Design for Scientific RENAISSANCE

JASER

Simulation Of Frequency Hopping Spread Spectrum And Jamming In Wireless Communication Systems

Husham J. A. Alqaysi

Cihan University, College of Engineering
Communication and Computer Engineering Department
hushamjakh@yahoo.com, dr.hisham.j@cihanuniversity.edu.iq

Article Info

Received: 20/10/2013
Accepted: 28/11/ 2013
Published online:1/12/2013

ISSN 2231-8844

Abstract

In this paper, a simulator is designed to simulate a frequency hopping spread spectrum (FHSS) communication system using VisSim/Comm software which is mainly implemented to design and analyze problems of communication systems. The simulation of FHSS system requires to simulate both the transmitter and the receiver as well as the medium (noise/jamming) between them. This paper presents how these three items are simulated and more over how the performance of such system can be evaluated. Among many methods of evaluation, the Bit-Error-Rate (BER) plot is adopted in this paper which is defined as the probability of bit error (Pe) against the ratio of bit energy (Eb) to the noise energy No (Eb/No).

Keywords: Frequency hopping spread spectrum FHSS, interference, Narrow band noise jamming, Wireless Communications, Simulation of Communication Systems..

1. Introduction

Spread spectrum systems (SSS) is a class of wireless digital communication systems mainly designed to overcome a jamming situation, i.e., when an intruder intends to disrupt the communication. The name spread spectrum comes from the fact that the transmitted signals occupy a much wider frequency bandwidth than what is required.

It is well known that the intentional jamming situation is most found in military applications, and as a consequence of this, spread spectrum systems were originally developed specifically for military purposes (Taub and Schilling, 1986; Don T., 2005). However, in later years, spread spectrum systems have been introduced in many commercial applications that require good anti-jamming properties.

The bandwidth necessary for the transmission of a digital communications signal is determined by the data rate, R_b, (measured in the number of information bits transmitted per second) and the chosen type of modulation format. For binary pass-band modulation, the minimum required bandwidth is approximately $W_{min} = R_b$ Hz. If the actual bandwidth of the transmitted signal is denoted by W_{ss}, then for a spread spectrum system W_{ss} will be much larger than R_b. The spectral efficiency of the spread spectrum communication link is Rb/Wss bits/second/Hz. It is noticed that, by definition, the spectral efficiency of a spread spectrum system is very low. However, this is not necessarily the case since several users using spread spectrum signals can share the same bandwidth, and the system's spectral efficiency (measured in the total number of information bits transmitted per second) is considered very good, although the individual links have low spectral efficiencies.

There are many different ways to use the bandwidth. The most common ones are called direct-sequence (DSSS) and frequency-hopping (FHSS) spread spectrum. A frequency hopping spread spectrum (FHSS) is defined, when the base-band data is modulated with frequency randomly hopping from one frequency to another (Massaro, 1975; Schmidt and McAdam, 1975; Schmidt, 1975). Frequency hopping was first used for military electronic countermeasures, because the transmitted signal that uses frequency hopping is difficult to detect and monitor.

In FHSS systems the carrier frequencies of individual users are varied in a pseudorandom (PN) manner within a wideband channel. FHSS allows multiple users to simultaneously occupy the same spectrum where each user dwells at a specific narrowband channel at a particular instance of time, based on the PN code of the user. In a FH receiver, a locally generated random frequency sequence is used to synchronize the receiver's instantaneous frequency. If the rate of change of the instantaneous frequency is greater than the symbol rate, the system is referred to as a *fast frequency hopped system* (Shin and Lee, 2001; Teh et al., 1998). On the other hand, if the channel frequency changes at a rate equal to or less than the symbol rate, the system is said a *slow frequency hopped*. Figure (1) shows a block diagram of a typical wireless communication system using BPSK modulation operating in the presence of a noise jammer. .

