Performance Analysis of DSSS and FHSS Techniques over AWGN Channel

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Abstract

With the ever-growing advancements in the field of technology, Digital communication systems are becoming increasingly attractive and flexible for a secure form of data communication. Spread Spectrum overcomes the severe levels of interference that are encountered in the transmission of the digital information and rely upon shift register codes. This paper is in accordance with the design of Spread Spectrum techniques, namely Direct Sequence Spread Spectrum (DSSS) and Frequency Hopped Spread Spectrum (FHSS) which involve spreading the bandwidth of the signal to minimize the troubles that can arise from the vulnerabilities of conventional circuits, through channel. This paper further elaborates about the performance analysis of the above techniques which includes Signal-to-Noise(S/N) ratio and transmitted power parameters, when the transmitted signal is corrupted by Additive White Gaussian Noise (AWGN).

Keywords: *Communication Systems, AWGN, DSSS, FHSS, maximum length PN sequence, SNR ratio, Spread Spectrum.*

1. Introduction

The history of communication gives us insight into the way it influenced the development of civilization and still exerts an influence on modern societies. Communication can be defined simply as ‘sending and receiving messages’, or ‘the transmission of messages from one person to another’. Effective communication occurs only when the receiver understands the exact message sent by the transmitter. But the interference of the noise signal in the communication channel reduces its efficiency. Interference in the channel with a noise signal may be intentional, by a jammer, who is intended to jam the transmitting message or unintentional interference by another user who uses the same transmitting channel. One such technique wherein the access of unauthorized persons is avoided by increasing the channel bandwidth, thus providing a secure form of communication is the “Spread Spectrum Technique.” Spread Spectrum technique is a Wide-Band technique. It uses a special code which is known only to the transmitter and receiver of that message. The special code appears as a noise signal to the jammer who tries to jam the channel. Most widely used Spread Spectrum techniques are DSSS and FHSS.

2. PN Sequences

They are periodic, deterministic and binary sequences with a noise like wave form. It is also known as Pseudo-random noise since it looks random for the user who does not know the code. The longer the period of PN spreading code, the harder will be the detection of the sequence. This sequence can be generated using feedback shift registers which are made up of m flip-flops that have two states memory stages and logic circuit as shown in figure (1).

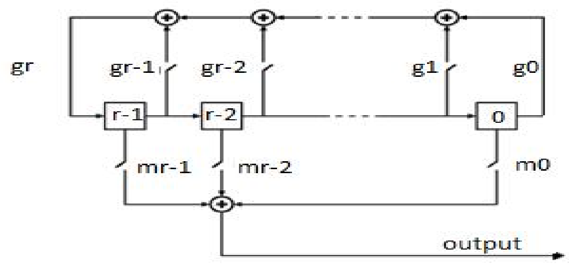


Fig. 1: Block diagram of PN sequence

A feedback shift register consists of an ordinary shift register made up of m flip-flop (two-state memory stages) and a logic circuit that are interconnected to form a multi-loop feedback circuit.

2.1 Properties of PN Sequences

1. Balance Property: In each period of PN sequence, the number of "1"s in the sequence is one greater than the number of "0"s.

2. Run property: A "run" is a sub-sequence of "1"s or "0"s. Of all the "runs" in the sequence of each type (i.e. runs consisting of "1"s and runs consisting of "0"s).

- One half of the runs are of length 1.
- One quarter of the runs is of length 2.
- One eighth of the runs are of length 3 etc..,

3. Autocorrelation Property of PN Sequences: If the period of the sequence is compared term by term with any cyclic shift of itself, it is best if the number of agreements differs from the number of disagreements by not more than one count. Theoretically the autocorrelation of PN-sequence is a two valued function given by,

$$C_{aa}(l) = \begin{cases} 1, & l = kN \\ 1/N, & l \neq kN \end{cases} \qquad (1)$$

Where k=0, 1, 2…N-1.

Some of the spreading sequences are listed below:

- Maximum length Pseudo Noise (PN) sequence

- Gold sequences
- Kasami sequences
- Barker sequences

3. Introduction to Spread Spectrum

Bandwidth and power are the major issue in the study of digital communication systems. These two important parameters need to be improved in order to reach effective performance. But, in some cases, we are forced to sacrifice this efficiency to provide an important objective in communications i.e., Security. There will be no meaning for a system, where messages can be detected by unwanted listeners.

