# Correlation Based Analysis of Interleavers for IDMA Systems

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***Abstract:*** **Interleave Division Multiple Access (IDMA) is one of the competitors for next generation wireless system. IDMA not only inherits all the advantages of CDMA but also has the capability to overcome its deficiencies. This paper outlines a survey on interleave-division multiple-access (IDMA) technique which exploits the interleaving as only means of user separation instead of by different signatures as in a conventional code-division multiple-access (CDMA) scheme. In this paper we consider the design of practical interleavers for interleaver division multiple access (IDMA) systems. A set of interleavers is considered to be practical if it satisfies two criteria one it is easy to generate (i.e., the transmitter and receiver need not store or communicate many bits in order to agree upon an interleaver), and second no two interleavers in the set "collide". We show that a properly defined correlation between interleavers can be used to formulate a collision criterion, where zero-correlation (i.e., orthogonality) implies no collision. Computing the correlation among non-orthogonal interleavers is generally computationally very expensive, so we also design an upper-bounding technique to efficiently check whether two interleavers have low correlation. We then go on to propose several methods to design practical interleavers for IDMA: one method to design orthogonal interleavers, and two methods to design non-orthogonal interleavers (where the upper-bounding technique is used to verify their cross-correlation is low). Simulation results are presented to show that the designed practical interleavers in an IDMA system.**

***Index Terms*-IDMA,orthogonal interleavers, correlation between interleaver.**

## I INTRODUCTION

Multiple Access technique is one of the key techniques in the wireless communication system, especially in the cellular mobile communication systems. In the past few years, the request for bandwidth has started to surpass the availability in wireless networks. Different techniques have been studied to improve the bandwidth, efficiency and increase the number of users that can be accommodated within each cell. Data rates up to 100 Mbps for high mobility and up to 1 Gbps for low mobility or local wireless are predicted . Systems fulfilling these requirements are usually considered as fourth generation (4G) systems. But 3G systems provide data rate of around 3.6-7.2 Mbps . Existing multiple access techniques used in 1G/2G/3G systems (such as FDMA/TDMA/CDMA respectively) are basically suitable for voice communication only and unsuitable for high data rate transmission and burst data traffic which would be the dominant portion of traffic load in 4G system. In modern communication system Code-Division-Multiple Access (CDMA) has made its impact in wireless communication. It offers well known features such as dynamic channel sharing ,soft capacity, reuse factor of one, low dropout rate and large coverage (due to soft handoff means make before break),ease of cellular planning, robustness to channel impairments and immunity against interference. Interleaver division multiple access (IDMA) is a technique that relies on different interleavers to separate signals from different users in a multiuser spread-spectrum communication system. In [1][2], an IDMA system that uses randomly and independently generated interleavers is presented. With these interleavers, the IDMA system in [1] performs similarly and even better than a comparable CDMA system. The condition for the IDMA to be successfully implemented is that the transmitter and receiver agree upon the same interleaver.

## II. FUNDAMENTAL OF IDMA

This paper presents an asynchronous interleaver division multiple access (IDMA) scheme for spread spectrum mobile communication systems, in which users are distinguished by different chip-level interleavers instead of by different signatures as in a conventional CDMA system incorporating the principle[3]. The scheme considered is a special case of CDMA in which bandwidth expansions is entirely performed by low-rate coding. This scheme inherits many advantages from CDMA such as dynamic channel sharing, mititigation of cross-cell interferences, asynchronous transmission, ease of cell planning, and robustness against fading. It also allow a low complexity multiple user detection techniques applicable to systems with large numbers of users in multipath channels. We will show that the proposed IDMA scheme can achieve performance close to the capacity of a multiple access channel.

