Security Enhancement of Wireless Systems by Using Frequency Hopping Technique

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Abstract

The aim of this work is to design and simulate a frequency hopping spread spectrum system (FHSS). FHSS technique can prove the security of communication system across communication path. It is one of the essential types of spread spectrum techniques. Random binary sequence is used in the system to present the data and PN generator to control the sequence of output hops. The system has (63) random frequency hopping channels with hopping rate of 1600 hop/sec. The system data rate is (1Mbps) and data is modulated with GFSK modulation type. The RF channel that used in this system is the additive white Gaussian noise channel (AWGN). The transmitted data is received and (BER) of the system is obtained. The system is simulated by using MATLAB2013-Simulink program.

Keywords: Wireless communication system, FHSS, PN generator, AWGN channel, BER.

1. Introduction

The spread spectrum technique is based on Shannon Information Theory. This technique spreads the signal over a wide bandwidth in order to give safety against such attacks (Pintukumar & Usha, 2015). Spread spectrum technique offers several advantages and characteristics some are low probability of detection, low probability of intercept, low probability of exploitation, anti-jamming, resistance to fading, and multiple access (Mosa, 2007), (Richard, 2011). Frequency hopping spread spectrum (FHSS) is a branch of spread spectrum communication system. Because of its excellent performances, FHSS is widely used in military and civilian applications (Pintukumar & Usha, 2015), (Ravi & Imran, 2014).

Frequency hopping spread spectrum is the periodic change of the carrier frequency of a transmitted signal (Kumar, 2014). The communication systems can get a better interference resistance because of this time-varying feature. Frequency hopping system depends on the avoidance process in order to prevent interference. Even if the avoidance process fails the frequency hopping stills suppress interference because this failure is temporary as the carrier frequency changes in periodic manner. By using the channel codes the effect of the interference can be reduced (Don, 2011).

The sequence of frequencies that determined by the frequency hopping system is called hopping pattern and hopset is the M available frequencies {f_1, f_2, …, f_M}. The rate of the change of carrier frequency is called hopping rate while the hopping band is the band that contain M channels where the hopping done over this band. The code sequence produced by the code generators determines the hopping patterns by controlling the frequency synthesizer .The frequency hopping signal generated by combining the data signal after modulation with output of the frequency synthesizer (Don, 2011), (Olšovský & Podhoranský). FH Spread spectrum

systems can be divided into two different types they are Slow frequency hopping (SFH), and Fast frequency hopping (FFH) (Jack, 2007), (Adeel & Rahat, 2012).

2. System Design

In the Simulink page the system uses a random binary sequence to present the data. After the data is modulated using a modulation scheme it is multiplied by the hopping output. The hopping output is controlled by PN sequences. The multiplied data is send during a channel and then this data is multiplied again using the same hopping sequence in order to get the modulated data. To recover the original binary sequence the same modulation scheme is used. Figure 1 shows the block diagram of frequency hopping system considered in this paper.
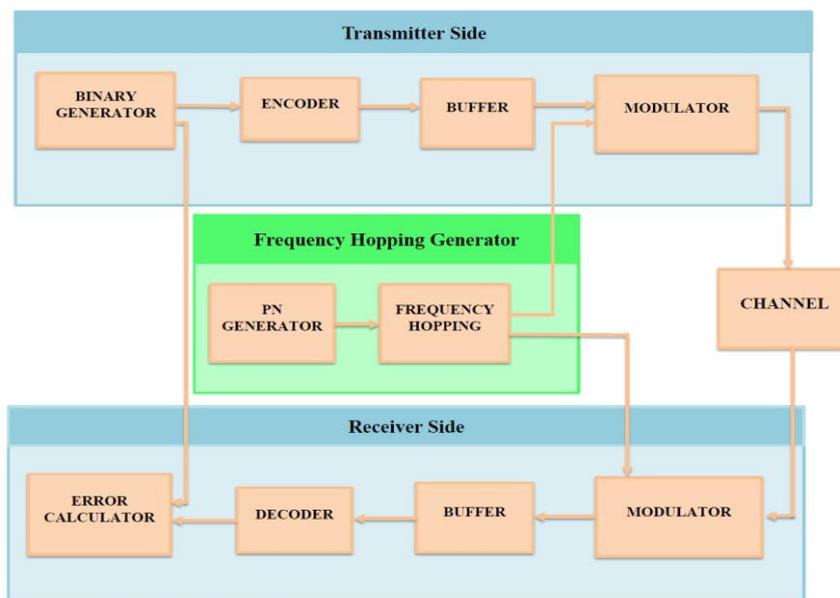

Figure 1: Simulation system design

The system consists mainly of the following parts: transmitter, channel, receiver, and frequency hopping generator.

i. Transmitter side

The transmitter side sends the frequency hopping signal through a specific channel. When the data is generated it must pass through number of a blocks to process it in order to produce the hopping signal. The blocks that the Transmitter consist of are binary generator , encoder, buffer, and Modulator.

