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ANALYSIS OF THE EFFECT OF PROCESSING GAIN ON OPTICAL CODED IDMA AT MINIMUM LOSS USING RANDOM AND TREE INTER-LEAVER

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ABSTRACT

In this article, the effect of processing gain has been analyzed on optical coded IDMA at minimum loss. Processing gain is efficient parameter for direct–sequence spread spectrum communication on performance of optical IDMA system. IDMA is a recent multiple access technique through which multiple access interference (MAI) and inter symbol interference (ISI) can be minimized in the communication network. The convolutional codes are also used in this communication system for better error correction with variable processing gain and using random and tree inter-leaver in optical coded IDMA technique. In this article, the low rate convolutional codes are used, provides significant improvement in probability of error (P_e). By increasing the processing gain the performance of system will be enhanced. In this article effect of spreading i.e. processing gain variation is observed for random and tree inter-leaver for different number of users.

Keywords: optical coded IDMA, direct sequence spread spectrum, processing gain, convolution code, PSK modulation.

1. INTRODUCTION

In communication system, interleaving is known to be method generally used to overcome related channel noise as well as burst error or fading. Interleaving has been frequently used in communication system to improve the performance of forward error correcting codes. The user specific inter-leaver play vital role in the efficiency of IDMA system. Existing multiple access technique used in 1G/2G/3/G system has maximum data rate is approximately 72 Mbps. In 4G system, we must require more data rate as compared to 72 Mbps [1-2]. CDMA system used frequently in wireless communication has its own limitations of multiple access interference (MAI) and inter symbol interference (ISI) multiuser detection (MUD) is also complex issue appeared specially for large number of users. To improve the problems associated in CDMA as well as MC-CDMA (multicarrier) CDMA the new technique supports the criteria of 4G systems is IDMA. IDMA can be considered as a special case of direct sequence code division multiple accesses DS-CDMA.

InIDMA, data streams are separated by various inter-leavers instead of different spreading codes as used in DS-CDMA [3-4]. The O-IDMA system proposed is a technique in which inter-leaver are used in optical channel rather than wireless channel. As we know the better performance of optical channels in terms of SNR, BER, ISI, cost as well as supports good data rate as thousands of Gbps. In the system iterative chip by chip multiuser detection algorithm is used to reduce the complexity of MUD. Due to this it supports higher number of users.

In O-IDMA technique forward error correcting codes (FEC) can be used. For this we can use RS (Read-Solomon Codes), BCH codes, convolutional codes [5-7]. In proposed system low rate (1, 3) convolutional codes having less number of trellis are used for error correction. Random inter-leavers are the basic inter-leaver taken for analysis purpose. Effect of spreading length which basically indicates processing gain (PG) of the overall system is varying and effect of gain (PG) variation as proposed O-IDMA system with random inter-leavers are observed which gives a significant glimpse on improvement of BER of the whole system.

2. OPTICAL IDMA SYSTEM

In the block diagram of IDMA system is shown in figure 1, having q different users, offering single path of optical window 1550 nm. In consequence of q users having shown as $d_q= [d_q(1), d_q(ii)\ldots\ldots d_q(N)]^w$. If all q users have converted in code length n, it is assumed to be low rate. Where length of chip is indicated by w[8-10].

The chip c_q is interleaved by a chip level interleaver 'π_q', producing a transmitting chip sequence x, q = $[x_q(1), x_q(j), \ldots X_q(J)]T$. after transmitting through the channel, the bits are seen at the receiver side as u = $[u_q(1), u_q(2), \ldots U_q(J)]^w$. The channel opted is additive white Gaussian noise (AWGN) channel, for simulation purpose.

In receiver section, after chip matched filtering, the received signal from the q user can be written as

$$\mathrm{u}(j)=\sum_{q=1}^{q} h_q x_q(j)+n(j),\ \mathrm{j}=1,\ 2,\ \ldots..\ \mathrm{J}. \qquad (1)$$

Where h_q the channel coefficient for user-q and {n (j)} are samples of an AWGN process with zero mean and variance $\sigma^2 = n_0/2$, we assume that the channel coefficient $\{h_q\}$ are known a priori at the receiver.

In the receiver side, elementary signal estimator is used for multiple detection. APP and $SDEC_s$ have variable iterative mechanisms.

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The obtained outputs of various components for receiver are based on LLR_S. Which is expressed as

$$e(x_q(j)) = \log\left(\frac{p(x_q(j)=+1)}{p(x_q(j)=-1}\right) \text{for all q, and j} \qquad (2)$$

The produced LLR are further classified in two ways, one which is produced by PSE and another which is generated by DEC.

