A New Scheme for Spreading & De-spreading in the Direct Sequence Spread Spectrum Mechanism

M.I.Khalil

Princess Nourah bint Abdulrahman university, Faculty of Computer and Information Sciences, Information Technology (networks) Department, Riyadh, Kingdom of Saudi Arabia

***Abstract*:** Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS) techniques are widely used to implement code-division multiple access (CDMA) in wireless communication systems. Both DSSS and FHSS systems help reducing the effects of interference on the transmitted information making it robust against channel impairments. DSSS uses a signal bandwidth that is much broader than the information signal bandwidth. Traditionally, the wide band signal is generated by multiplying the narrowband information signal with a binary code, often designated as a spreading code, to generate the wideband signal that is transmitted. The original information signal can be recreated at the receiver by multiplying the received wideband signal by the same binary code (now designated as a de-spreading code) used to generate the wideband transmitted signal. To extract the original information signal, the spreading and de-spreading codes must be in synchronism at the receiver and amplitude match with each other. A new modification for the direct sequence spread spectrum is proposed in this paper. The mechanism introduced in this approach implicates generating the wideband signal by circularly shifting the spreading code (PN) by *n* places, where *n* represents the value of the current byte of information signal. The yielded signal is modulated using BPSK modulator before transmitting it. The original information signal is extracted at the receiver by correlating the received signal (which is actually the original spread sequence circularly shifted by *n* places) with a locally generated replica of the spreading code. The position of the maximum value of the cross-correlation vector represents the value of the information signal byte. The proposed configuration has been implemented using Simulink simulator and the obtained results show that its performance is identical with the conventional DSSS.

***Keywords*:** DSSS, CDMA, Cross-correlation, PN Sequence Generator, BER**.**

1. Introduction

At the time being, multiple access techniques are widely used to allow a large number of mobile users to share and utilize the allocated spectrum in the most efficient manner. Various multiple-access schemes have been devised for wireless communication systems such as frequency division multiple-access (FDMA), time division multiple-access (TDMA) and code division multiple-access (CDMA) [1-3]. In FDMA, the total frequency bandwidth allocated to the system is separated among the various users. In TDMA, the total time resource are separated among the various users. Unlike FDMA and TDMA, in CDMA both the total bandwidth allocated to the system and the total time resource are available to each subscriber. CDMA is a channel access method where many transmitters can send information over a single communication channel where each user can use the total frequency bandwidth allocated for this channel. CDMA is characterized by its low power spectral density, where the signal is spread over a very high bandwidth. CDMA uses all allocated frequencies yielding limited interference and multipath affects. DSSS and FHSS are two common forms of spread spectrum techniques and are used for wireless communication in many mobile phone standards, Bluetooth and global satellite positioning systems (GPS). At the time being, there is a race between the limited available radio frequencies and increasing communication needs. The spread-spectrum techniques are a way of calming this race. In DSSS, the original data signal at the sending station is combined with a higher data rate bit sequence, or chipping code, that divides the user data according to a spreading ratio [4-7]. In other words, the baseband information signal (data) to be transmitted is multiplied (mixed) by a pseudorandom code sequence or pseudo noise (PN) signal. PN is much shorter in duration and accordingly has a higher bit-rate (wide bandwidth) than the information signal (wide duration and narrow bandwidth). Accordingly, the spectrum of the baseband information signal is spread to the total frequency bandwidth allocated to the system. In other words, the information is diffused in a larger bandwidth. Conversely, at the receiver, the spread spectrum code is removed from the received signal by multiplying it by a locally generated replica of the spreading code (PN) yielding the original information signal. The de-spreading process requires that the receiver already knows the spread code (PN) being used by the transmitter. In DSSS, multiple transverse share the same channel for communication using different PN sequences with limited cross correlation property between them to avoid interference. Consequently, a unique spreading code (PN) is dedicated for each user and any other signal that does not have the key / signature (PN) applied to the transmitted information signal is rejected when received at this receiver. The chip rate (chips per second) of the spread code is defined as the number of pulses per second. Symbol rate is defined as the number of message bits per second. The chip rate is much larger than the symbol rate. The spread sequence rate, referred to as the chip rate, is increased to N times the original data rate. The code length parameter N is called the spreading factor and is defined as:

$$N = \frac{chip\ rate}{symbol\ rate} \quad (1)$$

A new approach for spreading the baseband information signal to the total frequency bandwidth allocated to the system is introduced in this paper. It is based not on multiplying the original data signal with a higher data rate bit sequence , but on rotational shifting the bits of the spread sequence a number of places equal to the value of a data piece (i.e. byte). The original information bytes are inferred by cross-correlating the received signal with a locally generated replica of the spreading code.

