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Direct Sequence Spread Spectrum with Barker Code and QPSK

Saed Thuneibat
Department of Electrical Engineering, Al-Balqa Applied University, Jordan

Abstract: - Spread Spectrum technique is a digital passband 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. In this paper, we present the Direct Sequence Spread Spectrum. Firstly, we show an overview of Direct Sequence Spread Spectrum, then, we simulate Direct Sequence Spread Spectrum using MATLAB. The results of simulation are presented in this paper. We are clearly demonstrating the benefits of Direct Sequence Spread Spectrum in a digital communication system in providing privacy and antijamming. The simulation by MATLAB program simplifies the study, analysis and development of these techniques in modern digital communication networks.

Keywords: - *Spread Spectrum, DSSS, BPSK, MATLAB Simulation.*

I. INTRODUCTION

In real communication system we have links with limited bandwidths. The wise use of these bandwidths has been, and will be, one of the main challenges of electronic communications; the issue is different in optical communications. However, the meaning of wise may depend on the application. Usually, we need to combine several low bandwidth channels to make use of one channel with a larger bandwidth. Sometimes we need to expand the bandwidth of a channel to achieve goals such as privacy and antijamming. There are two broad categories of bandwidth utilization: multiplexing and spreading. In multiplexing, our goal is efficiency; we combine several channels into one. In spreading our goals are privacy and antijamming; we expand the bandwidth of a message signal to insert redundancy, which is necessary to achieve these goals.

In literature, last years, a number of research papers have been published. In [1], authors compared between Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS) in terms Bit Error Rate (BER) as the performance parameter for the comparison. It was found that DSSS with different sequence codes provides better BER than FHSS. Paper [2] discussed various techniques like Direct Sequence (DS), Frequency Hopping (FH), pseudorandom noise (PN) sequences. MATLAB simulation is performed and a comparative study among various techniques is achieved. For comparison the parameters discussed are error probability, noise, power spectral density, error rate performance, interference and bandwidth**.** Authors concluded that Spread Spectrum (SS) techniques become more and more popular. DS and FH are the two major methods of SS. They have different strongpoint and are equally important. M-sequence and Gold-sequence have almost the same performance with single information transmission. However, the multi-user situation is demanded now days.

In paper [3], MATLAB Simulink software was used to design and simulate the operation of equivalent base-band binary phase shift keying (BPSK) and DSSS system. The performance evaluation was tested by simulating the design to get the received data which compared with transmitted data, and also to study the effect of additive white Gaussian noise (AWGN) and calculate BER. The simulation results shows that the performance of the system in presence of AWGN is better when using Integrator and Dump in active correlator than using digital LPF in active correlator.

II. SPREADING SPECTRUM TECHNIQUES

SS is a modulation method that spreads narrow band signals over a wide range of frequencies at the transmitting end and then dispreads it into the original data bandwidth at the receiving end [4]. The SS technique increases the bandwidth of the transmitting signals to a value much larger than is needed to transmit, thus, if the required bandwidth for each station is B, SS expands it to B_{ss} [5], Such that $B_{ss}>>B$, as shown in figure 1. The expanded bandwidth allows the source to wrap its message in protected envelope for a more secure transmission.

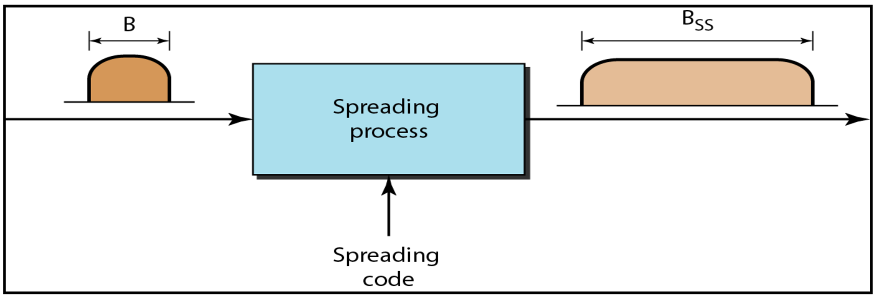

Fig. 1: spread spectrum

Based on the kind of spreading modulation, spread spectrum systems are broadly classified as: FHSS, DSSS and Hybrid spread spectrum systems (HSSS).

