CONTRIBUTION OF BARKER AND NESTED BARKER CODE IN CDMA TECHNOLOGY

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ABSTRCT

Radar signal processing mainly based on extraction of desired signal from the received signal by rejecting the unwanted one. During signal transmission signal gets corrupted by noise therefore its detection becomes difficult. Conventional techniques are not capable to detect the signal where the received power is appreciably less. Barker and Nested Barker codes are good choice for such application. It is possible to implement these codes with the help of low cost hardware architecture and FPGA. This paper presents a generation strategy of barker and nested barker sequence. Comparative performance analysis of both the sequences have been done on the basis of autocorrelation, cross-correlation, merit factor and bit error rate. It is observed that the nested barker code gives good rang resolution but provide minimum side lobe.

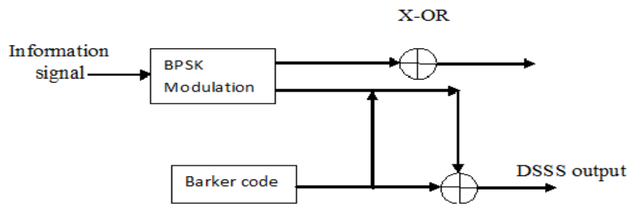
Keyword - Barker code, nested barker, correlation, bit error rate, merit factor.

I. INTRODUCTION

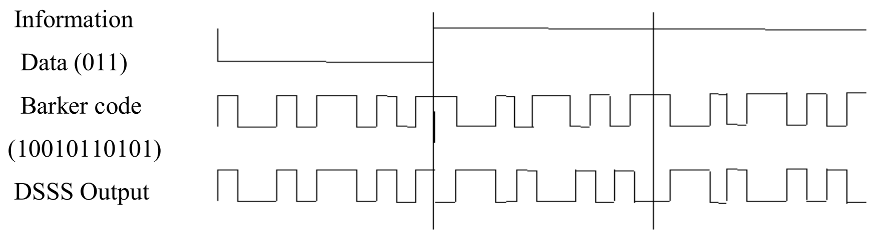
Most of the radar system and signal processing applications utilize low probability of intercept (LPI) while keeping the detection capability of radar. LPI signals are designed via pulse compression which is further used to secure data while communicating. On the other hand in pulse compression to obtain information for distances higher than distances between transmitted pulses, phase coding is used and for this radar needs short pulses and for this radar needs short pulses. Pulse compression combines the resolution of short pulse to long pulse of high energy [1, 2, 3]. In pulse compression transmitted pulse is modulated and correlated with received signal. Therefore radar applications need suitable codes to maximize the sensitivity and resolution. The best choice for radar application is Barker code and Nested Barker code [4, 5, 6, 7]. These codes are used as spreading codes. Barker codes are of limited lengths, maximum length of the code is 13 and PSLR is -22.3 dB [8, 9]. In radar application, minimum PSLR required is -30dB. By increasing the length of Barker codes, resolution of range can be improved. In this paper Nested Barker codes are constructed by two Barker codes using product of two Kronecker functions to increase the length of code. Maximum length is increased to 65. These codes are compared on the basis of autocorrelation, cross-correlation, and merit factor and bit error rate.

The spreading code helps to retrieve the original data from transmitted one, even if transmitted bits of data got damaged while transmission. The codes may have different length or different size. IEEE 802.11 standards uses long codes with code period larger than bit period, and short codes have code period equals the bit period. IEEE

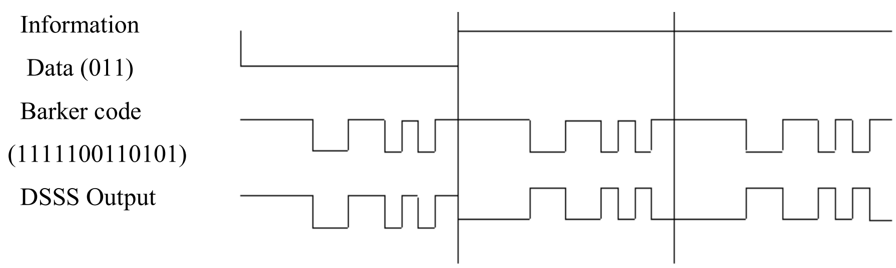
802.11b Direct Sequence Spread Spectrum used spreading codes known as Barker code. These codes are sequences of binary bits of length 11 and 13 [10]. Barker code is shown in Figure: 1.



