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EFFECT OF CODE RATE VARIATION ON PERFORMANCE OFOPTICAL CONVOLUTIONALLY CODED IDMA USING RANDOM AND TREE INTERLEAVERS

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ABSTRACT

Optical interleave division multiple access technology (IDMA) is used in recent communication system to cope up with higher code rate, longer traffic intensity as well as superior interference rejection capability. In present article the qualitative performance of OIDMA is analyzed using random and tree interleavers and optimum selection of interleavers are decided by comparing BER performance of random and tree interleavers. Convolutional coding technique is used here for error correction purpose. Code rate has been changed by varying number of Ex-OR gates in encoder design. The memory elements which decide the constraint length is kept fixed. Code rate variation of fixed constraint length convolutional code has been incorporated in encoder design and effect of qualitative performance of OIDMA has been observed and BER is calculated for different users.

Keywords: O-IDMA, random interleaver, tree interleaver constraint length, LLR, APP.

1. INTRODUCTION

Spread spectrum technique possess key features such as good security, interference and fading avoiding capability, low probability of intercept, as well as multiple access capability which is major issues for modern era communication systems [1-2]. CDMA is a special type of direct sequence spread spectrum technique (DSSS) in which various DSSS signals are multiplexed and send in the common channel. To avoid interference and fading between various users, each users is multiplexed with unique PNS sequence. If users are large in number, then problem of MAI and ISI comes in picture which degraded the overall performance of system. To overcome these difficulties special type of CDMA using interleavers for user separation instead of PNS codes, are used. Such type of CDMA is called IDMA. Optical fiber channel possesses its attractive features such as low weight, less crosstalk, low BER, larger data rate is used in modern technologies. If optical channel is used in IDMA the system is termed as OIDMA which has included the all good features of optical technology.

A lot of researchers have been carrying on work on this burning topic to enhance the quality of system by varying the various blocks of OIDMA system [3-4]. Processing gain variation which introduce as security features has been changed by researchers and analysed their effect. The coding part is also changed by scientist and various types of error correcting codes such as cyclic codes, block codes, RS codes, and convolutional codes are used in this system. Comparative study and selection of optimum coding scheme which suits best for the OIDMA system is area of modern research. By varying optical channel parameters such as optical source characteristics, detector characteristics, fiber NA (numerical aperture), attenuation and dispersion characteristics and their effect on BER and quality of transmission is also being studied by scientists.

2. OPTICAL IDMA SYSTEM

The block diagram of optical coded IDMA system shown in figure 1.In the block diagram first block represent the encoder [5-6].Encoder is used in any communication system for reducing errors produced by channel. Since there are k users so k encoders are used.After coding, spreading of coded data is done with the help of PNS sequence. Due to this security and interference rejection capability of system is increased. This signal is then interleaved randomly and passes through single path of optical window. After transmitting through the channel, the bits are seen at the receiver side.

In receiver portion the noisy signal experiences chip matched decoding process and goes to the ESE (elementary signal estimator), for multiuser detection. In ESE expected noise sample patterns are previously stored and their effect and correlation on incoming signal are checked chip by chip.LLR(long likelihood ratio) is the prime factor for deciding the particular user. If there is problem in recognizing the particular user feedback mechanism is used for correction and in feedback path interleavers are connected to properly check and identify the specific users.

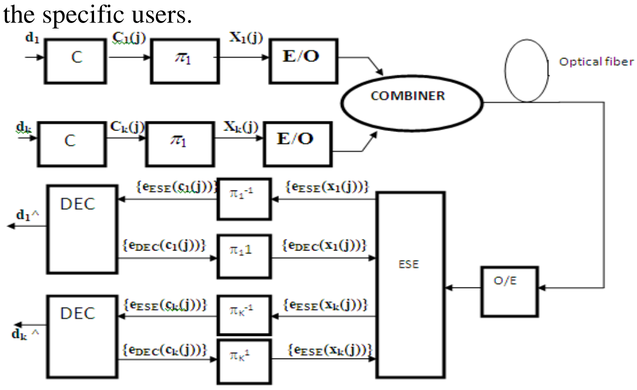

Figure-1. Optical IDMA transmitter and receiver structure.