FHSS is a transmission technology used in wireless networks. It's a technique uses M different carrier frequencies that are modulated by the source signal, through frequency shift keying modulation (FSK) scheme. At one moment, the signal modulates one carrier frequency; at the next moment, the signal modulates another carrier frequency. Although the modulation is done using one carrier frequency at a time, M frequencies are used in the long run. The bandwidth occupied by a source after spreading is B_{FHSS}>>B.

The general layout for FHSS, explained in figure 2. A PN code creates a k-bit pattern for every hopping period (T_h). The frequency table uses the pattern to find the frequency to be used for this hopping period and passes it to the frequency synthesizer. The frequency synthesizer creates a carrier signal of that frequency and the source signal modulates the carrier signal.

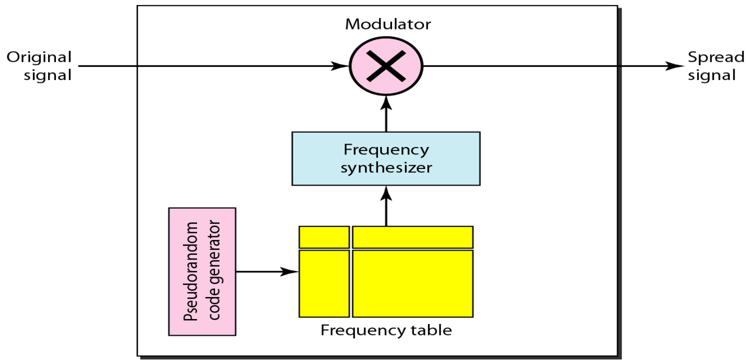

Fig. 2: FHSS.

Figure 3 illustrates the principles of FHSS. In this case, M is 8 and k is 3. The PN code generator will create 8 different 3- bit pattern which are mapped to different frequencies in the frequency table.

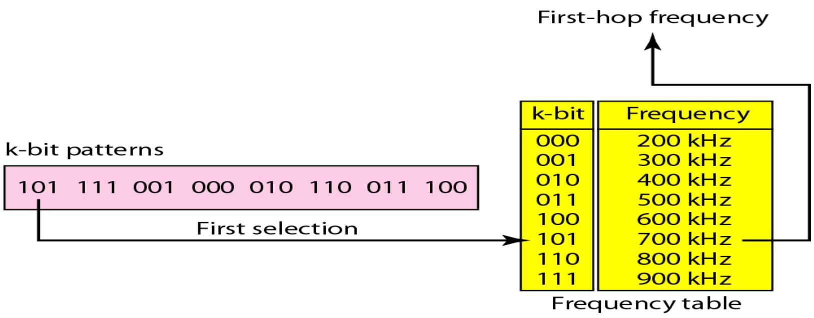

Fig. 3: Frequency selection in FHSS.

When the hopping sequence is completed, it is then repeated, and this process continues until the information being communicated has been transferred. Additionally, a dwell-time is specified, which determines how long each frequency will be utilized before hopping to the next position in the hopping sequence; as shown in figure 4.

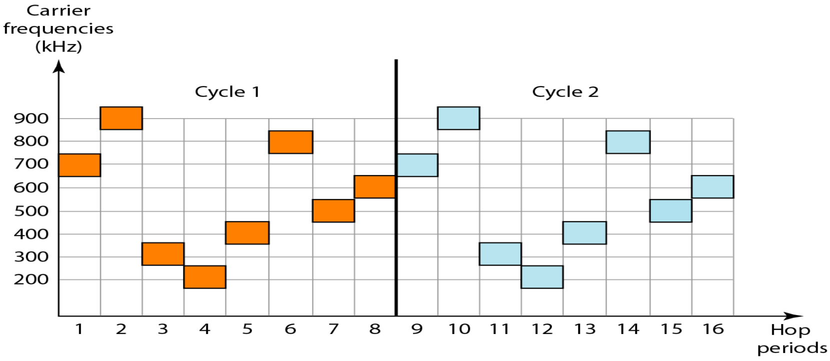

Fig. 4: FHSS cycles.