(a)



(b)



(c)

Figure.1 – (a), (b) and (c) Spreading The Information By Barker Code 11 and 13 bit

II. BARKER CODES

A Barker code is a finite length sequence of binary numbers with the minimum aperiodic autocorrelation. In pulse compression for radar systems this code results in better range and resolution without shortening a radar pulse or increase in power. Sequences of Barker are of short length and show good correlation properties and satisfies the condition $|r(\tau)| \leq 1$ for $(\tau \neq 0)$ where τ is a delay element[11]. The maximum possible length of Barker code is 13 which is the ratio of main lobe level of autocorrelation function to the side lobe level of the autocorrelation function.

The Barker sequence $x_1, x_2, x_3.....x_N$ is of N length, and its aperiodic Autocorrelation function is given by:

$$R(K) = \sum_{n=1}^{N} X_n X_{n+1} \qquad (1)$$

Where K= - (N-1)………+ (N-1), The Integrated Side Lobe Ratio (ISLR) is obtained by dividing the energy side lobes to the energy of main lobe of its autocorrelation function. As given below:

$$\mathrm{ISLR(dB)} = \frac{2\sum_{K=1}^{N-1}|R(K)|^2}{|R(0)|^2} \qquad (2)$$

Peak Side Lobe Ratio (PSLR) is the ratio of absolute maximum among the side lobes to the main peak level in the Autocorrelation function is given as:

$$\mathrm{PSLR\ (dB)} = 20\log 10\ \frac{\max_{1\le K\le N}|S(K)|}{|S(0)|} \qquad (3)$$

Over PN sequences Barker sequences work well and show several advantages. These sequences not only satisfy the run and balance property but also have uniform and low side lobes (≤1) in autocorrelation function, but the size of these families is small. Table.1 lists all known Barker codes.

Table.1- A List of Barker Sequences

Sequence	**Length of Sequence**
2	[1 -1], [1 1]
3	[1 1 -1]
4	[1 -1 1 1], [1 -1 -1 -1]
5	[1 1 1 -1 1]
7	[1 1 1 -1 -1 1 -1]
11	[1 1 1 -1 -1 -1 1 -1 -1 1 -1]
13	[1 1 1 1 1 -1 -1 1 1 -1 1 -1 1]

III. NESTED BARKER CODE

Barker codes show the bi-phase property and with these codes it is possible to achieve smallest side lobes in autocorrelation function. However, the odd length Barker code is proven to be of length 13 [2] and considered to be major disadvantage. Barker codes of length 2 and 4 are the only ones of even length. For length 13 code maximum achievable ratio of a main lobe to peak side lobe is only 22.8 dB which is less than 30dB which is practically required [12].

In the Table given below Nested binary codes are shown. It is found that these codes improve the PSLR compared to the Barker codes [3]. By taking Kronecker product of two Barker codes Nested Barker codes can be generated with good initial filter response. Let a Barker code of N-bits is and denoted by BN, and a Barker code of M-bits is and denoted by BM, then an MN bit code can be constructed as BN⊗BM. The Kronecker product is the BN code repeated M times, with each repetition multiplied by the corresponding element of the BM code and vice versa Table given below shows the Nested Barker sequences.

Table .2- Nested Barker sequences

S. No.	Kronecker product	Length of sequence
1	B7	7
2	B11	11
3	B13	13
4	B2⊕B7	14
5	B4⊕B4	16
6	B4 ⊕ B5	20
7	B4 ⊕ B7	28
8	B7 ⊕ B7	49
9	B5⊕B11	55
10	B5 ⊕B13	65

IV. GENERATION OF THE CODES

Barker and Nested Barker binary sequence are generated by Linear Feedback Shift Register (LFSR) which consists of 'n' number of D type flip-flops. Combination of flip flop produces sequences of 1"s and 0"s in a pre defined manner

Linear Feedback Shift Register (LFSR)

LFSR is a n-bit shift register utilizes the feedback. By shifting the contents of its registers into adjacent register positions or to a position at the end of the register it usually works. The contents are binary bits. If a shift register carries the bit pattern 1101 than a single shift to right would result in 0110; another shift yields 0011 [13-14]. To provide the feedback XORing or XNORing is performed over the outs of register pairs. The outputs of interest of selected stages are referred to as taps by John G. Proakis [13]. Each register is excited by a single clock pulse externally applied. The taps can be placed anywhere at any stage with XOR or XNOR feedback.

