complexity will be increases. After randomization of the burst error that has to rearrange the whole block of the data afterwards it can now be easily detected and corrected. Spreading is one of the essential characteristic of random interleavers. Random interleaver is used in IDMA system for user separation, so interleaver must satisfy certain design criteria. Interleavers of different users do not collide for user separation. The property of minimum collision amongst user specific interleavers depends on property of orthogonality. It is referred as an important factor in generating the interleavers [1].

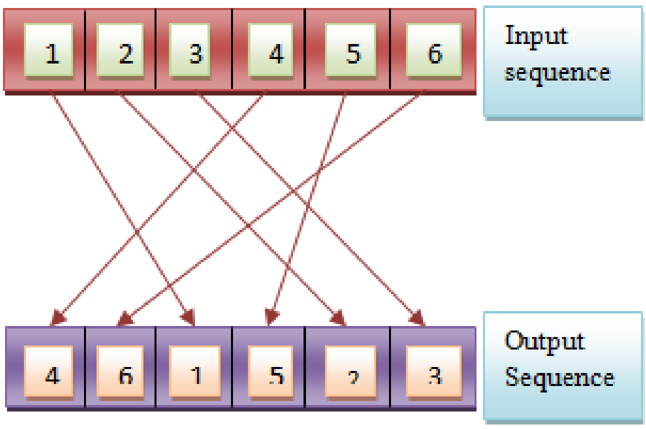

Figure 2: Random interleaver

Two interleaver are said to be orthogonal when

$$\pi (j) = \pi (i) \quad (1)$$

Whenever, correlation between two code words x and y satisfy the following relation

$$C (\pi(i), x, \pi(j), y) =\{ \pi(i) (f(x)) \pi(j) (f(b))\} \quad (2)$$

Above condition is for checking orthogonality from "Fig.3," between user-specific interleavers [8]. If the interleaver is not randomly generated, the system performance degrades considerably and the MUD is unable to resolve MAI problem at the receiver resulting in higher values of bit error ratio (BER) [5]. If random pattern are generated for different interleavers, then MUD resolves MAI problem. Hence it results in improving BER.

3.2 Helical interleaver

Helical interleaver reduces the burst error correction capability. In this interleaver, interleaver indices are read in a deterministic order for generating helical interleaver. Initially the data elements in helical interleaver are arranged row wise and column wise, then data can be read in diagonal-wise as shown in "Fig. 1," Helical interleaved index is calculated by using the following formula given as,

$$j = i(k_x + 1)mod(k_x k_x), i = \{0,1,2 \ldots . k_x, k_x - 1\} \quad (3)$$

Where i= original index value, j = helical index value, k_x= x dimension bits, k_x= y dimension bits [8].

The generation of helical interleaver can be explained as first to generate primary interleaver of length L, then write data sequence in matrix form having k_r rows and k_c column, where L is length of interleaver can be depicted as L= $k_r \times k_c$. Then, helical interleaver can be obtained with the generation of primary interleaver by reading interleaver element column wise. In final step by reading the value of interleaver indices from diagonal element of the matrix in cyclic manner, other interleaver can be easily generated.

