PERFORMANCE ANALYSIS OF BARKER CODE BASED ON THEIR CORRELATION PROPERTY IN MULTIUSER ENVIRONMENT

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ABSTRACT

Spread-spectrum communication, with its inherent interference attenuation capability, has over the years become an increasingly popular technique for use in many different systems. They have very beneficial and tempting features, like Antijam, Security, and Multiple accesses. This thesis basically deals with the pseudo codes used in spread spectrum communication system. The cross-correlation and auto-correlation properties of the long Barker Code are analyzed. It has been seen that the length of the code, auto-correlation and cross-correlation properties can help us to determine the best suitable code for any particular communication environment. We have tried to find out the code with suitable auto-correlation properties along with low cross-correlation values. Barker code has good auto-correlation properties and we have found the pairs with the low cross- correlation so that they can be used in multi-user environment.

KEYWORDS

TDMA, CDMA, DSSS, Barker, PN sequence

1. INTRODUCTION

With the proliferation of radio communication systems and its traffic, interference problems are becoming of a major concern. A solution to this problem is to employ spread spectrum multiple access schemes, which enhance the capability of many users to share a finite amount of radio spectrum without interfering with one another significantly [1].The wireless communication system has grown extremely fast over the past few decades, with the demand doubling roughly every two years. Much of this growth has been due to the public increasing demand for mobile telephones and more recently, wireless data system. The increasing number of wireless users has spurred communications engineers to improve the quality of service and to use the available spectrum more efficiently. Clearly, wireless communication today encompasses many technologies, systems and services, aimed at many different applications of these; the most widely used are cellular mobile radio systems. Cellular mobile radio systems aim to provide high-mobility, wide-ranging, two-way wireless voice communications. These systems accomplish their task by integrating wireless access with large-scale networks capable of managing mobile users. Performance of PN code is measured using their correlation property. By means of simulation using Matlab we can show that our approach leads to significant capacity improvement.

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2. RELATED WORK

The first CDMA networks were commercially launched in 1985, and provided roughly 10 times more capacity than analog networks - far more than TDMA or GSM. In CDMA applications, he choice and availability of large families of spreading sequences with good correlation properties remains a primary design consideration [1].The main fact of signal transmission at any time in a logical channel in CDMA is determined by PN spreading code. A typical system might use multiple PN sequences. It might use repeated spreading codes of known lengths to ensure orthogonality between signals intended for different users. The channel assignment is essentially determined by the set of codes that are used for that particular link. Performance evaluation of PN sequences is known to be a much more difficult task in comparison with other classical diversity schemes. For instants, Hallstein Lervik have founded that radio systems used in mobile applications will very often not use the frequencies in a very efficient way [2].

The authors suggest a new algorithm for binary coding waveform sidelobe reduction after matched filtering and present a general method by which optimized sidelobe suppression filters for Barker codes can be obtained with a peak output sidelobe 2.62 dB lower than the results found in the literature (for 13-b Barker code). This optimization algorithm is also promising for other binary coding waveforms, such as truncated pseudonoise (PN) sequences and concatenated codes. This new approach can readily be applied to sidelobe-reduction filter design for other binary coding waveforms, such as truncated PN sequences, concatenated codes, etc., which often find their applications in radar systems and spread spectrum communication systems[3].

A new modulation and transmission scheme, Barker code position modulation (BCPM), is introduced. This scheme is suitable for use either in frequency bands where spectral spreading is obligatory (such as the ISM bands), or in cases when it might be desirable due to other considerations. Methods to efficiently decode BCPM signals in the presence of intersymbol interference are also described. These algorithms may also be applied to decoding a class of orthogonal and quasi-orthogonal signals, and can be used to construct optimal and suboptimal receiver structures for systems which use these signals to communicate over dispersive channels [4].

In this paper we propose a computationally efficient channel estimation algorithm for the IEEE802.11 system which is based on the Barker code. The method exploits the correlation results of the Barker code matched filter at the receiver and estimates the channel impulse response with the strong regulatory of them. In order to be optimal, this estimator performs the combination of the initial estimation linearly to correct the results. Moreover the average of multiple symbols is attached to reduce the noise influence. As a result, it has a significantly lower complexity and better tracing capability than previously methods. Simulation results confirm the excellent estimation performance of our method, which is thus an attractive add-on to WLAN receivers in high-mobility scenarios [5].

