MODELING OF SPREAD SPECTRUM COMMUNICATION SYSTEM USING MATLAB

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To my beloved Father, mother and family..

Not forgetting to my fun loving friends...

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ABSTRACT

Spread spectrum technology was initially developed for military purposes due to its anti-jamming capability and low probability of intercept. Many spread spectrum technologies have been declassified since World War II and are now available for non-military applications. Nowadays, many communication applications are using spread spectrum technologies since spread spectrum techniques provide solutions for the problem of conventional communication systems. Therefore, the first section of this thesis introduced the conventional communication system and spread spectrum communication system while the fundamentals of spread spectrum technology are discussed in the second and the third section of this thesis. The understanding of spread spectrum concept which is explained in the second and third section is very important in order to complete the main objective of this thesis that is to model a spread spectrum communication system using Matlab software that will be explain in the fourth section.

ABSTRAK

Teknologi penyebaran spectra mula digunakan dalam bidang ketenteraan disebabkan ketahanannya terhadap gangguan dan kebarangkalian tergendala yang rendah. Selepas Perang Dunia II, banyak teknologi penyebaran spektra telah dikemukakan dan boleh digunakan dalam bidang bukan ketenteraan. Hari ini banyak sistem komunikasi telah menggunakan teknologi penyebaran spektra kerana ia menyediakan penyelesaian kepada masalah-masalah yang dihadapi oleh sistem komunikasi tradisi. Oleh itu, bahagian pertama tesis ini memberi pengenalan mengenai sistem komunikasi tradisi dan teknologi penyebaran spektra, sementara bahagian kedua dan ketiga membincangkan bagaimana operasi dan konsep teknologi penyebaran spektra. Kefahaman dalam konsep penyebaran spektra yang diterangkan dalam bahagian kedua dan ketiga adalah amat penting dalam menyiapkan objektif utama tesis ini, iaitu untuk membuat model sistem komunikasi penyebaran spektra menggunakan perisian Matlab, yang mana akan diterangkan dalam bahagian keempat.

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CHAPTER 1

INTRODUCTION

Communication systems are designed to send messages or information from a source that generates the messages to one or more destinations. The basic elements of spread spectrum digital communication system are illustrated in Figure 1.1. Channel encoder and decoder and the modulator and demodulator are the basic elements of a conventional digital communication system.