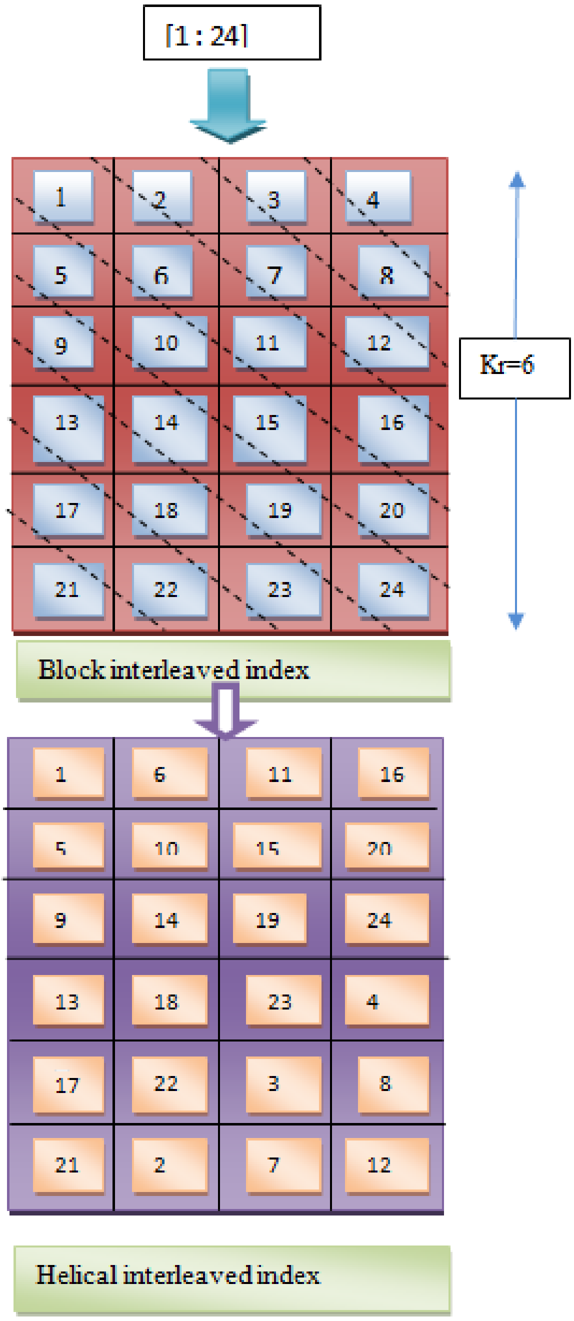

Figure 3: Helical interleaver

Mathematically, ith helical interleaver can be given as,

$$\pi_i[k] = \pi_i[l_{modL}],\ 0 \leq k < k_c \quad (4)$$

Where

$$l = k_{mod\ k_r} \cdot k_c + (\frac{|k|}{|k_r|} + (k_{mod\ k_r} \cdot (\mathrm{i}-1)) \bmod k_c \quad (5)$$

If parameter is chosen properly then interleaver element that have to used are spread out in an effectively. Different users are used by different interleavers. Constructing a layer specific shift, can be optimized as

$$\pi_i[k] = \pi(l + i, s)\ mod_{k_c} \quad (6)$$

Where S represents the interleaver shift constant.

3.3 Tree Based Interleaver

Tree Based Interleaver (TBI) is used as different chip-level interleaving sequences used for different users in an IDMA system. The operation involves reducing computation complexity. This method of generating interleaving sequence solves the memory cost problem and also reduces the amount of information exchange between mobile stations and base stations that required for specify the interleaver. The algorithm for TBI is based on the selection of combination of two master interleavers. The odd number of users is taken upside and even number of users is taken downside. In that way, a large number of users may be allocated with user specific interleavers having very less complexity. By using a combination of randomly selected master interleavers, interleavers are designed.

Here $\pi 1$ and $\pi 2$ are two master interleavers which are randomly selected. The $\pi 2$ interleaver is reserved for initiation for lower branch. Upper branch is selected for odd user count while lower branch is selected in case of user count is even. For first user interleaver will be $\pi 1$ while the interleaver will be $\pi 2$ for second user. In case of third user it will be $\pi 1(\pi 1)$ and the interleaving sequence will be $\pi 2\,(\pi 1)$ for fourth sequence. The memory requirement of tree based interleaver is extremely low as compared to the random interleaver and it is slightly high in comparing with master random interleaver [5]. The IDMA system in comparison with random interleaver will imposes the problem of extra bandwidth consumption in the channel in responding to the high memory requirement at the transmitter and receiver ends. Hence the memory requirement for storing the user specific interleavers is user dependent in case of random interleavers. In IDMA scheme, it is found to be at minimum level. For tree based interleaver, the memory requirement is observed to be little bit high in comparison to that required in case of master random interleaver. While it is extremely less in compare with requirement in case of random interleaver.

