# PERFORMANCE COMPARISON OF VARIOUS SHORT CODES IN DIRECT SEQUENCE SPREAD SPECTRUM (DS/SS) SYSTEM [+]

# مقارنة أداء انواع مختلفة من الرموز القصيرة في منظومة الطيف المنتشر نوع التتابع المباشر

**Sadiq Kamel Gharkan** [*]

**Abstract:**

**A spread spectrum system is largely categorized by its coding scheme,the type of code depend on its length, and its chip-rate all define the overall system parameters. In order to improve the system's spreading capability it is necessary to alter the coding arrangement. This paper compares the performance of the direct sequence spread spectrum (DS/SS) system-baseband QPSK modulation with various types of short codes: Barker ,Walsh,Hadamard,Kasami ,M-sequence and Gold code by measuring the probability of error ($P_e$) and shows the autocorrelation and crosscorrelation of these code in presence of Rayleigh Fading (Flat Fading) channel and Additive White Gaussian Noise (AWGN) channel.**
**The results were shown the probability of error (Pe) for Barker code was 3.817 x$10^{-5}$ at 20dB signal- to-noise ratio (SNR), so the best choice in short code DS/SS system was Barker code,in addition to it had good autocorrelation and crosscorrelation functions.**
**Also the results were shown the probability of error (Pe) for Gold code was 3.13x$10^{-3}$ at 20dB signal- to-noise ratio (SNR), so the worst case in DS/SS system was Gold code.**

المستخلص:

**الطيف المنتشر يصنف بشكل واسع بالاعتماد على اشكال الترميز ونوع الترميزيعتمد على طول الترميز ومعدل سرعة الترميز وهذه العوامل تحدد عمل منظومة الطيف المنتشر .ولكي نحسن قابلية منظومة الطيف المنتشرمن الضروري ان نغير ترتيب الترميز.**
**لمختلف انواع الترميز القصيرةQPSK هذا البحث يقارن أداء منظومة الطيف المنتشرنوع التتابع المباشر-الحزمة القاعدية**
**)عن طريق قياس احتمالية الخطاء للبيانات المستلمة Barker,Hadamard,Walsh ,Kasami,M-sequence and Gold)**
**بالاضافة الىFlat Fading نوع Rayleigh واظهارالارتباط الالي والتقاطعي لهذه الانواع من الترميزوبوجود قناة رايلي**
**AWGN. قناة كاوس**
**عند ٢٠ ديسبل من نسبة الاشارة$10^{-5}$x 3.817 كانت Barkerالنتائج اظهرت ان احتمالية الخطاء للبيانات المستلمة**

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للترميز
الى الضوضاء،لذلك فان افضل اختيار للترميز القصير في منظومة الطيف المنتشر – نوع التتابع المباشركان **Barker**
نوع
بالاضافة الى دالة الارتباط الالي والتقاطعي الجيدة التي يمتلكها هذا النوع من الترميز.
ايضا النتائج اظهرت ان احتمالية الخطاء للبيانات المستلمة **Gold** كانت $3.13x10^{-3}$ عند ٢٠ ديسبل من نسبة
للترميز نوع
الاشارة الى الضوضاء،لذلك فان اسواء حالة للترميزالقصيرفي منظومة الطيف المنتشر –نوع التتابع المباشركان **Gold.**
نوع

## Introduction:

Pseudo-noise (PN) sequences are commonly used in a variety of situations such as ranging and error checking, the codes used in spread spectrum systems are inherently much longer than those found in other systems as they are intended for bandwidth spreading rather than information transfer.
A spread spectrum system is largely categorized by its coding scheme. The type of code employed, its length, and its chip-rate all define the overall system parameters. In order to alter the system's spreading capability it is necessary to alter the coding arrangement [1].
Direct Sequence Spread Spectrum (DS/SS) signals are generated by spreading the information signal with a pseudo-random or pseudo-noise (PN) code sequence .Typically, modulo-two addition of the information signal and the PN sequence is used to create the DS/SS signal.

The PN code rate is much higher than the information rate so the spectral characteristics of an RF modulated carrier are dominated by the PN code rate rather than the information sequence. DS/SS was originally developed for military applications because of its inherent resistance to jamming and the low probability of intercept (LPI) due to the pseudo-randomness of the signal. The resistance to jamming and interference is a function of the processing gain used in the system. At the receiver, the interfering signal is spread by the correlating structure that is used to receive the spread signal. This anti jamming capability has made DS/SS popular in the crowded unlicensed band where DS/SS may be used in the presence of narrowband users already present [2].In this paper the various short code will be discuss with DS/SS system.