For special case of random interleave mechanism which is based on chip by chip type u (j)

$$u(j) = h_q x_q(j) + \rho_q(j) \qquad (3)$$

$$\rho_q(j) = u(j) - h_q x_q(j) = \sum_{q' \neq q} h_{q'} x_{q'}(j) + n(j) \qquad (4)$$

Where $\rho_q(j)$ is the distortion (including interference-plus-noise) in $u(j)$ with respect to user-q.

The concept and ethics involved in CBC has shown in equation 2, the function of ESEB and APP decoders are based on users. The obtained values of LLRS for both SDEC and ESEB are shown in the expression.

$$e_{SDEC}(x_q(j)) = 2h_q \frac{r(j) - E(u(j)) + h_q E(x_q(j))}{Var(u_j) - |h_q| Var(x_q(j))} \qquad (5)$$

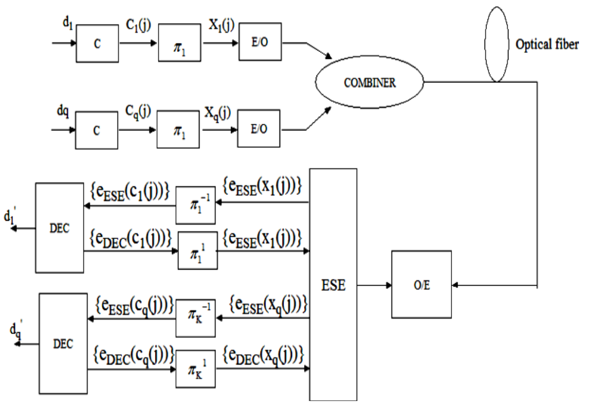

Figure-1. Optical IDMA transmitter and receiver structure.

3. RANDOM INTER-LEAVER

Interleaving is the mechanism of rearranging the ordering of data sequence in one to one deterministic format [11-12]. The basic role of an inter-leaver is to construct a block long code from small memory convolutional codes as long codes can approach the Shannons capacity limit. Secondary it spreads burst errors. The inter-leavers provides scrambled information data to the second component encoder and de-correlates inputs to the two component decoder so that an iterative suboptimum decoding algorithm based on uncorrelated information exchange between the two component decoder can be applied. The final role of the inter-leaver is to break low weight input sequence and hence increases the code free hamming distance or reduce the number of code words with small distances in the code distance spectrum.User Specific inter-leavers can be generated independently and randomly. The transmitter and receiver need to store or communicate many bits in order to agree upon an inter-leaver. It provides very good results in terms of BER (Bit Error Rate). The only disadvantage of random inter-leaver is that it suffers from the problem of large memory requirement which is undesirable.

The Random Inter-leaver rearranges the elements of its input vector using a random permutation. 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.

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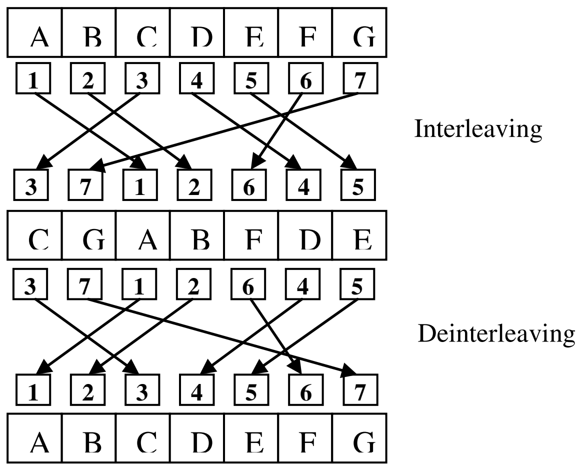

Figure-2. Random interleaver.

3.1. Tree based interleaver

The Tree Based Inter-leaver (TBI) is basically aimed to optimize the problems of the computational

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complexity and memory requirement which occurs in MRI and RI respectively. 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, using 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 14^{th} user, the TBI mechanism needs only 2 cycles of clock, as compared to many more cycles needed in case of master random inter-leaver method.