The binary data used in this system are produced using Bernoulli expression. The binary value are generated according a probability p. The zero value has a probability of p and the one value has a probability of 1-p. In this system the value of the probability p will be (0.5) which means that the 0's and 1's having the same generation probability. The sample time of the output is ($1.5*10^{-6}$ sec) and the sample per frame is 10.

The encoder type used in this system is Binary Cyclic Encoder. The Binary Cyclic Encode produces a systematic cyclic code with K data length and N codeword length. In this system K will has a value of 10 while the N has a value of 15. The output bits of the cyclic encoder must put into packets format in order to avoid the bit by bit modulation of information. Where each packet contains 625 bits.

The output of the buffer is modulated using GFSK modulator. GFSK modulation can be achieved by using continuous phase modulation (CPM) block with M-array number parameter equal to 2 and Gaussian shape is selected for output Frequency pulses. The total modulation is done when the output of the GFSK modulator is

multiplied with the output of the frequency hopping block. The result of this multiplication is the Gaussian frequency hopping signal.

ii. Channel

The frequency hopping signal produced by the modulator block is applied to a channel. The channel type used in this system is the additive white Gaussian noise (AWGN). The (AWGN) channel add noise to the input signal in order to represents the real transmission environment. The channel mode used in this system is the signal to noise ratio E_b/N_o and a sample period of (10^{-6} sec).

iii. Receiver side

The output of the AWGN channel is applied to the receiver side. At the receiver side the frequency hopping signal is demodulated by using the same code sequence and the second process is to recover the binary data. The receiver consists of number of blocks to do this operations. The receiver side blocks are demodulator, buffer, decoder, and error calculator.

The total demodulator is done by multiplying the output of the AWGN channel by the output of the frequency hopping block. Therefore the hopping sequence will be removed. To recover the data the output of the multiplication is applied to 2-FSK demodulator. The output of the 2-FSK demodulator is applied to the buffer. The operation of the buffer in this section is to put the incoming bit into a new packet length. The packet length must be equal to the length of codeword N of the Binary Cyclic Encode therefore N must be equal to 15.

To obtain the original signal the out of the buffer is applied to the binary cyclic decoder. The decoder will decode the 15 bits vector resulted from the buffer. Finally The error calculator used to calculate the bit error rate (BER) of the system. The error rate calculation block will compare data that comes from the binary source (transmitter side) with the data comes from the decoder (receiver side). The error rate is calculated by dividing the number of unequal pairs of data by the total number of input data. The error rate is displayed by using BER display.

iv. Frequency hopping generator

The frequency hopping generator generates the carriers frequencies and these carriers produced in random manner. The PN generator uses linear feedback shift register (LFSR) to generate its pseudorandom binary numbers. The PN generator controls the output frequency of the hopping generator. The PN generator used in this system has 6 bits and output sequence is chosen to be according m –sequence algorithm.

The output of the PN generator is converted into integer number by using bit to integer converter. The generated integer numbers are used to produce the hopping carriers. The sample time of this PN generator determines the hopping rate of the system and it is equal to 1⁄9600 sec which means that the PN hop rate is 9600 hop/sec but the bit to integer converter block has 6 bits which means that the PN rate is divided by 6, therefore the system hopping rate will be 1600 hop/s. The overall simulation system is shown in Figure 2.

The output of the PN generator is then applied to the MFSK modulator. The MFSK modulates the input signal using the M-array frequency shift keying method. In this system the number of frequency channel M will be equal to 64. Which means that the output of this block will be 63 different carrier frequency.