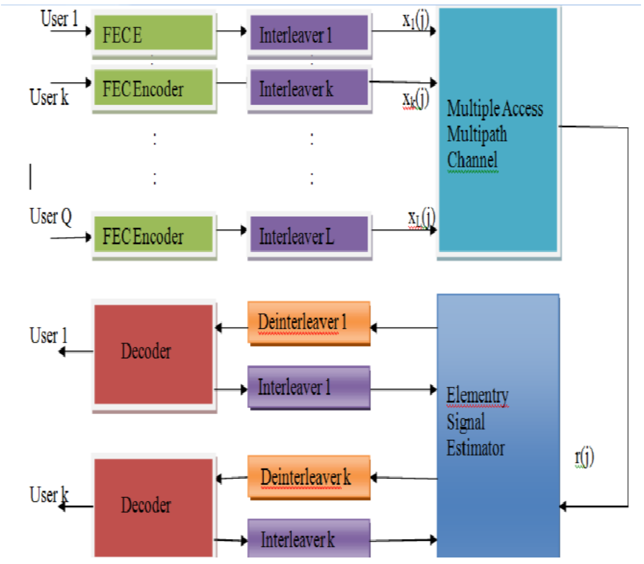


Figure 1.Transmitter and Receiver structures of IDMA scheme K simultaneous users

## III. DIFFERENT TYPES OF INTERLEAVERS

Interleaving is a process of rearranging the ordering of a data sequence in a one to one deterministic format. Interleaving is a practical technique to enhance the error correcting capability of coding. In turbo coding, interleaving is used before the information data is encoded by the second component encoder. The basic role of an interleaver is to construct a long block code from small memory convolution codes, as long codes can approach the Shannon capacity limit. Secondly, it spreads out burst errors [Ping 2004]. The interleaver provides scrambled information data to the second component encoder and decorrelates inputs to the two component decoders so that an iterative suboptimum-decoding algorithm based on uncorrelated information exchange between the two component decoders can be applied. The final role of the interleaver is to break low weight input sequences, and hence increase the code free Hamming distance or reduce the number of code words with small distances in the code distance spectrum. The size and structure of interleavers play a major role in the performance of turbo codes. There are a number of interleavers, which can be implemented.

### *A. Random Interleavers*

Random interleavers scramble the data of different users with different pattern. Patterns of scrambling the data of users are generated arbitrarily. Because of the scrambling of data, burst error of the channel is randomized at the receiver side The user specific Random Interleaver rearranges the elements of its input vector using a random permutation [Ping 2006]. The incoming data is rearranged using a series of generated permute indices. A permuter is essentially a device that generates pseudo-random permutation of given memory addresses. The data is arranged according to the pseudo-random order of memory addresses. If random interleavers are employed for the purpose of user separation, then lot of memory space will be required at the transmitter and receiver ends for the purpose of their storage. Also, considerable amount of bandwidth will be consumed for transmission of all these interleaver as well as computational complexity will be increase at receiver ends.

After randomization of the burst error—which has rearranged the whole block of the data—the latter can now be easily detected and corrected. Spreading is the important characteristic of random interleavers.

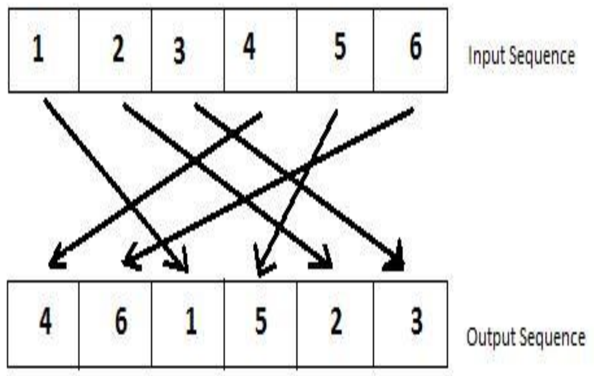


Figure 2. Random Interleaving of data

### *B.Master Random Interleaver*

n random interleavers, the base station (BS) has to use a considerable amount of memory to store the random patterns of interleavers—which may cause serious concern of storage when the number of users is large. Also, during the initial link of setting-up phase, there should be messages passing between the BS and mobile stations (MSs) to inform each other about their respective interleavers. In master random interleavers or 'power-interleaver' method, a master interleaver pattern Φ is assigned. Then $K$ ($K$ is an integer) interleavers can be generated using $\pi k = \Phi_k(c)$.

