DSSS & FHSS BASED CDMA TO OVERCOME JAMMING SIGNALS

Shailaja Yadav[1], Pooja Panwar[2], Ritika Tripathi[3]

[1,2]UG, Department of Electronics &Communication Engineering,
[3]Asst. Prof., Department of Electronics &Communication Engineering,
Raj Kumar Goel Institute of Technology for Women, UP (India)

ABSTRACT

Jamming resistant broadcast communication is crucial for safety-critical applications such as emergency alert broadcasts or the dissemination of navigation signals in adversarial settings. These applications share the need for guaranteed authenticity and availability of messages which are broadcasted by base stations to a large and unknown number of (potentially untrusted) receivers. In this paper, we introduce spread spectrum links that can be used to overcome intentional jamming. The problem of communicating in the presence of jamming is very much akin to the problem of communicating over fading channels. Hence, by finding out how to defeat jamming by spread spectrum will also reveal how to overcome fading. Common techniques to counter jamming attacks such as Direct-Sequence Spread Spectrum (DSSS) and Frequency Hopping are based on secrets that need to be shared between the sender and the receivers before the start of the communication. We analyze the security and latency of DSSS and FHSS and complete our work with an experimental evaluation on a prototype implementation.

Keywords: CDMA, DSSS, FHSS.

I INTRODUCTION

Wireless communications is vulnerable to jamming attacks due to the shared use of wireless medium. A jammer can simply take advantage of a radio frequency (RF) device (e.g. ,a waveform generator) to transmit signals in the wireless channel .As a result, signals of the jammer and the sender collide at the receiver and the signal reception process is disrupted. Therefore, jamming resistance is crucial for applications where reliable wireless communications is required.

Spread spectrum techniques have been used as countermeasures against jamming attacks. Spread-spectrum techniques are methods by which energy generated in a particular bandwidth is deliberately spread in the frequency domain resulting in a signal with a wider bandwidth. Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS),are two common forms of spread spectrum techniques [3]. In classic spread spectrum techniques, senders and receivers need to pre-share a secret key, with which they can generate identical hopping patterns, spreading codes, or timing of pulses for communication. However ,if a jammer knows the secret key, the jammer can easily jam the communication by following the hopping patterns, spreading codes, or timing of pulses used by the sender .Originally there were two motivations: either to resist enemy efforts to jam the communications(anti-jam, or AJ), or to hide the fact that communication was even taking place, sometimes called low probability of intercept(LPI).Frequency-hopping spread spectrum (FHSS) is a method of transmitting radio signals by rapidly switching a carrier among many frequency channel, using a pseudorandom sequence known to both transmitter and receiver.

1.1 CDMA

Code division multiple access (CDMA) is a channel access method used by various radio communication technologies. It should not be confused with the mobile phone standards called CDMA One and CDMA2000 (which are often referred to as simply CDMA), which use CDMA as an underlying channel access method.One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a band of frequencies (see bandwidth). This concept is called Multiple Access. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (TDMA) divides access by time, while frequency-division multiple access (FDMA) divides it by frequency. CDMA is a form of spread-spectrum signaling, since the modulated coded signal has a much higher data bandwidth than the data being communicated.

1.2 DSSS

Direct sequence spread spectrum is one of the most widely used spread spectrum techniques. The basic elements of DSSS digital communication system are illustrated in Figure given above in the figure.
In DSSS, the baseband signal is multiplied by a pseudorandom code or pseudo noise (PN) signal, which has a higher bit rate than the original signal. This will spread the spectrum of the baseband signal. In next section, DSSS technique is described in detail.