Figure 2 shows the structure used to generate random sequence of Length 2n-1 states (n is no. of flip-flops). By the exhaustive search method the Barker code is selected.

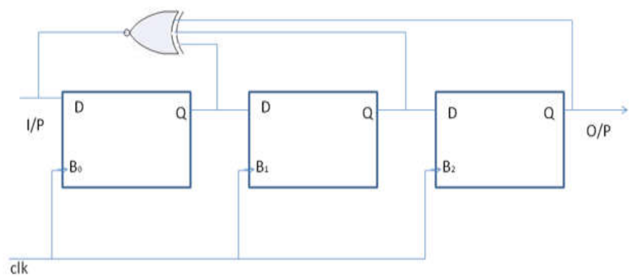


Figure.2 -1:3 bit LFSR

Table. 3- 1:3 bit LFSR sequence

B0	**B1**	**B2**	**Output stream**
0	**1**	**0**	
1	**0**	**1**	**0**
1	**1**	**0**	**1**
1	**1**	**0**	**0**
1	**1**	**1**	**0**
0	**1**	**1**	**1**
1	**0**	**1**	**1**
1	**1**	**0**	**1**
1	**1**	**1**	**0**

7 Bit Barker Sequence

Not Considerabl

Table 3 is an example of LFSR with initial value 010. The output of the feedback is XNOR of B0, B1 and the output stream.

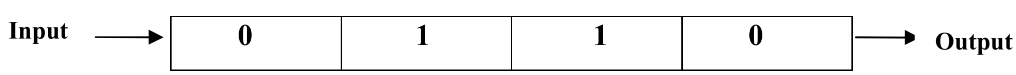


Figure.3- Shift Register

V. PERFORMANCE MEASURE AND It's ANALYSIS

Correlation Measure - The Mean Square Aperiodic Auto-Correlation (MSAAC) and Mean Square Aperiodic Cross-Correlation (MSACC) are very useful and widely accepted performance measures to check the correlation properties of the sequences. These correlation measures are first introduced by Oppermann and

Vucetic [15]. Let c_i is a sequence of length N, s_i (n) denotes non-delayed version of s_k (i), and s_j(n+τ) denotes the delayed version of s_k(j) by 'τ 'units. The discrete Aperiodic correlation function is given by:

$$P_{i,j}(\tau) = \frac{1}{N}\sum_{\tau=1-N}^{N-1} S_I S_j(n+\tau) \quad (4)$$

MSAAC value P_{AC} for a given code set containing M sequences is defined as:

$$P_{AC} = \frac{1}{M}\sum_{i=1}^{M}\sum_{\tau=1-N,\tau\neq 0}^{N-1} | r_{i,j}(\tau)|^2 \quad (5)$$

$$P_{CC} = \frac{1}{M(M-1)}\sum_{i=1}^{M}\sum_{j=1,j\neq 1}^{N}\sum_{\tau=1-N}^{N-1} |r_{i,j}(\tau)|^2 \quad (6)$$

Both the measures are used for comparing the sequence sets. The sequence which shows poor cross-correlation properties shows good auto-correlation properties, and vice-versa. The sequences with less MSAAC values means low correlation between the bits within a sample, and sequences with less MSACC values means less the sample to sample correlation, which makes the information signal less intelligible.

Bit Error Rate (BER) - The BER is a measure of the percentage of bits having less error relative to the total number of bits. It is expressed as a ratio of number of bits with error & total numbers of bits transmitted. As defined below:

$$\text{BER} = \frac{\text{Number of Bits with Error}}{\text{Total No.of Bits Sent}} \quad (7)$$

BER is the most fundamental measure of system performance [16]. The performance of a system communicating information digitally is quantified by the probability of bit detection errors in the presence of thermal noise.

