DESIGN OF ADAPTIVE DIGITAL RECEIVER FOR INTERFERENCE REJECTION [+]

تصميم مستلم رقمي موالف لمنع التداخلات

Muhammed Salah Sadiq [*]

Abstract:

The procedure used in this paper was to reduce the impact narrow band interference (NBI) which cause the main distortion influence on the direct sequence binary phase shift keying spread spectrum system(DS-BPSK-SSS).

A transform technique from time domain to frequency domain was used in this work .The mean used for reduction of distortion is put a design for a on/off switch ,called notch filter to eliminate noise and (NBI) .To determine the internal signals ,two types of windows were utilized ; rectangular and hamming window.

Computer simulation models with Matlab system (7) for performance assessment in the presence or absence of notch filter.

Results reflected that the system characteristics improved (SNR) as compared with (BER) when hamming windows has been used more than rectangular in all cases tested compared to other methods used to manipulate noise and interference. Index terms-Spread spectrum, interference excision, transform domain processing, windows filter.

المستخلص:

إن الطريقة المستخدمة في هذا البحث لتقليل تأثير تداخلات الحزم الضيقة (NBI) التي هي أكثر أنواع التشويه تأثيرا على نظام المتتابعة المباشرة للطيف المنتشر (DS-BPSK) حيث تم استخدام تقنية تحويل المجال(TDP) من المدى الزمني إلى الترددي.

أن الوسيلة المستخدمة لتقليل تأثير التشويه هو عمل مرشح يعمل كمفتاح (on/off) في Frequency domain يدعى مرشح العقدة لإزالة الضوضاء وتداخلات الحزم الضيقة (NBI) وقد تم استخدام النافذة Windowing في هذا العمل لتحديد الإشارات الداخلة وقد تم استخدام نوعين من النوافذ هما Rectangle. window and Hamming window

لقد استخدمت المحاكاة بالحاسوب وبنظام الماتلاب لتقييم أداء النظام بوجود و بعدم وجود مرشح العقدة وقد بينت نتائج الاختبارات إن خواص النظام تحسن من ربح (SNR) مقارنة مع (BER) عند استخدام نوافذ Hamming أكثر من Rectangle في جميع الحالات مقارنة بالطرق الأخرى المعالجة للتداخلات والضوضاء.

Introduction:

Interference is any signal that tends to hamper the normal reception of a desired signal and can be classified into two type's wideband and narrow band interference

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[*] Asst.Lecturer/Technical College /Al-Musyaib

but the (NBI) is the most effective type of interference against direct sequence spread spectrum system, because it produced high power density at correlator output [1]. Spread spectrum (SS) is a mean of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information data. The band spreading is accomplished by transmitted data with independent spreading code is usually a pseudo random noise (PN) code with higher rate than original data and the detection is accomplished by correlation of the received signal replica of the PN code used in the transmitter.

The main property of all spread spectrum systems is their ability to reject interference[2]. The purpose of using DS- BPSK system is to provide more accurate range measurment and more amenabl to coherent detection receivers than other types of (SS) technique frequency hopping (FH) schemes . Also (FH)systems are more suitable of renatively simple partial band jamming than (DS) systems [3]. In general there are three main ways for detect the original data in the presence of noise and narrow band jamming (NBJ) ,one method operates in time domain, and the second operates in the frequency domain that is discussed in this work. The third method uses adaptive antenna array. [4]. Among the techniques which have been proposed in the recent years there is a general method of (TDP) that used a different transforms such discrete Fourier transform(DFT) and Karhaunen Loeve Transform (KLT) in the receiver for (NBI) rejection[5],and another technique operated on the attraction of the time frequency domain that used an adaptive hierarchical lapped orthogonal transform (HLOT) exciter for tracking, localizing and rejecting the non stationary interference [6].

2.System Model

1 Transform domain processing (TDP) system

In the (TDP) technique the interference excision takes place exclusively in the frequency domain , after which the signal is restored to the time domain when the rest of the signal processing takes place. The general form of the receiver is as shown in figure.(1) It consists of a Fourier transformation to the input signal which is then multiplied with the notching function and then the inverse Fourier transformed is taken[7]

The received signal is given as:-

$$r(t)=s(t)+n(t)+j(t) \tag{1}$$

where:

s(t) is the modulated spread spectrum signal.
n(t) is the additive white Gaussian noise (AWGN).
j(t) is the interfering signal.