The separation between each channel and the other is set to (10^6) Hz while the samples per symbol is equal to ($6.25*10^4$) sample. The result of dividing samples per symbol by symbol period of the input is the sampling frequency. In order to avoid aliasing in the output signal the sampling frequency should be greater than the product of M-array and the separation frequency.
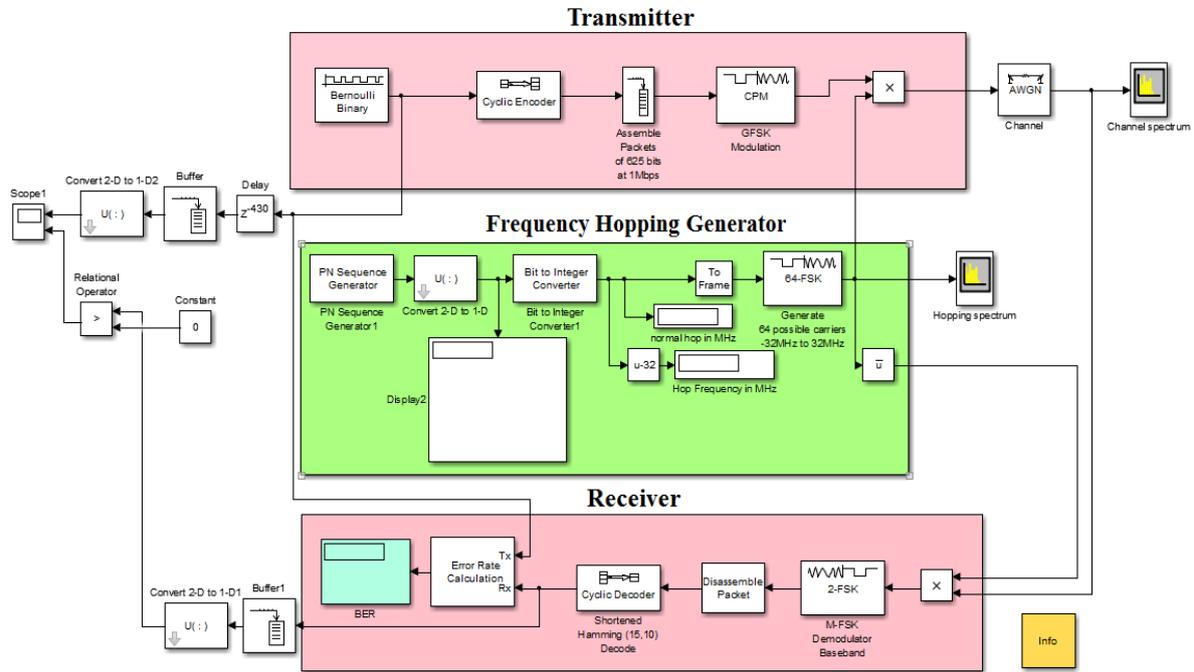
Figure 2: MATLAB simulation of FHSS

