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Simulation and Comparison Between Slow and Fast FH/BPSK Spread Spectrum Using Matlab

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Abstract

This paper investigates the properties and applications of Frequency Hopping Spread Spectrum (FHSS). FHSS is radio communication technique by which the sender of information sends the data on a radio channel, which changes the frequency of transmission based on a predetermined sequence of code. The FHSS has many advantages over traditional modulation methods, it can overcome fading, multipath channels and interferences. Hence the interception becomes difficult. This security feature makes FHSS more preferable for military applications. At the receiver side, the signal is demodulated by the same carrier signal for which frequency changes by the same code sequences used by the sender. This paper presents two types of FHSS, slow and fast. The simulation procedures of both types were implemented and applied on Frequency Hopping /Binary Phase Shift Keying (FH/BPSK) spread spectrum system using MATLAB. The simulation sequences for fast and slow frequency hopping is the same in number and frequencies of spreading carriers and both used BPSK traditional modulation type. The comparison results based on their power spectral density show that the fast frequency hopping is more resistive to noise the slow one.

Keywords : Frequency Hopping, Spread Spectrum, Slow & Fast Frequency Hopping, Matlab, Power Spectral Density.

الخلاصة

يتناول البحث خصائص وتطبيقات الطيف المنتشر للقفز الترددي FHSS. FHSS هو احد انواع الاتصالات الراديوية التي يقوم بها المرسل بتغيير تردد الإرسال استنادا إلى تسلسل محدد سلفا. ان FHSS لديها العديد من المزايا مقارنة بوسائل الارسال التقليدية، حيث يمكنها التغلب على التلاشي، والقنوات متعددة المسارات والتدخلات. ومن ثم يصبح اعتراضها صعبا. ان الخاصية الامنية هذه جعلت منه ان يكون نظاما مفضلا في التطبيقات العسكرية. وفي جانب المستقبل، يتم إزالة التشكيل الإشارة بواسطة إشارة الموجة الحاملة نفسها التي يتغير ترددها وفقا لنفس تسلسل الشفرة التي يستخدمها المرسل. في هذا البحث تم تناول نوعي FHSS وهما السريع والبطيء. ان طريقة المحاكاة المستخدمة للنوعين انفي الذكر استخدمت (FH/BPSK) في الماتلاب. ان متابعة المحاكاة المستخدمة للنوعين البطيء والسريع للقفز العشوائي كانت متشابهة من عدد وقيم الترددات الحاملة ونفس نظام (FH/BPSK). اعتمدت طريقة المقارنة لكلا النوعين على كثافة الموجة الطيفية وقد وجد ان النظام السريع مقاوم للضوضاء اكثر من النوع البطيء.

الكلمات المفتاحية: - تردد القفز، الطيف المنتشر، تردد القفز البطيء والسريع، ماثلاب، الموجة الطيفية للكثافة الطيفية .

1. Introduction

Frequency Hopping Spread Spectrum (FHSS) is the technique in which the carrier hops from one frequency to another randomly (Stalling, 2005 ; Kumar, 2016; Shukla, 2016). Firstly, frequency hopping was used for military purposes because the transmitted signal is rather difficult to intercept and detect due to the spread of power along with wider band. Figuer.1 illustrates the frequency hopping pattern, In which the spread spectrum has a hop set (f_1, \dots, f_L) represents the carrier frequencies which also called the frequency pattern, where L represents the frequency channels and the modulated information will hop among these frequencies according to a certain sequence.

In FHSS the frequency of the signal is constant for a certain period of time, which is called the hop time t_h . Then, the hop period can be defined as the time spent by the

sender information in a particular frequency slot of bandwidth B . Further, $B \ll W$, where W is the spread bandwidth.