Merit factor - As good cross correlation degrades the auto correlation properties and degradation in auto correlation directly affects the frequency response of the sequence. Merit factor is calculated to check the suitability of the frequency response of the sequences in particular application. It is defined as the ratio of energy in the main lobe of Auto Correlation Function to the total signal energy in side lobes [17]. The Merit Factor for a sequence, c_i(n), of length N having the auto-correlation function is defined as follow.

$$F_X = \frac{r_{i,j}^2(0)}{\sum_{\tau\neq 0}|r_{i,j}(\tau)|^2} = \frac{N^2}{2\sum_{\tau=1}^{N-1}|r_{i,j}(\tau)|^2} \quad (8)$$

we may use the inverse of the value calculated for the RAC as the MF.

V. RESULT AND DISCUSSION

Barker and Nested Barker codes for different length are generated and implementation on MATLAB 7.0 version. The performances of these codes are checked by obtaining MSAAC, MSACC, BER and Merit factor values.

Tables. 4 and 5 shows the Aperiodic Auto and Cross correlation for Barker code of length 11 and 13 and Nested Barker codes of different lengths. In this experiment, efforts are done to maximize auto correlation and minimize cross-correlation. Cyclic shifts of the sequences are done to test Cross correlations thoroughly. This function for Barker code is perfect but with the limitation of restricted length. The longest Barker code is only of 13 bit long therefore only serve the purpose of spreading code in CDMA systems for single user. The Barker code has a very good cross-correlation, with side lobe values less than or equal to 1/N in size and uniform distribution codes are of limited length when compared to nested barker.

Tables. 6 and 7 shows the merit factor and for Barker code of length 11 and 13 and Nested Barker codes of different lengths. Both the tables show that merit factor changes with the length of the codes and both the codes are giving good merit factor. Resolution of the range in radar application can be improved by reducing main lobe width, side lobe levels and reducing the grating lobes. By suppressing the grating lobes one can increase the range resolution. In Nested Barker codes grating lobes are suppressed. PSLR is achieved for nested Barker code of different length ranges from -13.9 dB to -30.8 dB. When compared to the Barker codes PSLR are improved in nested Barker codes.

Figure (4-10) show plot of MSAAC and MSACC for Barker code of length 11 and 13 and Nested Barker codes of different lengths. Figure 11 and 12 show the plot of BER versus SNR for Barker code and Nested Barker codes of different lengths. BER is a powerful method to test the digital transmission system which gives indication of the performance of the system. Both the codes show BER within limits therefore systems utilizing these codes will operate satisfactorily.

Table.4- MSAAC and MSACC of Barker Sequence

S. No.	Length of Barker Sequence	MSAAC	MSACC
1	11	0.0826	0. 6463
2	13	0.0710	0.7690

Table.5- MSAAC and MSACC of Nested Barker Sequence

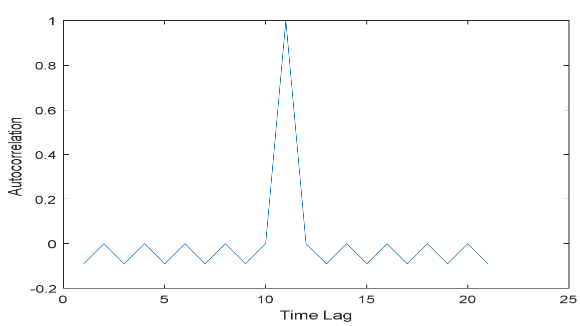
S. No.	Length of Nested Barker Sequence	MSAAC	MSACC
1	14	0.6837	0.5255
2	16	0.6875	0.7188
3	20	0.4500	0.5100
4	49	0.2599	0.2403
5	55	0.2559	0.5556
6	65	0.2424	0.1574