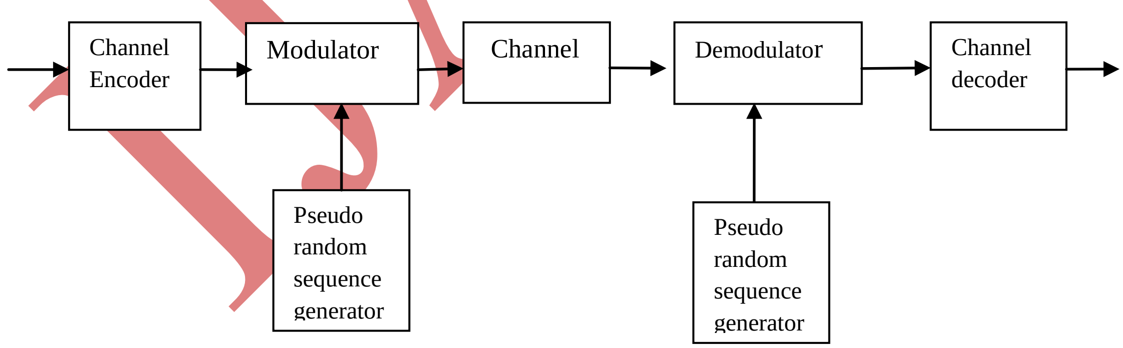

Figure1: Model of Direct Spread Spectrum Digital Communication System

We observe that in addition to the basic elements of a conventional digital communication system, a spread spectrum system includes two identical pseudorandom sequence generators, one interfacing with the modulator and the other with the demodulator. As with all spread spectrum schemes, DSSS uses a unique code to spread the baseband signal, allowing it to have all the advantages of spread spectrum techniques. A random or pseudo noise signal is used to spread the baseband signal, causing fast phase transitions in the carrier frequency that contains data. The basic method for accomplishing spreading is shown in Figure 1. The spreading sequence is a pulse stream with pulse values of +1, -1. After spreading the base-band signal, the resulting Spread signal is then modulated and transmitted through the specified medium. Binary phase shift keying (BPSK) is a widely used digital modulation scheme for spread spectrum systems and we use the same in this thesis.

When the modulated data is received at the demodulator port, the signal is demodulated using a BPSK demodulator that has a synchronized carrier frequency with the transmitter one. The spread signal will be at the output of the demodulator. This is then multiplied with the locally generated PN sequence. If the locally generated PN sequence is correlated with the one that was used in transmitter, the signal is de-spread, yielding the original signal. Spreading factor of the spread spectrum is an important parameter which defines the overall gain of the system. It is also termed as processing gain, which is defined by:

$$i, t, p, BW$$

$$G = BW$$

is the ratio of the transmission bandwidth *t BW* and the information bandwidth *i BW* . It helps in determining the number of users that can be allowed in a multiple access system ,the amount of multi-path effect reduction and the difficulty to jam or detect signals. For spread spectrum systems, it is always better to choose a high processing gain. But this comes as a trade off with system complexity.

A DSSS digital communication system can be classified into four major parts ,which are: pseudo noise sequence generator, spreading and modulation (transmitter),demodulation and de-spreading (receiver), PN synchronization. Each part of the DSSS communication system is described in detail as follows.

1.2.1 Pseudo Noise Sequence Generator:

Pseudo Noise (PN) signals play a key role in DSSS systems, as they are the ones responsible for the spreading and de-spreading of the baseband signal. These signals are generated in a deterministic way but appear to be random or noise-like. PN sequences are considered to have noise like properties for an outsider, but they are known to the two devices using them. They are considered pseudo random because the sequences are actually deterministic and are known to both the transmitter and the receiver.

There are three basic properties that can be applied to a periodic binary sequence as a test of the appearance of randomness. They are balance property, run property and correlation property. One of the well known and easy to generate PN sequences are the maximum length sequences (MLS). MLS satisfy all three PN properties. An MLS is generated by the use of shift registers and some logic circuitry in its feedback path. A feedback shift register is said to be linear if its feedback logic circuit consists entirely ofmodulo-2 adders (XOR gates).

1.2.2 DSSS Transmitter

In DSSS the baseband waveform is multiplied by the PN sequence. The PN is produced using a PN generator. This generator consists of a shift register, and a logic circuit that determines the PN signal. After spreading, the signal is modulated and transmitted. The most widely used modulation scheme is binary phase shift keying(BPSK).In BPSK a transition from a one state to a zero state (or the other way around)will cause a 180 degree phase shift in the carrier signal. A BPSK modulator consists of a multiplier circuit that directly multiplies the incoming signal with the carrier frequency generated by the local oscillator. Other transmitter schemes also exist. Some of them use the PN spreading after the baseband signal is modulated using BPSK. This will spread the pass band signal. In the receiver, the de-spreading takes part before the signal gets demodulated. Based on the system architecture, one might decide which scheme to use.

