appeared in Table1.

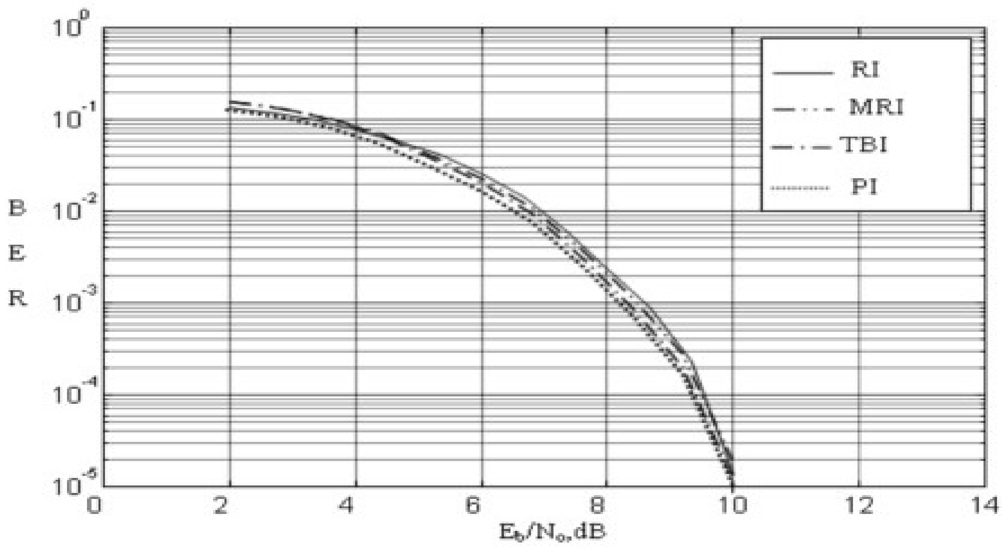

Figure 3 Error Rate Performance

REFERENCES

[1] L. Ping, et al, "Interleave division multiple access," IEEE Transactions on Wireless Communications, Vol. 5, No.4, PP. 938-947, 2006.
[2] I. Pupeza, et al, "Efficient generation of interleavers for IDMA," in Proc. IEEE International Conference on Communications, ICC 2006, Vol. 4, PP. 1508-1513, 2006.
[3] H. Wu, et al, "User-specific chip-level interleaver design for IDMA system," Electronics Letters, Vol.42, No.4, 2006.
[4] D. Hao, et al, "Analysis and design of interleaver sets for interleave-division multiplexing and related techniques," in Proc. 5th International Symposium on Turbo Codes and Related Topics, pp. 432-437, 2008.
[5] M. Shukla, et al," Analysis and design of optimum interleaver for iterative receivers in IDMA scheme," Wireless Communications and Mobile Computing, Vol.9, Issue 10, PP. 1312-1317, 2009.
[6] M. Shukla, et al," Simple diversity scheme for IDMA communication system," International Journal of Applied Engineering Research, Vol.4, No.6,PP.877-883, 2009.
[7] M. Shulka,"Performance evaluation of IDMA scheme in wireless communicatiom," Ph.D Dissertation, Dept. of Electronics and Communication Eng., Motilal Nehru National Institute of Technology, India, 2010.
[8] K. Gupta, et al," Iterative IDMA receivers with random and tree based interleavers ," Journal of Information Engineering and Applications, Vol.1, No.3, 2011.
[9] K. Choudhary, P S Sharma," Interleavers for IDMA technology: A comparison survey," International journal of Advanced Research in Computer and Communications, Vol.1, issue 2, PP.55-61, 2012.

Izz K. abboud was born in Erbil, Iraq 1962. He received B.Sc. degree in electrical & Electronic engineering from Sarajevo, Bosnia 1984 and M.Sc. degree in Electronic & communication engineering from University of Belgrade, Serbia 1986, in 1994. he had worked at airplanes repairing factory in electronic department, Baghdad, Iraq, in 1996 he had worked in Air force training institute communication department/ Baghdad, raq, in 2000 he worked as a lecturer in Institute of Technology/Baghdad/Iraq, in 2005 he worked as a lecturer in Al-Mustansiriyah University, Faculty of Engineering, Computer Enginering department, Baghdad, Iraq and currently he still three. His research interests electronics fields and communications fields, he has many research papers more than twenty in different journals and conferences E-mail: izz_kadhum@uomustansiriyah.edu.iq.

Muaayed F. AL-Rawi was born in Iraq, 1969. He received B.Sc. degree in electrical and nuclear engineering from Baghdad University, Iraq, in 1992, and M.Sc. degree in communication and electronics engineering from Jordan University of Science and Technology, Jordan, in 1999. He had worked as nuclear and electrical engineer for several years at Iraqi Atomic Energy Organization, Iraq. Currently he is with department of electrical engineering, AL-Mustansiryia University, Iraq. His research interests include computer communication networks, digital communications, analogue and digital electronics, digital signal processing, and biomedical engineering. E-mail,. muaayed@uomustansiriyah.edu.iq

Nasir Ahmad Al_awad was born in Iraq, 1957. He received B.Sc. degree in control and system engineering from Technological University, Iraq, in 1981, M.Sc. .degree in control and instrumentation engineering from Technological University, Iraq, in 1984,He is currently Assist Prof. and the head of computer engineering department, Al-Mustansiriyah University, Iraq. His research interests include control theory, computer control and computer aided design of control system, E--mail: nasir.awad@uomustansiriyah.edu.iq.