DSSS methods are the most frequently used spread spectrum technique and explained in the next sectioIf we are really paranoid about being eavesdropped, we can take further steps to make signal difficult to find. A commonly used example is that of a HSSS using both FH and DS techniques. Such schemes typically employ FH of the carrier wave, while concurrently using a DS modulation technique to modulate the data upon the carrier. In this technique an essentially DS modulated message is hopped about the spectrum, Figure 5 illustrated this technique. To successfully intercept such signal, first crack the FH code, and then crack the DS code. If we want to be further secure, we encrypt data stream with a very secure crypto code before feed into DS modulator, and employ cryptographically secure PN codes for the DS and FH operations. The eavesdropper then has to chew his way through three levels of encoding. Such a scheme is used in the military systems.

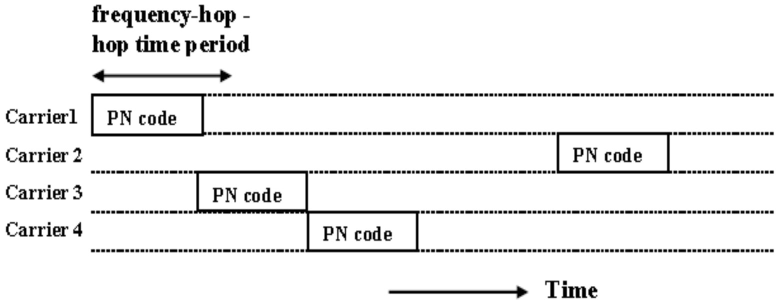

Fig. 5: A hybrid DS-FH spreading scheme.

III. DSSS CONSEPT, APPIICATIONS AND BENEFITS

DS modulation is achieved by modulating the carrier wave with a digital code sequence which has a bit rate much higher than that of the message to be sent. This code sequence is typically a PN code. In effect we are transmitting a wideband noise like signal which contains embedded message data. In telecommunications, DSSS is a SS modulation technique. SS systems are such that they transmit the message bearing signals using a bandwidth that is in excess of the bandwidth that is actually needed by the message signal. In DSSS, we replace each data bit with n bits using a spreading code. In other words, each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit. Figure 6 shows the concept of DSSS.

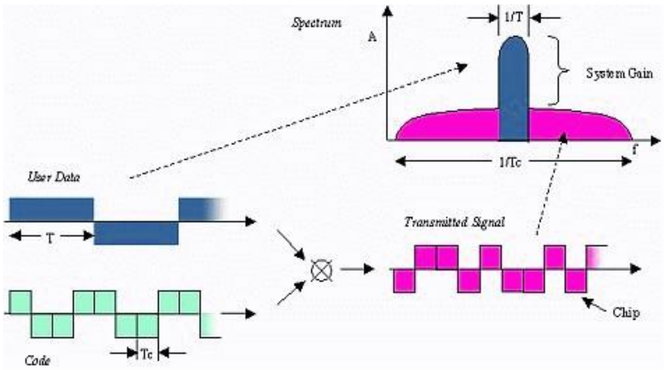

Fig. 6: Concept of DSSS.

In military communications, interception of hostile communications is commonly used for various operations such as identification, jamming, surveillance or reconnaissance. The successful interceptor usually measures the transmitted power in the allocated frequency band. Thus, spreading the transmitted power over a wider band undoubtedly lowers the power spectral density, and thus hides the transmitted information within the background noise, as shown in figure 7. The intended receiver recovers the information with the help of system processing gain generated in the spread process. However, the unintended receiver does not get the advantage of the processing gain and consequently will not be able to recover the information. Because of its low power level, the spread spectrum transmitted signal is said to be a low probability of interception (LPI) signal.