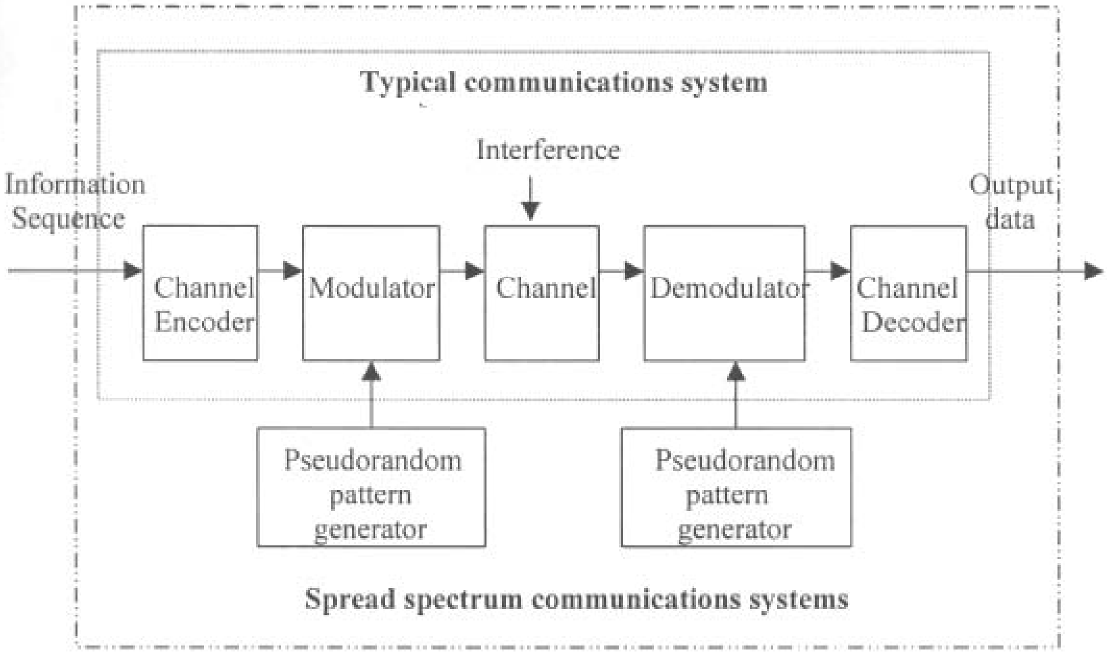

Figure 1.1: Model of Spread Spectrum Digital Communications System[3].

In addition to these elements, a spread-spectrum system employs two identical pseudorandom sequence generators, one which interface with the modulator at the transmitting end and the second, which interfaces with the demodulator at the receiving end. These two generators produce a pseudorandom or pseudonoise (PN) binary-valued sequence that is used to spread the transmitted signal in frequency at the modulator and to despread the received signal at the demodulator.

An important characteristic of spread spectrum systems is that the two generators have to be synchronized prior to the transmission of information so that the received signal can be properly despread. Despreading is performed by a correlator, which does not respond to man-made, natural or artificial noise or interference. It only responds to spread spectrum signal with identically matched signal characteristics (i.e. PN code at the receiver is identical to the one encoded with the information signal).

Interference is introduced in the transmission of the spread-spectrum signal through the channel. The characteristics of the interference depend to a large extent on its origin. The interference may be generally categorized as being either broadband or narrowband (partial band) relative to the bandwidth of the information-bearing signal, and either continuous in time or pulsed (discontinuous) in time.

1.1 Objectives

The main objective of this project is to model, analyze and simulate the performance of a Spread Spectrum Communication System using MATLAB software.

Understanding the operation and characteristic of the Spread-Spectrum system. This project's developing process needs a detail study and analysis on the functions and characteristic of spread spectrum.

Furthermore, it is the opportunity to put the theoretical knowledge that has been gained into practical especially in the simulation part.

CHAPTER 2

SPREAD SPECTRUM COMMUNICATION

2.1 History of Spread Spectrum

Spread Spectrum (SS) communications is a mostly digital communications technology that was originally developed during World War II. First used for "Secret" military communications and later for Radar countermeasures, SS has been improved, honed, refined and applied to a wide variety of even consumer-based applications. SS systems like Global Positioning System (GPS) and Wireless Local Area Networks (WLANS) are being used by literally millions of people today.

Now let us touch on the born of Spread Spectrum system. Hedy Lamarr and George Antheil invented the earliest form of spread spectrum technology during World War II. Both were prominent figures in society during their times, but neither in the field of communication science. Lamarr was a celebrated Hollywood actress while Antheil was a forerunner in experimental music. In other words Hedy Lamarr and George Antheil is spread spectrum's technology conceptual parents.

In Austria Lamarr's first husband was doing research for using wireless torpedo launchers for the Nazis. Wireless control eliminated the need for a physical connection but created a security problem of allowing enemies to jam the control signal.

Lamarr has no technical education, but she witnessed most of her husband's technical discussions and meetings. Ultimately she left him and went to Hollywood where she sought out George Antheil. Antheil was one of the first people to compose mechanical music synchronizing several player pianos for musical composition.

Lamarr told him of her idea for a communication system that could guide torpedoes from their source to their destination using multiple, randomly changing frequencies for sending messages securely between the transmitter and the receiver. If the enemy tuned in on the frequency, it would quickly change frequency preventing interception. Lamarr smartly deducted that Antheil's experience with sound synchronization could help solve the frequency synchronization issue. In fact, he did use his musical background to utilize player piano type perforated rolls to maintain frequency synchronization between the transmitter and receiver. Two identically perforated rolls driven by small motors were placed at the transmitter and receiver. The perforation pattern defined the frequency path. As long as the two-roll movement were started at the same time and rate, the transmitter and receiver would stay in synchronization.