1.2.3 DSSS Receiver

In the demodulator section, we simply reverse the process. We demodulate the BPSK signal first, pass it through a low pass filter, and then de-spread the filtered signal, to obtain the original message. The receiver carrier frequency should be synchronized with the transmitter one for data detection. As for the PN sequence in the receiver, it should be an exact replica of the one used in the transmitter, with no delays, otherwise it might cause severe errors in the incoming message. Usually a delay locked loop is used to overcome this issue, and lock the timing of the transmitted PN sequence with the one locally generated. Once the incoming PN code is correlated with the locally generated one, we can de-spread the signal .After the signal gets multiplied with the PN sequence, the signal de-spreads, and we obtain the original bit signal that was transmitted. The signal is then applied to a decision device that will take care of the signal shaping, and leveling . The original data signal is then obtained. In the presence of noise, extra circuitry is needed to compensate the signal degradation that affects the transmitted signal.

1.2.4 PN Synchronization

In a spread spectrum system, the generated PN code at the receiver end must be aligned to the received PN sequence, otherwise, the PN code misalignment will result in ineffective de-spreading of the signal. Synchronization is usually accomplished first by an acquisition of the initial PN code alignment and then followed by a tracking process to eliminate a possible new phase shift introduced to the received signal during the signal reception process. Without synchronization, the spread spectrum will appear as noise and ineffective de-spreading will be achieved at the receiver end. Therefore, synchronization of the PN code is crucial for data reception .Interference is added to the spread spectrum signal during transmission through the channel. The characteristics of the interference depend to a large extent on its origin .Usually the interference is categorized as being either broadband or narrowband relative to the bandwidth of the information bearing signal, and either continuous in time or pulsed in time. In this thesis we don’t apply any specific constraints or statistical meanings to the interference except a fundamental power limitation on the interfering signal.

1.2.5 FHSS

The FHSS method does exactly what its name implies—it causes the carrier to hop from frequency to frequency over a wide band according to a sequence defined by the PRN. The speed at which the hops are executed depends on the data rate of the original information. One can, however, distinguish between fast frequency hopping (FFHSS) and low frequency hopping (LFHSS). The latter method, the most common, allows several consecutive data bits to modulate the same frequency. FFHSS is characterized by several hops within each data bit. The transmitted spectrum of a frequency-hopping signal is quite different from that of a direct-sequence system.

Instead of a $((\sin x)/x)^2$-shaped envelope, the frequency hopper's output is flat over the band of frequencies used . The bandwidth of a frequency-hopping signal is simply N times the number of frequency slots available, where N is the bandwidth of each hop channel.

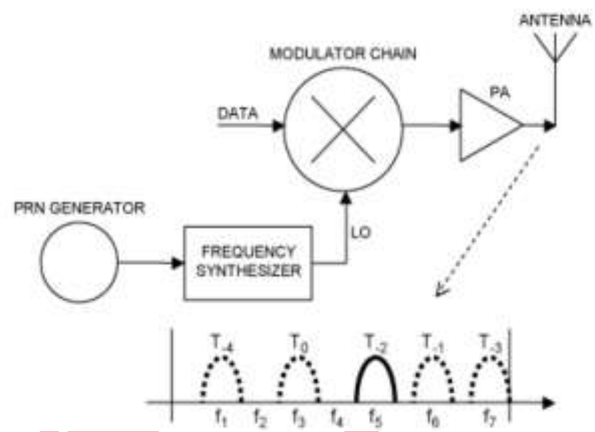

Figure 2. Spectrum Analyzer Photo of FHSS Signal

III CONCEPT OF SIGNAL SPREADING

Let's take a straight forward binary signal of symbol rate 2.

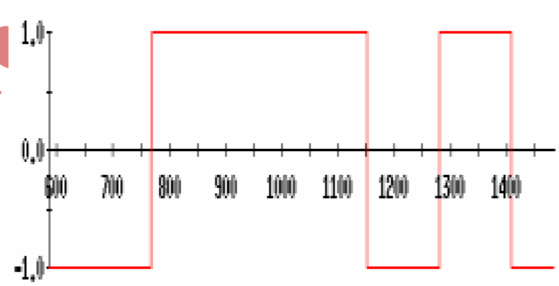

Figure 3. A Binary Information Signal

To modulate this signal, we would multiply this sequence with a sinusoid and its spectrum would look like as in figure 2. The main lobe of its spectrum is 2 Hz wide. The larger the symbol rate the larger the bandwidth of the signal.