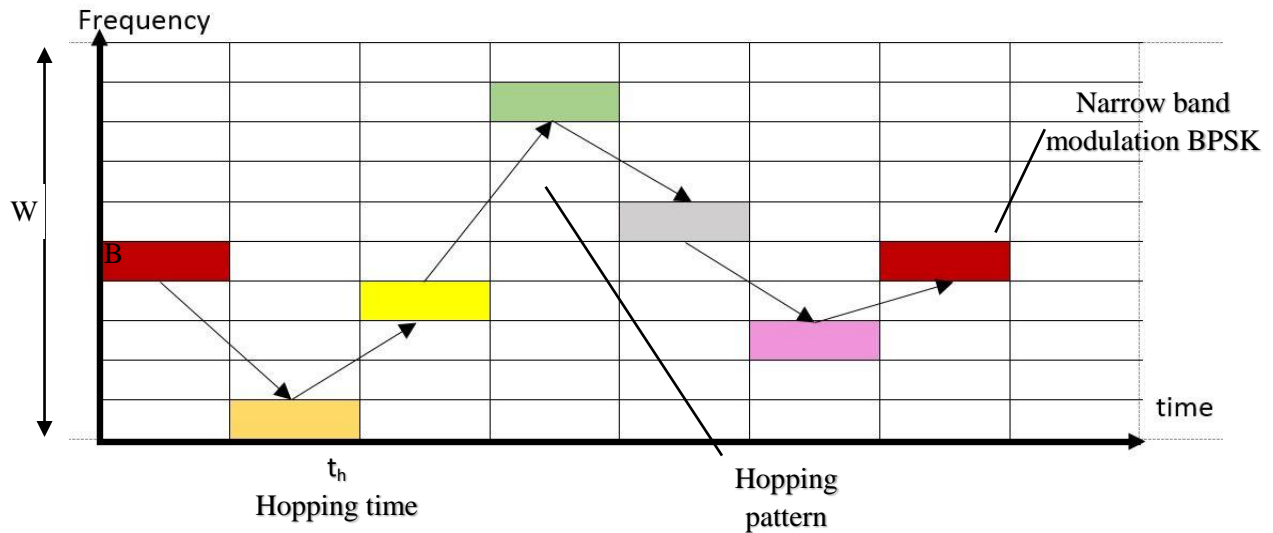


Figure.1 Frequency Hopping Pattern

To understand that further consider Figure .2 which represents FHSS band , used by Bluetooth device.

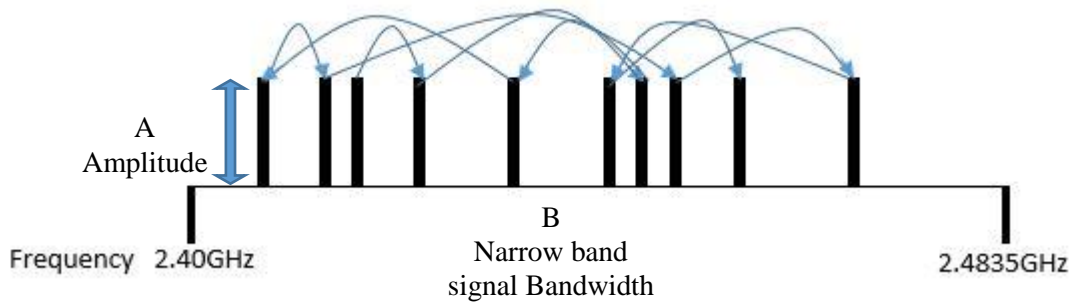


Figure.2 With Frequency Hopping Spread Spectrum, the signal is transmitted on different frequencies at intervals to spread the signal across a relatively wide operating band.

FHSS spreads a narrowband signal by “hopping” across a given frequency band (in a pattern known by both the transmitter and receiver) i.e. according to pseudo-random manner which is repeated periodically. Each channel has a defined spectral region that include single carrier frequency as its center frequency with bandwidth B that include most of the information signal within a specific carrier frequency.

