19AIE204 “ Intro to Communication Systems ”

Project Report

Plot Bit Error Rate (BER) Performance curve for the BPSK, DBPSK, QPSK, MSK, Coherant BFSK using Additive White Gaussian Noise (AWGN) channel

Bachelor of Technology in
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Submitted by Group No.: 11

Roll No	Names of Students
AM.EN.U4AIE20032	GUGGILAM SAI PRABHAT
AM.EN.U4AIE20052	NATTE SAI BHARATH
AM.EN.U4AIE20060	RAJA PAVAN KARTHIK
AM.EN.U4AIE20067	SISTA SAI SUBRAHMANYA MRINAAL

Subject Teacher
Dr. Prasanth M. Warrier A
Aiswarya S.

AMRITA VISHWA VIDYAPEETHAM

SCHOOL of COMPUTER SCIENCE & ENGINEERING
Kollam, Kerala, India – 690 525.

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Contents

Objective

The objective of our topic is to plot and compare the Bit Error Rate (BER) Performance curve of the modulation Binary Phase Shift Keying, Quadrature Phase Shift Keying, Minimum Shift Keying, Coherent Binary Frequency Shift Keying, Differential binary phase-shift keying in the Additive White Gaussian Noise channel. The bit error ratio is a unitless performance measure, often expressed as a percentage. The bit error ratio can be considered as an approximate estimate of the bit error probability. The performance of the channel can be evaluated from the bit error rate (BER) versus signal-to-noise ratio (SNR) curve. Noise means unwanted energy. So, if the Probability of error or BER is lower than higher the performance.

Introduction

The performance of transmitting and receiving systems is critical in recent times for fast-growing wireless technologies. A significant technical advancement over the preceding two decades has created potential growth in the sector of digital communication, and many new applications and technologies are being developed on a daily basis for justifiable reasons. Digital modulation techniques help to the advancement of mobile communications by boosting wireless network capacity, speed, and quality. Digital modulation systems enable larger information-carrying capacity, higher communication quality, data security, and RF spectrum sharing to support additional services. As a result, we must examine the characteristics, components, and architectures of the channels.

The bit error rate is the main performance parameter of a digital communication system. The performance of the channel can be evaluated from the bit error rate (BER) versus signal-to-noise ratio (SNR) curve. Noise means unwanted energy. Noise may interfere with the signal at any point in the communication system which will affect when the signal is weak. In the study of communication systems the classical (ideal) additive white Gaussian noise (AWGN) channel, with statistically independent Gaussian noise samples corrupting data samples free of inter-symbol interference (ISI), is the usual starting point for understanding basic performance relationships. The primary source of performance degradation is thermal noise generated in the receiver. The thermal noise usually has a flat power spectral density over the signal band and a zero-mean Gaussian voltage probability density function

Additive White Gaussian Noise (AWGN)

The channel is the most critical aspect of any type of communication system. The performance of a communication channel is influenced by noise. Additive White Gaussian Noise originates from a variety of natural sources, including the vibrating of atoms in a conductor, shot noise, radiation from the earth and other heated things, and astronomical sources such as the Sun. There are different types of communication channels. The AWGN channel is the most basic type of channel and is best suited for wired communication. This channel is linear and time-invariant

(LTI). When a signal goes across the AWGN channel, it adds white Gaussian noise to the signal. The amplitude-frequency response of this channel is flat, and the phase response is linear at all frequencies. It allows modulated signals to flow through without amplitude loss or phase distortion.

$$r(t) = x(t) + n(t)$$

Where $n(t)$ represents the noise, has Gaussian distribution with 0 mean and variance as the Noise power, and $x(t)$ represents transmitted signal.

Bit Error Rate (BER)

In digital transmission, BER is the number of bits with errors divided by the total number of bits that have been transmitted, received, or processed over a given time period. That is

$$BER = \frac{Number\ of\ bits\ with\ error}{total\ number\ of\ bits\ sent}$$

Bit Error Rate, BER is used as an important parameter in determining the performance of data channels. When transmitting data from one point to another, whether through a radio/ wireless link or a wired telecommunications link, the key parameter is how many errors will emerge in the data that appears at the distant end. As such Bit Error Rate, BER is applicable to everything from fiber-optic links, to ADSL, Wi-Fi, cellular communications, IoT links, and many more. Even though the data links may utilize very different types of technology, the basics of the assessment of the bit error rate are exactly the same.

