Performance of Direct Sequence Spread Spectrum System (DSSSS) in Presence of Single and Multi Tone Jamming

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ABSTRACT

There are various impairments or problems on direct sequence spread spectrum communication channel especially jamming problems, in order to focus on this problem a direct sequence spread spectrum(DSSS) communication system using Gold code was used as point -to-point with fully synchronized between transmitter and receiver under the effect of Additive White Gaussian Noise (AWGN) channel and single tone jamming(STJ) and multi tone jamming(MTJ).
The performance evaluation of the DSSS system was simulated in MATLAB-Simulik by measuring the bit error probability (P_e) of receiving data as a function of noise power spectral density ratio (E_b/N_o) and also for different cases of jamming to signal power ratio (J/S).

The simulation results showed the performance of DSSS system under the effect of STJ at carrier frequency is better than the system under the effect of MTJ at different frequencies. Also the results show when J/S increases the P_e also increases, the J/S effect has been overcome by increasing the processing gain.

Keywords: Direct sequence, Single tone Jamming, Multi tone jamming, jamming to signal power ratio, processing gain.

أداء منظومة الطيف المنتشر التتابع المباشر بوجود التشويش المنفرد والمتعدد التردد

الخلاصة

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هناك انواع متعددة من المؤثرات اوالمشاكل التي تعاني منها قناة اتصالات الطيف المنتشر نوع التتابع المباشر وبالخصوص مشاكل التشويش ، ولكي نسلط الضوء على هذه المشكلة تم التعامل مع منظومة طيف منتشر نوع التتابع المباشريستعمل الشفر ة الذهبية كموقع الى موقع مع فرض تزامن تام بين المرسلة والمستقبلة تحت تاثير قناة ضوضاء كاوس وتشويش منفرد ومتعدد التردد.
ان تقييم أداء منظومة الطيف المنتشر نوع التتابع المباشر قد تمت محاكاته في بيئة البرنامج MATLAB-Simulinkعن طريق قياس احتمالية الخطاء في البيانات المستلمة كدالة لنسبة طاقة الاشارة للبت الواحدة الى قدرة الضوضاء (E_b/N_o) وايضا لحالات مختلفة من نسبة قدرة التشويش الى قدرة الاشارة المرسلة (J/S).
نتائج المحاكاة أظهرت بان أداء منظومة الطيف المنتشر نوع التتابع المباشر والتي تقع تحت تاثير التشويش المفرد التردد عند تردد الاشارة للموجة الحاملة كان افضل منها عند التشويش المتعدد التردد لترددات مختلفة .ايضا النتائج اظهرت بانه عند زيادة نسبة قدرة التشويش الى قدرة الاشارة المرسلة (J/S) فان احتمالية الخطاء تزداد ايضا وتم التغلب على هذا التاثير عن طريق زيادة معالج الكسب.

INTRODUCTION

Spread spectrum (SS) is a modulation method that spreads a narrow band signal over a wide range of frequencies at the transmitting end and then dispreads it into the original data bandwidth at the receiving end. The spread spectrum technique increases the bandwidth of the transmitting signals to a value much larger than is needed to transmit it. Thus, the power per unit bandwidth is minimized [1].

Two predominant types of SS communication techniques are Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). This paper presents investigate the performance of DSSS communication system when the channel is subject to a jamming signal as well as additive white Gaussian noise.

The purpose of all jamming is to interfere with another's ability to transmit information from one point to another. The basic technique of jamming is to transmit an interfering signal along with the desired signal.

Jamming is effective when the interfering signal is strong enough to prevent the receiver from recovering the required information from the desired signal. This is either because the information content in the desired signal is overwhelmed by the power of the jamming signal or because the combined signals have characteristics that prevent a processor from properly extracting the desired information [2].

Jamming activity can impact the timeliness of the information exchange, at least temporarily, slowing that exchange. Jamming can also affect the relevancy of information, because if it arrives at the intended destination too late to be of use ,the information then becomes irrelevant [3].

The optimum communication system has Pe lower than around 10-3 (on average, one bit is in error out of 1000). Jamming techniques attempt to raise the Pe to 10-1 or higher. If this level of Pe is achieved then a jammer is said to be successful [4].Jamming signals come in various different forms, e.g., single-tone jammer, multiple tone jammer, partial-band jammer, pulsed-noise jammer, etc.[5,6,7].

Principle of DSSS system

In DSSS the spreading of the signal bandwidth occurs at baseband by multiplying the baseband data pulses with a chipping sequence as shown in the block diagram in Figure (1),this chipping sequence is a pseudo-random binary waveform with a pulse duration of Tc and a chipping rate of Rc=1/Tc. Each pulse is called a chip and Tc is the chip interval. For a given information symbol of duration Ts and a symbol rate of Rs=1/Ts, the duration of each chip is much less than the pulse length of the information symbol (i.e., Tc<<Ts) and chipping rate is much higher than the symbol rate (i.e.,Rc>>Rs) [8].