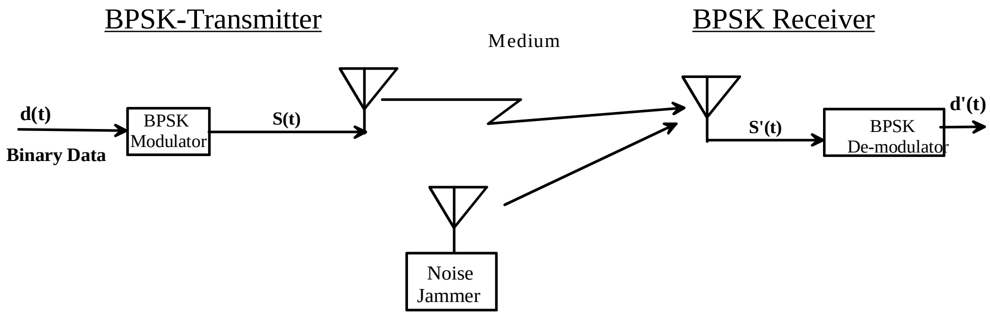

Fig.1: Transmitter, Receiver and Noise Jammer Block Diagram of BPSK Wireless System.

One way to reduce the effect of jamming is to use frequency hopping spread spectrum (FHSS). Figure (2) shows a block diagram of BPSK-FHSS wireless communication system.

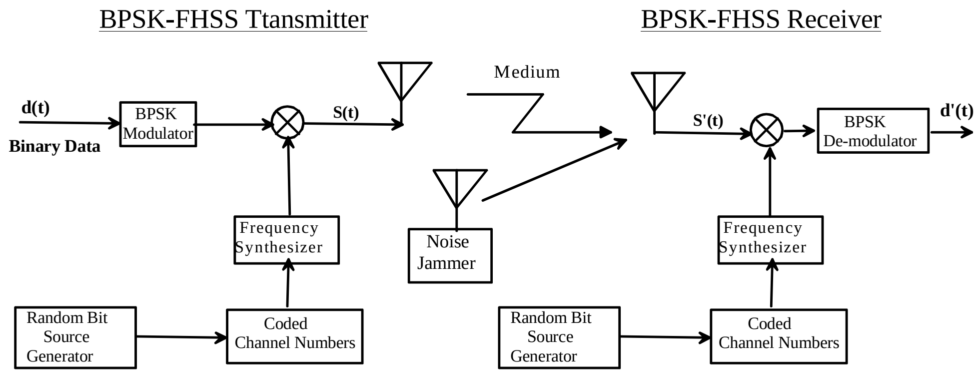

Fig.2: Transmitter and Receiver and Noise Jammer Block Diagram of BPSK-FHSS Wireless System.

A random (or pseudo noise PN sequence) converts a narrowband signal to a wideband noise like signal before transmission. Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits, independent of rate of transmission (Waylan, 1975: Shanmugan and Breipoh, 1988) .

This paper is organized around four sections. Section 1 discusses a general introduction as is given above. Section 2, describe simulation of communication systems. In section 3, results of simulation application of BPSK-FHSS system is introduced. Finally the discussion and conclusion of the application of the designed simulator is presented in section 4.

2. Simulation Of Communication Systems.

In this paper, simulations of BFSK and BFSK-FHSS are built using VisSim/comm. This program which is mainly designed to simulate and analyze communication systems. This is performed by selecting and connecting proper simulation blocks. Figures (3) and (4) show block diagrams of simulating BPSK and BPSK-FHSS wireless communication systems which are shown in Figs(1) and (2) respectively.

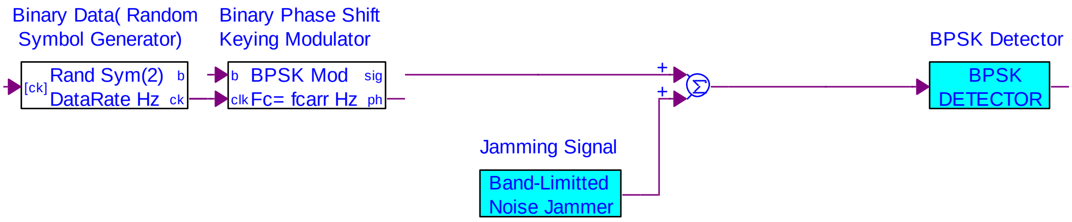

Fig.3: Simulation block diagram of BPSK communication system.