SIGNAL TO NOISE RATIO

The term Signal to Noise Ratio is defined as a ratio of the transmitted signal power to channel noise power. In a transmission system, high SNR is good for the transmitter and receiver. The SNR is calculated by the following Eq.1

$$SNR = \frac{P_s}{P_n}$$

Where P_s = transmitted signal power and P_n = channel noise power

Block diagram & Description

Binary Phase Shift Keying (BPSK)

Binary Phase-shift keying (BPSK) is a digital modulation scheme that conveys data by changing or modulating, two different phases of a reference signal (the carrier wave). The constellation points chosen are usually positioned with uniform angular spacing around a circle. This gives maximum phase-separation between adjacent points and thus the best immunity to corruption. They are positioned on a circle so that they can all be transmitted with the same energy. In this way, the moduli of the complex numbers they represent will be the same, and thus so will the amplitudes needed for the cosine and sine waves.

Digital modulation is the process by which digital symbols are transmitted into waveforms that are compatible with the characteristics of the channel. The modulation process converts the signal in order to be compatible with available transmission facilities. At the receiver end, demodulation must be accomplished by recognizing the signals. The modulation technique used in this project is BPSK (Binary Phase Shift Keying) and it is widely used in digital transmission.

BPSK modulation is the simplest form and most robust of all the PSK modulation techniques. The BPSK modulator is quite simple and is illustrated in. The binary sequence m(t) or modulating signal is multiplied with a sinusoidal carrier and the BPSK modulated signal s(t) is obtained. The output of the BPSK signal generated by the modulator With Binary Phase Shift Keying (BPSK), the binary digits 1 and 0 may be represented by the analog levels $+\sqrt{Eb}$ and $-\sqrt{Eb}$ respectively.

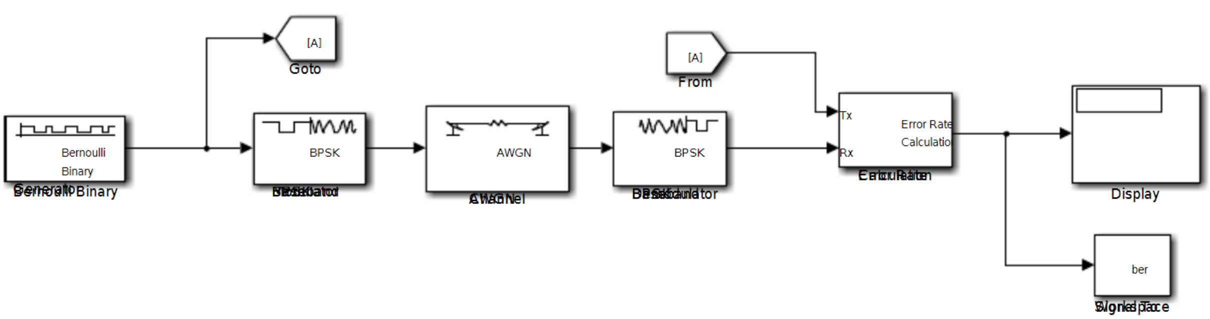
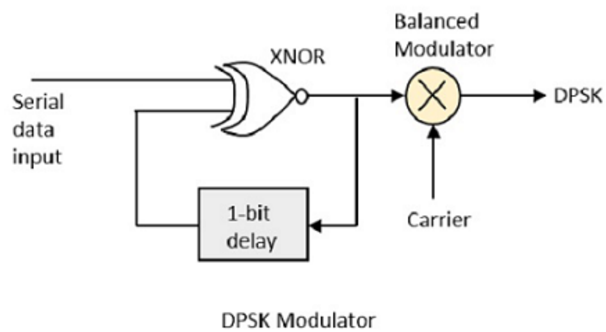


Fig 1: Block Diagram of BPSK

Differential binary phase-shift keying

DBPSK stands for "Differential binary phase-shift keying". It is a single type of phase switch used to transfer data by changing the carrier wave phase. In this case, the modified signal section is transmitted e-to the previous signal element. The signal category follows the low or high status of the previous element. This type of phase switch key does not require a network company that synchronizes the demodulator. The series of input bits can be changed so that the next part depends gradually. Therefore, bits previously received from the receiver are used to obtain the current bit. We denote the modulation scheme that uses differential encoding and differential demodulation as DBPSK, which is sometimes simply called DPSK.DPSK is a BPSK mode, where there is no phase signal for reference. Here, the transmission signal is used as a reference signal. A DPSK module diagram is shown below.
This variable includes two different signals which are a network company signal and a module signal. The change in the signal level of each signal is 180 °.



