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Comparative Estimation Of Prime & Helical Interleavers In Oidma System

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Abstract
This article presents a comparative analysis of prime and helical interleavers in the OIDMA system. Previous research has explored various interleaver types for OIDMA, including random, tree, prime, and helical interleavers. In this paper, we used a fixed seed length of 7 for the prime interleaver and a fixed helical radius of 100 for the helical interleaver. We estimated the Bit Error Rate (BER) by varying the number of users and thoroughly analyzed the results. The entire OIDMA system was simulated using MATLAB.

Keywords- *Prime interleaver, Seed length, Helical interleaver, Helical radius, OIDMA, BER*

1. INTRODUCTION-

In telecommunications, interleaving enhances information transmission by consolidating data from diverse sources into a single channel. This method optimizes bandwidth utilization and reduces latency, ensuring smoother and more efficient communication. Error correction benefits from interleaving techniques are possible using various types of interleavers. In this method, parity bits are distributed across data segments, enhancing the system's ability to detect and correct errors, particularly those occurring in burst patterns. This significantly boosts data integrity and reliability in storage and transmission systems. In optical communication systems that utilize Interleave Division Multiple Access (IDMA) and Code Division Multiple Access (CDMA), interleaving plays vital roles that are specifically adapted to the unique challenges and goals of each generation. In Optical IDMA (O-IDMA), interleaving plays a critical role in enhancing the system's resilience to various optical impairments, including fiber dispersion and nonlinear effects. By rearranging data symbols across different time slots or frequency bands, interleaving helps mitigate burst errors and enhances the system's tolerance to channel impairments. This rearrangement also helps maximize spectral efficiency and reduce inter-symbol interference, enabling higher data rates and improved performance in optical networks. On the other hand, in Optical CDMA (O-CDMA), interleaving operates at the bit level by rearranging bits before transmission to disperse errors caused by noise and fading. This approach ensures that errors affecting consecutive bits do not compromise the entire data packet, thereby enhancing the reliability of data transmission in optical CDMA systems [1-3].

Overall, interleaving plays a crucial role in optimizing the performance and reliability of both Optical IDMA and CDMA systems, making them well-suited for high-speed and robust optical communication applications. Interleaving is essential in telecommunications, data storage, error correction, and cognitive psychology, where it enhances performance, reliability, and efficiency [4-6].

Optical Interleave Division Multiple Access (OIDMA) has emerged as a significant advancement in optical communication systems, offering improved spectral performance and flexibility in resource allocation. This paper examines the significance and potential of OIDMA in modern optical networks. OIDMA employs interleaved subcarrier modulation to effectively utilize optical channel resources, enabling multiple users to operate simultaneously while maintaining resilience against impairments. This summary provides an overview of the fundamental principles of OIDMA, highlighting its advantages over traditional multiple access techniques such as Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA). Through theoretical analysis and simulation studies, the performance metrics of OIDMA-such as spectral efficiency, scalability, and resilience to optical channel impairments-are assessed. The findings demonstrate OIDMA's capability to meet the increasing demands of high-speed and bandwidth-intensive applications in optical communication networks. This research advances OIDMA as a promising solution for future-proof optical network deployments, tackling challenges related to efficient and reliable data transmission over optical fibers [7-9].

Swaminathan et al. present a method for blind identification of convolutional and helical interleaver parameters using advanced algorithms for unsynchronized, convolutionally encoded data in the presence of bit errors. In summary, the numerical results indicate that the interleaver parameters have been successfully estimated under erroneous channel conditions using the proposed algorithms. Finally, the performance of the proposed algorithms for both interleavers, considering various bit error rate values, has been analyzed. This paper examines different types of interleavers to understand their advantages and disadvantages. Additionally, the placement of interleavers within turbo encoders and decoders is also discussed. Quality parameters such as Bit Error Rate (BER) and the BER curve are also analyzed to compare the quality of communication achieved with different interleavers. This paper discusses a recently developed method known as helical interleaving and highlights some of its applications. It examines the advantages of helical interleavers in comparison to traditional interleavers and also explores the relationship between helical interleavers and convolutional interleavers [10-13].

