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Performance of OFDM ISP system using Viterby Code to Overcome CFO

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Abstract--The telecommunications industry has evolved significantly, with advancements from 1G to 4G and now towards 5G, promising enhanced data speeds and connectivity. Orthogonal Frequency Division Multiplexing (OFDM) is crucial in this transition due to its efficient spectrum utilization and ability to handle frequency-selective fading. However, OFDM is susceptible to Carrier Frequency Offset (CFO), leading to Inter-Carrier Interference (ICI) and degraded performance. This research explores the integration of OFDM with Improved Sinc-power Pulse (ISP) and Convolutional Channel Coding to mitigate ICI and enhance system reliability in the 5G era. Using MATLAB simulations, we assessed the impact of CFO on OFDM systems with and without ISP pulse shaping and Convolutional Coding. Results showed that Convolutional Coding significantly improves performance by reducing ICI, achieving a Bit Error Rate (BER) of approximately 0.0018. ISP pulse shaping, combined with Convolutional Coding, effectively minimizes frequency offset effects and improves system performance, offering a robust solution for future wireless communication systems.

Keywords--OFDM, 5G, CFO, ISP, Convolutional.

Introduction

Rapid developments in telecommunication technology, particularly in wireless communication systems, have driven an increasing need for greater data capacity and higher transmission reliability. One of the key technologies that plays an



important role in meeting these needs is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is able to divide a signal into a number of mutually orthogonal frequency subcarriers, thus optimizing the use of available spectrum and reducing the effects of frequency selective fading. This technology is widely adopted in modern communication standards such as 4G LTE and is the main foundation in the development of 5G networks.

However, OFDM also has drawbacks in the form of high sensitivity to Carrier Frequency Offset (CFO), which can lead to Intercarrier Interference (ICI) between subcarriers. This condition has the potential to significantly degrade system performance, especially in variable multipath channel environments. Therefore, an effective mitigation method is required to overcome this problem.

One promising approach is the use of Improved Sinc-Power Pulse (ISP Pulse), which is proven to reduce the impact of ICI more efficiently. In addition, the application of Viterbi Code as a channel coding technique also makes an important contribution in maintaining data integrity and correcting errors that occur during transmission. The combination of pulse shaping and coding techniques offers a solution that is more resilient to interference and dynamic channel conditions, making OFDM systems more reliable.

This study aims to evaluate the performance of OFDM systems with ISP Pulse in the face of Carrier Frequency Offset variations, and analyze how the application of Viterbi Code can improve the overall performance of the system. MATLAB simulation is used to test the effectiveness of the proposed method in various fading channel scenarios, focusing on transmission quality improvement and ICI reduction. Through this approach, it is expected that the research results can provide new insights in the optimization of wireless communications in the next generation.

Methods

Orthogonal Frequency Division Multiplexing (OFDM) is a transmission method that uses multiple carrier frequencies (multicarriers), where each sub-carrier is orthogonal and harmonized. This allows overlap between sub-carriers without causing inter-carrier interference (ICI). Compared to conventional modulation such as Frequency Division Multiplexing (FDM), OFDM offers higher spectral efficiency [6]. In an OFDM spectrum, each subcarrier consists of a main lobe and several side lobes. When the orthogonality between subcarriers is disturbed, these side lobes can generate ICI power in the center area of the subcarrier. The increase in ICI occurs due to the Carrier Frequency Offset (CFO). Pulse shaping techniques are designed to suppress the amplitude of side lobes that can cause ICI, so that the performance of OFDM systems can be improved [7].

Carrier Frequency Offset (CFO) occurs due to the influence of the Doppler effect or the frequency difference between the transmitting and receiving oscillators, which results in the loss of orthogonality between subcarriers. This triggers ICI, where the side lobe of one subcarrier interferes with another subcarrier. CFO is represented by the normalized value ϵ , which indicates the amount of subcarrier shift detected by the receiver oscillator [8][9][10][11].

In this research, data is obtained through simulation. The simulation stage includes OFDM modeling using Matlab Script for selective fading channels affected by frequency offset. The model includes random bit generation, BPSK modulation, OFDM signal processing, and OFDM system testing over AWGN and selective fading channels. To assess the system performance, performance metrics such as Bit Error Rate (BER) and bit energy to noise density ratio (E_b/N_0) are calculated. The parameters used in the simulation are presented in Table 1 below.

