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Performance Comparison Of Two Codes In Direct Sequence Spread Spectrum (DSSS) System Under The Effect Of Jamming

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Abstract :

This paper focuses on the performance comparison of two direct sequence spread spectrum (DSSS)systems one system using Gold code and the other system using Walsh code under the effect of single tone jamming(STJ) and multi tone jamming(MTJ) in presence of Additive White Gaussian Noise (AWGN) channel ,thesetwo systems was carried out by using MATLAB program.

The performance evaluation of two systems was tested by measuring the bit error rate (BER) of receiving data for different cases of energy per bit to noise power spectral density ratio (E_b/N_o) and also for different cases of jamming to signal power ratio (J/S).
The comparison results showed the BER of DSSS system using Gold code is better than the system that using Walsh code under the effect of both STJ and MTJ in communication channel.
Keywords: Direct sequence, Single tone jamming, Multi-tone jamming, Walsh code, Gold code.

مقارنة أداء نوعين من الشفرات في منظومة الطيف المنتشر- التتابع المباشر تحت تأثير التشويش

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الخلاصة :

هذا البحث يركز على مقارنة أداء منظومتين طيف منتشر نوع التتابع المباشر أحداهما تستعمل شفرة Gold والأخرى تستعمل شفرة Walsh تحت تأثير التشويش المفرد التردد والتشويش المتعدد التردد وبوجود قناة كاوس،وهاتين المنظومتين تم تنفيذهما باستخدام برنامج MATLAB .

أن تقيم الأداء لهاتين المنظومتين تم اختبارهما بواسطة قياس معدل الخطاء في البيانات المستلمة لحالات مختلفة من نسبة طاقة الإشارة للبت الواحدة الى قدرة الضوضاء (E_b/N_o) وأيضا لحالات مختلفة من نسبة قدرة التشويش الى قدرة الشارة المرسلة (J/S).

نتيجة المقارنة أظهرت بان معدل الخطاء في البيانات لمنظومة التتابع المباشر والتي تستعمل شفرة Gold كانت أفضل من المنظومة التي تستعمل شفرة Walsh وتحت تأثير كلا النوعين من التشويش المفرد التردد والمتعدد التردد في قناة الاتصال.

1. Introduction

Spread spectrum techniques use data-independent, random sequences to spread a narrowband information signal over a wide (radio) band of frequencies[1,2].Direct Sequence Spread Spectrum has a strong performance of anti-interference[3].

In direct sequence spread spectrum (DSSS), the information sequence is multiplied with a pseudo-noise (PN) sequence to construct a longer sequence. Since the PN sequence resembles noise, it is inherently wideband and as a result it spreads the spectrum of the information sequence too to create a noise-like sequence. Since this sequence is spread over a large frequency band, it is less prone to interference while its noise-like characteristics make it difficult to detect. Spread spectrum communication systems have an inherent immunity to interference, but it is not difficult to jam such systems either, particularly if the spread spectrum system uses very low power levels for communication [4].

The interference immunity of a DSSS communications system can be further improved by processing the signal prior to cross correlation, where the objective is to reduce the level of the interference at the expense of introducing some distortion to the desired signal. This processing can be accomplished by exploiting the wideband spectral characteristics of the desired DS signal and the narrowband characteristic of the interference[5].

More literature is mainly about anti-jamming performance of DSSS systems over additive white Gaussian noise (AWGN) channel while to the factitious interference few people probe into performance of DS with difference jamming techniques[6,7,8,9].

A variety of techniques are available for separation and removal of jamming interference signals using adaptive filtering [10 ,11], time-frequency domain filtering [12] , subspace processing [13] and amplitude domain filtering [14].Some research found the bit error rate of DS with STJ has relation with more parameters, not only the carrier frequency difference ,it will be also influenced by the PN sequence, frequency or phase difference of the jamming and communication systems and PN- code length [15].In this paper, the performance of direct sequence spread spectrum communication under the effect of jamming will be introduced based the two different typical types of PN- code have the same length.