In this paper, Section 2 outlines the block diagram of Optical Interleave Division Multiple Access (OIDMA). A section 3 and 4 comprises the detail processes of helical and prime interleaver, respectively. Section 5 presents the simulation results and their discussion, while Section 6 concludes with a summary and explores future prospects.

2. OVERVIEW OF OPTICAL IDMA SYSTEM

An Optical Interleave-Division Multiple Access (OIDMA) system employs distinct interleavers to differentiate between the data of various users. At the transmitter, data from multiple users is encoded using Forward Error Correction (FEC) codes for error correction, interleaved with unique patterns, and modulated using a suitable modulation scheme. An Optical Interleave-Division Multiple Access (OIDMA) system utilizes distinct interleavers to differentiate the data of various users. These modulated signals then modulate an optical carrier generated by a laser diode [3-5].

The optical signals from all users are combined into a single optical signal for transmission through a fiber optic cable. At the receiver, the combined optical signal is separated into individual user signals using an optical demultiplexer. Each signal is converted back into an electrical signal using a photodetector, then demodulated to retrieve the interleaved data and de-interleaved using the corresponding unique pattern. The data is subsequently decoded with the FEC decoder to correct any errors, recovering the original user data. This system enables multiple users to efficiently share the same optical channel, enhancing bandwidth utilization and communication robustness. The detailed working principle of block diagram is explained below.

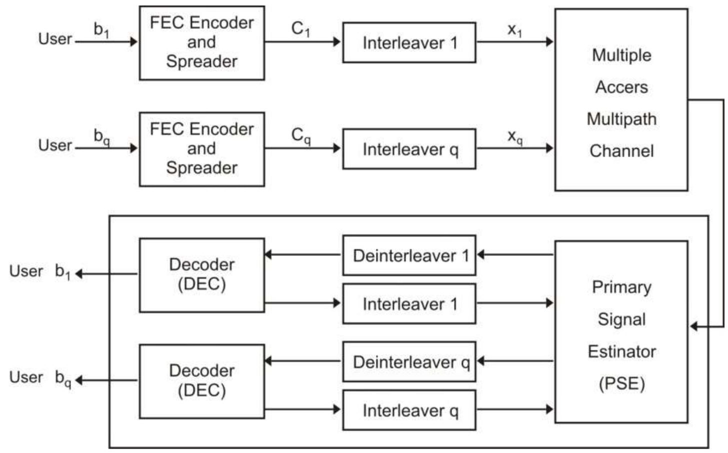

Fig. 1. Block Diagram of Optical Interleave-Division Multiple Access (OIDMA)

The block diagrams of the IDMA system illustrate the transmitter and receiver systems, which are explained below. Each user has a dedicated data source that generates a data stream for transmission. These data streams can represent different types of information, including text, audio, or video. Each user's data stream is processed through a Forward Error Correction (FEC) encoder. Common FEC codes include Low-Density Parity-Check (LDPC) and Turbo codes. This step adds redundancy to the data, enabling the receiver to detect and correct any errors that may arise during transmission. After encoding, each user's data is interleaved using a unique pattern. Interleaving rearranges the data bits according to a specific algorithm, allowing for the differentiation of various users' data even when they are combined. The interleaved data is then modulated using an appropriate modulation scheme, such as Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM) [9-12].

Modulation transforms the digital data into a format suitable for optical transmission. The modulated electrical signals are then used to modulate an optical carrier, usually produced by a laser diode. This process converts the electrical signals into optical signals. The optical signals from all users are then combined into a single optical signal using a multiplexer, which is subsequently transmitted over an optical fiber. Upon reaching the receiver, the combined optical signal is separated into individual user signals using an optical demultiplexer. This device splits the combined signal back into its component parts based on wavelength or other distinguishing characteristics. Each separated optical signal is converted back into an electrical signal using a photodetector. This conversion is essential for subsequent processing in the electrical domain [14-15].