In [6], a new class of pseudo noise even balanced (PN-EB) binary spreading sequences is derived from existing classical odd-length families of maximum-length sequences, such as those proposed by Gold, by appending or inserting one extra-zero element (chip) to the original sequences. From this analysis a new definition for PG is established, from which it becomes clear that very high processing gains (PGs) can be achieved in band-limited direct sequence spread-spectrum (DSSS) applications by using spreading sequences with zero mean, given that certain conditions regarding spectral aliasing are met. To obtain large families of even balanced (i.e., equal number of ones and zeros) sequences, two design criteria are proposed, namely the ranging criterion (RC) and the generating ranging criterion (GRC). PN-EB sequences in the polynomial range $3 \leq n \leq 6$

are derived using these criteria, and it is shown that they exhibit secondary autocorrelation and cross-correlation peaks comparable to the sequences they are derived from.

In [7], mismatched processing of long binary signals is revisited. The filter is optimised for minimum integrated or peak sidelobes. The importance of choosing a signal with favourable autocorrelation is demonstrated using a few examples.

In [8], a seed accumulating sequential estimation (SASE) method based on accumulating seeds of the received PN sequence is proposed, which performs well at low SNR also. The mean acquisition time of the proposed SASE method is derived by the generating function flow graph technique, and correct chip, detection, and false alarm probabilities are obtained. Finally, numerical results show that the proposed SASE dramatically performs better than the conventional SE at low SNR and the improvement becomes larger as the period of PN sequence increases.

This [9] paper proposes a radio frequency position tracking system for a virtual environment utilizing spread-spectrum (SS) communication technology. The system utilizes two unique characteristics of spread-spectrum technology that are important to position tracking in a virtual environment: code division multiple access (CDMA) and precision ranging.

It is the purpose of this [10] paper to describe the features of Spread Spectrum systems. The emphasis will be on the Direct Sequence Spread Spectrum (DS-SS) scheme, Pseudo Noise signals (PN), Modulators and Demodulators, a DS-SS example about Global Positioning Systems (GPS). In this paper [11], a combination method is presented to estimate the PN sequence's period of the direct sequence spread spectrum (DSSS) signal in strong narrow-band interference environment. An overlapping windowed FFT algorithm is first used to transform the received data signals to the frequency-domain where the elimination or drastical attenuation of the strong narrow-band interference is performed. Then a reprocessing of the power spectrum density algorithm is proposed to detect and estimate the Pseudo-random code (PN) sequence's period of the DSSS signal in low SNR, which solves the difficult problem of PN sequence's periodic detection and estimation of weak DSSS signals with interference.

The algorithm to retrieve the PN sequence & pattern of spectrum in spread spectrum system that will increase the wireless network security & solve the problem of accessing the wireless network in secured way. Because, when only sender end knows the PN sequence & pattern of spread spectrum communication system the network security will be enhanced. Spread spectrum is a means of transmission in which data sequence occupies a much more bandwidth than minimum required bandwidth necessary to send it. The spectrum spreading at transmitter & de-spreading at receiver is obtained by PN-sequence which is independent of data sequence [12].

3. METHODOLOGY

The origin of the name pseudo-noise is that the digital signal has an autocorrelation function which is very similar to that of a white noise signal: Impulse like. The autocorrelation function for the periodic sequence pn is defined as the number of agreements less the number of disagreements in a term by term comparison of one full period of the sequence with acyclic shift (position s) of the sequence itself:

$$Ra(s) = \int_{-NcTc/2}^{NcTc/2} pn(t).pn(t+s)dt$$

It is best if not larger than one count if not synchronized (s=0).

pn(0) = +1 +1 +1 -1 +1 -1 -1

pn(0) = +1 +1 +1 -1 +1 -1 -1

+1 +1 +1 +1 +1 +1 +1 = $\sum$ = 7 = Ra (s=0)

pn(0) = +1 +1 +1 -1 +1 -1 -1

pn(1) = +1 +1 -1 +1 -1 -1 +1

+1 +1 -1 -1 -1 +1 -1 = $\sum$ = -1 = Ra (s=1)

Cross-correlation: Cross-correlation describes the interference between codes pn_i and pn_j:

$$Rc(t) = \int_{-NcTc/2}^{NcTc/2} pn_i(t).pn_j(t+s)\,dt$$

Cross-correlation is the measure of agreement between two different codes pn_i and pn_j. When the cross-correlation Rc (t) is zero for all s, the codes are called orthogonal. In practice, the codes are not perfectly orthogonal; hence the cross-correlation between user codes introduces performance degradation (increased noise power after despreading), which limits the maximum number of simultaneous users.