2. QPSK Spreading With Data Phase Modulation

Modulation types other than BPSK may be used in DSSS communication systems, both for the data and for the spreading. For example, **Figure.(1)** shows a transmitter/receiver structure for QPSK spreading with arbitrary data phase modulation[16].
A QPSK signal is generated by two BPSK signal and it was introduced in [17]. To distinguish the two signals, we use two orthogonal carrier signals. One is given by $\cos(2\pi f_c t)$, and the other is given by $\sin(2\pi f_c t)$. The two carrier signals remain orthogonal in the area of a period[17]**.**This type of modulation will be used here for simulation of DSSS.

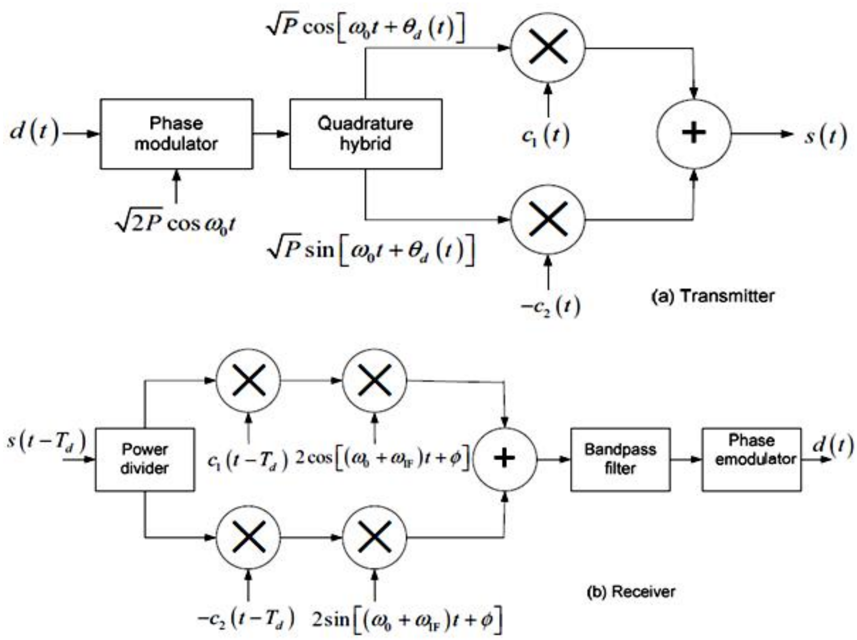


Fig.1: Block diagrams of : (a) transmitter and (b) receiver for QPSK spreading with arbitrary phase modulation.

3. Jamming on Spread Spectrum

The performance of a spread spectrum communication system in the presence of AWGN is the same as without spread spectrum using the same data modulation technique as the spread spectrum system. In order to make a spread spectrum communication system's performance unacceptable, an enemy might resort to jamming, i.e., radiating a signal in the same band being used by the spread spectrum system in order to raise its error probability to an unacceptable level. Another possible source of interference in spread spectrum systems is multiple-access interference [18].

4. Jamming Waveforms

A class of jamming waveforms is selected to illustrate the basic spread-spectrum communication concepts and includes (to a good approximation) the worst types of jammer to the spread-spectrum systems of interest. There is no STJ waveform that is worst for all spread-spectrum systems and there is no single spread-spectrum system that is best against all jamming waveforms .Jamming can take many forms, some examples are [19,20]:

1) Broadband Noise Jamming:

Broadband noise (BBN) jamming places noise energy across the entire width of the frequency spectrum used by the target communication systems. It is also called full band jamming and is sometimes called barrage jamming. The spectrum of BBN jamming is illustrated in **Figure.2 (a, b).**

2) Partial-Band Noise Jamming:

Partial-band noise (PBN) jamming places noise-jamming energy across multiple, but not all, channels in the spectrum used by the targets. These channels may or may not be contiguous. The spectrum for PBN jamming is illustrated in **Figure.2(c, d); Figure.2(c**) illustrates contiguous channels while **Figure.2 (d)** illustrates noncontiguous channels.