The signal s(t) is (DS-BPSK) can be expressed as :

$$S(t) = \pm 2 p_s \sqrt{[\alpha i \oplus PN]} \cos w_o t \tag{2}$$

Where:

P_s is the signal power
α_i denotes the input digital signal and equal to[1,-1]
PN is the pseudo noise sequence.
W_o is the carrier frequency.

The interfering signal j(t) can be expressed as :

$$j(t) = 2p_j\sqrt{\cos[(w_o + \sigma w_o)t + \phi]} \qquad (3)$$

The duration of input signal is (T_b) and is equal to (T_b=NT_c)

Where:
N is the processing gain.
T_c is the chip period.

The Fourier transform of the received signal r(t) can be implemented as shown below

$$S(w) = \int_0^{T_b} r(\tau).\exp(jw_o\tau - \beta\tau^2).\exp(jw_o(t-\tau) + \beta(t-\tau)^2 d\tau \qquad (4)$$

by taking the real part of equation (4)

$$S(w) = \int_0^{T_b} r(\tau).\exp(w_o t - \beta t^2).\exp(-\beta t\tau)d\tau \qquad (5)$$

$$S(w) = \exp(w_o t + \beta t^2).\int_0^{T_b} r(\tau)\exp(-2\beta t\tau)d\tau \qquad (6)$$

The equation above show the Fourier transform of the received such as

$$S(w) = \int_{-\infty}^{\infty} r(\tau).\exp(-jwt)dt \qquad (7)$$

where w represent the chirp slope (βt) in eq. (6) in which

case the term $\int_0^{T_b} r(\tau)\exp(-2\beta t\tau)d\tau$ in equation (6) represent the Fourier transform of the signal r(t) when w=βt [8].

s(w) now represents the real time Fourier transform in frequency domain.

The output data passes through another filter with center frequency at the jammer location and then multiplied with a chirp filter $\exp(j(w_1 t-\beta t^2))$ and the result is the inversed Fourier transform of input signal in time domain.

After that the output data passes through low pass filter with cutoff frequency at the cutoff of original signal input .Then the correlator is matched to specific original PN sequence at the transmitter[9].

The detector consists of an integrator and decision circuit. When the output received bit equal to the input transmitted bit so the receiving is correct but if the output received bit not equal the input transmitted this is error detected.

The notch filter function H(w) shown in fig.(2) is an equivalent to an on/off switch to perform the notching function in the frequency domain in this way a large part of interfering energy will be eliminated

it's required to transmit binary data over passband communication channel, it is necessary to modulate the signal into carrier wave (usually sinusoidal) [10].

