“MULTI USER SPREAD SPECTRUM COMMUNICATION”

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CERTIFICATE

This is to certify that project report entitled **"MULTI USER SPREAD SPECTRUM COMMUNICATION"**, submitted by **"Ambika Sharma, Krishika Parihar and Archana"** in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision. This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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DECLARATION

We hereby declare that the work reported in the B. Tech report entitled **"MULTI USER SPREAD SPECTRUM COMMUNICATION"**, submitted by **"Ambika Sharma, Krishika Parihar and Archana"** at Jaypee University of Information Technology, Waknaghat, Solan is an authentic record of our work carried out under the supervision of **Prof T.S.Lamba**. This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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ABSTRACT

One of the most common modern methods for reducing the effects of interference is an approach broadly termed as Spread Spectrum (SS). Spread spectrum communication has achieved widespread commercial acceptance in the last several years. The increased interest in spread spectrum for wireless communications can be attributed to the high spectrum efficiency of code division multiple access techniques, and to the natural resistance of spread spectrum signal to the effects of multipath propagation, as well as jamming.

In this report we have introduced the basic concepts of spread spectrum communication. We have implemented one of the basic techniques of spread spectrum, that is, Direct Sequence Spread Spectrum (DSSS) technique in which the transmitter and receiver architectures have been implemented. At the receiver side, matched filter and correlation detectors have been designed. Apart from this, the report also highlights the characteristics of spread spectrum such as immunity from noise and multipath, resistant to jamming, multiple user access capability, reduction of eavesdropping etc. Spreading sequence design is the most essential step in DS/CDMA systems, in which the codes have to be designed so as to accommodate the required number of users and also be able to transmit user's data faithfully. In this project we have compared some of the common sequences such as PN sequence, GOLD sequence and analyzed their performance in terms of their correlation value on MATLAB software.

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LIST OF SYMBOLS AND ACRONYMS

PN	Pseudo random noise
LFSR	Linear feedback shift register
FHSS	Frequency hopping spread spectrum
DSSS	Direct sequence spread spectrum
CDMA	Code division multiple access
SNR	Signal to noise ratio
BPSK	Binary phase shift key
BER	Bit error rate
MAI	multiple access interference
BW	Bandwidth
RF	radio frequency
GSM	Global system for mobile communication

CHAPTER 1

SPREAD SPECTRUM

1.1 Introduction

Analog mobile phones are called first generation mobile communication systems. The second generation mobile communications systems – such as global system for mobile communication (GSM) , code division multiple access (CDMA) use digital technology to achieve better performance, quality, security, and spectral efficiency. Third generation (3G) mobile communication are expected to provide high quality global roaming capability for voice, data, internet browsing, and multimedia applications. This 3G technology will utilize some form of spread spectrum technology in the converging wireless, data communication and internet standards. Spread spectrum, first developed by the military, became increasingly popular largely due to its interference tolerance and coexistence capabilities. Today's spread spectrum outside the military, only realm, ranges from digital cellular phones and wireless pc's to wireless LANS (for local area wireless transmission).

With the growth in wireless communication and increasing demand for better methods of communication has raised the need for more robust and effective technology to improve communication systems. One such technique is Spread Spectrum, which has become very popular and important method for communication. Spread Spectrum involves spreading the desired signal over a bandwidth much larger than the minimum bandwidth necessary to send the signal. Though Spread Spectrum was first used for military purposes, but it has become very popular in commercial communication system recently. Spread Spectrum methods have many advantages over other basic communication methods, such as very good interference performance, resistance to jamming, good performance in multi path fading, more robust in noise etc. In this chapter we will cover the detail behind the method of Spread Spectrum communication as well as describe too many types of Spread Spectrum systems, Direct-Sequence Spread Spectrum (DSSS) and Frequency-Hopped Spread Spectrum (FHSS). We will talk about the benefits of Spread Spectrum techniques. We also discuss in brief that how Spread Spectrum technique can be combined to have a good effective communication system. Finally a general comparison between the two will be given, trying to indicate the positives and negatives for each with respect to the other, and to indicate when one system might be preferable over the other.

1.2 Literature Survey

Spread Spectrum scheme was first proposed by a well known Austrian actress Hedy Lamarr and the music composer George Antheil. This technique was proposed to control torpedoes over long distances. The traditional guiding system for torpedoes was prone to detection and can easily be jammed, so to have a better and more robust guiding system which is immune to jamming and detection, the Spread Spectrum technique was proposed. This new guiding system which mainly implemented the Frequency Hopping Spread Spectrum (FHSS) was very effective against jamming and detection as their signal would hop from one frequency to another in a pseudo random fashion known only to an authorized receiver. This would cause the transmitted spectrum to spread over a range much greater than the message bandwidth. Later the Frequency Hopping Spread Spectrum (FHSS) was patented by Lamarr and Antheil.

Spread spectrum techniques can be very useful to overcome the communication problems like security and efficient usage of power. In this technique, the information signal to be transmitted is multiplied by the PN code, called spreading code signal. The receiving side acquires the transmitted signal, which is then multiplied by a same spreading code signal, so that the original signal is recovered. It can be seen that the required signal gets multiplied twice but the interference gets multiplied only once, which will reduce the interference and that will be a great protection against jamming. The main property of the spreading signal is the bandwidth expansion factor (Be=Width/Data rate), which is much greater than unity, that means the redundancy involved in the spread signal can easily overcome the interference The processing gain is used to measure the amount of the improvement of system with the use of spread spectrum system. Processing gain is defined as the ratio of spread signal bandwidth to the information rate.

In Spread Spectrum system each user is assigned a pseudo noise sequence (PN) for the purpose of spreading as well as de-spreading. There are other so many sequences such as gold codes, kasami codes, Walsh and Hadamard codes etc that can be employed for better results.

Gold codes were introduced by a mathematician and coding researcher Robert Gold in August of 2000.

PN sequences are commonly used in wide variety of wireless application such as data encryption and decryption. The codes used in spread spectrum systems are longer than the codes used in other systems, as they are proposed for bandwidth spreading rather than transmitting the information.

Autocorrelation, cross correlation, and power spectrum of PN codes are the main functions which are used to measure the performance of spread spectrum communication systems. Spreading codes have good correlation properties so that each spread spectrum signal is uncorrelated with every other signal sharing the same bandwidth. The PN sequence is unique to each user, thus allowing bandwidth sharing without any loss of information.

Spread Spectrum (SS) is termed as a means of transmission in which the signal occupies bandwidth much in excess of the minimum necessary to send the information. It can be perfectly reconstructed for the intended receiver and it seems to be random-like for others. This randomness of the sequence should satisfy the properties like balance, run and autocorrelation. While the spread Spectrum naturally means that each transmission utilizes a large amount of spectrum, so that a considerable number of users might share the same spectral band. A distinct code has been assigned for each transmitter in CDMA. So there exists a possibility of high interference between the users when they are very close to each other. The interference may be intentional, as in military communications, or it may be non-intentional as in a spectral overlay system. In any case, the receiver achieves higher signal to noise ratios (SNR's) at the decision device input if an interference rejection filter is used before despreading. The rejection filter is usually adaptive and relies on the pseudo-white properties of the spread spectrum signal. Spread spectrum communication has advantages of strong anti-interference ability, good security, high-speed rate, being easy to realize CDMA and less interference to other narrowband systems in the same band. The performance of wireless communication system is limited by fading and jamming, the former arises from signals multipath propagation, while the latter results from the reuse of frequencies. It is widely used in military and civilian applications for its excellent performances and the spreading codes has high autocorrelation and low cross correlation properties.

1.3 Direct Sequence Spread Spectrum

In the Direct Sequence Spread Spectrum technique, the pseudo random noise is applied directly to data before the modulation stage. The modulator has to modulate a much larger data which is because of spreading of data by PN sequence just before modulation. At the modulator the spread signal is used for modulation of the carrier. Thus modulator has to handle large data rate, which is the chipping rate of the PN sequence. Modulating an RF carrier with such a code sequence produces a direct sequence modulated spread spectrum with $((\sin x)/x)^2$ frequency spectrum, centered at the carrier frequency.

The main lobe of the frequency spectrum null to null has a bandwidth twice the clock rate of the modulating code , and the side lobe have null to null bandwidths equal to the code's clock rate. Illustrated in Figure 1 is the most common type of direct sequence modulated spread spectrum signal. Direct sequence spectra vary somewhat in spectral shape, depending on the actual carrier and data modulation used. Below is a binary phase shift keyed (BPSK) signal, which is a most common modulation type used in direct sequence systems.

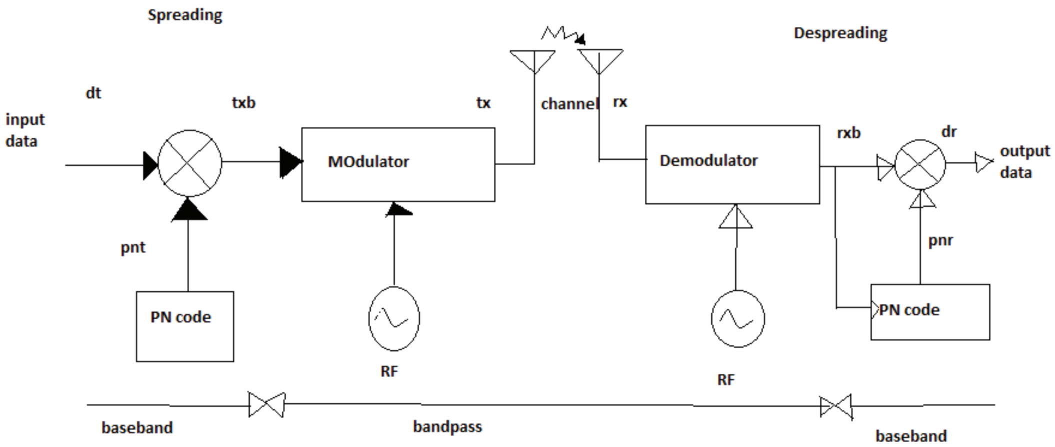


Figure1.3.1: Basic Block Diagram of DSSS [3]

Let f be the frequency of the data signal, with appropriate pulse time T=1/f. Let the PN sequence be transmitted at a rate f_c , so that the increase in data rate is f_c /f . The frequency f_c is known as the chipping rate , with each individual bit in the modulating sequence known as a chip. Thus the width of each pulse in the modulating sequence is T_c , or a chip time. The following figure illustrates the two signals, the data signal for one pulse width , and the PN sequence over same time (since the PRN sequence takes values of ±1,the indicated PN sequence also indicates anormalized version of the signal to be transmitted).

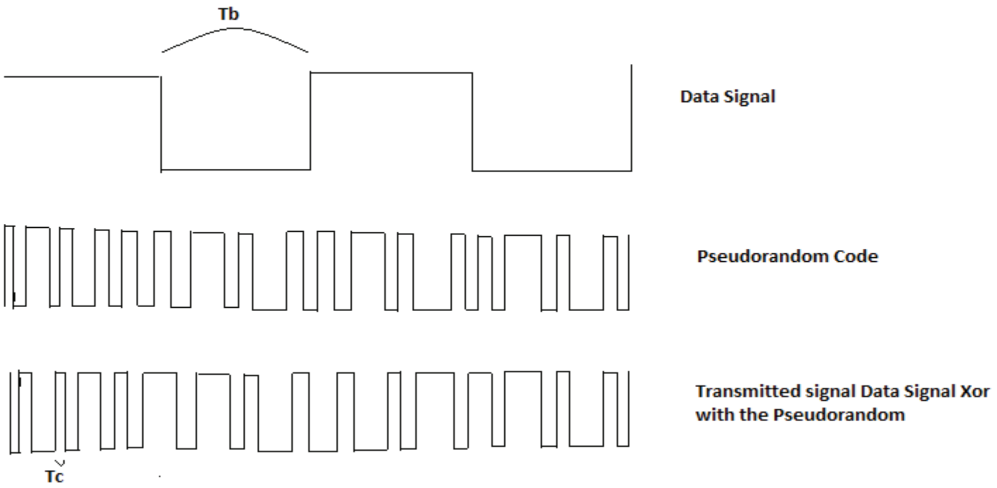


Figure 1.3.2 Data signal and PN sequence in time domain [10]

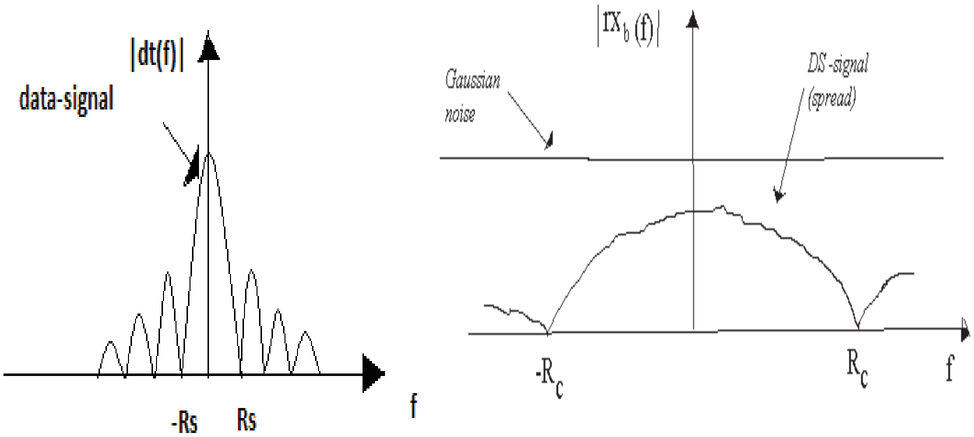


Figure 1.3.3 Data signal and PN sequence in frequency domain [5]

As a result, the frequency domain will look something like the diagram shown in Figure 1.3.3. Mathematically, the following happens. Let the data signal be d(t), transmitted at frequency f, and let the PRN sequence be PN(t),with frequency f_c. So the transmitted signal is

$$\mathbf{S(t) = d(t)*PN(t)}$$

$$\mathbf{R_{PN}(\tau) = \begin{cases} 1 & t=0, N, 2N \\ -1/N & \text{otherwise} \end{cases}}$$

Where N is the length of the PRN sequence ,therefore, when the signal is correlated with the PRN sequence at the receiver , the received signal will be recovered exactly (assuming that there is synchronization between the send and the receive PRN sequences), i.e.

$$\mathbf{rx(t).PN_r(t) = d(t).PN_t(t).PN_r(t) \quad \{PN_t=PN_r\}}$$

$$\mathbf{= d(t)}$$

1.4 Frequency Hopping Spread Spectrum(FSSS)

In frequency hopping spread spectrum method the PRN sequence is applied to frequency synthesizer or local oscillator such that the local oscillator generates different carrier frequencies at different times in a random fashion. In this way the carrier frequency keeps hopping from one frequency to other frequency over wide band according to a sequence defined by the PRN . The speed at which the hops are executed depends on the data rate of the original information .There are two types of FHSS method one is fast frequency hopping (FFHSS) and the other is low frequency hopping(LFHSS). In low frequency hopping(LFHSS) several consecutive data bits modulate the same frequency, whereas in fast frequency hopping FFHSS is characterized by several hops within each data bits.