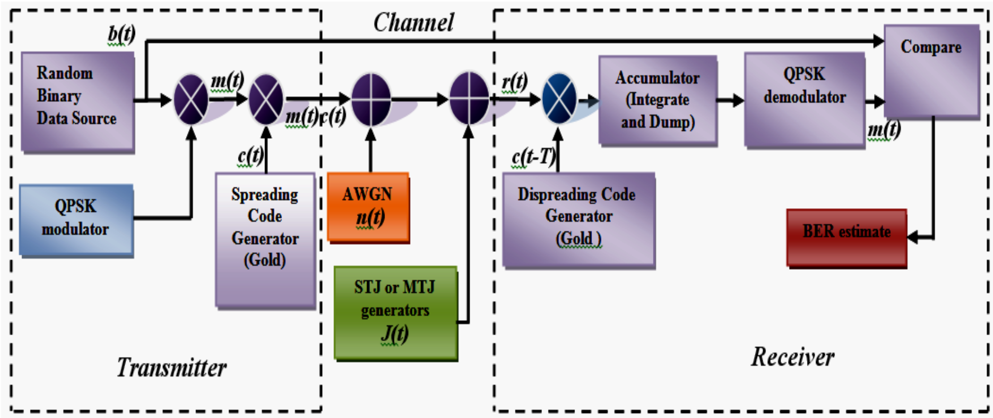

Figure (1) DSSS system model.

In practical systems, the number of chips per symbol must be an integer number with the transition of the data symbols and the chips occurring at the same time. The ratio of chips to symbols is called the spreading gain or processing gain which can be expressed as [8,9]:

$$k= Nc= Ts/Tc= Rc/Rs \qquad ....(1)$$

A PN code has a fixed-length of N chips and can be classified as either long or short. In a short code the entire chip sequence is transmitted within every data bit. In a long code only a portion of the sequence is transmitted within each data bit and typically N/Nc>>1. The chipping sequence and the data sequence are combined by modulo-2 summing the binary sequences or by multiplying the two pulsed waveforms. The relationship between chips and symbols and the resulting spread data sequence is seen in waveform in Figure (2).

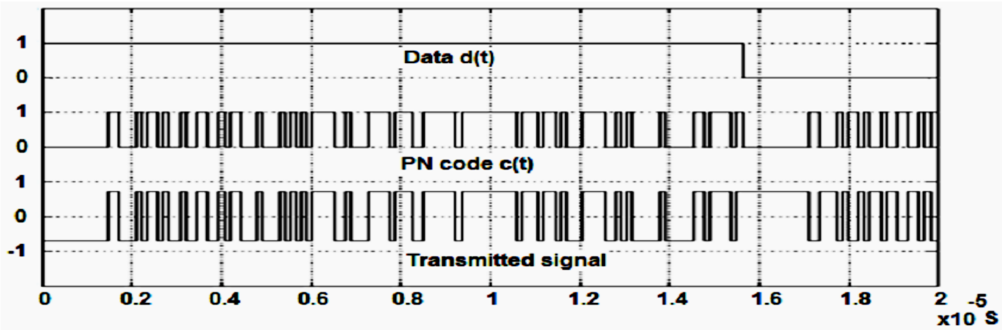

Figure (2) The relationship between the spreading sequence c(t) and the information sequence b(t) for a DS signal with 127 chips per bit.

The chip duration is chosen in order to spread the signal over the maximum available bandwidth of the channel. A rectangular pulse of length T has a null-to-null bandwidth BW = 2/T. Therefore for a channel bandwidth W[8].

$$T_c = 2/W \text{ or } R_c = W/2 \qquad ...(2)$$

Meaning that the chip rate should be half the available channel bandwidth. Despreading of the DSSS signal in the receiver is accomplished by again multiplying the signal by the same PN sequence.

In this paper three values of spreading factor or processing gain will be introduce with both types of jamming (STJ and MTJ), because of the effect of jamming signal is reduced by processing gain [10,11].

Also the jammer will need extreme power to overcome the processing gain when the processing gain is large enough [6, 7].

Tone Jamming

In tone jamming, one or more jammer tones are strategically placed in the spectrum. Where they are placed and their number affects the jamming performance [3].

Two types of tone jamming are illustrated in Figure (3) [12,13].STJ places a single tone where it is needed and is illustrated in Figure (3a). MTJ distributes the jammer power among several tones and is illustrated in Figure (3b).

