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Spread Spectrum Modulation Techniques using MATLAB

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***Abstract*- In any communication system, effective utilization of bandwidth, is of prime importance. The message signal should reach the intended receiver uncompromised. We achieve this by allowing a trade-off between the bandwidth performances of the system. In this journal, simulation of the two spread spectrum modulation techniques, Direct Sequence Spread Spectrum (DSSS) as well as Frequency Hop Spread Spectrum (FHSS) was done and their performance studied. The simulation process is done using MATLAB version 7.6.0 .**

***Index Terms*- Bandwidth, Signal-to-Noise Ratio, DSSS, FHSS, Spectrum**

I. INTRODUCTION

One of the major issues concerning digital communication in the recent years is the efficient and optimum use of power and bandwidth. Bandwidth and power are considered as important resources as far as communication is concerned.

At the same time, it is of utmost importance to ensure the integrity of the message signal. The message signal needs to be protected in the hostile environments. In order to achieve this motto, we can use a class of signaling techniques called the spread-spectrum modulation.

Spread spectrum is a means of transmission in which the data sequence occupies a bandwidth in excess of the minimum bandwidth necessary to send it. A spread spectrum system should fulfill the following requirements [3]:

- The modulated signal occupies a bandwidth much in excess of the minimum bandwidth necessary to send the data.
- The spectrum spreading is accomplished by means of wideband spread signal, often called a code signal, which is independent of data sequence.
- The same code is used in the receiver to recover the original data sequence. Thus both the transmitter and the receiver are synchronized in their operation.

Though in frequency modulation and pulse code modulation, the modulated signal has a wider bandwidth it doesn't make use of the same code in transmitter and receiver.

Spread spectrum modulation was developed to have a reliable communication insusceptible to interference [1]. It was primarily used in military communication. Spread Spectrum techniques exploit the concept that the narrow band signals are easily detected since the frequency band is narrow and fixed. Hence it is easy to jam a narrow band signal compared to a wide band signal in the same band. Therefore the spread signals are intentionally made to be much wider band than the information they are carrying to make them more noise-like [2]. The Spread-Spectrum technique has numerous advantages with the suppression of interference from the channel being the most popular among them. Other advantages include energy density reduction, multipath rejection, multiple-access communication and fine time resolution [6][9].

The two types of spread spectrum techniques are:

- Direct Sequence spread spectrum
- Frequency hop spread spectrum

II. DIRECT SEQUENCE SPREAD SPECTRUM

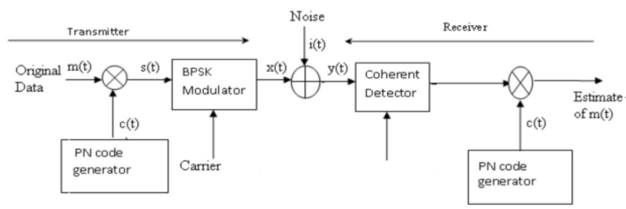

Fig 2.1 Block Diagram of Direct Sequence Spread Spectrum at the Transmitter and Receiver end

Generation of PN Sequence:

The first step in the technique is to generate the Pseudo-noise (PN) sequence. A PN sequence is a periodic binary sequence with a noise-like waveform [12]. They may appear random in nature to an outsider but they are perfectly deterministic in nature.

If the period of the PN sequence is longer , it will be difficult to track the sequence. They are generated by means of a feedback shift registers made of m flip-flops. Therefore the PN sequence generated becomes periodic with a period of at most 2^{m}. When the period of the PN sequence is equal to 2^m-1, it is called a m-sequence.

Product Multiplication:

If m(t) is the original data sequence which is narrowband in nature and c(t) is the wideband PN sequence, the resultant signal m(t) is the multiplied product of the m(t) and c(t). Thus the product modulated signal s(t) will have a resultant spectrum that is nearly the same as the wideband PN sequence c(t) [12]. In other words the data sequence is spread by the PN sequence. Then the spread signal s(t) is applied to a BPSK modulator. Note that any modulation scheme can be used in place of BPSK as shown in the schematic in Fig2.1. The transmitted signal is can be called a direct sequence spread binary phase shift keyed signal (DS/ BPSK).