3.1. Barker Codes

PN sequence may also be a periodic. Such sequences are known as Barker sequences. 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. Barker sequences are too short to be of practical use for spectrum spreading. A correlation sidelobe is the correlation of a codeword with a time-shifted version of itself. Autocorrelation function of the balanced 11 chip barker code is shown in figure 1. The correlation sidelobe, C_k for a k-symbol shift of an N-bit code sequence, {Xj} is given by

$$C_k = \sum_{j=1}^{N-k} X_j X_{j+k}$$

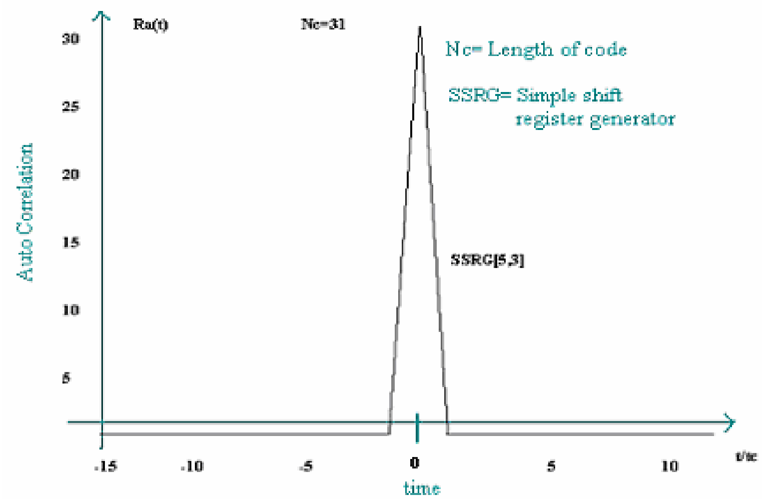

Figure 1: Autocorrelation function of the balanced 11 chip barker code.

Where, Xj is an individual code symbol taking values +1 and -1, for 0<j<N, and the adjacent symbols are assumed to be zero. The Barker Code Generator block provides the codes listed in the following table:

Table1. The Barker Codes lists

Code Length	Barker Code
1	[-1]
2	[-1 1]
3	[-1 -1 1]
4	[-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]

3.2. PN Matched Filter

The output of the matched filter (without Doppler shift) is the aperiodic autocorrelation function, whose values for positive delays are given by

$$C_k(S) = \sum_{Ii=1}^{N-K} s_i\, s_{i=k}, \quad k = 0,1,2,3,\ldots\ldots\ldots\ldots N-1$$

Because the signal is real valued, the autocorrelation is real and symmetric about the zero delay. The energy in the autocorrelation sidelobes (positive delays) is

$$E(S) = \sum_{Ii=1}^{N-K} C_k^2 (S)$$

Because of the symmetry of the autocorrelation, the total sidelobe energy is 2E(S). The merit factor, which corresponds to the inverse of the normalised integrated sidelobes, is

$$F = N^2 /2 E(S)$$

Barker code of length 13 has the largest merit factor (=14.083). A typical value of F for good very long codes is 7[7].

3.3. Direct Sequence Spread Spectrum

In *Direct Sequence Spread Spectrum (DS-SS)*, each bit in the original signal is represented by multiple bits in the transmitted signal, using a spreading code. The spreading code spreads the signal across a wider frequency band in direct proportion to the number of bits used. Figure 2 shows example of the process of spreading and dispreading [13]. *DS-SS* is widely used in CDMA and Multiple-Access techniques because of its features. A direct application of DSSS is in Global Positioning System.