3. Results

The simulation results consists of the spectrum of frequency hopping generator, spectrum of AWGN, system bit error rate, transmitted and received data signals. The output of the hopping generator can be seen by using spectrum analyzer tool (hopping spectrum) as shown in Fig. 3. The hops frequencies that shown in Figure 3. are -28, -13, 0, 12, and 31 MHz respectively. This reading according to display of spectrum analyzer while the real frequencies reading are 32, 4, 44, 19, and 63MHz respectively. These hops are multiplied with the modulated data to produce the frequency hopping signal.
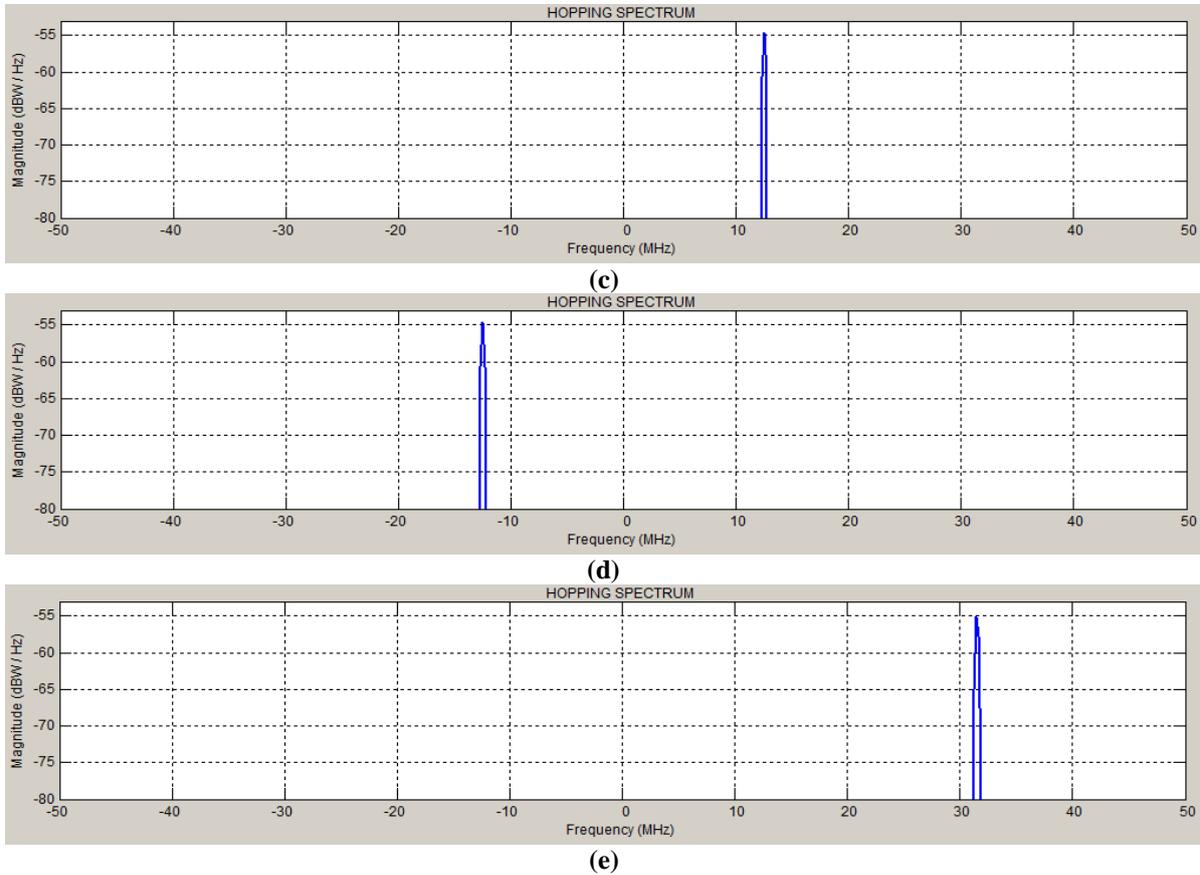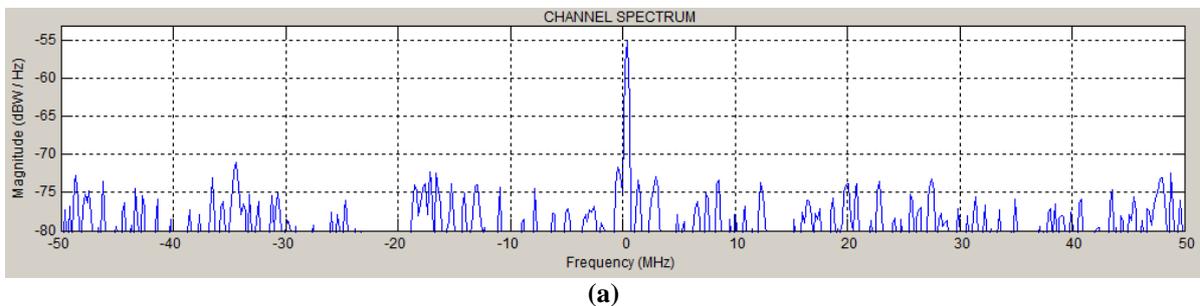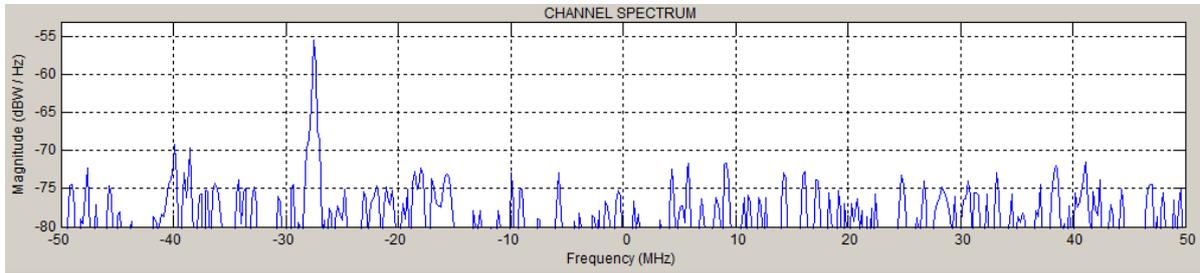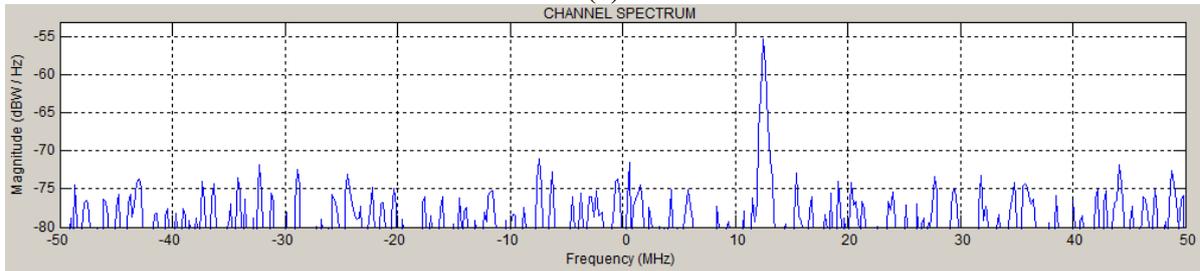