After working with an MIT electrical engineer, a patent was granted for the "Secret Communication System" and given to the government for the war effort. The military never bought into the concept of the unreliable mechanical components. Consequently utilization of the patent did not happen until the 1950's when Sylvania Electronics Systems Division used digital components to replace the mechanically driven paper rolls. Subsequently the U.S. military adopted electronic spread spectrum system for secure military communications.

This particular approach of sharing the single frequency spectrum by jumping from frequency to frequency is now known as Frequency Hopping Spread Spectrum (FHSS). An interesting note is that the pseudo-random frequency path created by the perforated piano rolls is one of the first practical examples of cryptography [2]. In the mid-1980's commercial application began to be developed for spread spectrum technology after the military declassified it and the patent had long expired.

Many spread spectrum technologies have been declassified since World War II and are now available for commercial use. Commercial applications of spread-spectrum have attracted considerable attention because of its possible use for CDMA. Spread spectrum also reduces detrimental effects of multipath. Today, both voice and data oriented systems employ spread spectrum system. Modern applications of spread spectrum range from low speed fire safety devices to high-speed wireless local area network.

2.2 Fundamentals of Spread Spectrum

The term Spread Spectrum (SS) has been used in a wide variety of military and commercial communication systems. In spread spectrum systems each information signal requires significantly more radio frequency (RF) bandwidth than a conventional modulated signal would require. The expanded bandwidth provides certain desirable features and characteristics that could otherwise be difficult to obtain.

Spread spectrum communication system have the characteristic attributes that the required transmission bandwidth is greater (often much greater) than the base band message signal bandwidth and that the transmission bandwidth is determined by a spreading signal that is independent of the message.

The process of spreading the transmitted signal bandwidth is performed to gain signal-to-noise (S/N) performance. This is possible because the spreading process increases the probability that the received information will be correct since each signal is comprised of a principal signal at the fundamental frequency and many other small signals at its harmonics. Hence, a more accurate reconstruction of the original signal can be obtained.

Sklar [1] states that:

A system is defined to be a spread spectrum system if it fulfills the following requirements:

1. The signal occupies a bandwidth much in excess of the minimum bandwidth necessary to send the information.
2. Spreading is accomplished by means of a spreading signal, which is independent of the information signal.
3. At the receiver, dispreading (recovering the original data) is accomplished by correlating the received spread signal with a synchronized replica of the spreading signal used to spread the information.

One measure of system performance is the bandwidth expansion factor. It is known as the processing gain of the system and can also be defined as the ratio of spreading bandwidth to base bandwidth (refer to Figure 2.1). The processing gain describes the received signal fidelity gained at the expense of the bandwidth. Processing gain of 10 to 100 are common for commercial system while for military system, the value can be as huge as 1,000,000.

Spread spectrum systems are usually used in channel with poor signal-to-noise ratio (S/N) i.e. the average power of noise, N and interference, I are much larger than that of a desired signal S. For the systems, the signal-to-noise and interference ration (S/N+1) is often less than –20dB. In such band channel conditions, it is important that the processing gain of the system be sufficiently large so that the stream of chips of the transmitted signals can be recognized through a process known as correlation detection. The processing gain, in this case, represents the capability to suppress noise as well as interference.