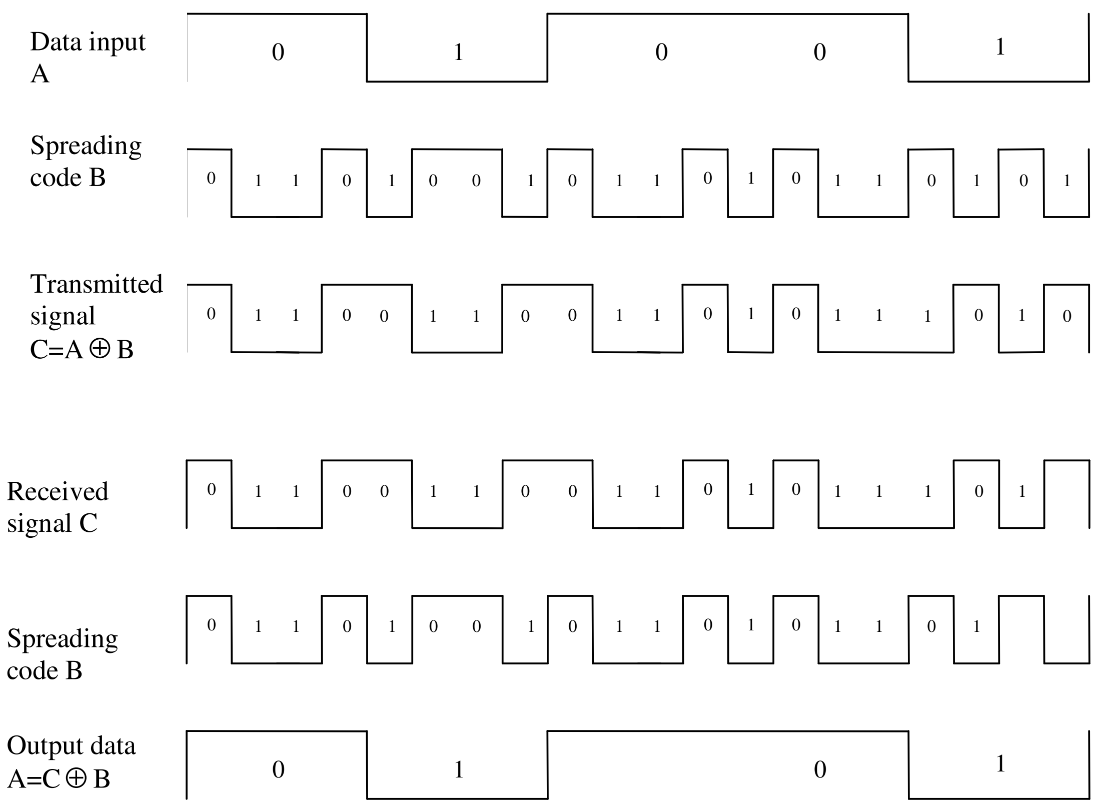

Figure 2. Example of DS-SS

3.4. PN Sequence in Direct Sequence Spread Spectrum

For BPSK modulation the building blocks of a DSSS system are [14]

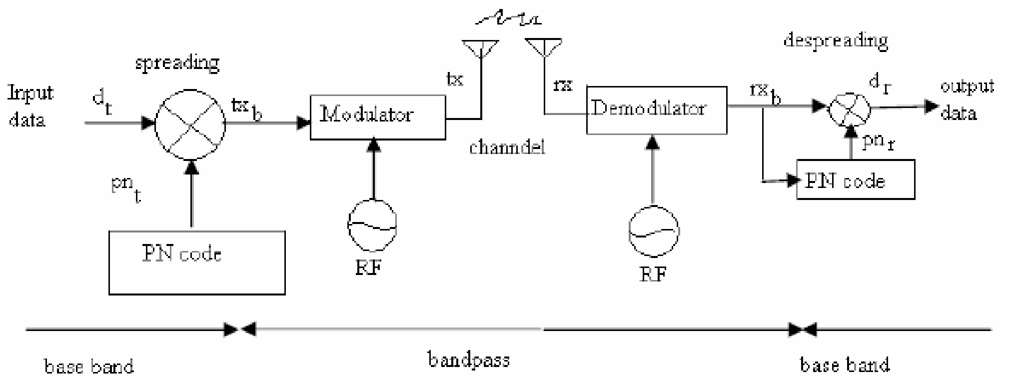

Figure 3. Block diagram of a DS-SS system

Input

- Binary data d_t with symbol rate, $R_s=1/T_s$ (which is equal to bitrate R_b for BPSK)
- Pseudo-noise code pn_t with chip rate, $R_c= 1/T_c$ (an integer of R_s)

Spreading

In the transmitter, the binary data d_t (for BPSK, I and Q for QPSK) is directly multiplied with the PN sequence pn_t, which is independent of the binary data, to produce the transmitted base-band signal tx_b: $tx_b= d_t.pn_t$ The effect of multiplication of d_t with a PN sequence is to spread the base band bandwidth R_s of d_t to a base band bandwidth of R_c.