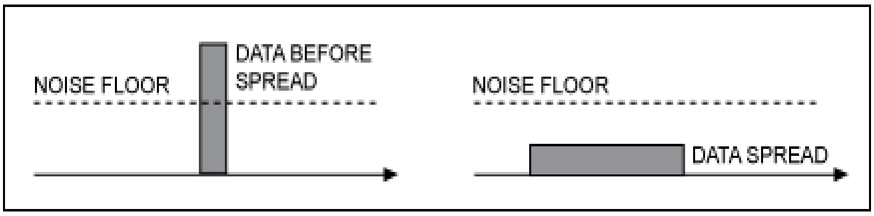

Fig. 7: Buried SS signal under the noise level.

The transmitted information over the SS system cannot be recovered without knowledge of the spreading code sequence. Thus, the privacy of individual user communications is protected in the presence of other users. Furthermore, the fact that spreading is independent of the modulation process gives the system some flexibility in choosing from a variety of modulation schemes.

In a multipath propagation environment, the receiver acquires frequent copies of the transmitted signal, as shown in figure8. These signal components often interfere with each other causing what is commonly described as signal fading. The resistance of the SS signals to multipath fading is brought about by the fact that multipath components are assumed to be independent. This means that if fading attenuates one component, the other components may not be affected, so that unfaded components can be used to recover the information.

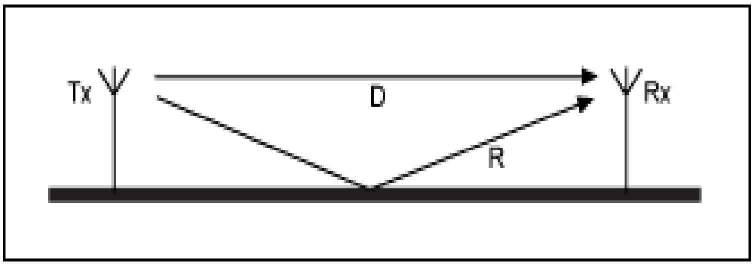

Fig. 8: Illustration of multiple paths.

As the signal is spread over a large frequency-band, the Power Spectral Density (PSD) is getting very small, as explained by figure 9.

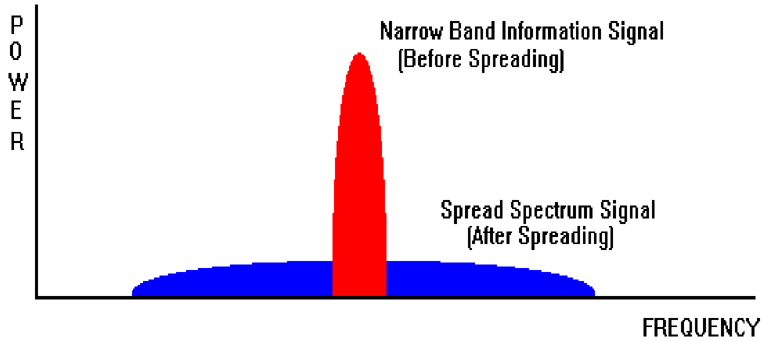

Fig. 9: Power and frequency in SS.

The biggest demerit of using a SS technique is the complex circuitry involved in generation and reception of spread signal waveforms. These results Increased cost of operation and maintenance. SS involves using a larger bandwidth than that required to transmit the information. Thus the technique is inherently bandwidth inefficient. But these disadvantages might be very nominal considering the unique advantages that SS provides under certain conditions.

Figure 10 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) [6]. 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). In the receiver, the received signal is demodulated using coherent detector and is then multiplied again by the same (synchronized) PN code. Another observation is that the despread operation is the same as the spread operation.