In the receiver, the de-spread is carried out which is the same as the spread operation using the same PN sequence.

III. FREQUENCY HOP SPREAD SPECTRUM

In Frequency Hopping Spread Spectrum, the modulated data sequence covers a wider band by randomly hopping from one frequency to other. Hence the modulated data sequence is spread sequentially rather than instantaneously as seen in Direct Sequence Spread Spectrum. Any modulation scheme can be used for Frequency Hopping system such as M-ary frequency-shift keying (MFSK) which is widely used for FH systems. In our simulation, we have used BPSK modulation scheme as shown in the Fig3.1

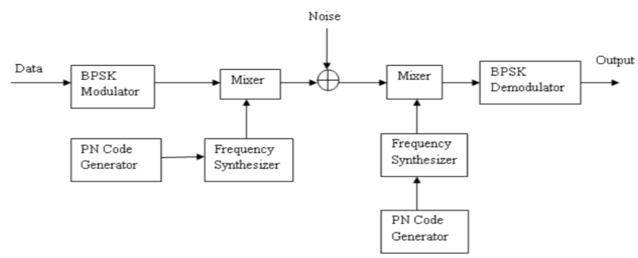

Fig 3.1 Block Diagram of FHSS at the Transmitter and Receiver End

Since the spread spectrum is not instantaneous, two additional parameters are considered for Frequency Hopping System. One is the rate at which the hops occurs (R_h) and the other is the Hopping period (T_h). A PN sequence generator is employed to generate k-bit pattern which is created for every hopping period. Next a frequency synthesizer is used for the purpose of creating multiple signals varying in frequencies. Here the purpose of the PN sequence generator is to determine the carrier frequency to be used for the frequency modulation. At the receiver end , the same operation as in the transmitter is carried out to get the demodulated data. The schematic of the Frequency Hopping System used in transmitter and receiver end is represented in Fig 3.1

IV. SIMULATION OF DIRECT SEQUENCE SPREAD SPECTRUM

By using Matlab version 7.6.0 simulator, simulation of Direct Sequence Spread Spectrum is done and is shown as follows. Fig 4.1 and Fig 4.2 shows the generated data sequence and the Pseudo-Noise sequence respectively.

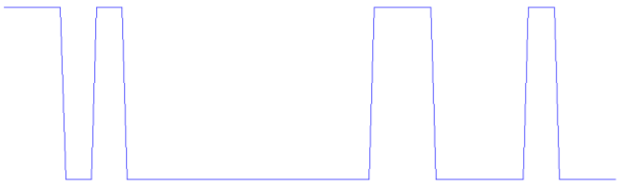

Fig 4.1 Data Sequence

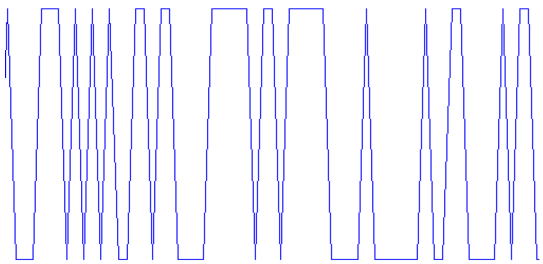

Fig 4.2 Pseudorandom bit sequence

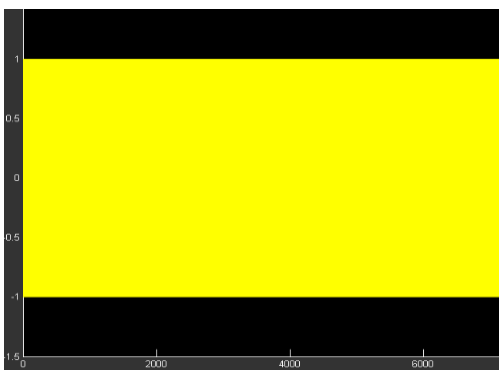

Fig 4.3 DSSS Signal Spectra

In the above figure (Fig 4.3) shows the spectra of Direct Sequence Spread Spectrum signal. The Fast Fourier transform of the BPSK signal is shown in Fig 4.4.