The rest of this paper is organized as follows: Section II reviews some of the significant research in the field of using code division multiple-access techniques specially the direct sequence spread spectrum one in mobile communication. Section III illustrates briefly the basics of DSSS transmitter and receiver mechanisms. The proposed methods will be introduced in section IV, while the implementation and experimental results will be illustrated in section V. The obtained results will be concluded in section VI.

2. Literature Review

Ainnur Eiza Azhar, et al., introduced an enhanced of SINR based on serving and neighboring path loss to mitigate co-channel interference by using DSSS technique in LTE-Wi-Fi network. The work aims to improve the signal-interference-to-noise ratio (SINR) value at UEs. Herby, the path losses for both serving and its neighbouring base stations in the network is considered. As a result, the SINR at MUE using the proposed technique gives better SINR performance [8]. Gowrilakshmi Ponuratinam and Syed S Rizvi introduced spread spectrum links that can be used to overcome intentional jamming. They uses a simple point-to-point communication system with fully synchronized transmitter and receiver in a simple channel with white Gaussian noise and arbitrary jamming signal. They prove that in traditional systems the channel converges to a Gaussian noisy channel in the limit in the case of almost any jamming signal, and in our new ideal modified system the channel converges to a white Gaussian noisy channel in the limit in the case of any jamming signal when the processing gain goes to infinity [9]. M. Edrich and R. Schmalenberger introduced a comprehensive overview of the requirements for medium-range UAV data links. Special emphasis is given to requirements and solutions which are related to the application of spread spectrum techniques. Based on the analysis of requirements and possible design solutions, the system concept and the hardware structure of a production-stage datalink system for a medium-range UAV carrying an electro-optical sensor payload is presented [10]. RuiMin Lu , et al., proposed a new concept of "normalized throughput of information" according to the property of jammed signals, the performance of FHSS and DSSS signal with on-board processing is compared based on the new concept. they conclude that performance of FHSS signal is better than that of DSSS signal, and FHSS signal is suitable to be used in military satellite communications [11]. M. Hasan, J. M. Thakur, and P. Podderr mainly focuses the design of spread spectrum techniques, namely Direct Sequence Spread Spectrum (DSSS) and Frequency Hopped Spread Spectrum (FHSS) which involve for spreading the bandwidth of the signal to minimize the troubles that can arise from the vulnerabilities of conventional circuits through the channel [12]. A. Wautier ; S. Ammari The studied the influence of the spreading sequence on the bit error rate performance of a single-user RAKE receiver. Analytical expressions of the bit error rate are derived for non-ideal sequences. This study shows that sequences of a family set do not have the same behavior on a particular channel profile. RAKE receiver sensitivity to the number of fingers can also be easily evaluated with the analytical approach. RAKE performance degradation due to channel estimation and to multiple users are also evaluated [13]. N. Benvenuto, G. Sostrato, in order to combat the overall interference, they proposed four efficient joint detection schemes based on zero-forcing and minimum-mean square error criteria. By exploiting the Toeplitz-block structure of matrices and the asymptotic equivalence between finite-order Toeplitz matrices and circulant matrices, most computations can be carried out very efficiently through extensive use of discrete Fourier transform (DFT) and independent DFT (IDFT) transforms. Performance results based on the UMTS scenario are presented [14]. Harshali Mane, et al., in their paper, introduced a Direct Sequence Spread Spectrum (DSSS) transmission and reception method using a compression technique. Text and binary signals are transmitted and received through DSSS. Also speech and image are transmitted and received using Huffman Compressive techniques. Discrete cosine transform that compresses speech and image signals through DSSS. The suggested methods are assessed with DSSS signals using Binary Phase-Shift-Keying modulation under Rayleigh channel fading and Additive white Gaussian noise (AWGN). The analysis has performed by comparing Bit Error Rate (BER) for different Signal-to-Noise-Ratio (SNR) levels of AWGN. The results indicate the better performance even for low SNR with good compression ratio [15]. Rehman Ansari, Shahnawaz Uddin, Sameena Naaz used the noise rejecting property of the matched filter and Binary Phase Shift Keying (BPSK) modulation in Direct Sequence Spread Spectrum (DSSS) system for secure communication. In their work, DSSS system has been developed and simulated using C-programming language on windows platform. In order to perform the simulation, different parameters are initialized and message bits are generated by random function. With the help of binary message signal and PN sequence, a SS signal is generated which is modulated using BPSK modulation technique at the transmitter side. In the channel, noise/jamming signal is added to the transmitted signal. Then the received signal is demodulated using coherent BPSK receiver (i.e., correlation receiver) and matched filtering is followed by despreading the demodulated signal at the receiver side. Finally, the received binary message bits are detected by threshold detector and various parameters such as input SNR, output SNR, probability of error are calculated [16]. M.Raj kumar and Sri K.Raju presents the FPGA implementation of spreading code generator in direct sequence spread spectrum modulator, in this Direct Sequence Spread Spectrum where by the original data signal is multiplied with a pseudo noise spreading code to be transmitted. This process can be done through the spreading code generator which can be implemented using VHDL in DSSS modulator on Spartan 6 FPGA family. spreading code has a Programmable chip rates up to 60 Mchip/s and spreading factor from 3 to 65335.Modulation is BPSK/QPSK and raised cosine square root filter with 20% rolloff where Filter can be bypassed [17]. Mahdiyar Sarayloo , Ennio Gambi and Susanna Spinsante have investigate new sets of sequences that can be applied as spreading codes in multiple user communications as it is still an active area. They focuses on the Zero Correlation Zone (ZCZ) property exhibited by a family of nonlinear binary sequences featuring