3. PRIME INTERLEAVER

A prime interleaver is a technique used in virtual communications to rearrange data bits before transmission, minimizing the impact of burst errors and improving error correction capabilities.

It systematically shuffles the order of bits based on a sequence of prime numbers. Prime interleavers are a type of data reordering technique used in communication systems to enhance reliability and efficiency. They work by rearranging data into a non-sequential order before transmission. Prime interleavers are widely used in digital communication technologies, including wireless networks, satellite communication, and digital broadcasting, to ensure robust and error-resistant data transmission. Their ability to disperse errors across a wider spectrum is essential for maintaining data integrity in today’s communication systems [16-19].

For example, let's consider a series of data bits to be interleaved: [1, 2, 3, 4, 5, 6, 7, and 8]. we’ll choose a prime number, in this case, 5.

Interleaving Process:

Divide the series into groups based on the prime number (5 in this case). Then, rearrange the bits within each group according to a specific order, typically determined by a mathematical method that involves the group index and the prime number [1, 18].

Applying this to our example: Interleave the bits within each group according to a predefined pattern. For simplicity, let's reverse the order of each group.Divide the collection into five businesses:

Group 1: [1, 6]
Group 2: [2, 7]
Group 3: [3, 8]
Group four: [4]
Group 5: [5]

Group 1 interleaved: [6, 1]
Group 2 interleaved: [7, 2]
Group 3 interleaved: [8, 3]
Group 4 interleaved: [4]
Group five interleaved: [5]

Combine Interleaved Groups: Concatenate the interleaved groups to form the very last interleaved collection.

Final interleaved sequence: [6, 1, 7, 2, 8, 3, 4, 5]

This rearranged sequence, [6, 1, 7, 2, 8, 3, 4, and 5], is then transmitted or processed in the same manner. The receiver knows the interleaving pattern and can de-interleave (reverse the process) to recover the original sequence of bits.

4. HELICAL INTERLEAVER

Helical interleaving is an advanced technique used in access methods such as Iterative Decoding Multiple Access (IDMA) to improve error performance by dispersing each user's data bits over a longer duration [11, 13].

Mathematically, helical interleaving for 2-Dimensional TPCs can be calculated as follows. If the original elements in a 2-D array are indexed by rows and columns (as seen in software arrays or hardware RAM), the index for helically reading the bits is determined as follows:

$$j = i(n_x + 1) mod\ (n_x n_y), \quad \text{(1.1)}$$

$$i = \{0,1,2 \ldots n_x n_y - 1\} \quad \text{(1.2)}$$

Where, i is the original index, j is the helical index, n_x is the number of bits in the x dimension code and n_y is the number of bits in the y dimension code. Similarly, in the 3-D case the helical index is computed as

$$j = i(n_x n_y + n_x + 1) mod\ (n_x n_y n_z), \quad \text{(1.3)}$$

$$i = \{0,1,2 \ldots n_x n_y n_z - 1\} \quad \text{(1.4)}$$

Where, n_z is the z dimension code.

In both instances, helical interleaving functions as an addressing scheme that adds minimal complexity.

We illustrate helical interleavers with the following example, which involves interleaving a code with a block length of four symbols, as shown in Figure 2.

The numbering indicates the time ordering of the symbols at the interleaver. The codewords are arranged in the columns of a helical array, as illustrated in Figure 2. Once completed, the rows of the array are read and transmitted.

1	*	*
2	5	*

3	6	9
4	7	10
13	8	11
14	17	12
15	18	21
16	19	22
25	20	23
26	29	24
27	30	33
28	31	34
	32	35
		36

Fig. 2: Helical Interleaving

This is an example of a code of length 4 with a helical interleaving depth of 3. A depth of 3 indicates that a burst must be at least 4 symbols long to affect any codeword more than once. It's important to note that consecutive symbols of a codeword are separated by exactly four symbols, allowing the receiver to maintain synchronization modulo 4. The deinterleaving process is the inverse of the interleaving process. In fact, the entire interleaver and deinterleaver operation is symmetric.

