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Binary Phase Shift Keying Simulation with MATLAB and SIMULINK

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ABSTRACT

Digital Communication follows one fundamental concept and it is the transfer of information from one point to another over an analog channel. In our modern society there is one method which is versatile and widely used in transferring digital data and this method is called Digital Phase Modulation. In Digital Phase Modulation it is possible to use discrete values in the carrier frequency or amplitude in order to represent their values in ones and zeros. Given this possibility, it can be concluded that it is also possible to represent digital data using phase. Such technique is called Phase Shift Keying. The easiest approach to Phase Shift Keying is the Binary Phase Shift keying or BPSK. In Binary Phase Shift Keying, hinted from the keyword binary, it uses only two phases with each used for logic high and logic low which can be represented with a minimum and maximum value of 0 degrees for logic low and 180 degrees for logic high. This Modulation Technique utilizes a balance modulator which consists of a carrier sine wave and a binary sequence which is to be used as input in order to generate the Phase Shift Keying Output desired.

Key words: Digital Communication, Digital Phase Modulation, Phase Shift Keying, Binary Phase Shift Keying.

1. INTRODUCTION

In communication systems, different layers are used in order to communicate. One necessary layer is the physical layer. A deep comprehension of the physical layer is needed to be able to understand the concept of information communication at the core level. It is also important to understand the concept of how information is being communicated from one point to another by physical means [1]. The physical layer is able to supply connectivity to two nodes that are connected with each other. The nodes may either be connected through a wire or through a wireless link.

The basic idea of digital communications is that digital data and information are moved from different points over a channel that is presented in analog. To be more specific, passband digital communication entails the modulation of the amplitude, phase, or frequency of an analog carrier signal with a baseband signal [2].

Digital communication of data at the physical level could be accomplished by using various different methods. One of these methods is the digital phase modulation. Digital phase modulation has a special case known as the phase shift keying or PSK. The phase shift keying technique is a method in which the data is used to shift the phase of the carrier [3]. Phase shift keying has two common types, namely, the quadrature phase shift keying (QPSK) and binary phase shift keying (BPSK) [4].

The binary phase shift keying, or BPSK, is known as the simplest form of digital phase modulation. The signal in this digital phase modulation is a sequence of ones and zeros, thus the term binary [5]. The carrier signal is directly phase modulated in this digital phase modulation. Each symbol in the BPSK signal represents a single bit. With the use of the input binary data, the phase of the carrier is shifted. In order to generate the BPSK signal, the carrier signal is applied to a balanced modulator.

This paper will focus on simulating BPSK to test its performance through simulations. Different bit binary sequence numbers will be tested. This is to fully understand the concept of the modulation and to realize how to maximize its uses.

2. BACKGROUND OF THE STUDY

As previously stated, a binary phase shift keying (BPSK) technique involves the use of binary symbols ‘1’ and ‘0’ to modulate the phase of the carrier signal [6,7]. It is assumed that the carrier is given as S(t) = Acos(2pifct), where A is the peak value of the sinusoidal carrier. With the use of the peak value, the power dissipated can be obtained by using P = (½)A2. In terms of the peak value, A is equal to the square root of the power dissipated multiplied to two. The phase of the carrier signal is changed by 180 degrees in the event the symbol is changed.

In BPSK generation, applying a carrier signal to a balanced modulator will generate a BPSK signal. The baseband signal b(t) is used as a modulation signal being fed into the balanced modulator [8]. The binary data sequence is converted into a bipolar NRZ with the use of an NRZ level encoder.

On the other hand, BPSK transmitter involves the balanced modulator acting as a phase reversing switch. The carrier signal could be transferred to the output in two ways. It may either be in phase or 180 degrees out of phase with the reference carrier oscillator when sent to the output. The balanced modulator has two inputs, namely, the carrier signal and the binary digital data. In the BPSK transmitter, the digital input voltage must be greater than the peak carrier voltage in order for the balanced modulator to work.