The wider bandwidth, the lower power of jamming signal relatively because total power of jamming is constant[20].The power spectral density(PSD) of PBJ can be represented as [21,22,23]:

$$JSR = N_J/E_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\rho = \frac{W_J}{W_{ss}} \le 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$N_J' = \frac{N_J}{\rho} = \frac{P_J}{W_{ss}}\frac{W_{ss}}{W_J} = \frac{P_J}{W_J} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

E_s power of symbol, P_J power of jamming signal, N_J' power spectral density (PSD) of PBJ, W_J bandwidth of jamming signal, W_{ss} whole signal bandwidth and ρ Jamming to Fractional Ratio (JFR).

3) Narrowband Noise Jamming:

Narrowband noise (NBN) jamming places all of the jamming energy into a single channel. The bandwidth of this energy injection could be the whole width of the channel or it could be only the data signal width or the complementary signal width. Narrowband noise jamming is illustrated in **Figure.2 (e**).

4) Tone Jamming:

In tone jamming (TM), one or more jammer tones are strategically placed in the spectrum. Where they are placed and their number affects the jamming performance. Two types of tone jamming are illustrated in **Figure.(2).** Single-tone jamming (STJ) places a single tone where it is needed and is illustrated in **Figure.2 (f).** Multiple-tone jamming (MTJ) distributes the jammer power among several tones and is illustrated in **Figure.2 (g).**
In this paper will be focus on the effect of those types of jamming to measure the performance of DSSS, also will be discussed in detail later in next section.

5) Swept Jamming:

A concept similar to broadband or partial-band noise jamming is *swept jamming*. This is when a relatively narrowband signal, which could be as narrow as a tone but more often is a PBN signal, is swept or scanned in time across the frequency band of interest. At any instant in time, the jammer is centered on a specific frequency and the only portion of the spectrum being jammed is in a narrow region around this frequency. However, since the signal is swept, a broad range of frequencies can be jammed in a short period.

6) Follower jamming:

A follower jammer attempts to locate the frequency to which the frequency hopping transmitter went, identify the signal as the one of interest (the target), and jam at the new frequency. This jamming waveform could be in the form of tones or it could modulate the tones with, say, noise using FM modulation. Follower jamming is also referred to as responsive jamming, repeater jamming, and repeat back jamming.

7) Smart jamming:

This category of jamming techniques attempts to disrupt portions of digital signals only, selecting only those portions necessary to deny communications, if possible. Some types of communication systems must be synchronized to operate properly, that channel alone could be attacked to degrade the synchronization process.

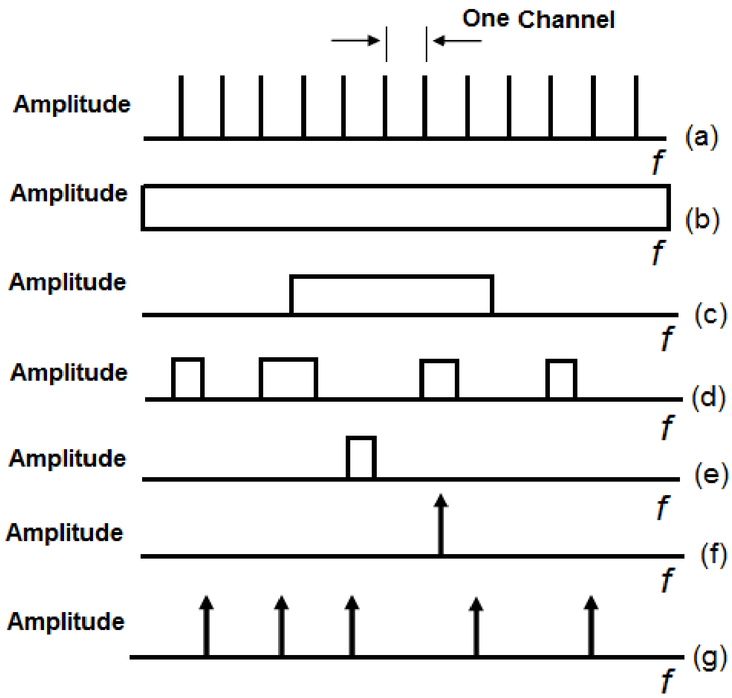


Fig.2: Possible strategies a jammer may use based on the channelized spectrum shown in (a) and (b) Broad-band jamming (BBN), (c) contiguous partial-band jamming (PBN),(d) noncontiguous partial band jamming (PBN), (e) narrow band noise jamming (NBN), (f) single-tone (ST) jamming, and (g) multi tone (MT) jamming

