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DESIGN OF DIRECT SEQUENCE SPREAD SPECTRUM SYSTEM USING AMPLITUDE SHIFT KEYING MODULATION

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Because DS spread spectrum has roughly compensations over other categories of spread spectrum modulation techniques such as best noise, anti-jam performance, it is the most difficult to intercept and fights well against multi-path effect. AMATLAB- Simulink instrument is castoff for manipulative DS-SS structure to attain system restriction and to examination the effect of signals on system. The system was considered with data proportion (100 Kb/s) and pseudo-Noise (PN) through cryptograph rate (5MHZ), 126 bits highest direct code.

The system was designed using amplitude shift keying (ASK) straight classification banquet band system. Then presentation estimation was established via simulating the proposal to contract the received information which compare through the transmitted information.

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Iraq

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Abstract

Spread band procedures invented in response to the requirements of military telecommunications. They are founded on signaling arrangements which significantly enlarge the transmitted spectrum qualified to the data rate. In current years, several members of the public customs of spread band were originate. There is increasing concentration in these techniques for custom in mobile, networks, radio and mutually telecommunication and placement claims in satellites. This book primarily essences on civilian submission of direct categorization spread spectrum.

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The system was designed using amplitude shift keying (ASK) straight classification banquet band system. Then presentation estimation was established via simulating the proposal to contract the received information which compare through the transmitted information.

Abbreviation

AGC	Automatic Gain control
AJ	Anti-jamming
ASK	Amplitude Shift Keying
AM	Amplitude Modulation
AWGN	Additive White Gaussian Noise
BER	Bite Error Rate
BPSK	Binary Phase Shift Keying
BW	Band width
CDMA	Code Division Multiple Access
DLL	Delay Locked Loop
DM	Delta Modulation
DS	Direct Sequence
DS-CDM	Direct Sequence Code Division Multiplexing
DS/FH	Combined Direct Sequence ,Frequency Hopping Modulation
DSP	Digital Signal Processing
DS/SS	Direct Sequence Spread Spectrum
EX-ORed	Exclusive OR (modulo-2 adder)
FCC	Federal Communication Commission
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiplexing Access
FH	Frequency Hopping
FH/SS	Frequency Hopping Spread Spectrum
FPGA	Field Programmable Gate Array
FSK	Frequency Shift Keying
Gp	Processing Gain
I-Q	Costas Loop(I-Q)

IS-95	Digital Cellular Standard
JPL	Jet Propulsion Laboratory
LAN	Local Area Network
LPF	Low Pass Filter
LPI	Low Probability of Intercept
Mj	Jamming Margin
NCO	Numerical Control Oscillator
PCM	Pulse Code Modulation
PCS	Personal Communication Services
PLL	Phase Locked Loop
PN	Pseudo Noise
PSK	Phase Shift Keying
QPSK	Quadratue Phase Shift Keying
RAM	Random Access Memory
RASE	Rapid Acquisition by Sequential Estimation
RARASE	Recursion-Aided Rapid Acquisition by Sequential Estimation
RF	Radio Frequency
Rx	Receiver
SLCU	Serial/Lock Control Unit
SNR	Signal to Noise Ratio
SS	Spread Spectrum
SSRG	Simple Shift Register Generator
SSS	Spread Spectrum System
SSS-AM	Single Side Band Amplitude Modulation SSSB-AM Single Side Band Amplitude Modulation
SWI	Async Worthiness Indicator
TH	Time Hopping
Tx	Transmitter
TDMA	Time Division Multiple Access

TDM	Time Division Multiplexing
VCO	Voltage Control Unit
WALNs	Wireless Local Area Networks
WGN	White Gaussian Noise
W-FM	Wide Band Frequency Modulation

Symbols

BRF	Radio frequency bandwidth (in HZ) .
B	Deviation Ratio .
C	Channel Capacity in Bits per Second .
c	Speed of light in the Propagation Medium .
C_e	Early Output of the Autocorrelation Function of DLL .
C_i	Late Output of the Autocorrelation Function of DLL . c_l(t.
d_r	Received Data .
d_t	Transmitted Data .
$F_{Doppler\ carrier}$	Doppler Frequency Shift .
f_c	Carrier Frequency .
Gp	Processing Gain .
g(t)	Control Waveform in Tau-Dither Tracking Loop .
g' (t)	Control Waveform in Tau-Dither Tracking Loop .
g(x)	Polynomial of PN Sequence .
i	Interference .
J-K	(J-K) Flip — Flop .
K	Number of Message Bits .
L	Number of Stages in the Shift Register .
Lsys	System Implementation Losses in dBs .
m(t)	Data sequence .
Mj	Jamming Margin .

N	Noise Power in dB .
Nc	Sequence Length .
P(t)	PN spreading Sequence .
pn_t	Transmitted PN code .
pn_r	Locally Generated PN Code .
$R_a(i)$	Auto — Correlation Function .
$R_c(i)$	Cross — Correlation Function .
rx_b	Received Signal without Carrier .
R,	Wide Band Interference .
$R;_{n\ fo}$	Information Rate .
R_S	Narrow Band interference .
S	Signal Power in dB .
$S_{SS}(t)$	Direct Sequence Binary Phase Shift Keying Signal
T_f	Frame Duration .
T_S	Data Symbol Duration .
Tc	Chip Duration (One Time Chip) .
V_t.	Relative Velocity .
W	Bandwidth in Hertz .
'r	Shift Position of the Sequence .
w_o	Carrier Angular Frequency .
0	Carrier Phase Angle .

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Aim of the Work:

The purpose of this book is to familiarize the researchers to the idea of spread spectrum in wide-ranging relationships and then precede with the details of designing a direct sequence SS system by using MATLAB Simulink simulation.

First: The transmitter will be premeditated with a data rate 100 Kbps modulo-2 adder with pseudo noise PN (126bits) highest direct code through cryptograph rate 5MHZ, and then controlled as a base band Amplitude Shift Keying modulator. The receiver drive to be considered by exploitation [correlator, ASK modulator]. The synchronization is down by setting perfect. This system will be implemented by using MATLAB (7). The performance of the system design can be checked by seeing waveform of the transmitted data and compared with the received data.

Chapter one

Introduction

1.1 General Considerations.

The digital BPF is used in spread spectrum systems as ultra-wideband transceiver for low transmit power, low immunity to noise and interference, high data rate . Also it is used in spread spectrum systems narrow band wireless transceiver for high selectivity, high immunity to noise and interference low data rate [1]. It is also used as basic element of a matched filter in tracking system for synchronization. Digital BPF is also used as adaptive or variable filter to cancel the noise or to make a parallel digital filter banks with adjustable cut off frequency [2]. In general the digital BPF is used in spread spectrum system in three areas. Firstly in transmitter to reject the one side band of FSK modulator after spread the data [3]. Secondly in receiver, it is used to reject unwanted signals before despreading. Thirdly it is used in unit of synchronisation as one part of matched filter, to achieve the tracking [4]. In this work design and simulate bank contiguous and noncontiguous parallel digital BPF banks for FFH/SS system receiver to achieve synchronization is presented.

1.2 Spread Spectrum Concepts.

Spread spectrum communications systems are often used when there is a need for message security and confidentiality, or when it is a requirement that the message be received error free [5]. A spread spectrum system is able to offer a very high degree of message security in a number of ways, depending on the system implementation. Such a system may spread the data over a very wide bandwidth, making it almost impossible for a narrow band receiver to decipher any useful information. Along a similar vein, the same system may be able to offer a very high degree of interference rejection, both from intentional and unintentional sources [6].

A spread spectrum communications system is usually characterised as one in which the transmission bandwidth is much greater than that necessary to transmit the required information. In addition, demodulation must be accomplished by correlating the received signal with a replica of the signal used to spread the information [7]. Spread spectrum modulation system was initially designed to permit digital data transmission under the difficult condition of very low signal-to-noise ratio (SNR) due to the low signal level and the presence of intentional or unintentional co-channel interference [8]. To be classified as spread spectrum, the modulation signal bandwidth must be at least 10 to 100 times the information rate, and must be independent of information bit rate [9]. Spread spectrum systems have many features, such as: selective addressing capability, CDMA, low power spectral density, message screening from eavesdroppers, navigation and high resolution ranging, interference rejection and improved reliability in frequency selective fading and multipath environment [10]. There are several basic spread spectrum techniques available for use in digital data communication, these are:

a-DS: in which the energy of the required baseband transmission spreads over the required bandwidth by multiplication with a pseudo-random digital code sequence at an appropriate rate.

b-FH: in which the instantaneous frequency of the baseband transmission is changed in pseudo-random manner over the required bandwidth [11,12,13].

c-Pulsed FM or chirp: in which the instantaneous frequency of the transmission is swept across the required bandwidth in an appropriate manner. d- TH: in which high-power bursts of wideband transmission occur at pseudo- random intervals of time.

e- Hybrid techniques: in which two of abovementioned techniques are combined (e.g. DS/FH, DS/TH,…etc.).

1.3 Spread Spectrum Technique.

Spread spectrum uses wide band, noise-like signals. Because spread spectrum signals are noise-like; they are hard to be detected. Spread spectrum signals are also hard to be intercepted or demodulated. Further, spread spectrum signals are harder to jam than narrow band signals.

These LPI and AJ features are why the military has used spread spectrum for so many years. Spread signals are intentionally made to be much wider band than the information they are carrying to make them more noise-like [14]. These special "spreading" codes are called "pseudo random" or "pseudo noise" codes. Spread spectrum transmitters use similar transmit power levels to narrow band transmitters. Because spread spectrum signals are so wide they transmit at a much lower spectral power density, measured in watts per hertz, than narrow band transmitters. This lower transmitted power density characteristic gives spread signals a big plus. Spread and narrow band signals can occupy the same band, with little or no interference. This capability is the main reason for all the interest in spread spectrum today [15].

1.4 Literature Survey.

Most of the previous works dealt with the design or analysis of a particular part of the frequency hopping system like the synthesizer, synchronization, modulation, demodulation and interference the previous works related to the present work are:

Scholtz, [16] introduced the Wozencraft Iterated Coding System (WICS) which is one of the earliest FH communication systems. This teletype FH system was developed in mid-1950's. It employs 155 different tones in a 10 kHz band to communicate at 50 words/minute.

Mundy and Pinches, [17], designed and implemented the Jaguar-V frequency hopping radio system which was developed by Racal Electronics Ltd for the British Army in the early 1980's. The hop rate was 50-500 hops/sec and the frequency synthesizer is based on a conventional single loop PLL with use of a dual modulus prescalar.

AL-Muraab [18] implemented a frequency hopping transmitter and receiver connected back-to-back. The modulation was FSK, the PN sequence length was 15(24-1), the frequency synthesizer was a DPLL with settling time of 250 msec, and the transmitted frequencies were in the range of 145 kHz- 211 kHz, with low data rate.

Meng [19] designed and analyzed of a coherent FH/SSS operating in the presence of both jamming and a nonideal channel response.

Glisic [20] achieved a new tracking approach for SFH/SS signal based on utilization of additional synch data carrying information for FH signal tracking purpose, which is added to the digital data stream.

Glisic [21] introduced a new algorithm for discrete tracking of SFH/SS signals. Each group of hopping is completely used for transmission of synchronization data. The motivation for introducing this algorithm is that it allows a large degree of flexibility with respect to trade of system performance, complexity and the redundancy introduced for tracking purposes.

Miller and lee [22] used parallel matched filter with adaptive threshold to reduce the acquisition time.

Borth [23], proposed an SFH personal communication system (PCS).In that system, the carrier hops at a rate of 500 hops/ sec. The hopping frequency synthesizer is based on a PLL and achieved a settling time of 0.6 ms.

Chen [24] analyzed the detectability of the frame synchronisation codes with such frame scheme under additive white Gaussian noise channel, applying decorrelation method to perform once observed detection, major decision detection and accumulation posterior detection. The analyses showed accumulation posterior detection method can give better performance under the strict restrictions.

Samuel [25], analyzed and designed a FH/SS transceiver for wireless personal communications. This design proposes SFH-CDMA transceiver with hop rate of 20 k hop/sec and data rate of 80 k bit/sec. The hopping frequency synthesizer is based on a PLL and achieved a settling time of 600 μ sec.

Subhi [26], implemented a wireless FH system by using a programmable transceiver and a microcontroller to test the proposed synchronization method. The system was intended at a low hopping rate.

Hammed [27], designed and implemented a frequency hopping communication system for both speech and data signal with hopping rate 9.6 k hop/sec and data rate 9.6 k bit/sec.

Chail [28], designed and implemented a branch hopping wavelet packet system instead of implementing FH/SS, in the first part of this work the synchronization had been assumed perfect and the system working in low frequency band.

AL-FHAAM [29], designed fast and multi carrier frequency hopping signals over Frequency Selective Rayleigh Fading channel (FSRF). This work proposed only theory without any numerical data for input or output results and without synchronizations between transmitter and receiver.

The above works suffer from one or more of the following drawbacks which are: -

1. Some of the above works are not study the jamming effect on those presented systems.
2. All the above works deal with slow settling time such as 250 m sec, 600 µ sec.
3. Some of above works assume there are perfect synchronization between transmitter and receiver.
4. All the above works do not mention anything about contiguous and non- contiguous filters techniques.
5. All the above works do not show the shapes of the signals at different stages of the work.
6. All the above works deal with low data rate such as 10 k bit/sec, 20 k bit/sec.
7. Most of the above works do not work in real time operation.
8. All the above works are not given clear idea about modulation or demodulation, such coherent or noncoherent, related with that works.