In the reception of the BPSK signal, it takes the form $S(t)= b(t)\sqrt{2P}\cos(2\pi fct+\theta) = b(t)\sqrt{2P}\cos 2\pi fc(t+\theta/2\pi fc)$, where the angle θ is a fixed phase shift. This phase shift is dependent on the length of the path from the transmitter to the receiver. The original b(t) signal is obtained again during demodulation.

3. STATEMENT OF THE PROBLEM

The simplest form of phase shift keying (PSK) is the Binary Phase Shift Keying (BPSK). The phase of the carrier is being controlled by the individual data bits. The modulator shifts to either a 180 degrees phase or **π** radians, in each interval of a bit [9]. Due to its simplicity and flexibility, this modulation technique has been used for numerous applications. It has several advantages, but at the same time, it also has its drawbacks, like how BPSK is not the best bandwidth efficient type of modulation, compared to the other types of modulation [10]. Being well informed of its limitation is essential in order to know how to adequately use the said technique by maximizing its performance and capabilities. The goal of this paper is to test the modulation technique all throughout knowing as well how it should work. The software to be used is MATLAB so as to better perceive its concept and its functions.

4. SIGNIFICANCE OF THE STUDY

The focus of this research is to further learn and understand the Binary Phase Shift Keying, or more commonly abbreviated as BPSK. This is a popularly used modulation technique by most cellular towers for long distance communication or for transmitting data. Binary zeros and ones are separated by a 180º phase shift of a carrier in this digital modulation technique [11]. This then makes it a robust modulation [12]. This property helps the modulated data from the binary phase shift keying (BPSK) to go on longer or farther distances from its respective transmission point to the receiving point. It is mostly used for telecommand and telemetry system, such as in satellite communication systems. This application was due to the advantages of BPSK [13]. Digital systems, in general, is easy to manipulate. It is also less costly compared to other modulations [14]. It is very flexible and is compatible with other digital systems, which is why two or more systems can be used together depending on what is needed [15,16]. Transmitted data through this does not degrade which is exceptionally advantageous for communication devices or systems [17].

In this paper, the goal is to comprehend how the said modulation works by testing the performance of BPSK. It is important to be well versed with this in order to be able to generate future advancements on the technology of communication.

5. DESCRIPTION OF THE SYSTEM

BPSK is a modulation technique in which the different phase states of the signal which are represented by ones and zeros. The output modulated signal requires two inputs which are the binary sequence and the carrier signal. The simulation of the BPSK system is done with the use of MATLAB and its functions. For the program code the parameters of the carrier signal have already been set and for the binary sequence which is a required input for the generation of the BPSK modulated signal a MATLAB function is used in order to generate a random bit sequence.

6. METHODOLOGY

The algorithm of the program which was made in MATLAB and used in the study follows various short processes, conversions and formulas in order to achieve the goal which is to calculate the BPSK modulated signal and display the resulting graphs displaying the binary bit sequence and the carrier signal which was used as input [18]. The parameters relating to the carrier signal wave such as the frequency and the sampling period, which is to be used as input has already been predefined, which is why the only variable that will vary between simulations aside from the output itself would be the binary bit sequence which is randomly generated. There are a total of 5 bit sequences generated for the 5 output BPSK modulation signals with bit lengths of two, four, six, eight and ten. The carrier signal wave is generated with the use of the plot function and the formula sin(2pi ft). Five outputs were generated in order to see the variety and the differences in the output BPSK modulated signal with regards to the varying input binary sequence.

7. REVIEW OF RELATED LITERATURE

In a study conducted, the performance of BPSK modulation scheme is analyzed for different channel conditions. The main purpose of the said study is to determine which of the two modulation schemes, Binary Phase Shift Keying and the Quadrature Phase Shift Keying is the most efficient and more practical in use. This is due to the usage of wireless sensor networks being more expensive in terms of power meaning that any room for error is not allowed or desirable. Various techniques, methods and approaches will be used to test the Binary Phase Shift Keying and the Quadrature Phase Shift Keying for each of its performances such as the amount of power or energy used and the Bit Error Rate which is one of the schemes implemented in order to control error rate and is essential for a wireless sensor network [19]. Other analysis parameters to be used in determining the performance of both the Binary Phase Shift Keying and the Quadrature Phase Shift Keying is by the introduction of the Additive White Gaussian Noise which simulates the natural noise generated and affected by environmental factors which may have an impact on the output signals of both the Binary Phase Shift Keying and the Quadrature Phase Shift Keying. Another is the Rayleigh Fading, this is a statistical model which simulates how the radio signal, which is the signal commonly used by wireless devices, is affected by environmental factors with regards to how the signal is propagated [20].