## Spreading codes:

Spreading codes are important ingredients in spread spectrum communications systems. Their ideal characteristics are that they should be easy to generate and have good auto- and crosscorrelation properties. Good autocorrelation means a well-defined zero-delay peak with low nonzero-delay side lobes. Good cross-correlation properties mean cross-correlation values of low magnitude, no matter what the delay.
A PN code sequence acts as a noise like (but deterministic) carrier used for bandwidth spreading of the signal energy. The selection of a good code is important, because type and length of the code sets bounds on the system capability. The PN code sequence is a Pseudo-Noise or Pseudo-Random sequence of 1’s and 0’s, but not a real random sequence (because periodic) random

signals cannot be predicted. The autocorrelation of a PN code has properties similar to those of white noise but it have[3 and 4]:

1- Not random, but it looks randomly for the user who doesn't know the code.
2- Deterministic [5], periodical signal that is known to both the transmitter and the receiver. The longer the period of the PN spreading code, the closer will the transmitted signal be a truly random binary wave, and the harder it is to detect.
3- Statistical properties of sampled white-noise.
4- Long code: The PN sequence period is much longer than the data symbol, so that a different chip pattern is associated with each symbol ( $N_c.T_c >> T_s$). The random spreading sequence model is a useful tool for performance analysis that is extensively used in system design [6].
5- Short code: The same PN sequence for each data symbol ($N_c.T_c=T_s$),where $N_c$ is the sequence length ,$T_c$ is the chip duration and $T_s$ data symbol duration. If the spreading sequence $\{s[l]\}$is periodic with period $N_c$ , we call it a short spreading sequence. In this case, the spreading waveforms $s(m;t)$ for different symbols are all identical, with [6].

$$s(m;t) \equiv s(t) = \sum_{l=0}^{N-1} s[l]\psi(t - lT_c) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where $s(m;t)$ is the spreading waveform modulating the mth transmitted symbol,$\{s[l]\}$is periodic with period N, and $\psi(t)$ the modulating pulse for this chip rate linearly modulated system is termed the chip waveform.

The transmitted waveform therefore has exactly the form that we considered for linearly modulated signals[6].

$$u(t) = \sum_{m} b[m]s(t - mT) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $u(t)$ isthe transmitted waveform, $b[m]$ is the chip rate symbol sequence ,and $s(t)$ isthe modulating waveform.

Except that the modulating waveform s(t) has bandwidth scaling with the chip rate $1/T_c = N/T_s$ instead of with the symbol rate $1/T_s$ [6].

For short spreading sequences, the waveform $u(t)$ is cyclostationary with period $T_c$.The types of PN codes will be discussed in the next subsections.

**<u>1-M-Sequences</u>**

The maximum-length shift register sequences, also known, as the M-sequences are the widely used PN code sequences. It has a length $L = 2^m - 1$ and is generated by m-stages shift register with linear feedback. The sequence is periodic with period L and has a sequence of $2^{m-1}$ ones and $2^{m-1} - 1$ zeros. The binary sequence of {0,1} is mapped into corresponding sequence of {-1,1}.

Table(1) below gives the feedback connections for generating maximum-length sequences[7].

**Table -1: Feedback connections for generating m-sequences**

| m | Stages Connected To Modulo-2 Adder | m | Stages Connected To Modulo-2 Adder | m | Stages Connected To Modulo-2 Adder |
|---|---|---|---|---|---|
| 2 | 1,2 | 13 | 1,10,11,13 | 24 | 1,18,23,24 |
| 3 | 1,3 | 14 | 1,5,9,14 | 25 | 1,23 |
| 4 | 1,4 | 15 | 1,15 | 26 | 1,21,25,26 |
| 5 | 1,4 | 16 | 1,5,14,16 | 27 | 1,23,26,27 |
| 6 | 1,6 | 17 | 1,15 | 28 | 1,26 |
| 7 | 1,7 | 18 | 1,12 | 29 | 1,28 |
| 8 | 1,5,6,7 | 19 | 1,15,18,19 | 30 | 1,8,29,30 |
| 9 | 1,6 | 20 | 1,18 | 31 | 1,29 |
| 10 | 1,8 | 21 | 1,20 | 32 | 1,11,31,32 |
| 11 | 1,10 | 22 | 1,22 | 33 | 1,21 |
| 12 | 1,7,9,12 | 23 | 1,19 | 34 | 1,8,33,34 |

The general m-stage shift register with linear feedback can be given in Figure (1) [7].

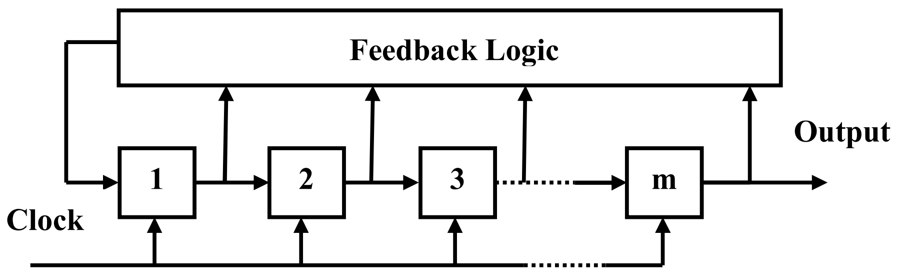



**Fig.(1) General feedback shift register with m -stages.**

M-sequences have good auto-correlation properties ,the auto-correlation function for m-sequences is ideal as[7]:

$$R_{mm}(k) = \begin{cases} L & \text{for } k = iL \\ -1 & \text{otherwise} \end{cases} \quad \text{……………………..….(3)}$$

But for CDMA systems with multiple users, good cross-correlation properties $R_{mm}(i)/R_{mm}(0)$ are required which is quite poor for m-sequences. Therefore methods of generating PN sequences with better cross-correlation properties than m-sequences have been developed by Gold and Kasami [6]. The length $L=2^4-1=$ 15-bit of polynomial (1, 4) will be used for simulation in this paper.

