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ORIGINAL ARTICLES

Design Of Ask 31 Channel Frequency Hopping Spread Spectrum Transciever System Using Banks Of Noncontiguous Band Pass Filters

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ABSTRACT

There are many available synchronization techniques that can be used in frequency hopping spread spectrum (FH/SS) transceiver system most of these techniques require complex search operation and hence need complex hardware. In this paper noncontiguous (NC) parallel digital band pass filter (BPF) banks for 31 channel FH/SS transceiver system has been designed and implemented successfully in real time using Matlab /Simulink. The proposed system is simple and efficient approach for synchronization of FH/SS transceiver. It can be used to transceive digital information with a data rate of 160 k bit /sec for frequency hopping rate of 160 k hop/sec and spread the transmitted data in the high frequency band, (3-12.6 MHz). Finally the proposed design was tested under sever jamming conditions using multi-tone jamming (MTJ) and hopper jamming (HJ) in the presence of Additive White Gaussian Noise (AWGN). The results obtained were vey encouraging.

Key words: *FH/SS, ASK, Noncontiguous BPF, Noise &Jamming.*

Introduction

In the last two decades, frequency hopping spread spectrum (FH/SS) communication system has played a growing role in modern communication systems from military to commercial application. The spread spectrum refers to the class of digital modulation that produces bandwidth of at least 10 to 100 times, the information rate must be independent of information bit rate (R.E.Zimmer and R.L.Peterson, 1985; C.W.Leon, 1997; H.N.AL-shammary, 2004). In FH/SS, the frequency of the carrier is changed periodically, each carrier frequency is chosen from a set of frequencies [(2^k-1), k is an integer number] which are spaced approximately the width of modulation data spectrum.

The spreading code does not directly modulate the data modulated carrier but it is used to control the sequence of carrier frequencies. Because the transmitted signal appears as a data modulated carrier which is hopping from one frequency to another, (FH spreader) this type of spread spectrum is called frequency hopping spread (FH/SS) (R.E.Zimmer and R.L.Peterson, 1985).

In the receiver side, de-spreader removes FH by mixing with received signal (J.R.Smith, 1988; T.S. Rappaport, 2000). The synchronization is achieved by using new simple and efficient approach by means of using digital band pass filter banks (31 digital BPF) . In this paper wireless frequency hopping communication system has been designed and simulated (using Matlab/ Simulink) for transmitting and receiving information with data rate up to 160 kb/sec. Amplitude Shift Keying (ASK) was used, for simplicity, in modulating and demodulating the transmitting information. The most efficient way to check the performance of any digital system is to measure its Bit Error Rate (BER).The BER performance of the implemented FH /SS transceiver is examined under Additive White Gaussian Noise (AWGN) and different types of jamming.

There are two main classes of digital filters: Finite Impulse Response (FIR) and Infinite Impulse Response (IIR). In this paper IIR Butterworth (BW) filter is used because it needs less number of coefficients and order than FIR (S.K.Mitra, 1998). The design of Digital filter is a task of determining a transfer function (TF) which is a rational function in Z^{-1}. This TF function must meet certain performance specification.

The general recursive filter TF can be given by the following formula (Zhan Wei,Zhang Xiaolin, 2010; L. C. Ludeman. 2001).

$$H(Z)=\left(\sum_{k=0}^{L} b_k Z^k\right) \Big/ \left(1+\sum_{k=1}^{R} a_k Z^k\right) \quad (1)$$

Where:

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L and R: are integer numbers and must satisfy the inequality $L \leq R$,
a_k and b_k: are the filter coefficients.
An important special case that is used as a building block occurs when L = R =2.
Thus *H (z)* is a ratio of two (quadratics in z^{-1}) terms called a bi-quadratic section, and is given by:

$$H(Z)=\frac{(b_o+b_1 Z^{-1}+b_2 Z^{-2})}{1+a_1 Z^{-1}+a_2 Z^{-2}}=\frac{b_o((1+(b_1/b_o)Z^{-1}+(b_2/b_o)Z^{-2}))}{1+a_1 Z^{-1}+a_2 Z^{-2}} \quad (2)$$

Or it can be written in the following form for the alternate realization:

$$H(z) = b_0 (1+ (b1/b_0)\, z^{-1} + (b_2/b_0)\, z^{-2}) / (1 + a_1.z^{-1} + a_2.z^{-2}) \quad (3)$$

The direct form II and alternative realizations of the bi- quadratic *H(z)* are shown in Figures (1) and (2) below. The alternative realization is more useful for amplitude scaling to improve filter operation.