In a study conducted which aims to create, implement and propose a transmitter and a receiver which is BPSK- Based. As stated by the authors of the study the BPSK communication system comprises of mainly a transmitter, a receiver, error detector and counter. The system used in the study utilizes a channel which provides artificial noise which emulates real environmental factors that generate noise and can impact the output signal of the system. The channel used is the Additive White Gaussian Noise. The authors of the paper conducted various tests in order to determine the performance and practicality of the proposed modem design that is BPSK-based such as the determination of the Bit Error Rate and the researchers also observed how the signal to noise ratio can affect the output and the error rate of the system. The researchers concluded that the Binary Phase Shift Keying based modem system can be implemented as a satellite modem, which functions mainly as a modulator and demodulator, without any issues. The authors of the paper have also observed that the use of BPSK in the modem communication system can reduce the Bit Error rate in data Communication and is particularly useful as well with situations that require data transmission and an error detection function [21].

In a study conducted which integrates the Binary Phase Shift Keying Modulation scheme onto Millimeter Wave Communication systems. The authors of the study were able to determine that the designed Binary Phase Shift Keying Modulators for Millimeter Wave Systems have a high degree of isolation between the ports of the carrier input and modulated carrier output. The balanced configurations which are set for the designed modulators have also affected the pulse width variations and the amplitude deviations of the output signal wave. The authors of the paper have also observed that combining two of the designed Binary Shift Keying Modulators will create a modulator that functions as a Quadrature Phase Shift Keying Modulator which works well with the point to point communication of millimeter wave system links. The authors of the paper concluded that with the integration of Binary Phase Shift Keying Modulators onto Millimeter wave systems can result in a low-cost, compact modulators which functions with high efficiency [22].

A study conducted which focuses on the Difference between the output signals of the Binary Phase Shift Keying modulation scheme and the Binary Frequency Shift Keying modulation scheme with the use of MATLAB and SIMULINK through the presence of an Additive White Gaussian Noise Channel with the same Signal to Noise Ratio to be used[23]. With the use of Bit Error Ratio the authors of the paper were able to conclude that the Binary Phase Shift Keying Modulation Scheme holds the upper hand over the Binary Frequency Shift Keying Modulation Scheme with regards to a specific Signal to noise Ratio [24].

8. THEORETICAL CONSIDERATIONS

The SIMULINK models made and the MATLAB algorithms done take into account the presence of environmental factors which may affect the output signal of the modulation schemes which is why the use of the Additive White Gaussian Noise Channel is a must in the simulation of the BPSK system or any digital communication system as it emulates the noise due to natural environmental factors[25]. Without the use of such artificial components which can simulate what can affect the system in actuality can hinder the accuracy of the resulting output signal as well as give a false reading on its practicality.

9. DATA AND RESULTS

A. Program Code

```
clc
clear all;
close all;

f = 2; %frequency of sine wave
fs = 100; %sampling period of the sine wave
t = 0:1/fs:1; %splitting time into segments of 1/fs
%setting the phase shifts for the different BPSK signals
p1 = 0;
p2 = pi;
%getting the number bits to be modulated
N = input('enter the number of bits to be modulated: N = ');
%generating the random signal
bit_sequence=round(rand(1,N));
%allocating the dynamic variables
time = [];
digital_signal = [];
PSK = [];
carrier_signal = [];

%GENERATING THE SIGNALS
for ii = 1:1:N
%the original digital signal is
if bit_sequence(ii) == 0
bit = zeros(1,length(t));
else
bit = ones(1,length(t));
end
digital_signal = [digital_signal bit];

%Generating the BPSK signal
```

```
if bit_sequence(ii) == 0
bit = sin(2*pi*f*t+p1);
else
bit = sin(2*pi*f*t+p2);
end
PSK = [PSK bit];

%Generating the carrier wave
carrier = sin(2*f*t*pi);
carrier_signal = [carrier_signal carrier];

time = [time t];
t = t + 1;

end

subplot(3,1,1);
plot(time,digital_signal,'r','linewidth',2);
grid on;
axis([0 time(end) -0.5 1.5]);
title('Bit Sequence')

subplot(3,1,2);
plot(time,PSK,'linewidth',2);
grid on;
axis tight;
title('BPSK Modulated Signal')

subplot(3,1,3);
plot(time,carrier_signal,'linewidth',2);
grid on;
axis tight;
title('Carrier SIgnal')
```

