ISSN 2278 – 1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 1, Issue 2, April 2012

Interleavers for IDMA Technology: A Comparison Survey

Kuldeep choudhary[1], P S Sharma[2]

Department of Electronics &Communications Department of Electronics & communication

Tula's Institute, Dehradun-248001, India[1] , Dehradun Institute of Technology, Dehradun-248001, India [2]

ABSTRACT— This paper provides a review on the IDMA (Interleave Division Multiple Access) technology in communication system based on different types of interleavers. IDMA employs interleavers as the only means in order to distinguish the users. This paper provides a comprehensive study of IDMA technique with orthogonal interleavers, power interleavers, prime interleavers, tree based interleavers and random interleavers. In this paper, we compare different interleavers based on computational complexity, bit error rate and memory requirement. The few basic requirements for future wireless 4G systems includes low receiver cost, decentralized (i.e. asynchronous) control, simple treatment of ISI, cross cell interference mitigation, diversity against fading, power efficiency (long battery life), multimedia services, high user number, high throughput and high spectral efficiency.

***Keywords*— computational complexity, interleaving; bandwidth requirement; memory requirement; orthogonality**

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.

These advantages are available due to spreading the information over a large bandwidth. The performance of conventional CDMA system is limited by multiple access interference (MAI) as well as Inter symbol Interference (ISI) [2]. Also, the complexity of CDMA multiuser detection has always been a serious concern for large no. of users. A 4G system is expected to provide a comprehensive and secure all possible solution where facilities such as IP telephony, ultra-broadband internet access, gaming services and streamed multimedia may be provide to users[1][2].

There are various numbers of multiple access techniques which are proposed for 4G system named as DS-CDMA (Direct Spread- Code Division Multiple Access), MC-CDMA (Multicarrier-CDMA), OFDMA (Orthogonal FDMA), IDMA (Interleave Division Multiple Access) etc. IDMA (Interleave Division Multiple Access) is a new technology that can remove the disadvantages of existing CDMA technique i.e. multiple access interference (MAI) and intersymbol interference (ISI). In CDMA interleaver are used for coding gain while in IDMA, they are employed for user separation. IDMA is a recently proposed scheme that employs chip- level interleavers for user separation and the receiver employ a simple chip- level iterative multiuser detector (MUD). Such a system is a logical development of the earlier research on introducing chip- level interleaving as a means of mitigating burst impulsive noise disturbances, multiple access interference, as well as intersymbol interference. The basic principle of IDMA is that two users are separated by an interleaver (and the

ISSN 2278 – 1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 1, Issue 2, April 2012

interleavers should be different for different users) while, OCDMA/IDMA, which uses the orthogonal spreading code and interleaver to distinguish different users, increase the receiver complexity of the user ends (UEs).

II. IDMA SCHEMES

As the demand for high data rate services grows in wireless networks, various challenging problems arise when the existing multiple access technologies are used. For orthogonal multiple access (MA) technologies such as TDMA, FDMA and OFDMA, the major problems include their sensitivity to inter-cell interference and frame synchronization requirement for maintaining orthogonality. For non-orthogonal MA technologies such as random waveform CDMA, although it mitigates inter cell interference and supports asynchronous transmission, the challenge is to combat intra-cell interference. So, there is a new technique known as IDMA (Interleave Division Multiple Access) which seems to be the solution for these problems. The advantages of interleaving over scrambling seems very important for cell edge subscriber stations to receive broadcast services such as common signaling broadcasting because some advanced transmitting techniques for uni casting cannot be used for broadcasting [18]. Interleave-division multiple accesses (IDMA) can be considered as a special case of direct-sequence code division multiple accesses (DS-CDMA).