1.5 Aims of The Work.

The aims of the present work are to:

1. design and simulate spread spectrum in wide-ranging relationships and then precede with the details of designing a direct sequence SS system using MATLAB-Simulink.

2. design and simulate a wireless transceiver for ASK and BFSK direct sequence SS system using MATLAB-simulink with following properties:

   a. the system spreads transmitted data in high frequency (HF) band with hopping rate 160 k hop/sec and data rate 160 k bit/sec.

b. design and simulate ASK demodulator to achieve the detection of data for ASK direct sequence system.

c. design and simulate BFSK modulator to modulate the data for BFSK direct sequence system.

d. design and simulate noncoherent demodulator to achieve the diction of data for FSK direct sequence system.

3. design and simulate two type of jamming model MTJ and HJ.

4. investigate the performance of the proposed systems in the presence of two model of jammers (MTJ and HJ) and noise.

5. investigate the performance of direct sequence by seeing the shape of the signals at different sequent stages of the designed systems.

1.6 Book Layout.

This Book consists of six chapters:

•Chapter one: includes general consideration, spread spectrum concept, how spread spectrum works, channel capacity of spread spectrum, literature survey, aim of the work, and thesis outline.

•Chapter two: presents a review for the direct sequence system and the related theory.

•Chapter three: covers the proposed design Direct Sequence Spread Spectrum (DS/SS) System.

•Chapter four: is concerned with Sources of Synchronization Uncertainty.

•Chapter five: presents the proposed design and simulation of Direct Sequence Spread Spectrum.

•Chapter six: gives the conclusions, recommendations and suggestions for future work.

Chapter Two
Spread Spectrum Concept and Types

2.1 Introduction

Spread band communication classifications are frequently used when there is a necessity for message safety and privacy, or where there is a obligation that the memorandum be received mistake free. A spread spectrum scheme is intelligent to over a actual high grade of message safekeeping in a number of customs, contingent on the system execution. Such a classification might spread the information over a identical extensive bandwidth, production it almost unbearable for a slight band receiver to decode any useful data. Lengthways a similar mood, the system may be talented to over a actual high degree of nosiness denunciation, mutually from premeditated and unpremeditated foundations.

A spread band telecommunications system is typically characterized as single in which the broadcast bandwidth is considerably better than that obligatory to transmit the mandatory information. Furthermore, demodulation requirement be proficient by comparing the received signal with a duplication of the signal secondhand to spread the data. There are numerous communication systems which gratify the first principles, for instance, broadband frequency modulation (BFM), nevertheless, they do not be suitable as spread band systems.

There are a number of compensations in distribution the transmitted information over a inclusive variety of frequencies, nevertheless there are correspondingly some drawbacks, most drawback focus around the enlarged hardware complication, and the software processes needed for well-organized operation. In this book, the generated direct sequence spread spectrum with high data rate can afford meaningful sources in telecommunication systems such as 4G LTE and 5G Massive MIMO [30 ,31]. Additionally, it can also help determine the properties and factors affecting most types of antennas [32].

2.2 How does spread spectrum works

Spread spectrum customs extensive band, noise comparable signals. Due to spread spectrum indications are noise identical, they are tough to distinguish. Spread spectrum signals are correspondingly tough to capture or demodulate. Additional, spread band signals are tougher to jam delay through than narrowband signals. This little possibility of Capture (LPC) and anti-jamming topographies are wherefore the military has used spread spectrum for several years. Spread signals are deliberately made considerable broader band than the data they are resonant to make them supplementary noise comparable.

Spread band signals usage debauched cods that run various times the data bandwidth or data proportion. These distinct "spreading" encryptions are entitled "Pseudo Random" or "Pseudo Noise" cyphers. They are named "Pseudo" since they are not physical Gaussian noise.

Spread band transmitters use comparable transmits power stages to narrow group transmitters. Because Spread band signals are accordingly wide, they transmit at a considerably lower spectral power concentration, restrained in watts per hertz, than slender band transmitters. This minor transmitted power concentration representative gives spread signals a large plus spread and slender signals can occupy the equivalent band, with slight or no nosiness. This competence is the core reason for all the concentration in spread spectrum nowadays.

2.3 Additional facts on spread band

Over the former 50 centuries, a period of modulation performances frequently named "Spread spectrum" has been advanced. This collection of modulation performances is categorized by its extensive frequency ranges. The modulated productivity signals reside in a considerably better bandwidth than the signal's dishonorable band data bandwidth. To be suitable as a spread band signal, two standards should be encountered:

1- The transmitted indication bandwidth is considerably better than the material bandwidth.
2- Approximately function other than the statistics existence transmitted is laboring to control the subsequent transmitted bandwidth

Furthermost marketable part 15.247 spread band arrangements transmit an RF signal bandwidth as widespread as 20 to 254 periods the bandwidth of the data being sent. Some spread variety systems have working RF bandwidths 1000 periods their data bandwidth. Mutual spread spectrum classifications are of the "direct sequence" otherwise "frequency hopping" category, otherwise some amalgamation of these two kinds (termed by "hybrid").

There are correspondingly "Time Hopped" and "Chirp" structures in survival. Time hopped blowout spectrum schemes have found no profitable submission to time. Nevertheless, the entrance of inexpensive random-access memory (RAM) and debauched micro-controller chips variety time hopping a worthwhile substitute spread band technique for the forthcoming.

"Chirp" signals are frequently working in radar classifications and only seldom used in profitable spread spectrum structures. Direct sequence spread band arrangements are named because they service a from top to bottom-speed code categorization, laterally with the straightforward information being directed, to modulate their RF transporter. The high speed cryptograph sequence is used straight to modulate the transporter, thus unswervingly setting the communicated RF bandwidth Binary code arrangements as rapid as 11 bits or as extended as (2^{89}-1) have been laboring for this determination, at code charges from under a bit per second to a more than a few hundred megabits per second.

The consequence of modulating an RF transporter with such a cypher sequence is to yield a signal adjusted at the carrier frequency, straight sequence modulated spread band with a $(\sin x/x)^2$ frequency range. The foremost section of this band has a bandwidth double the clock amount of the modulating cryptograph, from insignificant to null the adjacent lobes have a insignificant-to-null bandwidth identical to the cryptograph's clock proportion. the maximum mutual category of direct sequence modulated spread band signal. Direct sequence bands differ slightly in spectral outline contingent upon the authentic carrier and information modulation used. The signal demonstrated is that for an amplitude shift keyed (ASK) indicator, which is the greatest mutual modulation signal category, secondhand in direct sequence classifications.

A band Analyzer Photo of a straight sequence (DS) banquet spectrum signal frequency hopping arrangements the extensive band frequency field desired is engendered in a dissimilar method in a frequency hopping structure. It does impartial what its name suggests, that is, its "hops" since frequency to incidence over a extensive band. The exact order in which frequencies are engaged is a occupation of encryption sequence and the proportion of hopping from one frequency to alternative is a function of the data rate. The transmitted band of a frequency hopping indication is fairly dissimilar from that of a straight sequence system. In place of $(x/x)^2$ formed enclose, the frequency hopper's production is smooth completed the band of frequencies secondhand. A production range of a frequency hopping system. The bandwidth of an occurrence hopping signal is basically (w) times the quantity of frequency holes available, where (w) is the band width of individually hop network.

2.4 Spread Spectrum Concept and Types

In recent years ,the spread spectrum technique has been applied in communication systems ,navigation and equipment testing. These techniques have been effective results that are not imaginable through typical signal arrangements. Spread spectrum systems (SSS) are means of transmission in which the signal occupies a band width, very much wider, than the minimum band with necessary to send the information, the band spread is accomplished by means of a code which is independent of the data and at rate much greater than the data bit rate. A speech signal, for instance, can be guided with fullness modulation (AM) in a band width individual double that of the data itself. Supplementary methods of modulation such as Frequency Modulation (FM) or solitary sideband amplitude modulation (SSB-AM) correspondingly license data to be communicated in a band width equivalent to the bandwidth of the data itself. A spread band classification, alternatively, repeatedly revenues a base band signal (a speech channel for example) of a bandwidth of solitary a limited kilohertz and allocates it completed a band that whitethorn be several megahertz varied. The most familiar example of spectrum spreading is seen in conventional FM in which deviation ratios (B) greater than one are used. Bandwidth required by an FM signals a function not only of the information bandwidth but of the amount of modulation. Additionally, a signal-to-noise ratio gain in FM is expressed as,

$$3\beta^2\left(\frac{S}{N}\right)inf \ldots\ldots\ldots\ldots\ldots (2.1)$$

β=maximum deviation=deviation ratio, base bandwidth.

(S/N) in signal to noise proportion in the base band or material bandwidth.

Broadband (FM) possibly will not be confidential as a spread band performance because the band width mandatory by band (FM) is a occupation of the data band width while spread spectrum systems use wide band coded signal.

The basis for spreading the spectrum of an information bearing signal is Shannon's well-known theory which suggests the following exchange between signal to –noise ratio (SNR) and band-width (BW).

$$C = B\ log_2 \left(1 + \frac{S}{N}\right) \dots\dots\dots\dots\dots\dots (2.2)$$

Somewhere: -

C:-Measurements in bits per second B:- Bandwidth in Hertz

N: Noise influence

S: Signal influence

This equivalence demonstrations the association amongst the capability of a channel to transmission error-free data, associated through the signal to noise proportion prevailing in the network, and the band width castoff to transmit the material rate and changing bases, we find: -

$$\frac{c}{w} = 1.44\ log_2 \left(1 + \frac{S}{N}\right) \dots\dots\dots\dots\dots (2.3)$$

And for S-N insignificant, say < 0.1 (by way of one wished it to be an anti-jamming arrangement)

$$\frac{C}{W} = 1.44\frac{S}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

Since $log_2\left(1+\frac{S}{N}\right) = \frac{S}{N} - \frac{1}{2}\left(\frac{S}{N}\right)^2 + \frac{1}{3}\left(\frac{S}{N}\right)^3 \frac{1}{4}\left(\frac{S}{N}\right)^4 \ldots\ldots\ldots\ldots (-1 < \frac{S}{N} < 1)$

Through the logarithmic development, as of this equation we discovery:

$$\frac{S}{N} = 1.44\,\frac{W}{C} \cong \frac{W}{C}$$

And

$$W = N\frac{C}{S} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

We understand that for at all given noise to signal proportion we container have small data error rate through cumulative the bandwidth used to transmission the data.

Spread spectrum signal are divided into many basic types, these basic spread spectrum systems are different by their modulation formats.

1. Direct sequence (DS).
2. Frequency Hopping (FH).
3. Hybrids.
4. Time Hopping (TH).
5. Pulse-FM or chirp.
6. Time Hopping and chirp.

2.4.1 Direct Sequence.

A direct sequence flat band classification attains its distribution ability by modifying a slight bandwidth information with a extensive bandwidth distribution signal.

2.4.2 Frequency Hopping.

A straight Frequency Hopping telecommunication classification varies decidedly arrangement a direct sequence structure. Where as in a DS arrangement, the carrier frequency remainders persistent, and the information is banquet over a inclusive band of frequencies, in a frequency hopped classification, the information is transmitted exploitation a unadventurous narrow band performance, but the frequency is transformed in discrete stages over a inclusive width.

A characteristic FH spectrum is shown in figure (2-1). communication that the bandwidths of separately individual carrier may or may not intersection depend on the system strategy.

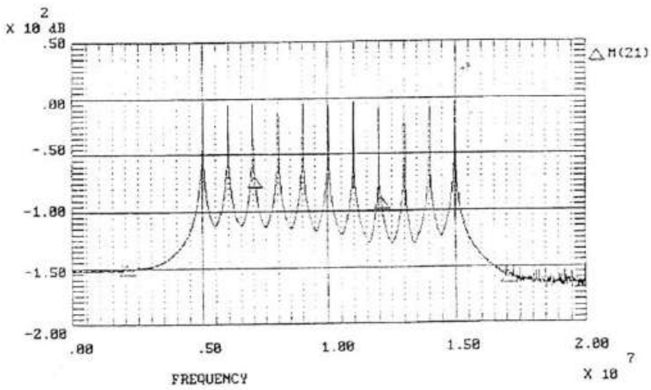


Fig. (2-1) A characteristic of Frequency hopping band

This performance is correspondingly actual protected in that a slight band receiver will be incapable to distinguish any valuable data, reception impartial a short rupture of material on unusual instance. Frequency hopping classification correspondingly consume ~6 capacity to discard both premeditated and un premeditated interference, while slightly more complicated that the direct sequence circumstance. Frequency hopping source is shown graphically in figure (2 -2) below.