B. Program Output

```
enter the number of bits to be modulated: N = 10
```

Figure 1: Command Prompt asking for the number of bits to be generated.

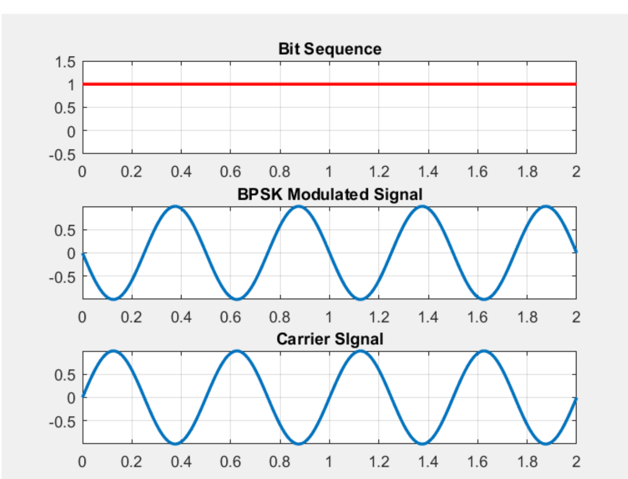

Figure 2: Generated plot displaying a random 2 bit binary sequence, Carrier Signal and BPSK Modulated Signal

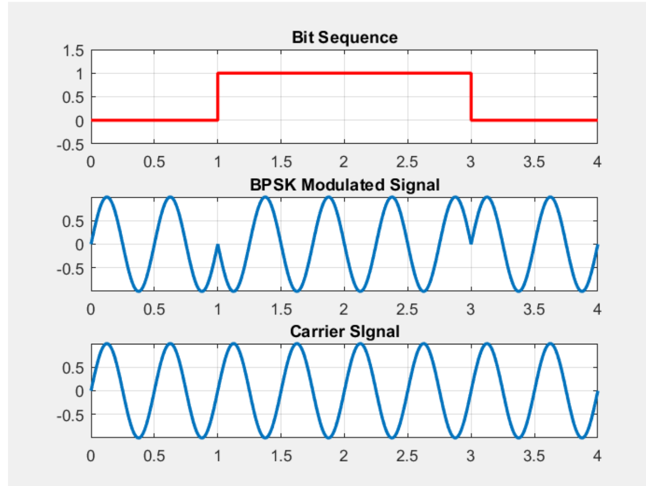

Figure 3: Generated plot displaying a random 4 bit binary sequence, Carrier Signal and BPSK Modulated Signal

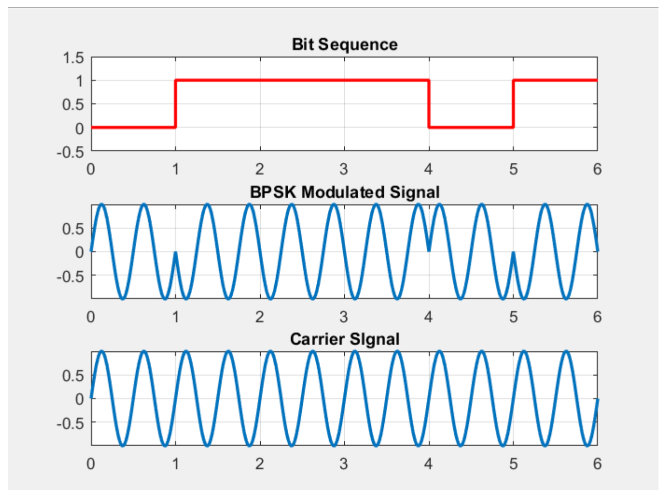

Figure 4: Generated plot displaying a random 6 bit binary sequence, Carrier Signal and BPSK Modulated Signal