2. Description of an FH/BPSK Spread Spectrum.

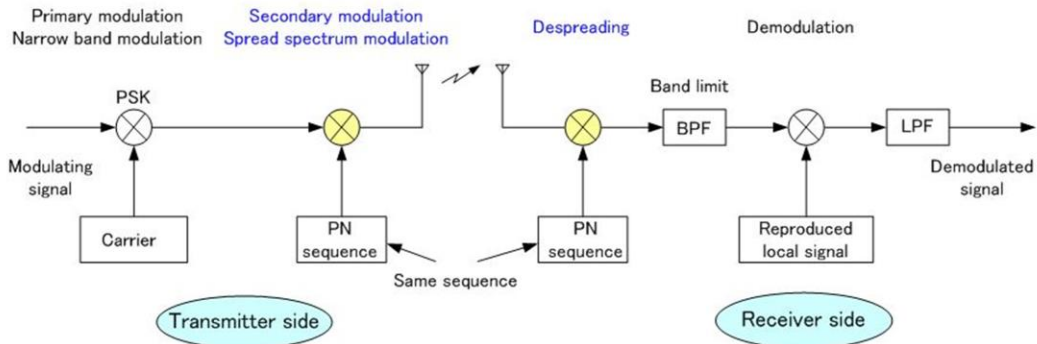


Fig.3 The Block Diagram of an FH/BPSK Spread Spectrum system

The block diagram of FH/BPSK is shown in Figure.3 (Olsovsky, 2012 ; Jasim, 2016 ; Kumar, 2016). Where the first part represents the FH/BPSK transmitter, which involves phase modulation and multiplication with PN sequences generated from Pseudo generator, the resulting signal is spread over a predefined frequency band W .

On the receiver side, an identical PN generator is used to disperse the signal by again multiplying the received signal with the PN sequence and a demodulator is used to get the baseband signal.

3. Slow and Fast Frequency Hopping Spread Spectrum.

There are two types of frequency hopping, according to the number of symbols that are transmitted per each hop (Olsovsky, 2012).

3.1 Slow frequency hopping

The frequency hopping is called slow type when $T_c > T_s$, where T_c and T_s are the carrier and symbol periods respectively. In this case, multiple symbols are transmitted per hop. Therefore $T_c = N T_s$. Figure.4 illustrates the operation of the slow FHSS system with 3 symbols per hop ($T_c = 3 T_s$, $N=3$).

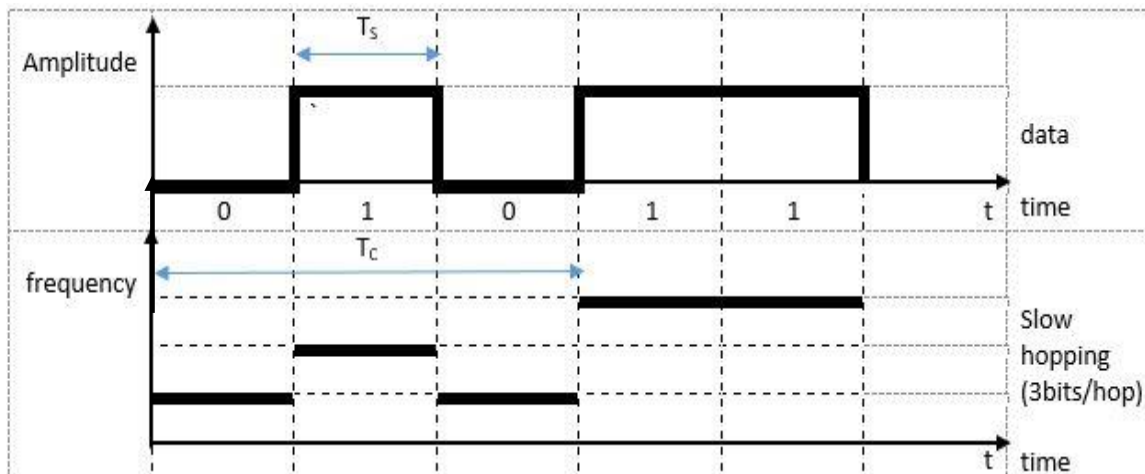


Figure. 4 Time Frequency plot of slow FHSS (T_c =carrier or hop period, T_s =symbol period)

It can be shown that with T_s seconds, the frequency is changed to one of 3 symbols according to data. Moreover, every T_c seconds, the center frequency of these symbols is changed also according to frequency hopping pattern.

