محاكاة أداء تقنية تعديل تبديل الطور الثنائي BPSK عبر قناة الضوضاء البيضاء الغاوسية المضافة AWGN .

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الملخص :

في هذه الورقة ؛ تتم مناقشة مخططات تعديل تبديل الطور الثنائي (BPSK) ويتم تحليل أداء معدل الخطأ لتعديل BPSK على الضوضاء البيضاء الغاوسية المضافة (AWGN) ، باستخدام محاكاة MATLAB. ترسم عمليات المحاكاة منحنى العلاقة بين معدل خطأ البت الأمثل (BER) ونسبة الإشارة إلى الضوضاء (SNR) لفهم تأثير الضوضاء على أداء BPSK. تظهر نتائج المحاكاة أن معدل خطأ البتات المحاكي لتشكيل BPSK يتوافق جيدًا مع معدل خطأ البتات النظري.

Simulate the performance of BPSK modulation technique
Over an AWGN channel .

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Abstract – In this paper; BPSK modulation schemes are discussed and the error rate performance of BPSK modulation on AWGN noise is analyzed, using MATLAB simulation. Simulations plot a relationship curve between Optimum Bit Error Rate (BER) and Signal to Noise Ratio (SNR) to understand the effect of noise on BPSK performance. The simulation results show that the simulated bit error rate of BPSK modulation is in good agreement with the theoretical bit error rate.

I. Introduction

Digital modulation offers more information capacity, higher data security and faster system availability with high quality connectivity, digital modulation technologies are in more demand due to their ability to transmit larger amounts of data than analog modulation techniques, it is simply not compatible with the digital world. For data transmission such as wireless networks, digital audio signals, and sensor measurements, digital modulation is used.

Digital modulation is the conversion of digital signals into waveforms compatible with the nature of the communication channel, there are types of digital modulation (amplitude shift keying, frequency shift keying, phase shift keying). Phase modulation(**PM**) and frequency modulation(**FM**) are considered modulation of angular modulation[4]. There are distinct characteristics when phase modulation is used instead of amplitude modulation (**AM**) because of its contribution to noise reduction, improving communication accuracy and more cost-effective in Energy use. Also, phase-shift switch modulation maintains signal quality by using a frequency band lower than that used to modulate the frequency-shift switch. Because of that, phase modulation requires complex electronic circuits in both the transmitting and receiving devices. There are several types of phase shift keying modulation , including(**BPSK,QPSK,8PSK,16PSK**,….) .

In Section II , Related papers are discussed. In Section III, Binary Phase Shift Keying Modulation Technique is presented. In Section IV, Additive White Gaussian Noise (**AWGN**) Channel is described. In Section V, Bit Error Rate (BER) for BPSK modulation is presented. In Section VI, Simulation and Results are explained.

II. Related Papers

Many methods have been implemented based on different technologies have been proposed in literatures. In this paper is discussed some of these works similar for our study.

Yazen Saifuldeen Almashhadani [8] .In this paper, BER is simulated against Eb/No in the non-faded and faded channels. Using the statistical Rayleigh model, the bit error rate (BER) for different channel fading types is the studied fading based on time delay propagation can have fixed fading or frequency selective fading and also based on Doppler the shift can have a slow fading or a fast fading considering the M-ary FSK modulation scheme. And the system was implemented using MATLAB.

Md. Golam Sadeque [2] . In this paper, three basic types of digital modulation techniques are discussed then the bit error rate performance characteristics of receiver are evaluated by using MATLAB Simulink model for FSK, PSK and QAM modulation techniques. the AWGN channel is used between transmitter and receiver. This paper focuses on the characterization and the design of analog signal waveforms that carry digital information and compares their performance on an AWGN channel.

K. Sushmaja, Dr. Fazal Noorbasha[7].In this paper the shift keying techniques is Simulated .Verilog HDL is used to implement the proposed techniques which were successfully simulated.

D.M. Motiur Rahaman[16].In this paper , the simulation Matlab is used for the comparison between performance different advanced modulation techniques such as BSK,4QAM, 4PAM, 4PSK, 16QAM, 16PSK .