As already stated, the mechanism of Tree Based user-specific inter-leaver generation is based on two master inter-leavers Π1 and Π2, which are randomly selected. User specific inter-leavers are designed using a combination of randomly selected master inter-leavers. The inter-leaver Π1 is opted for upper branch while Π2 is reserved for initiation for lower branch. Upper branch is selected for the case of odd user count while lower branch is selected with even user count. First user is allocated with inter-leaver Π1 while the second user, is reserved with the inter-leaver Π2. In case of third user, the user-specific inter-leaver is decided with Π1 (Π1) and for fourth user, the interleaving sequence will be Π2 (Π1).

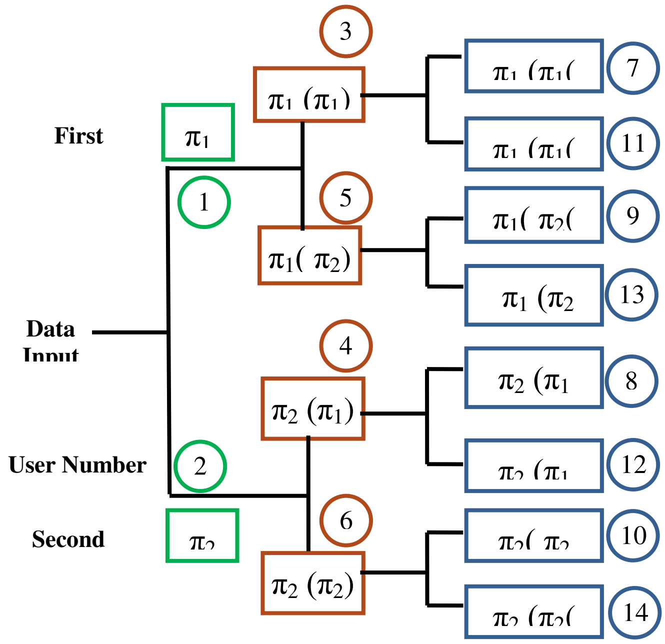

Figure-3. Tree based interleaving scheme.

4. CONVOLUTIONAL CODING

Two major types of codes are in common use: block codes and convolutional codes. Like block codes, convolutional codes can be designed to either detect or correct errors. However data are usually re-transmitted in blocks, block codes are better suited for error detection while convolutional codes are mainly used for error correction.

A convolutional coder creates redundant bits by using modulo-2 convolutions. Encoding of a convolutional code can be accomplished using general shift registers, and several practical procedure for decoding have also been developed.

In convolutional each n-bit encoded block not depend only on the k information bit input but it depends on the previous (m-1)q bit information bits[13-15]. The main difference between convolutional code and block code is that of memory existence in convolutional codes.

A general convolutional encoder is represented like (n, k, m) having m shift register and each register can store k bit information and also v-Ex OR gates are used to generate the encoded output sequence.

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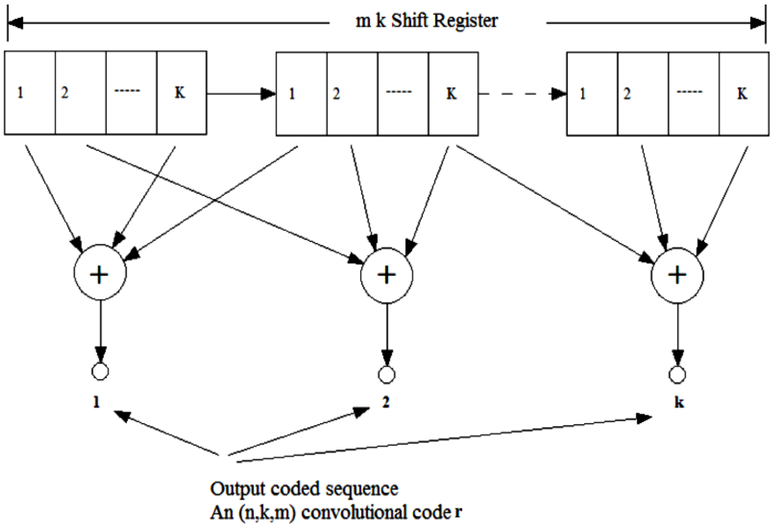

Figure-4. (n, k, m) convolution encoder.

4.1. Viterbi algorithm for decoding of convolutional codes

The Viterbi algorithm operates by computing a metric or discrepancy for every possible path in the trellis. The metric for a particular path is defined as the Hamming distance between the coded sequence represented by that path and the received sequence. Thus, for each node in the trellis and the algorithm compares the two path entering the code. The path with the lower metric is retained, and the other path is discarded. This computational is repeated for every level of trellis in the define range. The retained path are called survivor or active path.

