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Performance Evaluation of Spread Spectrum System Using Different Modulation Schemes

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Abstract

Wireless communication is one of the most popular areas in the communication field today. Development of next generation wireless networks depends on suitable wireless and access schemes. This scheme needs to provide high data rates needed to maintain a certain level of robustness against errors. There are numerous challenges to implement these systems. These problems include propagation effects in particular multipath propagation, capacity limits due to spectral availability and the need for asynchronous access. Spread spectrum system is a class of wireless digital communication systems specially designed to overcome jamming situation. One possible method to moderate the aforementioned problems is the use of spread spectrum communication.
This paper investigates the performance of different phase modulation techniques which are used for Direct Sequence Spread Spectrum (DSSS) systems in idealistic AWGN (Additive White Gaussian noise) channel .It has been observed that Direct Sequence Spread Spectrum - Binary Phase Shift Keying (DSSS-BPSK) spread spectrum system achieves a better error performance in terms BER as compared to other techniques.

Keywords: Multicarrier; Spread spectrum; Digital Modulation;Bit error rate; Additive White Gaussian Noise (AWGN).

1. Introduction

Spread spectrum communication has over the years become an increasingly popular technique for use in many different systems because of its interference attenuation capability. Applications include antijam system, Code Division Multiple Access (CDMA) system and system designed to combat multipath. Spread spectrum signals used for transmission of digital information are distinguished by the characteristic that their bandwidth W is much greater than the information rate R in bits/s so the bandwidth expansion factor $B_e = W/R$ for spread spectrum signal is much greater than unity. The large redundancy in spread spectrum signals overcomes the severe levels of interference encountered in the transmission. A second important element employed in the design of spread spectrum signals is Pseudo-randomness, which makes the signal appear similar to random noise but difficult to demodulate by receivers other than the intended ones. This characteristic makes Spread Spectrum signals Low Probability of Intercept (LPI).

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Spread spectrum is defined as, "Spread spectrum is a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information; the band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for dispreading and subsequent data recovery." [2]

The above definition states that the spectral efficiency of a spread spectrum system is very low .This seems that spread spectrum techniques are useless for systems that need to use spectrum efficiently .However this is not the case since several users using spread spectrum signals can share the same bandwidth and the system's spectral efficiency may still be very good, even though the individual links has low spectral efficiencies.

The spread spectrum technology was developed initially for military and intelligence applications Nowadays spread spectrum is a very popular technology in areas used for good anti jamming properties. Typical applications are Wireless LANS, cordless telephones, Bluetooth. Most of these commercial applications use ISM band around 2.4GHz, since for ISM band there is no central control over the radio resources unintentional or intentional jamming can disrupt the communication for non-spread systems.

2. Literature Survey

A fundamental issue in spread spectrum is how this technique protects against interfering signals with finite power. Robert A. Scholtz in [1] has discussed the development of spread spectrum communication systems which protects the system against interference signals. System's spectral efficiency and jamming margin is improved if several users share bandwidth and channel coding is used [2],[3]. The efficiency of Direct Sequence Spread Spectrum (DSSS) is about to double that of frequency hopping however, greater band spreading is achievable with frequency hopping technology [5].The quality of service provided by wireless communication system can be greatly enhanced with the help of correct selection of modulation scheme [6]. In addition to mitigating the multipath propagation, a spread spectrum may actually exploit the effect by use of RAKE receiver [8]. The combination of spread spectrum and OFDM (SS-OFDM) can provide a very reliable data link [9],[10]. Wong and Leung in their paper[10] stated that M- ary DSSS scheme with M different codes obtained by shifting the same PN sequence can increase the transmission efficiency of spread spectrum systems and also overcome the processing gain vs data rate limitation. The rest of the paper is organized as follows .Section 3 discusses mathematical analysis of spread spectrum. Section 4 describes different modulation techniques. Section 5 describes the performance of system using different modulation techniques. Section 6 discusses the conclusion and future scope.