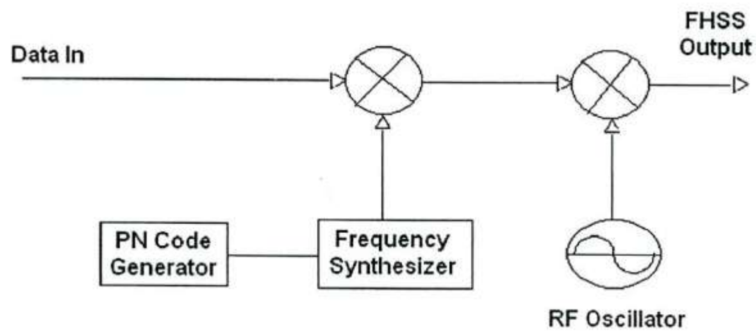


Fig. (2-2) Frequency hopping spread spectrum transmitter

The receiver uses the same technique as the transmitter, but in reverse, along a similar line to the DS/SS transmit/receive pair. Note that although a second mixer stage and RF oscillator are shown, their application depends on the desired carrier frequency .If the synthesizer is able to function at the required rate and generate the appropriate frequencies, them is no need for a subsequent mixing stage. The basic FH/SS system has a number of disadvantages, which can overcome quite elegantly [33]. Since a FH system can essentially be regarded as an instantaneous narrow band communications system, it suffer from the same problems with interference as any other conventional narrow-band modulation system, although the period of such degradation is considerably reduced. The classical example used to describe this aspect of FH/SS is a peak or spike of narrow –band noise somewhere in the desired spectrum. If the amplitude of this interference is sufficiently high, reception of a narrow – band signal at the same point in the spectrum is made difficult, if not impossible. This is the same for either a conventional narrow – band system, or a FH/SS system .In order to reduce the possibility of narrow –band interference degrading a FH/SS signal, a redundant method of transmission is used. Such a system generally transmits the same information at a number of different, discrete frequencies, over a short time period, with the receiver comparing the received signal at each frequency in order to compensate for any errors. That are two common methods of transmitting the redundant information. The first system, shown in figure (2-3a), transmits information at only one

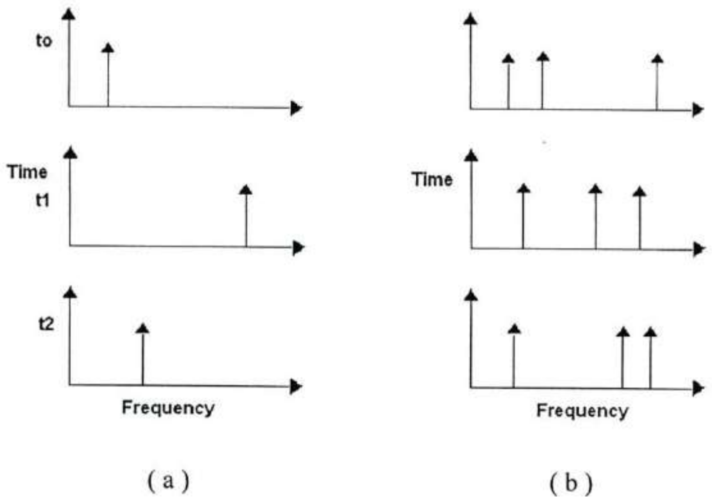


Fig.(2-3) Comparison between different methods of frequency hopping

point in the spectrum at any one time, but repeats the transmission at a number of different frequencies Although only one carrier frequency has been shown here, it is feasible to use more than one frequency, although with a corresponding ~~increase in c~~omplexity, and a reduction in the overall speed of operation. The second method shown in Figure (2-3b), transmits the same information at several different points in the spectrum simultaneously. Obviously, the second method requires more hardware and is slightly more complicated than the first system, but offers a higher degree of interference rejection. The method shown in Figure (2-3b) also offers a higher speed of operation, since there is no redundancy in time, time only in frequency.

2.4.3 Hybrid Spread Systems

A hybrid spread spectrum system generally consists of a combination of a direct sequence system, and a frequency hopping system. a system. Such a system, that is show in Figure(2-4).

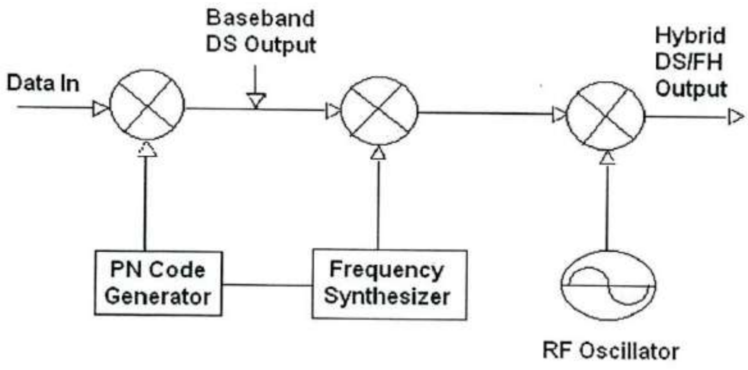


Fig (2-4) Hybrid DS/FH spread spectrum transmitter

Will usually possess a very high degree of information security, as well as a high ability to reject interference. The disadvantage of this type of system is the overall increase in complexity and operation. A hybrid system can be thought of as a direct sequence system in which the carrier frequency is changed periodically. The information to be transmitted is spread by mixing with a PN sequence, but the band of frequencies over which the data is spread is changed at a rapid rate.

It is very difficult for a narrow band listener to intercept and gather information from a direct sequence transmission, but when the entire spread bandwidth is hopping around the spectrum ,this task becomes almost impossible. Figure(2-5) shows the spectrum one can expect from a hybrid SS system .In this case the spectra are shown equally spaced ,although this need not be the case. individual direct sequence spectrum may be positioned anywhere in the frequency hoppers range ,and may even overlap with one another. [34,35,36]

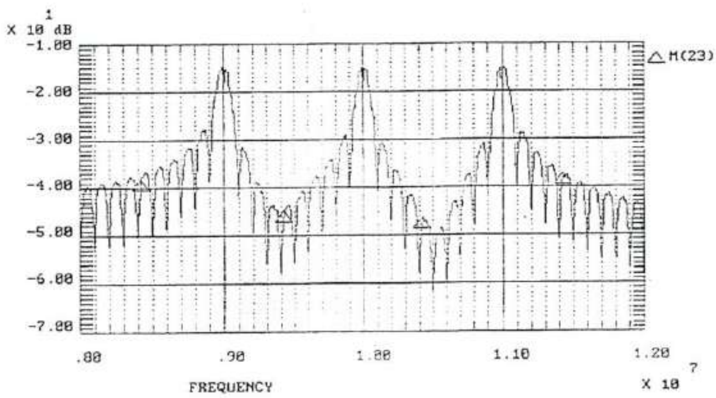


Fig.(2-5)Spectrum of hybrid DS/FH system

2.4.4 Time Hopping

Consider the time hopping waveform shown in Figure (2-6) Note that the time axis has been divided into intervals known as frames, with each frame divided into M time slot. During each frame only one time slot may be modulated by a message, with each particular time slot being chosen according to the output of PN generator. There are a total of M =2m time slots in each frame, and all of the message bits accumulated in the previous frame are sent in a burst during the selected slot [35,36,37].

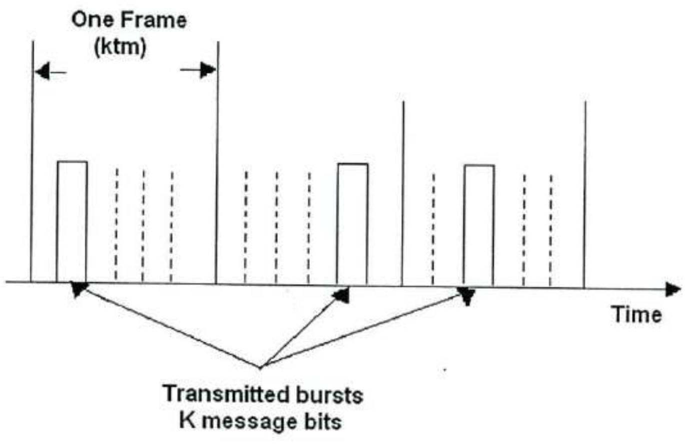


Fig. (2-8) A typical time hopping waveform

If we denote the frame duration by T_f, let k be the number of messages bits in one frame, and $T_f = k\ t_m$,then the width of each time slot is T_f /M , and the width of each bit in the time slot is $T_f / kM = t_m / M$. This indicates that the transmitted signal band width is 2M times the message bandwidth, and hence the processing gain of a time hopping system is simply twice the number of time slots in each frame when BPSK modulation is used, and half this when QPSK modulation is used. Interference between simultaneous users in a time hopping system can be minimized by coordinating the times at which each user is allowed to transmit. This also has a secondary implication, in that it avoids the possibility of the near-far problem occurring.

2.4.5 Chirp.

A spread spectrum system using chirp modulation varies the frequency of the carrier in a linear fashion to spread the bandwidth. Linear frequency modulation is a technique very common in radar systems, and is occasionally used for communication systems. Assume that T is the duration of a given waveform, and B is the bandwidth over which the frequency is varied. In this case, the processing gains is given simply by the product BT [35,36].

2.4.6 Time Hopping and Chirp.

Both times hopping and chirp modulation schemes have been used to implement spectrum systems. Their use in communications systems is not as common as direct sequence or frequency hopping, however they are mentioned here for completeness [36].

2.5 Spread Spectrum Systems Advantages.

Modem spread spectrum is a well developed technology. In the past, SS used to be strictly used by the military. As this technology became declassified and available to the public, many commercial applications have been found for spread spectrum. More recent, applications of SS have attracted attention because of its properties which can be used for code division multiple access (CDMA) operation, the possibility of spectral overlay, and the availability of the unlicensed commercial bands which where allocated mainly to SS systems. After the May 1985 Federal Communication Commission FCC release of the ISM bands for SS use ,many commercial products have appeared ranging from low-speed fire safety devices to high speed wireless local area networks (WLANs).Today, both voice and data communication industries are developed new products using spread spectrum technology [37,38].

There are many reasons for spreading the information signal spectrum and then collapsing (dispreading) it through coherent correlation with a stored reference signal contained in the receiver, some of these are:

1- Interference rejection: Undesired signal (jamming interference) are not synchronized with the receiver code reference; therefore they will spread to the bandwidth equal to its own bandwidth plus bandwidth of code reference and most of the spread noise power will be rejected by the correlate [39].
2- Low probability of intercept : Because of the wide-band signal spectra generated by code modulation ,the power transmitted is low in narrow region ,which makes it very difficult to intercept [35].
3- Selective addressing :Spread spectrum system can be allow many users of a wide bandwidth transmit simultaneous radio message in such a way that the message are received only by the intended receivers .This is done by employing different code sequence for each user with minimum cross-correlation between them [39].

4- Code Division Multiplexing (CDM): The application known as code division multiplexing is similar to selective addressing , but in this case the objective is for a signal transmitted to send several messages by means of one transmission without using frequency division multiplexing (FDM) or time division multiplexing (TDM) In FDM all users transmit simultaneously ,but disjoint frequency bands .In (TDM) all users occupy the same RF bandwidth, but transmit sequentially in time. When user are allowed to transmit simultaneously in time and occupy the same RF bandwidth as well, some other means of separating the signals at the receiver must be available. In DS-CDM each user is given its own code which is orthogonal (i.e. has low cross-correlation) with the code of the other users [39,40].

5- High resolution ranging: Spread spectrum signals of the direct sequence type excel in their capability to provide high resolution range measurements. This property is due to the high speed code used for modulation. Since synchronizing a spread spectrum receiver depends on the receiver matching its code reference to the signal it receive to within one code bit (chip) (typically ,a spread spectrum receiver's code will be match to the incoming signal's code within one tenth or one hundredth of a chip), the inherent resolution capability of the signal is better than the range which corresponds to a bit period [35].

6- Message privacy : Message privacy is inherent in spread spectrum signals because of their coded transmission. The degree of privacy or security is a function of the codes used. Only the authorized receiver can detect and demodulate the data because it has the key (code) for dispreading the spread spectrum signal [41,42].

7- Spread spectrum system systems have inherent frequency diversity. If the signal spectrum is sufficiently wide to span several fading troughs, some frequency component of the signal will cancel and others reinforce. Thus the signal cannot be entirely destroyed [37].

8- Spread spectrum signal is protected against multi-path problem : SSS are less subjected to multi-path signal variation than conventional systems. In direct sequence receiver , if the reflected is delayed (compared with direct rate the smaller its multi-path problem and as the code chip rate is increased the path length for which the reflected signal interferes is further reduced [35].

Similarly frequency hopping system overcomes the problem to the extent that a sufficiently high hopping rate is used to ensure that the multi-path interference arrives at the receiver after the dehopper has already hopped to a new frequency [39]. While SSS have many advantages, there are many disadvantage. Chief among these are:-

1- More difficult frequency allocation.
2- Greater system complexity.
3- Code synchronization problem.

Chapter Three

Direct Sequence Spread Spectrum (DS/SS) System

3.1 Introduction

A DS/SS system is one of the main spread spectrum systems and is the most common version use today, due to simplicity and ease of implementation, in which a modulation of a carrier is performed by a code sequence. in actual practice the baseband information is digitized and Module-2 added to the code sequence and then modulated by using amplitude modulation [43].

A spread spectrum system is largely categorized by its coding scheme. The type of code employed, its length, and its chip-rate all define the overall system parameters In order to alter the system's spreading capability it is necessary to alter the coding arrangement.

3.2 Direct Sequence Modulation.

In direct sequence system the encoding signal is used to modulate a carrier usually by amplitude-shift keying (ASK) at the code rate [35].