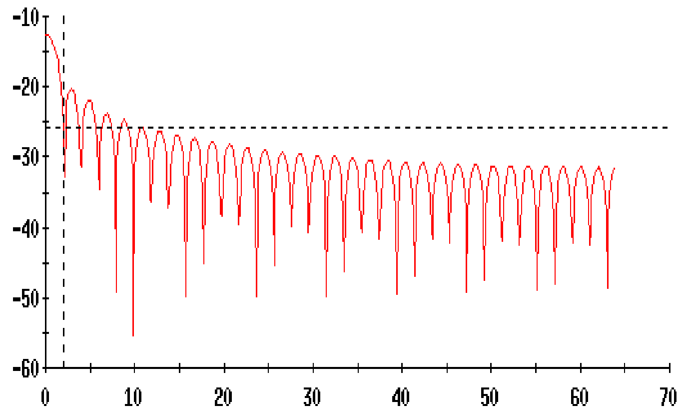

Figure 4. Spectrum Of A Binary Signal Of Rate 2 Bps.

Now we take an another binary sequence of data rate 8 times larger than of sequence shown in Fig. 1.

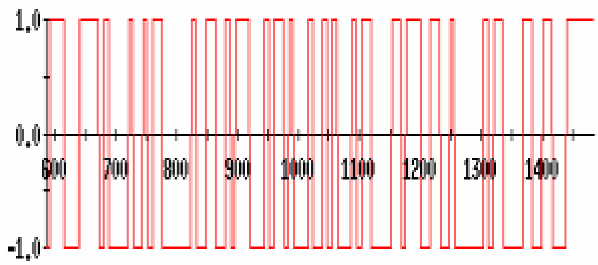

Figure 5. A New Binary Sequence Which Will Be Used To Modulate The Information Sequence

Instead of modulating with a sinusoid, we will modulate the sequence 1 with this new binary sequence which we will call the code sequence for sequence 1. The resulting signal looks like Fig. 4.Since the bit rate is larger now, we can guess that the spectrum of this sequence will have a larger main lobe.

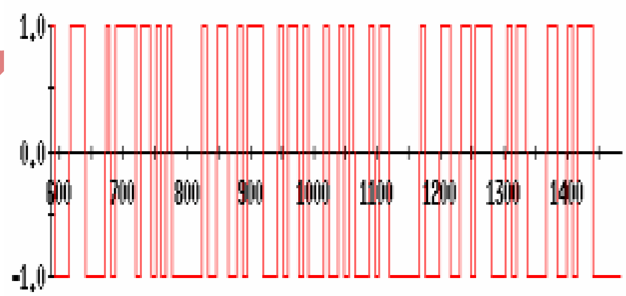

Figure 6. Each bit of sequence 1 is replaced by the code sequence

The spectrum of this signal has now spread over a larger bandwidth. The main lobe bandwidth is 16 Hz instead of 2 Hz it was before spreading. The process of multiplying the information sequence with the code sequence has caused the information sequence to inherit the spectrum of the code sequence (also called the spreading sequence).

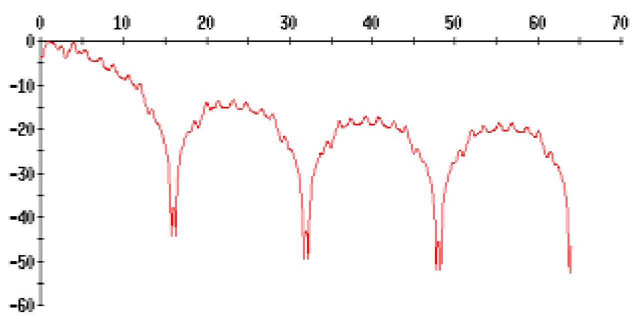

Figure 7. The Spectrum Of The Spread Signal Is As Wide As The Code Sequence

The spectrum has spread from 2 Hz to 16 Hz, by a factor of 8. This number is called the spreading factor or the processing gain (in dB s) of the system. This process can also be called a form of binary modulation. Both the Data signal and the modulating sequence in this case are binary signals.

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