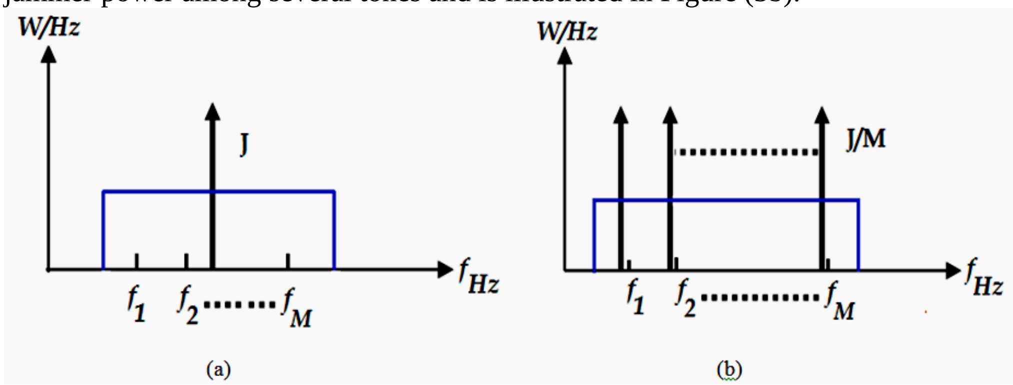

Figure (3) Power spectral density of (a) STJ and (b) MTJ.

In this paper, we analyze these two kinds of jamming .Total power of jamming signal is constant because power of jammer is limited. Characteristics of jamming are bellow.

A. Single tone jamming (STJ)

A jamming signal transmitted at a single frequency was shown in Figure (3a). Thus, the jamming signal is a continuous wave tone placed at a single frequency. STJ is also called spot jamming [3].

A continuous wave tone centered at the carrier frequency is well known to be a good jamming signal against a direct sequence system [14,15].The STJ can be expressed as[16,17,18]:

$$J(t) = A\cos(2\pi f_c t + \theta) \quad \text{....(3)}$$

Where: A is the amplitude, f_c is frequency of STJ , and θ is the initial phase which is uniform distribution between (0, 2π).

B. Multi tone jamming (MTJ)

Tone-jamming is impulse signal having high power. So, MTJ means there are some impulse signals in certain frequency of whole bandwidth such as Fig.3(b). Because total power of jamming signal is limited, the more the number of tone-jamming signals is increasing, the more power of each tone jamming signal is lower. Each tone-jamming signal can be expressed as [19]:

$$j(t) = \sqrt{\frac{2P_J}{N_T}} \sum_{j=1}^{N_T} \cos(2\pi f_j t) \quad \text{.....(4)}$$

Where: P_J and N_T are total jamming power and the number of multi tone jamming respectively. P_J is divided into same power equally depending on the number of multi tone jamming and f_j is jamming frequency.

System Model

The direct sequence system is carried out by MATLAB-simulink as shown in the block diagram in Figure (1).This communication system in the presence of jammer, captures direct sequence (DS) transmitted signals that have been corrupted with Additive White Gaussian Noise (AWGN).

In the transmitter the data sequence is baseband modulated quadrature phase shift keying (QPSK) modulation is first spread by multiplication with the DS spreading waveform generated by pseudo-noise (PN) codes (Gold code 127-bit) 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 [20].

$$s(t) = \sqrt{P}c_1(t)\cos[\omega_o + \theta_d(t)] + \sqrt{P}c_2(t)\sin[\omega_o + \theta_d(t)] \ldots \quad (5)$$

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 a channel can be represented by[21,22]:

$$r(t) = s(t) + n(t) + J(t) \ldots\ldots \qquad (6)$$

Where: n(t) is additive white Gaussian noise (AWGN) of spectral density No/2, and $J(t)$ is STJ or MTJ which described previously in equations (3) and (4) respectively.

Simulation Results

The DSSS was simulated under the parameters for STJ and MTJ as in Tables (1) and (2) respectively. The DSSS system was simulated under three values of processing gain k for three cases of impairments [without jamming AWGN only, with STJ and with MTJ].

Table (1) Simulation parameters for DSSS system under the effect of STJ.

parameter	value	unit
Data bit rate	64	Kb/s
Carrier frequency (QPSK baseband)	8	MHz
Code rate	8	MHz
Codes type	Gold	
Code length	127	Chip
Processing gain *k*	18,21,24	dB
Jammer frequency at carrier frequency	8	MHz
Jammer-to-signal(J/S)	0 and 18	dB
Gaussian noise (E_b/N_o)	0 to 14	dB

parameter	value	unit
Data bit rate	64	Kb/s
Carrier frequency (QPSK baseband)	8	MHz
Code rate	8	MHz
Codes type	Gold	
Code length	127	Chip
Processing gain *k*	18,21,24	dB
Jammer frequency	fc , ±2fc , ±3fc	MHz

Jammer-to-signal(J/S)	0 and 18	dB
Gaussian noise (E_b/N_o)	0 to 14	dB

Table (2) Simulation parameters for DSSS system under the effect of MTJ.

The simulation results can be classified as follows:

A. Simulation without jamming

The frequency spectrum of DS transmitted signal is shown in Fig.(4) at processing gain k is equal to 24dB, this signal was spreaded over a 8MHz bandwidth.