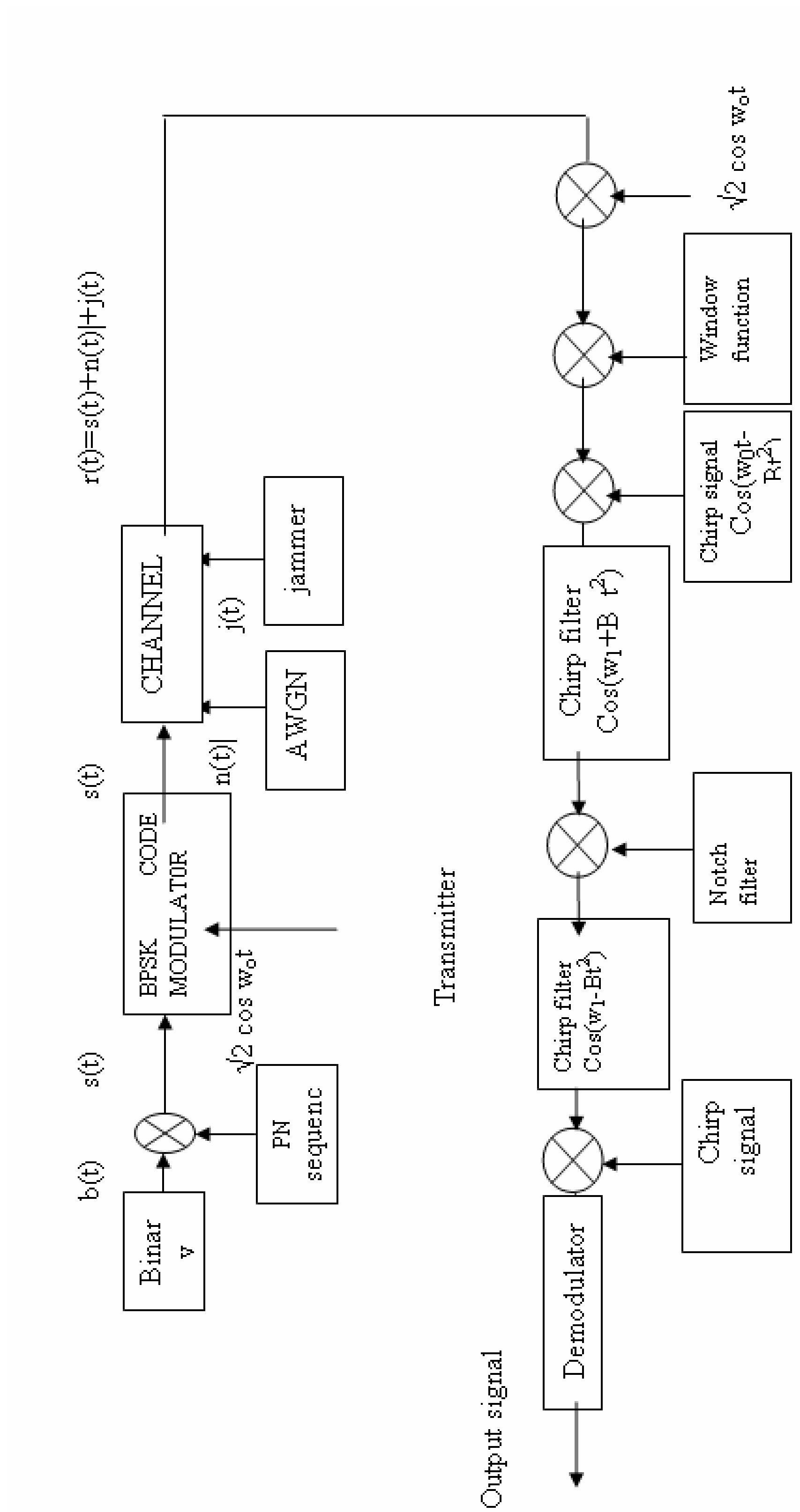
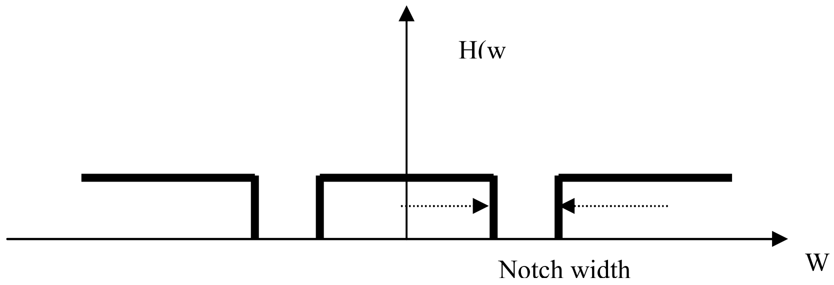


Figure.(1) Block diagram of (TDP) system



Figure(2)Ideal notch filter frequency response

2 Windowing:

The purpose from using window function is for time limiting operation transforms the spectrum of the ideal sinusoidal carrier from a delta function to a sinc(x) function and then minimized the side lobes which are introduced in the spectrum of the ideal signal therefore the effect of interference is attenuated.

A windowing function which introduces lower side lobes as compared to the rectangle is the hamming window . It reduces the side lobe levels by introducing a smoother signal roll off at the beginning and the end of the signal , thus avoids the larger discontinuities associated with the rectangle window[7]
The received data multiplied with a suitable window function in time domain to reduce any discontinuities at edges of signals that causes a wide mixture of frequencies in frequency domain when takes real time Fourier transform for received data but without windowing the spectral output leakage and it may lead to difficulties of interpretation.
Here are some of the most effective windows:-

2-1 Rectangular window:

This basically the response one gets through the use of the sinc function also defined as the point by point multiplication of the time domain impulse response by a rectangular window

$$\begin{cases} 1 & |n| \leq (N-1)/2 \end{cases}$$

$$Wrect(n) = \quad 0 \qquad |n| > (N-1)/2 \tag{8}$$

This offers the best least square error but the greatest ripple. The first side lobe will be only (-13dB) down from the main lobe.