3. RANDOM INTER-LEAVER

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A random interleaver is simply a fixed random permutation and one to one mapping for user sequences to interleaved sequences [7-8]. If the lengths of user sequences (N) are large enough then larger permutation and combination of interleaved sequences are possible which acquire larger memory space. Though random interleavers are simply to generate but as N becomes larger system complexity and cost enhances rapidly. In present figure-2 process of random interleaving is shown by taking user codeword length 7.

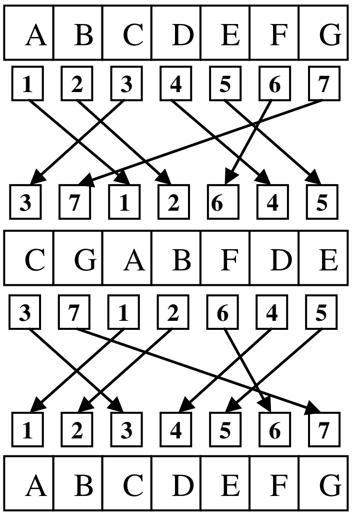

Figure-2. Random interleaver.

3.1 Tree based interleaver

The Tree Based Inter-leaver (TBI) is basically aimed to optimize the problems of the computational complexity and memory requirement which occurs in MRI (Master random interleaver) and RI (random interleaver) respectively [9]. In addition to it, TBI also targets consumption of optimal bandwidth during communication process.

In case of TBI generation mechanism, two randomly generated master inter-leavers Π1 and Π 2, are initially taken. These inter-leavers are bound to have orthogonality between each other. The zero cross correlation between two randomly selected inter-leavers ensures the minimal cross correlation between other generated user-specific inter-leavers, used in tree based inter-leaver generation algorithm. The allocations of the interleaving masks follow the tree format as shown in Figure-3 demonstrating tree based inter-leaver mechanism. The interleaving masking diagram is shown upon fourteen users only for the sake of simplicity. For obtaining the interleaving sequence of the user, the TBI mechanism needs only 2 cycles of clock, while many more cycles needed in case of master random inter-leaver method.

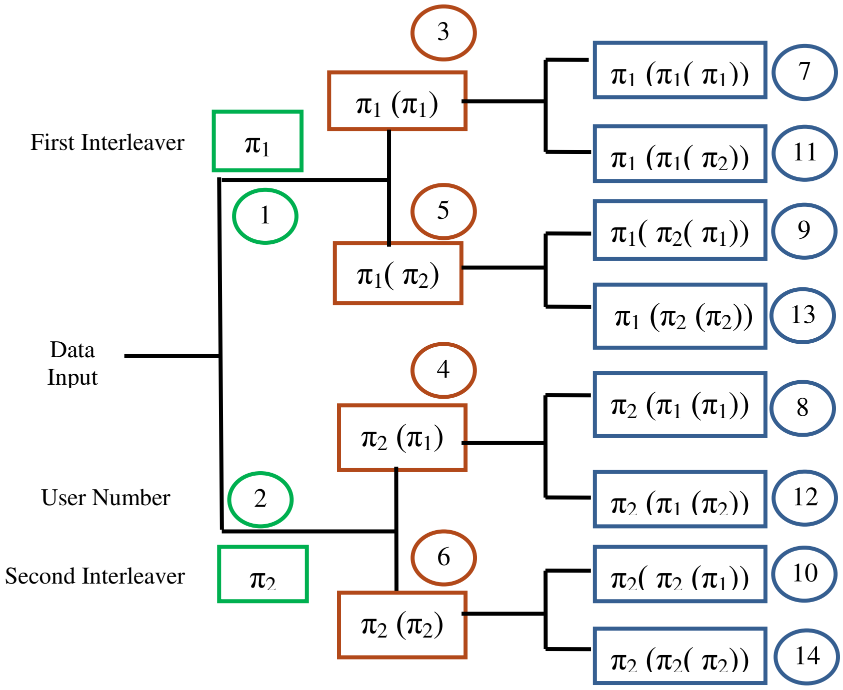

Figure-3. Tree based Interleaving scheme.