**2-Gold code.**

Gold codes are constructed by summing "*preferred pairs*" of M-sequences, or maximal length sequences, the Gold sequences are constructed using these m-sequences .The following table (2) provides a short list of preferred pairs[8 and 9].

**Table -2: short list of preferred pairs of Gold code.**

| n | N | Preferred polynomial[1] | Preferred polynomial[2] |
|---|---|---|---|
| **4** | 15 | [4 1 0] | [4 3 0] |
| **5** | 31 | [5 2 0] | [5 4 3 2 0] |
| **6** | 63 | [6 1 0] | [6 5 2 1 0] |
| **7** | 127 | [7 3 0] | [7 3 2 1 0] |
| **9** | 511 | [9 4 0] | [9 6 4 3 0] |
| **10** | 1023 | [10 3 0] | [10 8 3 2 0] |
| **11** | 2047 | [11 2 0] | [11 8 5 2 0] |

The Figure below shows the polynomials (3,4) and (1,4) sequences generating a Gold sequence of $L=2^4-1=$ 15-bit will be used for simulation in this paper[10].
These two feedback connection ensure the maximal length of the Gold code.

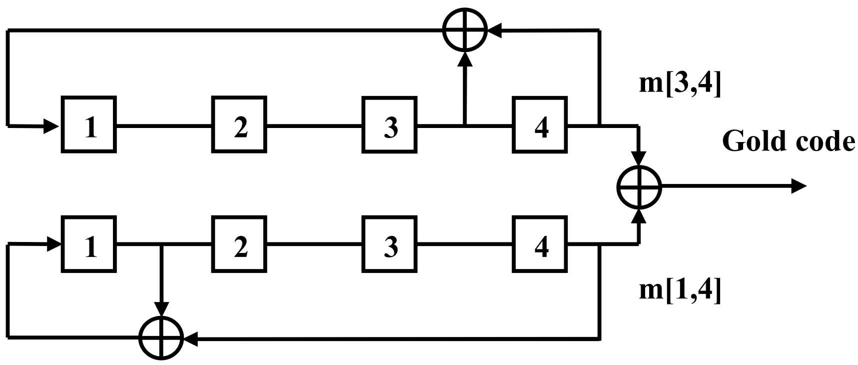



**Fig.(2) Generating Gold codes by combining two preferred pairs of m-sequences**.

In CDMA systems, it is often important that codes assigned to different users have low cross correlation with each other independent of the relative delays. Such situations are called nonsynchronous and result when the different users are at different distances from a receiver being accessed by one or more of them. Gold codes are codes whose possible cross correlations are limited to three values, given by [11 and 12]:

$$-t(n)/N\,, -1/N\,, [t(n)-2]/N,$$

Where

$$t(n)=\begin{cases}1+2^{0.5(n+1)} & for\ n\ odd\\ 1+2^{0.5(n+2)} & for\ n\ even\end{cases} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

With the code period being $N=2^m-1$. Gold codes are generated by modulo-2 adding certain pairs of *m*-sequences, known as preferred pairs, delayed relative to each other which have these cross-correlation values as well. Thus, in order to generate a family of Gold codes, it is necessary to find a preferred pair of *m*-sequences[12].

**3-Kasami code**

Following a procedure similar to that used to produce Gold codes will generate a smaller set of binary sequences known as Kasami sequences. A set of Kasami sequences consists of $M = 2^{m/2}$ binary sequences with a period of $n = 2^m - 1$, provided that *m* is even. Starting with an *m*-sequence, say A, a second sequence, B, can be obtained by taking every $2^{m/2} + 1$ bit of A, or in other words, sequence B is generated by decimating A by $2^{m/2} + 1$. It can be shown that the resulting sequence is periodic with period $2^{m/2} - 1$ . By taking $n = 2^m - 1$ bits of the sequences A and B, a new set of sequences is formed by modulo-2 adding the bits from A and the bits from B, and all the $2^{m/2} - 2$ cyclic shifts of the bits from B. By including A in the set, a set of $2^{m/2}$ binary sequences of length $2^m - 1$ is obtained. The auto and cross correlation functions of Kasami sequences can assume values from the set$\{-1, -(2^{m/2} + 1), 2^{m/2} - 1\}$. Hence, the maximum value of cross correlation for any pair of sequences from the set is $2^{m/2} + 1$ [13 and 14].

There are two classes of Kasami sequences: the ***small set*** and the ***large set***. The large set contains all the sequences in the small set. Only the small set is optimal in the sense of matching Welch's lower bound for correlation functions. Small Set of Kasami Sequences for n even given:

$$K_s(u,n,m) = \begin{cases} u & m = -1 \\ u \oplus T^m w & m = 0, \ldots 2^{n/2} - 2 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Which *T* denotes the left shift operator, *m* is the shift parameter for *w*, and $\oplus$ denotes addition modulo-2 adding.