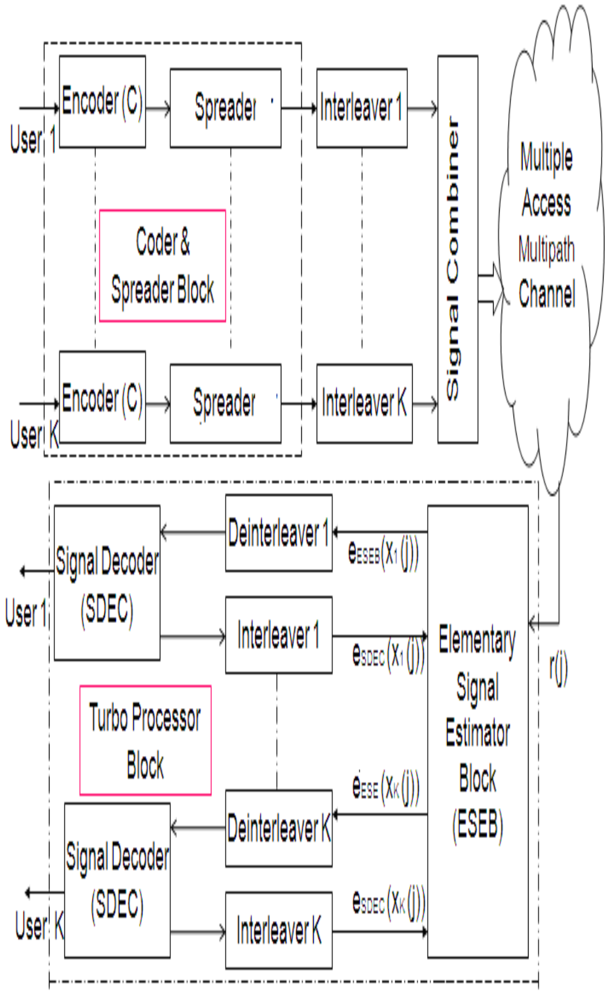

Figure 1. Transmitter and Receiver structures of IDMA scheme with *K* simultaneous users.

In IDMA, data streams are separated by different interleavers rather than by different spreading codes as employed in DS-CDMA. Each data stream is encoded by the same low-rate channel encoder. The data rate can be adapted by superimposing many encoded and interleaved data streams. In contrast to other system designs, channel coding is an integral part of the system design. Separation of the data streams at the receiver can be done in an iterative, low complexity way. These properties are advantageous for multi-user detection at the uplink and therefore make IDMA an attractive candidate for the 4G uplink, but also for an evolution of existing DS-CDMA systems

ISSN 2278 – 1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 1, Issue 2, April 2012

The block diagram of IDMA scheme is shown in figure 1 for K users. The principle of iterative multi user detection (MUD) which is a promising technique for multiple access problems (MAI) is also illustrated in the lower part of Fig. 1. The turbo processor involves elementary signal estimator block (ESEB) and a bank of *K* decoders (SDECs). The ESEB partially resolves MAI without considering FEC coding. The outputs of the ESEB are then passed to the SDECs for further refinement using the FEC coding constraint through de-interleaving block. The SDECs outputs are fed back to the ESEB to improve its estimates in the next iteration with proper user specific interleaving. This iterative procedure is repeated a preset number of times (or terminated if a certain stopping criterion is fulfilled). After the final iteration, the SDECs produce hard decisions on the information bits [4]-[7].

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 permuter 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.

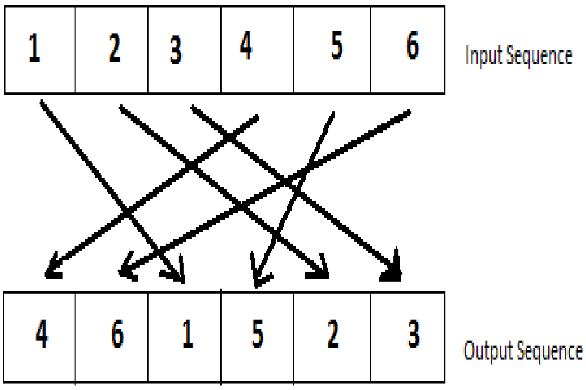

Figure 2. Random Interleaving of data

B. Master Random Interleaver

In 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 $\pi k = \Phi k$. Here, Φk (c) is, $\Phi 1$ (c) = Φ (c), $\Phi 2$ (c) = Φ (Φ (c)), $\Phi 3$ (c) = Φ (Φ (Φ (c))), etc. By this rule, every interleaver is a 'power' of Φ. The principle for this method is that if Φ is an 'ideal' random permutation, so are all $\{\Phi k\}$, and these permutations are also approximately