3.2.1 Generation of ASK

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave, in other words Amplitude shift keying (ASK) is a modulation scheme in which an amplitude of a carrier wave varies according to digital signal information. For example, in the modulation scheme, in order to modulate a binary digital signal, a carrier wave having a predetermined level of the amplitude is transmitted when the digital signal has a value of 1, and transmission of the carrier wave is suspended when the digital signal has a value of O. The ASK modulation scheme in which the carrier wave is present (ON) or absent (OFF) is called an on-off keying (00K) modulation scheme.

Amplitude shift keying -ASK- in the context of digital communications is a modulation process, which imparts to a sinusoid two or more discrete amplitude levels. These are related to the number of levels adopted by the digital message.

For a binary message sequence there are two levels, one of which is typically zero. Thus the modulated waveform consists of bursts of a sinusoid.

Figure (3-1) illustrates a binary ASK signal (lower), together with the binary sequence which initiated it (upper). Neither signal has been bandlimited.

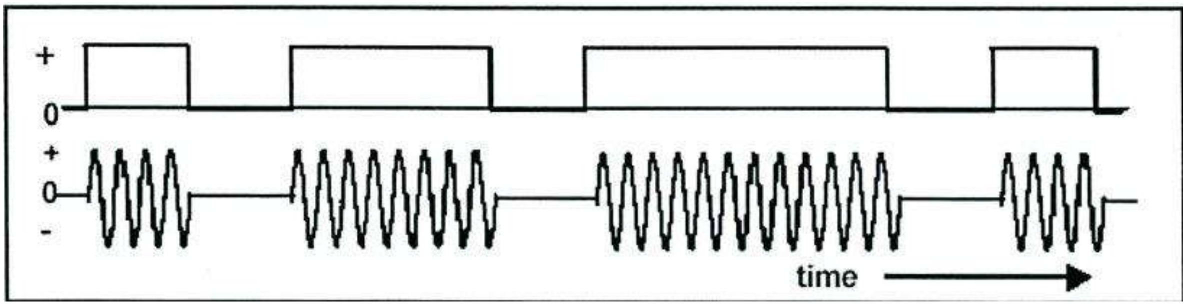


Fig. (3-1): an ASK signal (below) and the message (above)

There are sharp discontinuities shown at the transition points. These result in the signal having an unnecessarily wide bandwidth. Bandlimiting is generally introduced before transmission, in which case these discontinuities would be rounded off'. The bandlimiting may be applied to the digital message, or the modulated signal itself.

The data rate is often made a sub-multiple of the carrier frequency. This has been done in the waveform of Figure(2-1).

One of the disadvantages of ASK, compared with FSK and PSK, for example, is that it has not got a constant envelope. This makes its processing (eg, power amplification) more difficult, since linearity becomes an important factor. However, it does make for ease of demodulation with an envelope detector.

3.2.2 Introduction to Bandwidth Modification

As already indicated, the sharp discontinuities in the ASK waveform of Figure 1 imply a wide bandwidth. A significant reduction can be accepted before errors at the receiver increase unacceptably. This can be brought about by band limiting (pulse shaping) the message before modulation, or band limiting the ASK signal itself after generation.

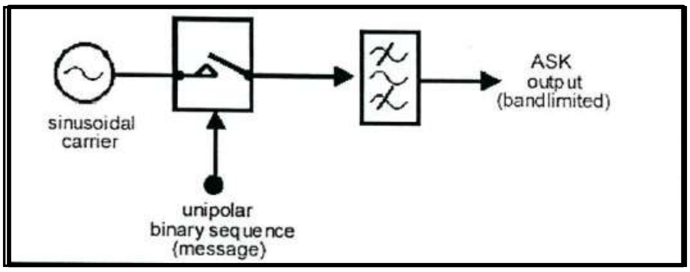


Fig (3-2): ASK generation method

Figure (3-3) shows the signals present in a model of Figure (3-2), where the message has been bandlimited. The shape, after band limiting, depends naturally enough upon the amplitude and phase characteristics of the band limiting filter.

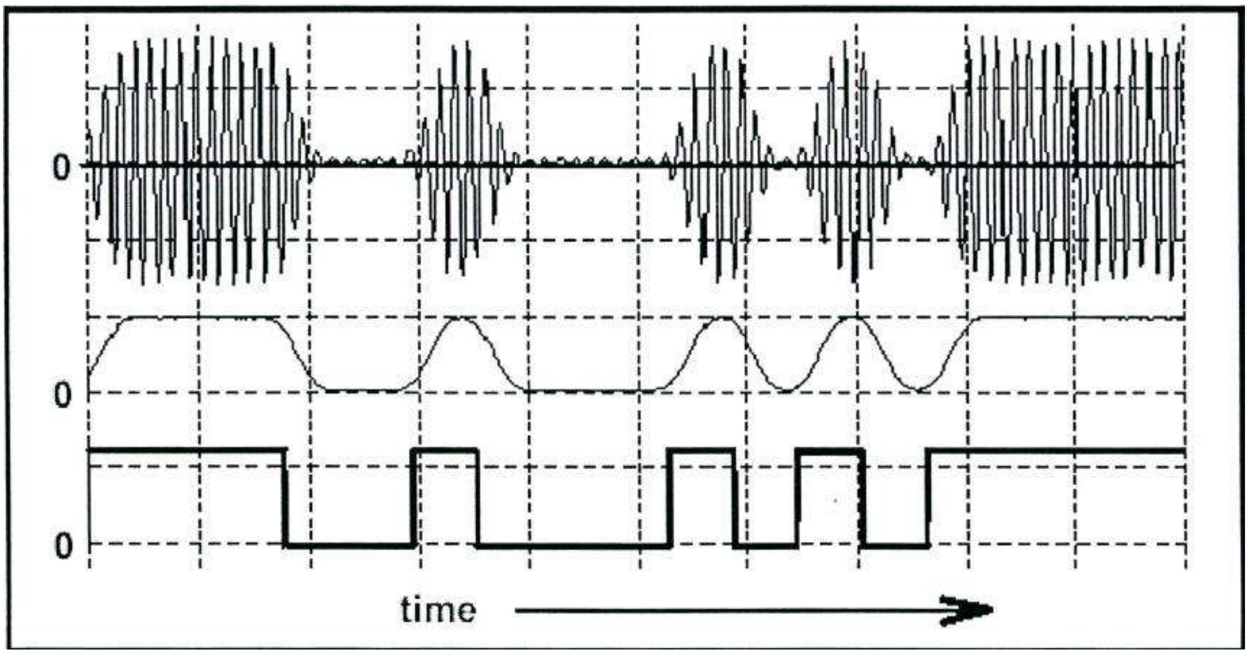


Fig. (3-3): original TTL message (lower), bandlimited message (center), and ASK (above)

The transmission of digital signals is increasing at a rapid rate. Low-frequency analogue signals are often converted to digital format (PAM) before transmission.

The source signals are generally referred to as baseband signals. Of course, we can send analogue and digital signals directly over a medium. From electro-magnetic theory, for efficient radiation of electrical energy from an antenna it must be at least in the order of magnitude of a wavelength in size; c = f1, where c is the velocity of light, f is the signal frequency and 1 is the wavelength. For a 1 kHz audio signal, the wavelength is 300 km. An antenna of this size is not practical for efficient transmission. The low-frequency signal is often frequency-translated to a higher frequency range for efficient transmission. The process is called modulation. The use of a higher frequency range reduces antenna size. In the modulation process, the baseband signals constitute the modulating signal and the high-frequency carrier signal is a sinusoidal waveform. There are three basic ways of modulating a sine wave carrier

For binary digital modulation, they are called binary amplitude-shift keying (BASK), binary frequency-shift keying (BFSK) and binary phase shift keying (BPSK). Modulation also leads to the possibility of frequency multiplexing. In a frequency-multiplexed system, individual signals are transmitted over adjacent, non over lapping frequency bands. They are therefore transmitted in parallel and simultaneously in time. If we operate at higher carrier frequencies, more bandwidth is available for frequency-multiplexing more signals.

3.2.3 Binary Amplitude-Shift Keying (BASK)

A binary amplitude-shift keying (BASK) signal can be defined by

$s(t) = A\, m(t) \cos 2pf_c t,\ 0 < t < T$ ……………..(3.1)

where A is a constant, $m(t) = 1$ or 0, f_c is the carrier frequency, and T is the bit duration. It has a power $P = A^2/2$,, so that $A = \sqrt{2P}$. Thus the equation (2.1) can be written as:

$s(t) = \sqrt{2P} \cos 2pf_c t,\ 0 < t < T$

$= ET^2 \cos 2pf_c t,\ 0 < t < T$ ……………………………..(3.2)

Amplitude-Shift Keying (ASK) Modulation

where E = P T is the energy contained in a bit duration. If we take

$f_1(t) {}^{=}2T\cos 2pf_c t$

The amplitude of a carrier is switched or keyed by the binary signal m(t).

This is sometimes called on-off keying (OOK).The Fourier transform of the BASK signal s(t) is

$S(f) = A^2 M(f - f_c) + A^2 M(f + f_c)$ …………………….(3.3)

The effect of multiplication by the carrier signal Acos $2pf_ct$ is simply to shift the spectrum of the modulating signal m(t) to f_c. Since we define the bandwidth as the range occupied by the baseband signal m(t) from 0 Hz to the first zero-crossing point, we have B Hz of bandwidth for the baseband signal and 2B Hz for the BASK signal.

3.3 Direct Sequence Coding.

This section introduces the concepts behind pseudo-random noise (PN) generation, and discusses the requirements of such a sequence generator in terms of direct sequence spread spectrum communications system. Only codes useful for communication systems will be discussed here, although PN sequences are commonly used in variety of situations such as ranging and error checking. The codes used in spread spectrum systems are inherently much longer than those found in other systems as they are intended for bandwidth spreading rather than information transfer [44,45,46,47].

A spread spectrum system is largely categorized by its coding scheme. The type of code employed, its length, and its chip-rate all define the overall system parameters. In order to alter the system's spreading capability it is necessary to alter the coding arrangement. Maximal length sequences will be discussed, along with a method which allows maximal codes to be combined to create Gold codes.

Auto and cross correlation will be introduced, and mention will also be made of other, not so common, spreading codes such as Kasami sequences.

A pseudo-Noise (PN) code sequence acts as a noise like (but deterministic) carrier used for bandwidth spreading of the signal energy. The selection of a good code is important, because type and length of the code sets bounds on the system capability. The PN code sequence is a Pseudo-Noise or Pseudo-Random sequence of 1's and 0's. but not a real random sequence (because periodic) random signals cannot be predicted .The autocorrelation of a PN code has properties similar to those of white noise but it have :-

1- Not random, but it looks randomly for the user who doesn't know the code.
2- Deterministic, periodical signal that is known to both the transmitter and the receiver. The longer the period of the PN spreading code, the closer will the transmitted signal be a truly random binary wave, and the harder it is to detect.
3- statistical properties of sampled white-noise.
4- Short code: The same PN sequence for each data symbol ($N_c.T_c=T_S$).
5- Long code: The PN sequence period is much longer than the data symbol, so that a different chip pattern is associated with each symbol (Nc.Tc>>TS) [44,45,46,47].

3.3.1 Properties of PN Sequences.

3.3.1.1 Balance Property.

In each period of the sequence the number of binary ones differs from the number of binary zeros by at most one digit (for No odd).

$Pn = +1 +1 +1 -1 +1 -1 -1 \rightarrow \Sigma = +1$

When modulation a carrier with a PN coding sequence, one —zero balance (DC component) can limit the degree of carrier suppression obtainable, because carrier suppression is dependent on the symmetry of modulating signal [35,48,49].

_3.3.1.2 Run-Length Distribution.

A run is a sequence of a single type of binary digits. Among the runs of once and zeros in each period it is desirable that about one-half the runs of each type are of length 1, about one-fourth are of length 2, one-eighth are of length 3, and so on.

3.3.1.3 Autocorrelation.

The origin of the name pseudo-noise is that the digital signal has an autocorrelation function which is very similar to that of a white noise signal: impulse like. The autocorrelation function for the periodic sequence PN is defined as the number of agreements less the number of the disagreement in a term-by-term comparison of one full period of the sequence with a cyclic shift (position i) of the sequence itself

$$R_a(\tau) = \int_{-NcTc/2}^{NcTc/2} pn(t) \,.\, pn(t+\tau) dt \ldots\ldots\ldots\ldots\ldots \qquad (3.4)$$

It is best if R_a (τ) is not larger than one count if not synchronized (τ =0)

$$\frac{\begin{array}{l} pn(0) = +1+1+1-1+1-1-1 \\ pn(0) = +1+1+1-1+1-1-1 \end{array}}{+1+1+1+1+1+1+1} = \sum = 7 = R_a(\tau = 0)$$

$$\frac{\begin{array}{l} pn(0) = +1+1-1+1+1-1-1 \\ pn(0) = +1+1-1+1-1-1+1 \end{array}}{+1+1-1-1-1-1-1} = \sum = -1 = R_a(\tau = 0)$$

For PN sequences the autocorrelation has a large peaked maximum (only). For perfect synchronization of two identical sequences (like white noise) as shown in Figure (3-4). The synchronization of the receiver is based on this property.