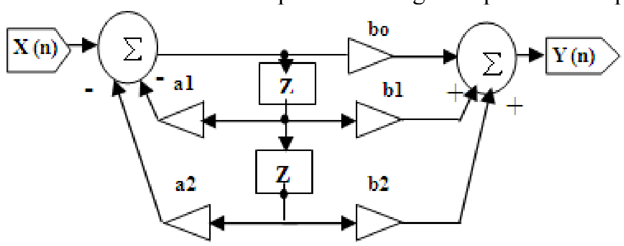

Fig. 1: The direct form II realization of the biquadratic section.

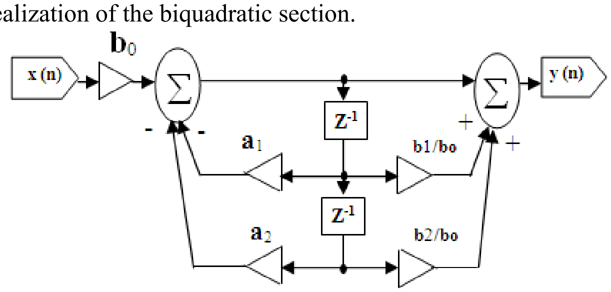

Fig. 2: An alternative realization of the bi quadratic section.

Design of 2nd order NC BW IIR BPF:

By using MATLAB-Simulink version 7 and depending on equation (3), the IIR second order Butterworth (BW) BPF01 with ($f_{L=}$ 3 MHz, f_H = 3.6 MHz, f_c =3.3 MHz and f_S = 30 MHz) is designed and its realization parameters are as below where as its magnitude response and pole zero configurations are shown in Figures (3) and (4) respectively,

b_o = 1, b_1 = 0b_2 = -1
a_1 = -1. 825327310364317
a_2 = 0. 939062505817493

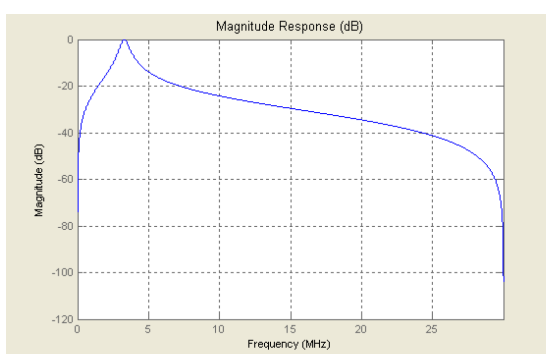

Fig. 3: The magnitude response of IIR second order Filter BPF01

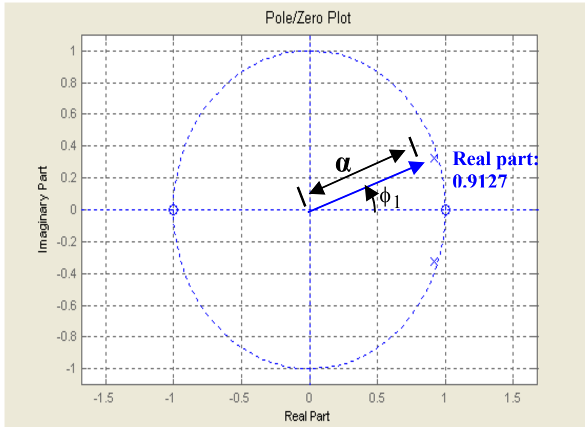

Fig. 4: The pole zero configuration of IIR second order BPF01

Design of parallel Noncontiguous NC IIR 2nd order BW BPF Banks for ASK FH/SS system:

In this design NC technique is used to make the overall bandwidth of FH /SS signal smaller than that used in contiguous technique (K.A. Humood & A.A. Ali 2010). The Schematic diagram of the proposed bank of filters is as shown in Figure (5). It consists of 31 IIR second orders NC BP BW filters whose transfer function parameters are given in Table (1). The realization of each filter is the same as that shown in Figure (2) above except that the coefficients values are different. Figure (6) shows the distribution of frequencies over the band of ASK FH /SS used in this system.

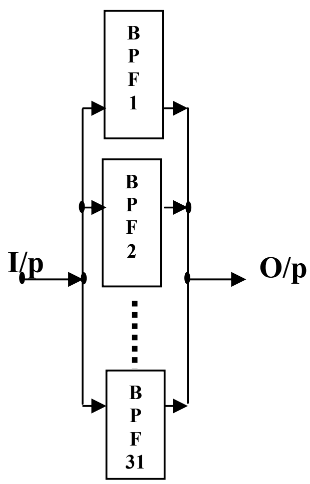

Fig. 5: Bank of Parallel IIR 2nd Order BW BPF.