III. Binary Phase Shift Keying Modulation Technique

Binary Phase Shift Keying Modulation(BPSK) also sometimes called Phase Reversal Keying(PRK) , is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned and they can be shown on the real axis at 0° and 180°.In BPSK, the phase of the sinusoidal carrier signal is changed according to the message level ("0" or "1"), while keeping the frequency and amplitude constant. A BPSK modulator can be implemented by coding the message bits using nun return to zero(NRZ) coding (1 represented by positive voltage and 0 represented by negative voltage) and multiplying the output by a reference oscillator running at carrier frequency ω. The following figure represents the block diagram of BPSK.

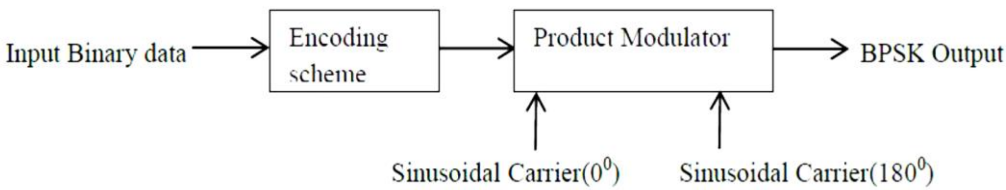

Figure. 1*:* Block diagram of BFSK

The general form for BPSK follows the equation[5]:

$$S_b(t) = \sqrt{\frac{2E_b}{T_b}}\, cos(2\pi f_c t + \pi(1-n)), n = 0,1.$$

(1)

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:

for binary "0",

$$S_0(t) = \sqrt{\frac{2E_b}{T_b}}\, cos(2\pi f_c t + \pi), n = -\sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$

(2)

for binary "1",

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}}\, cos(2\pi f_c t + \pi), n$$

(3)

Where f_c is the frequency of the carrier-wave.

The following figure represents the waveform of BPSK:-

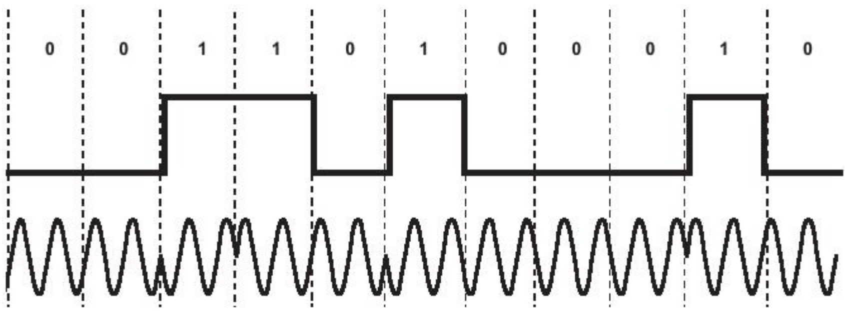

Figure. ***2***: BPSK signal waveforms

IV. Additive White Gaussian Noise (AWGN) Channel

The performance of any type of digital modulation system for communications is measured on noise. The AWGN channel is the simplest channel model for wired communication. This channel is linear and time-invariant (LTI). Added white Gaussian noise comes from many natural sources such as vibration of atoms in a conductor, lead noise, radiation from the earth and other warm objects and from celestial sources such as the sun. AWGN adds white Gaussian noise to the signal when the signal passes through it. The amplitude frequency response of this channel is flat and the phase response is linear for all frequencies [4]. The modulated signals pass through it without any amplitude loss and phase distortion. The received signal has been simplified as follows:-

$$r(t) = x(t) + n(t) \quad (4)$$

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

V. Bit Error Rate (BER) for BPSK modulation

The bit-error rate is the main performance parameter of a digital communication system [6]. The bit error rate (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval.

$$BER = \frac{Number\ of\ bits\ with\ error}{total\ number\ of\ bits\ sent} \quad (5)$$

The performance of channel can be evaluated from bit error rate (BER) versus signal to noise ratio (SNR) curve. BER is a unit less performance measure, often expressed as a percentage [5-1]. The bit error probability is the expectation value of the BER.

With Binary Phase Shift Keying (BPSK), the binary digits 1 and 0 maybe represented by the analog levels $+\sqrt{E_b}$ and-$\sqrt{E_b}$ respectively. The system model is as shown in the Figure 3.The ideal constellation diagram of a BPSK transmission (refer figure 4) contains two constellation points located equidistant from the origin. Each constellation point is located at a distance $\sqrt{Es}$ from the origin, where E_S is the BPSK symbol energy. Since the number of bits in a BPSK symbol is always one, the notations – symbol energy (E_S) and bit energy (E_b) can be used interchangeably(E_S=E_b)[3].