5. STJ and MTJ Forms

As mentioned before the tone jamming can be classified in to two types as follows:

5.1 Single Tone Jamming (STJ)

A jamming signal transmitted at a single frequency was shown in **Figure.2(f).** Thus, the jamming signal is a CW tone placed at a single frequency. Single-tone jamming is also called spot jamming. A continuous wave tone centered at the carrier frequency is well known to be a good jamming signal against a DS system [24, 25].For STJ with the same carrier frequency as the desired signal, a nearly exact, closed-form equation for the symbol error probability can be derived. The tone jamming or total jamming power has the form [26, 27]:

$$J(t) = \sqrt{2J}\cos[\omega t + \theta] \quad \dots\dots\dots\dots\dots\dots (4)$$

Where:

J tone power jamming.

5.2. Multi -Tone Jamming (MTJ)

A jamming signal transmitted at multi tones, randomly placed, or placed at specific frequencies. Multi-tone jamming is illustrated in Fig.2 (g).For MTJ using N_t equal power tones can be described by [22,25,28]:

$$J(t) = \sum_{l=1}^{N_t} \sqrt{2J/N_t} \cos[\omega_l t + \theta_t] \dots\dots\dots\dots \quad (5)$$

Where:

N_t: the number of multi tone jamming. These are shown in the frequency domain in **Figure.2(a)and(b)**.All phases are assumed to be independent and uniformly distributed over$(0, 2\pi)$ [29].

6. System Model

The block diagram of direct sequence system is shown in Figure (3) was carried out by MATLAB-simulink. The MATLAB and Simulink environments are integrated into one entity, and thus we can analyze, simulate, and revise our models in either environment at any point. We invoke simulink from within MATLAB. It proves the fact that the tool of simulink makes it a simple thing to build model for the direct sequence communication system since it eliminates the inconvenience to construct a real experimental system at the same time it has many advantages in observing the results and storing data [30].

The proposed communication system in the presence of jammer, shown in Figure.3, captures DSSS transmitted signals that have been corrupted with Additive White Gaussian Noise (AWGN).

In the transmitter the data sequence 64Kb/s is baseband modulated (QPSK-modulation) is first spread by multiplication with the DS spreading waveform generated by pseudo-noise (PN) codes ,Gold code or Walsh code (127-bit long for each code) with code rate 8Mb/s.
The bit stream, $m(t)$, and chip stream, $c(t)$ are clocked together so that the number of chips in a bit interval is an integer. The purpose of the direct multiplication of the bit stream by the chip stream is to spread the spectrum of the bit stream, For QPSK- DSSS, the transmitted signal is of the form [31].

$$s(t) = \sqrt{P} c_1(t) \cos[\omega_o + \theta_d(t)] + \sqrt{P} c_2(t) \sin[\omega_o + \theta_d(t)] \dots\dots\dots \quad (6)$$

Where:

$c_1(t)$,$c_1(t)$is the high speed PN codes sequence and P is the signal power.