2-2-2 Hamming window:

The effort here is to cancel the first side lobe of the sinc function

$$W_{ham}(n)= \begin{cases} 0.54+0.46\cos(([2n-N+1]Pi)/N) & 0\leq n \leq N-1 \\ 0 & \text{else} \end{cases} \tag{9}$$

Where: N is the length of the vector ,n is the increment .

The highest side lobe using this function is down –43dB from the main lobe[11].

Simulation Results

Computer simulation tests have been carried out to evaluate the performance of different signals under (NBI) and the improvements of the (BER) against (SNR) are be calculated in the digital receiver output.

In this paper a passband communication of the (TDP) system for interference rejection is modeled as shown in figure(1) and there are a few assumptions are considered, these are :

(a) Ideal channel between transmitter and receiver.
(b) perfect timing (synchronization) and tracking.
(c) no multipath is present.
(d) there is a time delay of exactly T_b second per Fourier transform.

The real parts of noise are assumed to be Gaussian random with zero mean and same variance.

The signal to noise ratio(SNR) is given by

$$SNR = 10 \log_{10} (2E_b/No) \tag{10}$$

Where: E_b is the average energy per transmitted bit , and $N_0/2$ is the two sided power spectral density of AWGN in the passband model[12].

the performance for all systems , are determined by calculating the BER (bit error rate) at different SNR , as

$$BER = \frac{\text{No. of erroneous bits}}{\text{No. of transmitted bits}} \tag{11}$$

The programs are written in Matlab(7) language ,and the flow chart of TDP system shown in Appendix (A)

Figure(3) shows the performance of BPSK and D
S-BPSK with processing gain(PG) equal 31 or 127 are the same results when the (AWGN) is the only channel effect (ideal channel) and there is no jamming or interference .Also it is clear that a bit error probability of $3*10^{-5}$ is achieved when SNR is 12.5 dB.

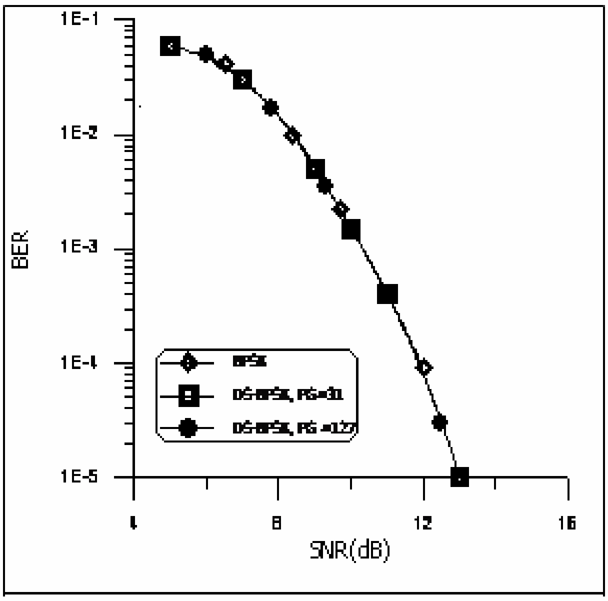
Figure(4) illustrates the performance of different signal at difference interference level (K) that added to DS-BPSK before TDP and its clear that good detection occurs by the receiver when the amplitude of tone jamming is equal 0.5 and no detection when the interference level above this value.

Figure(5) show the improvement achieved in the system as compared with figure(4) when the center of jamming at $\delta w_0 t=2*pi/T_b$ from carrier frequency and notch filter width=$2*pi/T_b$. It's clear that the performance of BER against SNR of figure(5) is better than figure(4) and this is due to effect of using TDP and the excising function (notch filter).

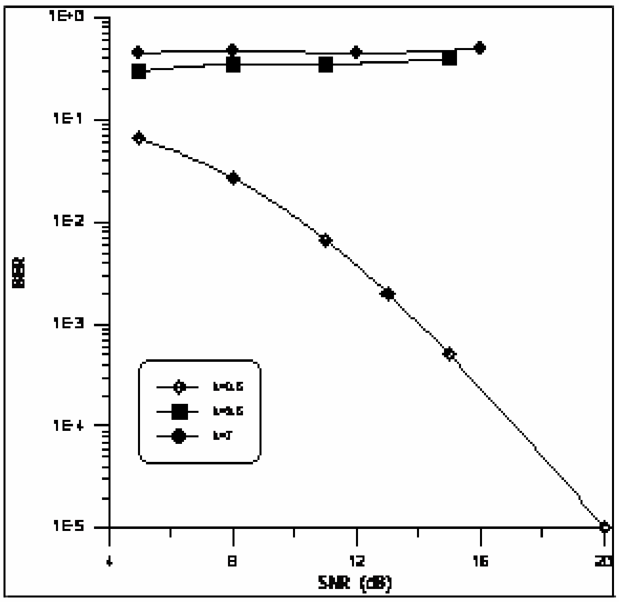
A comparison between the performance of the systems in figure(6) and figure(7) show that the system after TDP with hamming window is better than rectangular window at