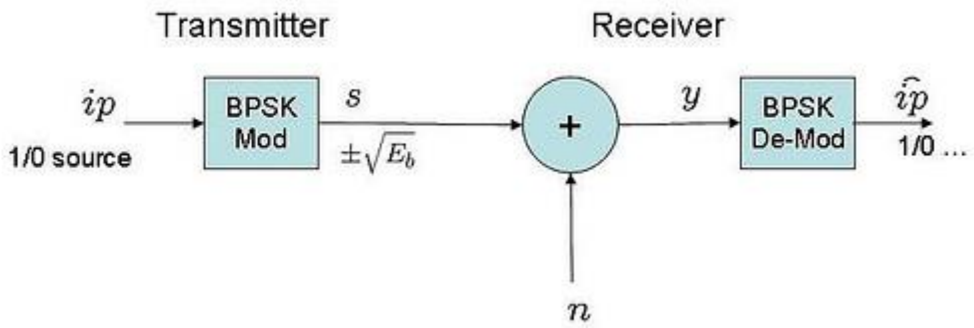

Figure 3: block diagram of BPSK transmitter - receiver

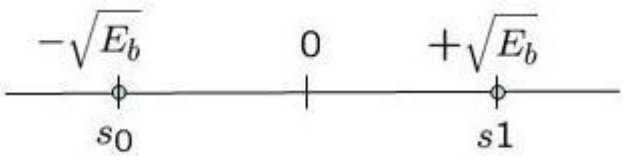

Figure 4: BPSK – ideal constellation

- **Calculation of Theoretical BER for BPSK over AWGN channel :-**

A. Channel Model

Assume that the BPSK symbols are transmitted through an **Additive White Gaussian Noise** (**AWGN**) channel characterized by variance= $N_0/2$ Watts. The transmitted waveform gets corrupted by noise n, typically referred to as **AWGN** . As the noise gets added (and not multiplied) to the received signal .The spectrum of the noise if flat for all frequencies Gaussian , the values of the noise n follows the Gaussian probability distribution function[3],

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} with\ \mu = 0\ and\ \sigma^2 = \frac{N_0}{2} \qquad (6)$$

B. Computing the probability of error

The received signal,

$y = S_1 + n$ when bit 1 is transmitted (7)

$y = S_0 + n$ when bit 0 is transmitted. (8)

The conditional probability distribution function (PDF) of y for the two cases are:

$$P(y/S_0) = \frac{1}{\sqrt{\pi N_0}} e^{\frac{-(y+\sqrt{E_b})^2}{N_0}} \quad (9)$$

$$P(y/S_1) = \frac{1}{\sqrt{\pi N_0}} e^{\frac{-(y-\sqrt{E_b})^2}{N_0}} \quad (10)$$

Assuming that s_1 and s_0 are equally probable [$P(s_1)=P(s_0)=1/2$] .

- if the received signal is y is greater than 0, then the receiver assumes s_1 was transmitted.
- if the received signal is y is less than or equal to 0, then the receiver assumes s_0 was transmitted.

$y>0 \Rightarrow s_1$ and $y \leq 0 \Rightarrow s_0$.

Probability of error given s_1 was transmitted

With this threshold, the probability of error given s_1 is transmitted is (the area in blue region):

$$P(r/s_1) = \frac{1}{\sqrt{\pi N_0}} \int_{-\infty}^{0} e^{-\frac{(y-\sqrt{E_b})^2}{N_0}} dy \quad (11)$$

$$= \frac{1}{\sqrt{\pi}} \int_{\sqrt{\frac{E_b}{N_0}}}^{\infty} e^{-z^2} dz = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

where,

$erfc(x) = \frac{2}{\sqrt{\pi}}\int_{x}^{\infty} e^{-x^2}\, dx$ is the complementary error function.

Probability of error given s_0 was transmitted

Similarly the probability of error given s_0 is transmitted is (the area in green region):

$$P(r/s_0)= \frac{1}{\sqrt{\pi N_0}}\int_{0}^{\infty} e^{-\frac{(y+\sqrt{E_b})^2}{N_.}}\, dy \qquad (12)$$

$$= \frac{1}{\sqrt{\pi}}\int_{\sqrt{\frac{E_b}{N_0}}}^{\infty} e^{-z^2}\, dz = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Total probability of bit error

$P_b = P(s_1)P(e/s_1) + P(s_0)P(e/s_0)$ (13)

Since a-prior probabilities are equal (P(s1)=P(s0)=1/2), the **bit error probability** is,

$$\boldsymbol{P_b} = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

(14)

Intuitively, the integrals represent the area of shaded curves as shown in the next figure[3].