3.2 Fast Frequency Hopping

On the other hand, for fast frequency hopping $T_c < T_s$. Therefore, in fast FH, there will be multiple hopping per symbol and $T_s = N T_c$. Figure.5 shows the operation of fast frequency hopping with $T_s = 3 T_c$.

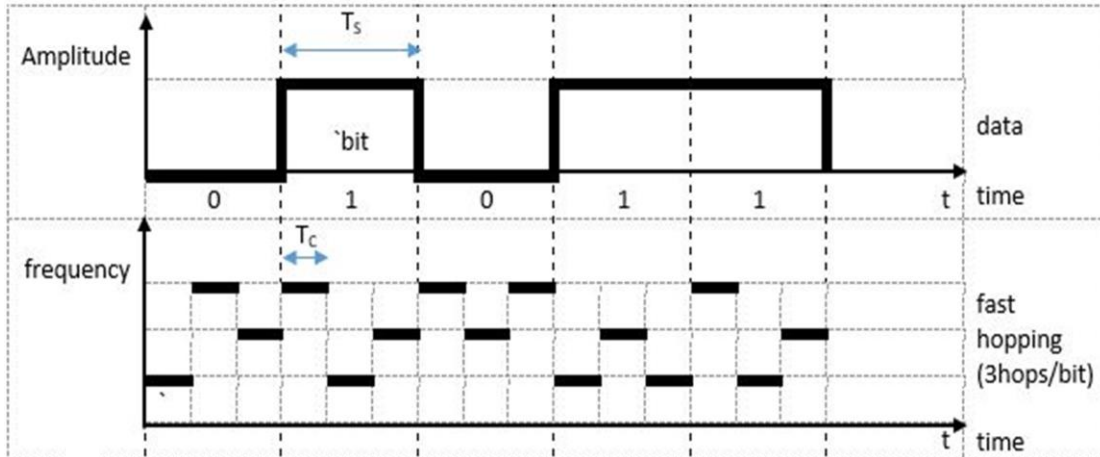


Figure.5 Time Frequency plot of fast FHSS (T_c =carrier or hop period, T_s =symbol period)

4. Fast Fourier Transform to Estimate the Power Spectrum in Matlab

The Fast Fourier Transform FFT is mainly used to represent the discrete data existing in time into the frequency domain. In fact, it needs lower computational efforts than Discrete Fourier transform DFT [M. Kalechman, 2009]. In general, for FFT the most important thing is that only how much information is contained in a signal without regards whether it is part of the cosine or sine series. As a result attention is focused on the absolute amount of FFT coefficients. Hence, the absolute value gives the amount of information in a certain frequency and the square of the FFT gives the power density .

For example :Remember that the absolute value of the Fourier coefficients is the distance of the complex number from the origin. To get the power in the signal at each frequency (commonly called the power spectrum) you can try the following commands.

```
>> N = 8;           % number of points
>> t = [0:N-1]/N   % define time
>> f = sin(2*pi*t); % define function
>> p = abs(fft(f))/(N/2); % absolute value of the fft
>> p = p(1:N/2).^2 % take the positive frequency half, only
This set of commands will return something much easier to understand
```

5. Practical Work

Most researchers have adopted fast frequency hopping/Binary frequency shift keying FH/BFSK (Olsovsky, 2012). In this project the Binary Phase Shift Keying BPSK is used as the modulation technique. Moreover, a simulation program was implemented for fast and slow Frequency Hopping/ Binary Phase Shift Keying FH/BPSK using Matlab and a comparison of the power spectral density between them is performed to understand the main differences. Fig. 6 represents the flow chart of FH/BPSK, it is the same for both fast and slow frequency hopping, except the condition mentioned in section 3 that should be considered in the simulation procedure. Figure.7 and 8 Represents the plots of the results for slow and fast FH/BPSK.

