Simulation and Examination of a Direct Sequence Spread Spectrum System Using Matlab/Simulink

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Abstract - **Computer simulation is the most suitable, powerful and efficient way to represent the actual or real situation of mobile radio system. The paper presents a Simulink model of Direct Sequence Spread Spectrum (DSSS) system. The model is simulated using binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK). The simulation is done under noise and multipath fading channel. In the paper are used two approaches: simulation using Simulink and simulation using m-files. When the necessary simulations are done, tables and graphs of bit error rate (BER) as a function of signal-to-noise ratio (SNR) for various parameters are plotted.**

Keywords - **Spread Spectrum, Direct Sequence, simulation, bit error rate.**

1. Introduction

Spread-Spectrum (SS) modulation, with its inherent interference attenuation capability, has over the years become an increasingly popular technique for use in many different systems. The SS Communications are widely used today for Military, Industrial, Avionics, Scientific, and Civil uses.

A definition of Spread-Spectrum that adequately reflects the characteristics of this technique is as follows [1,2]. Spread-Spectrum is a means of information transmission in which the modulated signal occupies a bandwidth in excess of the minimum necessary to send the information; the signal band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for despreading and subsequent data recovery. There are many types of spread spectrum techniques [1,2,3] as: Direct sequence (DS), frequency hopping, time hopping and hybrid system.

DSSS is at the moment the main technique to generate an SS signal. A DSSS system spreads the baseband data by directly multiplying the baseband data pulses with a pseudo-noise sequence that is produced by a pseudo-noise (PN) code generator [4]. The most widely modulation scheme in DSSS system is phase shift keying [1].

In this paper is presented a Simulink [5] model of DSSS system. Simulating a system is a two-step process with Simulink. First, a graphical model of the system is simulated, using the Simulink model editor.

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The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs.

Then, Simulink is used to simulate the behavior of the system over a specified time span.

2. Theoretical DSSS System and Channel Models

The transmitter blok diagram of DSSS system is shown in figure 1. If multiple phase shift keying (MPSK) modulation scheme is used in the DSSS system model, the transmitted signal can be represented as [1]:

$$s_{ss}(t) = \sqrt{\frac{2E_s}{T_s}}\left[x(t)\otimes d(t)\right]\cos\left(2\pi f_0 t + \frac{2\pi i}{M}\right) \quad , \qquad (1)$$

where: $x(t)$ is the data signal, $i = 1...M$, $0 \le t \le T$;

d(t) is the PN spreading sequence;

f_0 is the carrier frequency;

E_s is the symbol energy;

T_s is the symbol duration;

M is the number of symbols.

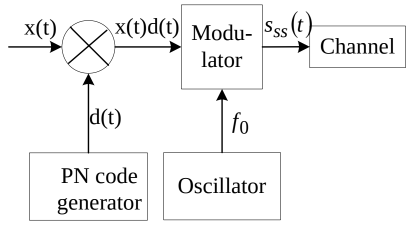

Fig.1. DSSS Transmitter block diagram

The demodulator (Fig.2), demodulates the modulated (PSK) signal first, low pass filter (LPF) the signal, and then despread the filtered signal, to obtain the original message.

The received signal $y'(t)$ at the input of the matched filter receiver is given by:

$$y'(t) = \int_0^{T_s} s_{ss}(t) * h(t) + n(t), \qquad (2)$$

where: * denotes convolution;

$h(t)$ is the pulse characteristic;

$n(t)$ is the additive white noise Gaussian process (AWGN) with power spectral density N_0.

Then:

$$x'(t) = y'(t) \otimes d(t) \quad . \tag{3}$$

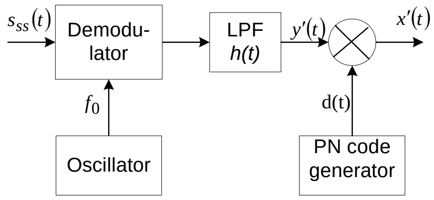

Fig.2. DSSS Receiver block diagram

It is clear that the spreading waveform is controlled by a PN sequence, which is a binary random sequence. This PN is then multiplied with the original baseband signal, which has a lower frequency, which yields a spread waveform that has noise-like properties. In the receiver, the opposite happens, when the pass-band signal is first demodulated, and then de-spreaded using the same PN waveform. An important factor here is the synchronization between the two generated sequences.