Note that the small set contains $2^{n/2}$ sequences.

The following table(3) lists some of the polynomials that you can use to generate the Kasami set of sequences.

**Table-3: Kasami set of sequences**

| n | M | Polynomial | set |
|---|---|---|---|
| **4** | 15 | [4 1 0] | small |
| **6** | 63 | [6 1 0] | large |
| **8** | 255 | [8 4 3 2 0] | small |
| **10** | 1023 | [1 0 3 0] | large |
| **12** | 4095 | [12 6 4 1 0] | small |

The polynomial [4 1 0] will be used for simulation in this paper because it is short code.

**4-Barker code**

Barker codes are short unique codes that exhibit very good correlation properties . Barker codes, which are subsets of PN sequences, are commonly used for frame synchronization in digital communication systems. Barker codes have length at most 13 and have low correlation sidelobes. A correlation side lobe is the correlation of a codeword with a time-shifted version of itself [15].

The table (4) below listed Barker code for N=3 ,4,5,7,11,and 13.

**Table-4: Barker code**

| N | Barker Sequence | N | Barker Sequence |
|---|---|---|---|
| 3 | 110 | 7 | 1110010 |
| 4 | 1110 or 1101 | 11 | 11100010010 |
| 5 | 11101 | 13 | 1111100110101 |

The Barker code with length 13 will be used for simulation in this paper.

## 5-Walsh code

Walsh codes are perfectly orthogonal to one another having very good crosscorrelation values. Unfortunately, they have bad auto-correlation properties, and also lose their orthogonality if the codes are not synchronized. Walsh codes can be constructed with the simple algorithm of generating Hadamard matrices[16].
Walsh codes are orthogonal sets of $2^n$ binary sequences, each of length $2^n$. They are defined as follows[12]:

$$W_{2^1} = \begin{bmatrix} W_{2^{n-1}} & W_{2^{n-1}} \\ W_{2^{n-1}} & \overline{W}_{2^{n-1}} \end{bmatrix} \equiv \begin{bmatrix} \omega_0 \\ \cdot \\ \cdot \\ \cdot \\ \omega_{2^{n-1}} \end{bmatrix} \quad \text{……………………………………(6)}$$

The 16 –bit code length of Walsh code will be used for simulation in this paper.

## 6-Hadamard code

The Hadamard Code Generator block generates a Hadamard code from a Hadamard matrix, whose rows form an orthogonal set of codes. Orthogonal codes can be used for spreading in communication systems in which the receiver is perfectly synchronized with the transmitter. In these systems, the despreading operation is ideal, as the codes are decorrelated completely.The Hadamard codes are the individual rows of a Hadamard matrix. Hadamard matrices are square matrices whose entries are +1 or -1, and whose rows and columns are mutually orthogonal. If N is a non-negative power of 2, the N-by-N Hadamard matrix, denoted HN, is defined recursively as follows [9]:

$$H_{N+1} = \begin{pmatrix} H_N & H_N \\ H_N & \overline{H}_N \end{pmatrix} \quad \text{…………………………(7)}$$

Where $\overline{H_N}$ is the inverse of $H_N$.

The Hadamard Code Generator block outputs a row of $H_N$. The output is bipolar. We can specify the length of the code, N, by the Code length parameter. The Code length must be a power of 2. We can specify the index of the row of the Hadamard matrix, which is an integer in the range [0, 1, ... , N-1], by the Code index parameter.
The 4x4 matrix of Hadamard code will be used for simulation in this paper.

## System simulation:

The model of direct sequence spread spectrum system shown in Figure (3) ,this system was design by using MATLAB2008b –simulink ,the system consist of transmitter ,channel and receiver .
The transmitter consist of four main parts: data generator ,baseband QPSK modulation, multiplier (spreader) ,and PN-code generator ,this part was simulated for various codes(Barker ,Walsh, Hadamard , Maximal –linear, Kasami and Gold) each of 100000 bits.
The channel in this system is Rayleigh Fading (Flat Fading) and Additive White Gaussian Noise (AWGN) channels ,the system test under this channels for different cases for signal –to –noise ratio (SNR) 0dB to 20dB.
The receiver also consists of four parts: despreader,integrate and dump,baseband QPSK demodulator and PN-code generator the same as generated in transmitter part.The probability of error (Pe) was calculated in the receiver for different cases for SNR by using error rate calculation block set.
The whole DS/SS system has the following specification.

1-The data rate 1Mb/s ($T_s = 1\mu s$).

2-The PN code rate 16Mb/s ($T_c = 0.0625\mu s$).

3-PN-code length 16-bit, $N_c T_c = 16 * 0.0625 * 10^{-6} = 1\mu s = T_S$

4-Short PN code 16-bit for (Walsh, Hadamard , Kasami, M-sequence and Gold) codes and 13-bit for Barker code.