3. Mathematical Analysis of Spread Spectrum Communication system.

A simplified model of DSSS - BPSK system transmitter and receiver is as shown in the Figure 1(a), 1(b)

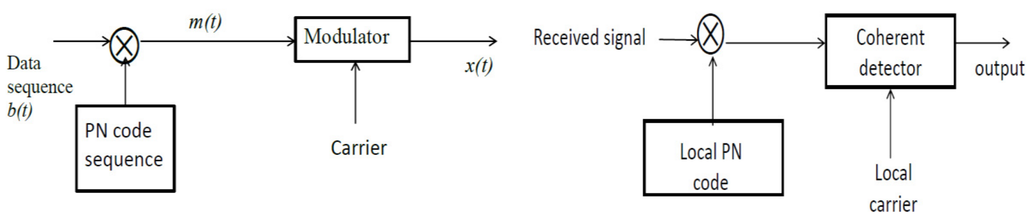

Fig. 1(a) Direct Sequence Spread Coherent Phase Shift Keying Transmitter (b) Direct Sequence Spread Coherent Phase Shift Keying Receiver.

3.1. DS-SS (Direct Sequence Spread Spectrum) Transmitter and receiver

The transmitter consists of two stages of modulation .The first phase consists of product modulator or multiplier with the data sequence and PN (Pseudo random Noise) sequence as the inputs. The second stage consists of modulator [Binary Phase Shift Keying (BPSK) in this case].The transmitted sequence is thus a direct- sequence spread binary phase shifted keyed (DS/BPSK) signal.

The information signal b (t) represents an antipodal pulse stream with values ±1 with a given data rate which is narrow band is multiplied by a spreading sequence c (t) with a much higher data rate called chip rate. Thus a narrow – band data sequence is transformed into a noise like wide band signal.

The second stage consists of a binary Phase Shift Keying (PSK) modulator which converts base band signal b (t) into band pass signal x (t).The receiver consists of two stages of demodulation .In first stage the received signal and the locally generated PN sequence are applied to a multiplier .The second stage consists of a coherent detector, the output of which provides the estimate of original data sequence.

3.2 Relation of Output signal to noise ratio and Processing Gain

The encoding and decoding by PN sequence in DS-SS system has the effect of increasing the SNR (signal to noise ratio) by code length N.

We define the output signal to noise ratio as the instantaneous peak power E_b divided by variance of equivalent noise component, so we can write

$$\text{Output } SNR(SNR)_O = \frac{E_b}{\frac{JT_c}{2}} \qquad (09) \qquad [2]$$

$$\text{Input } SNR(SNR)_i = \frac{E_b/T_b}{j} \qquad (10)$$

$$(SNR)_O = \frac{2T_b}{T_C}(SNR)_i \qquad (11)$$

$$10\,log_{10}(SNR)_O = 10\,log_{10}(SNR)_i + 3 + 10\,log_{10}(PG)db \qquad (12) \qquad [2],[11]$$

3.2. Antijam Characteristics

Probability of Error of DS-SS BPSK system is

$$P_e = erfc\left(\sqrt{\frac{2E_b}{JT_c}}\right) \qquad (13) \qquad [3],[11]$$

We may express bit energy to noise density ratio as

$$\frac{E_b}{N} = \frac{T_b}{T_C}\left(\frac{p}{j}\right)$$

$$\text{Jamming Margin}\left(\frac{J}{P}\right) = \frac{PG}{E_b/N} \qquad (14)$$

(Jamming Margin) db = (PG) db - 10 log $10(E_b / N)_{min}$ (15)

Where $(E_b / N)_{min}$ is the minimum bit energy – to – noise density ratio needed to support prescribed average Probability of Error.

From equation (15) we conclude that Processing gain (PG) is very important parameter for deciding the performance of system in jamming environment. Jamming margin can be improved by increasing the Processing gain (PG) and by reducing $(E_b / N)_{min}$ the minimum bit energy – to – noise density ratio.

4. Digital Modulation Techniques

The quality of service provided by a system greatly depends upon the correct selection of modulation scheme so we use different types of popular digital modulation techniques like BPSK, QPSK, 8PSK, 16PSK and QAM .The performance of each modulation scheme is measured by estimating its probability of error with an assumption that system are operating with Additive White Gaussian Noise [6].

The Binary Phase Shift Keying (BPSK) technique is referred to as the simplest form of phase modulation, as the carrier phase represents only two phase states [11]. Here, the phase of a constant amplitude carrier is switched between two values according to two possible signals corresponding to binary 1 and 0 respectively. This modulation is the most robust of all the Phase Shift Keying techniques [6].