There are two extreme cases of channel noise and fading that will be subjected to the DSSS system models.

Bit error rate (BER) is a performance measurement that specifies the number of bit corrupted or destroyed as they are transmitted from its source to its destination. Several factors that affect BER include bandwidth, signal-to-noise ratio (SNR), transmission speed, transmission medium and transmission speed.

3. SIMULATION MODEL

The Simulink model of DSSS system is shown in figure 3. It is simulated using BPSK (M=2) and it is followed by QPSK (M=4).

The random sequence of binary numbers (signal *x(t)*) is produced by Bernoulli Data Generator. Each user data is then multiplied with independent or different PN code, produced by a PN generator, using XOR logical operator. In this simulation the value of PN generator polynomial specifies as [11001], represent the same polynomial:

$$p(z) = z^4 + z^3 + 1 . \tag{4}$$

The multiplied signal of each user is represented as $s(t)$ after the signal is modulated by either BPSK or QPSK. Each signal is added before it is subjected to the channel. Firstly, the model is simulated under thermal noise, represented by AWGN (the AWGN Channel only). Then, the channel is simulated with various different parameters using Non-Line of Sight multiple reflected rays represented as multipath Rayleigh fading. The parameter “Doppler frequency” in multipath Rayleigh fading channel is determined with independence [6]:

$$F_d = \frac{vf}{c} \cos \vartheta \quad , \tag{5}$$

where f is the transmission carrier frequency;

c is the speed of light;

v is the speed of the move;

θ - the angle, that the mobile moves at speed v making of with the direction of wave motion.

In this model, to determine oppler frequency, is assumed:

f=2GHz, v =60km/h, $\theta = 60^0$.

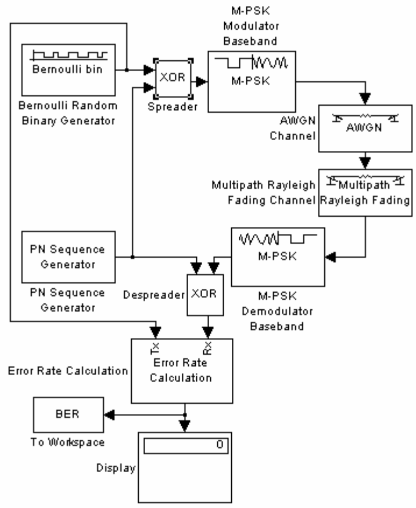

Fig.3 Simulink model of DSSS system

AWGN and Rayleigh fading are chosen to represent fading effect in the channel because we want to make a comparison of DSSS system models in two extreme channel conditions.
At the receiver, the signal $s(t)$ is demodulated before the user data is separated from PN code by XOR logical operator. Finally, when the necessary simulations are done, tables and graphs of BER as a function of SNR for various parameters are plotted.

4. SIMULATION REZULTS

In this simulation, a generic *m* file is used together with simulink to simulate the BER versus Eb/No [dB] graphs. Based on data generated by computer simulation of DSSS system models, relationship for multiple rays using BPSK and QPSK modulation techniques between BER as a function of the following parameters are obtained. They are:

- BER versus SNR in AWGN channel for BPSK and QPSK modulation technique;

-BER versus SNR in AWGN and multipath Rayleigh fading channel with Doppler shift at 60km/h for BPSK and QPSK modulation technique.

A. Simulation using Simulink.

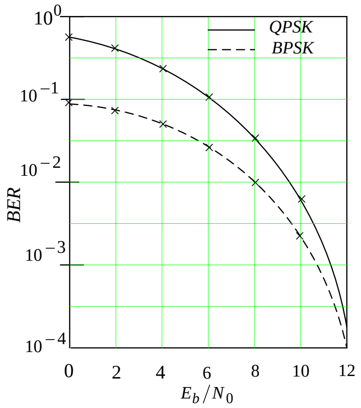

Fig.4. BER vs SNR in AWGN channel for BPSK and QPSK modulation scheme

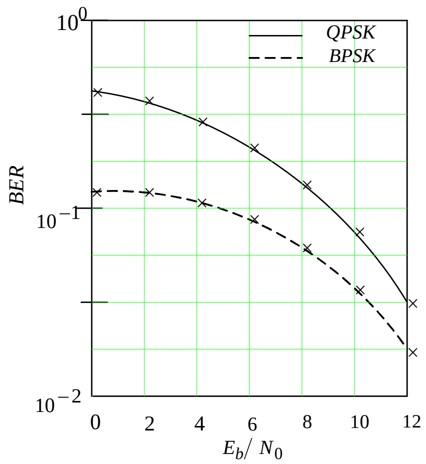

Fig.5. BER vs SNR in AWGN channel and multipath Rayleigh fading channel with Doppler shift at 60km/h for BPSK and QPSK modulation scheme