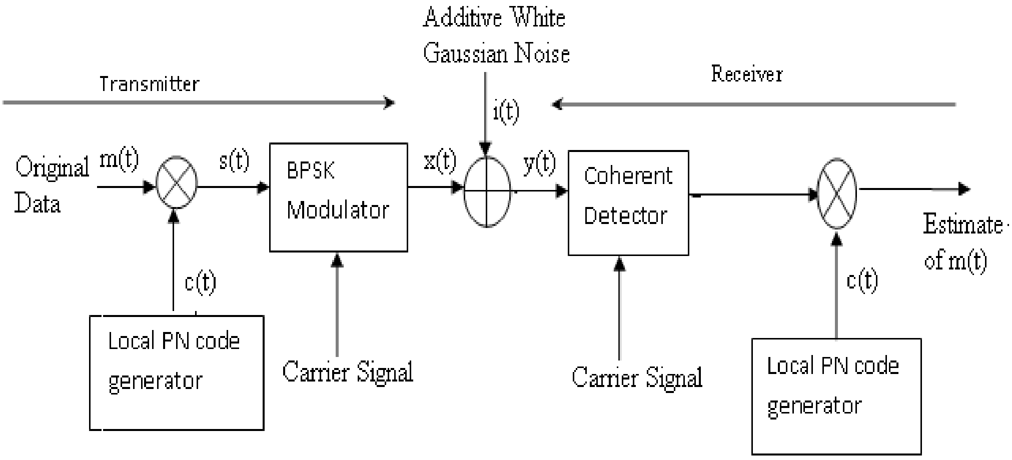

Fig. 10: Spreading and despreading in DSSS.

IV. SIMULATION RESULTS

Based on the above information, we had developed a MATLAB cod for the simulation of DSSS [7]. Several runs of the developed program were performed. The results of simulation are presented in figures from 11 to 16.

Figure 11 shows the message signal as an input to DSSS. This signal is encoded by polar NRZ. The original may be one of the following three types of information; analog multimedia traffic, for example voice and video, alphabet numerical data from keyboard and digital files from a memory.

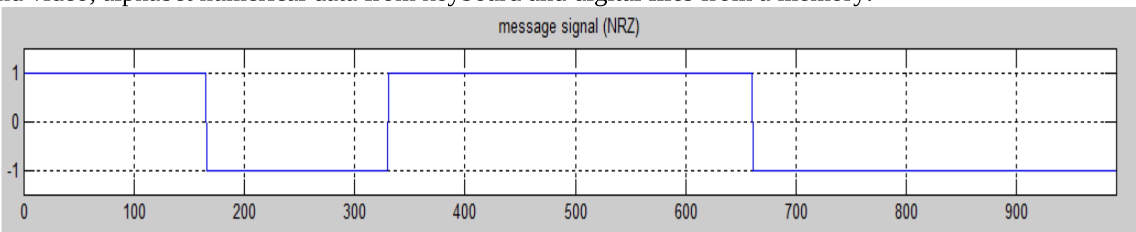

Fig. 11: Message signal.

There are different code sequences that can be used with DSSS scheme. Gold Sequences and Walsh Codes may be used as the pseudorandom codes for transmission. In this paper, for the simulation we used Barker code. 11 bit Barker code is encoded by polar NRZ, one example is shown as encoded sequence in figure 12.

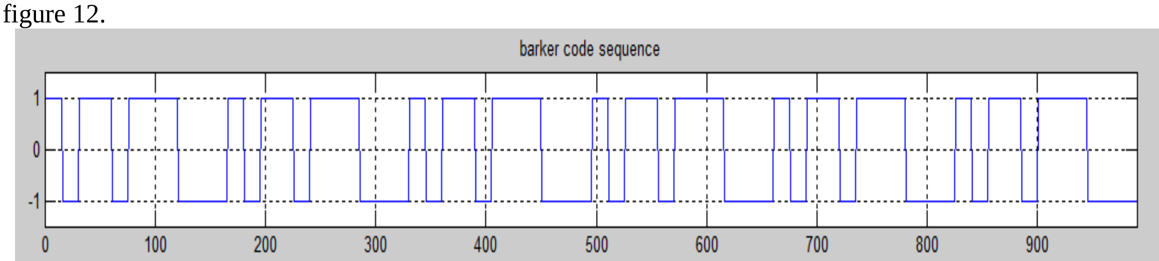

Fig. 12: Barker code.

The spreaded signal by DSSS is a result of multiplication of original signal by the Barker code sequence and shown in figure 13.