Quadrature Phase Shift Keying (QPSK) has more effective utilization of the available bandwidth as compared to Binary Phase Shift Keying, as two bits are combined as one symbol [11]. Noise immunity of QPSK is same as that of BPSK [6]. In QPSK digital modulation scheme, the division of the phase of the carrier signal is done by allotting four equally spaced values for the phase angle as π/4, 3π/4, 5π/4 and 7π/4, thus providing a major advantage over BPSK by having the information capacity double to it[6].

The energy efficient schemes such as BPSK or QPSK are used when channel conditions are poor whereas for good channel condition, Quadrature Amplitude Modulation (QAM) is to be used. The QAM is a modulation scheme where its amplitude is allowed to vary with phase [6]. This technique can be viewed as a combination of ASK as well as PSK.QAM is widely used in many digital data communication applications.

5. Results

A MATLAB Simulink model using different subsystem blocks is developed for Direct Sequence Spread Spectrum (DSSS) and the same system is tested under Additive White Gaussian Noise (AWGN) channel.

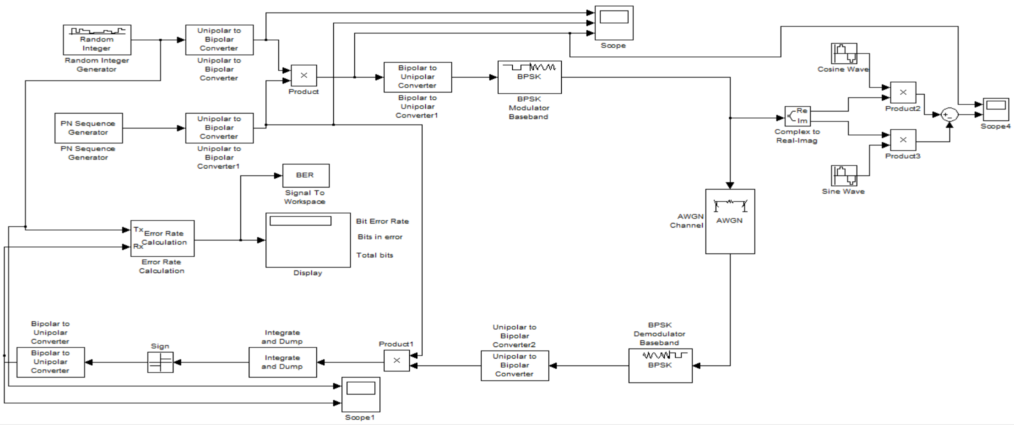

Fig.2. .MATLAB Simulink Model of Direct Sequence Spread Spectrum (DSSS) system;

Simulation results for each part of DSSS/BPSK System are discussed below.

Data source is the random Integer generator from the communication sources; communications block set which produces random uniformly distributed binary integers (0 and 1) at data time T_{b} = 1msec or a Data rate 1 Kb/sec. The PN Sequence generator block is used from sequence generators sub library of communication Sources which generates a sequence of pseudorandom binary numbers using a linear-feedback shift register (LFSR) as shown in fig 4. The l kb/s transmitted data is applied to modul-2 adder with a PN sequence to get a spreading data as shown in fig 5 below. BPSK modulator converts spreading data from unipolar to Bipolar with reverse phase (0 or 180) depending on the input to the BPSK modulator. Fig 7 shows the transmitted signal under AWGN at SNR equal to 10 db. If correct PN code is used in the transmitter, the received data from BPSK demodulator with respect to transmitted data is as shown in fig 8 where received sequence is equivalent to transmitted Sequence.