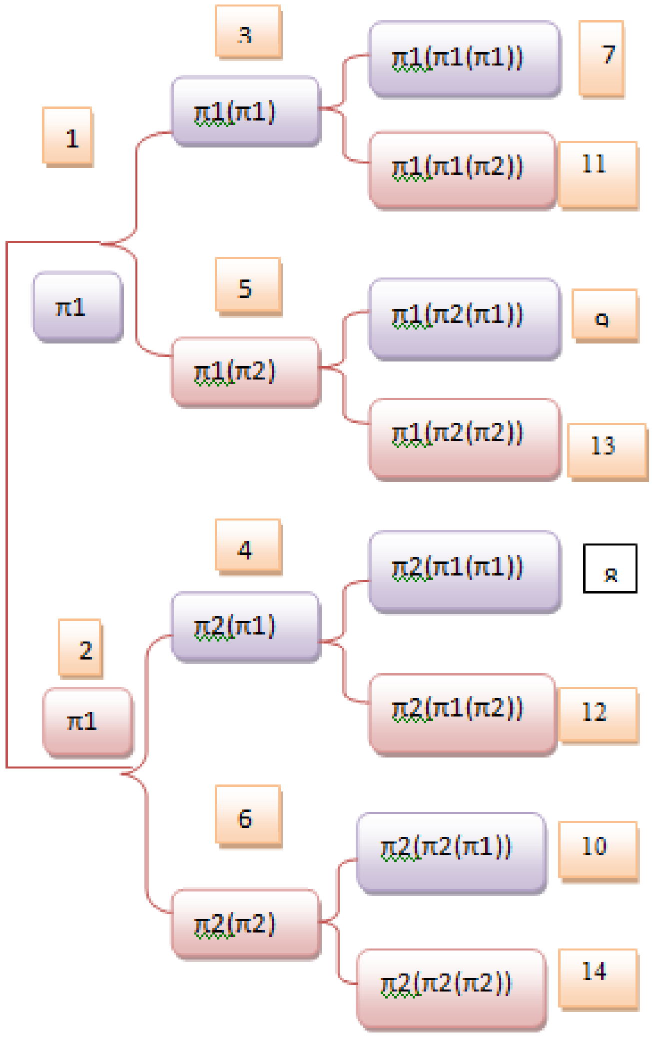

Figure 4: Tree based interleaver

The two interleaver combines in such a fashion as shown in “Fig.5” to form interleaving mask for the users. The interleaving sequences related to 14th user needs only 2 cycles,

$$\pi_{14} = \pi_2(\pi_2(\pi_2)) \quad (7)$$

$$\pi_7 = \pi_1(\pi_1(\pi_1)) \quad (8)$$

Where π_1 and π_2 are two master interleavers.

3.4 Prime interleaver

In prime interleaver, user specific interleaver is designed by using a combination of both master interleavers. The scheme is used very rarely in terms of bandwidth requirement and bit error rate. However, there is space required for development of other efficient interleavers for IDMA scheme. In IDMA scheme, different users are assigned for different interleavers that are very weakly correlated. For generation of interleavers, the computational complexity and memory requirement should be small. The Prime Interleaver is use to minimize the bandwidth and memory requirement that occur in other available interleavers with bit error rate (BER) performance are compared with the random interleaver

[5]. While in the generation of prime interleaver, the prime numbers are considered as seed of interleaver. In this scheme, user specific seeds are assigned to different users. For finding the mechanism of prime interleaver, consider a case of interleaving of n bits with seed p. First, let Gallois Field GF is n. Now, the bits are interleaved with a distance of seed over gallois field n[5]. In case, if {1, 2, 3, 5, 6, 7, 8… n} are consecutive bits that have 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 interleave 8 bits as {1, 2, 3, 4, 5, 6, 7, 8} and 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

Here, the new order of bits will be {1, 4, 7, 2, 5, 8, 3, and 6} [5]. The bandwidth requirement for the prime interleaver is smaller than other available interleavers. As very small amount of memory is required for the transmitter and receiver side, hence there is a need of seed value. While in master random interleaving scheme, the computational complexity and transmitter and receiver end is quite high. The prime interleaver results in reducing the computational complexity that occurs in master random interleaving scheme. Due to the computation of user specific interleaver, it is higher to that of tree based interleaving scheme.

3.4 Algebraic Interleaver

The algebraic interleaver is helps to rearranging the elements of its input vector using a permutation that can be algebraically derived. The parameter having number of elements N indicates that various numbers are available in the input vector. This will have column vector input signal. The output signal can inherit its data type from the input signal. The Type parameter indicates the algebraic method that having block users to generate the appropriate permutation table.

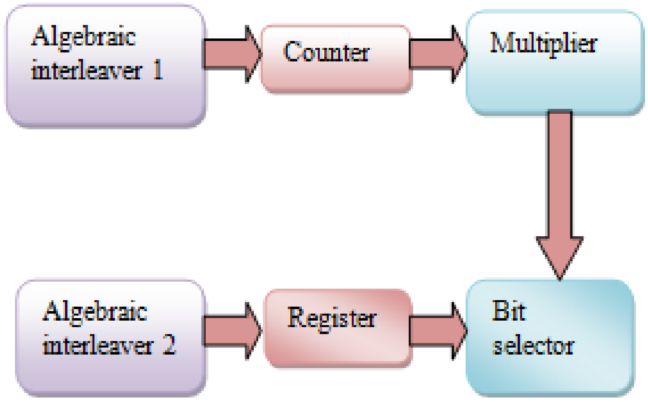

Figure 5: Algebraic interleaver

A Takeshita-Costello interleaver is uses a length-N cycle vector whose nth element is

$$C(n) = \text{mod}\ (k.n\ (n-1)\ 2, N) + 1, n \quad (9)$$

for integers n from 1 and N. The intermediate permutation function is obtained by using the following relationship:

$$\pi(c\ (n)) = c\ (n+1) \quad (10)$$

Where

$$n = 1: N \quad (11)$$

The permutation vector is the result of cyclic shifting of elements of the permutation vector π, by the cyclic shift parameter, h.

3.5 Power interleaver

The power interleaver $\emptyset$ is needed to be stored in particular way. Let the power interleaver be $\pi_1 = \emptyset$. After completing the detection cycle for user 1, the interleaver can be taken from $\pi_1 = \emptyset$ to $\emptyset(\pi) = \emptyset^2$. This will continues in recursive way. The new interleaver generation method is called as power interleavers that can take the place of random-interleavers without performance loss [3].