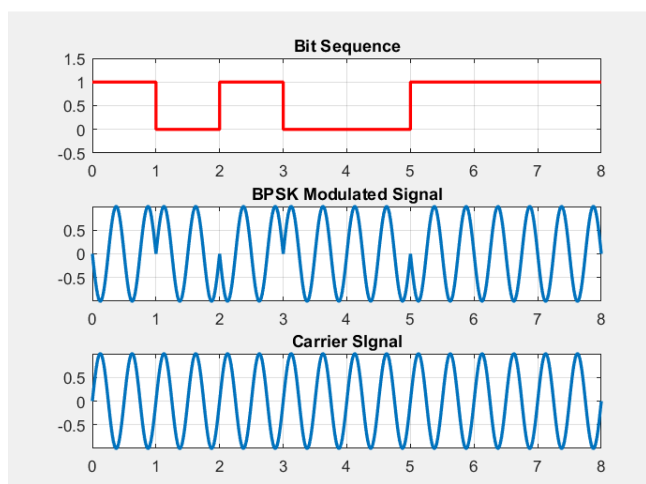

Figure 5: Generated plot displaying a random 8 bit binary sequence, Carrier Signal and BPSK Modulated Signal

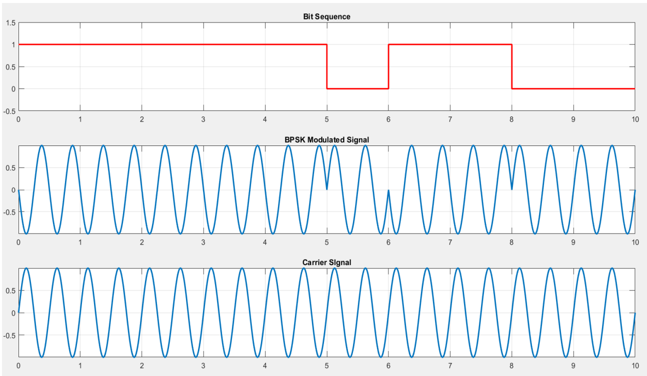

Figure 6: Generated plot displaying a random 10 bit binary sequence, Carrier Signal and BPSK Modulated Signal

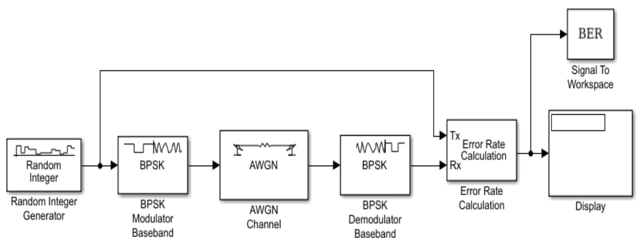

Figure 7: BPSK Modulator - Demodulator SIMULINK Model

10. ANALYSIS OF DATA

The program constructed generates a random binary bit sequence which is to be used as input and it undergoes the process of modulation by means of the binary phase shift keying technique and displays the generated output. The balance modulator has two inputs. These are the carrier signal and the binary digital data. These two inputs are shown in the generated output of the program. The program displays a binary data signal with the bits to be modulated based on the number of bits defined by the user which is to be randomly generated. In this project, there are five generated outputs and the number of bits to be modulated are two, four, six, eight, and ten in order to observe the various BPSK modulated signal wave outputs from various Binary Sequence Inputs. The code of the program generates the input binary data or information signal by defining the ones and zeros bits. The length of this input signal depends on the number of bits chosen as input by the user. The carrier signal is defined based on the default parameters set on the code which is 2Hz for the frequency and 100 for the sampling period. After which the program then uses this given variables to generate and calculate the carrier wave signal simply by equating it to the formula sin(2pi ft).