The transmitted spectrum of a frequency hopping signal is quite different from that of a direct sequence system. Instead of a$((\sin x)/x)^2$ – shaped envelope, the frequency hopper’s output is flat over the band of frequencies used (see figure 4). The bandwidth of a frequency hopping signal is simply N times the number of frequency slots available , where N is the bandwidth of each hop channel.

In FSSS, the signal itself is not spread across the entire large bandwidth; instead the wide bandwidth is divided into N sub-bands, and the signal “hops” from one band to the next in a pseudorandom manner. The centre frequency of the signal changes from one hop to the next, changing from one sub-band to another, as shown in Figure 1.4.

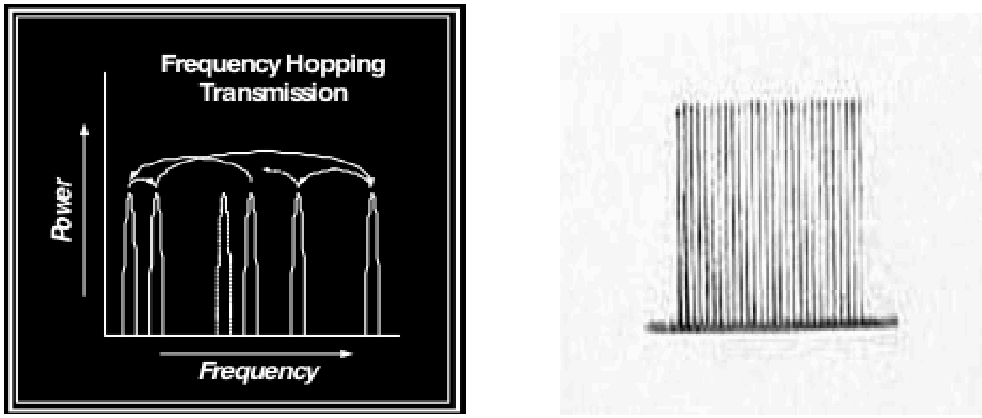


Figure 1.4 Frequency domain view of FSSS [5]

1.5 Different Modulating Spreading Techniques for Spread Spectrum

Different spread-spectrum techniques are distinguished according to the point in the system at which a PN is inserted in the communication channel. If the PN sequence is applied before carrier modulation then it is known as Direct sequence Spread Spectrum (DSSS) (in practical, the pseudo-random sequence is mixed or multiplied with the information signal, giving an impression that the original data flow was “hased” by the PN).if the PRN sequence is applied to the frequency analyzer which generates carrier frequency for modulation then it is frequency hopped spread spectrum (FHSS). If the PRN acts as an on/off gate to the transmitted signal, this is a time-hopping spread-spectrum techniques (THSS).

One can also mix these different techniques to get a combination. More preferred are DSSS and FSSS, but these two can also be used with THSS for better results.

1.6 Benefits of Spread Spectrum

(i) Resistance to interference and anti-jamming effects

There are many benefits to spread-spectrum technology. Resistance to interference is the most important advantage. Intentional or unintentional interference and jamming signals are rejected because they do not contain the spread-spectrum key. Only the desired signal, which has the key, will be seen at the receiver when de-spreading operation is exercised. You can practically ignore the interference, narrowband or wideband, if it does not include the spreading codes used in the de-spreading operation. That rejection also applies to other spread-spectrum signals that do not have the right key. Thus different spread-spectrum communication can be active simultaneously in the same band. Note that spread spectrum is a wideband technology, but the reverse is not true: wideband techniques need not involve spread spectrum technology.

(ii) Harder to jam than narrow bands

The most important feature of the spread-spectrum technique is its ability to reject interference. At first glance, it may be considered that spread-spectrum transmission would be most affected by interference. However, any signal is spread in the bandwidth, and after it passes through the correlator, the bandwidth signal is equal to its original bandwidth plus the bandwidth of local interference. The wider the interference bandwidth, the wider the output signals. Thus the wider the input signal, the less the effect on the system. This is because the power density of the signal after processing is lower as that of original signal.

(iii) Inherent security

In a spread spectrum system, a PN sequence is used to either modulate the signal in the time domain (direct sequencing) or select the carrier frequency (frequency hopping). Due to the pseudorandom nature of the PN sequence, the signal in the air is ‘randomized.’ Only a receiver that has exactly the same pseudo-random sequence and synchronous timing can despread and retrieve the original signal. Consequently, a spread-spectrum system provides signal security that is not available to conventional analogue wireless systems.

(iv) Better voice quality/data integrity and less static noise

Due to the processing gain and digital processing nature of spread-spectrum technology, a spread-spectrum based system is more immune to interference and noise. This greatly reduces the static noise induced by consumer electronics devices that is commonly experienced by conventional analogue wireless system users.

(v) Resistance to interception

Resistance to interception is the second advantage provided by Spread Spectrum techniques. Because non authorized listeners do not have the spreading codes used to spread the original signal, those listeners cannot decode it. Without the right key, the spread-spectrum signal appears as noise or as an interferer (Scanning methods can break the code, however, if the spreading codes are short). The spreading codes involved in PRN sequence or the other orthogonal sequences like gold and Kasami sequences. Even better, signal levels can be below the noise floor, because the spreading operation reduces the spectral density. The message is thus made invisible, an effect that is particularly strong with the Direct-sequence Spread Spectrum (DSSS) technique. Other receivers cannot “see” the transmission; they only register a slight increase in the overall noise level.

(vi) Resistance to fading (Multipath effect)

Wireless channel often include multi-path propagation in which the signal has more than one path for transmitter to receiver. Such multipath can be caused by atmospheric reflection or refraction, and by reflection by ground or from objects such as buildings. The reflected path can interfere with the direct path (D) in a phenomenon called fading. Because the de-spreading process synchronizes to signal D, signal R is rejected even though it contains the same key. Methods are available to use the reflected-path signals by de-spreading them and adding the extracted results to the main one. DS suppresses multipath by de-spreading the delayed signal. When multipath signals are delayed by more than one chip relative to the direct path signal, the signal has a processing gain advantage. When the multipath signal arrives within a one-chip delay, this creates fading. That is the direct signal can be either enhanced or suppressed.

Therefore, for DS to achieve significant multipath rejection, its bandwidth must be wider than the coherence delay of the environment.

(vii) Longer operating distances

A spread-spectrum device operated in the ISM band is allowed to have higher transmitted power due to its non-interfering nature. Because of the higher than transmit power, the operating distance of such a device can be significantly longer for a traditional analogue wireless communication device.

(viii) Hard to detect

Spread-spectrum signals are transmitted over a much wider bandwidth than conventional narrow-band transmissions—20 to 254 time the bandwidth of narrow-band transmissions. Since the communication band is spread, these can be transmitted at a low power without suffering interference from background noise. This is because when despreading takes place, the noise at one frequency is rejected, leaving the desired signal.

(ix) Low crosstalk interference.

Conventional cordless phones frequently suffer from crosstalk interference, especially when used in densely populated residential areas (such as apartment complexes). This problem disappears in spread-spectrum cordless phone systems because:

(i) Crosstalk interference is greatly attenuated due to the processing gain of the spread spectrum system.

(ii) The effect of the suppressed crosstalk interference can be essentially removed with digital processing where noise below certain threshold results in negligible bit errors. These negligible bit errors will have little effect on voice transmissions.

They are resistant to any kind of interference

Input signal: m(t)
Spreading code: s(t)
Product signal: c(t)

In Time Domain: -->

$y(t) = c(t) + i(t) \quad = \quad m(t)\, s(t) + i(t)$

$z(t) = s(t)\ y(t) \quad = \quad s^2(t)\, m(t) + i(t)\, s(t) = m(t) + s(t)\, i(t)$

Since $c^2(t)=1$

In Frequency Domain: -->

Let S(f) be the fourier transform of s(t)

M(f) be the fourier transform of m(t)

I(f) be the fourier transform of i(t)

So, $Y(f)=C(f) + I(f)$

$Y(f)= [S(f) * M(f)] + I(f)]$

After De-spreading

$Z(f) = Y(f) * S(f)$

$= [S(f) * M(f)] * S(f) \quad + \quad I(f) * S(f)$

$= \delta(f) * M(f) \quad + \quad I(f) * S(f) \quad \{\text{since } S(f)*S(f) = \delta(f)\}$

$$\boxed{Z(f)=M(f) + I(f) * S(f)}$$

1.7 Disadvantages:

1. Implementation is somewhat complex.
2. Large bandwidth required that is bandwidth inefficient

1.8 FHSS Vs DSSS

Frequency Hopping Spread Spectrum(FHSS)	Direct Sequence Spread Spectrum(DSSS)
When using FHSS, the frequency spectrum is divided into channels. Data packets are split up and transmitted on these channels in a random pattern known only to the transmitter and receiver.	The DSSS encoder spreads the data across a broad range of frequencies using a mathematical key. The receiver uses the same spreading codes to decode the data.
If interference is present on one channel, data transmission is blocked. The transmitter and receiver 'hop' to the next channel in the hop table and the transmitter resends the data packet.	In DSSS interference the wider band transmission is decoded bank to its original narrowband format while the interference is decoded to a lower power density signal, thereby reducing its effects. When broad-bands interference is present, however, the resulting decoded broadband interference can give a much higher noise floor, almost as high as the decoded signal.
Frequency hopping technology works best for small data packets in high interference environment.	DSSS works best for larger data packets in a low to medium interference environment.
Traditional FH signals lower their average power spectral density by hopping over many channels.	DS spreads its energy by rapidly phase chopping the signal so that it is continuous only for very brief time intervals. The total power is the same, but the spectral density is lower.

Table 1.8

CHAPTER 2

PN SEQUENCES

2.1 Introduction

Pseudo random binary sequences (PRBSs), also known as pseudo noise (PN), linear feedback shift registers (LFSR) sequences or maximal length binary sequences (m sequences), are widely used in digital communications. In a truly random sequence the bit pattern never repeats. However, generation of such a sequence is difficult and, more importantly, such a sequence has little use in practical systems. Applications demand that the data appear random to the channel but be predictable to the user. That is where the PN sequence becomes useful. A pseudo random binary sequence is a semi-random sequence in the sense that it appears random within the sequence length, fulfilling the needs of randomness, but the entire sequence repeats indefinitely. To a casual observer the sequence appears totally random, however to a user who is aware of the way the sequence is generated all its properties are known. PN sequences have several interesting properties, which are exploited in a variety of applications because of their good autocorrelation two similar PN sequences can easily be phase synchronized, even when one of them is corrupted by noise. A PN sequence is an ideal test signal, as it simulates the random characteristics of a digital signal and can be easily generated.

2.2 Generation of PN Sequences

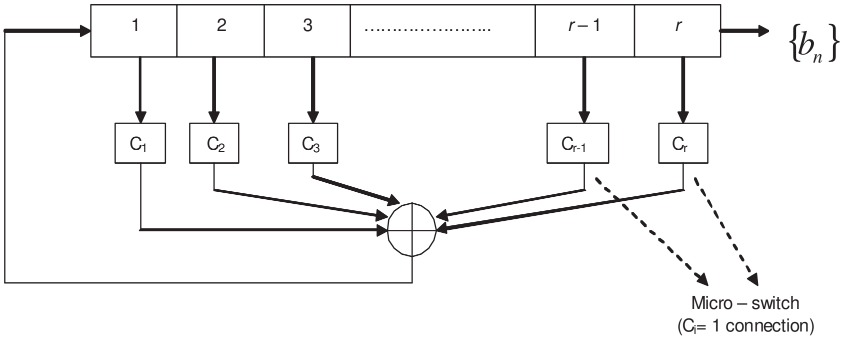


Figure 2.2.1 Generation of PN Sequences [6]

The PN generator for spread spectrum is usually implemented as a circuit consisting of XOR gates and a shift register, called a linear feedback shift register (LFSR). The LFSR is a string of 1-bit storage devices. Each device has n output line, which indicates the value currently stored, and input line. At discrete time instants, known as clock times, the value in the storage device is replaced by the value indicated by the input line. The entire LFSR is clocked simultaneously, causing a 1-bit shift along the entire register. The LFSR contains n bits. There are from 1 to (n-1) XOR gates. The presence and absence of a term in the generator polynomial (X), excluding the X^n term.

Shift Register Sequences:

Ideally, one would prefer a random binary sequence as the spreading sequence. However, practical synchronization requirements in the receiver force one to use periodic binary sequences. A shift register sequence is a periodic binary sequence generated by combining the outputs of feedback shift registers. A feedback shift register, which is shown in figure 2.2.2, consists of consecutive storage stages and feedback logic. Binary sequences drawn from alphabet {0, 1} are shifted through the shift registers in response to clock pulses. The content of the stages, which are identical to their outputs, are logically combined to produce input to the first stage. The initial contents of the stages and the feedback logic determine the successive contents of the stages. If the feedback logic consists of entirely of modulo-2 adders (exclusive-OR gates), a feedback shift register and its generated sequence are called linear.