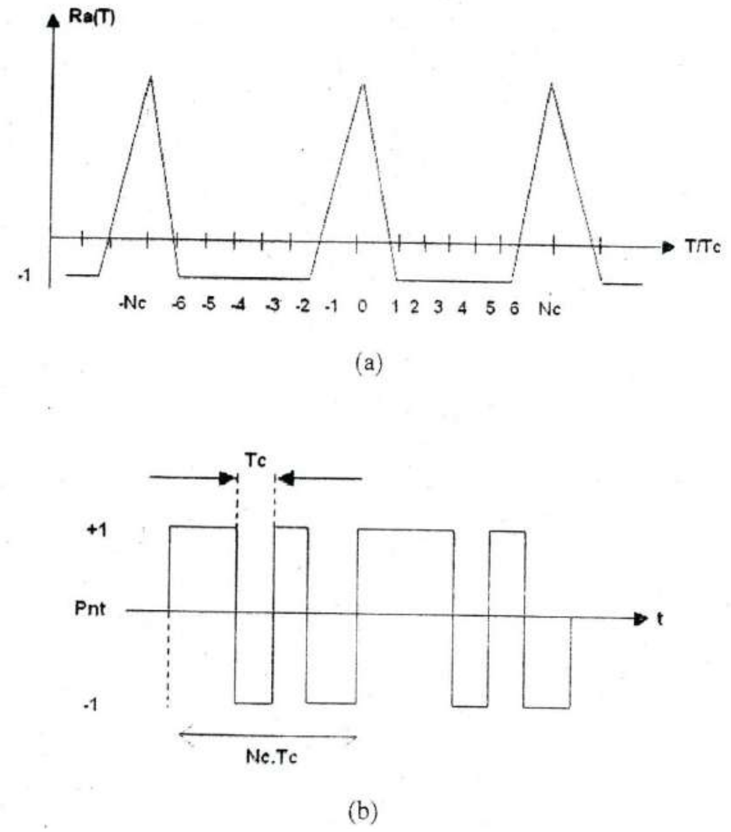


Fig. (3-4) PN sequence

(a) Autocorrelation function of PN (b) PN sequence with time

3.3.1.4 Cross-Correlation.

Cross-correlation describes the interference between codes pn_j and

$$R_c(\tau) = \int_{-NcTc/2}^{NcTc/2} pn(t)\,.pnj(t+\tau)dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.5)$$

Cross-correlation is the measure of agreement between two different codes pn_i and pn_i . When the cross-correlation R_c (τ) is zero for all τ, the codes are called orthogonal. In CDMA multiple users occupy the same RF bandwidth and transmit simultaneous When the user codes are orthogonal, there is no interference between the users after dispreading and the privacy of the communication of each user is protected. In practice, the codes are not perfectly orthogonal; hence the cross-correlation between user codes introduces performance degradation (increased noise power after dispreading), which limits the maximum number of simultaneous users.

3.3.1.5 Frequency Spectrum.

Due to the periodic nature of the PN sequence the frequency spectrum has spectral lines which become closer to each other which increasing sequence length N_c. Each line is further measured by data scrambling, which spreads each spectral line and further fills in between the lines to make the spectrum more nearly continuous .The DC component is determined by the zero-one balance of the PN sequence.

3.3.2 Types of the PN sequence.

3.3.2.1 M-Sequence

A maximal code is defined to be the longest code that can be generated by a given shift register of a given length. For a binary shift register sequence generator, the maximum sequence length is given by ($M=2^L-1$), where L is the number of stages in the shift register. A shift register sequence generator consist of a logical combinational of a select number of output stages being fedback to the input of the shift register, and the M-sequence is linear if combination have an even numbers of tape .An example is shown in figure (3-6) where arbitrary feedback has been shown. Maximal length shift register sequence generator maximal code sequence possess a number of important properties which are useful in spread spectrum applications. Each of these properties will be dealt with in more details in [35,50], (Carrier Balance, Linear Addition, State Exhaustion and Auto and Cross Correlation) [35, 49, 50].

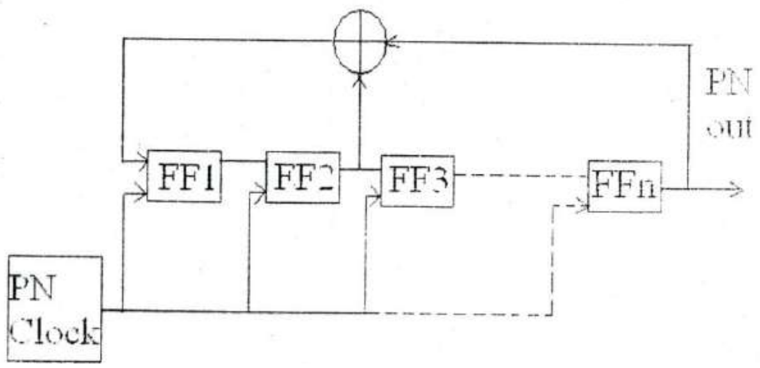


Fig (3.6) Generic maximal length shift register sequence generator

3.3.2.2 Barker Code.

The number of stages L in the simple shift register generator (SSRG) also determines the length (period) N,$^{=}2^{L}$-1 of the m-sequence codes. The Barker code gives codes with different and similar autocorrelation properties as the m-sequence.

Barker(11)$^{=}$1 -1 1 1 -1 1 1 1 -1 -1 -1 $\rightarrow \Sigma = +1$ (balanced)

Barker(13)=1 1 1 1 1 -1 - 1 1 1 -1 1 -1 1 $\rightarrow \Sigma = +5$ (unbalanced)

The autocorrelation function of the balanced 11 chip Barker code is shown in the figure (3-7) below [48]: -

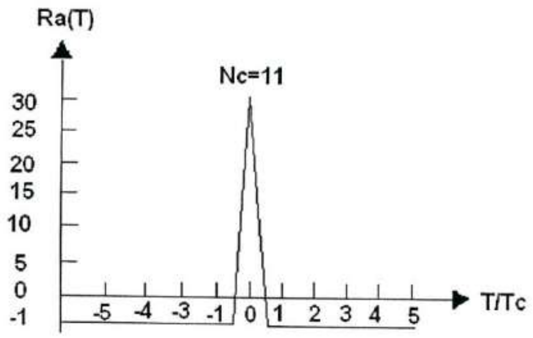


Fig. (3-7) Autocorrelation function of Barker Code

3.4 The Effect of Noise.

This section looks at the effects of introducing Additive White Gaussian Noise (AWGN) into the communications channel. This can be used to quiet atmospheric interference, as well as the effects of other co-channel users who are using properly correlated PN codes. Atmospheric interference varies markedly in its spectral representation, ranging from slight AWGN through to major bandwidth pollution. The presented here are not meant to account for all possible types of atmospheric interference, since this type of analysis can be found elsewhere .It was shown by Weberet al. that, under certain conditions, the effects of other simultaneous spread spectrum transmission can effectively by modeled as a Gaussian random variable. And although they use a discrete noise generator, this can be thought of as one or more separate transmitters using a properly correlated PN code. The system used to analyze the introduction of white noise into the system is shown in the Figure (3-8). For example a left hand side of this block diagram consists of a BASK transmitter, modulating a 10 MHz sinusoidal signal with a 10 stage (1023 bit) PN sequence. This signal is then mixed with an 800MHz carrier. Node (A) represents the transmitter output. From here, AWGN is added to the signal at various amplitudes, before entering the receiver. Both the carrier frequency and PN code phase are assumed to be synchronous, and this is represented simply by using the same oscillator as the transmitter. The receiver de-spreads and down-converts the signal, which is then low pass filtered at 20MHz. The recovered signal can be seen at node (B). System diagram showing the addition of AWGN . Four levels are introduced into the system, and the spectral are shown in Figure (2-9).

The first system uses a noise level significantly lower than the signal amplitude, and as would be expected, does not have any noticeable effects on the system. As the noise level is increased to just below the first major null, then midway into the main lobe, degradation in the received signal level becomes apparent. Finally, as the noise level is increased such that it exceeds the transmitted signal level, Further reduction in received signal level is observed. Note that as the noise level increases, the noise floor at the receiver also increases[,].

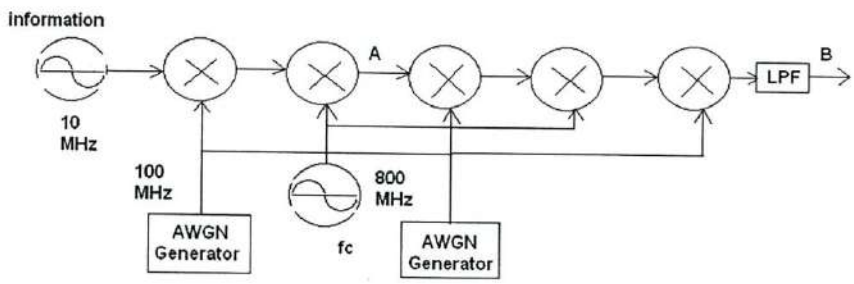


Fig. (3-8) System diagram showing the addition of AWGN

3.5 Processing Gain.

One of the most important aspects of any spread spectrum communications system in the presence of the interference its processing gain. This was defined as the ratio of the signal bandwidth to the input data rate, for a direct sequence system. [35]

$$G_p = \frac{BW_{RF}}{R_{info}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (3.5)$$

Figure (3-16) shows the effect on the transmitted spectrum as the processing

gain is varied .For example the input data was ASK modulated onto a 10MHZ carrier frequency ,and PN clock rates of 10, 50, 100 and 1000 times the data rate have been shown. It is clear that the lower orders of gain do not result in a desirable spectrum, and as outlined previously, the spectrum of the main lobe starts to become clearly defined as the PN clock rate approaches 100 times the data rate. At 1000 times the data rate ,a very clean and well defined spectrum is seen. In order to draw a comparison between these diagrams, the RF bandwidth has been kept constant. Since the bandwidth of the main lobe is directly proportional to the PN clock rate, it would be expected that the width of this lobe increases as the clock rate increases. However, this would make a direct comparison more difficult, and so in order to allow this, the data rate has been changed accordingly [36, 40, 44].

3.6 Jamming Margin.

Jamming margin takes into account the requirement for a useful system output signal -to-noise ratio and allows for internal losses; that is:

jamming margin = $M_j = G_p - [L_{sys} + (\frac{S}{N})_{out}]$ ....(3.6)

Where;

Lsys = system implementation losses in dBS.

$(\frac{S}{N})$out = signal-to-noise ratio at the information bandwidth in dBS.

For example, a system with 20 dB process gain, minimum $(\frac{S}{N})$out of 10 dB is required at the correlator output, and if Lsys is 2 dB, this system would have an 8 dB , jamming margin .It could not be expected to operate with interference more that 8 dB above the desired signal[35,40,51].

Chapter Four
Synchronization

4.1 Introduction

For it's proper operation a spread spectrum communication system required that the locally generated PN sequence (PN used in the receiver RX to dispread the received signal) is synchronized to the PN sequence of the transmitter generator (PN used to spread the transmitted signal in the transmitter TX) In both it's rate and it's position . Due to the sharp peak in the autocorrelation function , a misalignment in the PN sequence of T_c /2 gives a loss of a factor 2 in processing gain The choice of specific synchronization scheme depends largely on the following factor [52] :

1. The spreading modulation used (DS , FH TH , Chirp or Hybrid) because the structure of the signal to be acquired and it's characteristics must be known.
2. The intended application (military or civil , communication , ranging to tracking , continuous or burstly , ... etc).
3. The amount of uncertainly involved.
4. The amount of time allowed acquiring synchronization of specific probability of detection , probability false alarm and signal — to — noise ratio.
5. The environment in which the system will be expected (AWGN only , AWGN plus intentional interference).
6. The complexity, cost , size and weight.

4.2 Source of Synchronization Uncertainty

4.2.1 Time Uncertainty

1. Uncertainty in distance between TX—RX (propagation delay).
2. Relative clock shift.
3. Different phase between TX—RX (carrier , PN **sequence).**

4.2.2 Frequency Uncertainty

Relative velocity Vr between TX—RX (Doppler frequency shift) affects the carrier frequency fc (with C the speed of light in the propagation medium)

$$F_{Doppler\ carrier} = f_c\left(1 \pm \frac{vr}{c}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

For process of synchronization the locally generated PN sequence with the received PN sequence is usually accomplished in two steps :

1- Acquisition : The acquisition process is the most difficult procedure to be achieved in a DS/SS receiver . This process aligns the receiver's local PN code to within half a chip with the received code.

2- Tracking : The tracking process reduces the alignment error to a fraction of a chip, and maintains it for duration time of the transmitter. The tracking could be accomplished by using phase locked loop (PLL).

4.3 Acquisition methods

Before any communication can take place over a spread spectrum link , it is necessary to obtain initial synchronization at the receiver . Initial synchronization (i.e acquisition) is one of the most difficult problems in establishing a link . It is the process of attempting to line up , in phase , two identical PN- code sequences , one of which is corrupted by noise and interference while, the other one being generated locally .

To acquire synchronization , the local PN-code sequence is correlated with the incoming PN - code plus noise . If after time T, the partial auto correlation dose not exceed the threshold voltage , then the local sequence changes it's phase and the auto correlation process is repeated. This procedure is repeated until synchronization is acquired . Many techniques for achieving synchronization have been evolved, some with simple requirements ,other with complex implementation requirements. The choice of an acquisition technique depends on the application , the amount of time allowed for acquisition, and the amount of time—frequency uncertainty involved . In following, different acquisition techniques will be described .

4.3.1 Serial Search Acquisition.

Serial search acquisition consists of a search, usually in discrete steps, of the possible time alignments of a locally generated PN-code relative to a received pseudo noise sequence. The time uncertainty region is usually quantized into a finite number of search positions or cells. The cells are serially tested until it determined that a particular cell corresponds to within a fraction of a chip. The step size or separation between cells is typically one-half of a chip.