Where, $\Phi_k(c)$ is defined as

$\Phi_I(c) = \Phi(c)$ ……….. (1)

$\Phi_2(c) = \Phi(\Phi(c))$…….. (2)

Where Φ is an ideal random permutation

By this rule, every interleaver is a 'power' of Φ. So all

{$\Phi k$}, and these permutations are also approximately independent from each other. Now BS assigns the power index $k$ to each user $k$, and then $\Phi k$ will be generated at the MS for user $k$ accordingly. This method of generating patterns increases the performance in the term information that has to be sending by the base station to the mobile station.

*C Tree Based Interleaver (TBI)*

The Tree Based Interleaver (M.Shukla et al., 2008, 2009) is basically aimed to minimize the computational complexity and memory requirement that occur in power interleaver and random interleaver, respectively [4].The mechanism of Tree Based user-specific interleaver generation is based on two master interleavers, Π1 and Π2 which are randomly selected. The algorithm for TBI is based on the selection of combination of two master interleavers. The odd number of users is taken upside while even number of users is taken downside..

For the sake of understanding, from figure 3, for first user interleaver will be Π1 while for second user, the interleaver will be Π2. In case of third user it will be Π1 (Π1) and for fourth user, the interleaving sequence will be Π2 (Π1). The combinations of these two interleavers in a particular manner is shown in figure 3.

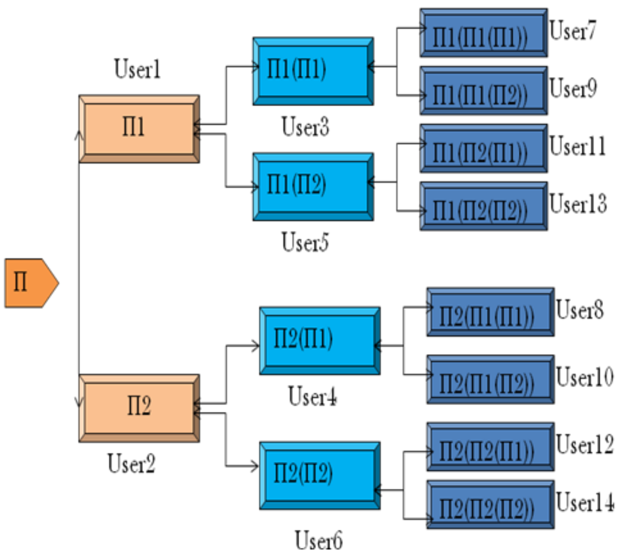


Figure 3. Interleaving masks allocation for the Tree Based Interleaving scheme .

The allocations of the interleaving masks follow the tree format. The interleaving masking diagram is shown upon fourteen users only for the shake of simplicity. It is shown through the figure that, for obtaining the interleaving sequence of the 14th user, it needs only 2 cycles of clock, as compared to many more cycles needed in case of master random interleaver method

Π 14 = Π 2 ( Π 2 (Π 2 )).

The Memory requirement of Tree Based Interleaver is extremely low as compared to that of the Random Interleaver, while is slightly high if compared with master random interleaver [5].

**Algorithm of tree based interleaver**

**Step 1**; Master interleaver $\Pi_1$ is randomly generated having data length of data block (data length x spread length.)

**Step 2**; Master interleaver $\Pi_2$ is randomly generated having data length of data block .

**Step 3**: According to user k level (L) of tree is determined. Hence, number of users in that level=$2^L$

**Step 4**: All the possible combination ($2^L$) of interleavers are generated as $\Pi_1$ ($\Pi_{1)}$, $\Pi_2$ ($\Pi_1$).