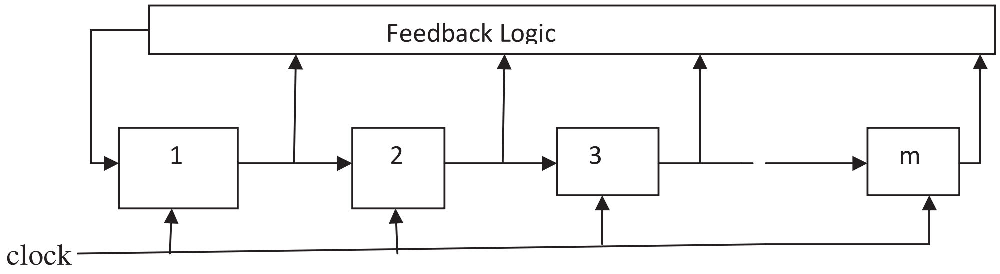


Figure 2.2.2 General feedback shift register with m stages [1]

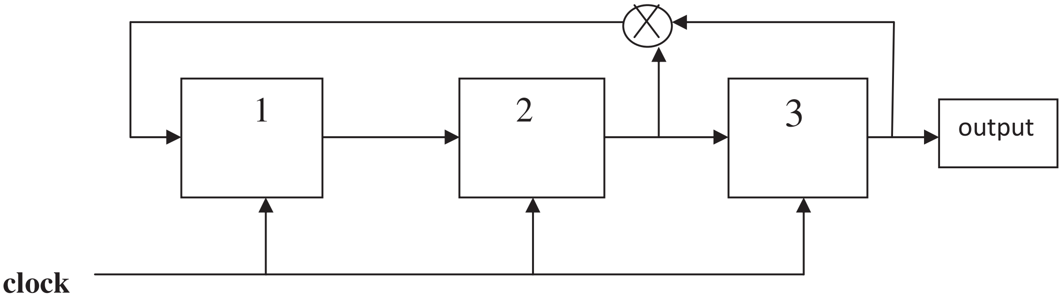


Figure 2.2.3 Three stage linear feedback shift register [1]

Shift	Stage 1	Stage 2	Stage 3
Initial	0	0	1
1	1	0	0
2	0	1	0
3	1	0	1
4	1	1	0
5	1	1	1
6	0	1	1
7	0	0	1

Table 2.2 Contents after successive shifts

Figure 2.2.3 shows a linear feedback shift register with three stages and an output sequence extracted from the final stage. The input to the first stage is the modulo-2 sum of the contents of second and third stages. After each clock pulse, the content of the first two stages are shifted to the right, and the input to the first stage becomes its content. If the initial content of the shift-register stages are [0 0 1], the subsequent contents after successive shifts are listed in Table 2.2.Since, the shift register returns to its initial state after seven shifts, the periodic output sequence extracted from the final stage has a period of 7 bits.

2.3 Generator Polynomials

Finite (Galois) field mathematics are used to derive m-sequence feedback taps. Any LFSR can be represented as a polynomial of variable X, referred to as the generator polynomial.

$G(X) = g_m X^m + g_{m-1} X^{m-1} + g_{m-2} X^{m-2} + . . .+ g_2 X^2 + g_1 X + g_0$

The coefficients g_i represents the tap weights, and are 1 for taps that are connected (feedback), and 0 otherwise. The order of the polynomial, 'm' represents the number of LFSR stages. Rules of linear algebra apply to the polynomial, but all mathematical operations are performed in modulo-2:

Modulo-2 addition:

$0 + 0 = 0$

$0 + 1 = 1$

$1 + 1 = 0$

Modulo-2 multiplication:

$0 * 0 =0$

$0 * 1 = 0$

$1 * 1 = 1$

The generator polynomial of m-sequence is primitive polynomial. g(X) is a primitive polynomial of degree m if the smallest interfere n for which g(X) divides $X^n + 1$ is $n = 2^m-1$. The generator polynomial is said to be primitive if it cannot be factored (i.e. it is prime). As mentioned above the sequence for n^{th} coefficient can be written in a mathematical equation as:-

$$a_n = c_1a_{n-1} + c_2a_{n-2} + \ldots\ldots + c_ra_{n-r} =\sum_{i=1}^{r} c_i\, a_{n-I} \qquad (2.1)$$

Where, c_1 to c_r are connection variables (1 for connection and 0 for no connection)

Multiplication is simple and addition is modulo-2(or "Exclusive XOR"). In the above equation linear

$$G(D) = a_0 + a1D + a_2D2 + \ldots = \sum_{n=0}^{\infty} a_n D^n$$

Where D is the delay operator and number of clock cycles of delay is the power of D of polynomial.

On combining equation (2.1) and (2.2), now we can reduce the equation (2.1) to finite recurrence relation

$$G(D)= \sum_{n=0}^{\infty} a_n D^n = \sum_{n=0}^{\infty}\sum_{i=1}^{r} a_n D^n$$

$$= \sum_{i=1}^{r} c_i D^i \left[\sum_{n=0}^{\infty} a_{n-1} D^{n-1} \right]$$

$$= \sum_{n=0}^{\infty} ci\ D^i [a_{-i}D^{-i}+....+ a_{-1}D^{-1} +G(D)]$$

Now we express the G(D) as a ratio of finite polynomials as

$$G(D)(1 - \sum_{i=1}^{r} c_i D^i) = \sum_{i=1}^{r} c_i D^i [a_{-i}D^{-i} +....+ a_{-1}D^{-1}]$$

$$G(D)=\left(\sum_{i=1}^{r} c_i D^i [a_{-i}D^{-i} +....+ a_{-1}D^{-1}]\right)/\left(\sum_{i=1}^{r} c_i D^i\right) = \left(g_0(D)\right)/\left(f(D)\right) \qquad (2.3)$$

Where $f(D)=1- \sum_{i=1}^{r} c_i D^i$ (2.4)

f(D) is called the characteristic Polynomial of the shift register sequence generator and depends solely on the connection vector $c_1,...,c_r$. The polynomial $g_0(D)$ depends as well on the initial condition vector $a_{-r},a_{-r-1},... a_{-1}.g_0(D)$ can be written as:

$$G_0(D)= \sum_{i=1}^{r} c_i (a_{-i} +a_{-i}D + ... +a_{-i}D^{i-1}) \qquad (2.5)$$

$$=c_1a_{-1} + c_2(a_{-2}+a_{-1}D) + (a_{-3} + a_{-2}D +a_{-1}D^2) + ... +c_r(a_{-r} + a_{-r+1} + ... a_{-1} D^{r-1}).$$

In the above equation, of all the connections variables, at least $c_r=1$, for otherwise the shift register would no longer need to have r stages .Here we consider the initial vector:

$a_{-r}=1$, $a_{-r+1}=...=a_{-2}=a_{-1}=0$,

in which case (2.5) and (2.3)reduce to

$$G_0(D)=1 , G(D)=1/ f(D) \qquad (2.6)$$

The mathematics used is very useful in determining the Generator polynomial. But engineers don't need to do all those calculations, as Generating Polynomials for many m-sequences are available in different literatures.

Number of shift Register stages, N	Sequence Length $L=2^N-1$	Number of m-sequences	Example Generating Polynomial
2	3	1	X^2+X+1
3	7	2	X^3+X+1
4	15	2	X^4+X+1
5	31	6	X^5+X^2+1
6	63	6	X^6+X+1
7	127	18	X^7+X+1
8	255	16	$X^8+X^6+X^5+X+1$
9	511	48	X^9+X4+1
10	1023	60	$X^{10}+X^3+1$
11	2047	176	$X^{11}+X^2+1$

Table 2.3 Maximal length Shift Register Sequences [5]

Though this table enlists some of the m-sequences, but there are many more sequences available for a particular length.

2.4 Properties of PN Sequences

PN sequences are deterministic but random like sequences, that is, they appears to be random within the sequence length, fulfilling the needs of randomness and after then the entire sequence repeats indefinitely .As multi user applications demand that the data appear random to the channel but be predictable to the user. This is where Pseudo noise sequences become useful. Some, of the important properties of PN sequence are as follows:

1. **Run Length**

In a PN sequence of any length the numbers of ‘1’s and ‘0’s differ only by one, i.e. the number of ‘1’s is just one more than the number of ‘0’s. For example, the PN sequence of length 15 contains eight ‘1’s and seven ‘0’s. A sequence of consecutive ‘l’s, or ‘0’s, is called a ‘run’ and the number of ‘1’s and ‘0’s are the run length. A PN sequence of length 2N- 1 contains one run of N ‘l’s and one run of **N-** 1 ‘0’s.The number of other runs, N- 2 to 1, of ‘1’s and ‘0’s increases as the power of 2.

2. Shift and Add

When a PN sequence is shifted and the shifted sequence modulo-2 added to the not shifted sequence with an exclusive-OR gate, the result is the same PN sequence with some other shift. For multi user application, all the cyclic shifted versions of a PN sequence are considered to be same. So, we need to generate different PN sequences for each user using different tap positions.

3. **Balance Property**

PN sequence contains 2^ (m-1) ones and 2^ (m-1)-1 zeros. In each period the number of 1’s is always one more then number of 0’s.

4. **Autocorrelation Property**

The normalized periodic autocorrelation function of an m sequence, defined as□

□□□□□

$$r(i) = 1 \qquad \text{for } i = 0$$

$$= -1/N \qquad \text{for } 1 <= |i| <= N-1$$

2.5 Periodic Autocorrelation of PN Sequence

The m-sequences have the best periodic autocorrelation in terms of minimizing the maximum value of the out-of-phase autocorrelation. It is best utilized if the synchronization window is longer than the own period. As the incoming sequence repeats after the fixed interval of time, the resultant values are always [1,-7] or [-1, 7] and peaks are occurring at the integral multiple of time period of PN sequence.

1	1	1	0	0	1	0	Autocorrelation Value
0	1	1	1	0	0	1	-1
1	0	1	1	1	0	0	-1
0	1	0	1	1	1	0	-1
0	0	1	0	1	1	1	-1
1	0	0	1	0	1	1	-1
1	1	0	0	1	0	1	-1
1	1	1	0	0	1	0	+7

Table: 2.5 Periodic Autocorrelation

As shown in Table2.5 One PN sequence has been kept fixed and the second same PN sequence is shifted cyclically bit by bit. With each bit shift the sequence is multiplied with the original sequence and added to give a desired value. As the incoming sequence repeats periodically, thus the value will also be periodic in nature, and have maximum peak of 7 or -7 at integral multiple of time period of sequence.

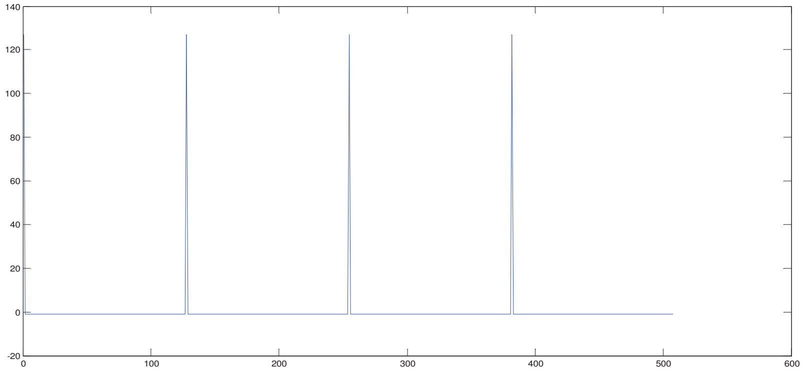


Figure 2.5: Periodic Autocorrelation of PN Sequences

2.6 Aperiodic Autocorrelation

If the synchronization window is only one period long or less, then the correlation is Aperiodic.

A formal definition of a Aperiodic autocorrelation of

X=(x0, x1,x2,…xN-1) is given by

$$C_{x,x}(i) = \sum_{j=0}^{N-1-i} XiXj + 1 \qquad 0 \leq i \leq N\text{-}1$$

$$= \sum_{j=0}^{N-1-i} Xj - 1Xj \qquad - N\text{-}1 \leq i \leq 0$$

1	1	1	0	0	1	0	Autocorrelation value
0							-1
1	0						0
0	1	0					-1
0	0	1	0				0
1	0	0	1	0			-1
1	1	0	0	1	0		0
1	1	1	0	0	1	0	7

Table 2.6 (Aperiodic Autocorrelation)

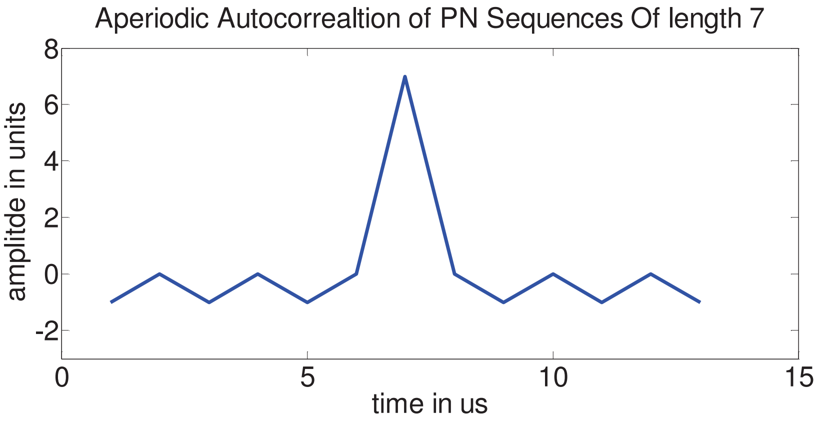


Figure 2.6 Aperiodic Autocorrelation of PN Sequences

2.7 Number of PN codes

With an N-bit shift register more than one sequence of length $L = 2^N - 1$ can be generated using different taps for feedback. Each sequence is different from the others, although of the same length. Table 3.1 gives the sequence length, L, for register lengths, N, up to 255, the maximum possible number of PN codes, C, and some of the taps to be used for feedback. One interesting observation is that for a given tap set there is a mirror that also provides a maximal length sequence. For example, the mirror of {5, 3} is {5, 2}, that of {6, 5} is {6, 1} etc. In the mirror set the first number, which is the register length N, is fixed. The other numbers in the mirror are obtained by subtracting the numbers in the original set from N. The maximum number of PN codes that can be generated with an N-bit register is of interest in spread spectrum communication, where each user must use a different code. For a sequence length L, the maximum number, C, of possible codes is given by

I. $C = 1/N \quad \Pi\{P_i^{\alpha i-1}(P_i-1)\}$

Where Pi are prime factors of α ; a_i are power of the i^{th} factor

2. When L is favorable with i distinct factors then

$C = \Pi(P_i - 1)/N$

3. When L is the prime number

$C = (2^N-2)/N$

L	$N=2^L-1$	Feedback Taps for M-sequences	# m-sequences
2	3	[2,1]	2
3	7	[3,1]	2
4	15	[4,1]	2
5	31	[5,3] [5,4,3,2] [5,4,2,1]	6
6	63	[6,1] [6,5,2,1] [6,5,3,2]	6

7	127	[7,1] [7,3] [7,3,2,1] [7,4,3,2] [7,6,4,2] [7,6,3,1] [7,6,5,2] [7,6,5,4,2,1] [7,5,4,3,2,1]	18
8	255	[8,4,3,2] [8,6,5,3] [8,6,5,2] [8,5,3,1] [8,6,5,1] [8,7,6,1] [8,7,6,5,4,2,1] [8,6,4,3,2,1]	16

Table 2.7.1 Different Tap positions for PN Sequence [1]

For N shift registers the peak correlation value of PN sequence is 2^n-1as shown in fig. 2.6.1 which is more than the required threshold value. In spite of, all the above shown properties of PN sequences, they are not widely used in communication system .The reason is that the cross correlation value of any two random pair of sequences is not as good as expected. This suggests that PN sequences are not suitable for multi user applications. Therefore, to overcome this limitation we need to choose certain preferred pair of PN sequences, which upon XORing shows low cross correlation properties. These resulted sequence, are thus called gold sequences. For any pair of gold sequence, one can get good cross correlation values. A famous mathematician and coding researcher Dr. Gold suggested some preferred pair of sequences .the product of these preferred pair sequence generate another sequences known as **Gold sequence.**

Gold codes have bounded small cross-correlations within a set, which is useful when multiple devices are broadcasting in the same frequency range. A set of Gold code sequences consists of $2^n - 1$ sequences each one with a period of 2^n-1.