a great cardinality of their set, and good security-related features, and provides evidence of their suitability to multiuser communications, in channels affected by multipath [18]. Domingos Terra, et al., addresses and implements a Direct Sequence Spread Spectrum (DSSS) transceiver for Visible Light Communication (VLC) systems based on FPGA. A transceiver was implemented including a transmitter capable of driving an array of light emitting diodes (LED) and a Pseudo-Noise (PN) matched decorrelator. The receiver architecture uses a discrete FIR correlator for data synchronization and acquisition. In this paper, a novel and simple PN code with a 10 bit sequence length is developed. This code offers a similar performance to the popular Barker code; however, it has a simple design. The used FPGA resources are presented along with a performance analysis [19]. Brahim Akbil and Driss Aboutajdine proposed two contributions to improve the performance of the IDMA. First, they propose a new interleaver design, called "NLM interleaver", which improves the computational complexity, reduces the bandwidth consumption and the memory requirements of the system. It also provides infinite sets and quasi-orthogonal spreading codes and interleavers based on only one parameter. Second, they proposed a new user grouping algorithm based on the correlation function to improve the resources (codes and interleavers). In fact, all users are divided into several equal-size groups where each group's data are transmitted at the same time, with the same frequencies and the same interleaver. The simulation results indicate that the proposed scheme achieves better performances compared to the existing algorithms [20].
The above-mentioned manuscripts address significant direct sequence spread spectrum issues: DSSS applications, hardware implementation, detection of signal information, security, synchronization and acquisition. The conventional configuration of DSSS has been used in all of them. The proposed approach implies realization and dealing with a new design for DSSS.

3. Direct Sequence Spread Spectrum (DSSS)

3.1 DSSS transmitter

As illustrated in Fig.1, the information signal *m(t)* is provided to the transmitter as a sequence of bits or symbols. A pseudo-random binary code (spreading code) consisting of a sequence of bits *c(t)*, called chips, having a much shorter duration than the data bits *m(t)* or symbols, is provided as well and is *XOR*ed (bitwise logic function) with the information bits to acquire the energy spreading. The generated bits *x(t)* are then modulated with a carrier signal.