MATLAB’s SIMULINK was also used in this study in order to simulate and observe a model of the BPSK Modulator with a Demodulator. The BPSK Modulator - Demodulator model includes an AWGN channel or the Additive White Gaussian Noise Channel which introduces noise and attempts to mimic various random processes which occur in real systems such as the BPSK system, onto the Modulated output signal to produce a more realistic result. The model also comes with an Error Rate Calculation Block which calculates the percentage of error between the signal input which is the signal to be transmitted and the signal output which is the received signal.

11. CONCLUSION

In this project, a program that contains an input binary bit sequence and a carrier signal that were generated randomly is created in order to be able to obtain a modulated signal with the use of the binary phase shift keying or BPSK technique. The input binary bit sequence, also known as the information signal, is presented in ones and zeros bits. The program demonstrates the modulation and demodulation of a binary phase shift keying (BPSK) technique. The inputs defined in the program are modulated and demodulated with the use of the binary phase shift keying (BPSK) blocks found in MATLAB’s Simulink. For the sake of running the simulation, the number of bits used are two, four, six, eight, and ten. For each output figure displayed that makes use of the number of bits, it is observed that the bit sequence and carrier signal are put together in order to generate the BPSK modulated signal. Based on observation, the BPSK modulated signal originally follows the normal shape and form of the carrier signal. The difference of the BPSK modulated signal from the carrier signal is that the form changes when the input binary bit response changes values. From the figures, it can be noted that the BPSK modulated signal displays a cut off positive signal when the binary bit response changes from one to zero. On the other hand, the BPSK modulated signal displays a cut off negative signal when the binary bit response changes from zero to one. It is also observed that when the binary bit is one, the BPSK modulated signal and the carrier signal are 180 degrees out of phase with each other. When the binary bit is zero, the two signals are in phase.

To conclude the project, the binary phase shift keying technique utilizes the information signal presented in binary bits and the carrier signal in order to generate and obtain the modulated signal output. Binary ones will cause the modulated signal to be 180 degrees out of phase with the carrier signal and binary zeros will keep the modulated signal in phase.

12. RECOMMENDATIONS

This paper mainly focused on understanding how it operates and the knowing fundamentals when using this modulation. It was shown how the modulation technique makes use of its input data and what output is produced. Different binary bits were used as input data to see how the modulated signal changes. With this knowledge inferred from the simulations done, the researchers recommend further studies regarding the performance of BPSK; comparisons on this and other modulation techniques using different methods or, minimizing bit errors [26]. A study was done that researched on the performance of BPSK with Orthogonal Frequency Division Multiplexing (OFDM) which compared how it performed between Additive White Gaussian Noise (AWGN) and Rayleigh fading distribution [27]. Studies like these could be done, but rather than simply doing it for BPSK, comparing two or more modulations can studied using the two aforementioned systems. There are studies that compared different modulation techniques using one system [28]. By combining the two studies, a more detailed understanding can be drawn. Bit error rate or BER, is an essential part for communication systems as a whole [29]. Hence conducting studies regarding minimizing BER is important is also recommended. There is another study conducted which focused on optical communications. This made use of BPSK to obtain state symbols [30]. Using the comprehension of how BPSK works from this paper, more research regarding gathering of optical data to be interpreted can be done. Starting with simple alphabets with bigger size for easier obtaining of data can be done. For coding errors the Rough Set Theory can be used [31]. The researchers also recommend using BPSK for improvements and innovations on digital communications. The data transmitted using this modulation reaches far and long distances. An example of how this advantage is used by BPSK, is, as stated earlier, how popularly used for satellite communications and/or telecommand systems. There are three key parts in regards to satellite communications, these are, modulation and demodulation, forward error coding, and lastly, multiple access techniques. As the modulation is the first step, it is a crucial area. If this research will be converted into a database it can follow this format [32,33,34]. Through continuous research, new technology or systems can be designed and produced for this, which in turn will then be used for the next step for telecommunication improvement/innovation.

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