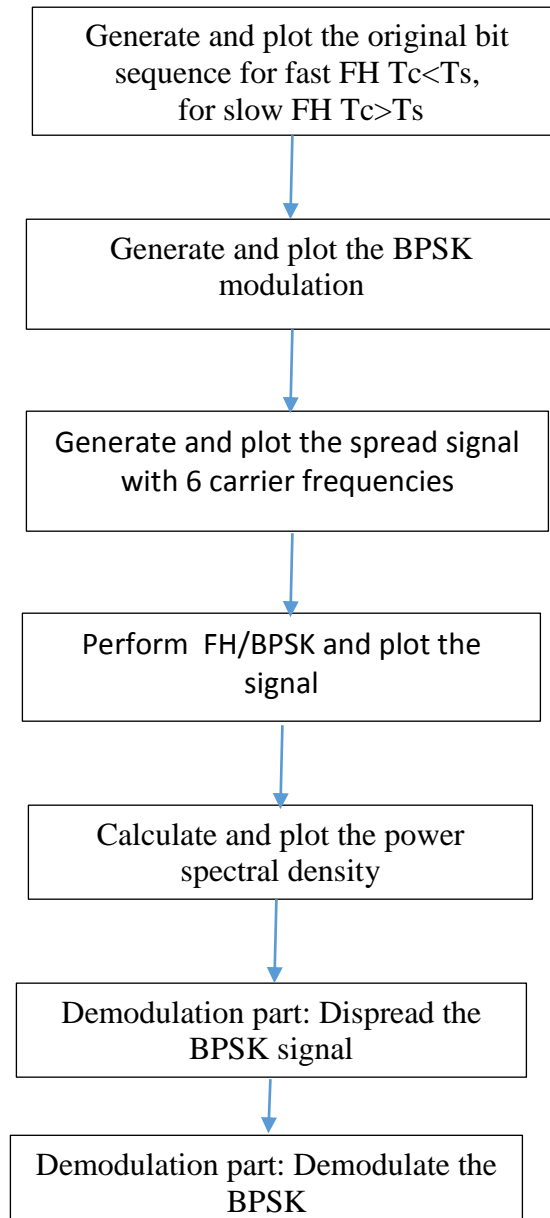
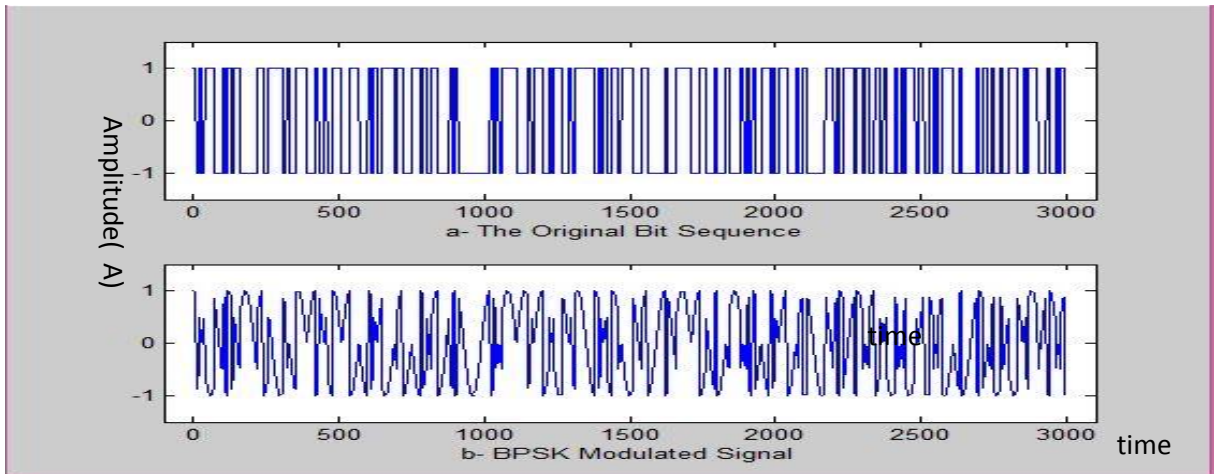
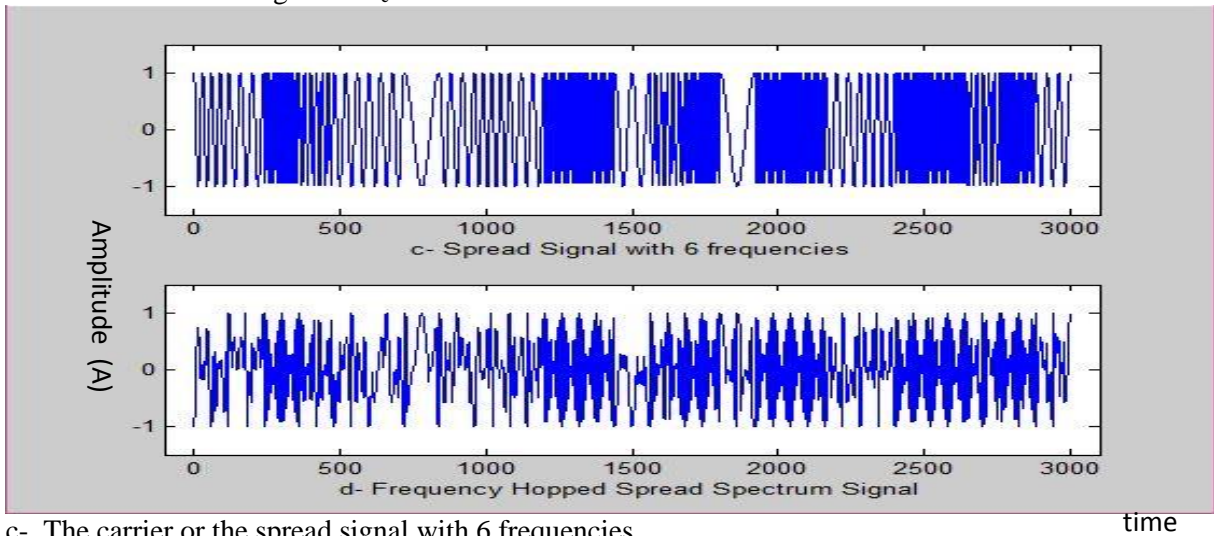