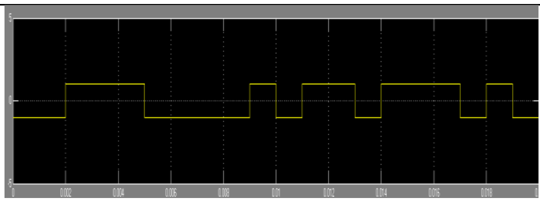

Fig.3. Random polar data sequence at the rate of 1Kb/sec

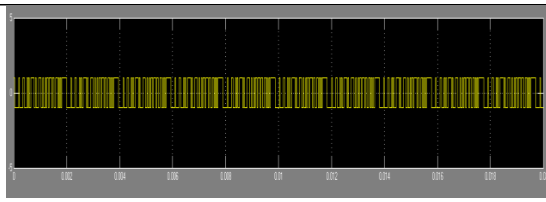

Fig.4 Random polar spreading sequence at the rate of 100 kb/sec

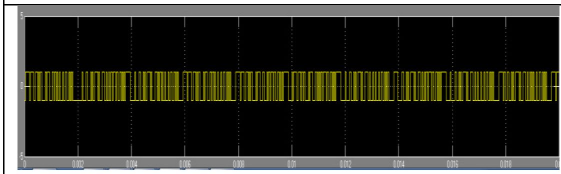

Fig.5.Spreading sequence at the input of BPSK modulator

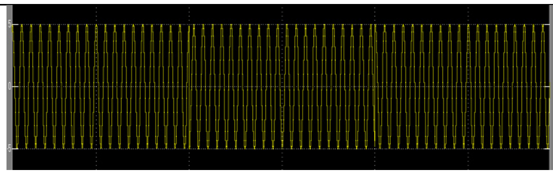

Fig.6. Transmitted Waveform at the output of BPSK Modulator.

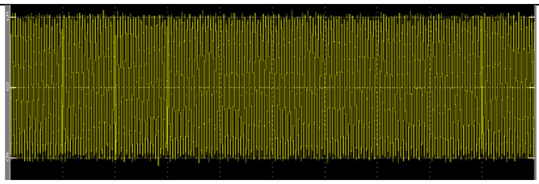

Fig.7.Waveform at the output of BPSK Modulator.

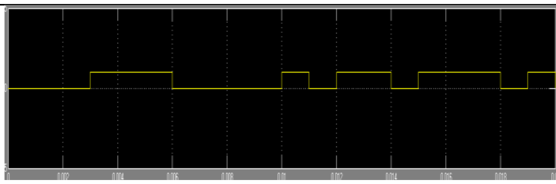

Fig 8.Waveform at the output of receiver equivalent to transmitted Sequence.

Table 1. Comparison of BER v/s Eb/N0 for DSSS various Modulation schemes

EbNo	DSSS- BPSK	DSSS-QPSK	DSSS-8PSK	DSSS-16PSK	DSSS-QAM
-5	0.1984	0.3058	0.4329	0.6756	0.3773
-4	0.1824	0.2544	0.3846	0.641	0.3484
-3	0.1661	0.2232	0.3401	0.6134	0.3164
-2	0.1373	0.1876	0.2881	0.5714	0.2994
-1	0.1169	0.1555	0.2469	0.5235	0.2531
0	0.093	0.1212	0.1851	0.4608	0.2183
1	0.069	0.083	0.1239	0.4132	0.184
2	0.05	0.053	0.083	0.3745	0.13
3	0.03	0.031	0.051	0.33	0.112
4	0.018	0.005	0.028	0.2724	0.082
5	0.008	0.003	0.016	0.2262	0.054
6	0.003	0.002	0.08	0.1818	0.04
7	0	0.001	0.004	0.0117	0.02
8	0	0	0.001	0.078	0.01
9	0	0	0	0.046	0.004
10	0	0	0	0.022	0
11	0	0	0	0.014	0
12	0	0	0	0.08	0