ISSN 2278 – 1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 1, Issue 2, April 2012

independent from each other. Now BS assigns the power index *k* to each user *k*, and then Φ*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 [6]. The mechanism of Tree Based user-specific interleaver generation is based on two master interleavers, 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. In this manner, a large number of users may be allocated with user specific interleavers with extremely less complexity. User specific interleaver is designed using a combination of these randomly selected master interleavers. Here Π1 and Π2 two master interleavers which are randomly selected. The interleaver Π1 is opted for upper branch while Π2 is reserved for initiation for lower branch. Upper branch is selected in case of odd user count while lower branch is selected if user count is even. 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 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 [6]. The IDMA scheme, inbuilt with random interleaver, imposes the problem of extra bandwidth consumption in the channel, along with high memory requirement at the transmitter and receiver ends. The result demonstrates that the memory required for storing the user-specific interleavers is user dependent for random interleavers in case of its deployment in IDMA scheme, while it is found to be at minimum level, in case of deployment of master random interleaver [16]. For tree based interleaver, the requirement of memory is observed to be little bit high in comparison to that required in case of master random interleaver, however, it is extremely less when compared with requirement in case of random interleaver.

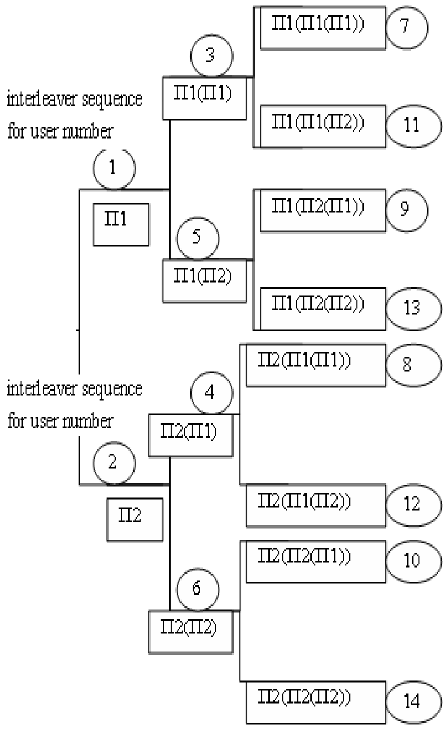

Figure.3. Interleaving masks allocation for the Tree Based Interleaving scheme .

The simulations were performed for 100 users with 256 bits of data length along with spread length to be 16. The simulation results conclude that the performance of tree based interleaver is very close to the desired ideal status of the results. The stated problems of extra channel bandwidth consumption and high memory requirement were solved by master random interleaver in [17]. However, the problem of computational complexity was raised with master random interleaver. In [8], the TBI is examined on the ground of computational complexity with that of master random interleaver [17] at transmitter end.

Considering the computational complexity at the receiver end, the technique mentioned in minimizes the computational requirement for master random interleaver. The computational requirement of all the considered interleavers is presented in table 1 at receiver end. The simulation results shown it is well demonstrated that, even at receiver end, the tree based interleaver performs better to that of master random interleaver. However its performance is inferior to that of random interleaver.

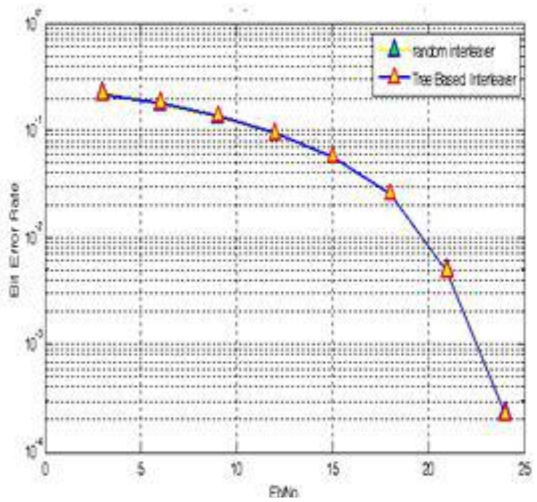

Figure 4. Graph Showing Computational Complexity between Random Interleaver, and Tree Based Interleave