(NBJ) because it's provided (0.35dB) improvement in SNR when J/S=8dB and notch filter width= $4*pi/T_b$. For example BER=10^{-4} is obtained at SNR=13.25dB when used rectangular window but the same result is obtained at SNR=12.9dB when hamming window exist at the same conditions of the system, therefore the difference between the SNR is (0.35dB).

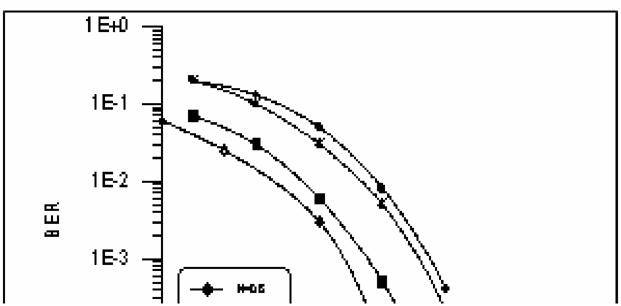
Figure(8) represents the performance of digital notch filter at notch width equal $2*pi/T_b$ and located at the bandwidth of PN sequence at carrier frequency 620 KHz.

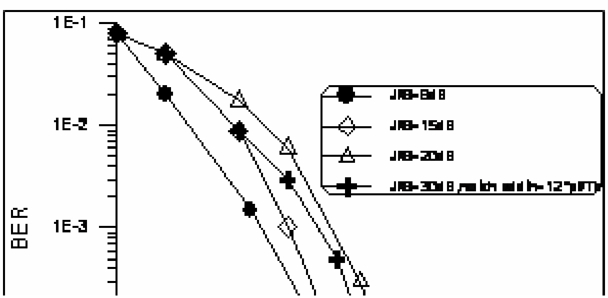


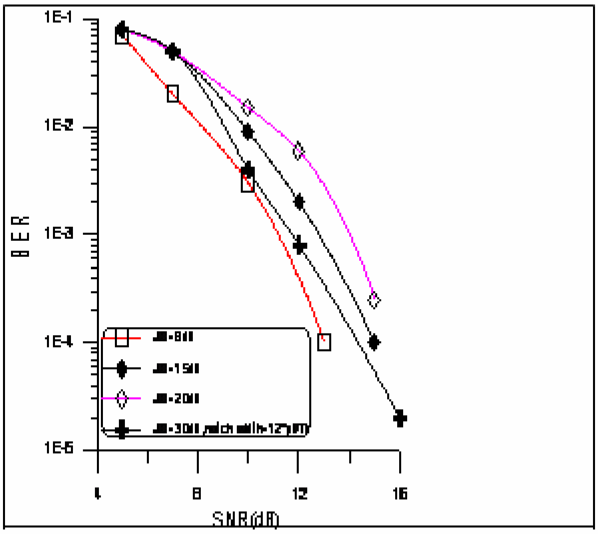
Figure(3) performance of different signals



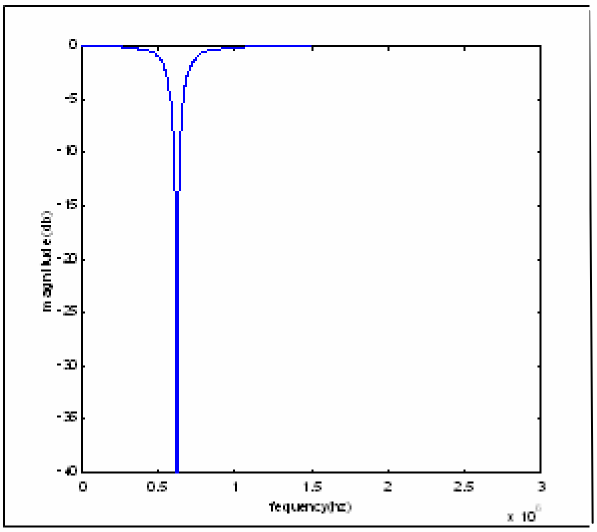
Figure(4) performance over DS-SS31 with different interference levels before (TDP)







Figure(7)Performance of different signals of DS SS(PG=31)with NBJ(B.W=10%) after (TDP)with Hamming window and notch width=4*pi/T_b.