The major advantage of Spread Spectrum (SS) is the ability to reject interference whether it is the unintentional interference (i.e. another user trying simultaneously to transmit over the channel) or the intentional interference (i.e. another trying to jam the transmission) [1].

Spread Spectrum modulation can be described in two ways:

- The signal occupies a bandwidth much in excess of the minimum bandwidth necessary to send the information.
- Spreading is accomplished by means of spreading signal which is independent of the data.
- Despreading is accomplished by the correlation of the received spread signal with synchronized replica of the spreading signal used to spread the information. [2]

Spread-Spectrum is a very useful technology with the following advantages:

1. Interference suppression.
2. Energy density reduction.
3. Multiple accesses.
4. Fine time resolution. [2]

There are two techniques used in Spread Spectrum modulation: Direct Sequence (DS) and Frequency Hop (FH). Both techniques operate in existence of noise like spreading code called pseudo-noise sequence or pseudo-random.

3.1 Direct Sequence Spread Spectrum

Figure (2) depicts transmitter, channel and receiver of DSSS system. In the transmitter stage, the baseband data signal m(t) is spread using PN-Sequence c(t).Then, the resultant spread signal s(t) is applied to (BPSK) modulator. The output signal of the (BPSK) modulator x(t) is transmitted over AWGN channel. Accordingly, transmitted signal is thus a direct-sequence spread binary phase-shift-keyed (DS/BPSK).

$$As\ c^2(t)=1 \qquad (2)$$

If, the spread sequence is again multiplied by c(t), the output of the receiver would be

$$d(t)c^2(t)=d(t). \qquad (3)$$

In the receiver, the received signal is demodulated using coherent detector and is then multiplied again by the same (synchronized) PN code. Since the code existed of +1s and−1s, this operation completely removes the code from the signal and the original data-signal is left. Another observation is that the de-spread operation is the same as the spread operation.

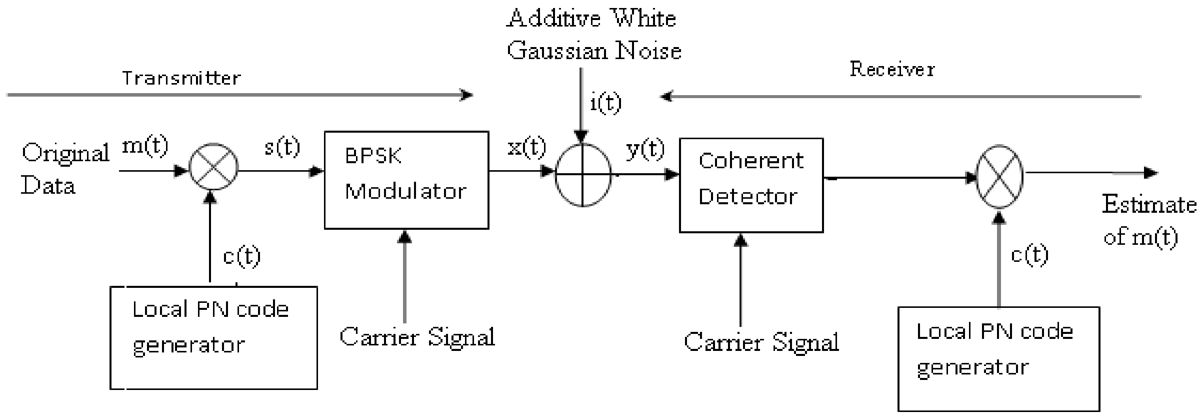


Fig. 2: Block Diagram of DSSS Technique

3.2 Frequency Hopping Spread Spectrum

The main problem with applying Direct Sequence spreading is the Near–Far effect which is less in FHSS. The type of Spread Spectrum in which the carrier hops randomly from one frequency to other is called frequency-hop spread spectrum. In FHSS, the input carrier frequency to the modulator itself varies within a fixed bandwidth. With respect to time, the frequency assigned for modulation is changed with a central frequency but with a fixed bandwidth. As the frequencies change from one to another and the allocation of frequency is pseudorandom, i.e., not in order (dependent upon a PN sequence), the term ‘hopping’ comes to represent the allocation of frequency with respect to time [7]. By this carrier frequency hopping, obviously the bandwidth of the signal is increased.