Chip modulation may be any version of coherent modulations, such as BPSK, QPSK, 8-PSK (Phase Shift Keying), but generally, binary phase shift keying (BPSK) is employed. A BPSK modulator shifts the phase of the RF carrier 180° according to the state of the modulating data bits or code chips "zero" or "one." BPSK is used as the modulation method to send information over the communication link. In BPSK, only one sinusoid is taken as the basis function. Modulation is achieved by varying the phase of the sinusoid depending on the message bits. Therefore, within a bit duration T_b, the two different phase states of the carrier signal are represented as:

$$\begin{aligned} s_1(t) &= A_c\cos(2\pi f_c t), \quad 0 \le t \le T_b \quad \text{for binary 1} \\ s_0(t) &= A_c\cos(2\pi f_c t + \pi), \quad 0 \le t \le T_b \quad \text{for binary 0} \end{aligned} \tag{2}$$

where, A_c is the amplitude of the sinusoidal signal, f_c is the carrier frequency (Hz), t being the instantaneous time in seconds, T_b is the bit period in seconds. The signal $s_0(t)$ stands for the carrier signal when information bit $a_k = 0$ was transmitted and the signal $s_1(t)$ denotes the carrier signal when information bit $a_k = 1$ was transmitted.

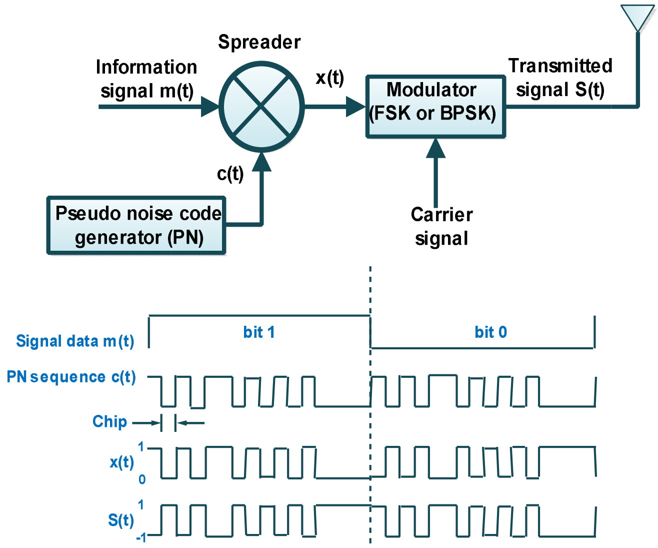

Fig.1 : The basic block diagram of conventional direct sequence spread spectrum (DSSS) transmitter

3.2 DSSS receiver

The DSSS Receiver performs demodulation of wideband DSSS signals, the received signal is fed to BPSK coherent demodulator operating at a carrier frequency f_c. The Receiver will produce a demodulated bit stream at this stage. Successful demodulation of the received signal requires that the receiver must synchronize its locally generated code sequence to the received signal [21]. Methods used to achieve coarse synchronization to the code sequence, also called acquisition of the code sequence. The receiver despreads the demodulated sequence by calculating the inner product of the received spread signal with a local copy of the pseudo code PN that was used to spread it. The locally generated despreading sequence is denoted by *c(t)*, and should be replica of *c(t)* of the transmitter. It is also necessary to synchronize to the code sequence PN that was used to produce the spectral spreading. The process of synchronizing with the local PN sequence is normally performed in two steps. Initially, the coarse acquisition process brings the sequences to less than a single chip difference. This is called PN acquisition. Then the fine synchronization system takes over, reduces the time difference, and maintains synchronization. This process is called PN tracking [22]. The time required to acquire a PN sequence is determined by the number of possible time and frequency bins that must be searched and how the bins are searched. The number of time bins is determined by the length of the PN sequence.
The block diagram of the direct sequence spread spectrum receiver is depicted in Fig.2.