5. PROCESSING GAIN

The processing gain is defines as the ratio of the bandwidth of spread message signal to the bandwidth of outspreaded data signal [16-18]. The processing gain represents the 'Gain' achieved by processing the spread spectrum signal over an outspreaded signal. For the NRZ bipolar signals the bandwidth of the signal is equal to 1/one bit period. The one bit period 'T_b' of data signal is equal to 'N' bits period of spreading pseudo-noise signal.

Thus is, $T_b = N\,T_C$ (6)

Processing Gain, P.G. = T_b/T_c (7)

5.1 PSK modulation

The general PSK method is called binary phase-shift keying (BPSK). It uses two differing signal phases (0 and 180 degree).The digital signal is cracked up time wise into separate bits. The stated of each bit is calculated according to the state of the preceding bit. If the phase of the wave does not change, then the signal state halts the same (0 or 1). If the phase of the wave changed by 180 degree that is, if the phase opposites then the signal state changes (from 0 to 1, or 1 to 0). Because there are two possible wave phases, BPSK is sometimes called bi-phase modulation.

The general form of BPSK equation:

$$S_n(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f t + \pi\,(1-n))\ , n = 0,1 \tag{8}$$

This provides two phases, 0 and π. In the specific form, binary data is regularly conveyed with the following signals:

$$S_0(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f t + \pi)\ for\ binary\ \text{"0"} \tag{9}$$

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f t)\, forbinary\ \text{"1"} \tag{10}$$

Where f is the frequency of the base band signal.
Bit Error Rate:

The bit error rate (BER) of BPSK in AWGN can be calculated as:

$$P_e = \frac{1}{2}\, erfc\sqrt{\frac{E_b}{N_0}} \tag{11}$$

Since there is only one bit per symbol, this is also the symbol error rate.

6. RESULT AND DISCUSSIONS

In this paper the simulation of optical IDMA with minimum loss optical window i.e. wavelength 1553nm is used for transmission and result of probability of error has been observed on MATLAB. Here processing gain which resembles to spread length is varied and result for different number of users using random inter-leaver and tree inter-leaver is observed.

For the simulation purpose data length is selected as 512 and 1024 spreading length varies from 16 and 32 maximum rate 1000Mbps. In optical domain transmitter power is 1mw using minimum attenuation window

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1553nm and optical detector APD having gain 1000, efficiency 0.85, and shape of pulse is Gaussian. The performance of OIDMA system may be upgraded by selecting the proper inter-leaver mechanism. In the system, random inter-leaver and tree inter-leaver are used. Random inter-leaver is simple in generation and it requires a lot of memory. In figure 5 the graph is plotted for bit error rate versus number of users having convolutional code rate (1,3) O-IDMA using random and tree inter-leaver with spreading length 16 and data length 512.In figure 6the graph is plotted for bit error rate versus number of users having convolutional code rate (1,3) O-IDMA using random and tree inter-leaver with spreading length 16 and data length 1024. In Figure-7 the graph is plotted for bit error rate versus number of users having convolutional code rate (1,3) O-IDMA using random and tree inter-leaver with spreading length 32 and data length 512. In Figure-8 the graph is plotted for bit error rate versus number of users having convolutional code rate (1,3) O-IDMA using random and tree inter-leaver with spreading length 32 and data length 1024.

The nature of graph is clearly indicates the theoretical trend that as number of user increases BER is enhanced. For increasing data length error is increasing rapidly.

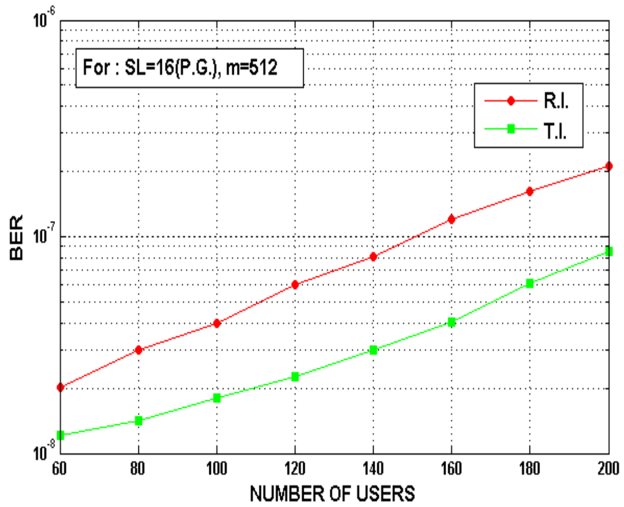

Figure-5. Convolutional coded rate (1, 3) O-IDMA using random and tree inter-leaver with processing gain = 16 and data length = 512.