4.4 Tracking (Fine synchronization)

Once code acquisition, or coarse synchronization has been accomplished, tracking or fine synchronization takes place. In many practical system , no data are transmitted a specified time, sufficiently long to ensure that acquisition has occurred. During tracking , data are transmitted and detected . The tracking maintains the PN code generator at the receiver in synchronism with the received signal

Note :-

The design is implemented by using perfect synchronization (i.e without using transmission channel).

Chapter Five

DS/ SS System Simulation using MATLAB- Simulink

5.1 Introduction

The DS/SS is designed by using MATLAB – Simulink version (7), because it's attractive simulation tool to provide the designer many facilities to rapidly design, implement and test the desired system. Also it gives a designer a clear imagination to the system parameters required to complete the design. This information gained from MATLAB–Simulink implementation will help us to correctly optimize the cost and speed in direct component, microprocessor — based, or using Field Programmable Gate Array (FPGA) implementation . The waveforms, and spectra at any point pof design can be obtained by using scope, or frequency spectrum, this is very necessary to check the design . This thesis used communication block set, DSP block set, Simulink – Extras and other block set of MATLAB – Simulink.

There are two designs that used MATLAB – Simulink simulation as follows :-

1- Baseband DS/SS system.
2- Radio frequency (RF) DS/SS system.

5.2 Base Band DS/SS System

Figure (5 - 1) shows a block diagram of the overall system. The basic block diagram Of the system shows the transmitter and receiver, in the following sections each part Of the system will be described.

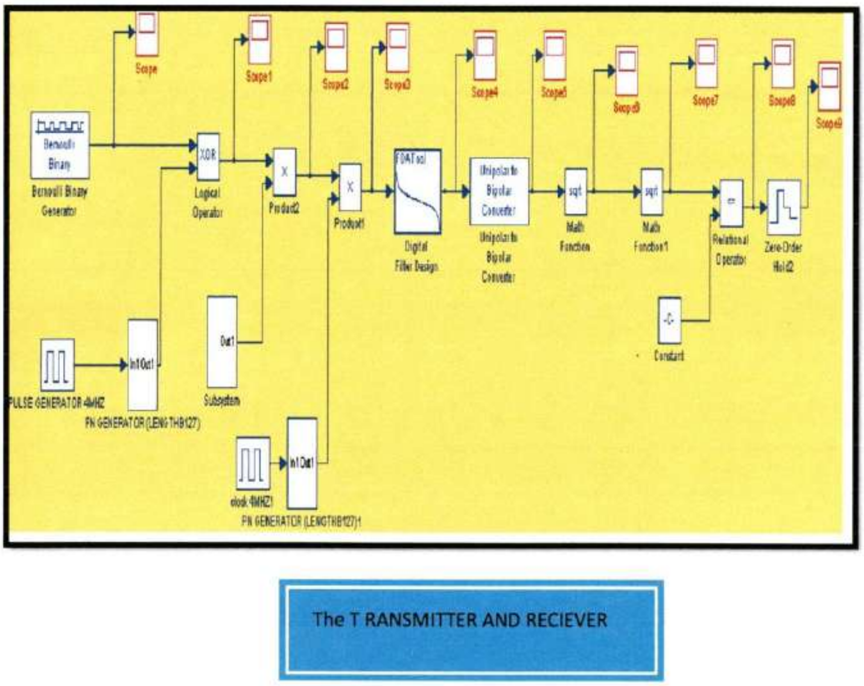


Fig (5 - 1) Block diagram of overall DS/SS system

5.2.1 System Specification

The system specification are as below :

1- Data rate : 100 Kb/s.

2- PN code rate : 4 MHz.

3- PN code length : 127 bits (maximal linear code).

4- Modulation type : baseband ASK.

5- Sampling frequency : 8 MHz.

6- Processing gain

$$Gp = \frac{B.W\ RF}{B.W\ data} = \frac{2 \times cloock\ rate}{data\ rate} = \frac{2 \times 4MH_Z}{100\ KH_Z} = 80$$

$(Gp)_{dB} =$ 101og80= 19 dB

In the following sections a brief description of each system component is given. All waveforms shown in the next figures have the following (X - axis in Second, Y - axis in Volt).

5.2.2 The Transmitter

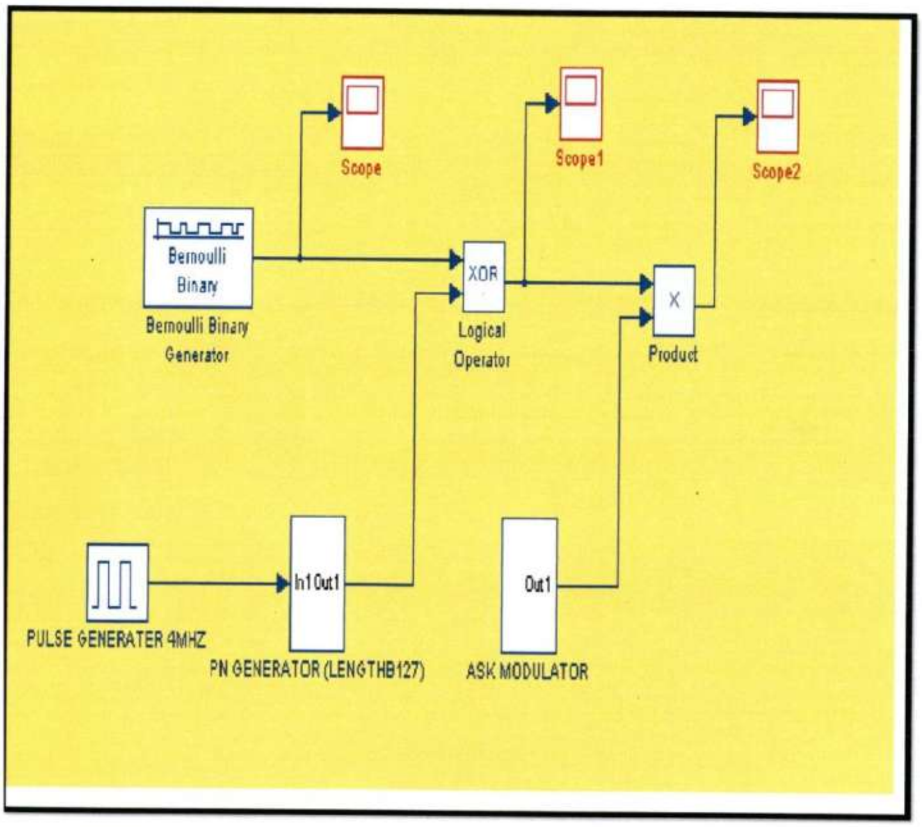
Figure (5 - 2) shows the block diagram of transmitter which contains data generator, PN generator is the same as in the receiver mixer (multiplier) Amplitude shift keying (ASK) modulator. Since modulation is performed in. Baseband, no radio frequency RF carrier is presented therefore the detected of the signal in the receiver used low pass filter (LPF). The transmitter contains:

1 — Data generator.

2 — PN code generator.

3 – Baseband ASK modulator.

In the following section a brief description of each sub system will be explained.



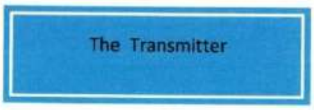


Fig (5-2) The block diagram of transmitter

5.2.2.1 Data Generator

Figure (5 -2) shows the block diagram of the transmitter which contains a data to be transmitted in data rate 100 Kb/s generated by using binary data generator (Bernoulli Binary) from communication block set with a probability of zero 50% and 50% one's, the wave form of data shown in figure (4 – 3).

It must be noted in direct sequence spread spectrum system, the data rate must smaller in order to ensure good performance system because the processing gain. equal to the ratio of signal band width to the data rate , therefore in most DS/SS system used a delta modulation (DM) [10] , rather than pulse code modulation (PCM) in voice applications to ensure a high processing gain.

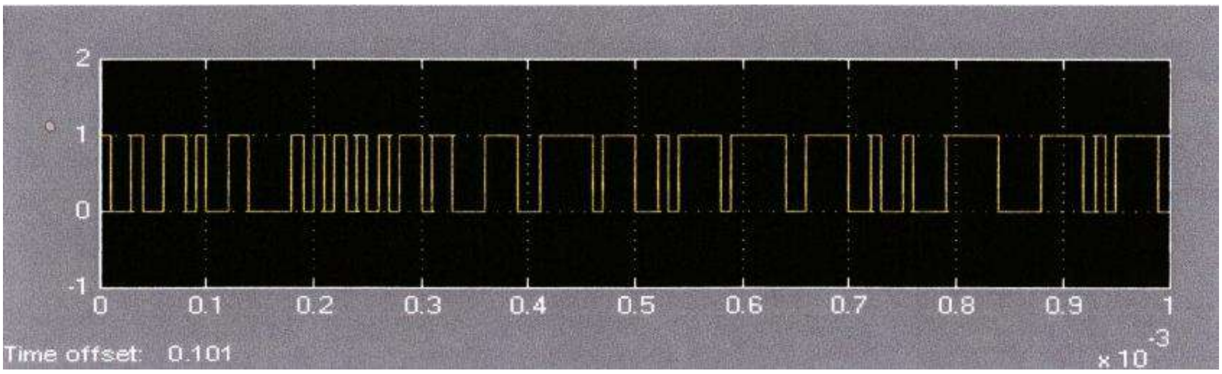
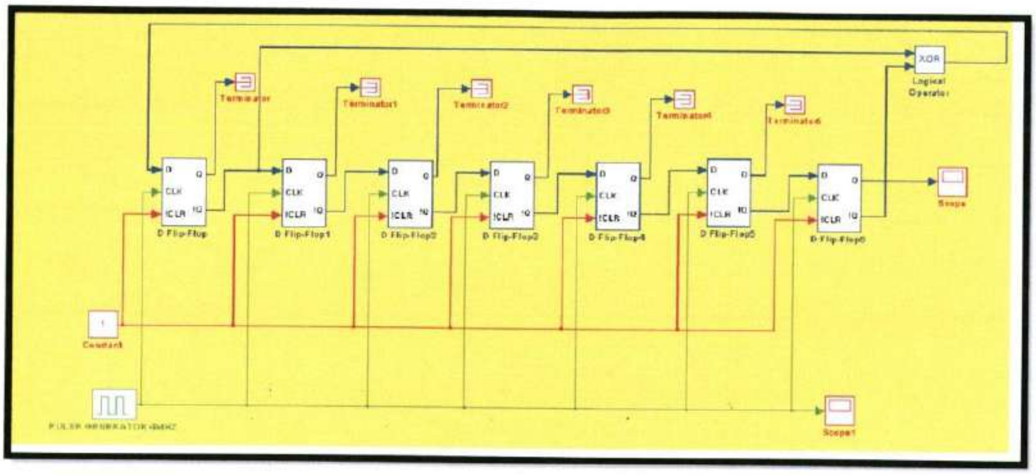


Fig. (5 - 3) Waveform of Data 100 Kb/s

5.2.2.2 PN Code Generator

The block diagram of implementing a PIA generator is shown in figure (4-4), a PN sequence is generated as maximal-linear code with a polynomial $g(x)=x^6+1$, the PN generated by using seven stages D Flip-Flop from simulink-Extras with a two feedback taped (x^6, x°) Ex-ORed to the input of the first stage D Flip-Flop , in order to get 127 bit length maximal-linear code (2^L -1) and the clock is gotten from digital clock 4MHZ as shown in figure (4 - 5) and waveform of PN1 code generator is shown in figure (5 - 6).



PN GENERATOR 127 BITS

Fig (4 -4) Block diagram of PN code generator

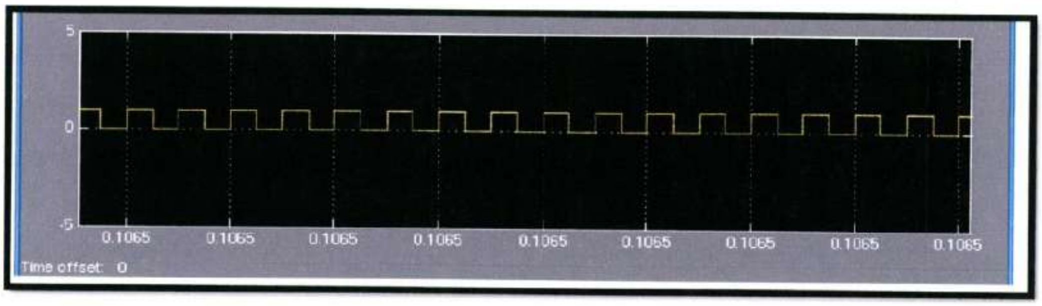


Fig (4- 5) Waveform of digital clock 4MHZ

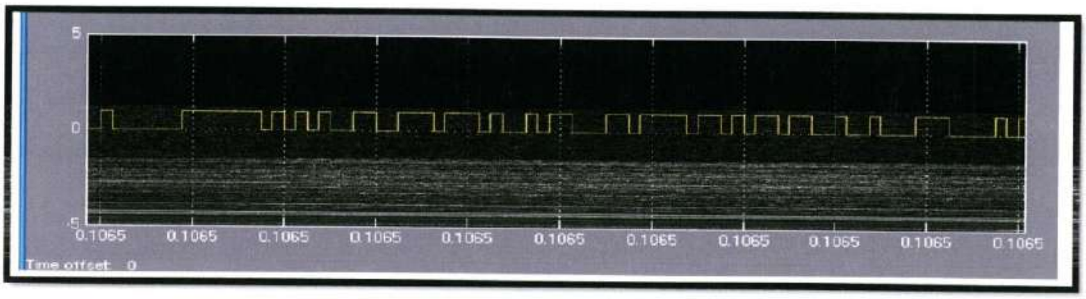


Fig (4 – 6) Waveform of PN code generator

5.2.2.3 Baseband ASK Modulator

The baseband ASK modulated the output digital signal mixer (multiplier) of data generator as shown in figure (5-7).