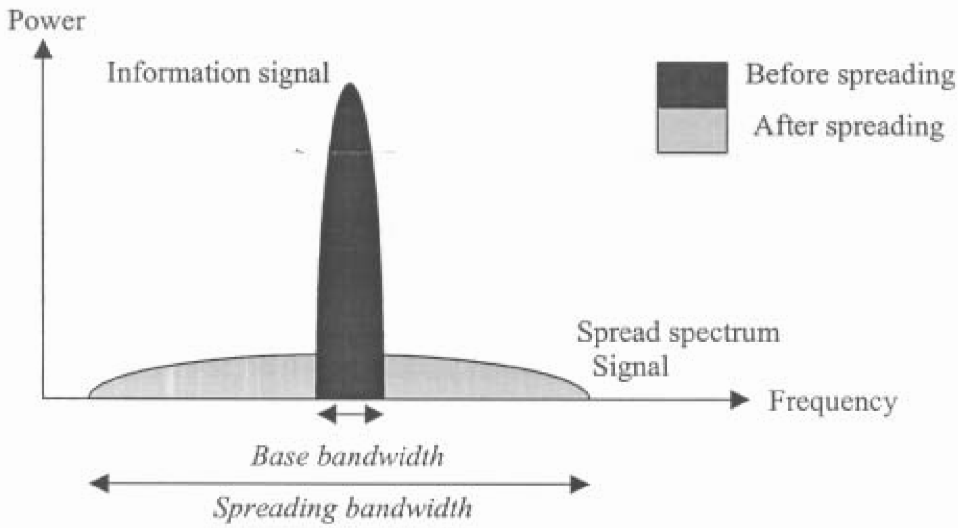

Figure 2.1: Bandwidth spreading of spread spectrum system.

The capacity of any communication channel is given by Claude E. Shanon's information rate theorem:

$$C = W \log_2 \left(1 + \frac{S}{N}\right) \qquad (2.1)$$

where C = Channel capacity (bps)

W = Bandwidth (Hz)

S = Signal Power (W)

N = Noise Power (W)

From equation 2.1, we find that for systems with low S/N, the channel capacity can be maintained or even increased by increasing the bandwidth. This means that the signal may be spread over a large bandwidth with smaller spectral power levels and still achieve the required data rate. In fact, the signal power is allowed to drop below the noise threshold without causing any loss of information when the signal is recovered.

The next issue that has to be considered is the spreading of the bandwidth. The spreading of the baseband signal is carried out by means of a spreading signal. This signal, which comprises fast codes with bit rates many times higher than the data rate or information bandwidth, has a unique property of being pseudorandom. The term pseudorandom, here means that the signal will appear to be random and noise-like to receivers other than the intended receiver. For this reason, the spreading signal is known as pseudonoise (PN) codes.

Various modulation techniques such as direct sequence, frequency hopping and time hopping are used to achieve the spreading process. These techniques will be discussed in detail in Section 2.3.

The reverse process of spreading is the despreading of the transmitted signal at the receiver end. A similar pseudonoise code is present in the intended receiver. Upon arriving at the receiver, the signal is despread using the local PN code through the correlation process mentioned earlier. When the received signal is matched to the desired signal, the baseband is retrieved.

There are three basic configurations used for recovery of the SS carrier [2]:

1. Transmitted Reference (TR) system achieves detection by transmitting two versions of the carrier, one modulated by data and other unmodulated. These two signals enter a correlation detector, which extracts the message.
2. In a Stored Reference (SR) system, both receiver and transmitter keep a 'copy' of the same pseudo-random signal. Carrier generator at the receiver is adjusted automatically in order to synchronize its output with the arriving carrier. Detection is thèn similar to TR system.
3. Matched filtering can also be used for reception of SS signals. Filter systems produce a wide-band, pseudo-random impulse response. Matched filter with such response is used at the receiver in order to recover transmitted signal. Pseudo-random characteristic of the impulse response ensures security of the transmitted signal.

2.3 Spread Spectrum Modulation Techniques

2.3.1 Direct Sequence (DS)

Direct sequence systems are the best-known and most widely used spread spectrum systems. This process is achieved by multiplying a radio frequency carrier (information signal) with a pseudo noise (see Figure 2.2(a)). The pseudo noise (PN-code) is a binary signal, which is produced at a much higher frequency then the data that is to be transmitted. (PN-code will be explained in more detail in chapter 3).