In the picture above, the serial input data can be applied to the XNOR gate and the o / p logic gate is restored to the input with a 1-bit delay.

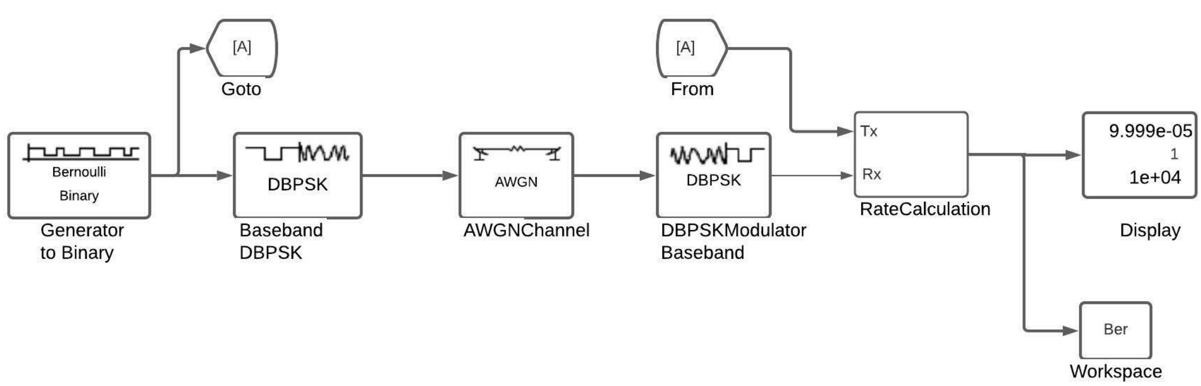
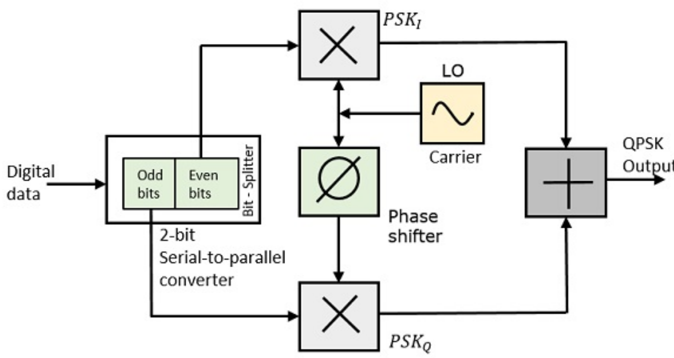


Fig 2: Block Diagram of DBPSK

Quadrature Phase Shift Keying(QPSK)

Quadrature Phase Shift Keying is a digital variable. In this way, the waveform of the network company is adjusted according to the digital baseband signal. The network company category is always the same when the input logic is 1 but goes through a phase change where the logic says 0. In Quadrature Phase Shift Keying, two bits of information are changed simultaneously, unlike Binary Phase Shift Keying where there is only one component. passed with each sign. Here, there are network company offsets with a phase difference of ± 90 ° with four possible combinations of two bits (00, 01, 10, 11). The duration of the token in this conversion is twice the minimum duration.
QPSK Modulator uses a bit-splitter, duplicates with a local oscillator, a 2-bit serial to parallel converter, and a summer circuit. Next is a drawing of the same block.



In the input converter, equal-bit bits (i.e., 2nd bit, 4th bit, 6th bit, etc.) and abnormal bits (i.e., 1st bit, 3rd bit, 5th bit, etc.) are separated by a dividing bit and repeated by the same network company to produce Strange BPSK (pronounced PSKI) and BPSK (pronounced PSKQ). The PSKQ signal is in any case a phase-shifted 90 ° before it is adjusted.