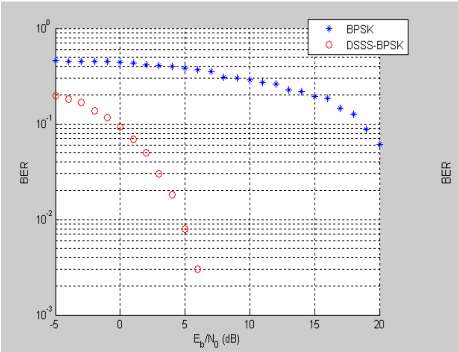

Fig.9 Plot of BER vs EbN0 plot for BPSK and BPSK-DSSS

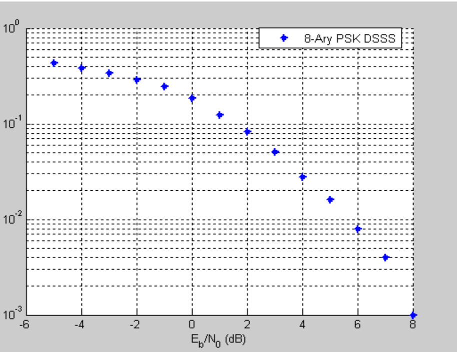

Fig.10. Plot of BER vs EbN0 plot for DSSS 8-ary PSK

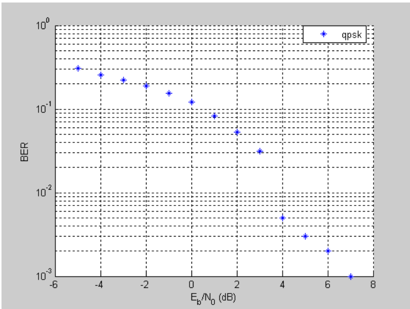

Fig.11. Plot of BER vs EbN0 plot for DSSS QPSK

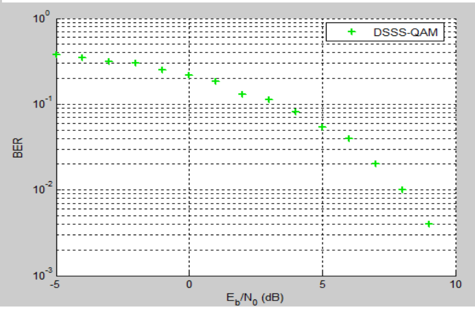

Fig.12. Plot of BER vs EbN0 plot for DSSS QAM

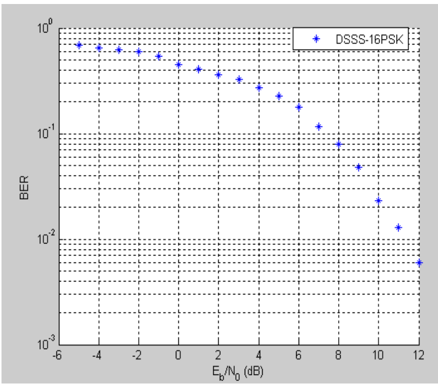

Fig.13. Plot of BER vs EbN0 plot for DSSS 16 PS

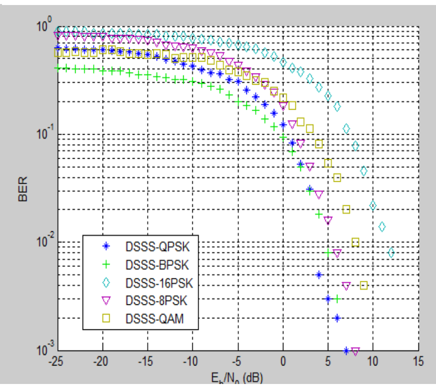

Fig.14. Plot of BER vs EbN0 plot for DSSS Various modulation Schemes

Using MATLAB Simulink model shown in the figure 2(Figure 2 shows MATLAB Simulink model.) The Simulink process was carried for testing the performance of the system in terms of BER .It was found that when the system is simulated for 10ms time, the total number of bits was 1000 and BER was found to be 0.008 at SNR equal to 5db, Using Monte Carlo simulation methods taking random sample of input numerical value of SNR, BER vs

EbN0. It is found that system performance improves with increase in EbN0. The BER analysis was also conducted with same parameters for BPSK band pass modulation and demodulation it was observed that the system performance of DSSS-BPSK is consistence and the performance is better as compared to BPSK band pass modulation and demodulation Techniques. It is found that DSSS/BPSK is far better in terms of BER performance as compared to BPSK Band pass modulation and Demodulation technique as seen in fig 9. The quality of service provided by a system greatly depends upon the correct selection of modulation scheme so the DSSS system was also simulated for its performance in presence of AWGN using different types of digital modulation techniques like BPSK, QPSK, 8PSK, 16PSK and QAM. A comparison study showed that for a given data rate and channel conditions DSSS-BPSK are better than other phase modulation techniques in terms of Error performance.

It is seen from fig 10 that to achieve a BER of 10^{-3} EbN0 of 6 is required whereas DSSS-QPSK, DSSS-4ary PSK, DSSS-16PSKand DSSS-QAM needs higher values of EbN0 to achieve the same BER.

The wireless channel is susceptible to a variety of transmission obstacles such as path loss, interference, and blockage. These factors restrict the range and the reliability of the wireless transmission. Additive White Gaussian Noise (AWGN) is a channel model in which only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. This model does not account for fading, frequency selectivity, interference, non-linearity or dispersion.

The extent to which these factors affect these transmission in fading environment it is important that the performance of DSSS system is tested under Fading channel environment like Rayleigh and Rician. Future scope includes testing the performance of system using different channels.

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