Figure.6 The Flow Chart of Simulation of Fast or Slow FH/BPSK



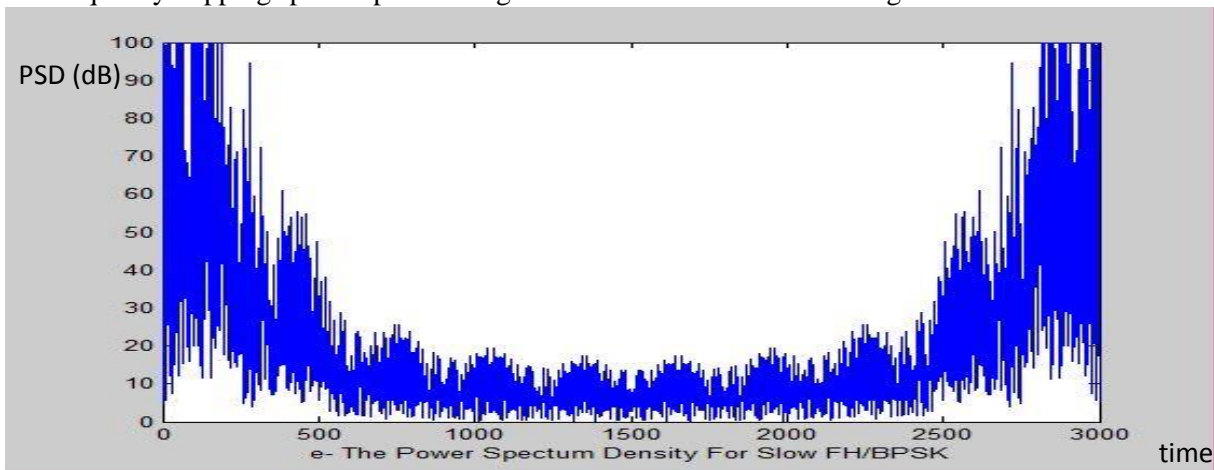
a- The original bit sequence with amplitude(A) of +1,-1 .