The center frequency (f_c) of each filter is given by (L.C. Ludeman. 2001; E. Strom and T. Ottosson 2004):

$$f_c = (f_H + f_L)/2 \tag{4}$$

Where:

f_H : 3dB band stop frequency

In this proposed design, the transmitter is designed to transmit the information with data rate ($1/T_b$) equals 200 kbits /sec.

$\frac{1}{T_b} = 200\,K\,bits/\sec$, where: $\frac{1}{T_b}$: data rate.

The bandwidth of each filter is approximately twice of data rate (R_b) (Don Torrieris, 2005).

$$R_b = 1/T_b \quad (5)$$

$$\Delta F = \left(2/T_b \right) + f_g \quad (6)$$

where:

ΔF : 3dB bandwidth of BPF, and

$$f_g = R_b / 2 \ = 1/2\, T_b \quad (7)$$

Where f_g: guard band

$$B_{ss} = (2^n - 1)\, \Delta F \quad (8)$$

where:

B_{SS}: spread spectrum bandwidth.

n: integer number (number of D-Flip Flop of the Pseudo Noise (PN) code).

f_L : 3dB band pass frequency.

Table 1: The *Denominators* of the *TF* of all the designed banks of filters for ASK FH/SS transceiver system, with all *Numerators* = $1\text{-}Z^{-2}$

Filter No.	*Center Frequency (MHz)*	*Filter TF's Denominator*
BPF01	3.3	$1- 1.452678572599146\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF02	3.6	$1- 1.374352894101055\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF03	3.9	$1- 1.290603272612059\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF04	4.2	$1- 1.201760229626613\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF05	4.5	$1- 1.108174388046856\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF06	4.8	$1- 1.010215088434197\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF07	5.1	$1- 0.908268931390862\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF08	5.4	$1- 0.802738251823930\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF09	5.7	$1- 0.694039531113274\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF10	6.0	$1- 0.582601753449814\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF11	6.3	$1- 0.468864712530910\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF12	6.6	$1- 0.353277277394375\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF13	6.9	$1- 0.236295617941000\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF14	7.2	$1- 0.118381407636811\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF15	7.5	$1- 0.000000000000000\ Z^{-1} + 0.88168592363189\ Z^{-2}$
BPF16	7.8	$1+0.118381407636811\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF17	8.1	$1+0.236295617941000\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF18	8.4	$1+0.353277277394375\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF19	8.7	$1+0.468864712530910\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF20	9.0	$1+0.582601753449814\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF21	9.3	$1+0.694039531113274\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF22	9.6	$1+0.802738251823931\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF23	9.9	$1+0.908268931390862\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF24	10.2	$1+1.010215088434197\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF25	10.5	$1+1.108174388046856\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF26	10.8	$1+1.201760229626614\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF27	11.1	$1+1.290603272612059\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF28	11.4	$1+1.374352894101055\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF29	11.7	$1+1.452678572599145\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF30	12.0	$1+1.525271192436898\ Z^{-1} + 0.881618592363189\ Z^{-2}$
BPF31	12.3	$1+1.591844263708227\ Z^{-1} + 0.881618592363189\ Z^{-2}$

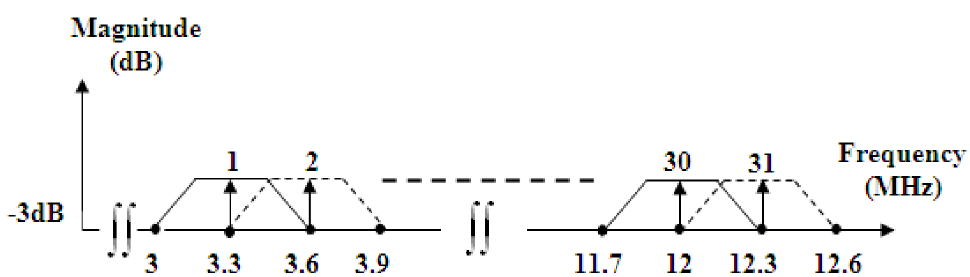

Fig. 6: The distribution of the frequencies over the band 3-12.6 MHz

Figures (7) and (8) show the magnitude response and pole zero configuration respectively for the second order (BPF02) Butterworth noncontiguous BP filter number 31 (f_L = 12 MHz, f_H = 12.6 MHz, f_S = 30 MHz)for ASK FH / SS transceiver system.