Table 1. Simulation Parameter

Parameter	Values used
Number of Bit	100.000
Modulation Type	BPSK
User Type	Single User
Channel Type	Frequency Selective Fading
System Type	OFDM
Subcarrier spacing	15 kHz
Carrier Frequency Offset	3kHz, 6kHz, 9kHz

Research Flow

This research follows a structured process to implement each stage of the study. Simulations are performed by applying frequency offset parameters to standard OFDM and ISP OFDM techniques. Then the effect of frequency offset on system performance is analyzed. After identifying the impact of frequency offset, channel coding techniques are applied to mitigate the effect. In this study, Viterbi channel coding is used for mitigation.

Simulation Procedure and Process

Simulation parameters are selected based on references from relevant literature and adapted to the research objectives. This research aims to evaluate the effect of Carrier Frequency Offset (CFO) on ISP OFDM systems, identify problems that arise, and offer solutions to these problems. To observe the impact of CFO, simulations are performed by comparing channel performance with and without frequency offset. Variations in frequency offset values are used to evaluate its effect, which is then measured through Bit Error Rate (BER). The higher the BER value, the greater the negative impact caused by the frequency offset.

Once the problem caused by frequency offset is identified through the BER value, the next step is to find a solution. In this study, the Viterbi coding method is used to minimize the negative impact of CFO on ISP OFDM systems.

This simulation compares the performance of three systems: OFDM, ISP OFDM, and ISP OFDM with Viterbi coding. The results of this comparison are displayed in a plot showing the relationship between BER and E_b/N_0 , where a lower BER value indicates better system performance.

Results and Discussions

Performance Analysis of OFDM IPS with Viterby Code using the Impact of Frequency Offset Variations

The block diagram of an OFDM system integrated with pulse shaping and viterby code techniques is depicted in Figure 2. Pulse shaping modifies the transmitted symbol pulses, where each symbol is multiplied by a pulse shaping function to suppress side lobes, resulting in a reduction of ICI (intercarrier interference).

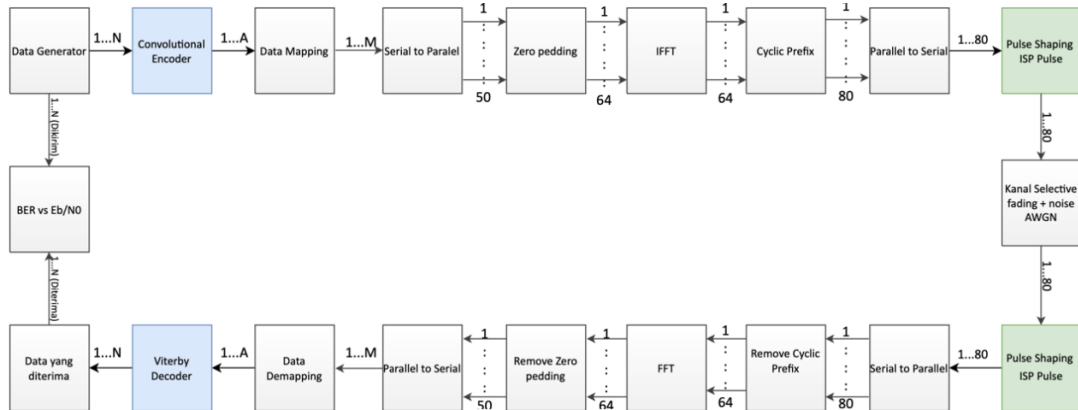


Figure 1. Block Diagram of ISP OFDM System with Convolutional Code

The application of Pulse Shaping as a solution to the frequency offset that occurs in the OFDM system. Briefly, it can be explained that the frequency offset makes the side lobe shift so that the signal becomes unorthogonal and interferes with other subcarriers. This can be reduced by pulse shaping which compresses the side lobe by reducing the amplitude of the side lobe so that it does not interfere with each other. In this simulation, the Improved Sinc Power Pulse (ISP) pulse shaping type is applied. Viterby code serves to protect information or data bits from errors that may occur during the transmission process by adding additional bits (redundancy) into the data to be sent. Then on the receiver side, the data is decoded to detect and correct errors so as to produce an output that is close to the transmitted bits.