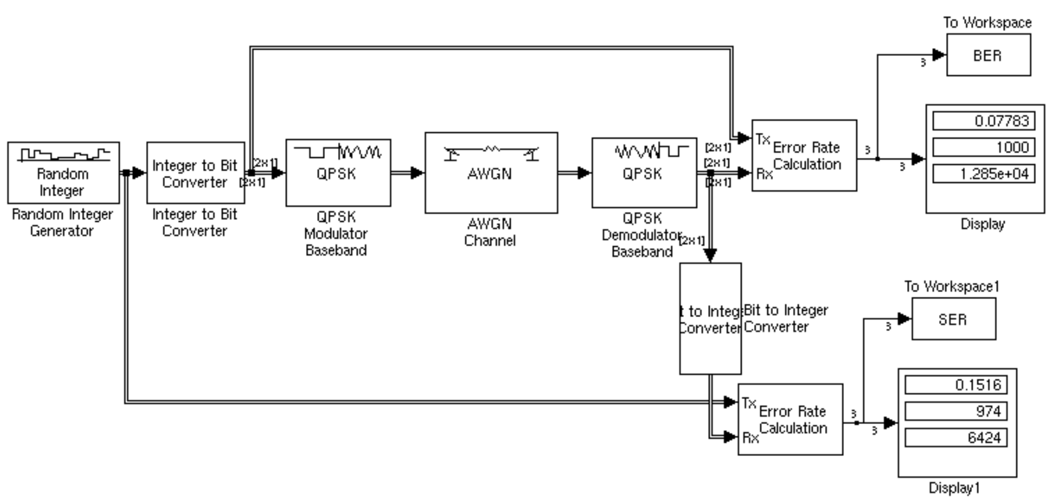


Fig 3: Block Diagram of QPSK

Minimum Shift Keying (MSK)

Minimum shift keying, MSK, is a form of frequency modulation based on a system called continuous-phase frequency-shift keying. Minimum shift keying, MSK offers advantages in terms of spectral efficiency when compared to other similar modes, and it also enables power amplifiers to operate in saturation enabling them to provide high levels of efficiency.
It is a type of Continuous Phase Modulation (CPM) that has been used in many wireless communication systems.
To be more precise it is Continuous Phase Frequency Shift Keying (CPFSK) with two frequencies f1 and f2. The frequency separation between the two tones is the minimum allowable while maintaining orthogonality and is equal to half the bit rate (or symbol rate, as both are the same). The frequency deviation is then given as Δf=Rb/4. The two tones have frequencies of fc±Δf where fc is the carrier frequency. MSK is sometimes also visualized as Offset QPSK (OQPSK) but we will not go into its details here.

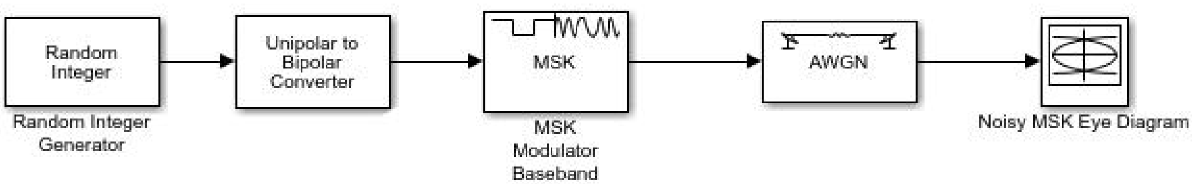


Fig 4: Block Diagram of MSK

Coherant Binary Frequency Shift Keying (CBFSK)

Coherent BFSK is demodulation based on the use of a multi-bit shift register, two multi-Bit XOR gates, and a mean value filter. In a binary FSK system, symbols 1 and 0 are distinguished from each other by transmitting one of two sinusoidal waves that differ in frequency by a fixed amount. A typical pair of sinusoidal waves is described by

$$s_i(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_i t) & 0 \leqslant t \leqslant T_b \\ 0 & \text{elsewhere} \end{cases}$$

where i = 1, 2, and Eb is the transmitted signal energy per bit, and the transmitted frequency equals

$$f_i = \frac{n_c + i}{T_b} \quad \text{for some fixed integer } n_c \text{ and}$$