(a)

(b)

(c)

(d)

(e)
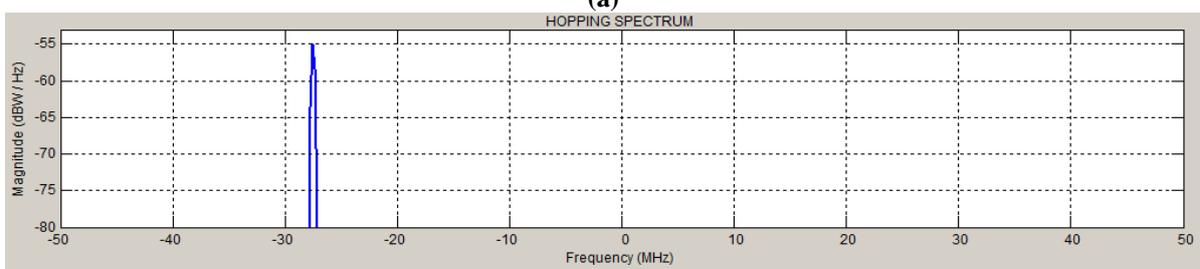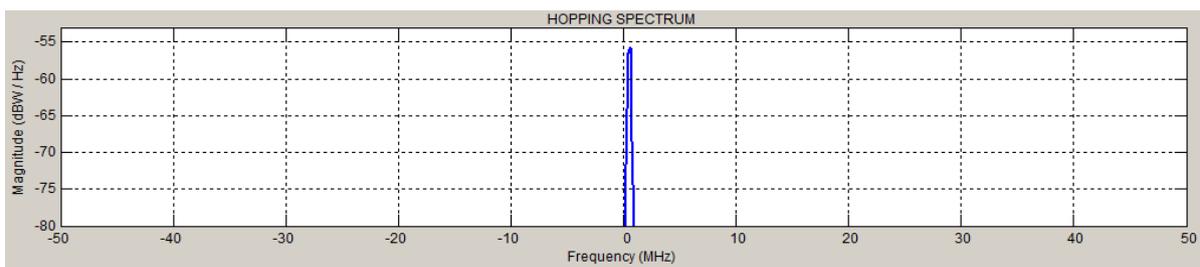
Figure 3: Hopping spectrum with frequencies of (a) 0 MHz, (b) -28MHz, (c) 12MHz, (d) -13MHz, and (e) 31MHz.