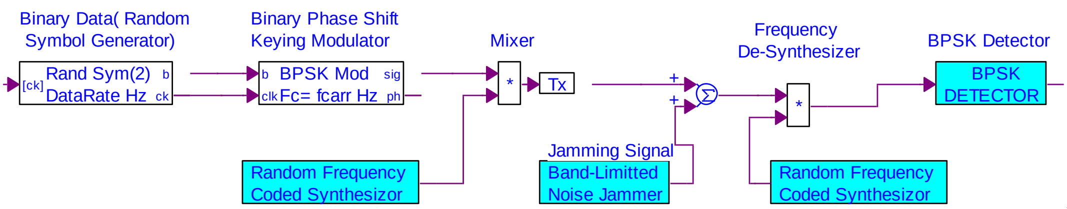

Fig.4: Simulation block diagram of BPSK-FHSS communication system.

In simulation process, true values of system parameters may not be used but relative values. Also, complex bocks are sometimes preferred to be adopted than real. The main reason for these is to reduce simulation time and computation memory.

In this paper, an example will be presented to show how the FHSS can protect communication system against narrow band jammers. Two cases are analyzed; the first case is that the original binary data is transmitted by using normal BPSK modulation as shown in Fig.3. The second case, the same binary data is transmitted through BPSK-FHSS system as shown in Fig.4. It is assumed in both two cases, that the two transmission systems are operated under similar narrow band jammer. Table 1 shows the data used in the simulation. The simulator designed in this paper is capable to track the signal at any point in the system. One of the valuable information in this case is the power density spectrum. Figures (5-7) show the power density spectrum at various points in the BPSK-FHSS system. This is plotted for the case study mentioned above. These figures show that the transmitted data occupies more bandwidth (spread) than the original binary data. The spread spectrum bandwidth depends on the number of hopped carrier frequencies and the spacing between adjacent carriers.

Table -1:-

Parameter	Value	Variable
Jamming Frequency	23000	Fj
Jammer Bandwidth	1000	BWj
No of Hopped Frequencies	11	NOHF
Data Rate (R)	100.	DataRate
Average Signal Jamming Power (dBm)	23.0	AverSigPower
Hopping Rate	512	HopRate
Voltage Controlled Oscillator (VCO) Center Frequency	11000	fvco
Gain Of VCO (Hz/Volt)	2000	VCOgain
BPSK Carrier Frequency	23000	fcarr
No. of bits/symbol	2	bps

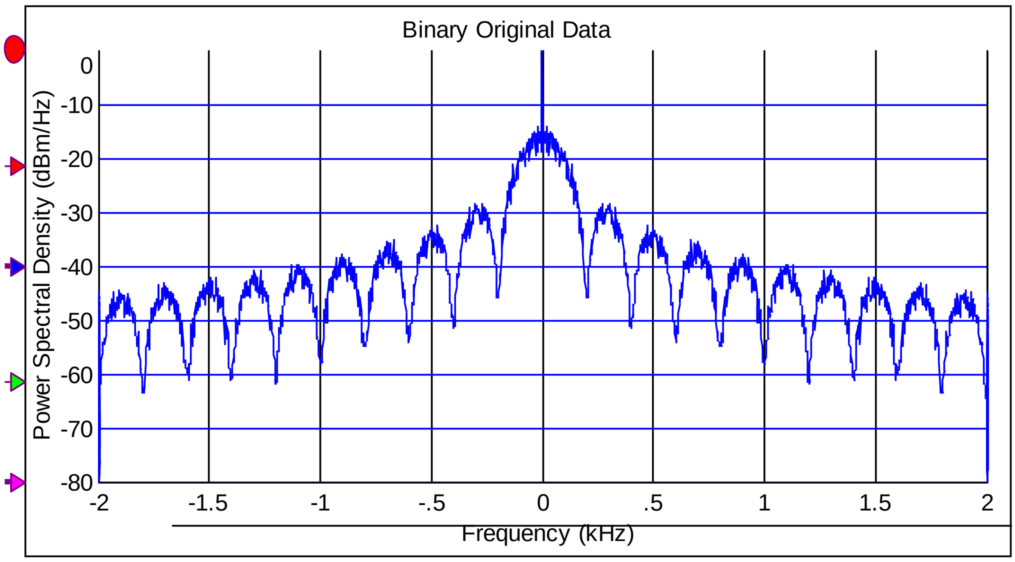

Fig.(5) Power spectral density for the original binary data.