Despreading

The spread spectrum signal cannot be detected by a conventional narrowband receiver. In the receiver, the received base band signal rx_b is multiplied with the PN sequence pn_r.If $pn_r= pn_t$ and synchronized to the PN sequence in the received data than there covered binary data is produced on d_r. The effect of multiplication of the spread spectrum signal rx_b with the PN sequence pn_t used in the transmitter is to despread the bandwidth of rx_b to R_s.If $pn_r \neq pn_t$, then there is no despreading action. The signal d_r has a spread spectrum. A receiver not knowing the PN sequence of the transmitter cannot reproduce the transmitted data.

3.5. Performance in the presence of interference

To simplify the influence of interference, the spread spectrum system is considered for baseband BPSK communication (without filtering).

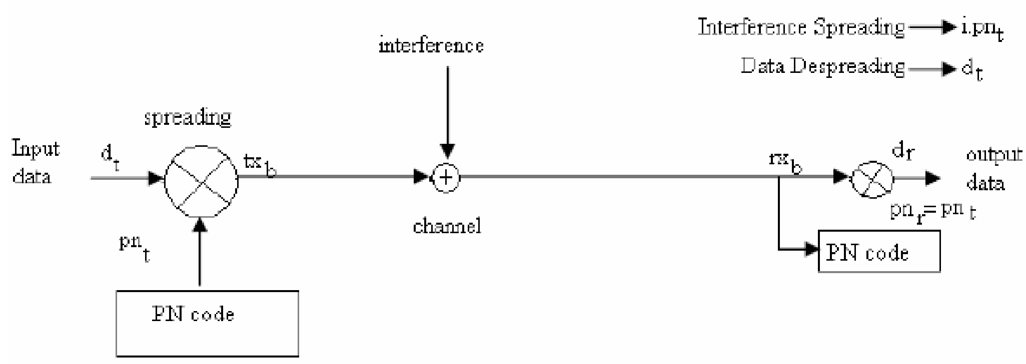

Figure 4. Addition of interference in DS-SS system

The received signal rx_b consists of the transmitted signal tx_b plus an additive interference i (noise, jammer etc):$rx_b=tx_b+ i = d_t.pn_t + i$

To recover the original data dt, the received signal rxb is multiplied with a locally generated PN sequence pn_r that is an exact replica of that used in the transmitter .The multiplier output is therefore given by:$d_r = rx_b.pn_t = d_t .pn_t .pn_t + i.pn_t$

The data signal dt is multiplied twice by the PN sequence pnt, whereas the unwanted interference is multiplied once. Due to the property of the PN sequence: $pn_t .pn_t = +1$ for all t

The multiplier output becomes: $d_r = d_t + i.pn_t$. The data signal d_t is reproduced at the multiplier output in the receiver, except for the interference represented by the additive term $i.pn_t$. Multiplication of the interference i by the locally generated PN sequence means that the spreading code will affect the interference just as it did with the information bearing signal at the transmitter. Noise and interference, being uncorrelated with the PN sequence, becomes noise-like, increased in bandwidth and decreased in power density after the multiplier. After despreading, the data component d_t is narrow band R_s whereas the interference component is wideband R_c. By applying the d_r signal to a baseband (low-pass) filter with a bandwidth just large enough to accommodate the recovery of the signal, most of the interference component i is filtered out .The effect of the interference is reduced by the processing gain (G_p) [14].The DS-SS has no effect on the white noise.

3.5.1. Narrowband Interference

The narrowband noise is spread by the multiplication with the PN sequence pn_r of the receiver. The power density of the noise is reduced with respect to the despread data signal. Only $1/G_p$ of the original noise power is left in the information baseband (R_s). Spreading and dispreading enables a bandwidth trade for processing gain against narrow band interfering signals. Narrowband interference would disable conventional narrowband receivers.The essence behind the interference rejection capability of a spread spectrum system: the useful signal(data) gets multiplied twice by the PN sequence , but the interference signal gets multiplied only once[14] .