The disadvantage of Frequency-Hopping over Direct-Sequence is that we obtain a high processing-gain. Since frequency hopping does not cover the entire Spread Spectrum instantaneously, we are led to consider the rate at which the hops occur. The two basic classifications of frequency hopping are:

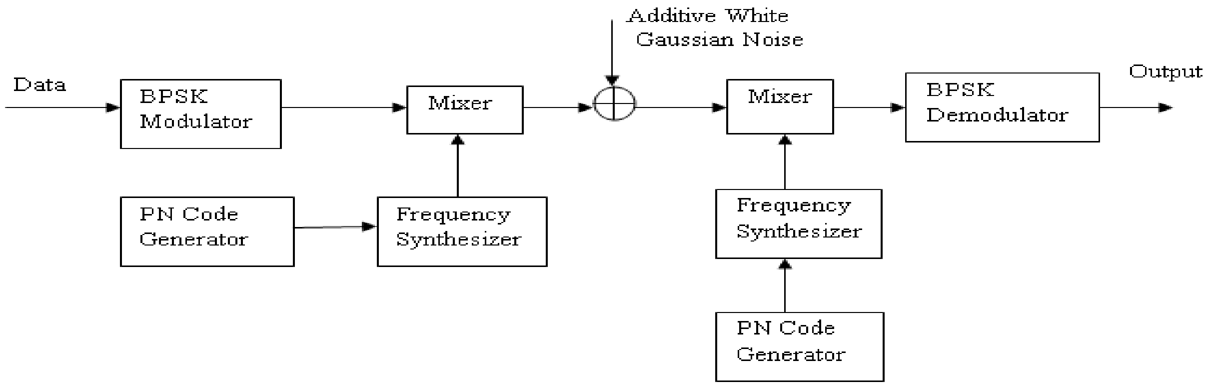
- Slow-frequency hopping: in which the symbol rate Rs is multiple of hop rate Rh.
- Fast-frequency hopping: in which the hop rate Rh is multiple of symbol rate Rs.

Fig.3 shows the general scheme of FHSS modulation. A PN sequence generator creates a k-bit pattern for every hopping period T_h. The frequency synthesizer creates a carrier signal of different frequencies, and the source signal modulates the carrier signal. At receiver the received signal is first de-spread using same PN-sequence and then demodulated to get the estimated data.

The carrier frequency used for frequency modulation is here dynamically determined by the PN sequence generator as discussed in the previous section. The modulated signal can be send to the mixer to spread the using locally generated PN-sequence. The resultant signal is therefore responsible for instantaneous transmission bandwidth.

3.3 Application of Spread Spectrum

- Most WLAN systems use Spread Spectrum technique (both frequency hopping and direct sequence).
- Space systems. In space stations, which are continuously accessible to interference, Spread-Spectrum methods have proved effective. This is especially true for communication satellites.
- Global positioning system (GPS): GPS is a satellite-based navigation system developed and operated by the US Department of Defense. The idea behind GPS is to transmit Spread-Spectrum signals that allow range measurement from an unknown satellite location.



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ig. 3: Block Diagram of FHSS technique

4. Results

The main aim of this paper is to transmit a data through Spread Spectrum techniques namely DSSS and FHSS. As a part of DSSS technique, the following figure shows the message signal being spread using the PN sequence and then modulated.