When a signal is received at the DS receiver, the effectiveness of the receiver can be studied by measuring the Pe at various values of bit energy Eb relative to the constant noise floor No (both above and below it). For each value of normalized bit energy, Eb/No , we have taken twenty thousand samples in order to attain a smooth curve.

The results without jamming are presented in Fig.(5) .Ideally the curve should fall drastically down to zero as Eb/No increases beyond 12dB.The processing gain, has a remarkable effect on the shape of the curve.

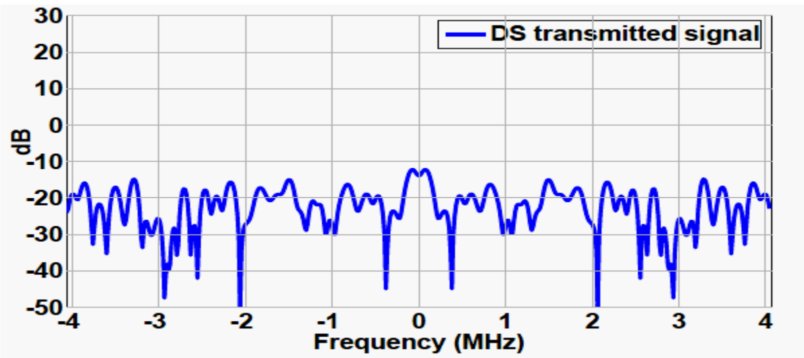

Figure (4) Frequency spectrum of DS transmitted signal.

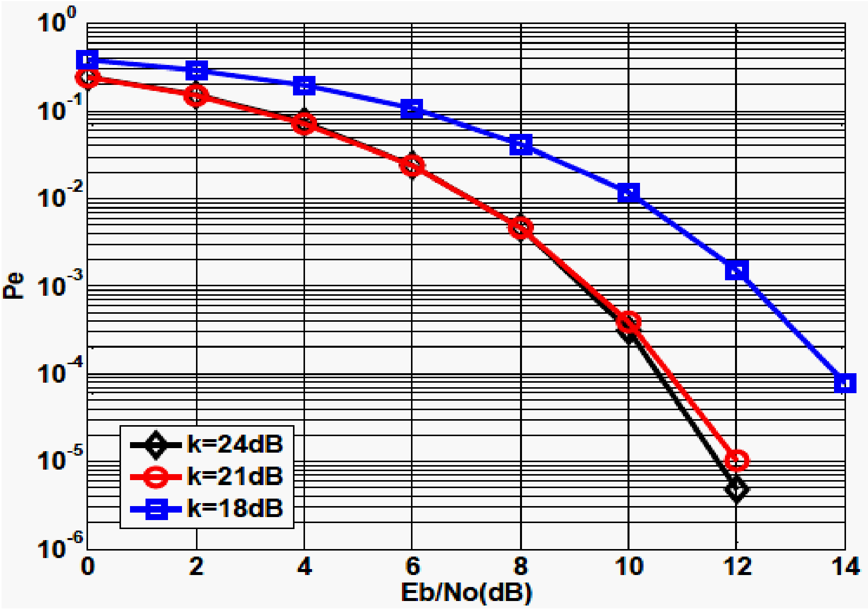

Figure (5)The Pe versus E_b/N_o for DS without jamming.

B. Simulation with STJ jamming

For single ton jamming, Figure (6) shows the frequency spectrum of the DS transmitted signal when the processing gain k is equal to 24dB under the effect of STJ at J/S=10dB, this signal was spreaded over a 8MHz bandwidth and the jamming at carrier frequency.

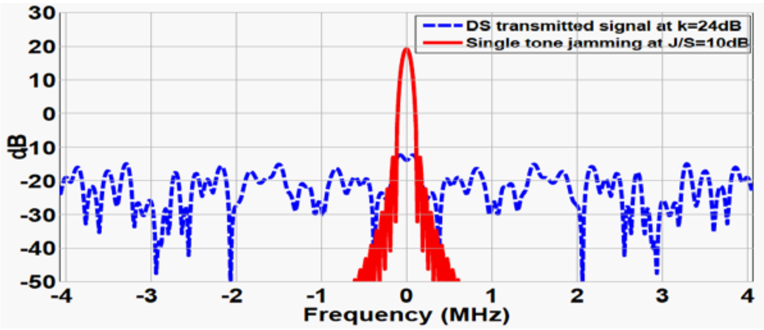

Figure (6) Frequency spectrum of DS transmitted signal under the effect of STJ for J/S=10dB.

The results in the presence of STJ for three cases of J/S are presented in Figure (7). The curve attained has maintained its downward slopping trend at the same time the bit error probabilities have substantially increased (the upward shift of the curve with the STJ relative to the one without it especially at J/S greater than 15dB).