5-Modulation type: Baseband QPSK modulation/demodulation.

6-Channel type : Rayleigh Fading (Flat Fading) channel and Additive White Gaussian Noise (AWGN) channel.

7- Receiver type: Active correlation

8-The system was assumed to be synchronized.

9-Processing gain or spreading factor $G_p = \frac{T_S}{T_C} = \frac{1/1\,MHz}{1/16\,MHz} = 16 \rightarrow \quad 10\log_2 16 = 12dB$.

10-The system was simulated at 100000 bits simulation process.

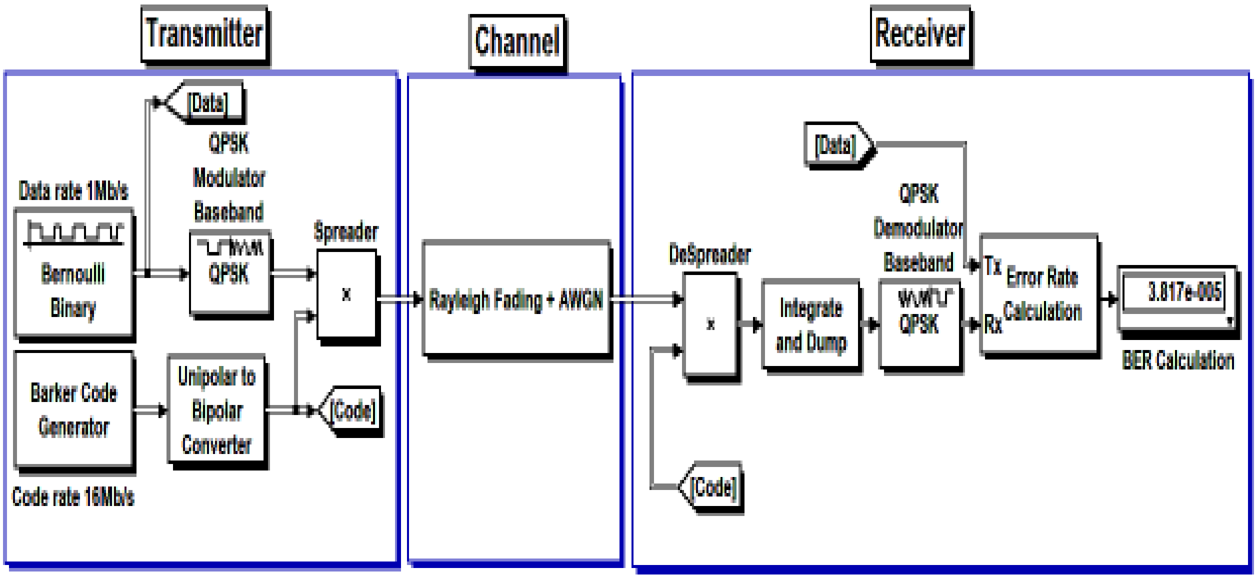



**Fig.(3) Block diagram of DS/SS system**.

**<u>Results</u>**:

The performance of the system for various codes are observed by using simulation tools like frequency spectrum ,autocorrelation and crosscorrelation .The simulation results shows the system using Barker code is the best system as shown in spectrum in Figures (4,5,6 ,and 7) at 0 dB SNR.
This result is nearby to the result in the paper of Carl Andren in reference[17].