b- The BPSK modulated signal before spreading stage obtained from modulating bit sequence in a with a sinusoidal carrier signal of $T_c=2\pi$



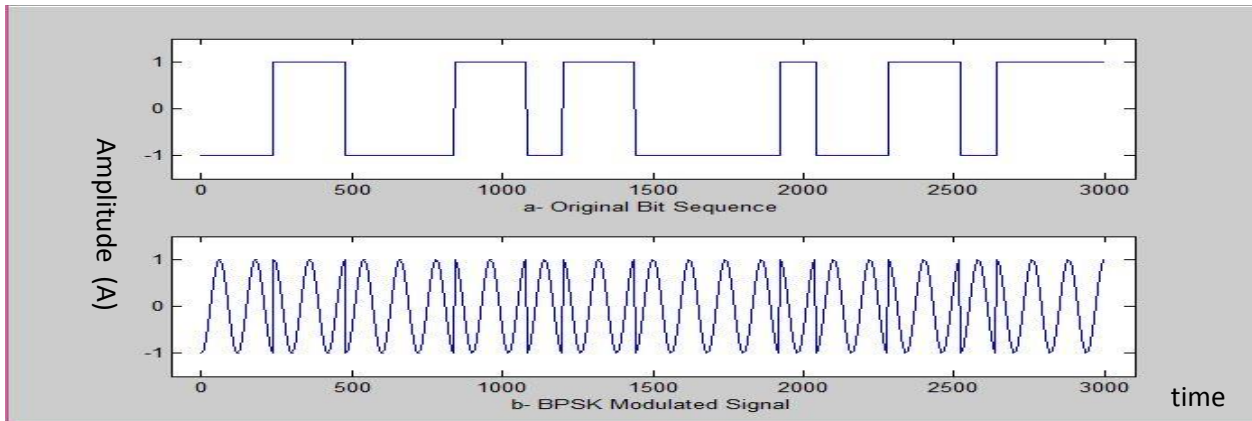
c- The carrier or the spread signal with 6 frequencies.

d- Frequency hopping spread spectrum signal resultant of modulation of signals in b and c.



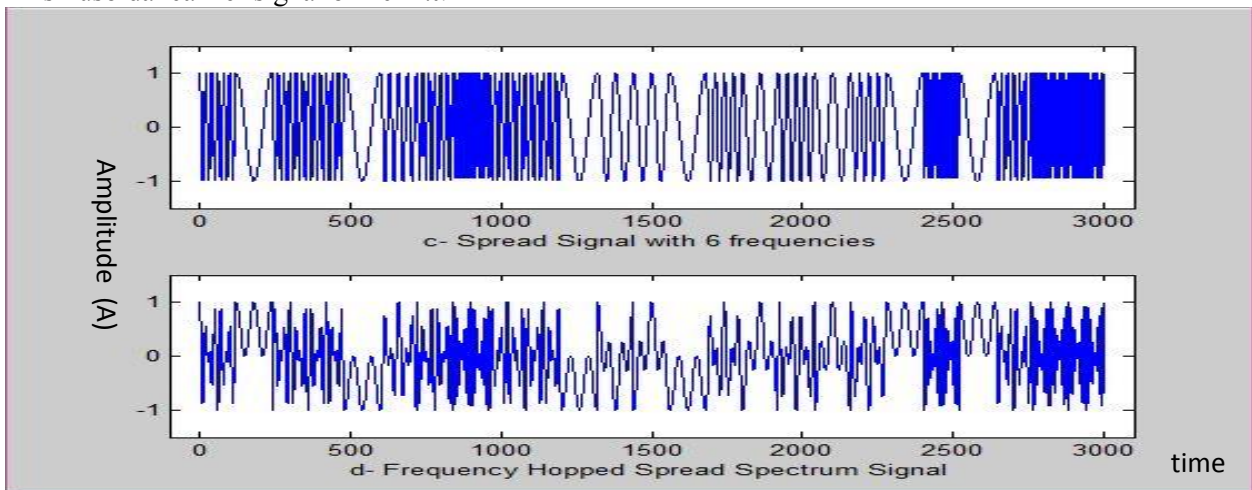
e- The Power Spectral Density (PSD) dB for the frequency hopped signal in d