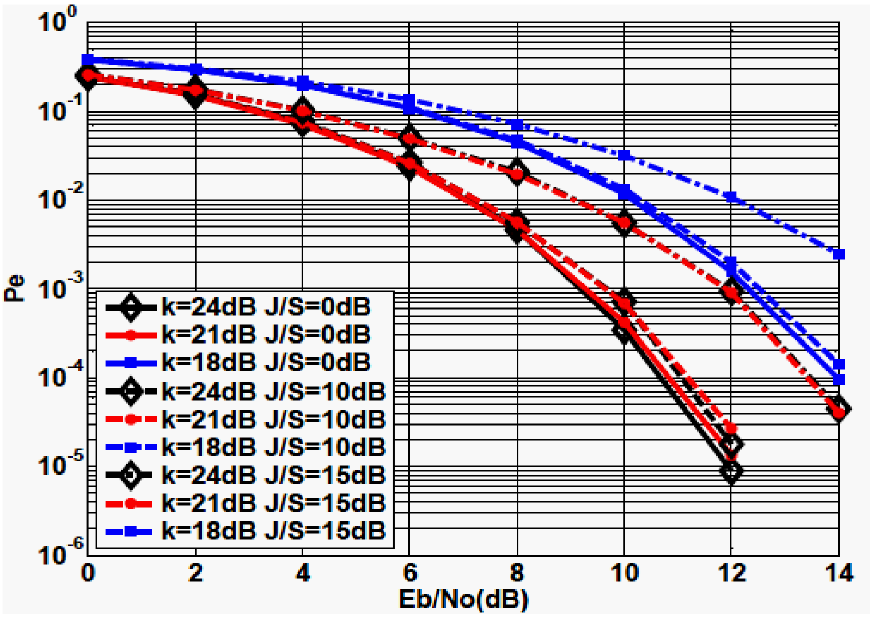

Figure (7) The Pe versus Eb/No for DS with STJ at different cases of J/S.

Figure (8) shows the relationship between Pe versus Eb/No without jamming and for three cases of J/S power ratio (0dB, 10dB, 15dB) with three values of processing gain.

If the curves in Figure (8) were compared with each other ,we find the Pe under the effect of jamming is best at processing gain is equal to 24dB when J/S is 0dB and it is worst when processing gain is equal to 18dB at J/S is 15dB.

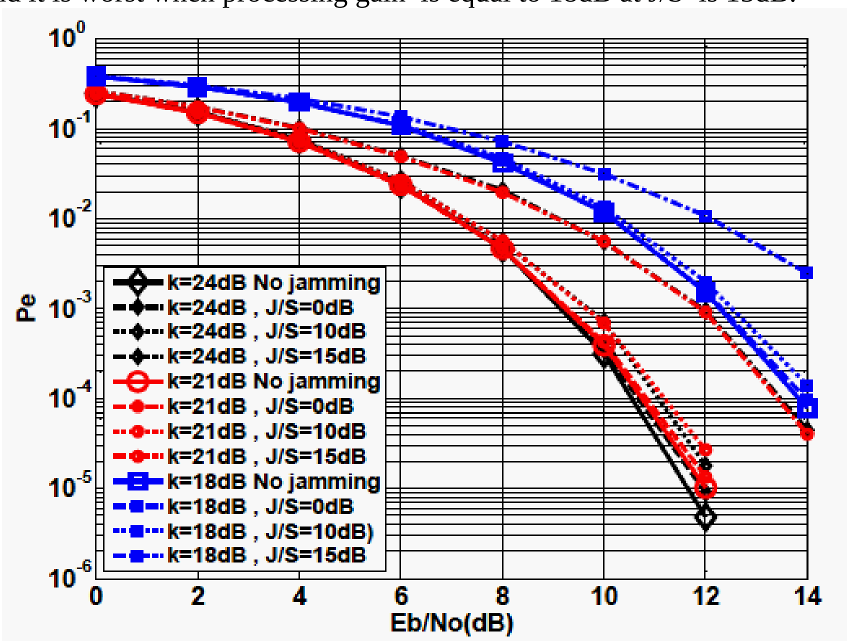

Figure (8) The P_e versus E_b/N_o for DS without jamming and with

STJ at different cases of J/S ratio.

C. Simulation with MTJ jamming

In similar way the MTJ in Figure (9) shows the frequency spectrum of the DS transmitted signal when the processing gain k is equal to 24dB under the effect of MTJ at J/S=10dB this signal was spreaded over a 8MHz bandwidth and the jamming frequencies are fc, ±2fc and ±3fc.