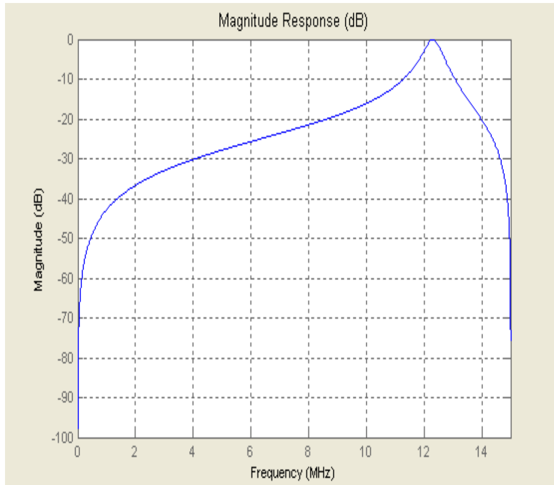

Fig. 7: Magnitude response of IIR second order Butterworth for BPF31

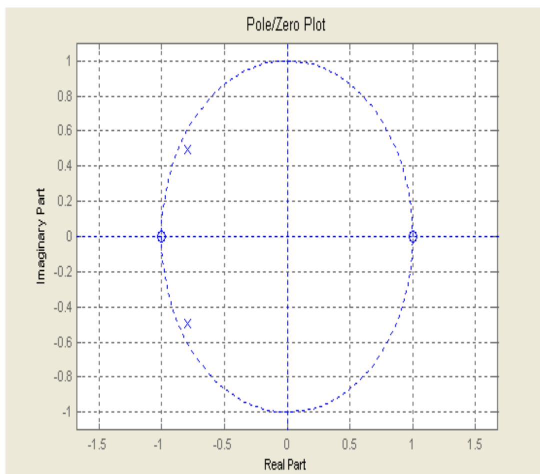

Fig. 8 Pole zero configuration of IIR second order Butterworth for BPF31

Proposed design:

Figure (9) shows the block diagram of the proposed transceiver system using NC BPF bank. It is designed for thirty one channel ASK FH/SS with hopping rate of 160 k hops/sec and 160 k bits/sec data rate using NC BW IIR BPF banks and simulated by MATLAB-Simulink version 7. It consists of three parts, the transmitter, transmission channel and the Receiver which contains the noncontiguous digital BPF banks (K.A.Humood, 2007; Simulink Block Library 2002).

The transmitter contains: data generator, spread code generator, serial/parallel converter, Direct Digital Frequency Synthesizer (DDFS), mixer (spreading ASK signals) and digital High Pass Filter (HPF). The transmission channel that used in the proposed transceiver system contains Additive White Gaussian Noise Channel (AWGN), Multi tone Jamming (MTJ) and Hopper Jamming (HJ) (K.A.Humood, 2007). It has been used as a path between the two sides of transceiver system.

Finally), the receiver side which contains, bank of parallel digital BPFs, spread code generator, serial/parallel converter, DDFS, mixer (de-spreading), ASK demodulator, bit error rate calculation blocks. Digital HPF is the same as that of the transmitter; it is used to reject the unwanted signals before de-spreading.