4. CONVOLUTIONAL CODING

Convolutional coding is very useful coding that is used in error correction [10-11]. Generally, convolution encoder is made up of combination of flip-flops and logic gates,D- flip-flops as its peculiar shifting property are commonly used in encoder hardware design.Constraint

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length depends on number of shift registers used in encoder. Normally constraint length is one ahead of number of registers used in encoder. Ex-OR gates are used in design of encoder to produce uncorrelated codeword. In present case X-OR gates are increased one by one in encoder design which produces code rate ½, 1/3, ¼ and 1/5.The prime difference between convolutional codes and linear block codes is that of memory existence in convolution codes.

4.1 Code rate

Convolutional codes are commonly represented by (n, k, m) having n indicates number of output bits, k indicates number of input bits and m indicates number of flip flops used in encoder design. The ratio of k and n is called as code rate (k/n) [13-14]. In present case we have fixed two flip flops in encoder design which makes constraint length of encoder as three. The Ex-OR gates are increasing one by one making the code like (1, 2) (1, 3) (1,4). Code rate are also changing as ½, 1/3, ¼ and variation of code rate on performance of OIDMA has been observed in our present work.

4.2 Design constraint of convolutional encoder by increasing Ex-OR gates

In the present design of convolutional encoder Figure-4 which is low rate (1,2) encoder having two memory element shift register and two adders are taken which makes constraint length 3. The optimum network topology considering the trellis diagram using MATLAB program is 3[5,7] which is taken from paper [convolutional coder chapter 10] reference 12, where 5 and 7 are written in octal number representation. By adding Ex-OR gates one by one in basic encoder design of Figures 4, 5 and 6, encoder design has been generated. The optimum trellis obtained for each case has been decided by the reference 12. In reference 12.the table is formed for different constraint lengths for (1,2), (1,3), and (1,4) encoders separately and optimum trellis structure depending on d_{free} has been given for each cases. Since bit error rate depends on d_{free} so results of P_e has been derived on that basis.

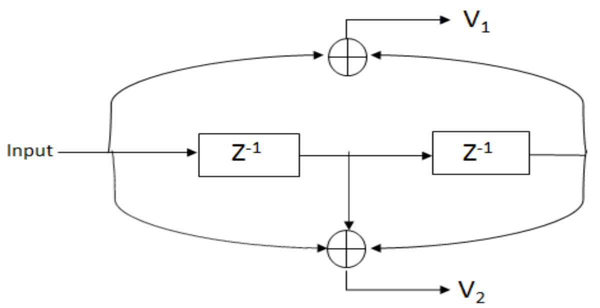

Figure-4. Convolutional encoder [1,2], 2 - Ex-OR gates network topology [3(5,7)]

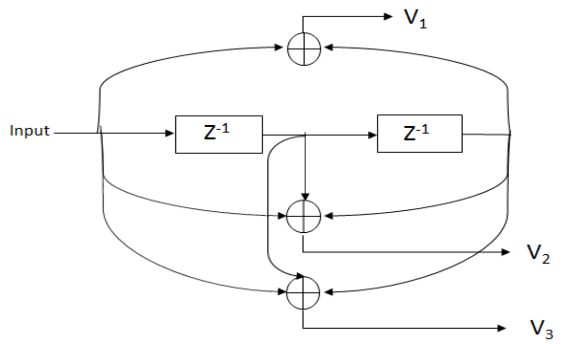

Figure-5. Convolutional encoder [1,3], 3 - Ex-OR gates network topology [3(5,7,7)].

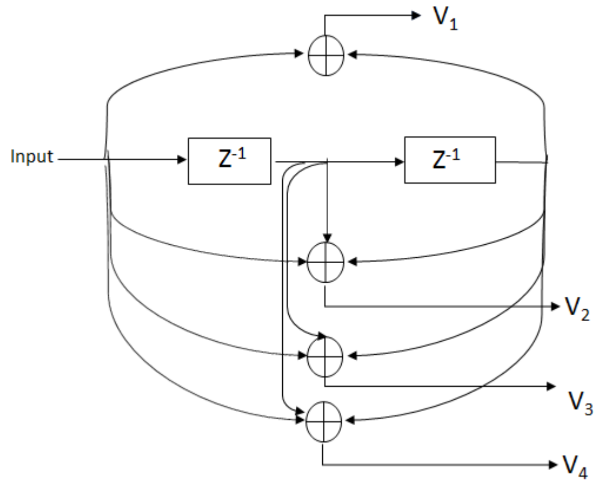

Figure-6. Convolutional encoder [1,4], 4 - Ex-OR gates network topology [3(5,7,7,7)].