Thus symbol 1 is represented by $s_1(t)$, and symbol 0 by $s_2(t)$

From Equation, we observe directly that the signals $s_1(t)$ and $s_2(t)$ are orthogonal, but not normalized to have unit energy. We, therefore, deduce that the most useful form for the set of orthonormal basis functions is

$$\phi_i(t) = \begin{cases} \sqrt{\frac{2}{T_b}} \cos\left(2\pi f_i t\right) & 0 \leqslant t \leqslant T_b \\ 0 & \text{elsewhere} \end{cases}$$

where i = 1, 2. Correspondingly, the coefficient sij for i = 1, 2, and j = 1, 2. is definers by

$$\begin{aligned} s_{ij} &= \int_0^{T_h} s_i(t)\phi_j(t)dt \\ &= \int_0^{T_h} \sqrt{\frac{2E_b}{T_b}} \cos\left(2\pi f_i t\right) \sqrt{\frac{2}{T_b}} \cos\left(2\pi f_j t\right) dt \\ &= \begin{cases} \sqrt{E_b} & i = j \\ 0 & i \neq j \end{cases} \end{aligned}$$

Thus a coherent binary FSK system is characterized by having a signal space that is two-dimensional (i.e., N = 2) with two message points (i.e., M = 2).

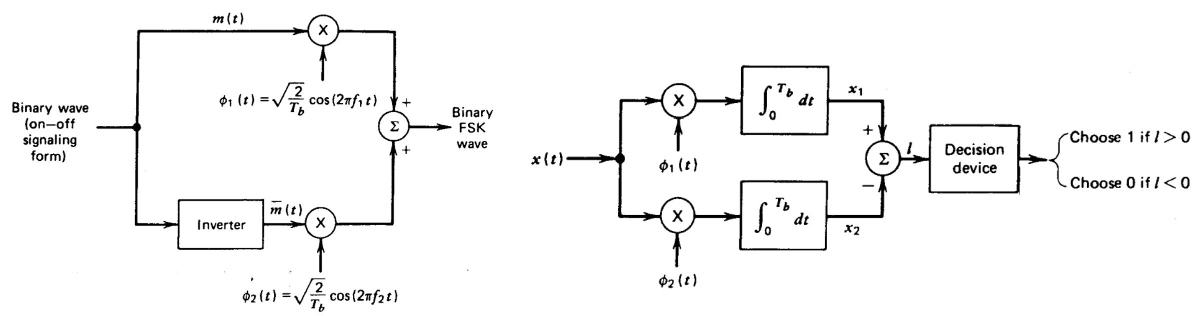
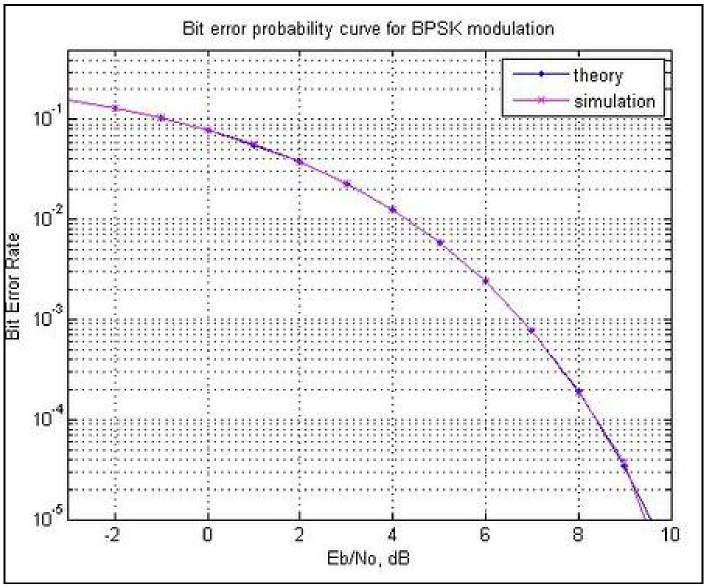