Table.6- Measure of Merit Factor of Barker Code Sequence

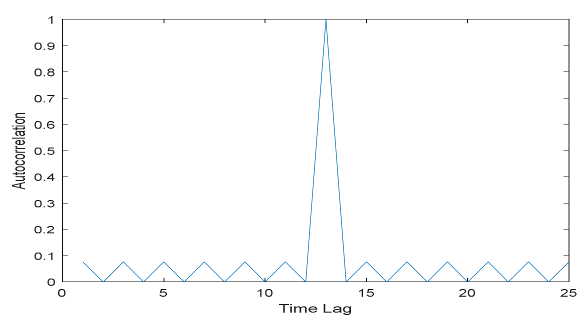
S.No.	Length Of Barker Sequence	Proposed Merit Factor	Literature MF	PSLR(dB)
1	11	12.10	12.10	-9.5
2	13	13.99	14.08	-12.0

Table.7- Measure of Merit Factor of Nested Barker Code Sequence

S. No.	Length Of Nested Barker Sequence	Proposed Merit Factor	Literature MF	PSLR(dB)
1	14	11.46	10.06	-14.0
2	16	11.45	10.48	-20.8
3	20	18.88	10.51	-22.3
4	49	13.84	10.82	-30.8
5	55	13.90	10.72	-13.97
6	65	14.13	11.81	-13.9

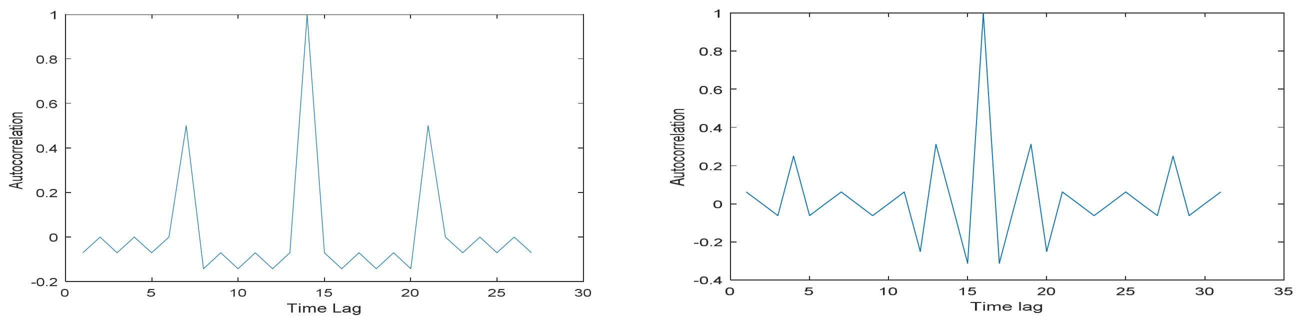


(a)



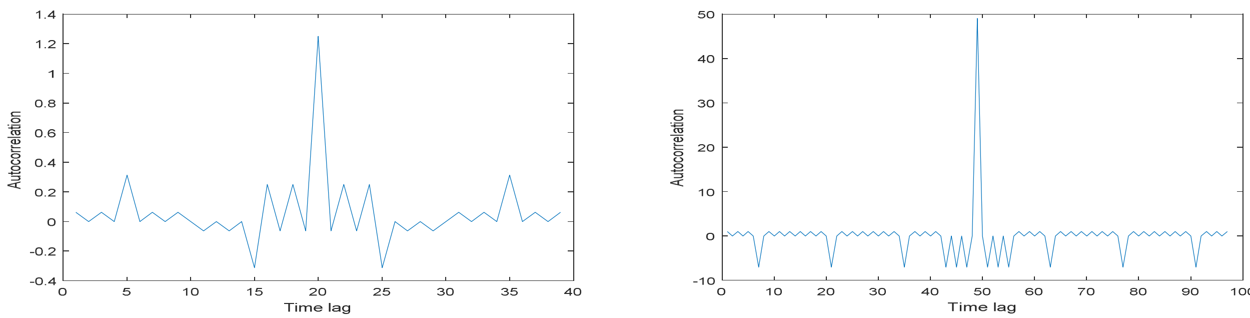
(b)

Figure.4 – (a)-(b) Aperiodic Autocorrelation Function of Barker Sequence of length 11 and 13bits