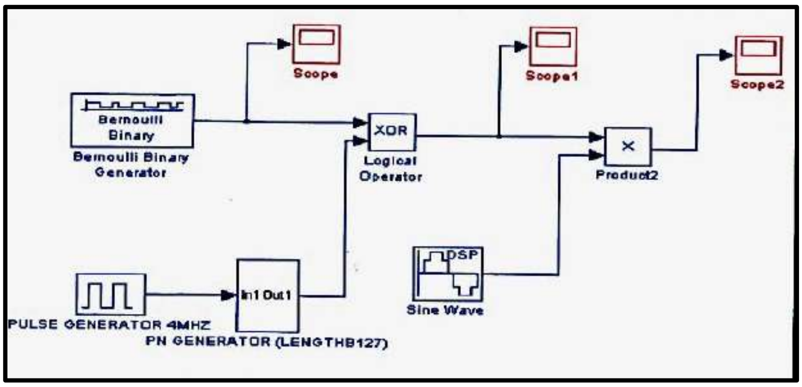


Fig (5-7) Baseband ASK modulator

Figuer above shows a practical amplitude shift keying modulator which consist of the output signal (Berrnoulli binary generator, EX-OR with the PN code generator) and sinewave (from signal processing block set- DSP sources) and then multiplier so the output of modulator is shown bellow in figure (5-8), which the output of the transmitter.

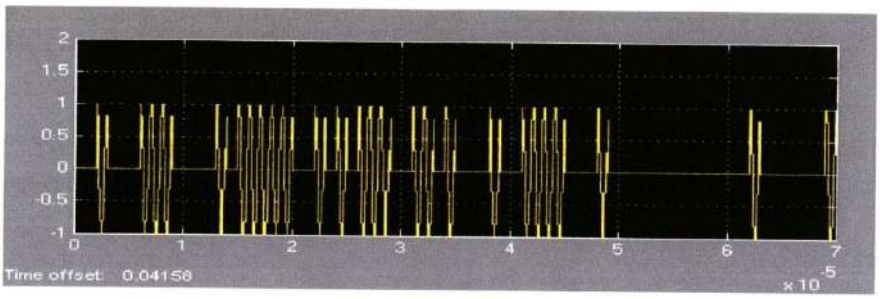


Fig (5-8) Baseband ASK modulator output

5.3 The Receiver

The receiver which the block diagram is shown in fig (5-9) has the task of recovering the original transmitting signal. it consist of the following :

1- Frequency Down Converter (De-spreader).

2- Baseband ASK demodulator.

3- Bipolar converter.

4- Comparator.

5- Zero-order Hold.

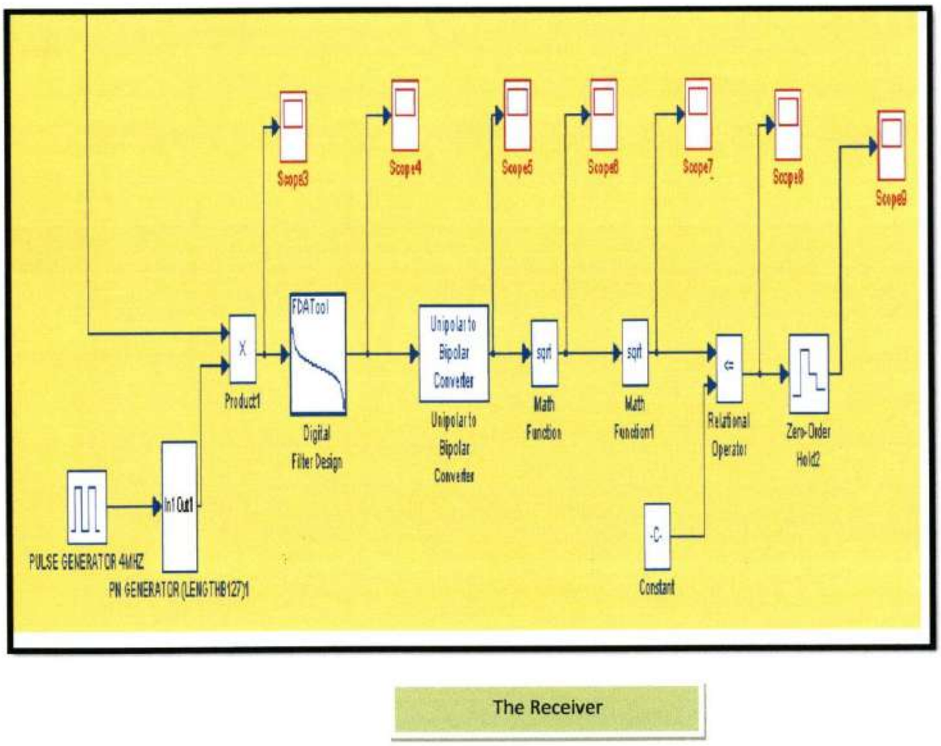


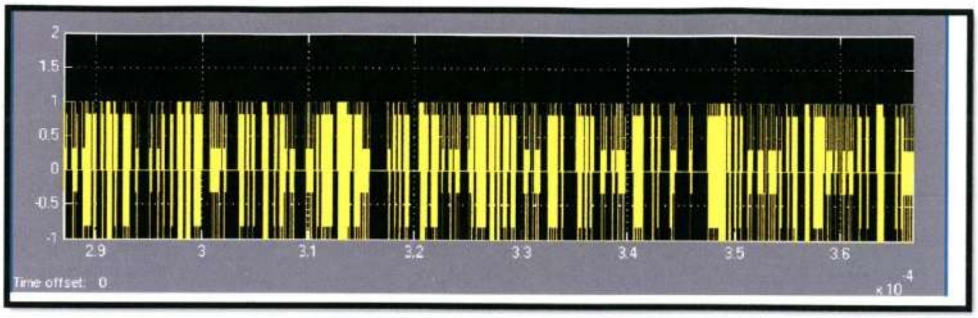
Fig (5-9) The Receiver

5.3.1 De – spreader

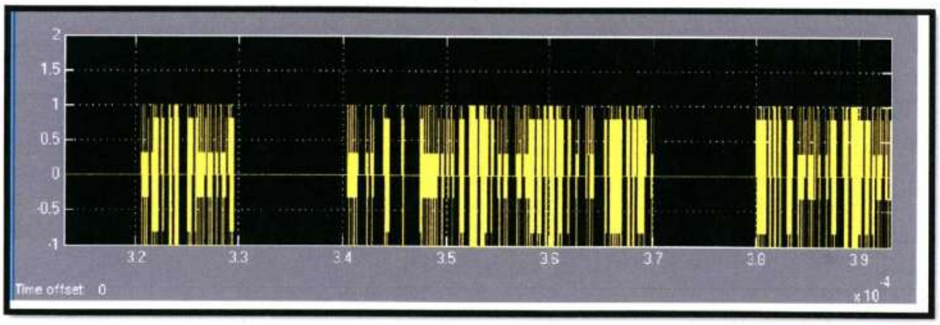
The de-spreader is similar to the spreader but it has the inverse function of it. In this case the PN code sequence is multiplied by the incoming signal so that the signal is decoded completely. Figures (5-10a) and (5-10b) indicate the shape of the de - spreader respectively.

5.3.2 Baseband ASK Demodulator

The received signal often raising through conversion - down (de – spreader) and raising through the LPF with cut off frequency 100 kb/s become as analog message. (5-11a) and figure (5-11b) indicates the signal before and after the demodulator.



(a)signal before de-spreader



(b)signal after de-spreader

Fig (5-10)

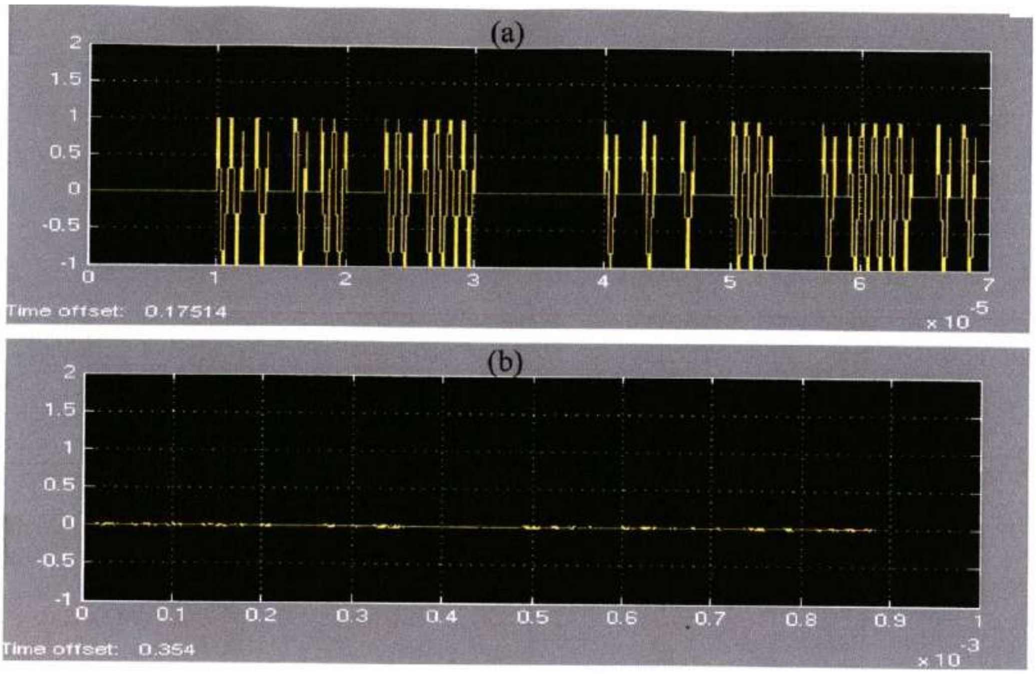
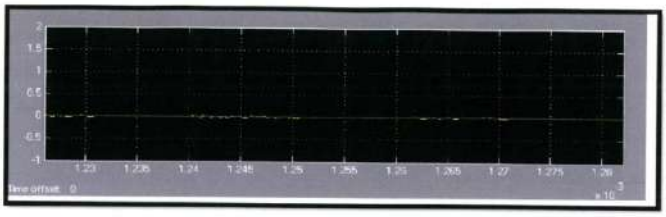


Fig (5-11)

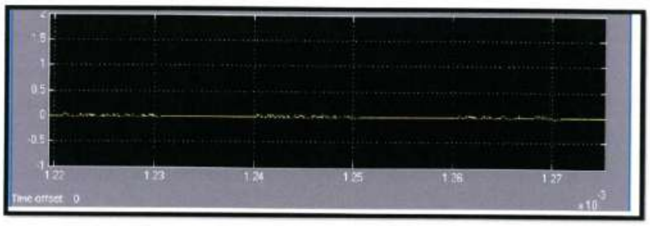
(a) The signal before the LPF (b)The signal after the LPF

5.3.3 Bipolar Converter

When the received signal become as analog message as unipolar, it is necessary to change it to unipolar in order to change it to a desired form in the following process, as shown in figure (5-12).



(a)indicates the message before unipolar to bipolar converter



(b)indicates the message after unipolar to bipolar converter

Fig (5-12)

5.3.4 Square Root

The receiver is after converts to a message it become less than one so by using a unit of sqrt the message becomes as long as possible depend on the number of sqrt unit used. Figures (5-13a) And (5-13b) indicates the message before and after the

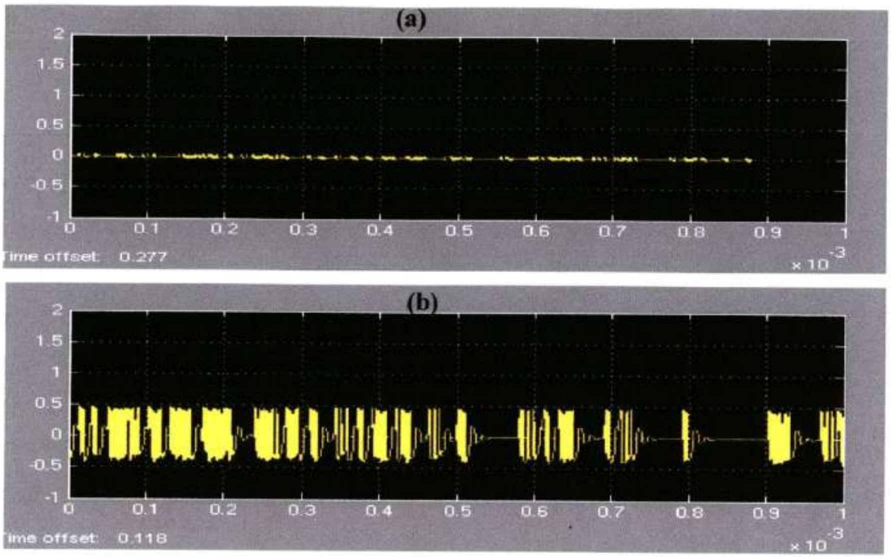


Fig (5-13)

(a) indicates the message before the sqrt unit.