**Step 5**: According to the user K particular combination of master interleaver i.e. $\Pi_1$ and Π2 is chosen and thereafter data is interleaved accordingly.

**Step 6**: In this interleaver not only interleaving assignment scheme is simplified and memory cost is greatly reduced, but also the computation complexity of interleaver matrix is greatly reduced.

## IV.Correlation:

The correlation of two interleavers is the important thing in the IDMA system. The sequences of different interleavers must be different. There must be no relation in any two interleaver sequences. If correlation between two sequences is 1‟ means they are strongly related to each other i.e. they can be superimposed on each other. If the correlation between two sequences is „0‟ means they are orthogonal to each other. The correlation of any two sequences lies between -1 to +1. If the correlation is near to „0‟ that means that these sequences are not matches to each other. For orthogonality condition the value should be near to zero.

*A.Mathematically Correlation is define as :*

Let X1 and X2 be two variables with joint pdf p(x1, x2). We define their joint moment of order (k, n) as

$$E[X_1^k X_2^n] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1^k x_2^n p(x_1, x_2) dx_1 dx_2$$

..........................(3)

When k=n=1. then the joint moment in such a case is known as correlation. Hence, correlation is defined as

*B.Correlation between Interleaver*

Since the separation of users is achieved by interleavers, an obvious interleaver design criterion is that every two interleavers out of a set of interleavers “collide” as little as possible. The goal in this section is to define correlation among interleavers for IDMA in order to measure the level of "collision" among interleavers.

Unlike in classical turbo coding/decoding, where the task of a single interleaver is to decorrelate different sequences of bits, here we have a set of interleavers, that not only need to decorrelate different bit sequences, but also different users[5][6]. The correlation between interleavers should measure how strongly signals from other users affect the decoding process of a specific user. Hence, the additive noise should not play a role in the correlation of interleavers, and throughout this section, we consider the noiseless IDMA system. In that case, a non-turbo decoder depicted in Figure 2 suffices, where the decoder for user j consists of the user-specific deinterleaver $\pi^{-1}$ and a de spreader.

*1) Definition of Correlation and Orthogonal Interleavers*

***Definition 1****:* Let $\pi_i$ and $\pi_j$ be two interleavers and let w and v be two words. We define the correlation $C(\pi_i, w, \pi_j, v)$ between $\pi_i$ and $\pi_j$ with respect to the words w and v as the scalar product between $\pi_i$ (f(w)) and $\pi_j$(f(v)):

$C(\pi_i, w, \pi_j, v) = \{ \pi_i (f(w)), \pi_j (f(v))\}$ .…….(5)

***Definition 2:*** Two interleavers $\pi i$ and, $\pi j$ (where $\pi i \neq \pi j$) are called orthogonal, if for any two words w and v, we have

$C(\pi i, w, \pi j, v) = \{ \pi i (f(w)), \pi j (f(v))\} = 0$ …… (6)

It is easy to verify that if a set of mutually orthogonal interleavers is used in the IDMA system. In this sense, zero-correlation (or orthogonality) implies no "collision" among interleavers.

*2) Bound on the Number of Orthogonal Interleavers:*

If S is the spreading length**.** for any block length *l*, a set of orthogonal interleavers has at most *S* elements, i.e., the number of orthogonal interleavers is at most *S*.

*3) Bounding the Correlation between Interleavers:*

We have shown that it is impossible to find a set of more than S orthogonal interleavers. If we want to build an IDMA system that allows more than S simultaneous users, we need to use interleavers with non-zero correlation[6]. However, evaluating the correlation between two interleavers with respect to every possible pair of two words is very computationally complex. This is because there are 2l possibilities to choose the first word and other 2l possibilities to choose the second word. In this section we suggest a method for upper bounding the correlation between interleavers.