3.5.2. Wideband Interference

Multiplication of the received signal with the PN sequence of the receiver gives a selective despread of the data signal (similar bandwidth, higher power density).The interference signal is uncorrelated with the PN sequence and is spread.
Origin of the wideband noise:

1. Multiple Spread Spectrum users: multiple access mechanism.
2. Gaussian Noise: There is no increase in SNR with spread spectrum. The larger channel bandwidth (R_c instead of R_s)increases the received noise power with Gp:

$N_{info} = N_o.BW_{info} \longrightarrow N_{ss} = N_o.BW_{ss} = N_{info}.\ G_p.$

The spread spectrum signal has a lower power density than the directly transmitted signal [14].

3. PERFORMANCE MEASUREMENT OF BARKER CODES

We note that the transmission performance is only dependent on the auto-correlations and cross-correlations values for the PN sequences. The correlations have a direct impact on the inter–symbol–interference (ISI) and the multiple–access–interference (MAI) [15].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 sidelobe is the correlation of a codeword with a time-shifted version of itself. We have obtained the curves from Matlab.

4.1. Figures and Tables

The autocorrelation of barker code 7, 11 and 13 are given in Figure 5, Figure 6 and Figure 7 respectively.

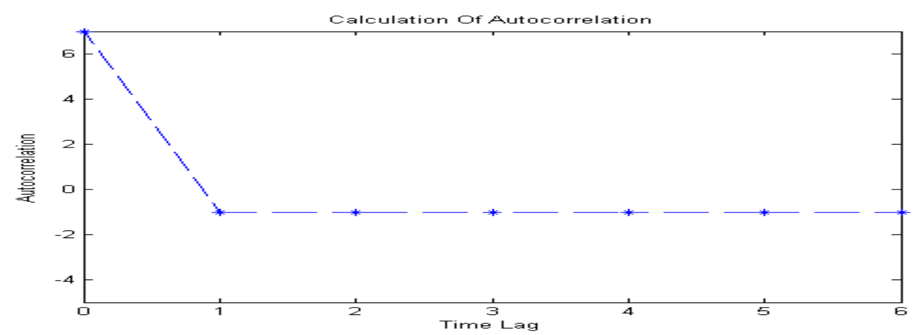

Figure 5.The autocorrelation of Barker code 7

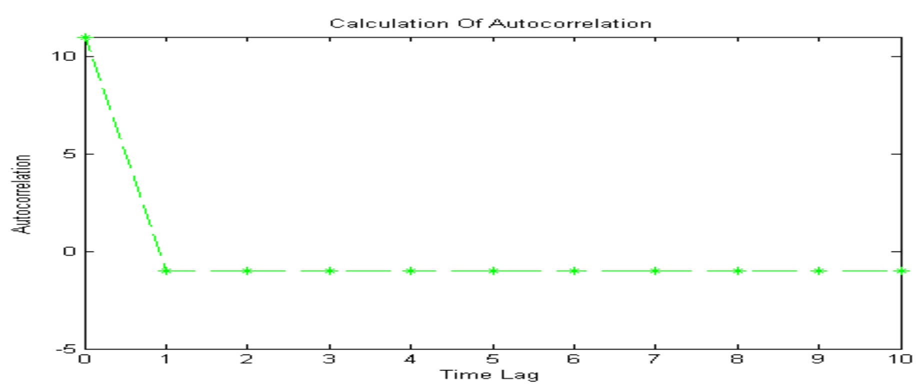

Figure 6.Autocorrelation of Barker code 11

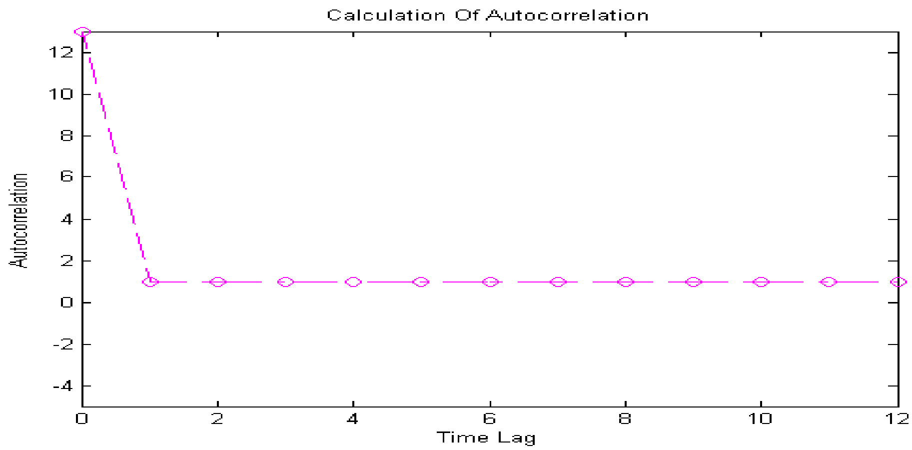

Figure 7.Autocorrelation of Barker code 13

Then we have measured the cross correlation between these three barker codes in a 16 bit chip length.

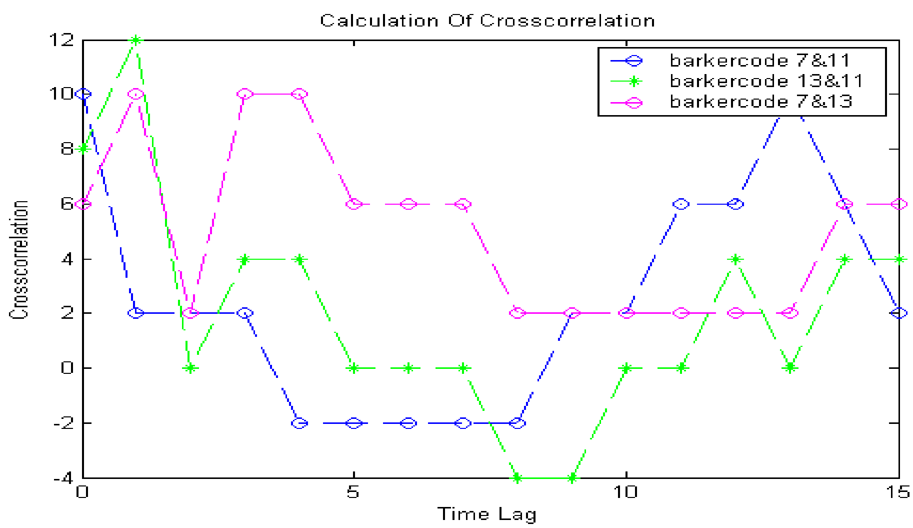