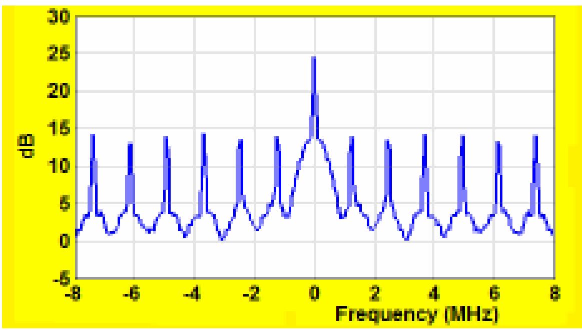



**Fig.(4) Spectrum of transmitted signal using**

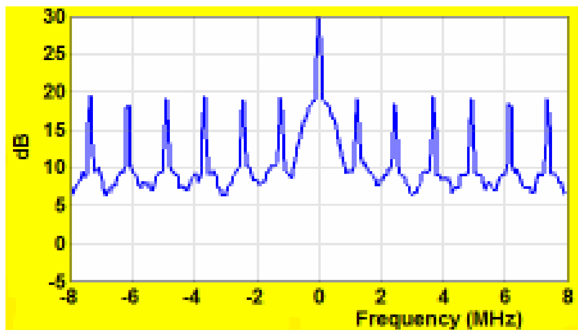



**Fig.(5) Spectrum of received signal using Barker**

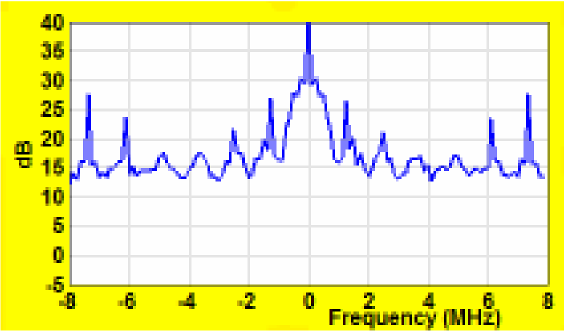



**Fig.(6) Autocorrelation of Barker code.**

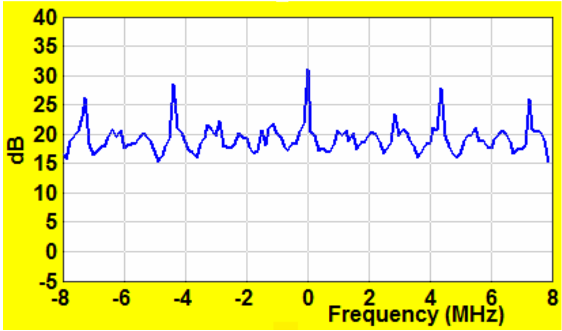



**Fig.(7) Crosscorrelation of Barker code (13 and 11).**

Whereas the result of the system using short Gold code is the worst system as shown in spectrum in Figures (8,9,10,and 11) at 0 dB SNR.

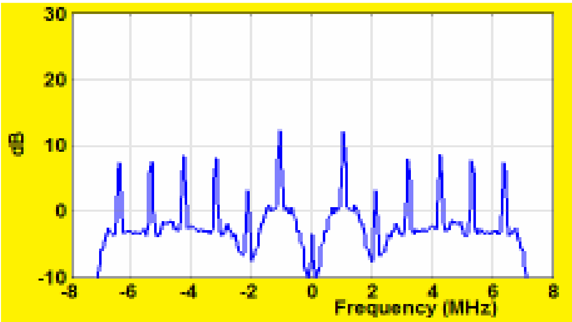



**Fig.(8)Spectrum of transmitted signal using Gold code.**

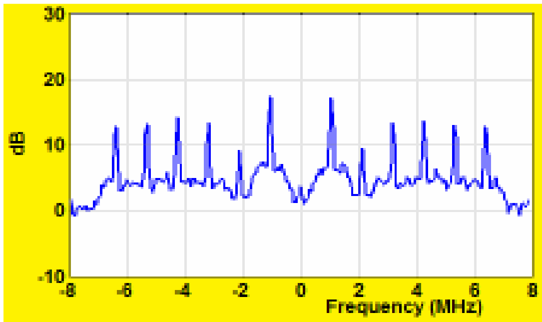



**Fig.(9)Spectrum of received signal using Gold code at 0 dB SNR.**

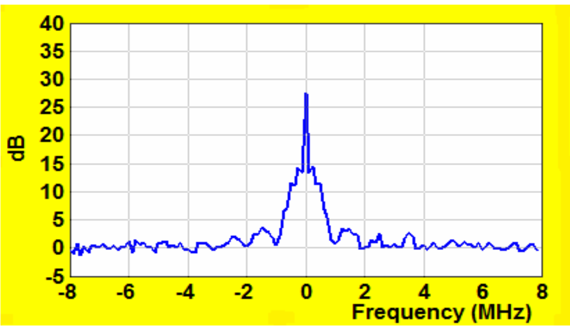



**Fig.(10) Autocorrelation of Gold code**.

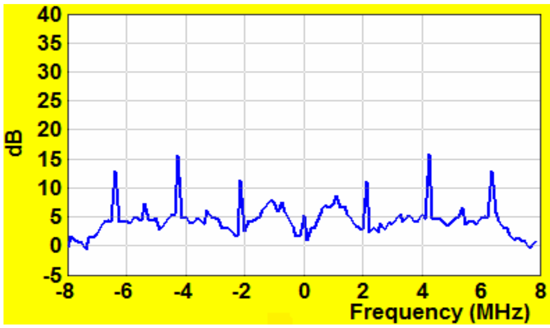



**Fig.(11) Crosscorrelation of Gold code.**

Also the other results of the other codes is illustrate in Figures (12,13,14,15,16,17,18 ,and 19) for autocorrelation and crosscorrelation.

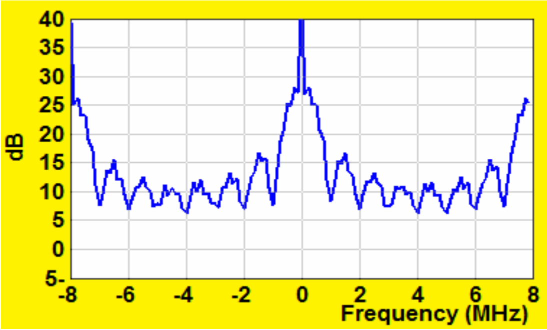



Fig.(12) Autocorrelation of  Walsh code.