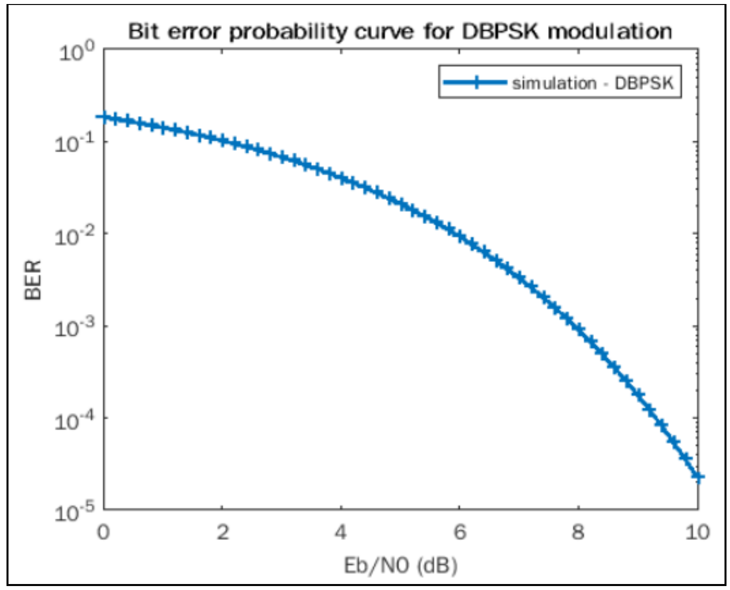
Fig: 5: Block Diagram Of Coherent BFSK

Simulation results

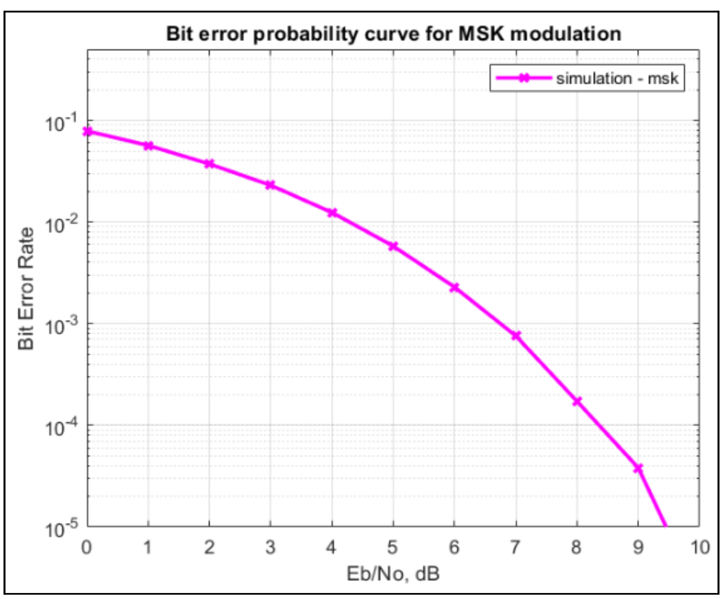
1. BPSK



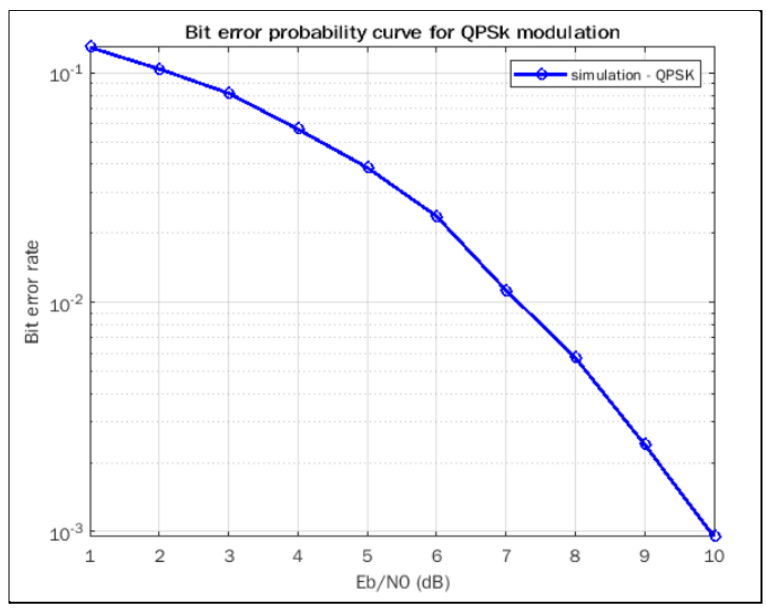
2. DBPSK



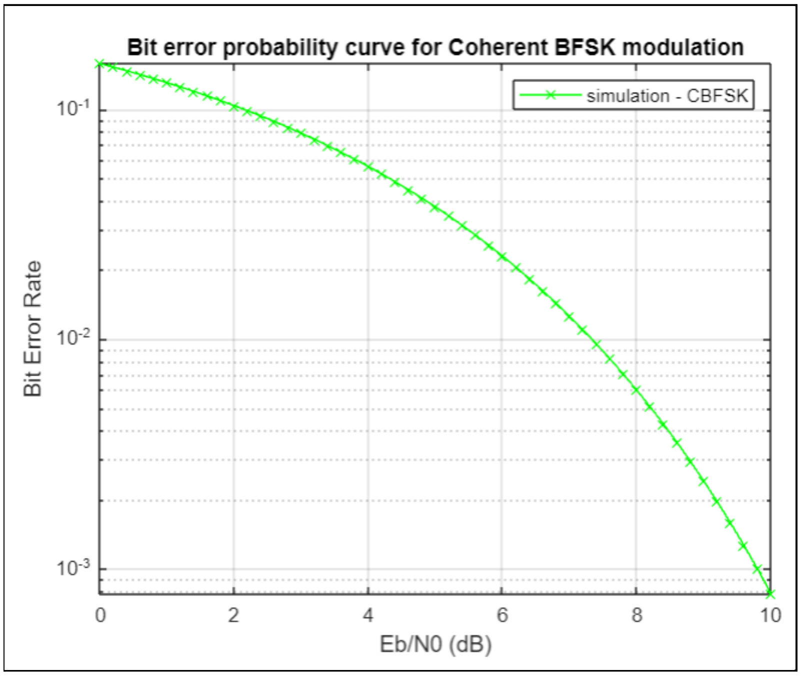
3. MSK



4. QPSK



5. Coherent BFSK



Inferences

The performance curves of the digital modulation schemes are listed above where the BER is plotted versus Eb/N0. As expected, the BERs for all the schemes decrease monotonically with increasing EbN0, with all the graphs having a similar shape in the form of a waterfall. The BER decrease with the increase of (Eb/No) in the AWGN channel. The BER is decreasing in the AWGN channel due to the increasing value of Eb / No for different modulation schemes. In the AWGN channel, for low SNR environments, the curve of analytical and simulated is similar, but in high SNR environments, there is a very small difference between the analytical and simulated curve. The AWGN channel is better than another channel for transmitting the above modulation schemes based on modulated signals.

Conclusion

In this paper, we have discussed five types of modulation. A number of modulation schemes such as BPSK, QPSK, DBPSK, MSK, and Coherent BFSK have been considered for MATLAB simulation purposes. Their BER (BIT ERROR RATE) has been calculated Using the MATLAB Monte Carlo simulation tool for additive white Gaussian noise channels. We have concluded