5. SIMULATION RESULT AND DISCUSSION

The convolutionally coded OIDMA system has been implemented on MATLAB. The spreading length is fixed as 16. At the input block lengths 50, E_b/N_o is 3, data length is 512 has been fixed. In the optical parameter the optical source wavelength is 1553nm, input power is 1mw, input pulse is Gaussian, fiber losses 0.15db, fiber cross section 8×10^{-11} is fixed. Optical detector having characteristics such as gain 1000, efficiency 0.85 type Avalanche photodiode have been used. In the encoder design memory element is fixed as 2 while Ex-OR are varying. For code rate (1, 2) (1, 3) and (1,4) observation have been taken for random and tree interleavers separately. The observed result for bit error rate verses number of users for various code rates has been arranged in tubular form for both interleavers. A graph is plotted between number of users verses bit error rate is shown in Figure-7 for random interleaver and figure 8 for tree interleaver.

The result shown by two tables as well as two graph clearly indicates the trend that as number of users increases the BER increases slowly for all code rates that is (1, 2) (1, 3) and (1,4) anonymously.

For table-1 and Figure-7 which is plotted for random interleaver indicates that BER for code rate (1, 2)-

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BERis 1.5469×10^{4}(250 users) while it reduces to 2.2969×10^{-5} (250 users) in (1, 3) and further reduces up to 1.25×10^{-6} (250 users) for (1, 4) convolutional encoders. Results of the table shows that when code rate is (1, 4) BER is appreciably improved 100 times than the code rate (1, 2).

For case of tree interleaver which is shown by table 2 and figure 8 clearly signifies that for code rate (1, 2), BERis 1.5078×10^{-4}(250 users) and it reduces up to 2.4844×10^{-5} (250 users) for code rate (1, 3), it further reduces to 6.2500×10^{-7} (250 users) for code rate (1, 4). These results also indicate that by changing code from (1, 2) to (1, 4) the BER appreciably improved 100 times.

If we compare the results of random and tree interleavers, tree interleaver gives the better results. As we see from result that for 250 users random interleavercase BER is 1.25×10^{-6} while it reduces to 6.2500×10^{-7} for 250 users in tree interleavers. By comparing the results of Table-1 (random) and Table-2 (tree) clearly gives the glimpse of supremacy of tree interleavers over random interleaver.

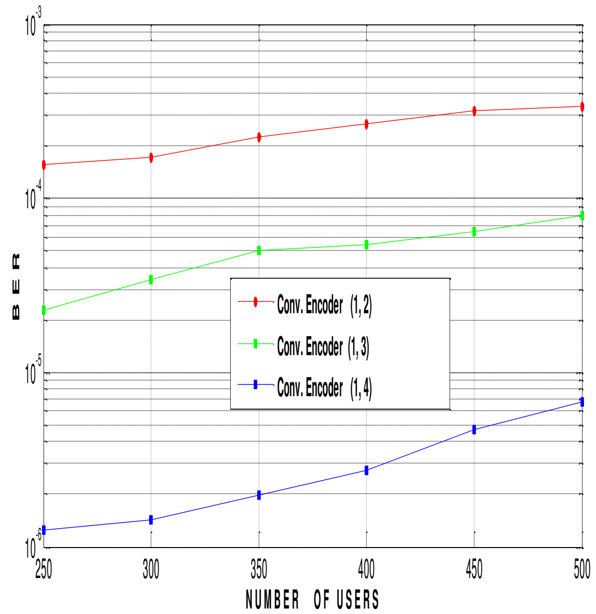

Figure-7.BER performance of coded (1, 2), (1, 3) and (1, 4) Optical IDMA of Random inter-leaver .