D. Prime Interleaver

Researchers has proposed various other interleavers in [8-10][12][15]. In [11], tree base interleaver (TBI) generation scheme is presented which employs two master interleavers, which are randomly selected. User specific interleaver is designed using a combination of both master interleavers. The scheme is optimum in terms of bandwidth requirement and BER [12]; however, still there is space for development of other efficient interleavers for IDMA scheme. In IDMA, different users are assigned different interleavers which are weakly correlated. The computational complexity and memory requirement should be small for generation of interleavers. The Prime Interleaver is basically aimed to minimize the bandwidth and memory requirement that occur in other available interleavers with bit error rate (BER)performance comparable to random interleaver.

In generation of prime interleaver we have used the prime numbers as seed of interleaver. Here, user-specific seeds are assigned to different users. For understanding the mechanism of prime interleaver, let us consider a case of interleaving n bits with seed p. First, we consider a Gallois Field GF (n). Now, the bits are interleaved with a distance of seed over GF (n). In case, if {1, 2, 3, 5, 6, 7, 8… n} are consecutive bits to be interleaved with seed p then location of bits after interleaving will be as follows

1===> 1
2===> (1+p) mod n
3===> (1+2p) mod n
4===> (1+3p) mod n
. .
n===> (1+(n-1)p) mod n

For Example if we have to interleave 8 bits such that {1, 2, 3, 4, 5, 6, 7, 8} and we wish to interleave these bits with seed 3 then the new location of bit will be as follows

1===> 1
2===> (1+1*3) mod 3===>4
3===> (1+2*3) mod 3===>7
4===> (1+3*3) mod 3===>2
5===> (1+4*3) mod 3===>5
6===> (1+5*3) mod 3===>8
7===> (1+6*3) mod 3===>3
8===> (1+7*3) mod 3===>6

Now, the new order of bits will be {1, 4, 7, 2, 5, 8, 3, and 6}.The bandwidth required by the Prime Interleaver (PI) is smaller than other available interleavers as now only seed is to be transmitted, in addition to very small amount of memory required at the transmitter and receiver side. In master random interleaving scheme the computational complexity and transmitter and receiver end is quite high due to calculation of user-specific interleaving masks. The prime interleaving scheme reduces the computational complexity that occurs in master random interleaving scheme; however, it is higher to that of tree based interleaving scheme due computation involved for calculation of user specific interleavers.

IV. COMPARISON OF INTERLEAVERS

In the below table the comparison between different interleavers used in IDMA technologies have been made on the basis of memory requirement, bandwidth requirement, complexity, bite error rate and also on the basis of hardware requirement for RI, MRI, and Tree Based Interleaver.

Table 1. Comparison between RI, MRI, TBI andPrime Interleaver

ISSN 2278 – 1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 1, Issue 2, April 2012

Parameters	**RI**	**MRI**	**TBI**	**PI**
Memory requirement	High	Low	Low	Lowest
Bandwidth requirement of Interleaver(30 users)	$1.5x10^{6}$	$0.01x10^{6}$	$0.02x10^{6}$	$0.0001x10^{6}$
Complexity	High	Very high	Low	Little high than TBI
Bite error rate for Eb/NO = 10 (24 users)	10^{-4}	10^{-4}	$0.4x 10^{-4}$	$0.5x 10^{-4}$
BER in coded environment for Eb/NO = 10 (24 users)	$0.6x10^{-5}$	$0.6x 10^{-5}$	$0.4x 10^{-6}$	$0.4x 10^{-6}$
BER in uncoded environment for Eb/NO = 10 (24 users)	$0.6x10^{-4}$	$0.2x 10^{-4}$	$0.2x 10^{-5}$	$0.2x 10^{-5}$
Specific user cross correlation	Low	Low	High	High

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

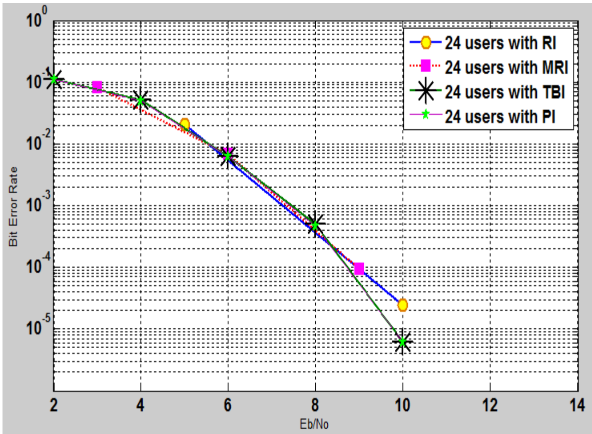

Figure 5 Comparison between RI, MRI, TBI and PI .