This signal is transmit over AWGN channel and under the effect of STJ or MTJ.In the receiver side the received signal is first dispreading with a local replica of the PN code sequence , here both PN code in the transmitter and receiver are assume synchronized and then the dispread signal is accumulated by using integrate and dump function, finally the QPSK-demodulation process is applied to get the original data. The received signal from an AWGN channel can be represented by[29,32]:

$$r(t) = s(t) + n(t) + J(t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

$$r(t) = s(t) + n(t) + \sqrt{2P_j}\cos[2\pi(f_c + \Delta f) + \emptyset] \dots\dots\dots\dots\dots (8)$$

Where:

n(t) is additive white Gaussian noise (AWGN) of spectral density No/2, *Pj* is the jammer power, *Δf* is the jammer frequency offset from the carrier, and Øis independent and uniformly distributed in [0,2π). The DSSS was simulated under the following conditions for STJ and MTJ as follows:-

1. Single tone jamming:- the DS signal is sent through a Gaussian Noise channel with energy per bit to noise power spectral density ratio (E_b/N_o) changeable from 0 to 10 dB, and STJ at carrier frequency with two cases of jamming to signal ratio (J/S) 0 and 10 dB.
2. Multi-tone jamming:-the DS signal is sent through a Gaussian Noise channel with (E_b/N_o) changeable from 0 to 10 dB, and the number of tones is chosen to be five tones with two cases of jamming to signal ratio (J/S) 0 and 10 dB. **Table (1)** gives simulation parameters for DSSS system under the effect of STJ and MTJ.

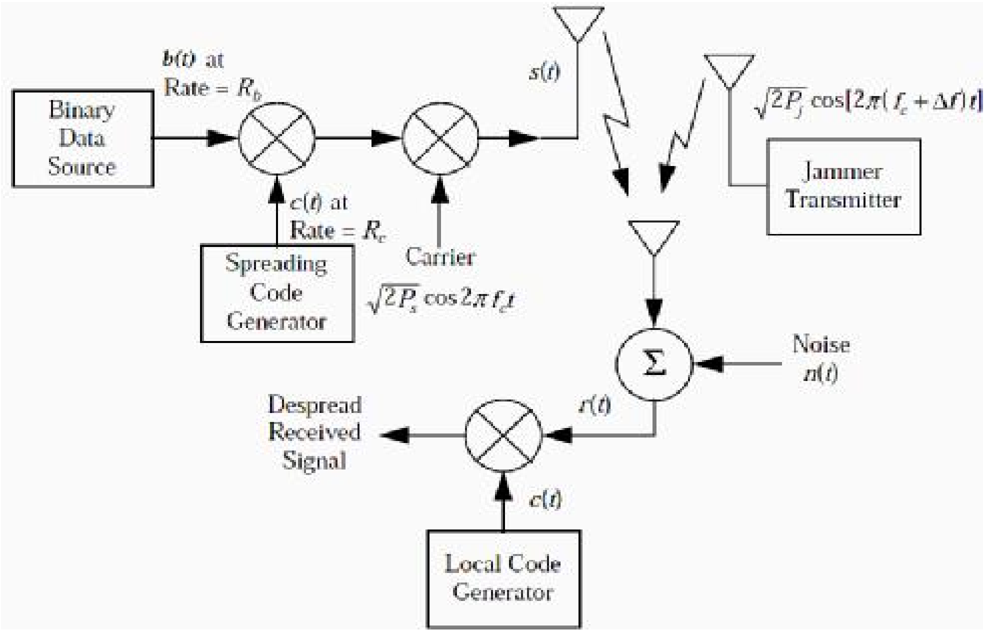


Fig. 3: DSSS system model.

Table (1):-Simulation parameters for DSSS system under the effect of STJ and MTJ.

parameter	value	unit
Data bit rate	64	Kb/s
Carrier frequency (QPSK baseband)	8	MHz
Code rate	8	MHz
Codes type	Walsh and Gold	
Code length	127	Chip
Jammer frequency	At carrier frequency for STJ and five tones (8-12) MHz for MTJ.	MHz
Jammer-to-signal(J/S)	0 and 18	dB
Gaussian noise (E_b/N_o)	0 to 12	dB

7. Results

The DSSS system was shown in Fig.(3) is simulated by using MATLAB-simulink under the effect of STJ and MTJ for two cases of jamming-to-signal ratio (J/S)in addition to Additive White Gaussian Noise for different cases of E_b/N_o as follows:-