For two "good" interleavers, the correlation term in (1) should be close to 0. For $i \neq j$ or $w \neq v$,[8] this is equivalent to minimizing the magnitude

$|C(\pi_i, w, \pi j, v)| = |\{ \pi_i (f(w)), \pi j (f(v))\}|$ . (3)

In order to find upper bounds for (3), some definitions are helpful. From now on, we assume that $i \neq j$ or $w \neq v$ and $l \geq 3$.The value of cross correlation is leis between -1,+1. if correlation is 1 it means the same interleaver is compared there is no difference in interleaver.

## V .SIMULATION RESULT:

**Performance of Uncoded IDMA** *:* For all the simulations in this paper, the IDMA decoding algorithm described in was used. The simulated curves in Figures 2 represent the average bit error rate of all users as a function of Eb/No[dB]. We have used the parameters *S* = 8 and *l* = 50. For every curve, the transmission of more than 20 blocks per user was simulated. For 8 users, the number of iterations performed in the decoding algorithm is 5. The used decoder is sub-optimal in the sense that the channel we use is not noiseless.

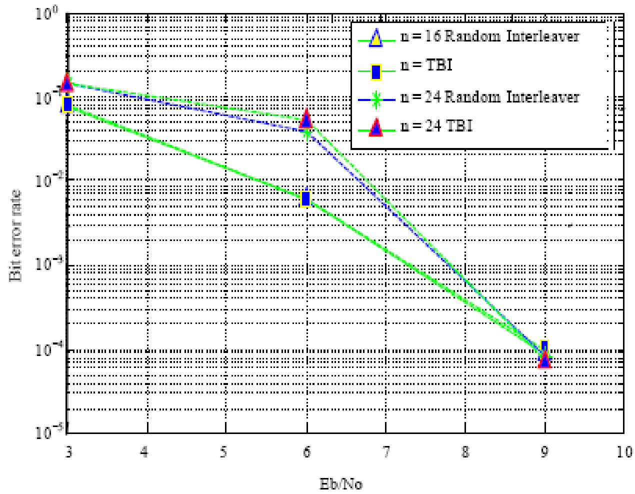


Figure 4. Performance of Interleavers in IDMA

*B. Correlation of Interleavers*: For master random interleaver no. of users n=64 ,data length m=32 the correlation is

Columns 1 through 16

0.2500 -0.2500 -0.1875 0.0625 -0.1250 -0.1250 -0.1250 -0.1875 -0.3125 -0.2500 -0.2500 -0.1875 0 0 0.0625 -0.25

Columns 17 through 32

0.5000 -0.6250 -0.6875 - 0.6250 -0.6875 -.5000 -0.6875 -0.7500 -0.8125 -0.8125

Columns 33 through 48

Comparision Based on Parameters

| **Parameters** | **RI** | **MRI** | **TBI** |
|---|---|---|---|
| Memory requirement | High | Low | Low |
| Bandwidth requirement of Interleaver(30 users) | $1.5x10^{6}$ | $0.01x10^{6}$ | $0.02x10^{6}$ |
| Complexity | High | Very high | Low |
| Bite error rate for Eb/NO = 10 (24 users) | $10^{-4}$ | $10^{-4}$ | $0.4x\ 10^{-4}$ |
| BER in coded environment for Eb/NO = 10 (24 users) | $0.6x10^{-5}$ | 0.6x $_{10}$-5 | 0.4x $_{10}$-6 |
| BER in uncoded environment for Eb/NO = 10 (24 users) | $0.6x10^{-4}$ | $0.2x\ 10^{-4}$ | $0.2x\ 10^{-5}$ |
| Specific user cross correlation | Low | Low | High |

**-0.8750 -1.0000 -1.3125 -1.4375 -1.6250 -.6250 -**

VI COMPARISON OF INTERLEAVERS

In the below table the comparison between different

Table 1.

