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Researching the impact of DC offset on communication and identifying optimal solutions

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Abstract. With the continuous advancement of communication methods, enhancing the quality of communication has become a crucial concern. Through the examination of this matter, it has been discovered that the increase in Bit Error Rate (BER) directly affects the overall quality of communication. This paper utilizes MATLAB to perform mathematical simulations, focusing on two main areas of study. Firstly, it investigates whether the DC offset is responsible for the increase in BER within the communication system. Additionally, it examines the effectiveness of three algorithms (IIR, FIR, and subtract mean) in mitigating the impact of DC offset on BER. By comparing these algorithms, FIR was determined to be the optimal method for eliminating DC offset. This article aims to offer a valuable reference for enhancing communication quality in the future.

Keywords: DC offset, MATLAB, IIR, FIR, subtract mean.

1. Introduction

Communication between individuals has become increasingly convenient in recent times because of the advancements that have been made in the field of communication technology. The methods of communication have also progressed over time, beginning with the use of ancient beacons and pigeons, and progressing to the use of mobile phone calls on smartphones and even more advanced satellite calls. To give one of the most intuitive examples, hundreds of years ago the main way to send a letter from the send to receive needed to wait for nearly a year, but now in different parts of the people just through the phone can immediately communicate with each other and can also see each other through the video call. Consequently, improving the quality of communication has become a persistent research concern in recent years. Many factors affect the quality of communication in a communication system, such as the strength and quality of the signal signals sent, interference and noise, and modulation and coding schemes. The primary focus of this paper is on the utilization of the mathematical model MATLAB to simulate DC offset to investigate and prove its influence on communication quality. Additionally, the paper examines the utilization of three distinct methods, namely Finite Impulse Response (FIR), Infinite Impulse Response (IIR), and subtract mean, to eliminate the influence of DC offset on communication quality, The optimal approach is determined by evaluating the Bit Error Rate (BER) reduction of a communication system when employing these three methods. The comparison is made under identical conditions, including the presence of noise and spectrum, as well as the same percentage of DC bias added to the original waveform. This article demonstrates the presence of DC offset through the

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utilization of MATLAB's mathematical model. It identifies the most efficient remedy for DC offset, offering valuable insights for enhancing communication quality in the future.

2. Literature review

Prior research has established that the problem of local oscillator leakage leads to a substantial direct current offset in the baseband and overwhelms the baseband circuits, thereby severely impacting the quality of communication [1]. This problem is challenging and requires resolution in the realm of communication. Consequently, three methods have been devised to address this issue, namely Finite Impulse Response (FIR), Infinite Impulse Response (IIR), and Subtract Mean, respectively [2]. First and foremost, it is crucial to possess a comprehensive comprehension of the concept of DC offset. The presence of DC offset is a result of leakage from the local oscillator. The presence of a powerful local oscillator (LO) signal and its harmonics result in the transmission of unwanted signals to the input of the mixer, leading to the generation of spurious signals in the proximity of DC, commonly referred to as DC offset [3]. DC offsets often lead to baseline shifts and distortions in the signal, which in turn impact the process of signal demodulation and recovery. Furthermore, DC offset is a significant design problem in communication circuits, as it leads to the inclusion of numerous undesired DC components [4].

3. Research part

3.1. Demonstrate DC offset improves the bit error rate.

The primary objective of this section is to investigate whether DC offset is responsible for an increase in the bit error rate (BER) of communication systems. The occurrence of errors in a transmission system is commonly known as the bit error rate or BER. This can be directly quantified as the cumulative number of errors, and the formula of bit error rate [5] is:

BER = number of errors / total number of bits sent

This paper chose to utilize a mathematical modeling approach and utilized MATLAB to generate BER curves for both cases: with and without the inclusion of DC bias, on identical frequency bands. Subsequently, a comparative analysis was carried out to assess the variation of the curves in the presence of equal chip energy and noise spectral density. The BER curves in the 2450MHz band were generated using MATLAB, then can get the following graph:

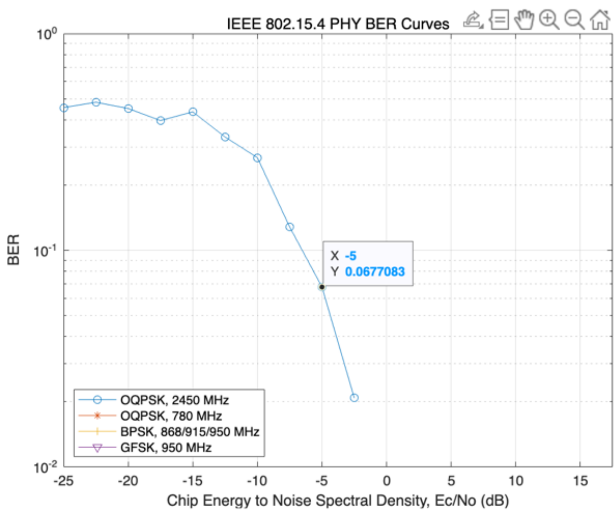

Figure 1. Before adding the DC offset.