Figure(8)Performance of notch filter at carrier frequency 620 KHZ and notch width=2*pi/T_b

Conclusions:

This paper shows that the proposed receiver based on (TDP) is a Fourier transformation from time to frequency domain and eliminate a large part of (NBI) in the (DS-BPSK-SSS) when employing an adaptive notch filter in the receiver. The increasing in length of spreading sequence has lead to improve the processing gain(PG) therefore, the effect of interference and jamming were reduced.

The function of windowing such as rectangle or hamming are used for time limiting the input signal, and minimize the side lobes which are introduced in transforming the input signal to frequency.

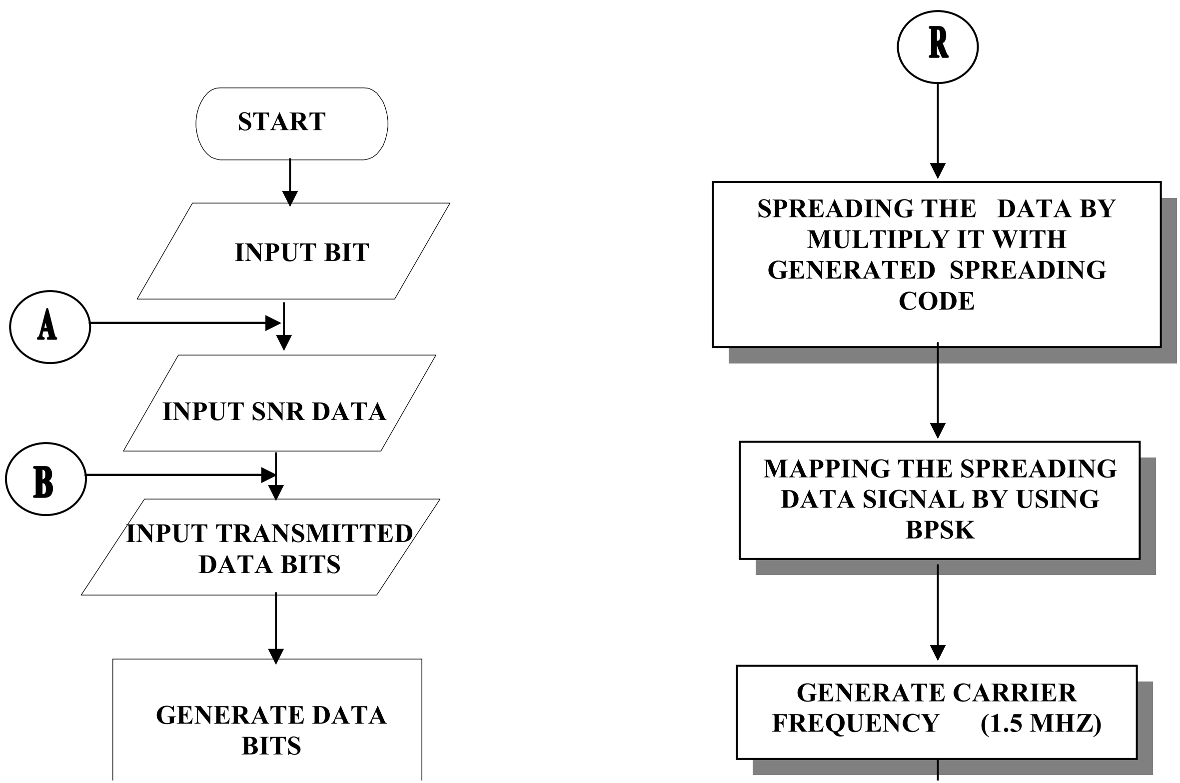
Hamming window reduced significantly the side lobe levels by introducing a smother signal at the beginning and the end of the signal and thus avoided larger discontinuities associated with the rectangle window. The performance of notch filter is to minimize the effect of interference or jamming and hence to improve the system performance while using this filter. The Simulation results showed that the improvement in BER is about