Figure 8.Measurement of the cross-correlation between these three barker code in a 16 bit chip length.

From the graph we can see that cross correlations between the PN codes are not so good. As an alternative measurement values are given in Table 1 along with calculations.

Table 2.Cross correlation values of the three codes

Time lag	Cross7&11	Cross11&13	Cross13&7	Abs value of Cross7&11	Abs value of Cross11&13	Abs value of Cross13&7
0	10	8	6	10	8	6
1	2	12	10	2	12	10
2	2	0	2	2	0	2
3	2	4	10	2	4	10
4	-2	4	10	2	4	10
5	-2	0	6	2	0	6
6	-2	0	6	2	0	6
7	-2	0	6	2	0	6
8	-2	-4	2	2	4	2
9	2	-4	2	2	4	2
10	2	0	2	2	0	2
11	6	0	2	6	0	2
12	6	4	2	6	4	2
13	10	0	2	10	0	2
14	6	4	6	6	4	6
15	2	4	6	2	4	6
Sum	40	32	80	60	48	80
Average	2.5	2	5	3.75	3	5

4. CONCLUSIONS

In our experiment, the selection is done to maximize self correlation and minimize cross-correlation. Cyclic shifts of these sequences and reversed sequences are also good. Cross correlations between these have been tested thoroughly, but the ratios will not lock up on reversed sequences or on different lengths. Cross-correlations between cyclic shifted versions will be high. The Barker code is perfect, but the numbers of codes are very limited. The longest known code in the family is 13 bit long. For that reason this codes are used only as spreading codes in single user CDMA systems. So, scrambling codes with the same properties as the Barker codes with the higher bit length and good correlation property might be successfully used in multi user system. In terms of good acquisition, 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. We hope our codes can contribute in this area too.

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