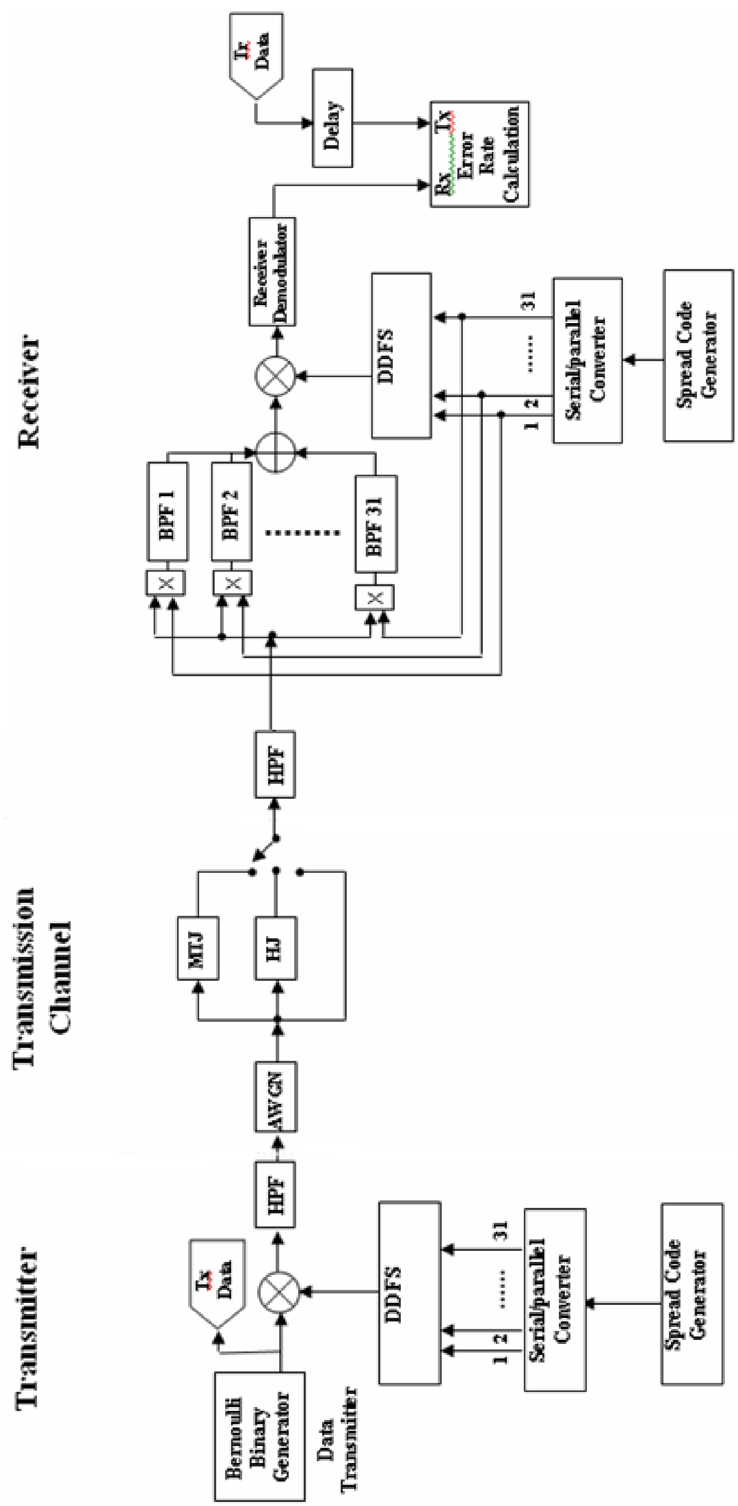

Fig. 9: Block Diagram of proposed ASK FH /SS Transceiver System.

Simulation Results:

The performance of digital transceiver system can be evaluated by the Bit Error Rate (BER) (NIIT, 2004) measurements. Moreover in this work the effects of the noise (AWGN) and jamming (MTJ, HJ) on the ASK FH/SS transceiver system using noncontiguous technique are studied.

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Effect of AWGN:

During simulation process and after 0.62 ms simulation time the number of bits is 10000 bits. Different values of SNR were taken for the AWGN and the BER were measured (using error rate calculation block from communication block set), the results then plotted as shown in Figure (10). The process gain (G_P) in dB, can be calculated using the following equation (K.A.Humood, 2007).

$$G_P = \frac{B_m \times 2^n - 1}{B_m} = 2^n - 1 \quad ,$$
$$G_P\left(dB\right) = 10 \log\left(2^n - 1\right) = 10 \log 31$$
$$= 14.9 \ dB_m \ , \ for \quad n = 5 \ 10^{-4}$$

Where:
Bm: message bandwidth
It is clear, from Figure (10), that the BER performance for ASK FH/SS transceiver using NC technique, can achieve 10^{-4} BER for only 14dB SNR, which means that the use of bank of noncontiguous filters is efficient.

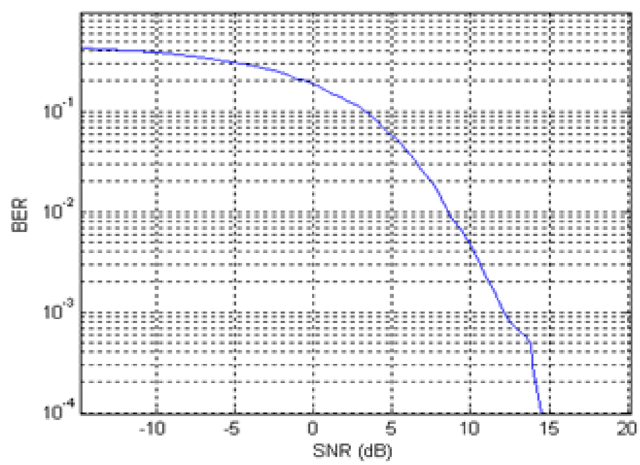

Fig. 10: BER performance of the transceiver under AWGN

Effect of Jamming:

The proposed system is tested under the types of jamming, the Multi-Tone Jamming (MTJ) and the Hopper Jamming (HJ) as will be shown below.