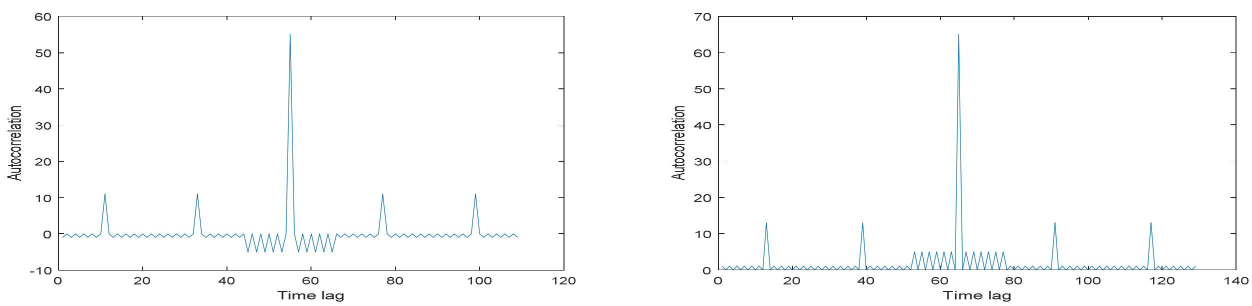
(c) **(d)**

Figure.5 – (c)-(d) Aperiodic Autocorrelation Function of Nested Barker Sequence of length 14 and 16bits



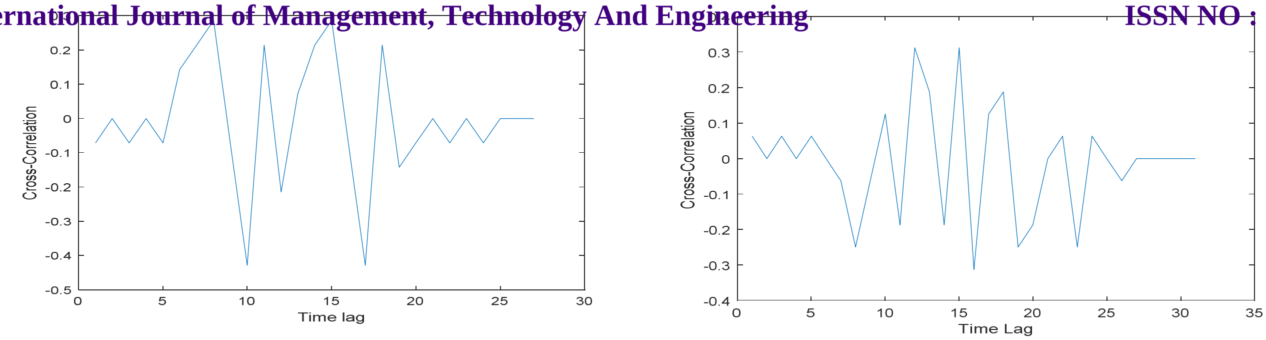
(e) (f)

Figure.6 – (e)-(f) Aperiodic Autocorrelation Function of Nested Barker Sequence of length 20 and 49 bit



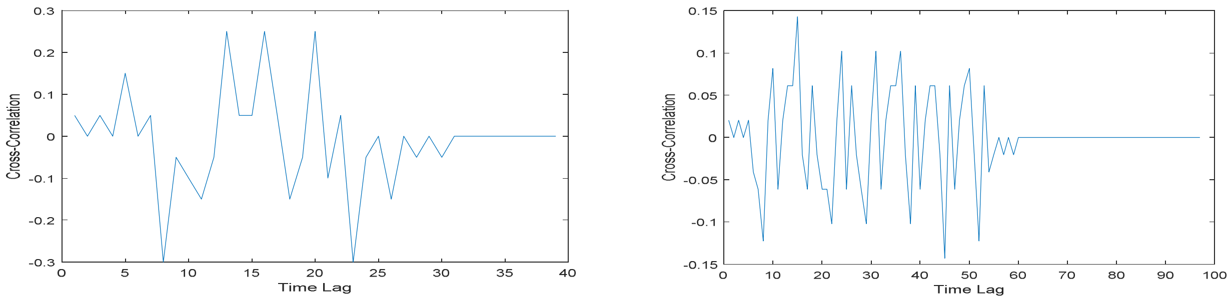
(g) (h)