While the spectrum of the transmitted signal (FHSS) can be seen by using channel spectrum tool as shown in Figure 4. The frequency hopping signal is transmitted through the AWGN channel and also the real reading of the transmitted signal frequencies according to Figure 4 are 32, 4, 44, 19, and 63MHz respectively. There are spikes in this figure that represents the data at the hopping signal.
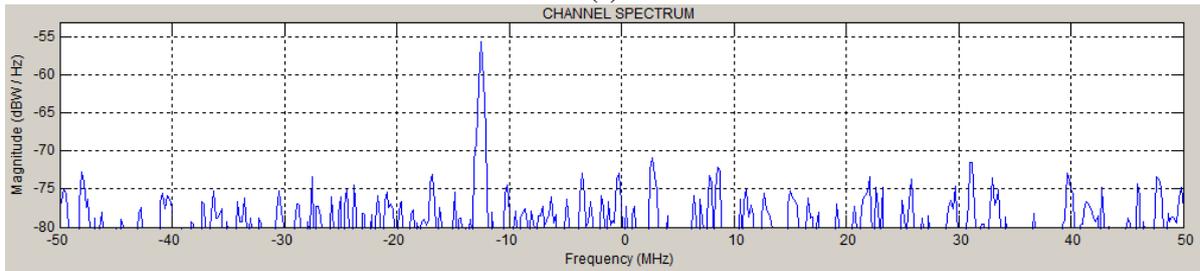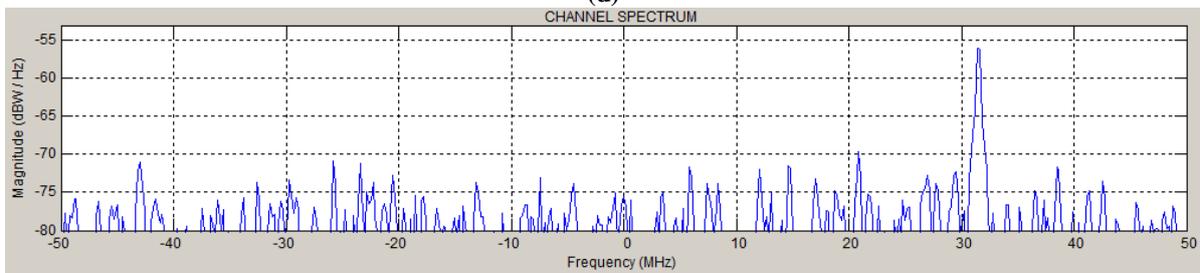

(a)

Figure 4: Spectrum of transmitted signal with frequencies of(a) 0 MHz, (b) -28MHz, (c) 12MHz, (d) -13MHz, and (e) 31MHz.

The received signal is modulated again with the same frequency hops in order to remove the hops pattern. Then its applied to 2-FSK modulator and cyclic decoder to obtain the received data bits. The received and the transmitted data can be seen using oscilloscope tool as shown in Figure 5. This Figure shows the matching between transmitted and received data.
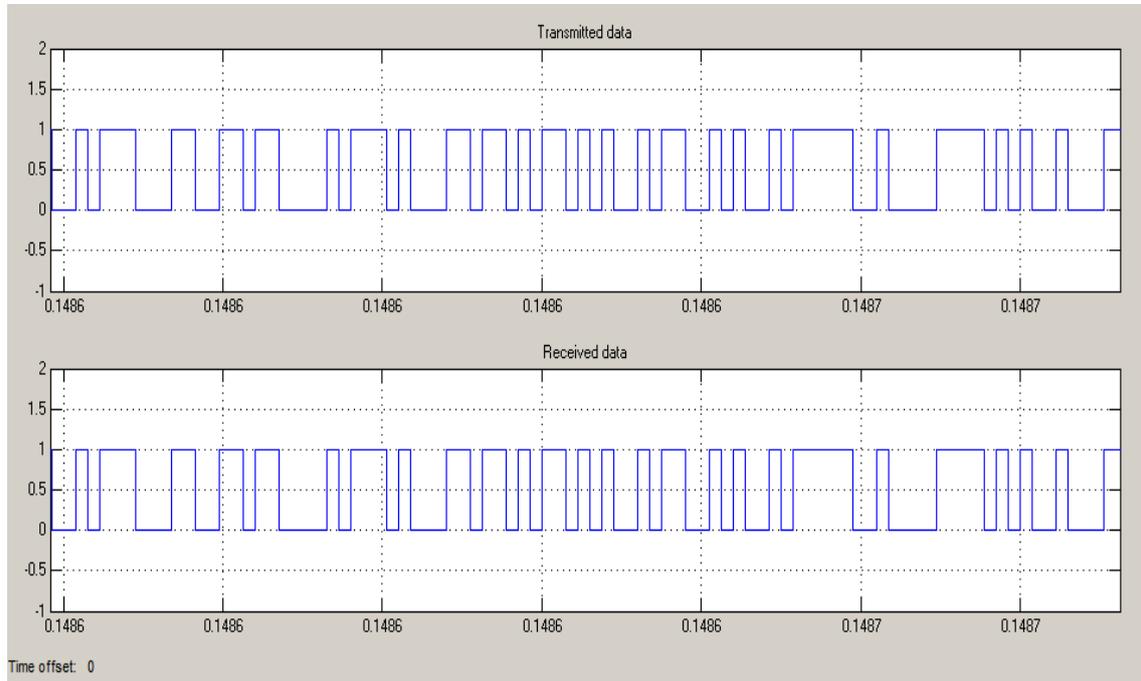
Figure 5: The transmitted and received data bits