Multi-Tone Jamming (MTJ):

Different values of Signal to Jamming Ratio (SJR) were taken and the corresponding BER were measured by using error rate calculation block from communication block set, during the simulation process after 0.62 ms simulation time, the number of bits is 10000 for each run. Figure (11) shows the relationship between BER and SJR (dB) for the FH/SS transceiver system under MTJ using NC technique. It is clear that the ASK FH/SS transceiver system under MTJ with noncontiguous technique still has good BER performance (10^{-3} BER achieved at 7dB SJR, i.e. still functioning properly). This in turn means that the designed system worked correctly and passed previous test successfully.

Effect of Hopper Jamming (HJ):

The hopper jamming (HJ) has a severe effect on the system than that of MTJ. The calculation of the effect of this type of jamming is done also by running the system for a period of 0.62 ms to get 10000 bit for each run in order to calculate the BER. The results of these calculations are shown in Figure (12) which again shows the plot of the BER and SJR (dB) for the FH / SS transceiver system under HJ using noncontiguous technique.

It is clear that the BER for ASK FFH/SS transceiver noncontiguous technique has less performance than the other type of jamming (10^{-3} BER can be achieved at about12dB SJR, which is higher than the case of MTJ, but still reasonable). This means that the proposed designed system worked correctly and passed all tests successfully.

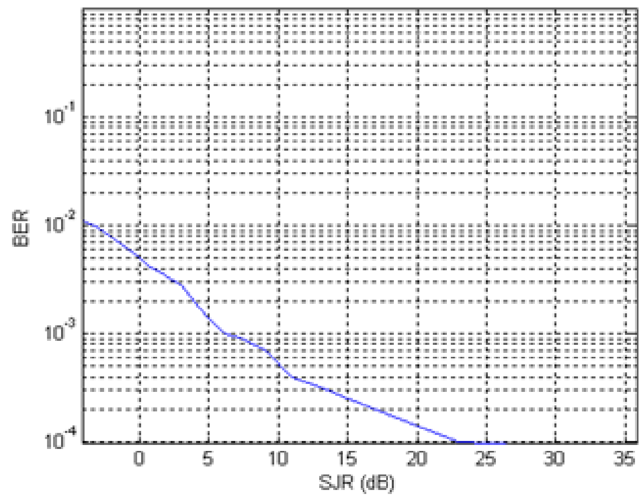

Fig. 11: BER versus SJR (dB) under MTJ

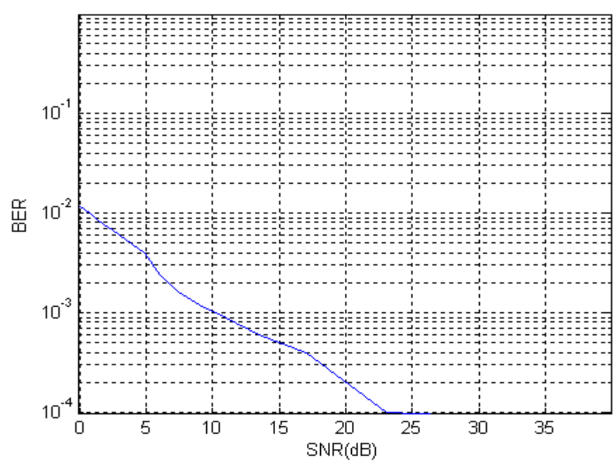

Fig. 12: BER versus SJR (dB) Hopper Jamming under HJ

Conclusions:

In this paper wireless frequency hopping communication system have been designed and simulated (using Matlab/ Simulink) for transmitting and receiving information with data rate up to 160 kb/sec. Though there are a lot of synchronizing techniques used for the synchronization between the transmitter and the receiver in the Frequency hopping/ spread spectrum communication systems, most of them require performing a complicated search. The proposed synchronization is achieved by using new simple and efficient approach that is by using digital band pass filter banks.

Simulation results of the proposed system shows that it performs very well in case when only AWGN present in that it can achieve low BER rate in low SNR. In addition the system performed reasonably when Multi Tone Jamming or Hopper Jamming exists.

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