V. 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 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 performance shown in figure 5. Tree based interleaver has low complexity than other interleavers in consideration.

REFERENCES

[1] Pingzhi Fan, "Multiple Access Technologies for Next Generation Mobile Communication s",6th International Conference on ITS Telecommunication Proceedings, 2006.

[2] Ramjee Prasad and Tero O Janepera, "A Survey on CDMA: A Evolution towards Wideband CDMA" in proc. of IEEE, 1998

[3] M. Shukla, V.K. Srivastava, S. Tiwari, "Analysis and design of optimum interleaver for iterativereceivers in IDMA scheme". Wirel. Commun. Mob. Comput. 2008; 8:1–6 DOI: 10.1002/wcm

[4] S. Brück, U. Sorger, S. Gligorevic, and N. Stolte, "Interleaving for outer convolutional codes in DS-CDMA Systems," IEEE Trans. Commun., vol. 48, pp. 1100–1107, July 2000.

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

[6] 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, pp. 11–15.

[7] S. Verdú and S. Shamai, “Spectral efficiency of CDMA with random spreading,” IEEE Trans. Inform. Theory, vol. 45, pp. 622–640, Mar. 1999.

[8] M. Shukla, V.K. Srivastava, S. Tiwari, “Analysis and Design of Optimum Interleaver for Iterative Receivers in IDMA Scheme”, Wiley Journal of Wireless Communication and Mobile Computing, Vol 9. Issue 10, pp. 1312-1317. Oct, 2009.

[9] Nirmal Chandrasekaran, “Diversity Techniques in Wireless Communication Systems” in *Proceedings of the 2005* Wireless Communication Technologies Spring, pp. 1-8

[10] Zliisong Bie, Weiling Wu,“PEG Algorithm Based Interleavers Design for IDMA System” in Proc. 41st IEEE Annual Conference on Information Sciences and Systems, CISS '07, pp. 480 - 483, (2007)

[11] Zhang Chenghai; Hu Jianhao; “The Shifting Interleaver Design Based on PN Sequence for IDMA Systems” In Proc. Future Generation Communication and Networking (FGCN `07) , Page(s): 279 – 284, (2007).

[12] M. Shukla, V.K. Srivastava, S. Tiwari, “Analysis and design of Tree Based Interleaver for multiuser receivers in IDMA scheme” In Proc. 16th IEEE International Conference on Networks, ICON `08, pp. 1– 4,(2008).

[13] Shuang Wu, Xiang Chen, Shidong Zhou,"A parallel interleaver design for IDMA systems" In Proc. International Conference on Wireless Communications & Signal Processing, WCSP '09, pp. 1 – 5,(2009)

[14] Ruchir Gupta, B.K. Kanauji, R.C.S. Chauhan, M. Shukla, Member IEEE,. “Prime Number Based Interleaver for Multiuser Iterative IDMA Systems” in International Conference on Computational Intelligence and Communication Networks, DOI 10.1109/CICN.2010.119.

[15] Zhifeng Luo, Wong, A.K., Shuisheng Qiu, "Interleaver design based on linear congruences for IDMA systems" In Proc. IEEE 10th Annual Conference on Wireless and Microwave Technology, WAMICON '09, pp. 1 – 4(2009).

[16] H. Wu, L.Ping and A. Perotti, “User-specific chip-level interleaver design for IDMA System,” *IEEE Electronics Letters*, vol.42, Feb 2006

[17] 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.

[18] Qian Huang, King-Tim-Ko, Peng Wang, “Interleave Division Multiple Access Based Broadband Wireless Networks”, IEEE Jun, 2006