The system bit error rate can be obtained by using bit error rate calculator tool. The error rate calculator has two inputs one comes from the generated data in the transmitter side and the second for the obtained data (output of cyclic decoder) in the receiver side. In the setting of AWGN channel the mode of the signal to noise ratio is set to Eb/No. The BER curve is shown in Figure 6. This figure can be obtained by increasing the Eb/No from 0 to 12 dB and recording the resulted BER in each step. According to Figure 6. when the Eb/No increases the BER of the system will reduce
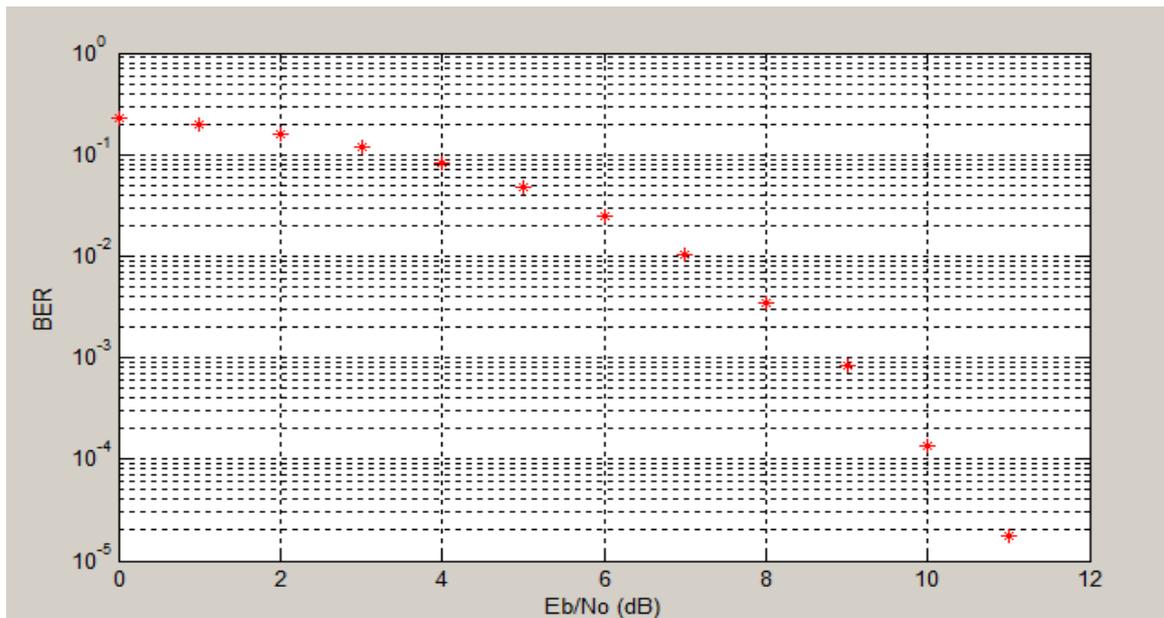

Figure 6: BER versus Eb/No of FHSS with 63 channels

4. Conclusions

Here, we design and simulate a transceiver model for frequency hopping spread spectrum system. The total system design is achieved with MATLAB2013-Simulink software. The system has 63 channels with hopping rate of 1600 hop/sec and the transmitted data has a data rate of 1Mbps. The spectrum of hopping generator and transmitted channel is obtained with different hopping pattern. In presence of AWGN channel we analyzed performance of model and plot the system BER also the matching between transmitted and received signals is obtained.

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