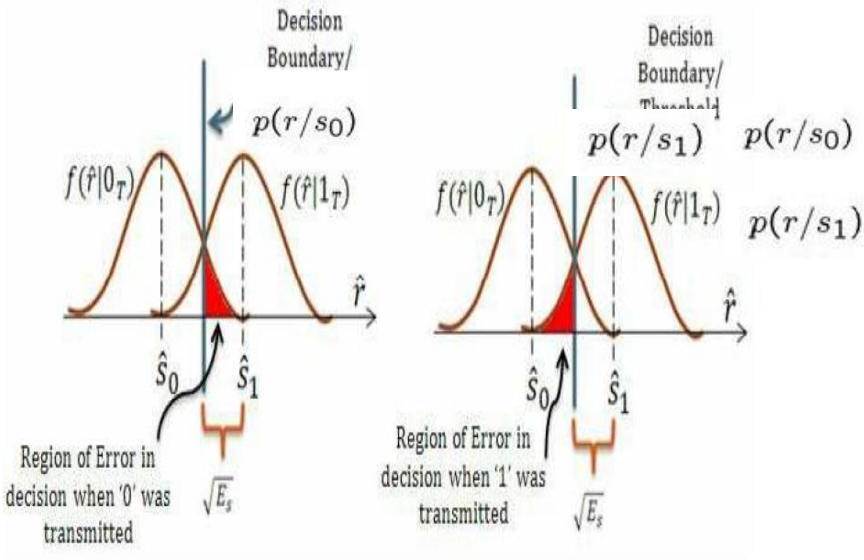

Figure 5: Conditional probability density function with BPSK modulation

VI. Simulation

Matlab is source code for computing the bit error rate with BPSK modulation from theory and simulation.
The code performs the following [3] :- ترجمة

A- <u>BPSK Modulation and Demodulation:</u>

In proposed system we are building simple BPSK modulation scheme in which a random binary stream is represented in Polar NRZ format and the resulting signal is multiplied by reference carrier frequency.

Transmitter:

For the BPSK modulation, a series of binary input message bits are generated of which 1′s are represented by 1V and 0′s are translated as -1V (equivalent to Polar NRZ coding).

AWGN channel:

For BPSK modulation the channel can be modeled as:-

$$y=ax + n \quad (15)$$

Where, y is the received signal at the input of the BPSK receiver, x is the modulated signal transmitted through the channel, ‘a’ is the channel amplitude scaling factor for the transmitted signal usually assumed as unity. ‘n’ is the Additive Gaussian White Noise random variable with zero mean and variance σ^2 .

For an AWGN channel, the noise variance in terms of noise power spectral density (N_0) is given by:-

$$\sigma^2 = \frac{N_0}{2} \qquad (16)$$

For M-ARY modulation schemes like M-PSK including BPSK, the symbol energy is given by:-

$$E_s = R_m R_c E_b \qquad (17)$$

Where,

E_S =Symbol energy per modulated bit (x),

R_m = log2(M) , (for BPSK M=2, QPSK M=4, 16QAM M=16 etc..,).

R_C is the code rate of the system if a coding scheme is used. In our work, since no coding scheme is used

R_c = 1.

E_b is the Energy per information bit.

Assuming ES=1 for BPSK (Symbol energy normalized to 1) E_b/N_0 can be represented as (using equations 16,17),

$$\frac{E_b}{N_0} = \frac{E_s}{R_m R_c N_0} = \frac{E_s}{R_m R_c 2\sigma^2} = \frac{1}{2R_m R_c \sigma^2} \qquad (18)$$

From the above equation the noise variance for the given E_b/N_0 can be calculated as:-

$$\sigma^2 = \left[2R_m R_c \frac{E_b}{N_0}\right]^{-1} \qquad (19)$$

For the channel model "randn" function in Matlab is used to generate the noise term. This function generates noise with unit variance and zero mean. In order to generate a noise with sigma σ for the given E_b/N_0 ratio, using the above equation, finding , multiplying the "randn" generated noise with this sigma, adding this final noise term with the transmitted signal to getting the received signal.

Receiver:

BPSK receiver can be a simple threshold detector which categorizes the received signal as ‘0’ or ‘1’depending on the threshold that is being set. The simulation parameters are produced in Table I [3].