CHAPTER 3

GOLD SEQUENCES

3.1 Introduction

A set of Gold codes can be generated using two shift registers and one modulo adder. For this we require two maximum length sequences of the same length $2^n - 1$ such that their absolute cross-correlation is less than or equal to $2^{(n+2)/2}$, where n is the size of the LFSR used to generate the maximum length sequence. The set of the $2^n - 1$ exclusive-ors of the two sequences in their various phases (i.e. translated into all relative positions) is a set of Gold codes. The highest absolute cross-correlation in this set of codes is $2^{(n+2)/2}+1$ for even n and $2^{(n+1)/2}+1$ for odd n.

The cross correlation of gold sequence gives three values as given in Table 3.2.

The exclusive or of two different Gold codes from the same set is another Gold Code in some phase. Within a set of Gold codes about half of the codes are balanced the number of ones and zeros differs by only one.

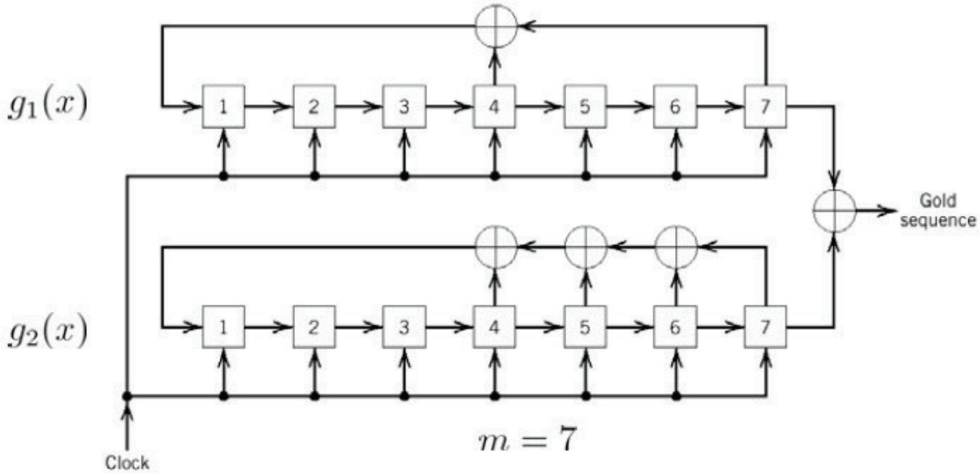


Figure 3.1 Gold Sequence Generation [1]

$g_1(x)$ and $g_2(x)$ are two maximum-length shift-register sequences of period $2m - 1$, whose "cross-correlation" lies in: {-1, -t(m), t(m)-2}, Where $t(m) = 2^{(m+1)/2} + 1$, m odd

$= 2^{(m+1)/2} + 1$, m even

The autocorrelation of PN sequence is very good but the cross correlation is not too good for CDMA and also the number of codes generated from PN sequence is less in number.

For this reason a particular class of PN sequences are used that is called GOLD sequence. They are chosen such that the cross correlation values between the codes over a set of codes are uniform and bounded.

GOLD sequence generated by modulo 2 operation of two preferred PN sequence of same length .The code sequence is added chip by chip.

Every change in phase position between the two preferred PN cause a new GOLD sequence.

$$R_{x,y}(i) = \sum_{j=0}^{N-1-i} x_j y^*{}_{j+1} \quad ,0<=i<=N-1$$

$$= \sum_{j=0}^{N-1+i} x_j - 1 y_j{}^* \quad ,-(N-1)<=i<=0$$

Three Valued Cross Correlation of Gold sequence

m Shift Register	Period	Cross – Correlation
m odd	$N = 2^m - 1$	$-1,-(2^{(m+1)/2} + 1),(2^{(m+1)/2} - 1)$
m even	$N = 2^m - 1$	$-1,-(2^{(m+2)/2} + 1),(2^{(m+2)/2} - 1)$

Table 3.1 Three Valued Cross Correlation of Gold sequence [1]

3.2 Properties of Gold Codes

- The number of Gold Codes is more than m sequences for the same number of registers.
- Any change in phase between the two generators causes a new sequence to be generated.
- The cross correlation function is uniform and bounded.

3.3 Applications of Gold Codes

- The Gold Code algorithm supports CDMA, Frequency hopping multiple accesses and ultra wide band spread spectrum communication systems.
- Gold Codes are used in Cell Phones, Secure wireless computer networks and military field radios and various other applications.

CHAPTER 4

BASIC TRANSMITTER AND RECEIVER ARCHITECTURE FOR DSSS (WITHOUTMODULATION)

4.1 Introduction:

In actual cases, the designing of a practical communication system is being done with the concept of modulation in it. So in order to reduce its complexity firstly, we need to design a basic architecture for DSSS system.

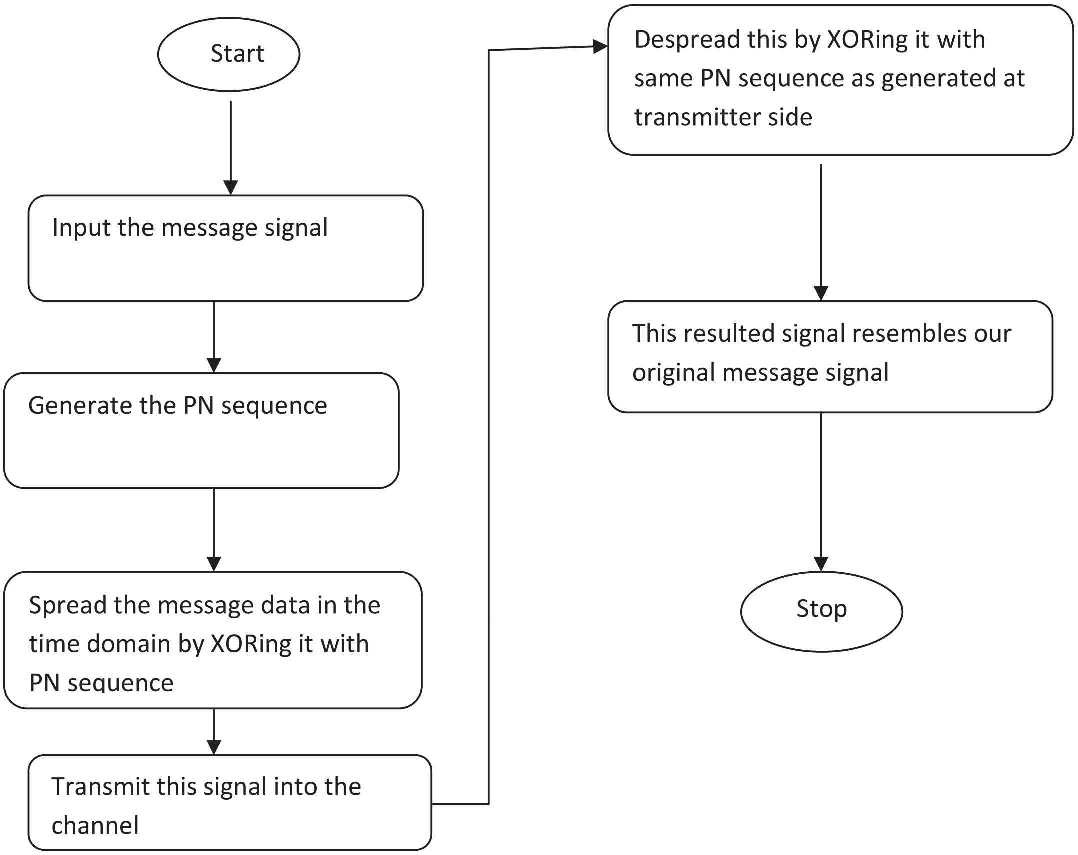


Figure 4.1.1 Basic flow chart for DSSS system

Direct sequence spread spectrum transmitter multiplies the data being transmitted by a deterministic but noise like signal. This noise like signal is pseudo random sequence of 1 and -1 values, at a frequency much higher than that of the original signal. The resulting signal resembles with the white noise in terms of its power spectral density. However this noise like signal is used to exactly reconstruct the original data at the receiving end, by multiplying it by the same pseudorandom sequence. This process is known as "despreading", which mathematically constitutes a correlation of the transmitted PN sequence that the receiver already knows the PN sequence.

4.2 Transmitter Architecture

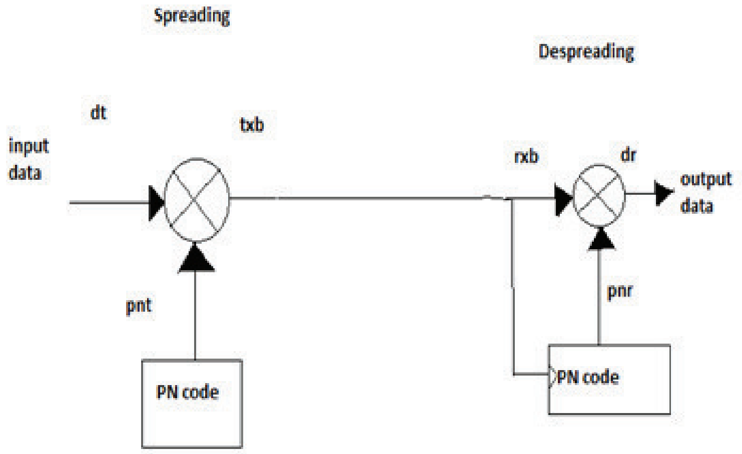


Figure 4.2.1 Basic Design of DSSS Transmitter

Each bit in original signal is represented by multiple bits (chips) in the transmitted signal Spreading code spreads signal across a wider frequency band

Spread is in direct proportion to number of bits used e.g. exclusive-OR of the bits with the spreading code. The resulting bit stream is used to modulate the signal
Since each bit it sent as multiple chips, you need more bps bandwidth to send the signal. Number of chips per bit is called the spreading ratio.

In a basic transmitter architecture, the information signal d_t having bandwidth BW_{data} is being spread over a larger bandwidth BW_{ss}, by multiplying it with the generated spreading sequence.

$$BW_{data} = R_s \quad << \quad BW_{ss} = R_c$$

The SS-signal spectrum is white noise-like.the amplitude and thus the power in SS-signal t_{xb} is the same as in the original information signal d_t. Due to the increased bandwidth of SS-signal the power spectral density must be lower. The bandwidth expansion factor, being the ratio of the chip rate R_c and the data symbol rate R_s, is usually selected to be an integer in SS systems.

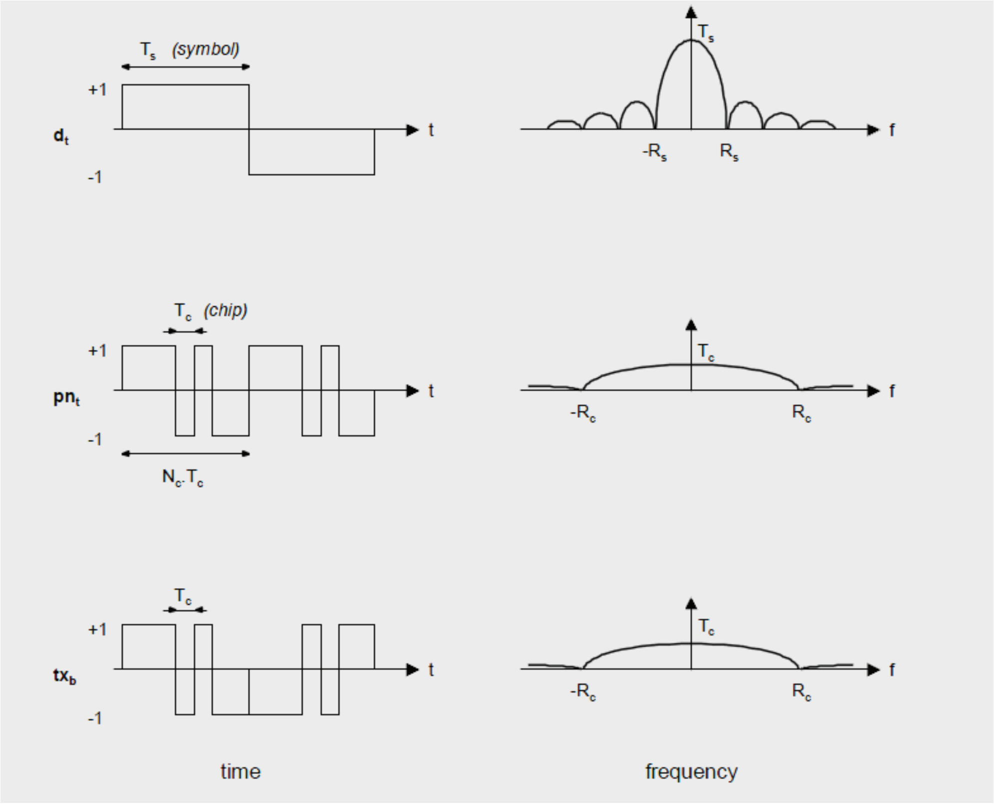


Figure 4.2.2 Spreading Spectral Signal

As shown in the figure 4.2.2, we have 2 bit message data d_t [1 0] being represented in both time domain and frequency domain. Each message bit is of duration Ts. Also, the second waveform shows the PN sequence of 7 bit having, each bit duration of Tc.

To modulate the message signal dt is multiplied with the PN sequence PNt, thus give us a signal having same bandwidth as that of PN sequence. This process is called “Spectrum spreading”. The resulted signal is same as that of PN sequence when message bit is 1 and in other case when message signal is 0 it is the inverted version of PN sequence.