B. Simulation using M files

- Simulation result for evaluation on BER vs. SNR of QPSK modulation for AWGN channel

TABLE I
RESULT FOR EVALUATION ON BER VS. SNR FOR AWGN CHANNEL

E_bN_0	BER
0	$7{,}8075.10^{-2}$
1	$5{,}667.\ 10^{-2}$
2	$3{,}76.\ 10^{-2}$
3	$2{,}24.\ 10^{-2}$
4	$1{,}2242.\ 10^{-2}$
5	$6{,}025.\ 10^{-3}$
6	$2{,}31.\ 10^{-3}$
7	$8{,}25.\ 10^{-4}$
8	$1{,}95.\ 10^{-4}$
9	$1{,}0.\ 10^{-5}$
10	$5{,}0.\ 10^{-6}$

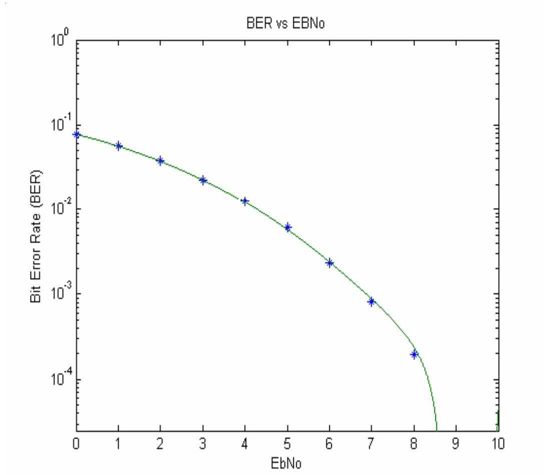

Fig.6. BER vs SNR in AWGN channel for QPSK modulation scheme

- Simulation result for evaluation on BER vs. SNR of QPSK modulation for AWGN and 2-ray Multipath Rayleigh Fading channel at 60 km/h

TABLE II
RESULT FOR EVALUATION ON BER VS. SNR FOR AWGN AND MULTIPATH RAYLEIGH FADING CHANNEL

E_bN_0	BER
0	$1{,}395.10^{-1}$
2	$1{,}022.\ 10^{-1}$
4	$7{,}264.\ 10^{-2}$
6	$4{,}871.\ 10^{-2}$
8	$3{,}247.\ 10^{-2}$
10	$2{,}098.\ 10^{-2}$
12	$1{,}463.\ 10^{-2}$
14	$9{,}44.\ 10^{-3}$
16	$6{,}305.\ 10^{-3}$
18	$4{,}58.\ 10^{-3}$
20	$3{,}07.\ 10^{-3}$

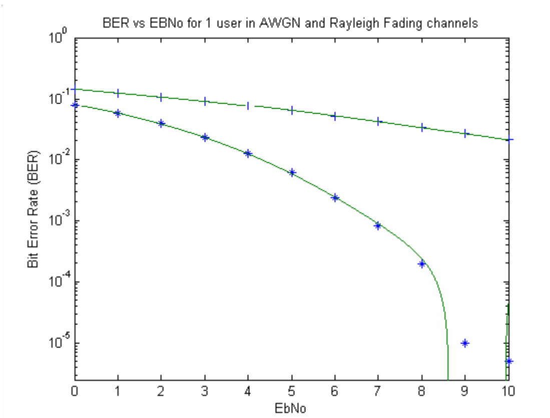

Fig.7. BER vs SNR in AWGN and 2-ray Multipath Rayleigh Fading channel for QPSK modulation scheme

5. Conclusions

From Fig.4 and Fig.5 it is shown that the higher-order modulations exhibit higher error-rates, in exchange however they deliver a higher raw data-rate. Comparison between BPSK and QPSK modulation schemes shows that QPSK performs very poorly in both AWGN and AWGN with multipath fading channel. Both simulation using Simulink and m files shows that each BPSK and QPSK modulation techniques in AWGN channel has good performance when it is compared to that of under multipath Rayleigh channel.

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