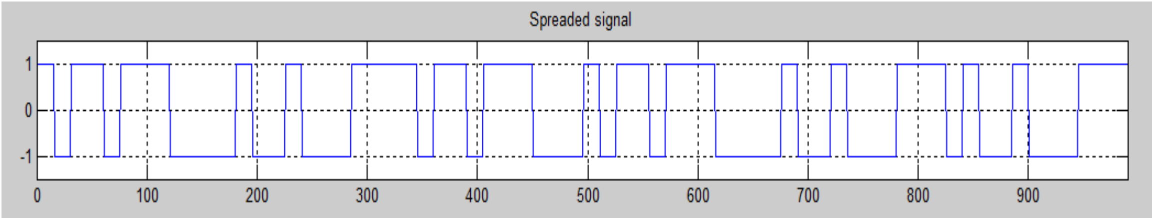

Fig. 13: Spreaded signal.

Usually, the DSSS spreaded signal is band passed using BPSK modulation technique for the transmission over wireless transmission media. BPSK modulated signal is shown in figure 14.

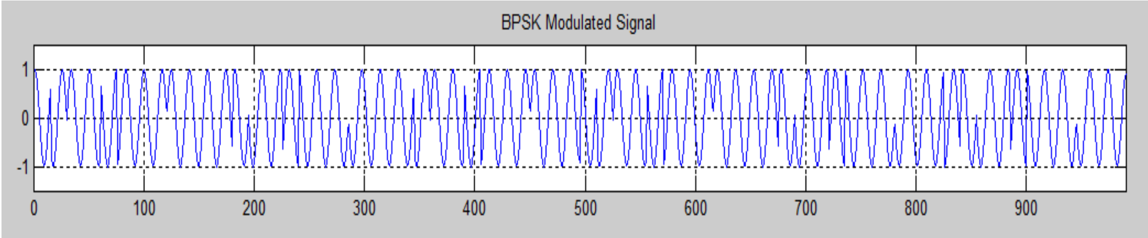

Fig. 14: BPSK modulated signal.

At the receiver end, the signal is firstly demodulated as depicted in figure 15.

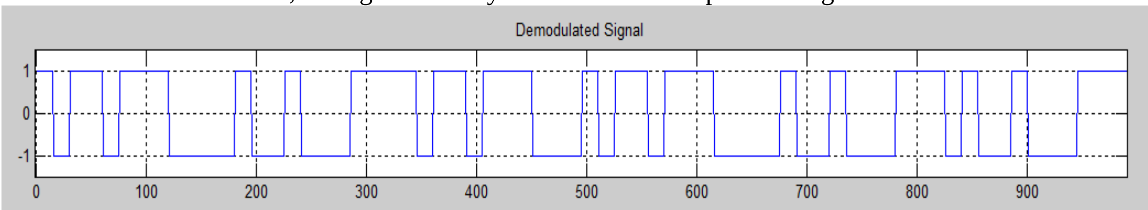

Fig. 15: Demodulated signal.

And finally despreaded by DSSS demodulator, figure 16 reflect the signal that was transmitted.

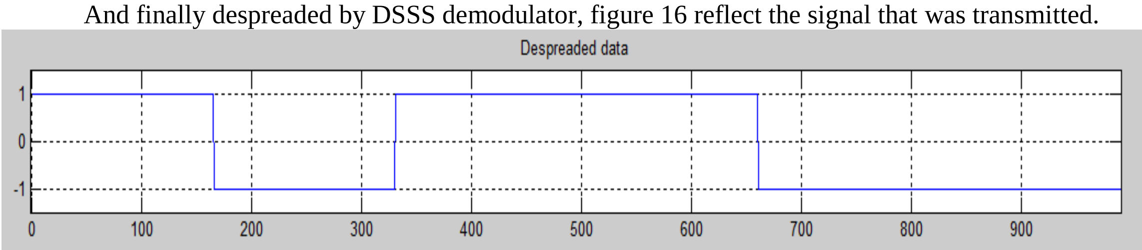

Fig. 16: Despreaded signal.

V. CONCLUSION

The goal of this paper is to explain and simulate the DSSS modulation using MATLAB environment to simplify the analysis and design of this technique. Results of simulation are clearly demonstrates that the goal is achieved.

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