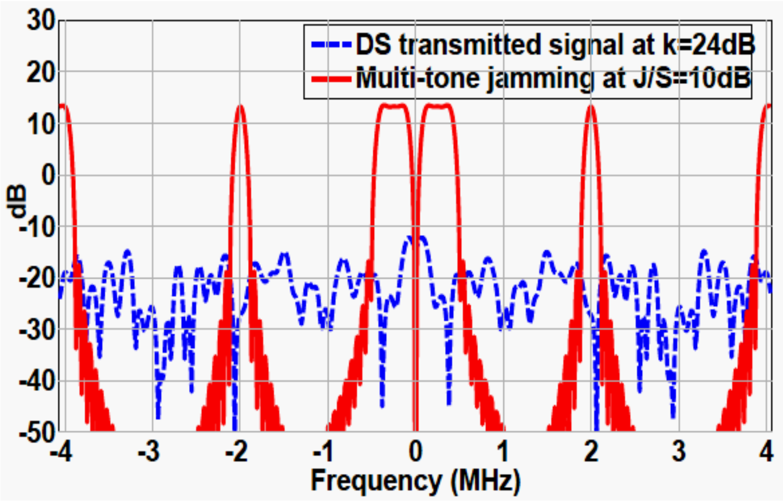

Figure.9:Frequency spectrum of DS transmitted signal under the effect of MTJ for J/S=10dB and tone.

The results in the presence of MTJ for three cases of J/S are presented in Fig.(10). The curve attained has maintained its downward slopping trend at the same time the bit error probabilities have substantially increased (the upward shift of the curve with the MTJ relative to both single ton jamming and without jamming especially at J/S greater than 10dB).

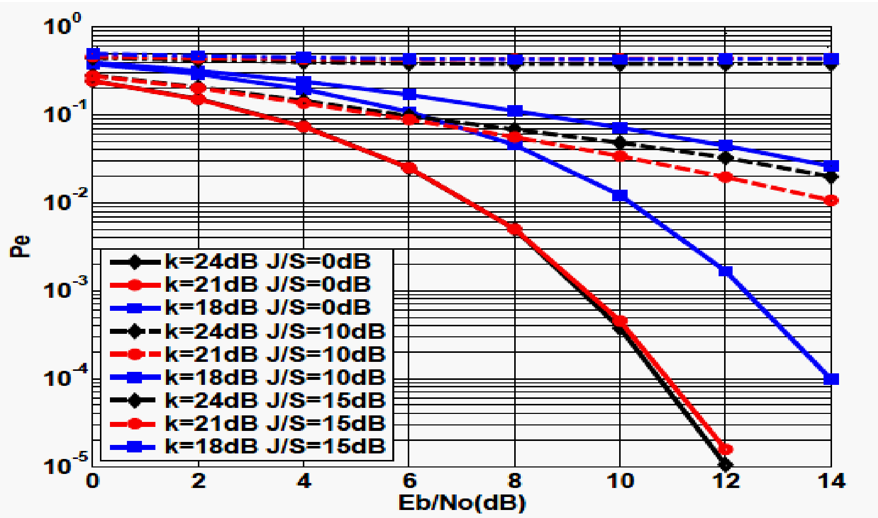

Figure (10) The P_e versus E_b/N_o for DS with MTJ at different cases of J/S ratio.

Figure (11) shows the relationship between Pe versus Eb/No without jamming and for three cases of J/S (0dB, 10dB, 15dB) with three values of processing gain. If curves in Figure (11) were compared with each other ,we find the Pe under the effect of jamming is best at processing gain is equal to 24dB when J/S is 0dB and it is worst when processing gain is equal to 18dB at J/S is 15dB.

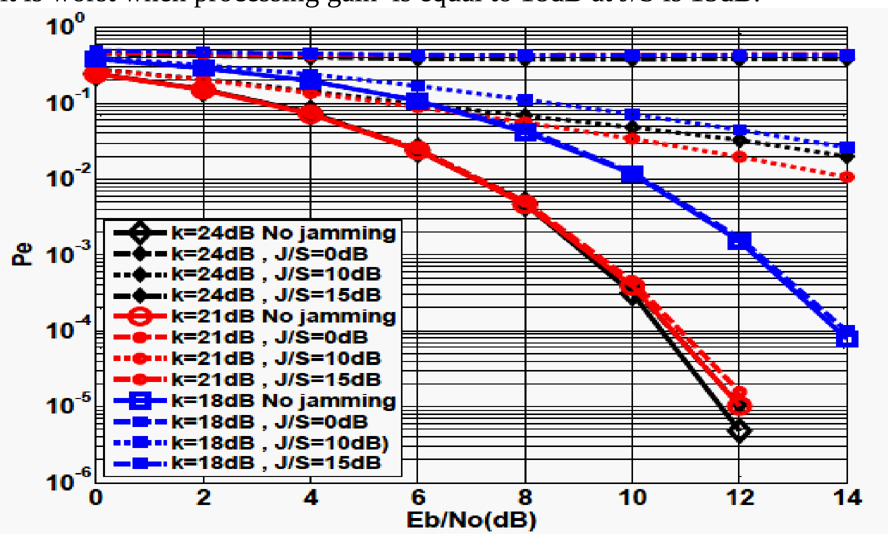

Figure (11) The P_e versus E_b/N_o for DS without jamming and with MTJ at different cases of J/S ratio.