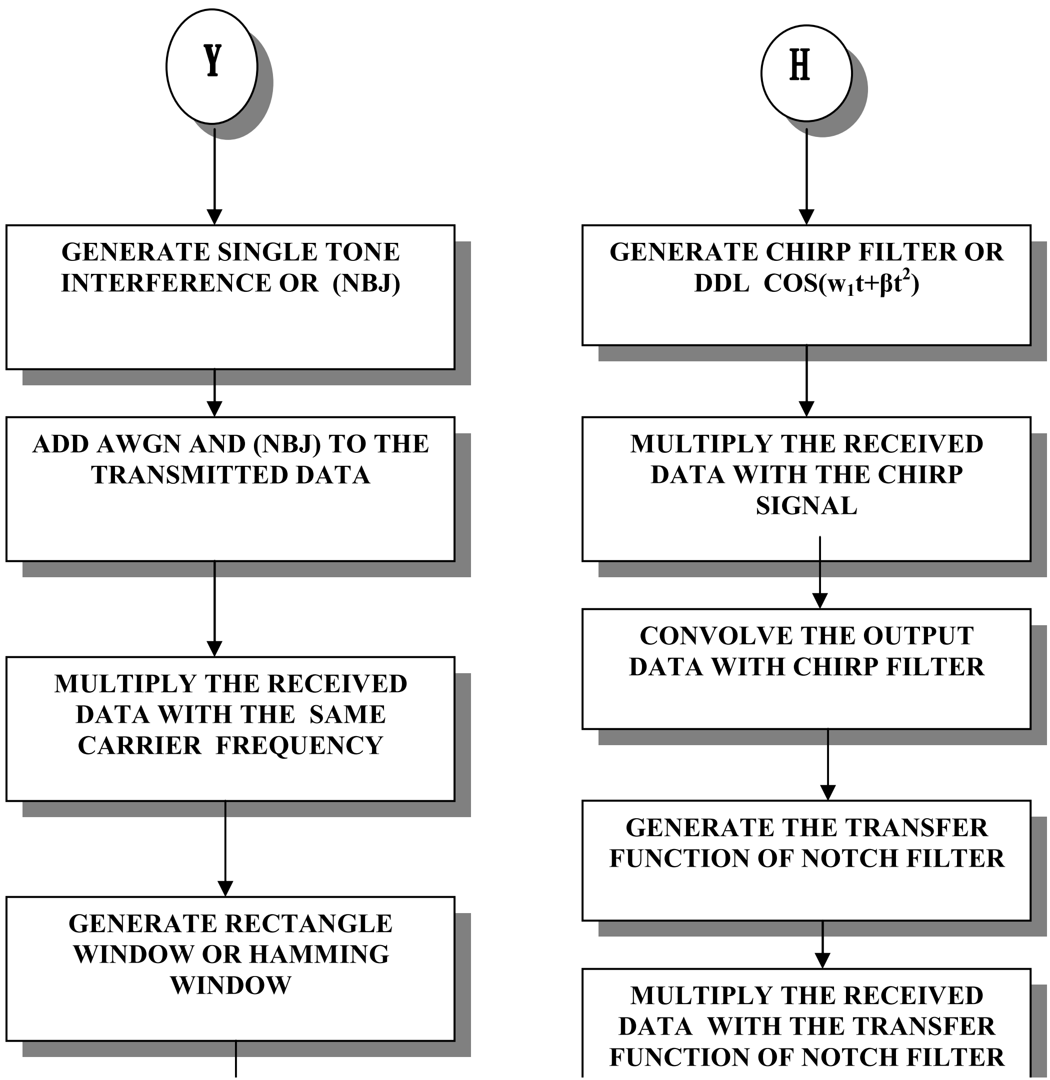
(0.35dB) in SNR by using the (TDP) algorithm with hamming window for interference rejection at J/S=8dB and notch filter width= 4*pi/T_b.