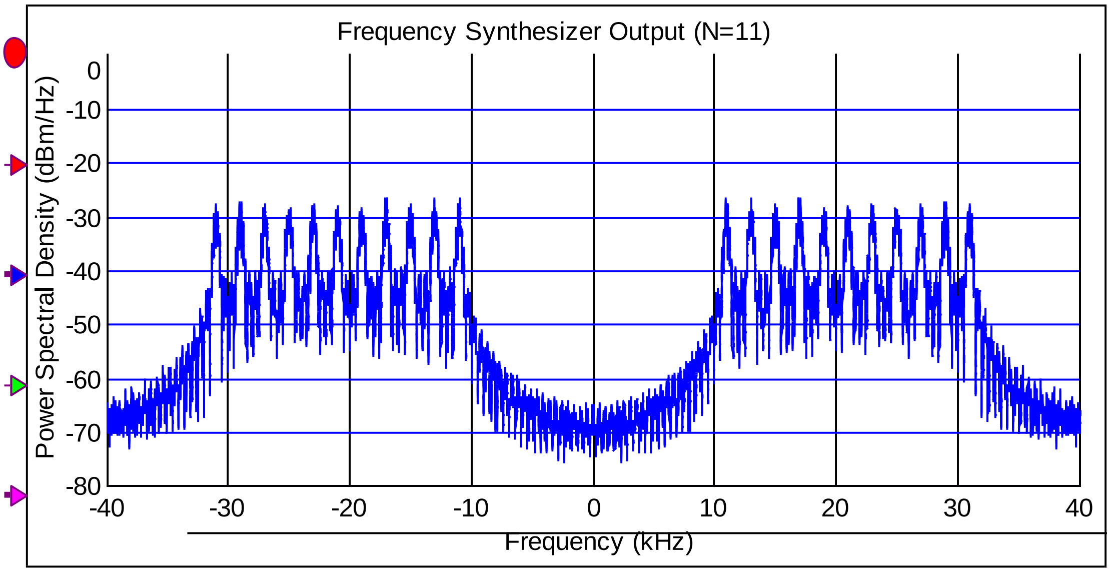

Fig.6: Power spectral density output of the synthesizer.

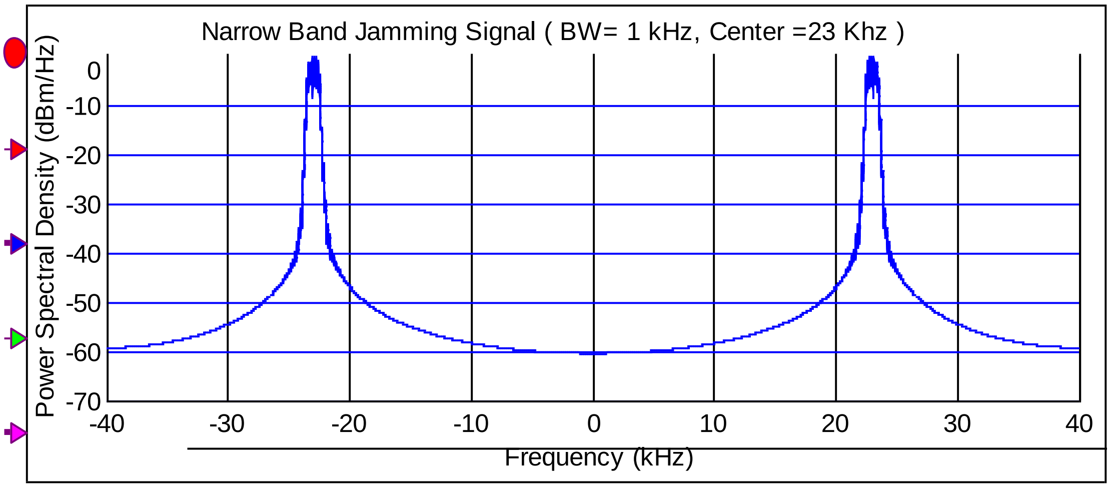

Fig.6: Power spectral density output of the Narrow Band Jammer.