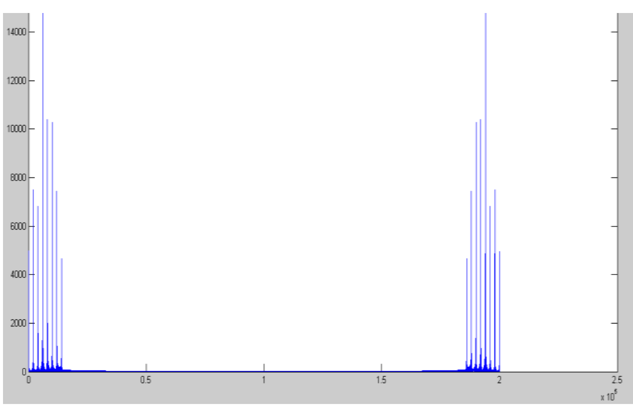

Fig 4.4 Fast Fourier transform of BPSK Signal

V. SIMULATION OF FREQUENCY HOP SPREAD SPECTRUM

The below figure Fig 5.1 shows the data sequence and the BPSK modulated data signal before applying to the mixer.

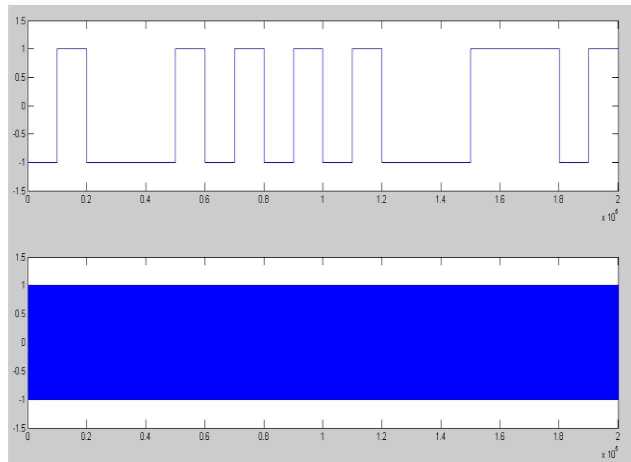

Fig 5.1 Data sequence and BPSK modulated signal

Fig 5.2 shows the Fast Fourier Transform of the Binary Phase Shift Keying modulated data sequence.

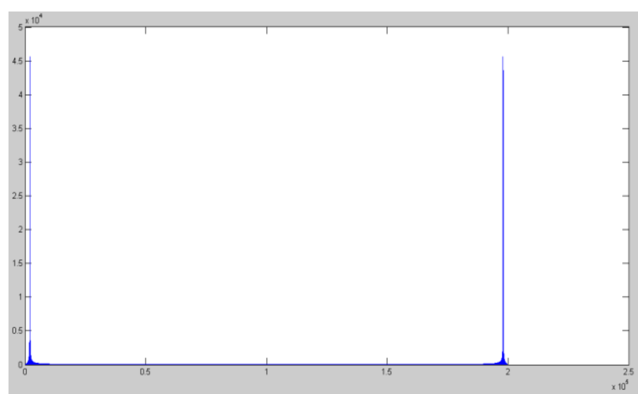

Fig 5.2 FFT of BPSK modulated signal

Fig 5.3 shows the carrier modulated Binary Phase Shift Keying modulated data sequence after the frequency synthesizer stage.