4.3 Basic DSSS Receiver Architecture

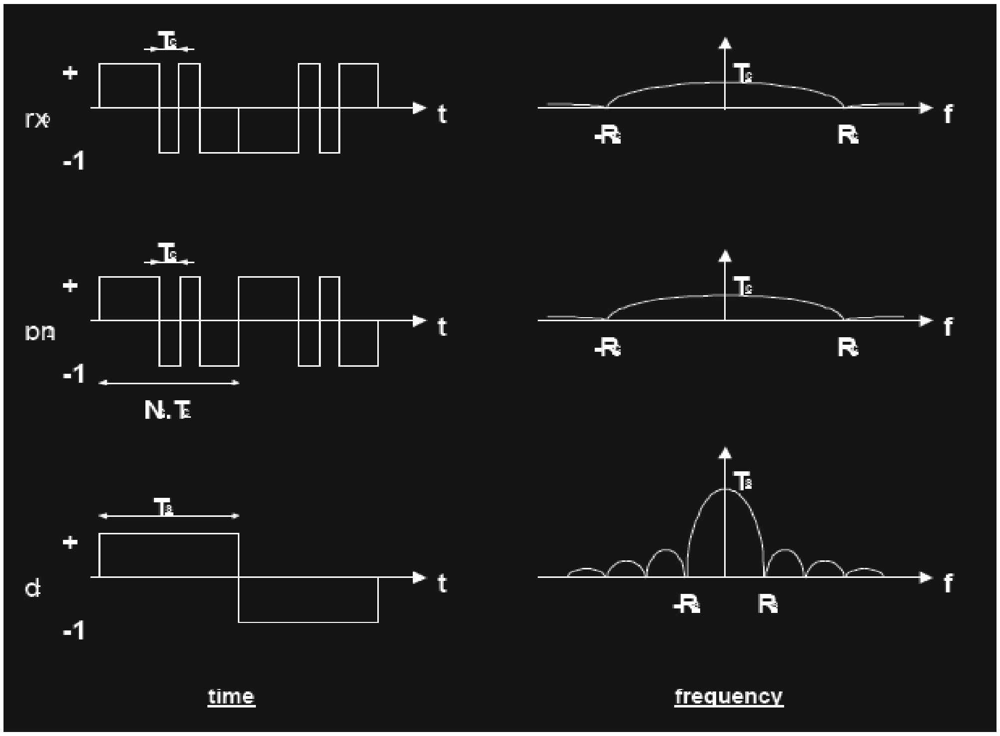


Figure 4.3.1 Despreading Spectral Signal

Two PN decorrelators's architectures can be used for dispreading spread spectrum signals: the matched filter and the active correlator.

4.3.1 Matched filter

A matched filter is a filter used in communications to "match" a particular transit waveform. It passes all the signal frequency components while suppressing any frequency components where there is only noise and allows to pass the maximum amount of signal power. The purpose of the matched filter is to maximize the signal to noise ratio at the sampling point of a bit stream and to minimize the probability of undetected errors received from a signal

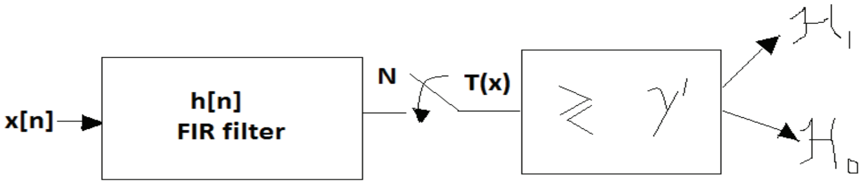


Figure 4.3.1.1: Block Diagram of Correlation Detector

To achieve the maximum SNR, we want to allow through all the signal frequency components, but to emphasize more on signal frequency components that are large and so contribute more to improving the overall SNR.

Let us consider a received model, involving a linear time-invariant (LTI) filter of impulse response h(t).

Let spreading waveform be

$$\mathrm{P(t)} = \sum_{i=-\infty}^{\infty} P_i(t - iT)$$

Where Pi(t) is one period of spreading waveform with T period.

$$P_i(t) = \left\{ \sum_{i=0}^{N-1} a_i(t - iT) 0 \le t \le T \right.$$

0 otherwise

$a_{i\,=}$ ±1 $\quad$ $T = NT_c$

Now consider x(t) lie [0 T]

Since Matched filter impulse response h(t) = x(T-t)

Filter output y(t)= $\int_{-\infty}^{\infty}$ x(u)h(t-u) du ,since y(t) = x(t)*h(t)

$$= \int_{-\infty}^{\infty} x(u)x(T-t+u)\,du$$

$$y(t) = \int_{\max(t-T,0)}^{\min(t,T)} x(u)x(T-t+u)\,du$$

We know that autocorrelation $R_x(\tau) = \int_{-\infty}^{\infty} x(u)x(u+\tau)\,du$

$y(t) = R_x(t-T)$

If output sampled at t=T => $y(T)=R_x(0)$ signal energy

Goal of the linear receiver:

To optimize the design of the filter so as to minimize the effects of noise at the filter output and improve the detection of the pulse signal.

Signal to noise ratio

$$SNR = \frac{|g_o(T)|^2}{\sigma_n{}^2} = \frac{|g_o(T)|^2}{E[n^2(t)]}$$

Where $|g_o(T)|^2$ is the instantaneous power of the filtered signal, g(t) at point t = T, and σ_n^2 is the variance of the white Gaussian zero mean filtered noise.

4.3.2 Correlation Detector

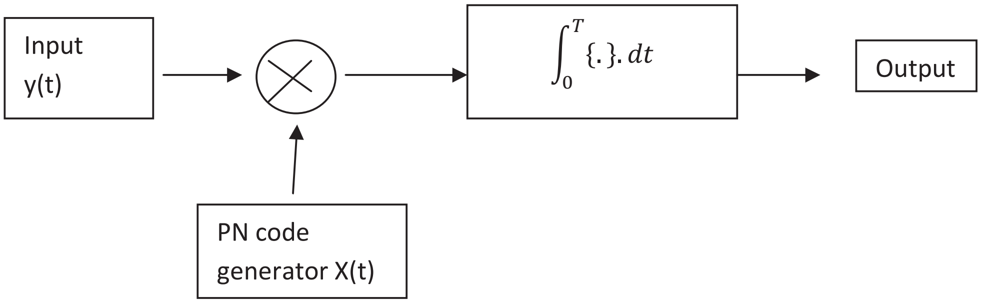


Figure 4.3.2.1 Block Diagram of Correlation Detector

A practical realization of the optimum receiver is the correlation detector. The detector part of the receiver consists of a bank of M product-integrators or correlators, with a set of orthonormal basis function that operates on the received signal to produce the observation vector. The signal transmission decoder is modeled as a maximum-likelihood decoder that operates on the observation vector to produce an estimate. When timing information is already available, then the simpler active PN correlator receiver can be used. This receiver only operates correctly when the local sequence is accurately matched and correctly timed, with respect to the spreading code within the received signal. Synchronization can be obtained by sliding the reference signal through the received signal. This can be an extremely slow process, however, for large spreading waveforms.

4.5 Synchronization of Spread Spectrum Systems

In practical scenario the system architecture is not ideal in nature as the system may suffer from various faults such as clock jitter, system error etc which may cause the delay in the sequence starting point.

In encryption systems, synchronization is a very important factor as it ensures that the receiving cipher is decoding the right bits at the right time. Although, there are many types of synchronizations like clock, carrier, data etc but in our project we have taken only data synchronization into consideration by assuming that clock and carrier synchronization has already been maintained.

Let us assume that the PN sequence generated at the receiver is different from the one generated at the transmitter. Now when the received signal is multiplied with this sequence, we will not be able to get a copy of our original message signal and thus causes a main problem in the data retrieval at the receiver end.

With unsynchronized case, the signal after multiplication at receiver side is:

$$d_r = rx_b \, . \, pn_r = \quad (d_t.pn_t).pn_r$$

$$\Rightarrow \; dr \neq dt$$

Echnology

Thus, it shows that there is a proper need of synchronization of data, detection of the desired message signal is achieved by correlation against a local reference PN sequence. For secure communication is multi-user environment, the transmitted data d_t may not be recovered by a user that does not know the PN sequence PN_t used at transmitter. Therefor :

Crosscorrelation $R_c(\tau)$=average($PN_t.PN_r$)<<1 for all τ is required.

4.6 Multiuser DSSS (CDMA)

The successful use of CDMA technology is based on the construction of large families of encoding sequences with good correlation properties. CODE-DIVISION MULTIPLE-ACCESS (CDMA) based on Spread Spectrum (SS) has emerged as one of the most important multiple access technologies for the second and third generations (2G-3G) wireless communication systems. The CDMA system is always considered as an interference-limited system mainly due to the existence of multiple-access interference (MAI) and multipath interference (MI). Many problems of a communication system based on CDMA technology stem from the unitary spreading codes/sequences, which includes two sub-categories, one being the orthogonal codes, such as Walsh-Hadamard codes and orthogonal variable spreading factor (OVSF) codes, and the other being pseudo-random or pseudo-noise (PN) sequences, such as Gold sequences, Kasami sequences, m-sequences, etc…

Pseudo-Random CDMA codes have been found to be more suitable for their use in many wireless applications since orthogonal CDMA codes usually perform extremely bad if they are used for asynchronous channel transmissions whereas other category of CDMA codes offer relatively uniform performance for their operation in both synchronous and asynchronous channels. But PN sequences are statistically uncorrelated, and the sum of a large number of PN sequences results in MAI(multiple access interference).

Pseudo Noise (PN) sequence generators generate PN codes which appear random yet they are completely deterministic in nature with a small set of initial conditions. The security of the concerned system is hence undesirably compromised at times. Practically the quality of transmission takes a toll as the number of users increases for a given code length. Spreading codes with good cross correlation properties have great significance in multi-user DS-CDMA.

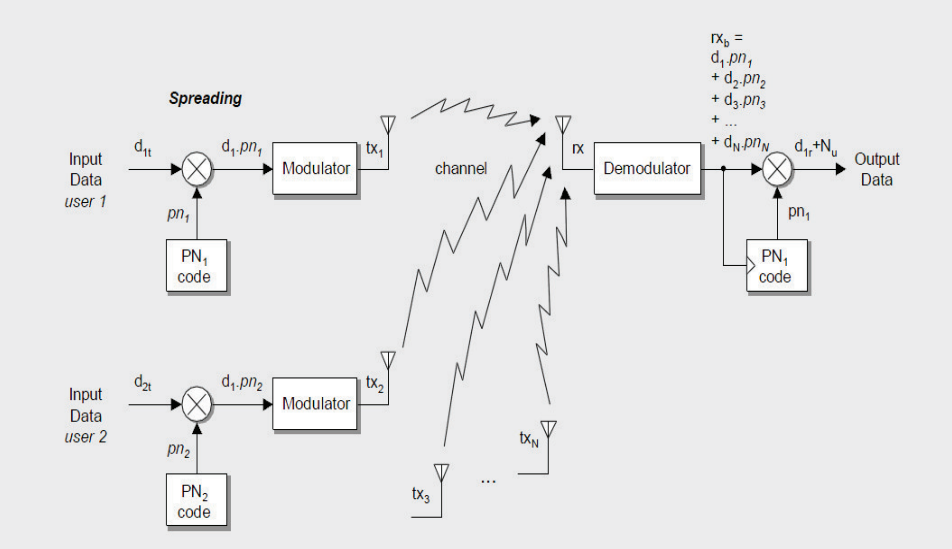


Figure 4.6 Block Diagram of DS-CDMA System [1]

For all the code division multiple access (CDMA) protocols, it is important that a distinguish codes are assigned to the different users. Thus it is possible to separate between the signal of a desired user and the signals of other interfering users. Usually the separation is made by correlating the received signal with a locally generated code of the desired user. The auto correlation of the code is also a very important aspect because this decides how well we are able to synchronize and lock the locally generated code signal to the received signal.

The maximum length sequence (m-sequence) which is generated by linear feedback shift registers (LFSR) is a good approximation for such codes that is why it generally employed in CDMA systems. A good measure of the rejection of the signals of interfering users is the ratio *R* of the maximum cross correlation coefficient and the auto correlation coefficient. The smaller this ratio is the better the interfering users' rejection.

Basically, code division multiple access (CDMA) is a method of multiplexing (wireless) users by distinct (orthogonal) codes. All users can transmit at the same time, and each is allocated the entire available frequency spectrum for transmission. CDMA is also known as spread spectrum multiple access (SSMA).

CDMA does not require the bandwidth allocation of FDMA, nor the time synchronization of the individual users needed in TDMA. A CDMA user has full time and full bandwidth available, but the quality of communication decreases with an increasing number of users (increase in BER).

In CDMA each user:

1.) Has its own PN code.
2.) Uses the same RF bandwidth.
3.) Transmits simultaneously(asynchronous or synchronous)

Correlation of the received baseband spread spectrum signal with the PN sequence of the desired user only despread the signal of that one user. The other users produce noise for that user only that portion of the noise produced by the other users falling in the information bandwidth of the receiver will cause interference with the desired signal.

The set of PN codes must have desired properties:

1.) Autocorrelation for good synchronization.
2.) Low crosscorrelation (orthogonal codes) for low MAI (multiple access interference).

Useful codes are:

1.) Gold codes, kasami Codes (asynchronous CDMA).
2.) Walsh-Hadamard Codes (synchronous CDMA).

Kasami codes are binary sequences of length 2^N-1 where N is an even integer. Kasami sequences have good cross-correlation (Low) values. There are two classes of Kasami sequences - the small set and the large set.

Small Set:

Let **u** be an m sequence and **w** be the decimation sequence of **u**

i.e. $\mathbf{w} = \mathbf{u}[\mathbf{s}(n)]$ where $\mathbf{s}(n) = 2^{n/2} + 1$.

w is a periodic m sequence with a smaller period equal to $2^{n/2} + 1$.
By adding the two m sequences for different cyclic shifts, we get $2^{n/2}$ sets of Kasami sequences.
The small set Kasami sequences is defined by the following formulas, in which **T** denotes the left shift operator is the shift parameter for **w**, and + denotes modulo-2 addition.

$$K_S(u, n, m) = \begin{cases} u & m = -1 \\ u \oplus T^m w & m = 0, \ldots, 2^{n/2} - 2 \end{cases}$$

Large Set:

The Large set Kasami sequences is defined as follows. Let **v** be the sequence generated by decimating the sequence **u** by $2^{n/2+1}$ + 1.The Large set is defined by the following table, in which k and m are the shift parameters for the sequences **v** and **w**, respectively.

$$K_L(u, n, k, m) = \begin{cases} u & k = -2, m = -1 \\ v & k = -1, m = -1 \\ u \oplus T^k v & k = 0, \ldots, 2^n - 2, m = -1 \\ u \oplus T^m w & k = -2, m = 0, \ldots, 2^{n/2} - 2 \\ v \oplus T^m w & k = -1, m = 0, \ldots, 2^{n/2} - 2 \\ u \oplus T^k v \oplus T^m w & k = 0, \ldots, 2^n - 2, m = 0, \ldots, 2^{n/2} - 2 \end{cases}$$

The sequences described in the first three rows correspond to Gold codes. In fact, Gold codes are a special case of Kasami codes.