The drawback of this scheme is that it has higher access time for user securing $\emptyset^n$ interleaver where n is the user number. Simulation result shows that similar results have been obtained as that achieved with Random Interleavers, but considerable amount of memory space has been saved.

3.5 Block interleaver

The Block Interleaver block having rearranging of the elements of its input vector without repeating of elements. If the input is having N elements. The Permutation parameter is contains column vector of length N. The column vector having indices, hence input elements are in form the length-N output vector that is, Output (k) = Input (Permutation vector (k)) for each integer k between 1 and N. The contents of permutation vector having integers between 1 and N and it have no repetitions. Both the input and the permutation vector parameter must have column vector signals.

This block can be output sequences that vary in length. To get more information for sequences which varies in length also with variable size signals. The output signal can inherit data type from the input signal [3]. For example, If Permutation vector is [4;1;3;2] and the input vector is [40;32;59;1], then the output vector must be [1;40;59;32]. Hence all of these vectors should have same length and that the vector Permutation vector is a permutation of the vector [1:4].

4. Comparison of Interleavers

The comparison between different interleavers used in IDMA technologies have been made on the basis of memory requirement, bandwidth requirement, complexity, bit error rate (BER) for random based interleaver, helical interleaver, tree based and prime interleavers.

Table 1: Comparative table for different interleavers

Interleavers				
Parameters	*RI*	*HI*	*TBI*	*PI*
Memory requirement	High	Low	Low	Lowest
Bandwidth requirement	1.5* 10(6)	0.01*1 0(6)	0.02* 10(6)	0.0001* 10(6)
Complexity	High	Very high	Low	Little high than TBI
Bit error rate for Eb/No=10(24 users)	10(-4)	10(-4)	0.04* 10(-4)	0.5*10(-4)
BER in coded environment for Eb/No=10(24 users)	0.6* 10(-5)	0.6* 10(-5)	0.4* 10(-6)	0.4* 10(-6)
BER in uncoded environment for Eb/No=10(24 users)	0.6* 10(-4)	0.2* 10(-4)	0.2* 10(-5)	0.2* 10(-5)
Specific user cross correlation	Low	Low	High	High

5. Conclusions

The four interleavers as random, helical, tree based, and prime interleaver are compared based on the BER performance, memory requirement and complexity for their generation. Tree based and helical interleavers have quite similar BER performance compared to that of random interleaver. Also, helical interleaver has less complexity than tree based and random interleavers taken in to consideration. Thus, helical and tree based interleaver are more suitable for IDMA system. Prime Interleaver is very easy to generate and is better than other interleavers in terms of bandwidth, memory, bit error rate etc. Prime Interleaver is better than random interleaver in terms of computational complexity. With tree based interleaver, the proposed interleaver seems to be having little bit more complexity due to involvement of higher calculation for user specific interleavers. These two interleavers, tree based and helical interleaver outperforms the random interleaver in terms of bandwidth and memory consumption, which results in saving a lot of memory space while transmission of interleaver sequences, hence it results in increasing the efficiency of IDMA system.

References

[1] P S Sharma, Kuldeep choudhary, "Interleavers for IDMA Technology: A Comparison Survey," International Journal of Advanced Research in Communication and Computer Engineering, Vol. 1, Issue 2, April 2012.
[2] M. Shukla, Aasheesh Shukla, V. K. Shrivasrav, S. Tiwari, " Designing factors of an IDMA System: An Overview," International Conference on Computer and Information Technology and Communication and Control, Vol. 2, January 2009.
[3] Sonam Sharma, Paresh Chandra Sau, Aashesh Shukla, "Performance survey of IDMA with different interleavers," IEEE Transaction on integrated network and signal processing, Vol. 1, Issue 2, January 2014.
[4] Kirti Bajpai, Vikas Shrivastav, "Iterative IDMA system with different types of interleavers and a comparison survey between RI, MRI, TBI, and PI," International Journal of Electronics & Communication Engineering, Vol. 4, Issue 1, January 2014.
[5] Shuang Wu, Xiang Chen, Shiong Zhou, "A parallel interleaver design for IDMA system," IEEE Transactions on Communication Networks and Computational Intelligence, Vol. 1, Issue 2, January 2009.
[6] M. Shukla, V.K. Srivastava, S. Tiwari, "Analysis and design of optimum interleaver for iterative receivers in IDMA scheme". Wirel. Commun. Mob. Comput. 2008; 8:1–6 DOI: 10.1002/wcm.
[7] Anurag Yadav,Aasheesh Shukla, "Performance analysis of IDMA and CODED IDMA system," IEEE Transactions on Communication Networks and Computational Intelligence, Vol. 1, Issue 2, March 2013