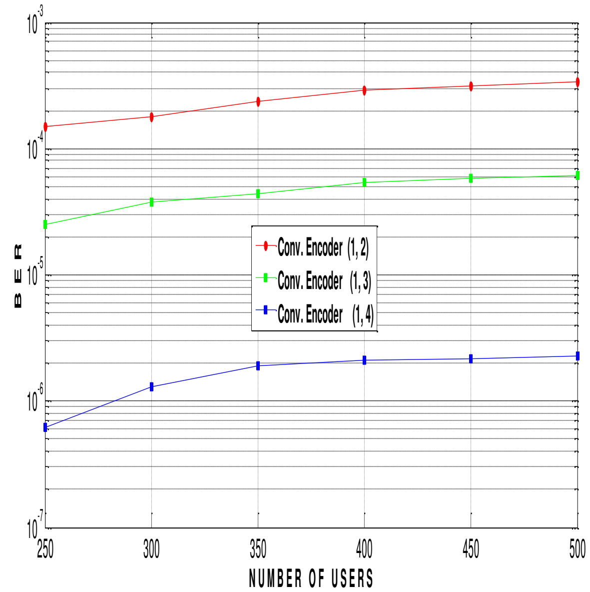

Figure-8. BER performance of coded (1, 2), (1, 3) and (1, 4) optical IDMA of tree inter-leaver.

Table-1. Variation of B.E.R. for different number of users using random interleavers at various code rate.

Random interleaver, spread length (S.L.=16), data length (m)=512, constraint length (L) = 3 and block =50			
Number of Users	**Convolutional [1,2] Encoding B.E.R.**	**Convolutional [1,3] Encoding B.E.R.**	**Convolutional [1,4] Encoding B.E.R.**
250	1.5469×10^{-4}	2.2969×10^{-5}	1.2500×10^{-6}
300	1.7279×10^{-4}	3.4115×10^{-5}	1.4375×10^{-6}
350	2.2567×10^{-4}	5.0000×10^{-5}	1.9935×10^{-6}
400	2.6602×10^{-4}	5.4102×10^{-5}	2.7344×10^{-6}
450	3.1684×10^{-4}	6.4063×10^{-5}	4.6755×10^{-6}
500	3.2758×10^{-4}	7.8985×10^{-5}	6.8125×10^{-6}

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Table-2. Variation of B.E.R. for different number of users using tree interleavers at various code rate.

Tree interleaver, spread length (s.l.=16), data length (m)=512, constraint length (L) = 3 and block =50			
Number of Users	**Convolutional [1,2] Encoding B.E.R.**	**Convolutional [1,3] Encoding B.E.R.**	**Convolutional [1,4] Encoding B.E.R.**
250	1.5078×10^{-4}	2.4844×10^{-5}	6.2500×10^{-7}
300	1.7969×10^{-4}	3.7370×10^{-5}	1.3021×10^{-6}
350	2.3527×10^{-4}	4.3750×10^{-5}	1.8973×10^{-6}
400	2.8730×10^{-4}	5.351×10^{-5}	2.0878×10^{-6}
450	3.1259×10^{-4}	5.7726×10^{-5}	2.1833×10^{-6}
500	3.4234×10^{-4}	6.1562×10^{-5}	2.2656×10^{-6}

6. CONCLUSIONS

The OIDMA system simulated results using fixed input parameters and fixed optical channel parameters gives the good expected result clearly resembles the theoretical aspects. We have seen from both the graph that by increasing traffic intensity (number of users) the BER enhance slowly with a continuous manner. As Ex-OR gates are increasing in hardware produces more un correlation in code words creates more redundancy and so reduces BER appreciably. In present work since memory elements are fixed so its effect with increasing Ex-OR gates are not considered. In future work both parameters might be varied simultaneously and optimum number of shift register with Ex-OR gates may be calculated easily. The result also dignifies the supremacy of tree interleaver over random interleaver because tree interleavers have low memory, low power consumption, low cost and less complex decoding processes.

Overall we conclude that effect of variation of code rate on OIDMA improves its performance qualitatively and if we use tree interleaver along with it, system may be a prominent solution for future 4G and 5G technologies.

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