Foregoing shows that the best case is when the processing gain is equal to 24dB and the J/S is equal to 0dB for both STJ and MTJ, therefore Figure (12) shows the comparison between the Pe without jamming and with both types of jamming.Found that the Pe is 4.79x10-6 ,8.9x10-6 and 1.04x10-5 without jamming ,STJ and MTJ respectively.

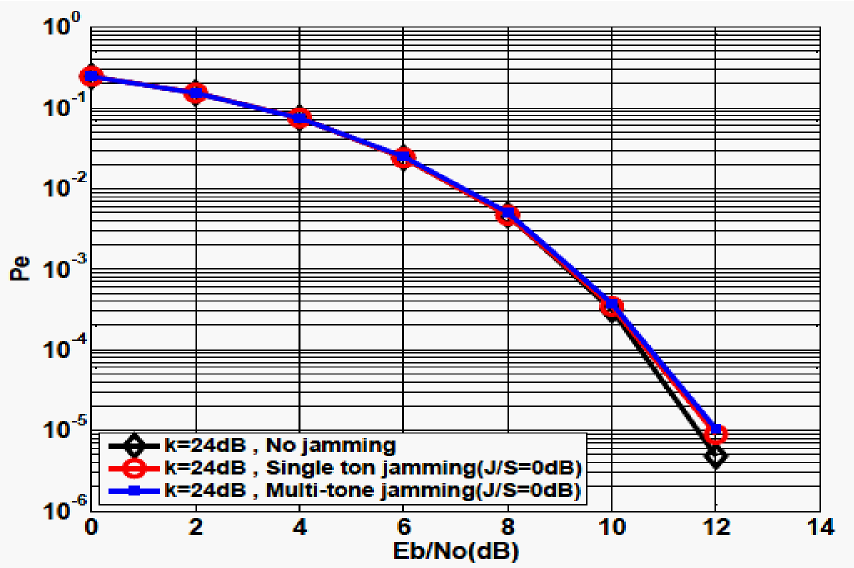

Figure (12) The P_e versus E_b/N_o for DS without jamming STJ and MTJ at J/S=0dB.

D. J/S Signal Power Ratio

The J/S at the receiver for the most part determines the degree to which jamming will be successful. For digital signals, the jammer’s goal is to raise this ratio to a level such that the Pe is above a certain threshold.

Figure (13and14) show the Pe versus J/S for different Eb/No with STJ and MTJ respectively. As expected, when J/S increases, the Pe increases also. The Pe increases rapidly to a level such that it is above a certain threshold especially at J/S is greater than 18dB and 12dB for STJ and MTJ respectively for the specific values of Eb/No .

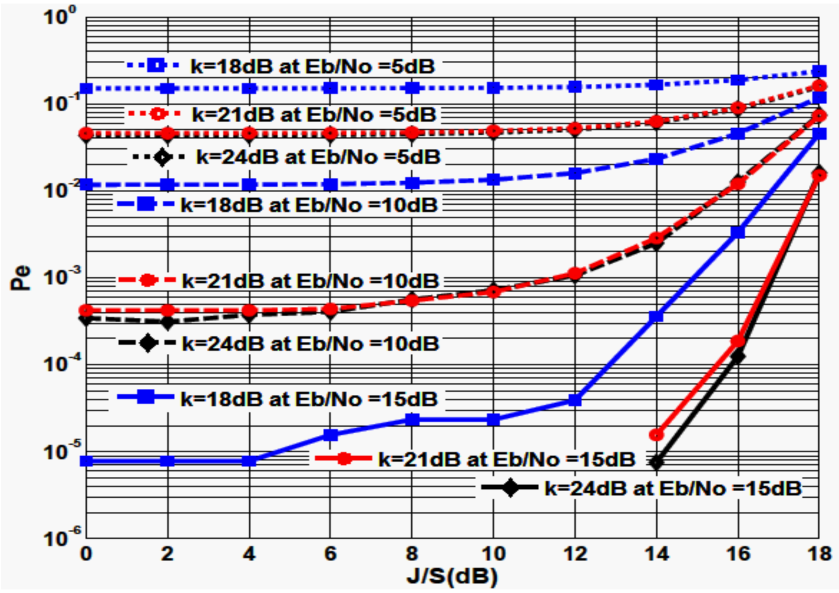

Figure (13) The P_e versus J/S for different E_b/N_o for DS with STJ.