7.1. Single tone jamming (STJ)

The performance evaluation of DSSS system was measured by using bit error rate calculation block found in MATLAB-simulink blocks set for two PN codes for 32000bits simulation process for two cases of J/S 0dB and 10dB with different cases of E_b/N_o 0dB to 12dB as shown in BER curve in **Figure.(4),these** results are shown the BER was $2.84x10^{-6}$and $1.13x10^{-5}$ by using Walsh code and Gold code respectively at E_b/N_o=12dB under the effect of AWGN only and the BER was $2.31x10^{-2}$and$1.42x10^{-5}$by using Walsh code and Gold code respectively under the effect of AWGN and J/S=0dB,whereasthe BER was $4.99x10^{-1}$and$3.12x10^{-5}$by using Walsh code and Gold code respectively under the effect of AWGN and J/S=10dB.

Also in order to check the performance evaluation of the DSSS system with different jamming power the BER was measured for different cases of J/S ratio 0dB to 18dB by using Walsh code and Gold code as shown in **Figure.(5).**

Figure.(6)and(7) show the frequency spectrum of the transmitted signal for Gold code and Walsh code respectively at J/S=10dB , this signal was spread over a 8MHz bandwidth.

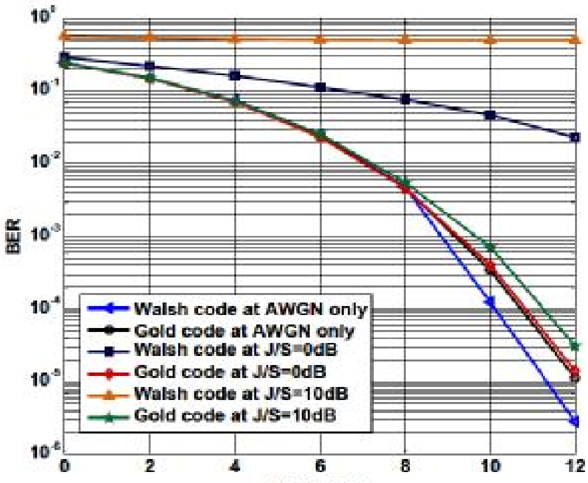


Fig.4: Comparison BER for DSSS in presence of STJ .

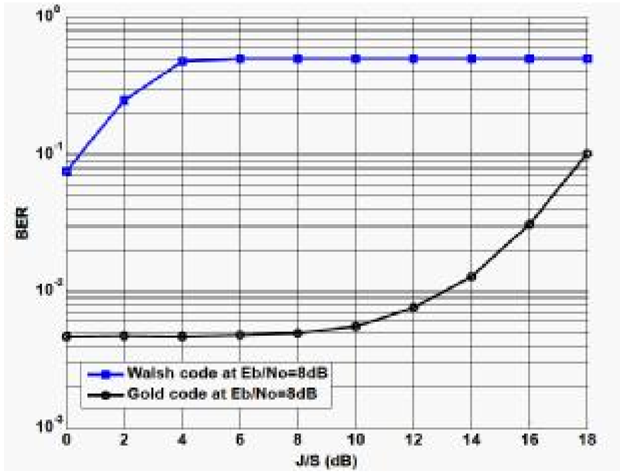


Fig.5: Comparison BER for DSSS in presence of STJ for different value of J/S ratio

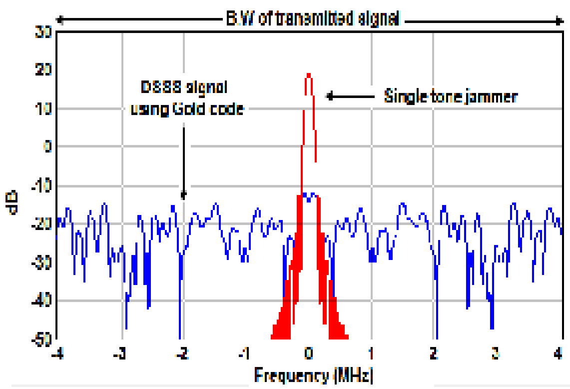


Fig.6:Frequency spectrum of the transmitted signal under the effect of STJ for J/S=10dB using Gold code