The correlation functions for the sequences take on the values

{- t (n), - s (n), - 1, s (n)-2, t (n)-2}

t (n) = 1+ $2^{n+2/2}$,n even

and s(n) = ((t (n) + 1)/ 2)

CHAPTER 5

ADVANCED TRANSMITTER AND RECEIVER ARCHITECTURE FOR DSSS

(WITH MODULATION)

5.1 Introduction:

In real communication systems, the data is being sent on wireless medium using antennas. As the frequency of transmitted signal is less which may lead to increase in antenna height and makes our system impractical. So, in real communication system design, modulation is an important step to be implemented. Also in wireless communication, multiplexing can only be implemented effectively if modulation is considered.

Basic premise is to add additional modulation to the digitally-modulated signal that increases its bandwidth, which will increase the processing gain.

In our project, we have employed BPSK modulation. In case of direct sequence technique of spread spectrum, the spreading signal is used to modulate a carrier, usually by phase- shifting keying (BPSK-Binary phase shift keying) at the code rate. Direct sequence technique will generate a wideband signals which are controlled by the code- sequence generator. In direct sequencing, modulation is used to generate the transmitted signal. After modulation we do spreading by multiply PN sequence to the modulated signal. The spreading signal now has more bandwidth then the message signal .This helps to hide the signal, that would contribute to interference rejection.

5.2 Transmitter Architecture:

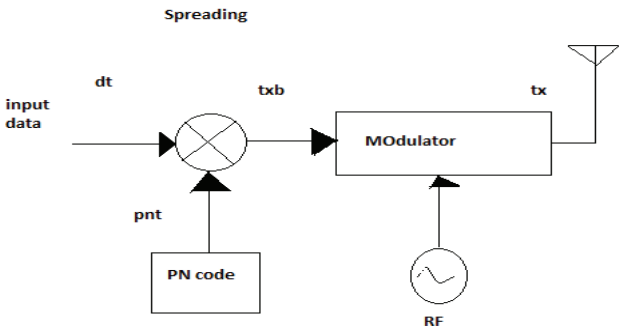


Figure 5.2 Transmitter block diagram for DSSS system

One needs to follow various steps in transmitter implementation:

1. Spread the input data d_t by multiplying it with generated PN sequence pn_t.
2. This signal tx_b need to be modulated by multiplying it with the carrier signal (cosine wave) of a frequency greater than the modulating signal frequency.
3. Transmit the modulated signal t_x into the channel.

The BPSK signal is given by

$S_d(t)=Ad(t)\cos(2\pi fct)$

-d(t) is the information data

$d(t)=\sum_{n=-\infty}^{+\infty} dnpTb(t-nTb)$, $d_n=\pm1$

After spreading the transmitter signal becomes

$s(t)=s_d(t)c(t) = a\, d(t)\, c(t)\cos(2\pi fc\, t)$

c(t)is the spreading code

$c(t)=\sum_{i=0}^{k-1} ci\, PTc\,(t-iTc)$, $0 \le t < T_b = kT_c$ $c_i=\pm1$

At the receiver, de-spreading is used to recover the information

$y(t)= s(t)\, c(t) = Ad(t)c^2(t)\cos 2\pi fc\, t = Ad(t)\cos 2\pi fc\, t$

5.3 Receiver Architecture

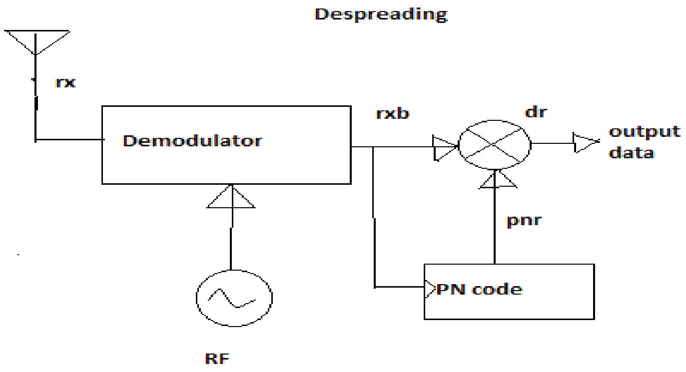


Figure 5.3 Receiver Architecture for DSSS with Demodulation

Once the signal is coded, modulated and then sent, the receiver must demodulate the signal. This is usually done in two steps:

1. Spectrum-spreading (e.g., direct sequence or frequency-hopping) modulation is removed.
2. The remaining information-bearing signal is demodulated by multiplying with a local reference identical in structure and synchronized with the received signal.

Step 1: Demodulation

In the first step the received signal is multiplied with the locally generated carrier signal, in order to get the demodulated signal. This signal will be similar to the spreading signal resulted at the transmitter.

Step 2: Despreading

In spectrum despreading, the demodulated signal is multiplied with the synchronized PN sequence, which results into a signal similar to original data pattern.

CHAPTER 6

SIMULATION AND RESULTS

6.1 Aperiodic Autocorrelation of PN Sequences

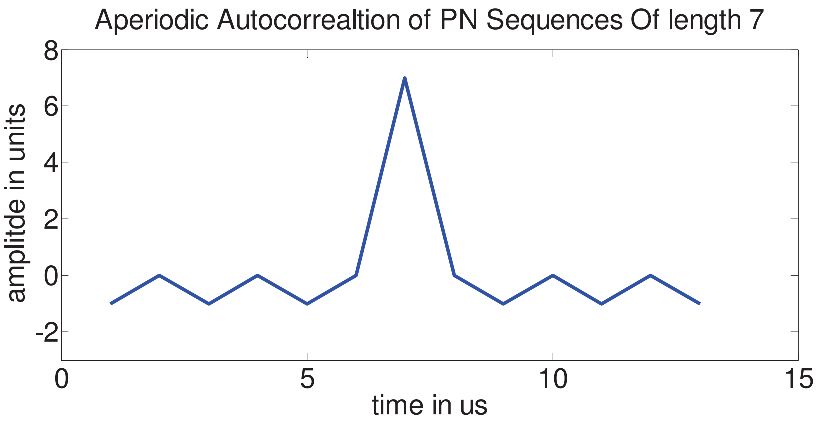


Figure 6.1 Aperiodic Autocorrelation of PN Sequences

Figure 6.1 shows the Aperiodic Autocorrelation of 7 length PN sequence. Only at integral multiple of period of PN sequence we are getting the peak value i.e.7 and at all other points we have either 0 or -1.

6.2 Periodic Autocorrelation of PN Sequences

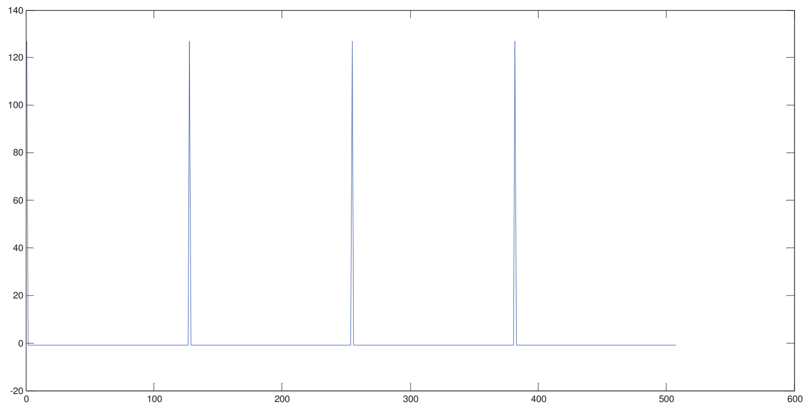


Figure 6.2: Periodic Autocorrelation of PN Sequences

Figure 6.2 shows the periodic Autocorrelation of 127 length PN sequence. Only at integral multiple of period of PN sequence we are getting the peak value i.e.127 and at all other points we have -1 value.

6.3 Comparison between Crosscorrelation of PN and GOLD Sequences

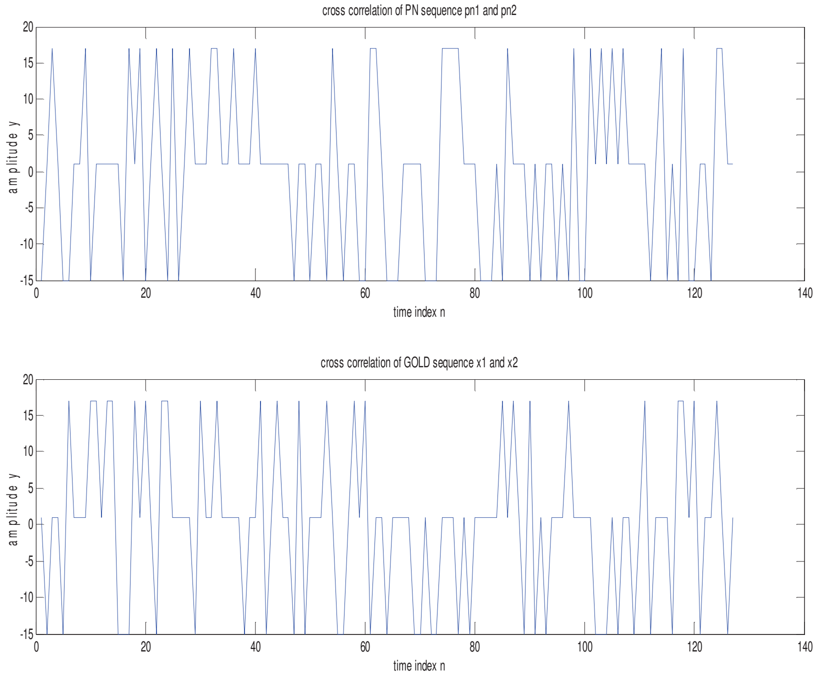


Figure 6.3 Comparisons between Crosscorrelation of PN and GOLD Sequence

From figure 6.3, we have found that the cross correlation value of Gold Sequences is less than equal to PN sequences, which is what required for multi user applications. Thus, our results are matching with the theoretical results. Also with low cross correlation value of Gold Sequences we can generate more number of unique codes which are required by each user for code divison multiple access communication.

6.4 Implementation of DSSS Receiver on Matlab

6.4.1 Matched filter Implementation

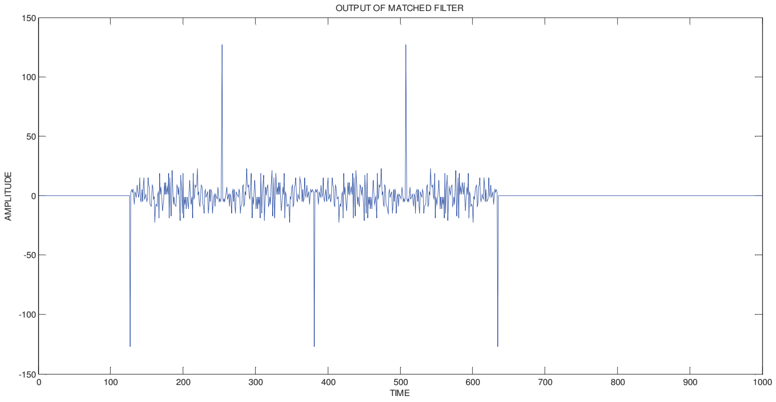


Figure 6.4.1: Matched filter Implementation on Matlab for 127 Length PN sequence

Clearly seen from figure 6.4.1 we are able to get the matched filter output peak value at the sampling positions and at other positions we have less peak value (much less than the threshold value).

6.4.2 Correlation Detector Implementation on Matlab

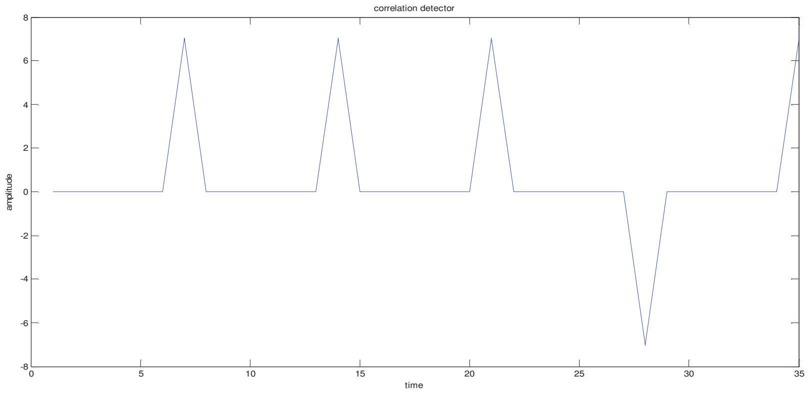


Figure 6.4.2 Correlation Detector Implementation on MATLAB for 127 Length PN Sequence

Figure 6.4.2 shows the output of correlation detector for synchronized received signal with the spreading code of receiver. At the sampling positions we are getting our peak values (as integration has been done over one period of PN sequence) and at other we have zero output as expected.