When the chip energy to noise spectral density is equal to -5dB, the BER can be determined to be 0.0677083, which is the bit error rate (BER) without adding the DC offset. Then, a new BER curve is created by choosing 0.3 times the maximum waveform as the DC offset value, again using MATLAB to plot the BER curve for the 2540MHz band. The following graph is then obtained:

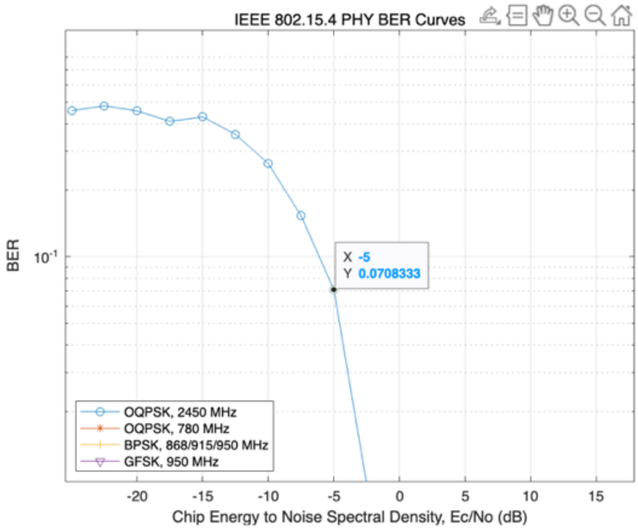

Figure 2. After adding the DC offset.

The BER is equal to 0.708333 with the same chip energy to noise spectral density of -5dB, as shown in figure 2. This results from adding the DC offset, which we can see from the figure. Upon examining these two graphs, it is evident that the Bit Error Rate (BER) will be greater when the data is accompanied by a DC offset, as compared to the original data without the additional DC offset. The equivalence of chip energy to noise spectral density allows people to have an intuitive understanding of this concept. According to the data provided, it is evident that DC offset leads to an elevated bit error rate (BER) in the communication system. The presence of a DC offset that is 0.3 times the maximum waveform value results in a bit error rate (BER) that is approximately 0.003 times higher compared to the BER without any DC offset. This is observed when the chip energy to noise spectral density is precisely -5dB.

3.2. Finding the most efficient algorithm.

In the previous section, it was shown using a mathematical model that DC offset leads to an increase in the bit error rate (BER) of a communication system when the chip energy is held constant with the noise spectral density. This was demonstrated by demonstrating that DC offset causes an increase in the bit error rate. As a result, it is of the utmost importance to get rid of the DC offset that is present in the reception signal. Three distinct estimation algorithms can be employed to eliminate the DC offset of the input signal for the purpose of resolving this issue. The algorithms mentioned are the Infinite Impulse Response (IIR), Finite Impulse Response (FIR), and Subtract Mean. The main objective of this research part is to identify the algorithms among the three options using mathematical modeling in MATLAB to find out the most effective algorithm among these options to reduce the bit error rate (BER) due to DC offset.

3.2.1. Infinite Impulse Response (IIR). First, a DC blocker system object is created using the IIR algorithm and named dcblker. The purpose of this object is to eliminate the DC offset in each channel (column) of the input signal by ensuring that the value of dcblker is equal to dsp. DC Blocker is a device used to remove direct current (DC) components from an electrical signal. The use of IIR is widespread in various communication systems to tackle diverse problems [6]. Currently, the focus is on the DC offset problem. By implementing a DC blocker, the convergence time was observed to vary in one-second intervals. In the MATLAB mathematical model, configure the Infinite Impulse Response (IIR) algorithm to operate with the dc1 setting. Additionally, it is programmed to process the input signal through a DC blocker every second. In addition, it was configured to transmit the signal through the blocker at a frequency of once per second. As a result, the following figure was obtained:

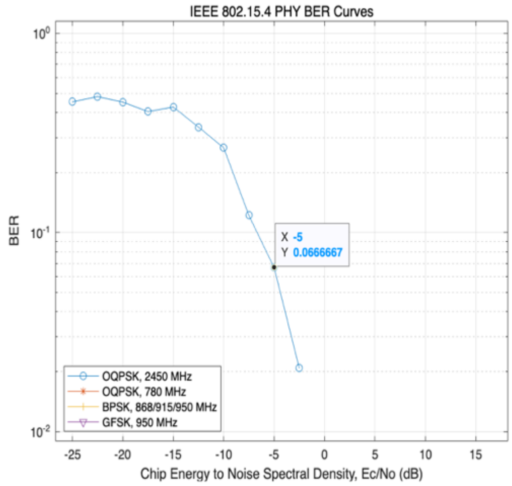

Figure 3. After using IIR

As can be seen from Figure 3, the bit error rate (BER) is equal to 0.0666667 when the chip energy to noise spectral measurement is equal to -5dB. When compared to Figure 2, which only includes the addition of DC offset, the BER rate has decreased, and the value has decreased by approximately 0.003.