(b) indicates the message after the sqrt unit.

5.3.5 Comparator

When the message become as long as possible after passing through the square root, then inter to the comparator unit i.e with logical unit by compare it with very small content (0.00001) to change it to discrete refer to zero pulse (RZ), which is like the transmitted pulse .Figures (5-14a) and (5-14b) indicate the message before and after this unit.

5.3.6 Zero - Order - Hold

The Zero - Order - Hold block sample and hold the input for the specified sample period. The block accepts one input and generate one output both of which can be scalar or vector, all the elements of the vector are hold for the same sample period. The sample time set to -1. The figures (5-15a) and (5-15b) demonstrate the shape of the message before and after the unit.

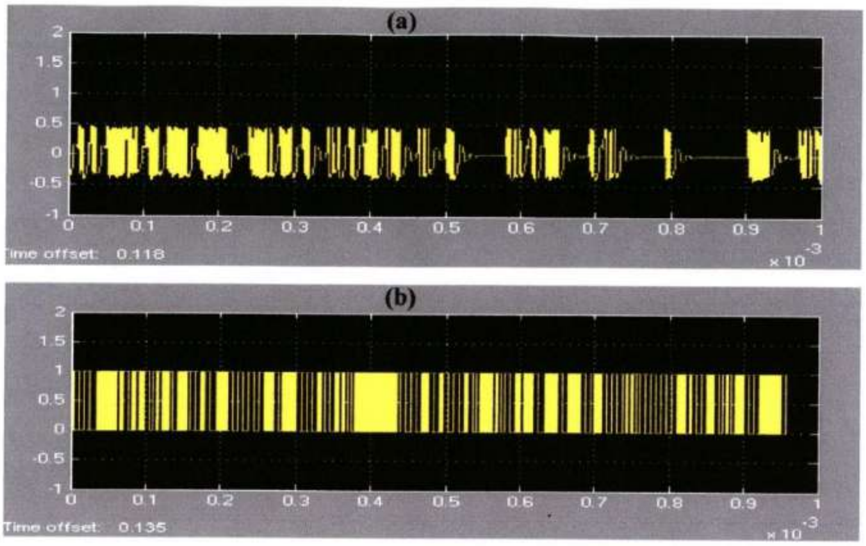


Fig (5-14)

(a) indicate the message before the comparator

(b) indicate the message after the comparator

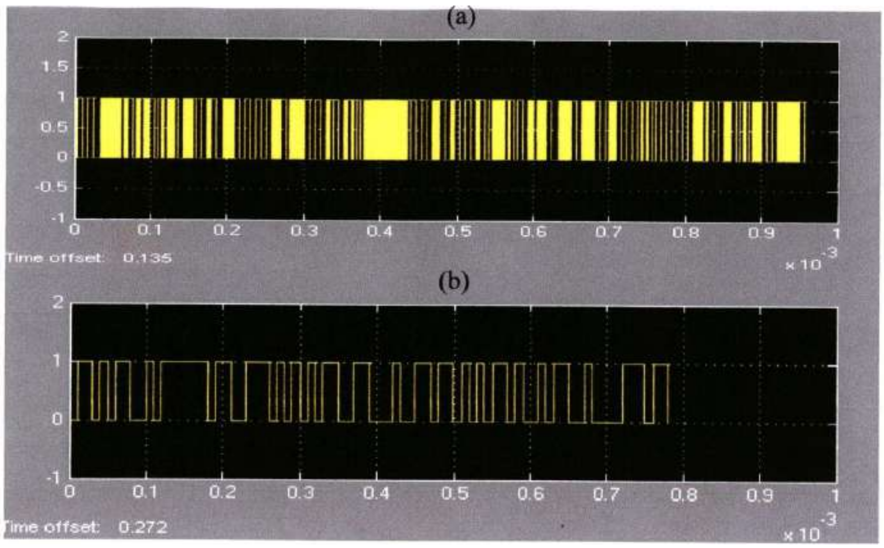


Fig (5-15)

(a) demonstrate the shape of the message before Zero – Order - Hold.
(b) demonstrate the shape of the message after Z

Chapter Six
Result and Discussion

6.1 Introduction.

The performance of any digital communication system is the measuring of the bit error rate for received data. The performance of DS/SS system here can be tested by using incorrect PN code in the transmitter to compare the waveform of transmitted data with received data.A comparison between the two designs is carried graphically from the simulation result, by using MATLAB-Simulink simulation.

6.2 Equivalent Baseband (DS/SS) System Result.

From the overall DS/SS system design during the simulation process after (1ms) simulation time. The performance of the system design can be tested as follows:-

If correct PN code (PN) is used in the transmitter, the received data from BASK demodulator with respect to transmitted data will be shown in figure (6-1).

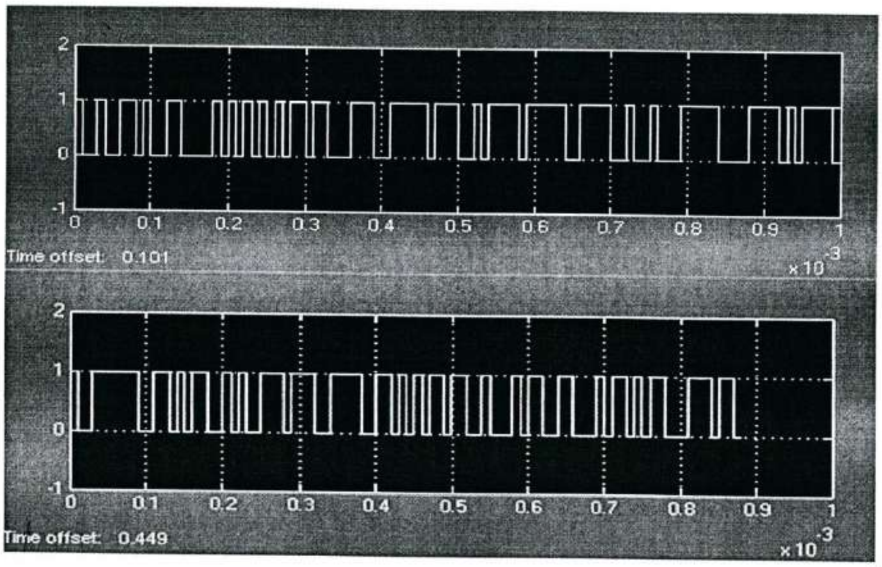
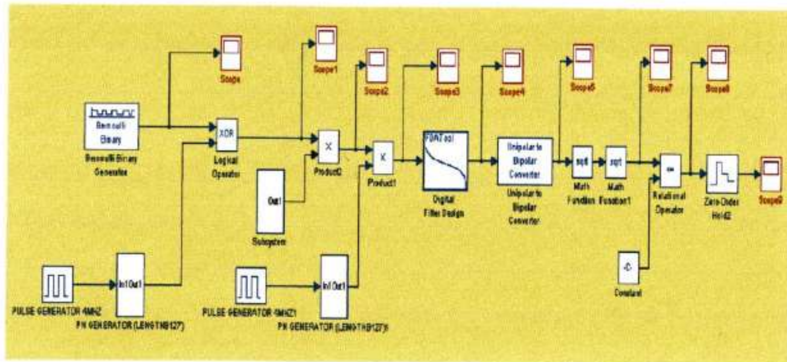


Fig.(6. 1) Waveform of data at correct PN code

(a) Transmitted data (b) Received data

From the block diagram of overall DS/SS system as shown in Figure (6-2)



The transmitter AND Receiver

Fig (6.2) Block diagram of overall DS/SS system during simulation process

6.3 Application and uses of DS/SS system.

1- The United States GPS, Russian Glonass , and European Galileo satellite navigation systems.
2- CDMA cellular phones.
3- Cordless phones operating in the 2.4 and 5.8 GHz bands.
4- The 802.11 and 802.1l b Wi-Fi standards. (The faster modes in 802.11g use OFDM, not spread spectrum, although it can fall back to the slower 802.1l b modes.)
5- ZigBee /802.15.4
6- 6-Automatic meter reading
7- Wireless Local Area Networks (WLAN) (ranges allocated for use with Spread Spectrum technology is 2.4 GHz to 2.4835 GHz).

6.4 Conclusions.

The use of special pseudo noise codes in spread spectrum (SS) communications makes signals appear wide band and noise-like. It is this very characteristic that makes SS signals possess the quality of low Probability of Intercept. SS signals are hard to detect on narrow band equipment because the signal's energy is spread over a bandwidth of may be 100 times the information bandwidth . The spread of energy over a wide band, or lower spectral power density, makes SS signals less likely to interfere with narrowband communications. Narrow band communications, conversely, cause Little to no interference to SS systems because the correlation receiver effectively integrates over a very wide bandwidth to recover an SS signal. The correlate then "spreads" out a narrow band interferer over the receiver's total detection bandwidth. Since the total integrated signal density or SNR at the correlate's input determines whether there will be interference or not. All SS system have threshold or tolerance level of interference beyond which useful communication ceases. This tolerance or threshold is related to the SS processing gain. Processing gain is essentially the ratio of the RF bandwidth to the information bandwidth. A typical commercial direct sequence radio might have a processing gain of from 11 to 16 dB, depending on data rate. Iµ can tolerate total jamming power levels of from 0 to 5 dB stronger than the desired signal. Yes, the system can work at negative SNR in the RF bandwidth. Because of the processing gain of the receiver's correlate, the system functions at positive SNR on the baseband data. Besides being hard to intercept and jam spread spectrum signals are hard to exploit or spoof.

Signal exploitation is the ability of an enemy (or a non-network member) to listen in to a network and use information from the network without being a valid network member or participant. Spoofing is the act of falsely or maliciously introducing misleading or false traffic or message's to a network. SS signals also are naturally more secure than narrowband radio communications. Thus SS signals can made to have any degree of message privacy that is desired. Messages can also, be cryptographically encoded to any level of secrecy desired. The very nature of SS allows military or intelligence levels of privacy and security to be had with minimal complexity. While these characteristics may not be very important to everyday business and LAN (local area network) needs, these features are important to understand .

The DS/SS system in the begging in this thesis was designed by using (Electronic Work Bench version 5.12) software and (Circuit Maker version 6.2) software, these two software gives very good results in designing the transmitter but the main problem with the receiver, the advantages of these software's were the flexibility of deals with discrete component, its more closer to the practical application, easy to monitoring the flow of signals in time domain, easy to change the condition of library components and have fast simulation time, but these software also have some disadvantages which make us to discontinuous the DD/SS system design in this way such as, difficult to deals with radio frequency (100 MHZ), it didn't have more devices such as frequency spectrum to seen the spectrum of some signals, bit error rate calculation and the main and limited problem the number of component in each design don't exceed 100 component per design whereas.

The DS/SS system design demand more than 150 discrete component therefore this advantage leads to another software.

Secondly the DS/SS system was implemented to (COMMSIMM 2001) software, this software only deals with communication block set and it has good library of blocks set but also has some disadvantage such as difficulty to change the parameter of blocks set with demanded design. Therefore, implementing simple system has low bits rate, low code rate and low radio frequency, this design gives impression on DS/SS system design when implemented on another software's . Therefore, the DS/SS system was implemented by using (MATLAB 6.5) software. This software is very good for implementing DS/SS system design for monitoring the flow of signals in time and frequency domain and deals with blocks set in flexibility and no limitation in blocks per design but I found from the second design slow simulation because it deals with analog signal but it is fast with first design, because it deals with digital signal.

From the MATLAB-simulink simulation of the two system design we can conclude that the first design of the system performance in presence of AWGN with using Integrator and Dump in active correlator is better than using digital LPF in active correlator as shown in the relationship between BER with SNR in chapter 5. Whereas the second design is better than the first design for less than (-14 dB) and the first design using Integrator and Dump in active correlator is better at greater than (-14 dB) as shown in three curves of comparison of the BER with SNR in chapter five.

6.5 FUTURE WORK

There are several suggestions that may lead to develop a more reliable DS/SS system.

1- Developing the work by conversing all system (I .F and RF) parts in both transmitter and Receiver, with using the MATLAB – simulink version 7 which contains RF block set which is not found in version 6.5 .

2- Using different type of code and different length of PN generator such as (JPL, Gold, Kasimi, Barker, etc) to ensure security and complexity of spread spectrum system.

3- Using higher order of modulation such as QPSK, 8PSK, 16PSK to reduce the bandwidth of the system and studying the bit error rate with different SNR values with the above order of modulation.

4- Adding more effect of interference such as (wide band interference, narrow band interference, jamming signals, Doppler, and multipath fading) to design a necessary circuitry to eliminate the problems, in order to obtain actual modeling of DS/SS system.

5- Using another type of acquisition such as a parallel search Acquisition to reduce the Acquisition time with long PN codes.

6- Using DSP techniques like TMS320 families for realizing DS/SS system.

7- Using 0's-based system design to implement the DS/SS system.

8- Using of field Programmable Gate Array (FPGA) to implement the DS/SS system.

9- Using error correction and detection method in the DS/SS system.

10- Designing of DS/SS system using neural network approach.

11- Designing of DS/SS system using wavelet approach.

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