from the above figures depending on the bit error rate that BPSK is the most effective modulation scheme in a practical communication system. This paper demonstrates that the better channel from AWGN is based on the transmission and analysis of BER performance with respect to various SNR for BPSK, QPSK, DBPSK, MSK, and Coherent BFSK-based modulated signal transmission. Through practical simulations.

Appendix

% BPSK %

```
 N = 10^6 % number of bits or symbols
rand('state',100); % initializing the rand() function
randn('state',200); % initializing the randn() function
% Transmitter
ip = rand(1,N)>0.5; % generating 0,1 with equal probability
s = 2*ip-1; % BPSK modulation 0 -> -1; 1 -> 1
n = 1/sqrt(2)*[randn(1,N) + j*randn(1,N)]; % white gaussian noise, 0dB variance
Eb_N0_dB = [-3:10]; % multiple Eb/N0 values
for ii = 1:length(Eb_N0_dB)
   % Noise addition
   y = s + 10^(-Eb_N0_dB(ii)/20)*n; % additive white gaussian noise
   % receiver - hard decision decoding
   ipHat = real(y)>0;
   % counting the errors
   nErr(ii) = size(find([ip- ipHat]),2);
end
simBer = nErr/N; % simulated ber
theoryBer = 0.5*erfc(sqrt(10.^(Eb_N0_dB/10))); % theoretical ber
% plot
close all
figure
semilogy(Eb_N0_dB,theoryBer,'b.-');
hold on
semilogy(Eb_N0_dB,simBer,'mx-');
axis([-3 10 10^-5 0.5])
grid on
legend('theory', 'simulation');
xlabel('Eb/No, dB');
ylabel('Bit Error Rate');
title('Bit error probability curve for BPSK modulation');
```