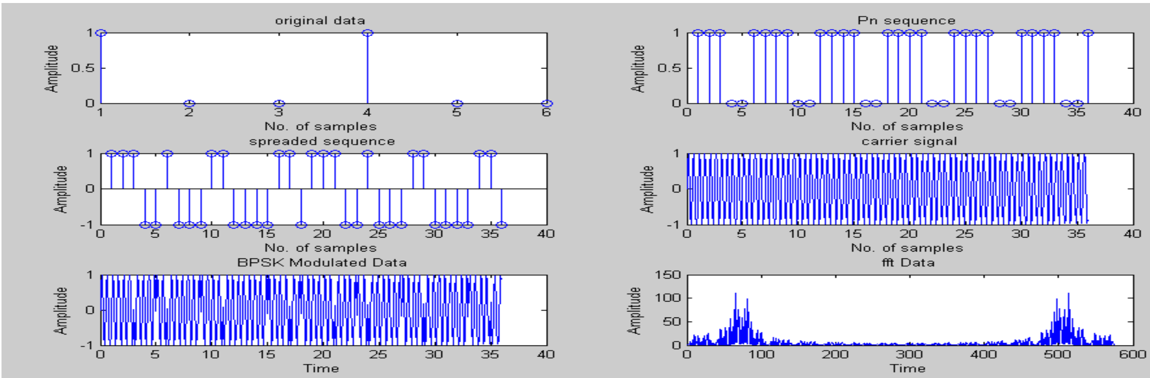


Fig. 4:Implementation of DSSS technique

The modulated data is transmitted over the AWGN channel which is shown in the following fig. 5

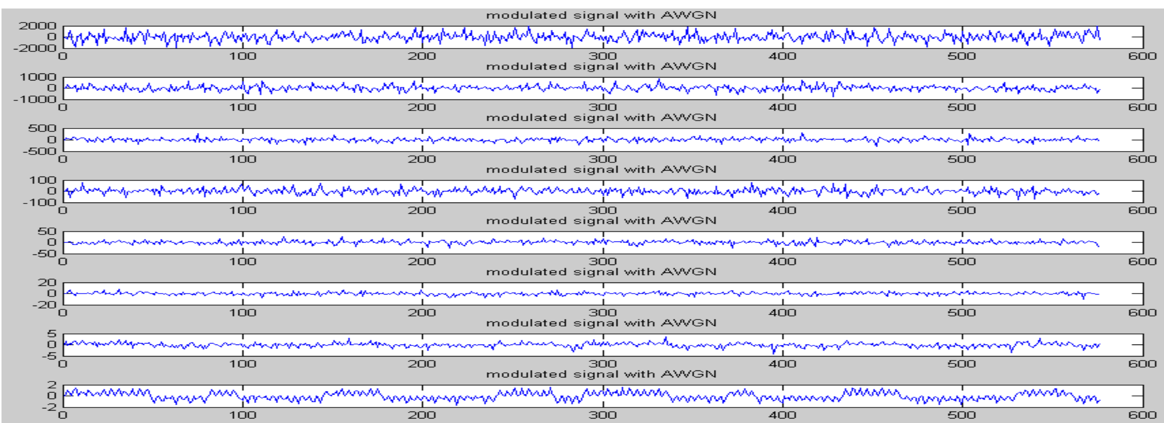
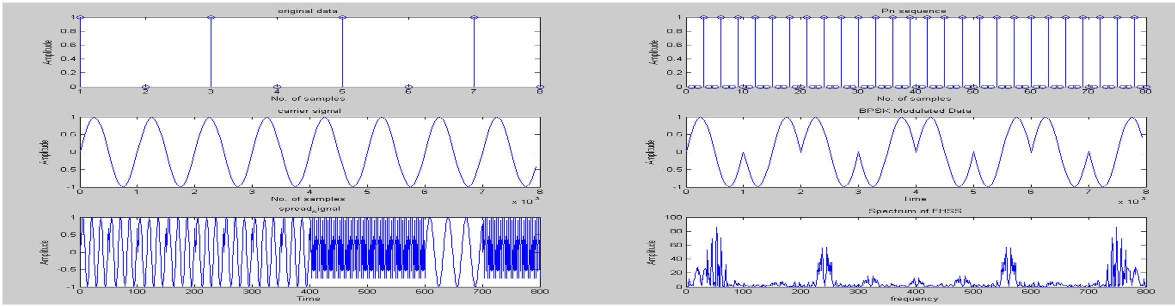


Fig. 5: Modulated signal transmitted through AWGN channel in DSSS technique

In the FHSS technique, as in DSSS, the data is modulated and spread using PN sequences.


original data
No. of samples
Amplitude
Pn sequence
No. of samples
Amplitude
carrier signal
No. of samples
Amplitude
BPSK Modulated Data
Time
Amplitude
spread_signal
Time
Amplitude
Spectrum of FHSS
frequency
Amplitude