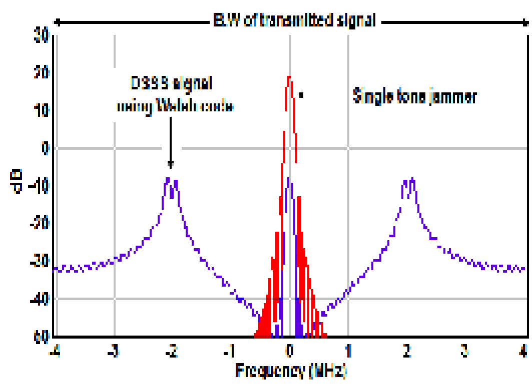


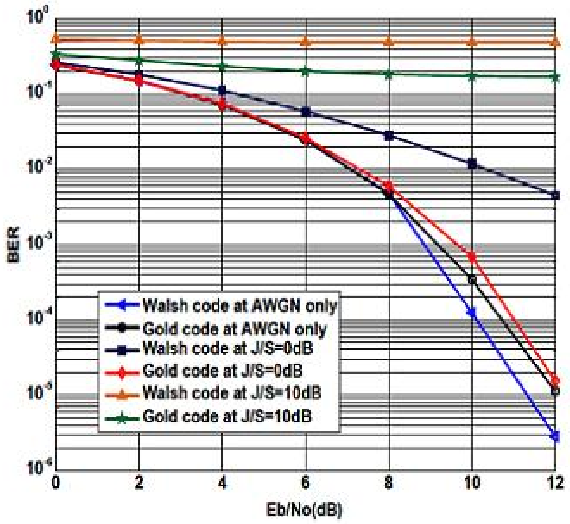
Fig.7:Frequency spectrum of the transmitted signal under the effect of STJ for J/S=10dB using Walsh code.

7.2. Multi-tone jamming (MTJ)

The performance evaluation of DSSS system was measured by using bit error rate calculation block found in MATLAB-simulink blocks set for two PN codes for 32000bits simulation process for two cases of J/S 0dB and 10dB with different cases of E_b/N_o 0dB to 12dB as shown in BER curve in **Figure.(8),**these results are shown the BER was $4.53x10^{-3}$and$1.56x10^{-5}$by using Walsh code and Gold code respectively at E_b/N_o=12dB under the effect of AWGN and J/S=0dB,whereasthe BER was $4.89x10^{-1}$ and$1.69x10^{-1}$by using Walsh code and Gold code respectively under the effect of AWGN and J/S=10dB.

Also in order to check the performance evaluation of the DSSS system with different jammer power the BER was measured for different cases of J/S ratio 0dB to 18dB as shown in **Figure.(9). Figures.(10)and(11)** show the frequency spectrum of the transmitted signal for

Gold code and Walsh code respectively at J/S=10dB,this signal was spread over a 8MHz bandwidth.



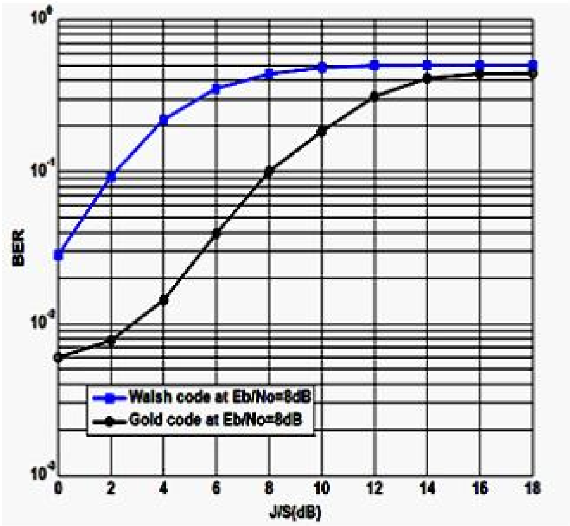
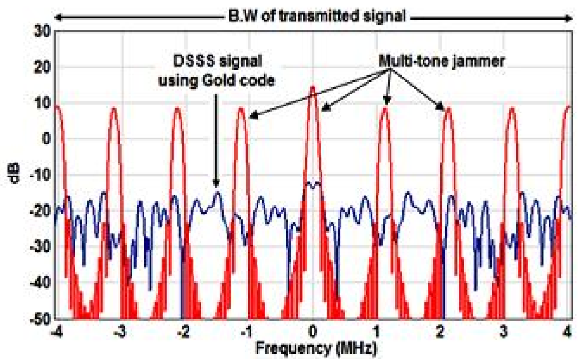


Fig.8: Comparison BER for DSSS in DSSS in Presence of MTJ.