% END OF BPSK %

% MSK %

```
N = 5*10^5; % number of bits or symbols
fsHz = 1; % sampling period
T    = 4; % symbol duration
Eb_N0_dB = [0:10]; % multiple Eb/N0 values
ct = cos(pi*[-T:N*T-1]/(2*T));
st = sin(pi*[-T:N*T-1]/(2*T));
for ii = 1:length(Eb_N0_dB)
    % MSK Transmitter
    ipBit = rand(1,N)>0.5; % generating 0,1 with equal probability
    ipMod =  2*ipBit - 1; % BPSK modulation 0 -> -1, 1 -> 0
    ai = kron(ipMod(1:2:end),ones(1,2*T));  % even bits
```

```
    aq = kron(ipMod(2:2:end),ones(1,2*T));  % odd bits
    ai = [ai zeros(1,T)  ]; % padding with zero to make the matrix dimension match
    aq = [zeros(1,T) aq ];  % adding delay of T for Q-arm
    % MSK transmit waveform
    xt = 1/sqrt(T)*[ai.*ct + j*aq.*st];
    % Additive White Gaussian Noise
    nt = 1/sqrt(2)*[randn(1,N*T+T) + j*randn(1,N*T+T)]; % white gaussian noise, 0dB variance
    % Noise addition
    yt = xt + 10^(-Eb_N0_dB(ii)/20)*nt; % additive white gaussian noise
%MSK receiver
% multiplying with cosine and sine waveforms
    xE = conv(real(yt).*ct,ones(1,2*T));
    xO = conv(imag(yt).*st,ones(1,2*T));
    bHat = zeros(1,N);
    bHat(1:2:end) = xE(2*T+1:2*T:end-2*T) > 0 ; % even bits
    bHat(2:2:end) = xO(3*T+1:2*T:end-T) > 0 ;  % odd bits
    % counting the errors
    nErr(ii) = size(find([ipBit - bHat]),2);
end
simBer = nErr/N; % simulated ber
theoryBer = 0.5*erfc(sqrt(10.^(Eb_N0_dB/10))); % theoretical ber
% plot
close all
figure
semilogy(Eb_N0_dB,simBer,'mx-','LineWidth',2);
axis([0 10 10^-5 0.5])
grid on
legend('simulation - msk');
xlabel('Eb/No, dB');
ylabel('Bit Error Rate');
title('Bit error probability curve for MSK modulation');
```

% END OF MSK %

% Coherent BFSK %

```
snr_range=0:0.2:10; %range of SNR
SNR = 10.^(snr_range/10);
pe=zeros(1,length(SNR));
%%%%####_Coh BFSK_###%%%%%%%%%
for i=1:length(SNR)
pe(i)=qfunc(sqrt(SNR(i)));
end
semilogy(snr_range,pe,'g-x')
xlabel('Eb/N0 (dB)');
ylabel('Bit Error Rate');
title('Bit error probability curve for Coherent BFSK modulation');
grid on
legend('simulation - CBFSK');
hold on
```

% END OF Coherent BFSK %

% DBPSK %

```
snr_range=0:0.2:10; %range of SNR
SNR = 10.^(snr_range/10);
pe=zeros(1,length(SNR));
for i=1:length(SNR)
pe(i)=0.5*(exp(-SNR(i)));
end
semilogy(snr_range,pe,'-+','LineWidth',2);
xlabel('Eb/N0 (dB)');
ylabel('BER');
legend('simulation - DBPSK' )
title('Bit error probability curve for DBPSK modulation');
```

% END OF DBPSK %

% QPSK %

```
clear all;
close all;
l=10000;
snrdb=1:1:10;
snrlin=10.^(snrdb/10);
for snrdb=1:1:10
  si=2*(round(rand(1,l))-0.5);
  sq=2*(round(rand(1,l))-0.5);
  s=si+j*sq;
  w=awgn(s,snrdb,'measured');
  r=w;
  si_=sign(real(r));
  sq_=sign(imag(r));
  ber1=(l-sum(si==si_))/l;
  ber2=(l-sum(sq==sq_))/l;
  ber(snrdb)=mean([ber1 ber2]);
end
snrdb=1:1:10;
snrlin=10.^(snrdb/10);
semilogy(snrdb,ber,'-bo','LineWidth',2)
legend('simulation - QPSK' )
title('Bit error probability curve for QPSk modulation');
xlabel('Eb/N0 (dB)');
ylabel('Bit error rate');
grid on;
```

% END OF QPSK %