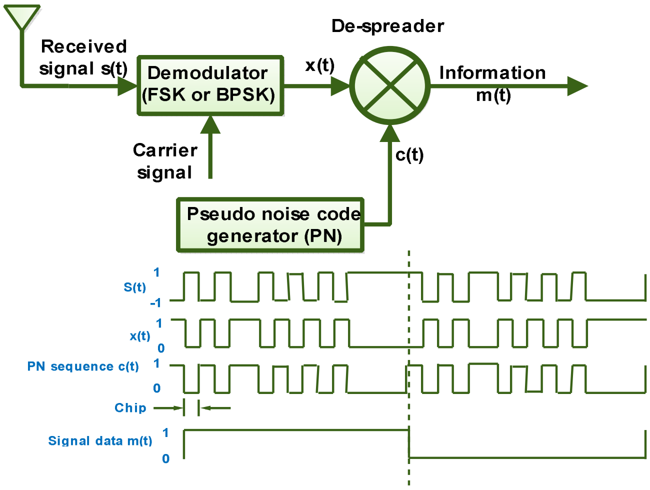

Fig.2 : The basic block diagram of conventional direct sequence spread spectrum (DSSS) receiver

4. The Proposed System

4.1 System organization

Unlike the conventional DSSS implementation, the key concept behind the new approach is simply based on acquiring the information signal as 8-bit integer symbols. The pseudo code, PN, dedicated for the user is loaded into a circular shift-right register (CSRR) where the length of the CSRR and consequently the PN is related to the sample's length (8-bits) in such way that CSRR can be right-shifted by n places whatever the value of the sample (0 →255):

$$length\ of\ CSRR = 2^{sample\_length} \quad (3)$$

And for sample-length = 8, the Length of CSRR = 256 bits. The 256-bit pseudo noise sequences (PN) used in this papers are generated by a 8^{th} order maximal length sequence shown in equation four,

$$G(x) = z^8 + z^7 + z^4 + z^2 + 1 \quad (4)$$

The block diagram of the new DSSS transmitter of the suggested approach is shown in Fig.3. The timing control unit generates the timing signals required to direct the operation of the other units. According to the sampling rate, the integer value of each symbol is used to shift the contents of the shift register CSRR circularly to right. The new contents of the CSRR is fed serially bit by bit to the Binary Phase Shift Keying (BPSK) modulator. Accordingly, the spectrum of the baseband information signal is spread to the total frequency bandwidth allocated to the system.

The block diagram of the receiver scheme of the proposed DSSS system is shown in Fig.4. The receiver performs the task of dispreading by cross-correlating the received signal with a locally generated replica of the spreading code (PN).

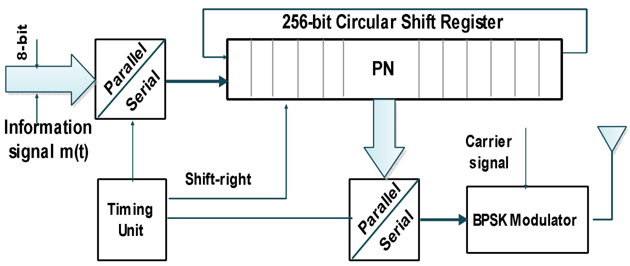

Fig.3 : The basic block diagram of the suggested DSSS transmitter

In the proposed scheme, the received signal is demodulated using binary phase shift keying (BPSK) demodulator. On every subsequent 256-bits of the yielded demodulated signal, the buffer contents are loaded into 256-bit register "A". A replica of the spreading code (PN), which is included in register "B", is cross-correlated with the contents of register "A", producing a correlation score. The maximum value of the yielded cross-correlation vector (correlation peak) represents the value of the transmitted symbol. The output of the cross-correlation process is compared with a predefined threshold level in acquisition and if the threshold is exceeded, the yielded value is considered. In the conventional DSSS scheme, this locally generated code must be synchronized (in phase and frequency) to the received code to despread the received signal successfully. In the proposed scheme, the correlation process is of twofold purpose, the first one is to despread and get the value of the received sample and the second purpose is to cope with the problem of synchronization inherent in the conventional method.