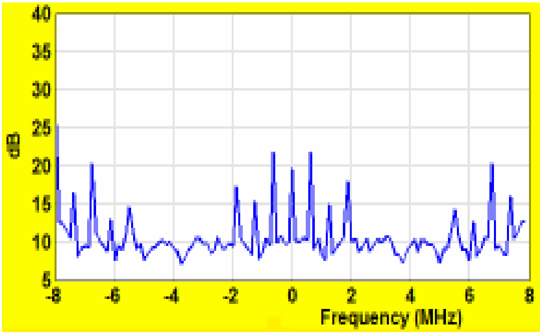



Fig.(13) Crosscorrelation of  Walsh code.

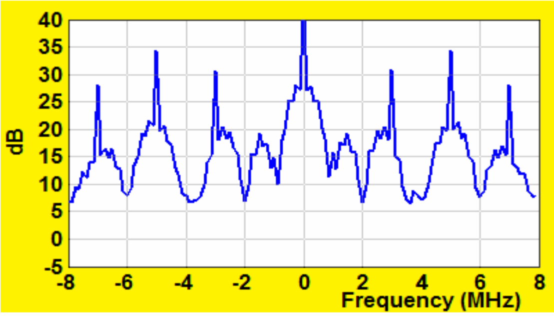



Fig.(14) Autocorrelation of Hadamard code.

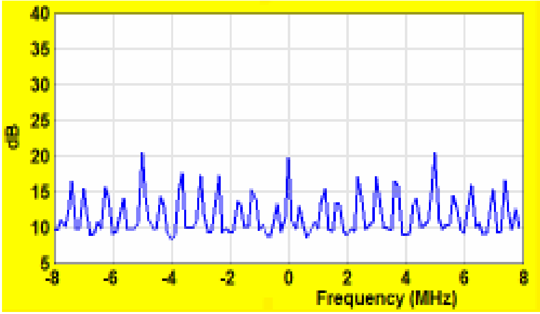



Fig.(15) Crosscorrelation of Hadamard code.

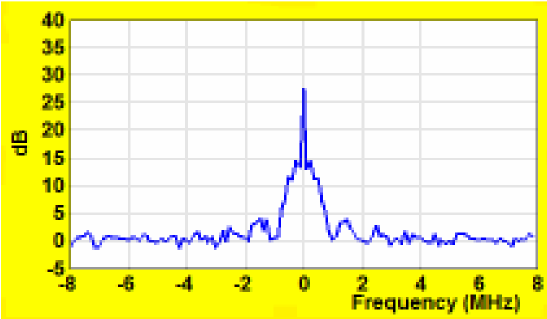



Fig.(16) Autocorrelation of Kasami code.

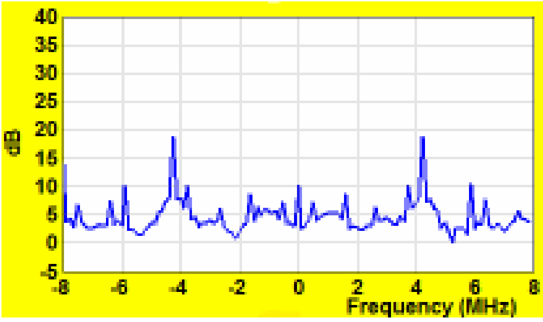
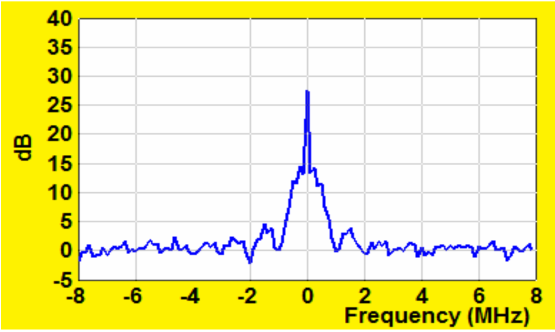



Fig.(17) Crosscorrelation of Kasami code.



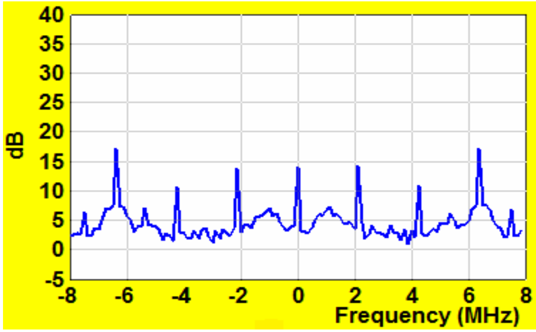




**Fig.(18) Autocorrelation of M-sequence code.**

**Fig.(19) Crosscorrelation of M-sequence code.**

Now to check the probability of error for DS/SS system using various codes ,the different cases of SNR was taken and measuring the $P_e$ from simulink block set after end of simulation process at 100000 bits, the result was tabulated in table(6) below and Figure (20) illustrate the relationship between the SNR and $P_e$ for various PN code.