Fig.9: Comparison BER for presence of MTJ for different Values of J/S ratio.



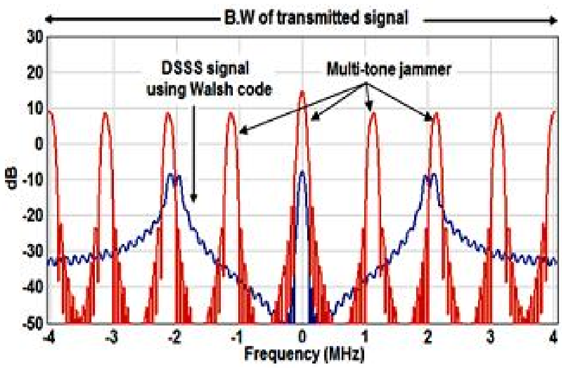


Fig.(10):Frequency spectrum of the Transmitted signal under the effect of MTJ for J/S=10dB using Gold code.

Fig.(11):Frequency spectrum of the Transmitted Signal under the effect of MTJ forJ/S=10dB using Walsh code.

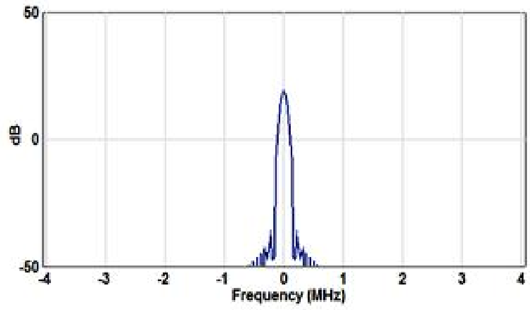


Fig.(12): Autocorrelation function of Gold code.

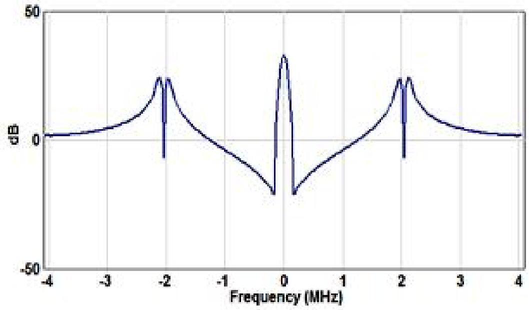


Fig.13: Autocorrelation function of Walsh code.

8. Conclusions

Several conclusions can be observed in this paper; the most important results can be summarized as follows:

1. The BER of the DSSS system using Walsh code is better than the system that using Gold code under the effect of AWGN only especially at higher values of E_b/N_o ratio.
2. In STJ the BER for DSSS system using Gold code is better than the system that using Walsh code especially at lower values of E_b/N_o ratio and for all values of J/S ratio was tested in this paper, this is because of the Gold code has good autocorrelation function over Walsh code as shown in Fig.(12) and (13).
3. In MTJ the BER was good for the DSSS system using Gold code at J/S=0dB but was bad at higher values of J/S ratio, whereas the BER was worse for the DSSS system using Walsh code at all values of J/S ratio.
4. When the power jamming increases the probability of error also increases and vice-versa.
5. The above results show the effect of MTJ on DSSS system increases the probability of error to$1.0053x10^{-1}$at J/S =8dB and E_b/N_o=8dB for using Gold code, this is the worst case of jamming if compared with STJ on DSSS system. Therefore in order to decrease or overcome the effect of jamming we must deal with some- one way of jamming rejection techniques.

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