The above helical interleaver construction method can be generalized to any block length N with interleaving depth N-1. The total interleaving delay is (N-2)*(N-1) and the memory requirement is N(N-1)/2; both are only about one half of the corresponding parameters for a block interleaver of equal depth[8]. The conventional depth (N-I) block interleaver for a code with length n requires the receiver to know the synchronization modulo N*(N-1).

5. SIMULATION RESULT AND DISCUSSION-

The whole OIDMA system is simulated on MATLAB. Some parameters such as spread length 16, block length 100, E_b/N_O is 3, and data length 512 has been fixed. Optical parameters like optical source of 1330 nm zero dispersion wavelength, fiber length, A_{eff} and APD detector etc.

Table 1 gives the tabular form representation and Fig. 3 gives the graphical form representation of BER verses number of users for prime and helical interleaver in OIDMA system. When the number of users is 50, the prime interleaver gives BER (7.8125×10^{-7}) and helical interleaver gives BER (5.3274×10^{-8}). When the number of users is 60, the prime interleaver gives BER (1.3021×10^{-6}) and helical interleaver gives BER (3.7240×10^{-7}). The observed reading of BER indicates the same trends from by varying users from 50 up to 110.

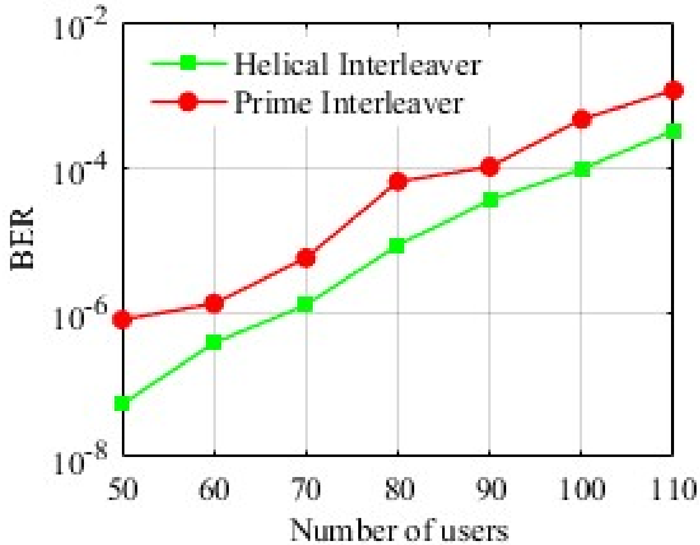

Fig. 3. Comparative BER Performance of Prime and Helical Interleaver in OIDMA System

Table1: Comparative BER Performance of Prime and Helical Interleaver in OIDMA System

S. N.	No. of Users	Bit Error Rate	
		Prime Interleaver PR = 7	Helical Interleaver R = 100
1	50	7.8125×10^{-7}	5.3274×10^{-8}
2	60	1.3021×10^{-6}	3.7240×10^{-7}
3	70	5.5112×10^{-6}	1.2435×10^{-6}
4	80	6.2510×10^{-5}	8.3140×10^{-6}
5	90	9.9979×10^{-5}	3.4340×10^{-5}
7	100	4.5352×10^{-4}	9.3462×10^{-5}
8	110	1.1354×10^{-3}	3.1690×10^{-4}

6. CONCLUSION

By analyzing the results it was observed that helical interleaver give low BER for larger traffic intensity as compared to prime interleaver. By increasing the helical radius results will be more optimistic because helical radius directly affects BER. We have used zero dispersion wavelengths 1330nm for transmission which also reduce the loss and improve the BER. Overall we can conclude that by using helical interleaver in OIDMA system is a better alternative to replace existing interleavers used in OIDMA technique in modern communication network.

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