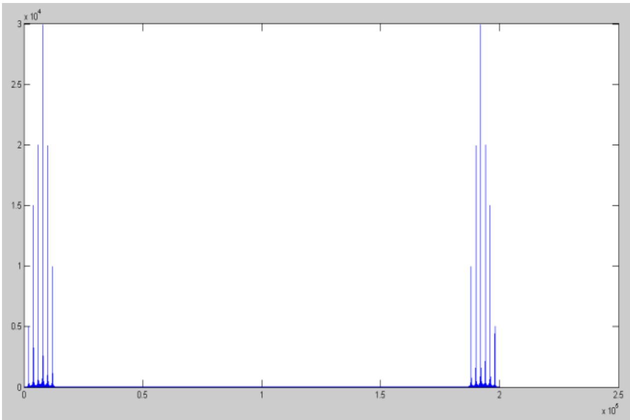

Fig 5.3 Frequency shifted signal

The transformation of the modulated BPSK signal from narrow band to wide band is shown in the Fig 5.4.

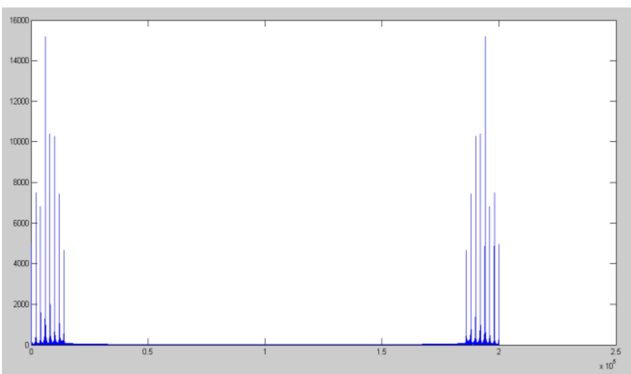

Fig 5.4 Transformation of BPSK signal into wider range

VI. COMPARISON OF DSSS AND FHSS

The error rate and the Signal-to-Noise ratio, by varying level of interference is obtained. It can be seen that the performance is affected as the interference increases.

The Signal-to-Noise ratio is the measure of the proportion of the signal power and the noise power expressed in decibels. Error rate determines the number of bits that have changed from their originality during the transmission through the channel. Both these parameters aid in analyzing the performance of the communication system.