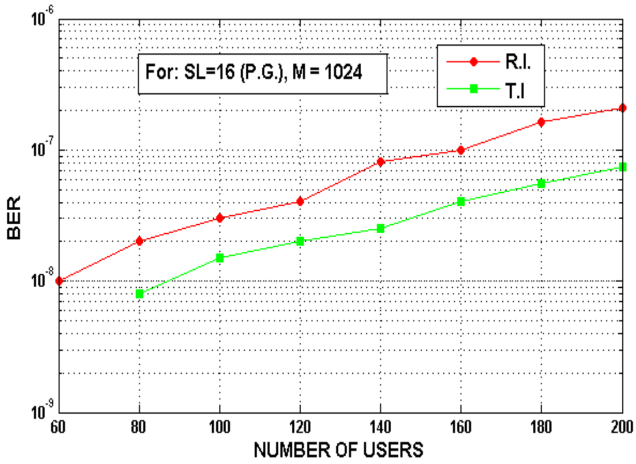

Figure-6. Convolutional coded rate (1, 3) O-IDMA using random and tree inter-leaver with processing gain = 16 and data length = 1024.

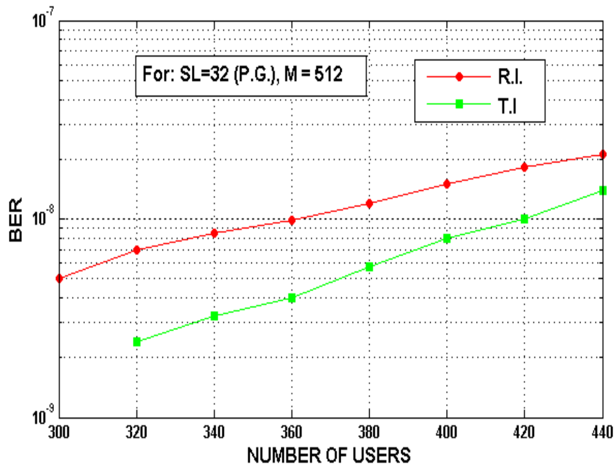

Figure-7. Convolutional coded rate (1, 3) O-IDMA using random and tree inter-leaver with processing gain = 32 and data length = 512.

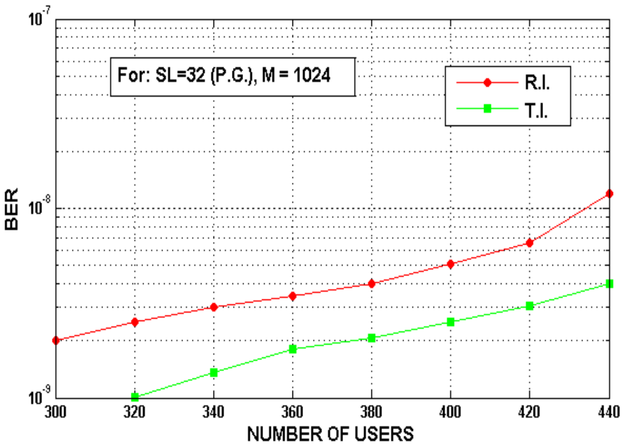

Figure-8. Convolutional coded rate (1, 3) O-IDMA using random and tree inter-leaver with processing gain = 32 and data length = 1024.

Where, RI = Random Inter-leaver, TI = Tree Inter-leaver, SL = Spread Length = Processing Gain (PG), m = data length

7. CONCLUSIONS

Spreading length is the important parameter which is used for processing gain measurement of the special type of DSSS system. When the processing gain varies from 16 to 32 then the performance of system is better. Therefore spreading length increases more and more, we find naturally more optimistic results. A random inter-leaver has its limited capability gives result of BER but tree inter-leaver provides better result in compare to random interleaver.

Thus it can be concluded that effect of processing gain variation on OIDMA is an efficient way of improving the performance of system. It gives high data rate, less multiple access interference, low ISI and cost dependent of number of users becomes one the better tool for forthcoming 4G systems.

Since we are using here APD in place of PIN detector performance is improved, as we know the qualities of APD have high internal gain and wavelength dependent responsively and high sensitivity characteristic. In further work by various efficiency and gain of APD we can get much improved performance of APD.

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