Table 2.
Hardware Requirement

| Parameter | RI | MRI | TBI |
|---|---|---|---|
| Flip Flop | 850 | 3528 | 108 |
| Adder/sub | 272 | 1152 | 32 |
| Register | 850 | 3528 | 108 |
| MUX | 576 | 2592 | 72 |

VII CONCLUSION

In this paper, comparisons between different Interleavers have been made on the basis of parameters like complexity, bit error rate (BER), memory requirement etc. Among all the comparisons discussed so far, the features of Tree Based Interleavers and Prime interleavers shows their suitability for the IDMA technology for fourth generation

uirement, bandwidth requirement, complexity, bite error rate and also on the basis of hardware requirement for RI, MRI, and Tree Based Interleaver

communication On the basis of above comparison in table 1, we can see that tree based interleavers and prime interleavers perform better than other interleavers. But if we consider 24 users and calculate the bit error rate then we find that these all interleavers have almost same.

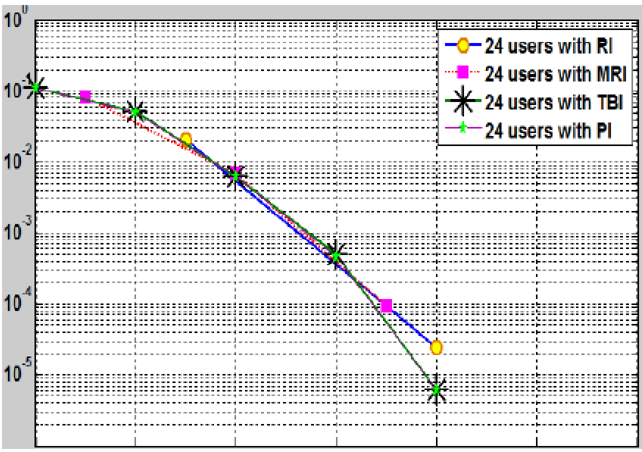

Figure 5. Comparison between RI, MRI, TBI

## REFERENCE

[1] A. Tarable, G. Montorsi, and S. Benedetto, "Analysis and design of interleavers for CDMA systems," *IEEE Commun. Lett.*, vol. 5, pp. 420– 422, Oct. 2001

[2] R. H. Mahadevappa and J. G. Proakis, "Mitigating multiple access interference and intersymbol Interference in uncoded CDMA Systems with chip level interleaving," *IEEE Trans. Wireless Commun.*, vol. 1, pp. 781–792, Oct. 2002

[3] R. H. Mahadevappa and J. G. Proakis, "Mitigating multiple access interference and intersymbol Interference in uncoded CDMA Systems with chip level interleaving," *IEEE Trans. Wireless Commun.*, vol. 1, pp. 781–792, Oct. 2002

[4] F. N. Brannstrom, T. M. Aulin, and L. K. Rasmussen, "Iterative multi-user detection of trellis code multiple access using a posterior probabilities," in Proc. ICC 2001, Finland, June 2001.

[5] R. H. Mahadevappa and J. G. Proakis, "Mitigating multiple access interference and intersymbol Interference in uncoded DMA Systems with chip level interleaving," *IEEE Trans. Wireless Commun.*, vol. 1, pp. 781–792, Oct. 2002

[6] L. Ping, L. Liu, K. Wu, and W. Leung, "On interleave-division multiple access," in *Proc. ICC 2004*, June 2004, pp2869–2873

[7] M. Shukla, V.K. Srivastava, S. Tiwari, "Analysis and Design of Optimum Interleaver for Iterative Receivers in IDMA Scheme",

[8] M. Shukla, Aasheesh Shukla, Rohit Kumar, V.K. Srivastava, S. Tiwari, "Simple Diversity Scheme for IDMA Communication System," *International Journal of Applied Engineering* Research, Vol. 4, No. 6, 2009, pp. 877-883.