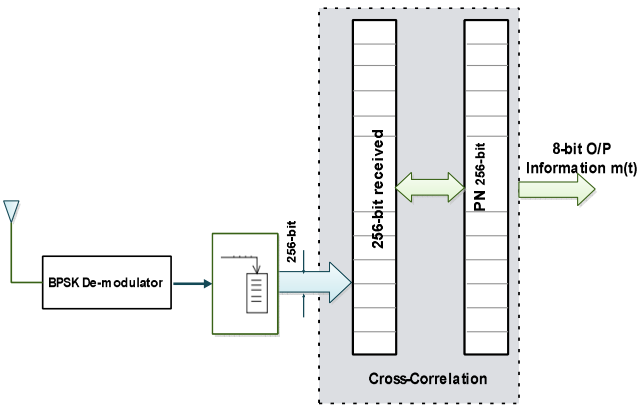

Fig.4 : The basic block diagram of the new DSSS receiver

The Matlab Simulink implementation of the proposed DSSS scheme is shown in Fig.5. The PN sequence generator produces a PN code of 256 chips length, and chip rate R= 256 kcps (kilo chips per second). The information symbol is set to be of 8-bit integer, and is acquired with arriving rate of 1000 symbol per second through random integer generator. Both the sequence number PN, and the acquired symbol are fed to a block function (triggered subsystem2), where the contents of PN is circularly shifted-right by n places where n is the value of the acquired symbol. By the end of this process, the output of the function is a stream of bits, which represent the spreading of the baseband information (acquired symbol with rate 1000 sample/second) to the total frequency bandwidth (256000 bit/second). The function of BPSK block is binary phase shift keying modulating of the output stream from the previous stage. The output of BPSK is provide to AWGN white noise channel, where the SNR parameter is varied from 40dB to -30dB. The output signal, with the superimposed noise, is received and demodulated by BPSK demodulator and then fed to cross-correlator. The signal is correlated with a replica of the sequence code, which is used in the transmission stage. The maximum value of the correlation vector represents the value of the transmitted symbol.

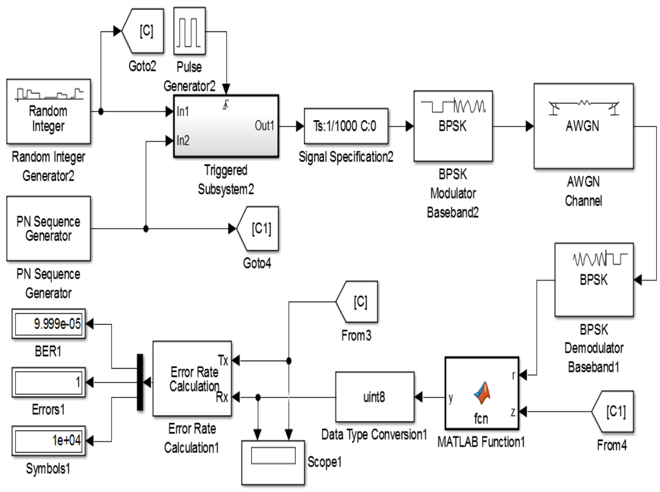

Fig.5 : The basic block diagram of Simulink implementation of the proposed DSSS

4.2 Performance evaluation

The performance of the proposed DSSS system is estimated under adaptive white Gaussian noise AWGN radio impairment for baseband phase shift keying modulation (BPSK). The input information signal is produced using random integer generator while PN is generated using PN sequence generator. The input information signal is plotted against the yielded one and the resultant, as shown in Fig. 6, shows that both input and output information signals are identical. The power spectral density of the transmitted signal is shown in Fig.7.

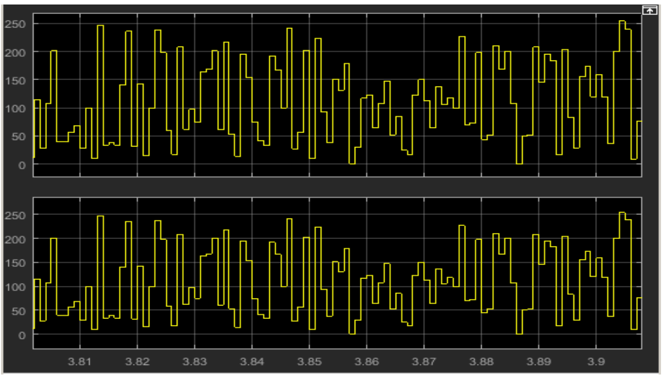

Fig.6 : Comparison between input and output signals for the proposed approach.