The block diagram of the OFDM system combined with the pulse shaping method and Viterby code can be seen in Figure 1. By performing simulations based on the block diagram modeling as shown in Figure 1, the results are obtained in the form of comparison graphs of the use of pulse shaping as shown in Figures 2 and 3. Frequency offsets of 3 kHz, 6 kHz and 9 kHz are used as samples in this simulation. Viterby code has an important role in protecting data bits from potential errors during transmission by adding redundancy bits. Simulations based on the block diagram in Figure 1 resulted in the comparison graph shown in Figure 3, with an example frequency offset of 3 kHz. From Figure 3, it is clear that the inclusion of Viterby code coding significantly improves the ICI reduction. This is achieved because the Viterby code protects the data bits from errors by adding redundancy bits. When received, the data is decoded to detect and correct errors, resulting in an output that is close to the original transmission.

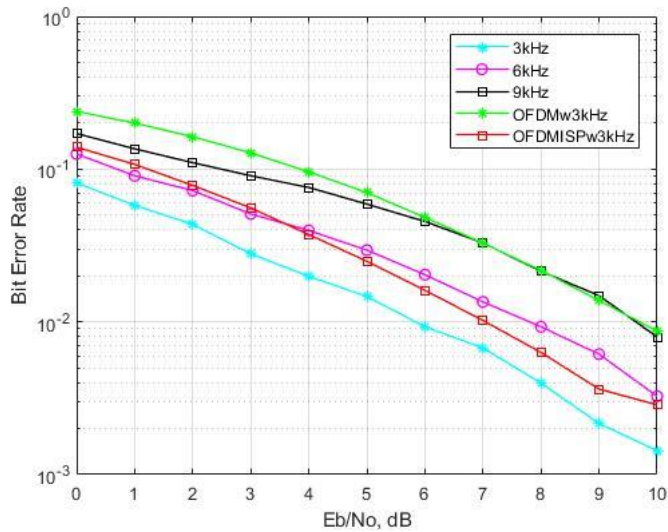


Figure 2. Performance Comparison with Viterby Code

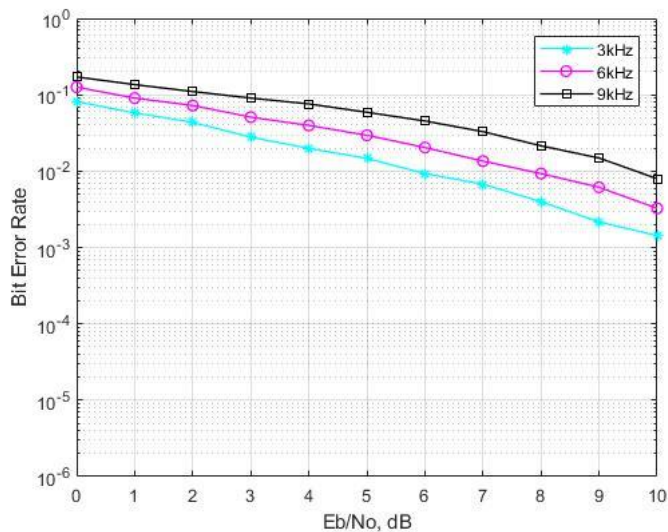


Figure 3. Performance Comparison with Frequency Offset Parameters

Simulation results analyzing the effect of Viterby Code on ISP OFDM systems with frequency offset show that Viterby Code improves system performance by minimizing inter-subcarrier interference and reducing ICI power. It is also concluded that convolutional coding is more effective in reducing ICI. In this simulation, the OFDM ISP system with convolutional coding provides the best solution to overcome CFO, achieving a BER of about 0.0018, which reflects the optimal system performance through BER reduction.

Conclusion

Research and discussion on the impact and mitigation of Carrier Frequency Offset (CFO) on Orthogonal Frequency Division Multiplexing (OFDM) systems show that OFDM systems using ISP and Viterbi coding are more effective in reducing Inter-Carrier Interference (ICI). This can be seen from the BER vs Eb/No graph, where the ISP technique consistently produces a lower BER compared to the OFDM ISP technique without pulse shaping. When combined with Viterbi coding, the system is able to achieve a BER value of around 0.0018. The ISP technique proved superior in reducing ICI by flattening the side lobes of each subcarrier, thus preventing interference between subcarriers when ICI occurs. Viterbi coding strengthens the protection against errors by adding redundancy bits that serve to protect the transmitted data from potential errors during the transmission process.

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