3.2.2. Finite Impulse Response (FIR). The second algorithm, also known as FIR, is utilized. The finite impulse response (FIR) digital filter is a filter that operates in the spatial domain and is represented in the frequency domain [7]. The FIR filter is built using multipliers, adders, and signal delay as its fundamental components [8]. The finite impulse response (FIR) is a nonlinear filtering technique that functions exceptionally well in the elimination of impulsive noise [9]. The graph displayed is the outcome of implementing the Finite Impulse Response (FIR) algorithm on a novel mathematical simulation system using MATLAB. This system exhibited identical spectrum and DC bias characteristics to its predecessor.

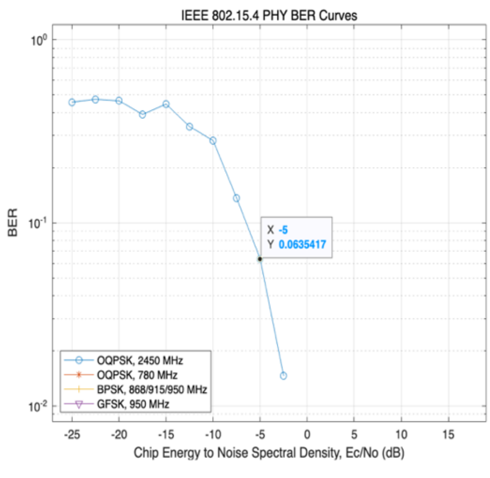

Figure 4. After using FIR

Based on the Figure 4, it can be determined that the bit error rate (BER) of the communication system is 0.0635417 when the chip energy to noise spectral density is below -5 dB. The addition of the FIR algorithm results in a significant reduction in the BER, which is significantly lower than the BER that was caused by the DC being turned off in Figure 2, it has decreased by approximately 0.007.

3.2.3. Subtract Mean. The algorithm that calculates the difference between the average value and each value is employed in the last part. The subtract mean can greatly improve the quality of voice calls made through the communication system [10]. In this section, the investigation will focus on the use of subtract mean filters for DC offset cancellation. By configuring the subtract mean filter to dc3 in the MATLAB simulation system and integrating it into the existing system environment, then can obtain the resulting graph.

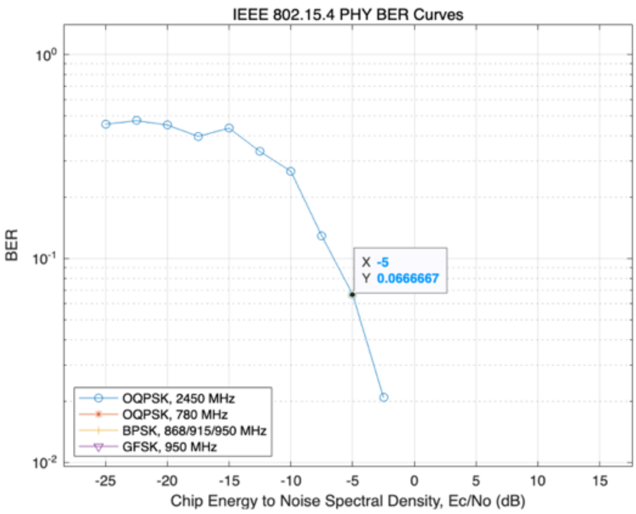

Figure 5. After using Subtract Mean.

When the energy-noise spectral density of the chip is -5, the bit error rate (BER) of the communication system can be determined to be 0.0666667. This is based on the figure that was presented earlier. Implementing subtract mean filters reduces the bit error rate (BER) by approximately 0.003.

3.3. Result of the research

Upon comparing the three methods, it becomes evident that the Bit Error Rate (BER) achieved using the Finite Impulse Response (FIR) algorithm is the lowest. Therefore, it can be concluded that FIR is the most effective method for eliminating DC offset.

4. Conclusion

This article uses MATLAB for mathematical simulations. In the first, waveforms that did not contain any DC offset were simulated and had a frequency of 2450MHz. Afterwards, the waveform with 30% DC offset is simulated on the same spectrum and the two results are compared in the case of the chip energy to noise spectral density of -5dB. Research has demonstrated that the Bit Error Rate (BER) of the communication system is increased when a DC offset waveform is included. Therefore, it is possible to conclude that the incorporation of DC offset results in an increase in the bit error rate (BER) of the communication system. In the second part, MATLAB is utilized to assign the names dc1, dc2, and dc3 to the three algorithms Infinite Impulse Response (IIR), Finite Impulse Response (FIR), and subtract mean, respectively. These algorithms are then incorporated into the waveforms with an equal amount of DC offset on the same frequency spectrum. Subsequently, they are compared to each other under the condition of a chip energy to noise spectral density of -5dB. By comparing the three algorithms to assess to what extent they reduce the bit error rate (BER). Thus, it can be inferred that the Finite Impulse Response (FIR) algorithm operates within the same environment to eliminate DC offset, which is the most efficient method for significantly enhancing communication quality. The limitation of this paper is that, because of the restricted research conditions, the comparison of the three solutions is restricted to the scenario where the energy-noise spectral density of the chip is -5dB. To obtain more precise results, future investigations will encompass a wider range of chip energy-noise spectral density cases.

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