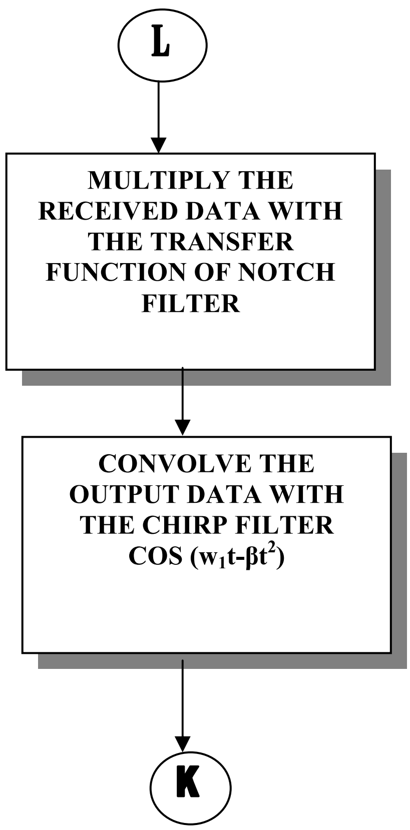
These improvements depend upon the value of (J/S) and location of the interference signal from the center of carrier frequency as compared to SNR with different interfer signals.

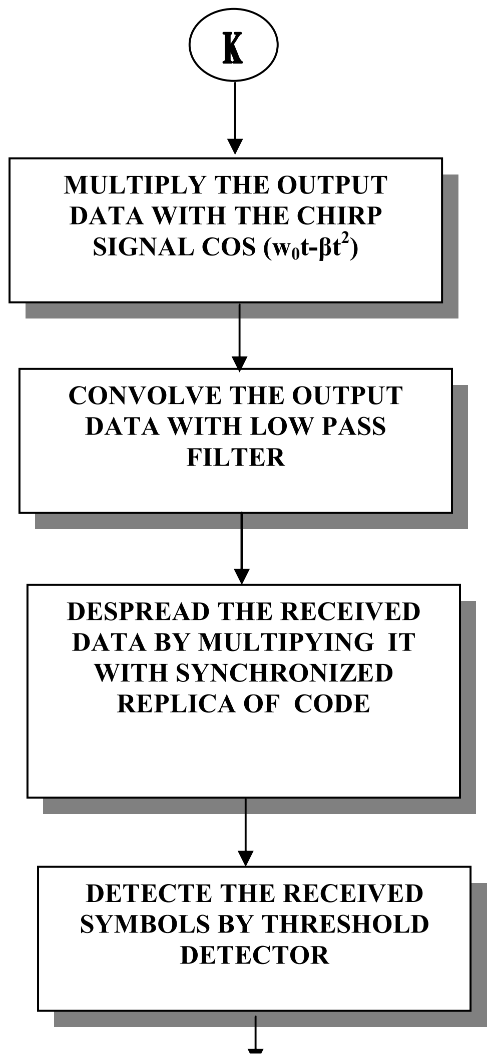
Results proved that the complexity of adaptive (TDP) receiver is higher than (DFT) and (KLT) receivers [5] or the methods used in time domain[2] but the system performance for interference rejection by using (TDP) was better improved than the other methods.

Appendix (A)
The flow chart of TDP system




Y
GENERATE SINGLE TONE INTERFERENCE OR (NBJ)
ADD AWGN AND (NBJ) TO THE TRANSMITTED DATA
MULTIPLY THE RECEIVED DATA WITH THE SAME CARRIER FREQUENCY
GENERATE RECTANGLE WINDOW OR HAMMING WINDOW
H
GENERATE CHIRP FILTER OR DDL COS(w1t+βt2)
MULTIPLY THE RECEIVED DATA WITH THE CHIRP SIGNAL
CONVOLVE THE OUTPUT DATA WITH CHIRP FILTER
GENERATE THE TRANSFER FUNCTION OF NOTCH FILTER
MULTIPLY THE RECEIVED DATA WITH THE TRANSFER FUNCTION OF NOTCH FILTER


L
MULTIPLY THE RECEIVED DATA WITH THE TRANSFER FUNCTION OF NOTCH FILTER
CONVOLVE THE OUTPUT DATA WITH THE CHIRP FILTER COS ($w_1t-\beta t^2$)
K


K
MULTIPLY THE OUTPUT DATA WITH THE CHIRP SIGNAL COS ($w_0t-\beta t^2$)
CONVOLVE THE OUTPUT DATA WITH LOW PASS FILTER
DESPREAD THE RECEIVED DATA BY MULTIPYING IT WITH SYNCHRONIZED REPLICA OF CODE
DETECTE THE RECEIVED SYMBOLS BY THRESHOLD DETECTOR

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