Figure.7 – (g)-(h) Aperiodic Autocorrelation Function of Nested Barker Sequence of length 55 and 65 bits



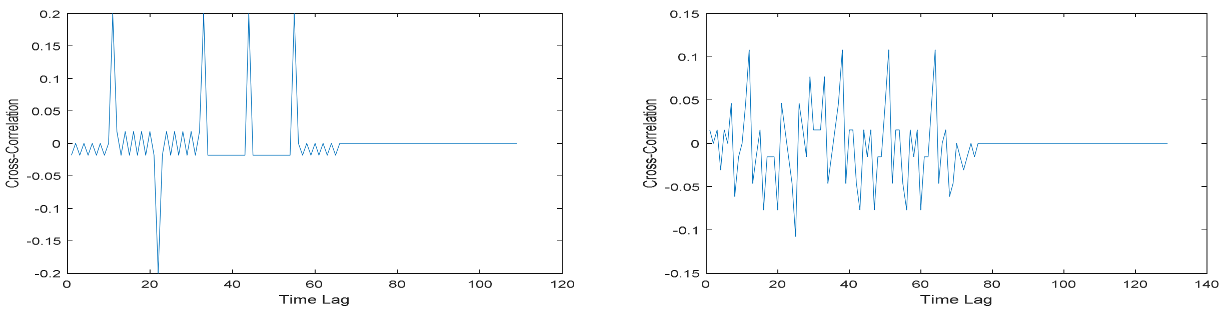
(i) (j)

Figure.8 - (i)-(j) Aperiodic Cross-correlation Function of Nested Barker Sequence of length 14 and 16 with 11 bits



(k) (l)

Figure.9 - (k)-(l) Aperiodic Cross-correlation Function of Nested Barker Sequence of length 20 and 49 with 11 bit



(m) (n)

Figure.10 - (m)-(n) Aperiodic Cross-correlation Function of Nested Barker Sequence of length 55 and 65 with 11 bits

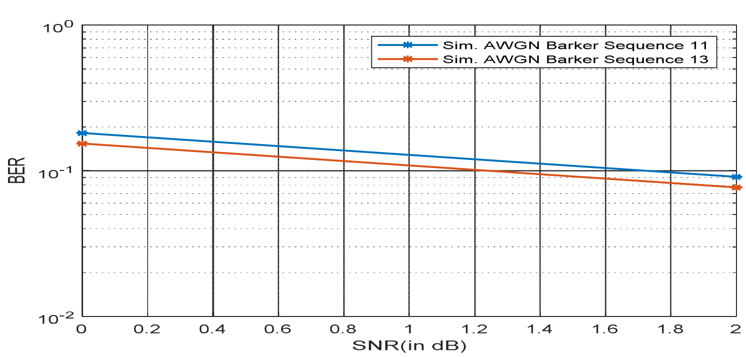


Figure.11- BER VS SNR of Barker Sequence

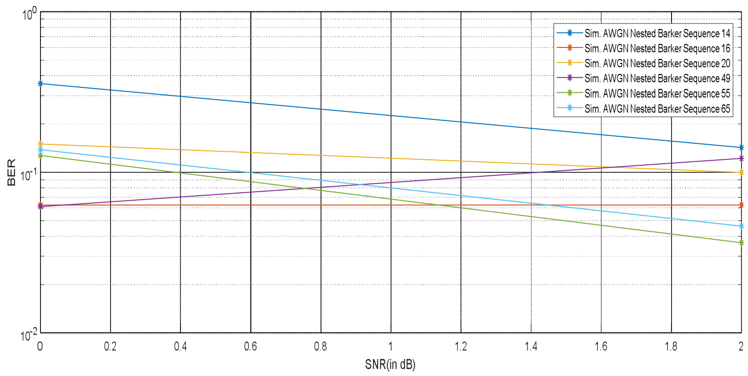


Figure.12- BER VS SNR of Nested Barker Sequence in Different length

VI. CONCLUSION

These paper discuses the generation of Barker & Nested Barker sequence and its performance parameters. These codes find enormous significance in data security as used in pulse compression. Particularly suited for radar application.

VII. ACKNOWLWDGEMENT

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