Table I. Shows variables OF THE DESIGNED BPSK Modulation

Parameter	Description
N=100	number of data bits
Noise Variance = 0.5	Noise variance of AWGN channel
data=randn(1,N)>=0.5	Generate uniformly distributed random data
R_b=1e3	bit rate
Amplitude=1	Amplitude of NRZ data
$F_s=16*R_b$	Sampling frequency
$T_s=1/F_s$	Sampling Period
$T_b=1/R_b$	Bit period

B- BER vs. Eb/N0 for BPSK modulation over AWGN

Calculation of Theoretical BER for BPSK over AWGN channel is discussed in section IV.

The simulation parameters are produced in Table II [3].

Table II. Shows variables Probability of bit error for BPSK modulation scheme .

Parameter	Description
N=10000000	Number of input bits
E_b/N_0dB = -6:2:10	E_b/N_0 range in dB for simulation
data=randn(1,N)>=0	Generate uniformly distributed random data 1s and 0s
bpskModulated = 2*data-1	Mapping 0->-1 and 1->1
M=2	Number of Constellation points
Rc=1	code rate for a coded system. Since no coding is used Rc=1
Ts=1/Fs	Sampling Period
Tb=1/Rb	Bit period

C- Simulation Results:

The output of the Matlab code shows how pass band BPSK modulation and demodulation can be done. Figure 6 shows plotting input binary data , polar NRZ encoded data ,the modulated signal and the Power Spectral Density of the BPSK modulated signal. Figure 7 shows plotting the modulated signal with AWGN noise and demodulated . Figure 8 it also shows the constellation at transmitter/receiver .