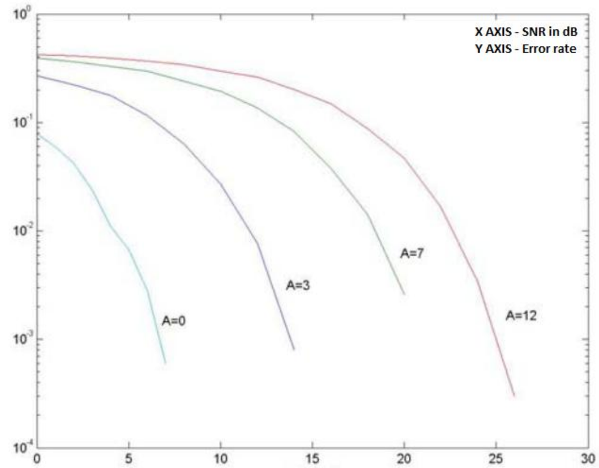

Fig 6.1 a Signal –to-noise ratio Vs Error rate for Direct Sequence

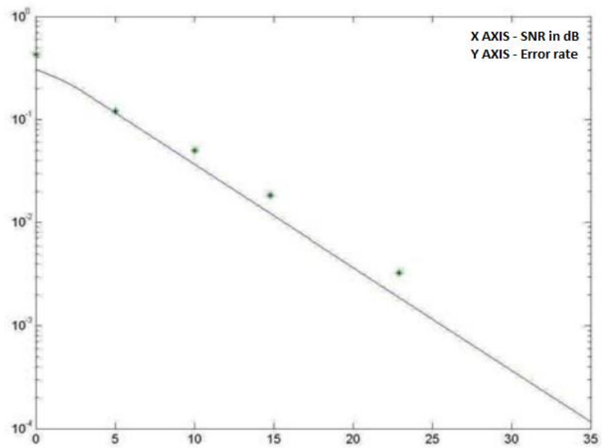

Fig 6.1 b Signal –to-noise ratio Vs Error rate for Frequency Hop

From Fig 6.1 a and Fig 6.1 b, it can be seen that under the same signal to noise ratio, direct sequence spread spectrum technique works better compared with frequency hopping. Also to be noted is that direct sequence performance is affected after certain interference threshold. The continuous line represents the theoretical values whereas the dots represent the practical values. It can been seen that there is a slight variation in the expected and the actual error rate. To further analyse the performance of the system gold codes can be used. Gold codes are nothing but a pre-selected set of m-ary sequences.

The m-ary sequence is used instead of the PN sequence whose autocorrelation is given by[7],

$$Rc(m) = L, m=0$$
$$\text{or } -1, 1 \le m \le L-1$$

The autocorrelation of Pseudo-random Noise is given by

Autocorrelation Rc(m)=ΣCnCn+m, 0≤m≤L-1

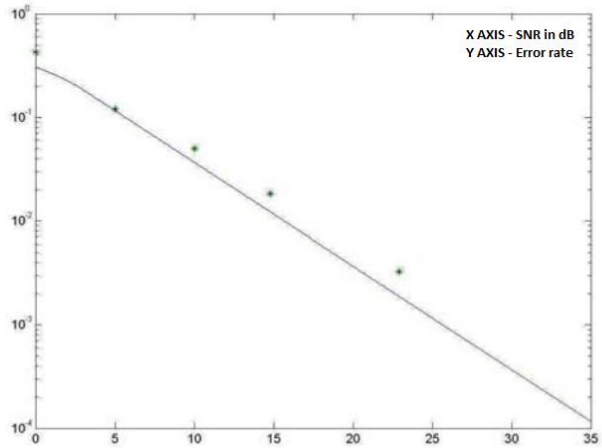

Fig 6.2 a Error rate in Rayleigh Channel with m-sequence in Direct Sequence

Thus the m-ary sequence can also be used in place of Pseudo-random Noise sequence. The use of gold sequence in PN sequence can also be investigated.

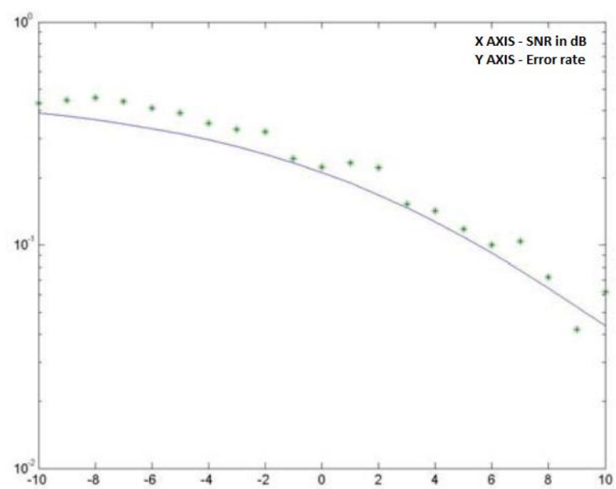

Fig 6.2 b Error rate with Rayleigh fading in Frequency hop

For varying values of Signal-to-Noise Ratio, the simulation is carried out for Direct Sequence Spread and Frequency Hop in Rayleigh fading. For better understanding of transmission over wireless medium, the Rayleigh fading is introduced instead of the commonly used Additive White Gaussian Noise channel.

VII. CONCLUSION

The various spread spectrum modulation techniques like direct sequence spread spectrum and frequency hop spread spectrum has been explained and the simulation has been carried out using MATLAB 7.6.0. The comparison of both the modulation spread spectrum techniques is done. However the selection of the better techniques between them depends on the environment where they are employed. Direct Sequence Spread Spectrum is more susceptible to broad band interfering signal. Further research of the spread spectrum techniques is also underway pertaining to multi-user scenario and their effect on bit error rate, bandwidth usage.

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