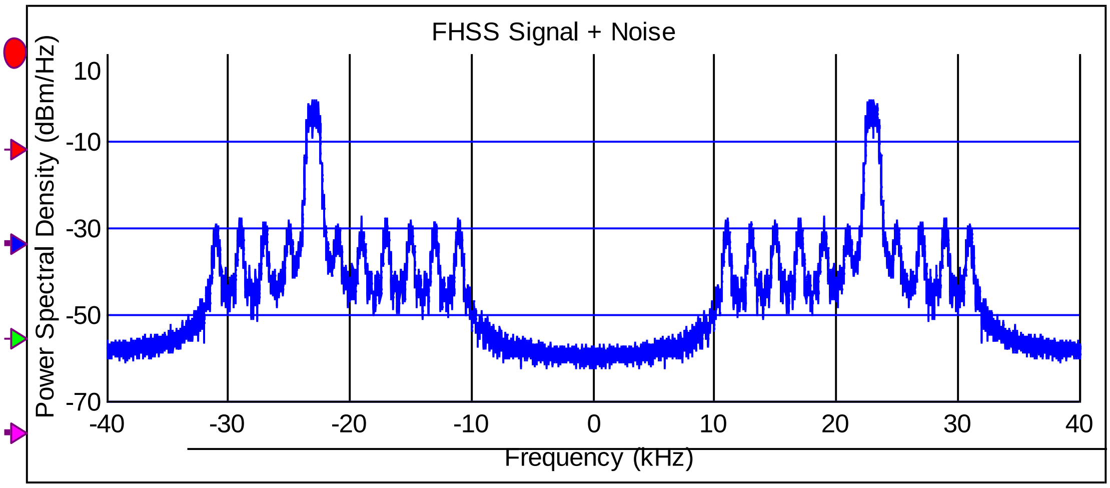

Fig.7: Power spectral density output FHSS + Jammer

3. Simulation Results

There are various methods of evaluating digital communication systems (Shanmugan and Breipohl, 1988: Choi and Stark, 2002). The method adopted in this paper is the BER (Bit-Error-Rate) plot. Figure (8) shows the BER block diagram used in the simulator designed in this paper.

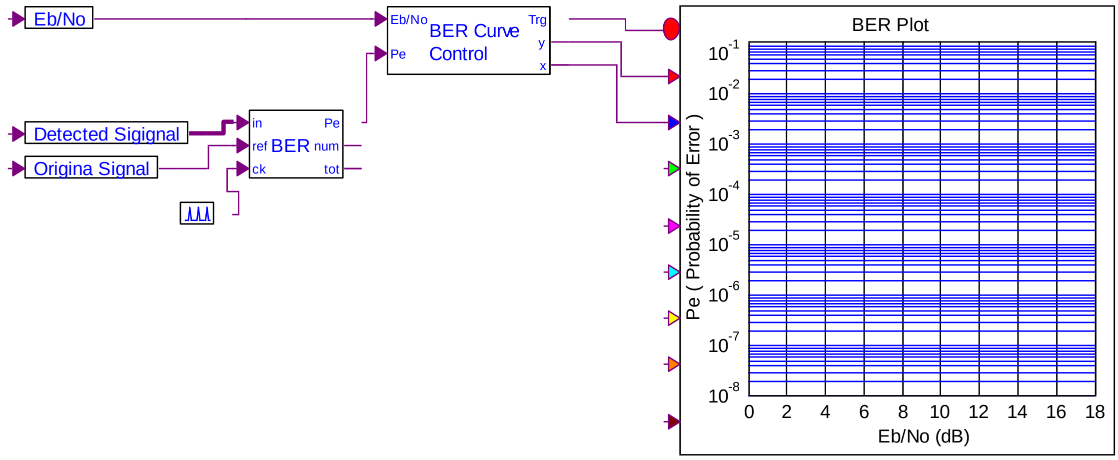

Fig.(8) Block diagram of BER.

The two case-study mentioned above are analyzed and evaluated. Figure (9) shows simulation results of BER when BPSK and BPSK-FHSS are operated under narrow band jammer. It can be noticed from fig.(9) the effect of frequency hopping on system performance which shows an appreciable reduction in the value of the probability of error particularly at practical values of Eb/No at or above 14 dB.