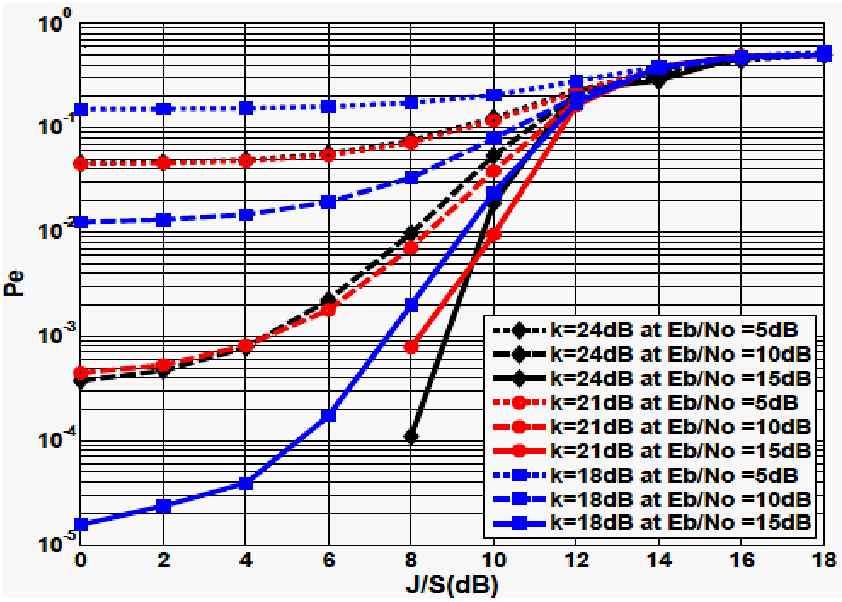

Figure (14) The P_e versus J/S for different E_b/N_o for DS with STJ.

Figure (15) shows the comparison between the effect of STJ and MTJ on DSSS system at k=24dB with different cases of Eb/No.

This figure shows the best case of Pe when Eb/No is equal to 5dB for both STJ and MTJ.The Pe is equal to 10-4 at J/S=16dB for STJ whereas the same value of Pe at J/S=8dB for MTJ,this means that the DSSS system work under the effect of STJ has twice the ratio of J/S from MTJ to get the same value of Pe.

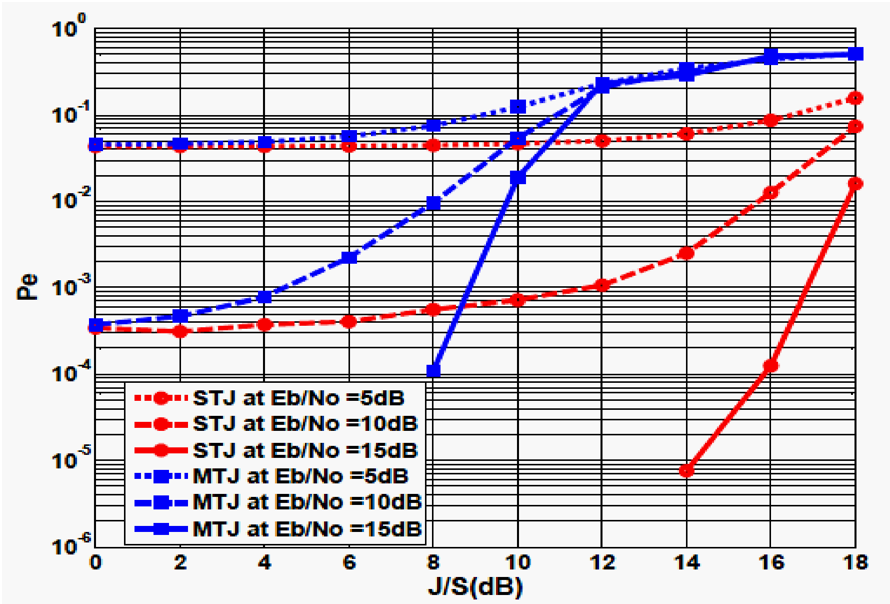

Figure (15) The P_e versus J/S for different E_b/N_o for DS at *k*= 24dB with STJ and MTJ.

CONCLUSIONS

From the analysis above, we can get some conclusions:

1- The performance of DSSS system with single-tone and MTJ has relations with the parameters Eb/No, J/S, and processing gain,these parameters have changed the Pe.

2-The Pe of the DSSS system under the effect of STJ is better than the system under the effect of MTJ.

3-In DSSS system the ability to overcome jamming is determine by the processing gain of the system. Received jamming signal is reduced by processing gain especially when the processing gain is large enough and the jammer will need extreme power to overcome the processing gain.

4-When the jamming power increases the Pe also increases and vice-versa.

5. The ratio of J/S is a figure of merit that provides a measure of how vulnerable a system is to interference, the larger the (J/S) the greater is the system's jamming rejection capability.

6- For a given J/S, the jammer will cause some irreducible error probability, when J/S increases the Pe also increases.The one way to reduce this error probability is to increase the processing gain.

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