6.5 MATLAB Implementation for Multi Users

6.5.1 Matched Filter Implementation for Multi Users

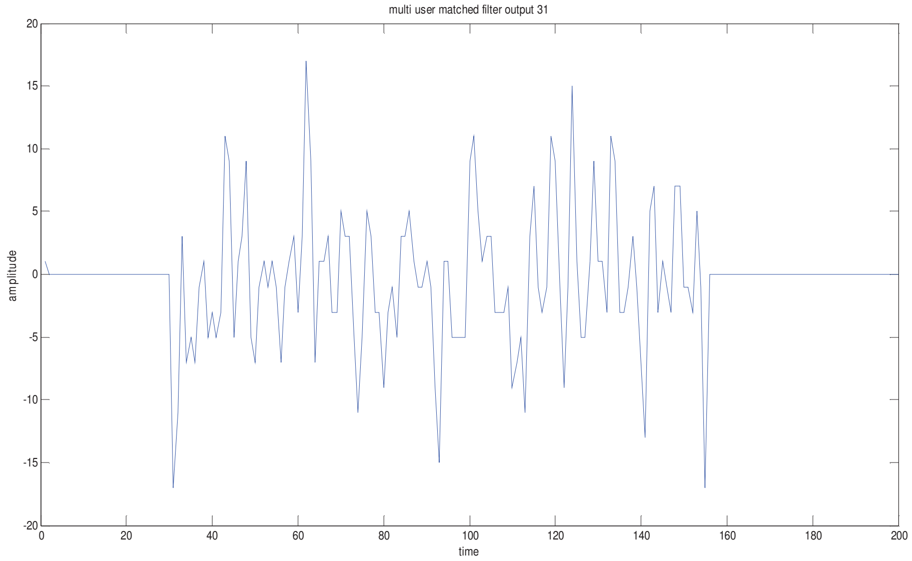


Figure 6.5.1: Matched Filter Implementation for Multiuser for 31 Length and 3 Users

6.5.2 Matched Filter Implementation for Multiuser for 127 Length and 3 Users

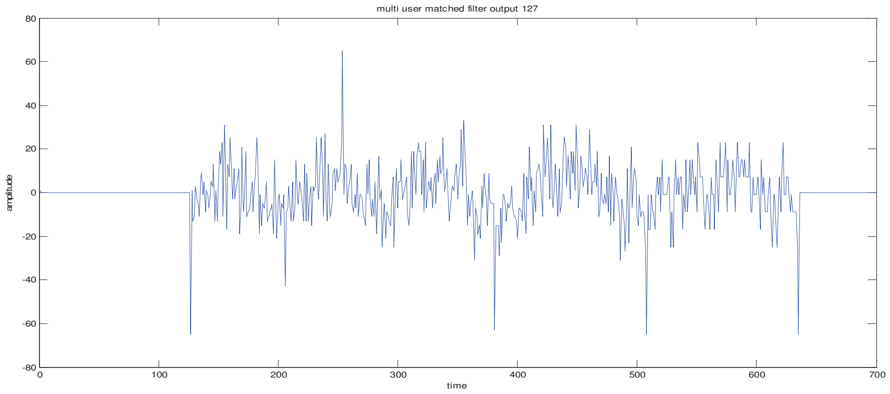


Figure 6.5.2: Matched Filter Implementation for Multiuser for 127 Length and 3 Users

6.5.3 Matched Filter Implementation for Multiuser for 127 Length and 50 Users

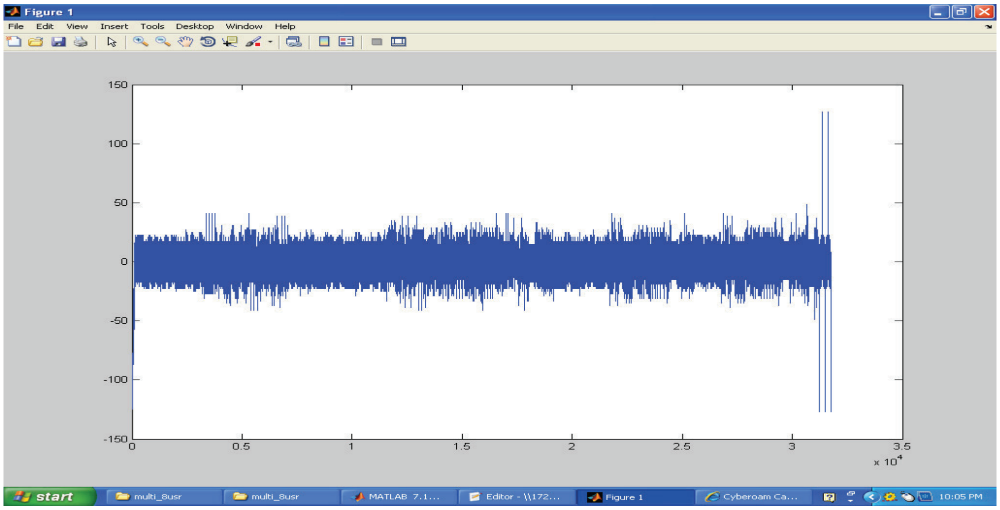


Figure 6.5.3: Matched Filter Implementation for Multiuser for 127 Length and 50 Users

In figure 6.5.1, we have implemented matched filter design for 3 users with 31 Length PN Sequence. It is clear from the output that is peak value is less than 31(period of PN Sequence), the reason is that the others users data is getting interfered with the desired user signal. But, even then we are able to detect our required message signal by setting an optimized threshold level and similarly in fig. 6.5.2 matched filter has been designed for 3 users with 127 length PN sequence. And further the users have been extended to 50 shown in figure 6.5.3.

6.5.4 Correlation Detector Implementation for Multiuser for 31Length and 3 Users

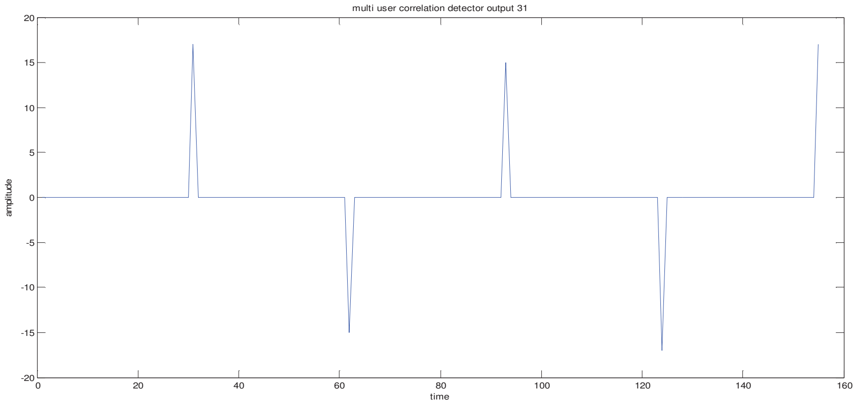


Figure 6.5.4: Correlation Detector Implementation for Multiuser for 31Length and 3 Users

In figure 6.5.4, we have implemented correlator design for 3 users with 31 Length PN Sequence. It is obvious from the output that is peak value is less than 31(period of PN Sequence)it is almost equal to 17, the reason is that the others users data is getting interfered with the desired user signal. But, even then we are able to detect our required message signal by setting an optimized threshold level.

6.6 MATLAB Implementation of DSSS with Modulation

6.6.1 for Single User

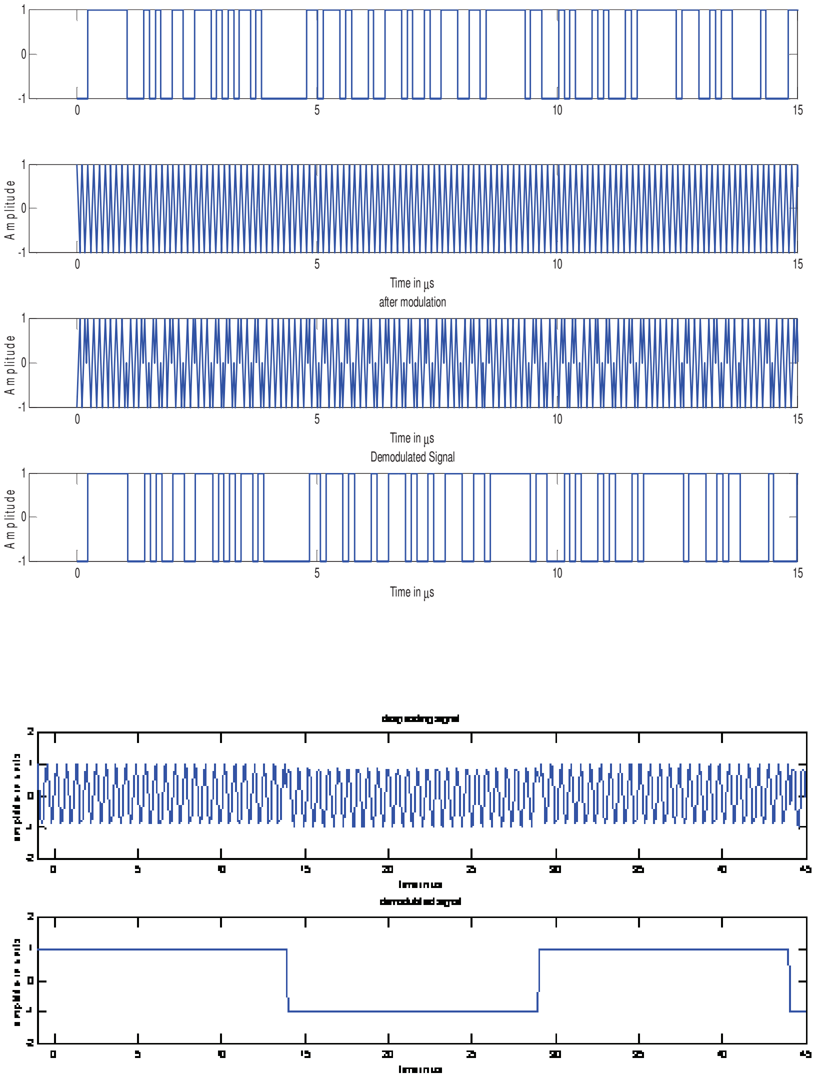
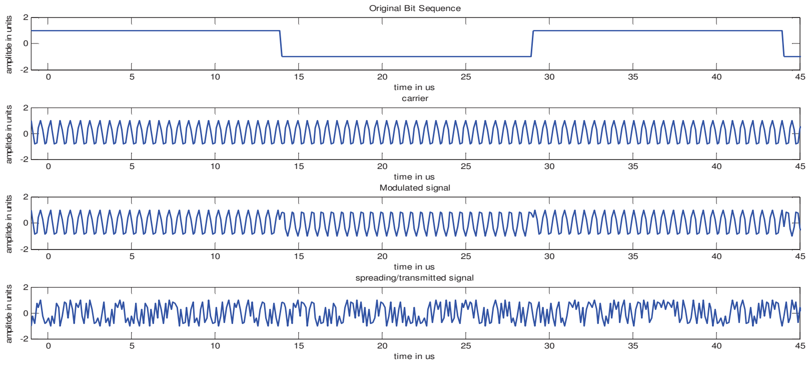
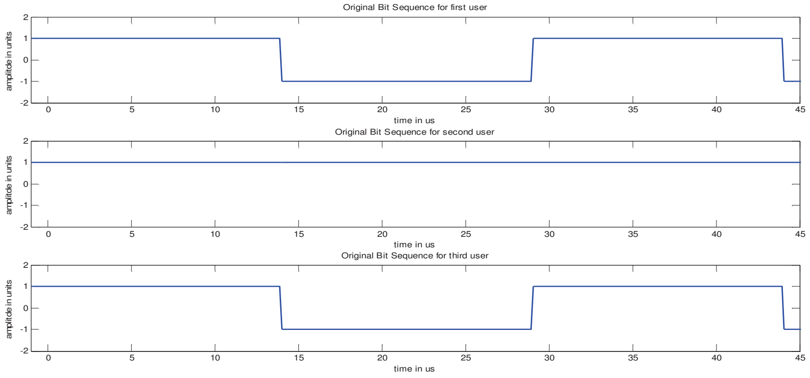


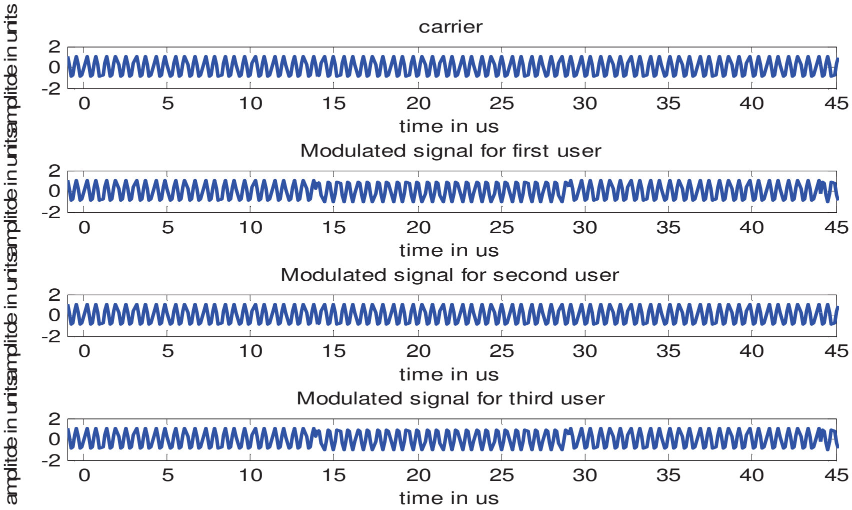
Figure 6.6.1 Matlab Implementation of DSSS with Modulation for Single User

Figure 6.6.1 shows the complete output waveforms for DSSS system with modulation. Initially the message has been expanded by multiplying it with the PN sequence. That is spreading is our first step. Next the signal has been modulated using a carrier. This modulated signal is our required transmitted signal. At last, at the receiver side signal is being demodulated first and then despreading has been done. The resultant waveform is comparable to our original data bits.

6.6.2 Multiuser transmission with modulation







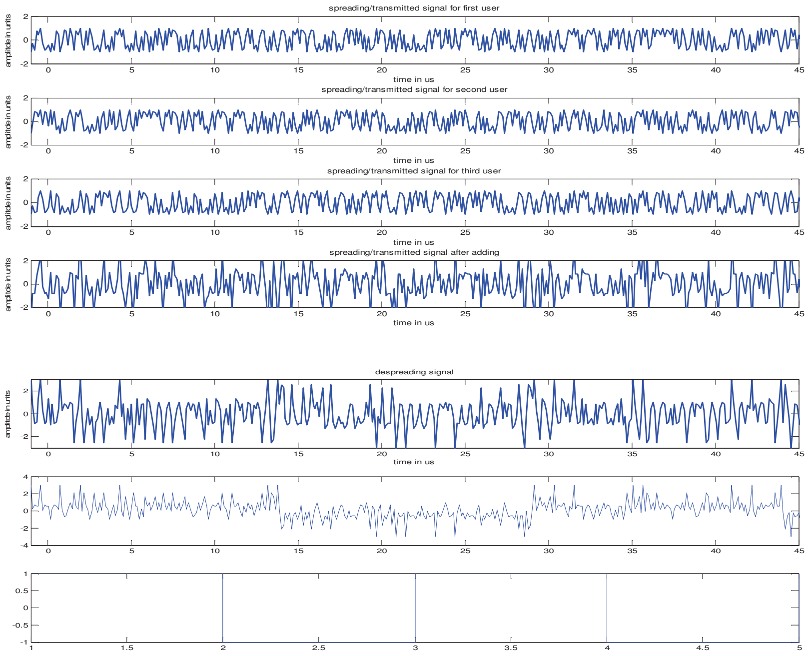


Figure 6.6.2: Matlab Implementation of DSSS with Modulation for Multi User

6.7 RESULTS

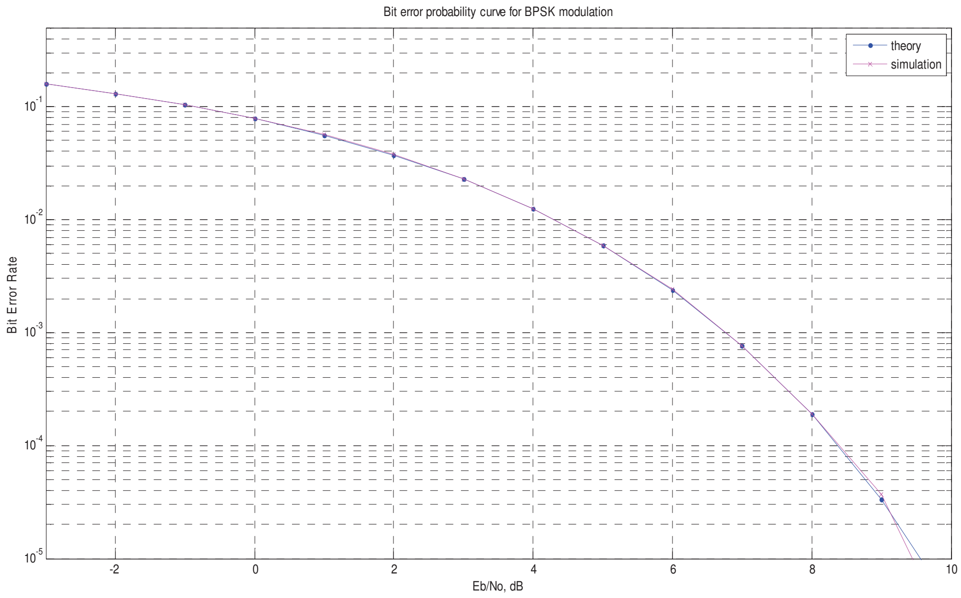


Figure 6.7.1 plot between BER Vs Eb/No

Figure 6.7.1 shows the resultant output plot between BER (Bit Error Rate) and Eb/No.