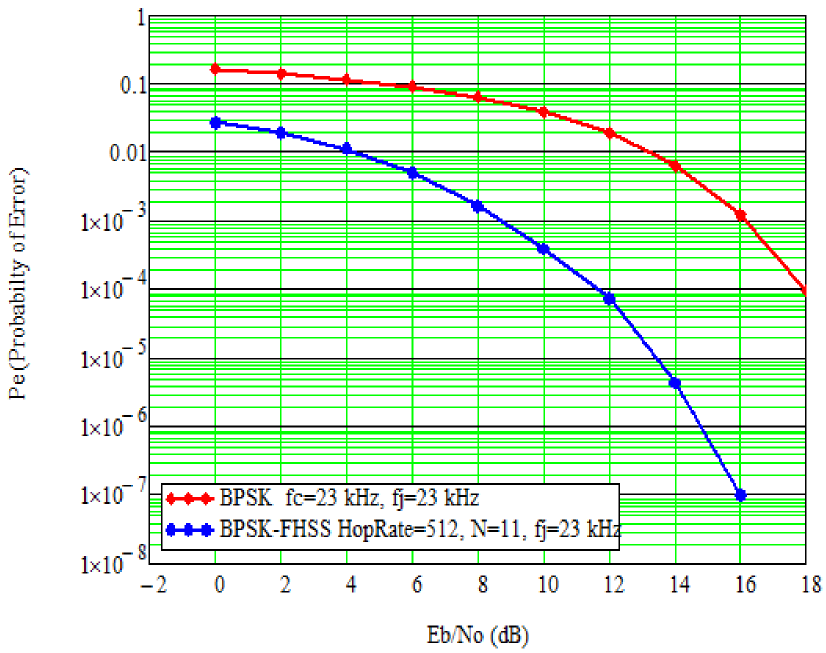

Fig.(9) Probability of error (Pe) against Eb/No (dB) when BPSK and BPSK-FHSS are operated under a narrow band jammer.

A comparison between slow and fast frequency hopping in BER performance is shown in Fig.(10). The results are obtained by running the simulator, keeping all parameters fixed and just changing the hope rates between 8 and 1024 hps for the data rate value of Rb=100 bps. Results indicate that good improvement in system performance is achieved (low Pe values for the same Eb/No) for the case of fast hopping compared with slow hopping case. Finally, the effect of number of hopped frequencies on the BER plots is shown in fig.(11) which shows that lower probabilities of error (Pe) are obtained as the number of hopped frequency is increased irrespective of Eb/No values.

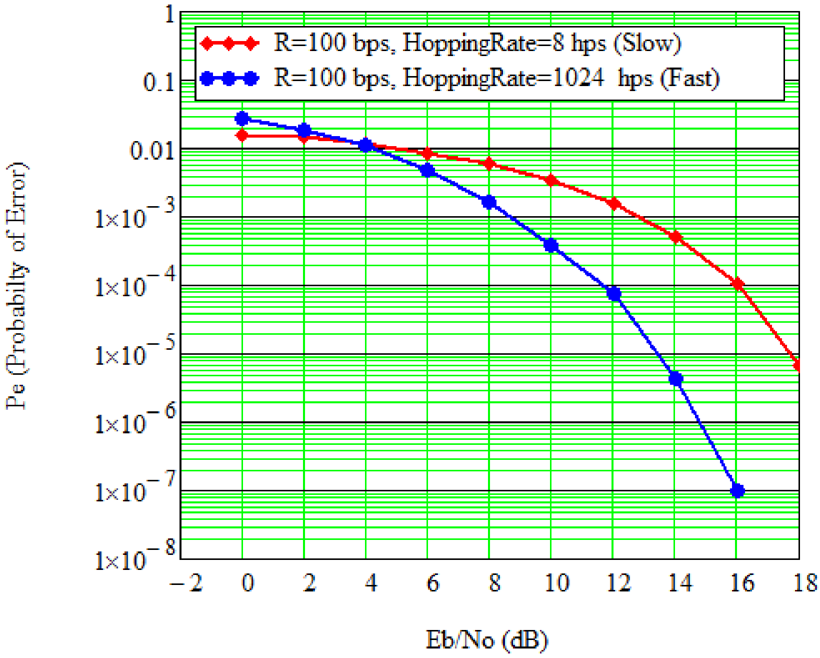

Fig.10: Simulation results of slow and fast hopping BPDK-FHSS system.