Figure.7 The Slow FH/BPSK result plots



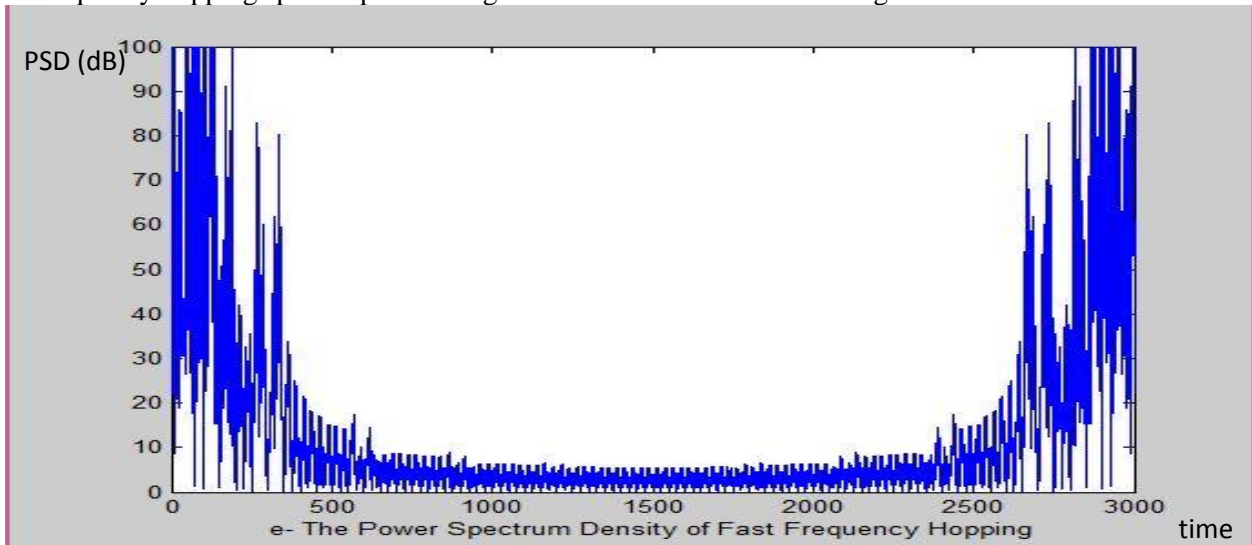
a-The original bit sequences with amplitude(A) of +1,-1 .

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c-The carrier or the spread signal with 6 frequencies.

d-Frequency hopping spread spectrum signal resultant of modulation of signals in b and c.



e-The Power Spectral Density (PSD) dB for the frequency hopped signal in d

Figure.8 The Fast FH/BPSK result plots

6. Discussion of the Results

The Waveform signals for the slow and fast frequency hopping were shown in fig.7 & 8 respectively, for the transmitter part only, because we are concerned about the comparison issue between the two types in this work and the demodulation part have been handled by many previous papers (Olsovsky, 2012). For fast FH/BPSK $T_s=8 T_c$ while for slow FH/BPSK $T_c=2T_s$.

The main difference between them is obvious from the power spectrum plot Fig.(7.e) & Fig.(8.e) from which we conclude the following difference points :-

- The power for the fast FH is more stable and smooth than that for slow over the entire band.
- The Power amplitude for fast FH is lower.
- The bandwidth for fast FH is wider.

7 .Conclusion

The spread spectrum techniques in general needs wider band in frequency and it requires more computational complexity than traditional modulation methods. In this paper, it was concluded that the fast frequency hopping requires less power for transmission than the slow method according to the power spectral density. This feature is highly important in secure systems that made FH suitable for military and security applications. Also, it can be seen that the fast method is more stable all over the frequencies than the slow frequency hopping time.

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