Evaluating the performance of the proposed configuration involves quantifying some performance metrics. The most basic metric is the Signal-to-Noise-Ratio (SNR), which is simply the relative measure or the ratio of the received signal power, P_s, to the in-band noise power, P_n:

$$SNR = \frac{P_s\,(Signal\ power)}{P_n(Noise\ power)} \tag{5}$$

The Bit Error Ratio (BER) of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system. BER of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period.

BER= (Bits in Error) / (Total bits received) (6)

Both SNR and BER parameters are supposed to be the most important factors that determine the efficiency of performance of the system. Here spreading code, modulation techniques are considered and the most commonly used channel for which BER is minimum, the Additive White Gaussian Noise (AWGN) channel is used where the noise gets spread over the whole spectrum of frequencies. For any given modulation, the BER is normally expressed in terms of signal to noise ratio (SNR). BER has been measured by comparing the transmitted information signal with the received one and computing the error count over the total number of bits. The BER vs. SNR relation of both DSSS over AWGN channel is shown in Fig.8.

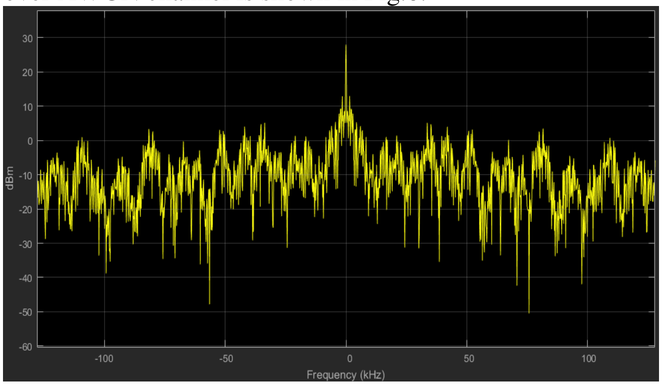

Fig.7. The power spectral density of the transmitted signal

The curve typifies two situations, one with a high signal to noise ratio (> -20dB) and hence a low bits error ratio, and one with a low signal to noise ratio (< -20dB) and hence a high bits error ratio. It is clear, from Fig.8, that both input and revealed signals are identical as long as the SNR > -21 dB.

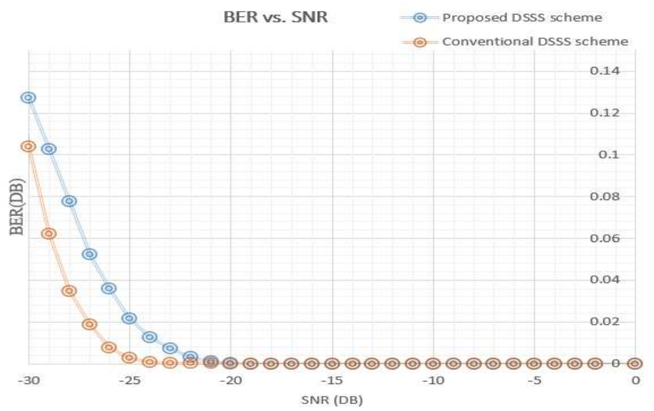

Fig.8. The BER vs. SNR relation of both DSSS over AWGN channel

5. Conclusion

A new approach for direct sequence spread spectrum is introduced in this paper to generate the wideband signal by circularly shifting the spreading code by *n* places where *n* represents the value of an acquired byte of the information signal. The original information signal is extracted at the receiver by correlating the consequent 256-bit frames of the received signal (which is actually the original spread sequence circularly shifted by *n* places) with a locally generated replica of the spreading code (256-bit). The position of maximum value of the yielded cross-correlation vector (correlation peak) corresponds to the value of one byte of the information signal. Unlike the conventional DSSS, the spreading and de-spreading codes, in this approach, are not required to be in synchronism. The signal recovering process is successfully done yielding the same performance as the conventional DSSS. To quantify the integrity of data transmitted through the proposed system, the Bit Error Ratio (BER) metric is measured versus the Signal-to-Noise-Ratio (SNR) metric, resulting value of BER= 0 for SNR < -21 dB. This means the proposed approach is reliable and robust against white noise. The design implementation of the new approach is much simpler compared to the original one and can be implemented with simple hardware components. Application results show this proposed scheme can provide significant improvement in implementation and performance as well.

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