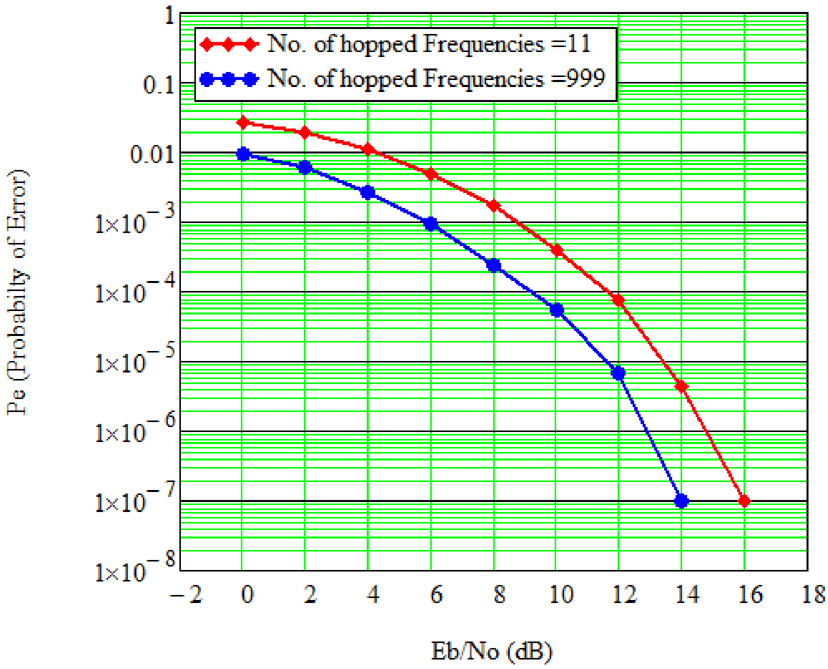

Fig.11: Simulation results of operating BPSK-FHSS system with two different numbers of hopped frequencies.

4. Discussion and Conclusions

Simulation results show that implementing BPSK-FHSS system significantly reduced the probability of bit errors (Pe) when compared with normal transmission (BPSK) systems. This is true if both are both communication systems are operating under the same environment of narrow band jammer conditions.

A simulator for frequency hopping is designed using VisSim/comm program. The simulator is capable of simulating a complete communication system operating under noise/interference jamming environment. The simulator has the capability to evaluate communication system performance through the use of BER plots. Results of simulation show that the present simulator could be used in designing communication systems and other research areas of relevant field. Undergraduate/postgraduate student can use this simulator in their study/research fields. This simulator can be developed to cover other types of digital communication techniques such as frequency, MFSK-FHSS, frequency hopping multiple access (FHMA) system, hybrid direct sequence frequency hopping system (DS/FH), Bluetooth systems and others.

References:

Choi J. and Stark W., (2002), Performance analysis of ultra-wideband spread spectrum communications in narrowband interference", " Proceedings of the 2002 IEEE Military Communications Conference (MILCOM’02) ", 7-10 October 2002.

Don T., (2005), Principles of Spread Spectrum Communication System, Springer, New York.

Massaro M., (1975), Error Performance of M-ary Noncoherent FSK in the Presence of CW Tone Interference,” IEEE Transactions Communication, vol. 23, pp. 1367-1369.

Schmidt H. and McAdam P., (1975), Modulation Techniques for Communications, Part 2: Anti- Jam Performance of Spread Spectrum Coded System,” in Proceedings of the IEEE 1975 National Aerospace and Electronics Conference. (NAECON 1975), pp. 59-65.

Schmidt H.,(1975), Modulation Techniques for Communications, Part 1: Anti-Jam Performance of Spread Spectrum Coded System, Proceedings of the IEEE 1975 National Aerospace and Electronics Conference (NAECON’1975), pp. 51-58.

Shanmugan K. and Breipohl A., (1988), Random Signals: Detection, Estimation, and Data Analysis. New York, NY: John Wiley and Sons, second ed.

Shin O. and Lee K., (2001), Performance Comparison of FFH and MCFH Spread-Spectrum Systems with Optimum Diversity Combining in Frequency- Selective Rayleigh Fading Channels, IEEE Transactions on Communications, vol. 49, pp. 409-416.

Taub H., Schilling D. L., (1986) Principles of Communication Systems, 2ed, McGraw-Hill, New York, 1986.

Teh K., Kot A., and Li K., (1998), Multi-tone Jamming Rejection of FFH/BFSK Linear-Combining Receiver Over Rayleigh-Fading Channels, Electronics Letters, vol. 34, no. 4, pp. 337-338.

Waylan J., (1975), Detection of Fast, Non-coherent, Frequency-Hopped FSK,” IEEE Transactions on Communications, vol. 23, pp. 543-546.