**Table-6: The $P_e$ at different SNR for various codes**

| SNR | Probability of error ($P_e$) | | | | | |
|---|---|---|---|---|---|---|
| | Barker code | Walsh code | Hadamard code | M- sequence code | Kasami sequence code | Gold sequence code |
| 0 | $3.214x10^{-2}$ | $3.614\ x10^{-2}$ | $3.607x10^{-2}$ | $9.252\ x10^{-2}$ | $9.614\ x10^{-2}$ | $9.488x10^{-2}$ |
| 2 | $2.401\ x10^{-2}$ | $2.759\ x10^{-2}$ | $2.633x10^{-2}$ | $7.152x10^{-2}$ | $7.381x10^{-2}$ | $7.267x10^{-2}$ |
| 4 | $1.611\ x10^{-2}$ | $1.973\ x10^{-2}$ | $1.855x10^{-2}$ | $5.610x10^{-2}$ | $5.492x10^{-2}$ | $5.687x10^{-2}$ |
| 6 | $1.111\ x10^{-2}$ | $1.389\ x10^{-2}$ | $1.359x10^{-2}$ | $4.137x10^{-2}$ | $4.145x10^{-2}$ | $4.202x10^{-2}$ |
| 8 | $7.29\ x10^{-3}$ | $9.351\ x10^{-3}$ | $9.084x10^{-3}$ | $3.080\ x10^{-2}$ | $3.088x10^{-2}$ | $3.16x10^{-2}$ |
| 10 | $4.733\ x10^{-3}$ | $6.145\ x10^{-3}$ | $5.839x10^{-3}$ | $2.225x10^{-2}$ | $2.317x10^{-2}$ | $2.313x10^{-2}$ |
| 12 | $2.595\ x10^{-3}$ | $3.359\ x10^{-3}$ | $3.702x10^{-3}$ | $1.557x10^{-2}$ | $1.676x10^{-2}$ | $1.645x10^{-2}$ |
| 14 | $1.603\ x10^{-3}$ | $1.794\ x10^{-3}$ | $1.985x10^{-3}$ | $1.065x10^{-2}$ | $1.149x10^{-2}$ | $1.126x10^{-2}$ |
| 16 | $6.488\ x10^{-4}$ | $6.488\ x10^{-4}$ | $1.107x10^{-3}$ | $7.175x10^{-3}$ | $7.671x10^{-3}$ | $7.213x10^{-3}$ |
| 18 | $1.908\ x10^{-4}$ | $3.435\ x10^{-4}$ | $4.962x10^{-4}$ | $4.313x10^{-3}$ | $4.656x10^{-3}$ | $5.038x10^{-3}$ |
| 20 | $3.817\ x10^{-5}$ | $1.145\ x10^{-4}$ | $2.290x10^{-4}$ | $2.328x10^{-3}$ | $2.901x10^{-3}$ | $3.13x10^{-3}$ |

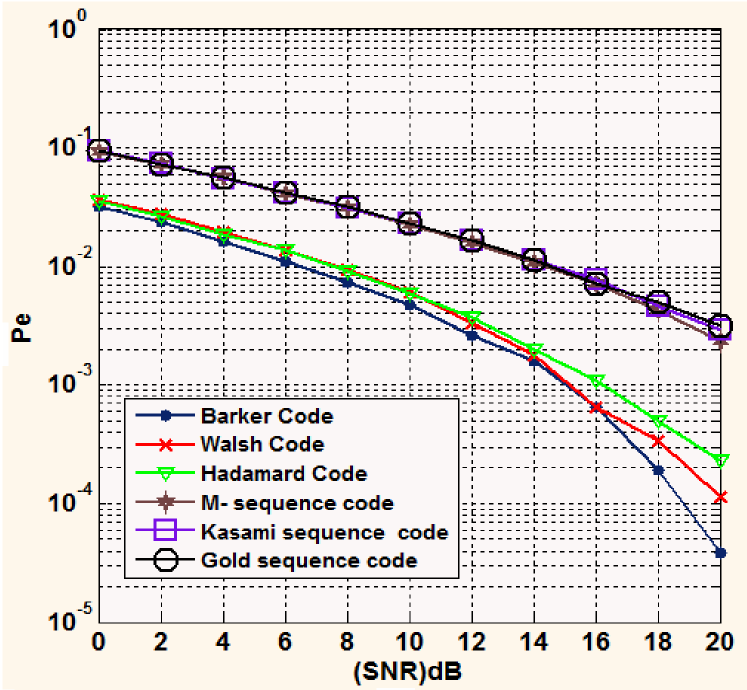



**Fig.(20)The relationship between SNR and $P_e$ for different types of PN-codes under the effect of Rayleigh Fading (Flat fading) and AWGN channels.**

## Conclusions:

1-The results shows the best choice for short code in DS/SS system is Barker code because of it has good specification of probability of error , autoorrelation and crosscorrelation.

2- The results shows the worst choice is Gold code because of it has higher probability of error in spite of it has good autocorrelation and crosscorrelation.

3-The Kasami , M-sequence and Gold code have convergent probability of error and divergent from other types in this paper.

4-The Walsh and Hadamard code have low probability of error if compare with the (Kasami , M-sequence and Gold) codes but still worst than Barker code.

5- The Walsh code better than the Hadamard code especially at greater than 16 dB SNR.

6- The a Gold, Kasami and M-sequence codes has good autocorrelation functions than Hadamard code but still Hadamard has low probability of error.

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