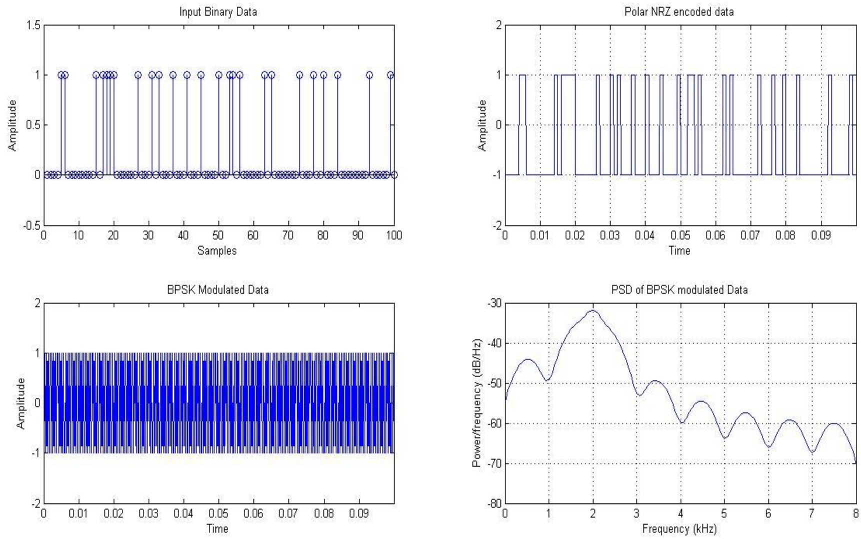

Figure 6: Pass Band BPSK modulation

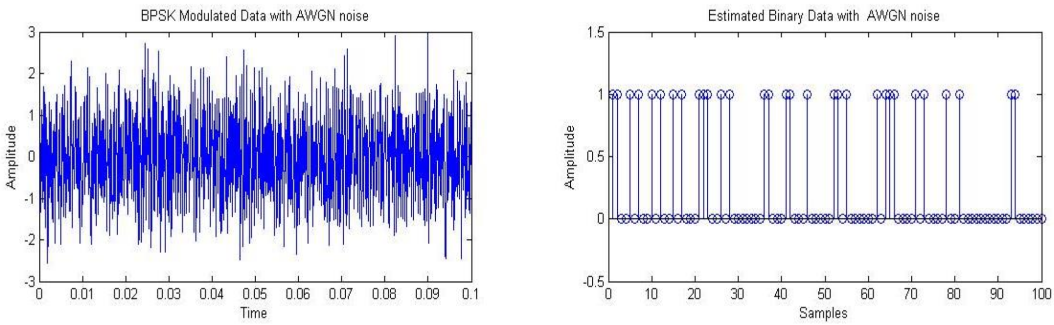

Figure 7: BPSK modulation with AWGN and demodulation

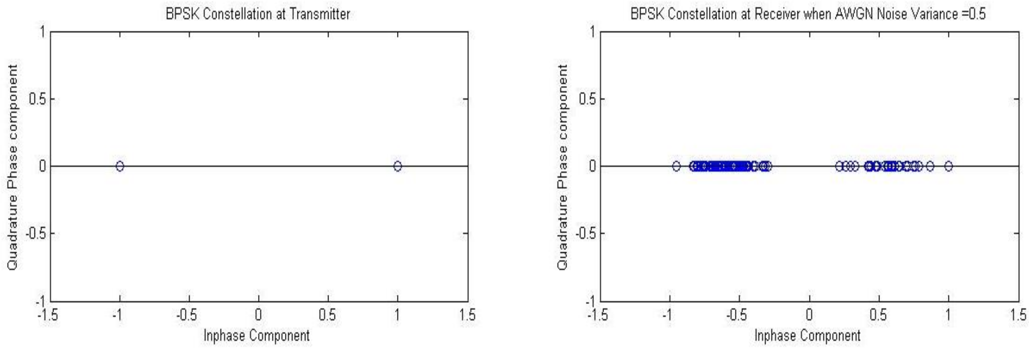

Figure 8: The constellation at transmitter/receiver

From figure(9) it is clear that bit error rate for BPSK is (-0.5dB) when signal to noise ratio per bit is (-6dB).

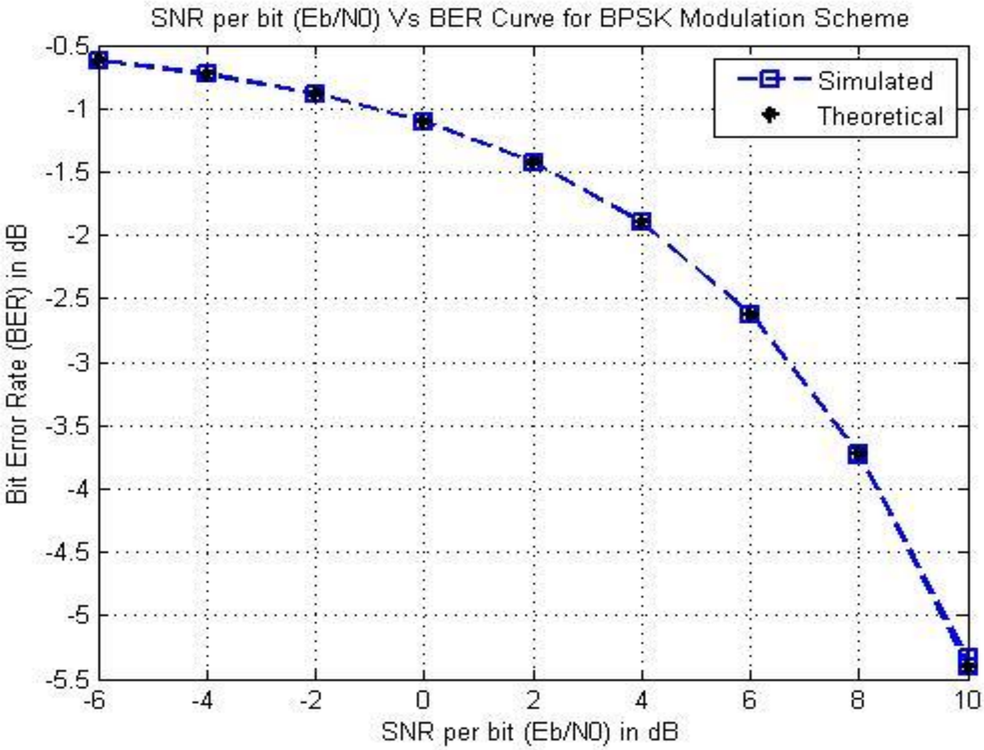

Figure 9: Bit Error Rate Performance for BPSK

Conclusion

1. Increase the radiate power efficiency in wireless communication modulation is needed to transmit long distance.
2. The performance of channel can be evaluated from bit error rate (BER) versus signal to noise ratio (SNR) curve.
3. The BER results obtained using Matlab simulation scripts show good agreement with the derived theo-retical results..
4. We have concluded from the figure 7 depending on bit error rate that BPSK is effective modulation scheme in a practical communication system.

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