It can be clearly shown from the plot that with increase in Eb/No ratio the BER is decreasing continuously. The reason is that as we increase our Signal energy, energy per bit is also increases which lead to less number of errors with in particular sequence length. Thus finally BER rate decreases.

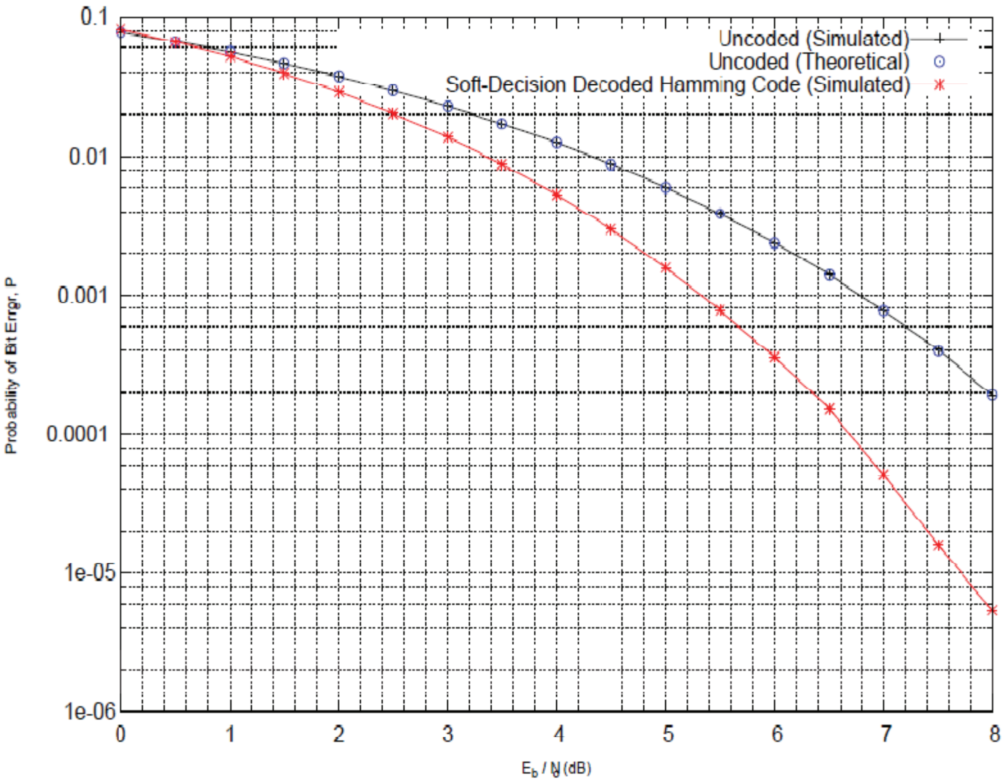


Figure 6.7.2

Figure 6.7.2 gives the comparison between

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 Summary of Research

Spread spectrum promises several benefits such as higher capacity and ability to resist multipath propagation, ability to resist interference and jamming and so on. Spread spectrum signals are difficult to interpret for an unauthorized person, they are easily hidden. For an unauthorized person, it is difficult to even detect their presence in many cases. They are resistant to jamming. They provide a measure of immunity to distortion due to multipath propagation. They have multiple access capability.

Spread spectrum is now finding widespread civilian and commercial applications such as cellular telephones, personal communications and position location. For example, DS/SS is used in electronic industries. They are used in position location systems like GPS and messaging systems.

In our project work, we have designed Linear Feedback Shift Register (LFSR) in order to generate PN sequences. After implementing all the necessary properties such as cross correlation, autocorrelation we found that our results are very much similar to the theoretical results. Then we implemented spread spectrum technique using matched filter and correlation detector and analyzed the performance of both techniques , and reach to a conclusion that matched filter have inbuilt synchronization while in correlation detector we need to synchronize the received data with the PN sequence .Since PN sequence do not yield good results in cross correlation in comparison to other sequences, (gold sequences, orthogonal sequences etc) so can’t be implemented efficiently for multi-user applications, thus, we move into the gold codes, and found that these sequences give us much better results in terms of large number of user accessibility.

The next step implemented was to design a transmitter and receiver architecture with modulation. For direct-sequence systems, the encoding signal is used to modulate a carrier, usually by phase-shift keying (e.g., Biphase BPSK or Quadriphase QPSK) at the code rate.

In direct sequence spreading, modulation is an important tool in any suppressed carrier system, used to generate the transmitted signal. Modulation helps to hide the signal, and there is no power wasted in transmitting a carrier that would contribute to interference rejection or information transfer. The next step done was multi-user spread spectrum communication

In CDMA spread-spectrum transmission, user channels are created by assigning different codes to different users. This type of system provides privacy by controlling distribution of user-unique code.

Thus, this project has presented the fundamental principles underlying the spread spectrum communication. These principles have been illustrated in terms of common system models and analysis techniques. Spread Spectrum is diverse and fascinating field and there is more scope of work into it.

7.2 Future Work

- Perform carrier and clock synchronization.
- Implementation with other sequences like Gold, Kasami etc.
- FHSS and THSS technique implementation of Spread spectrum.
- Verify the results by considering large number of users.

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APPENDIX

Code for PN Sequence Generation:

```
function[PN]=pnseq_gen()
G=127;
sd3 =[0 0 0 0 0 0 1];
pn1=[];
for j=1:G
pn1=[pn1 sd3(5)];
if sd3(1)==sd3(2)
temp1=0;
else temp1=1;
end
if sd3(3)==temp1
temp2=0;
else temp2=1;
end
if sd3(4)==temp2
temp3=0;
else temp3=1;
end
if sd3(5)==temp3
temp4=0;
else temp4=1;
end
if sd3(6)==temp4
temp5=0;
else temp5=1;
end
sd3(1)=sd3(2);
sd3(2)=sd3(3);
sd3(3)=sd3(4);
sd3(4)=sd3(5);
sd3(5)=sd3(6);
```

```
sd3(6)=sd3(7);
sd3(7)=temp5;
end
```

Code for Matched Filter Design:

```
pn1=pnseq_gen();
len1=length(pn1);
for f=1:len1
if(pn1(f)==0)
s(f)=-1;
else
s(f)=1;
end
end
s;
for f=1:len
if(p(f)==0)
qq(f)=-1;
else
qq(f)=1;
end
end
qq;
c(1,(len1))=[-1];
for i=1:(len)
w=i;
k=0;
for j=i:-1:1
c(j)=qq(len-k);
k=k+1;
end
sum=0;
for f=1:len1 %len1=7;
if(s(f)==c(f))
t(f)=1;
else
t(f)=-1;
end
sum=sum+t(f);
```

```
gg(w)=sum;
end
end
n(1,(1000-len))=[0];
jj=cat(2,gg,n);end
```

Code to Generate Spread Signal:

```
function[PN3,p]=LFSRrep3(msg)
PN= pnseq_gen()
l=length(msg);
k=1;
if(k<(l*s))
for i=1:l
for j=1:s
p(k)=xor(msg(i),PN(j));
k=k+1;
end
end
end
p
end
```

Code for Coherent Detector

```
clc
clear all
msg1=[1 0 1 0 1];
multi_userf(msg1);
function[]=finalf(s)
pn1=pnseq_gen();
for i=1:127
if(pn1(i)==0)
pn1(i)=-1;
else
pn1(i)=1;
end
end
a=ceil(100*rand(1,1))
pn=circshift(pn1,[0,a]);
```

```
gg=wkeep(s,127,'l');
len1=length(pn);
len=length(s);
c(1,(len1))=[-1];
for i=1:(len)
w=i;
k=0;
for j=i:-1:1
c(j)=s(len-k);
k=k+1;
end
sum=0;
for f=1:len1 %len1=127;
if(pn(f)==c(f))
t(f)=1;
else
t(f)=-1;
end
sum=sum+t(f);
hh(w)=sum;
end
end
subplot(2,1,1)
plot(hh)
sum=0;
for i=1:127
tt(i)=gg(i)*pn(i);
sum=sum+tt(i);
end
p=(sum/127)
for h=1:126
if(p~=1)
sum1=0;
pn=circshift(pn,[0,-1]);
for i=1:127
tt(i)=gg(i)*pn(i);
sum1=sum1+tt(i);
end
p=(sum1/127);
end
end
c(1,(len1))=[-1];
```

```
for i=1:(len)
w=i;
k=0;
for j=i:-1:1
c(j)=s(len-k);
k=k+1;
end
sum=0;
for f=1:len1 %len1=127;
if(pn(f)==c(f))
t(f)=1;
else
t(f)=-1;
end
sum=sum+t(f);
hh(w)=sum;
end
end
subplot(2,1,2)
plot(hh)
end
function[]=multi_userf(msg1)
pn1=pnseq_gen();
for i=1:127
if(pn1(i)==0)
pn1(i)=-1;
else
pn1(i)=1;
end
end
pn1
for i=1:5
if(msg1(i)==0)
msg1(i)=-1;
else
msg1(i)=1;
end
end
s=length(pn1);
l=length(msg1);
k=1;
if(k<(l*s))
```

```
for i=1:l
for j=1:s
if(msg1(i)==pn1(j))
p1(k)=1;
else
p1(k)=-1;
end
k=k+1;
end
end
end
p1
finalf(p1);
end
```

Code for Transmitter and Receiver Design with Modulation for 127 Users

```
b=[1 0 1 0 1];
pattern=[];
for k=1:3
if b(1,k)==0
sig=-ones(1,1016);
else
sig=ones(1,1016);
end
pattern=[pattern sig];
end
t=[0:45/3047:45];
subplot(4,1,1)
stairs(t,pattern,'linewidth',2);
axis([0 30 -2 2]);
title('Original Bit Sequence');
xlabel('time in us');
ylabel('amplitde in units');
pn1=pnseq_gen();
for i=1:127
if(pn1(i)==0)
pn22(i)=-1;
else
```

```
pn22(i)=1;
end
end
pn22
ps=[];
for i=1:127
if(pn22(i)==1)
pg=ones(1,8);
else
pg=-ones(1,8);
end
ps=[ps pg];
end
pp=[ps ps ps];
subplot(4,1,2)
t=[0:45/3047:45];
stairs(t,spreading,'linewidth',2)
axis([0 30 -2 2]);
title('spreading signal');
grid on
t=[0:pi/2:(3/2)*pi];
fc=1e9
carrier=[];
for i=1:762
carr=sin(t);
carrier=[carrier carr];
end
carrier;
car_len=length(carrier);
t=[0:45/3047:45];
t_len=length(t);
subplot(4,1,3)
plot(t,carrier,'linewidth',2)
axis([0 30 -2 2]);
title('carrier');
xlabel('time in us');
ylabel('amplitde in units');
mod_sig=spreading.*carrier
t=[0:45/3047:45];
grid on
subplot(4,1,4)
plot(t,mod_sig,'linewidth',2)
```

```
axis([0 30 -2 2]);
title('Modulated signal/transmitted signal');
xlabel('time in us');
ylabel('amplitde in units');
grid on
demod_sig=mod_sig.*carrier;
pp=[];
count=0;
count1=0;
k=0;
for i=1:381
FIRST=i+7*k;
mat= WKEEP(demod_sig,8,FIRST);
if(max(mat==1))
tt=ones(1,8);
else if(min(mat)==-1)
tt=-ones(1,8);
end
end
k=k+1;
pp=[pp tt];
end
demod_sig=pp;
figure
t=[0:45/3047:45];
subplot(6,1,1)
stairs(t,demod_sig,'linewidth',2)
axis([0 30 -2 2]);
title('demodulated signal','linewidth',2);
xlabel('time in us');
ylabel('amplitde in units');
k=0;
ff=[];
for i=1:381
count=0;
count1=0;
FIRST=i+7*k;
mat= WKEEP(demod_sig,8,FIRST);
for j=1:8
if(mat(j)==1 )
count=count+1;
else
```

```
count1=count1+1;
end
end
if(count==8)
kk=1;
else if(count1==8)
kk=-1;
end
end
k=k+1;
ff=[ff kk];
end
ff
x1=ff;
sk=[];
x1=ff;
x2=circshift(pn22,[0,4]);
x1=[x1 zeros(1,126)];
for c=1:607
sum=0;
b=wkeep(x1,127,'r');
jj=x2.*b;
for i=1:127
sum=sum+jj(i);
end
sk=[sk sum];
x1=circshift(x1,[0,1]);
for i=1:c
x1(i)=0;
end
end
sk;
mat=wkeep(sk,381,'l');
t=[0:45/380:45];
t_len=length(t);
subplot(6,1,2)
plot(t,mat)
axis([0 45 -128 128]);
fin=[sk(131) sk(258) sk(385)]
u=3;
for q=1:4
x1=ff;
```

```
sk=[];x1=ff;
x2=circshift(x2,[0,-1]);
x1=[x1 zeros(1,126)];
for c=1:607
sum=0;
b=wkeep(x1,127,'r');
jj=x2.*b;
for i=1:127
sum=sum+jj(i);
end
sk=[sk sum];
x1=circshift(x1,[0,1]);
for i=1:c
x1(i)=0;
end
end
sk;
mat=wkeep(sk,381,'l');
t=[0:45/380:45];
t_len=length(t);
subplot(6,1,u)
plot(t,mat)
axis([0 45 -128 128]);
u=u+1;
fin=[sk(130-q+1) sk(257-q+1) sk(384-q+1)]
end
```