Proposed sets of Polyphase Spreading Sequences for DS-CDMA System

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Abstract : - In direct sequence code division multiple access (DS/CDMA) systems, a large number of users share the same frequency band at the same time, and each user is assigned a unique signature sequence which spreads information bits through multiplication. In this paper, some of ployphase signature sequences for direct sequence code division multiple access (DS/CDMA) system is proposed. The proposed sequences have good aperiodic correlation properties. The new sets of polyphase spreading sequences are the multiplication of the polyphase chirp sequences by some other binary sequences for example : Barker & Willard binary sequences .The obtained new sets of polyphase sequences tested by using of Matlab program have good correlation properties and performance in DS/CDMA systems.

Keywords : - DSSS , Barker , Willard , Chirp sequences & new proposed polyphase sequence sets.

1 Introduction

Direct sequence spread spectrum (DSSS) is one of the techniques used to spread the frequency spectrum of the transmitting signal for each input user signal and sending them at the same time with the same frequency but each with it's own code (Code Division Multiple Access CDMA) system. This code may be binary sequence code or non-binary code, the main condition for each used spreading code is that it must have good correlation properties as mentioned in the next section.

2 Auto-correlation and cross-correlation functions and their properties

let us consider two complex sequences $\{a_n\}$, and $\{b_n\}$, both having a period N. Their discrete cross-correlation function $R_{a,b}(\tau)$ is defined as :

$$R_{a,b}(\tau) = \sum_{n=0}^{N-1} a_n b^*_{n+\tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where b^*_n denotes the complex conjugate of b_n .The discrete auto-correlation function $R_a(\tau)$ of the sequence $\{a_n\}$is defined as :

$$R_a(\tau) = \sum_{n=0}^{N-1} a_n a^*_{n+\tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Very often, instead of the above un normalized correlation functions, their normalized equivalents are used :

$$R_{a,b}(\tau) = (1/N) \sum_{n=0}^{N-1} a_n b^*_{n+\tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$R_a(\tau) = (1/N) \sum_{n=0}^{N-1} a_n a^*_{n+\tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The defined above discrete periodic correlation functions have got several useful properties, below is the short summary of some of the most useful of them :

a. The auto-correlation is an even function of τ :

$$R_a(-\tau) = R_a(\tau) \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

b. The peak auto-correlation occurs at zero delay : $R_a(0) \ge R_a(\tau)$, $\tau \neq 0$ …………………(6)

c. The cross-correlation functions have the following symmetry :

$$R_{a,b}(\tau) = R_{a,b}(-\tau) \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

d. Cross-correlation functions are not, in general, even function, and their peak values can be at different delays for different pairs of the sequences.[1]

So, each used sequence code must have good auto and cross correlation properties, i.e. minimum side lobe level in auto correlations and minimum peak in cross correlations with other codes. In this paper Barker and Willard sequence codes are used, it can be using other codes and this may be future paper.

These codes are used to spread the frequency spectrum and for security purpose in Ds-CDMA systems to send for than one user through one channel each with it's own spreading code.

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3 Binary sequences

There are many binary sequences for example : m-sequence, Barker codes, Willard codes, Walsh Hadamard sequence codes, in this paper, the proposed new polyphase sequences by multiplying the polyphase chirp sequences by the Barker & Willard codes :

3.1 Barker code

Barker codes are short unique codes that exhibit very good correlation properties. These short codes with N bits, with N=3 to 13 , are very well suited for DS spread spectrum.[3]. A list of Barker codes is tabulated in table (1).

3.2 Willard codes

Willard codes, found by computer simulation and optimization, and under certain conditions, offer better performance than Barker codes[3]. . A list of Willard codes is tabulated in table(1).
The inverted or bit reversed versions of the codes listed on table (1) can be used since they still maintain the desired autocorrelation properties :

	Willard sequence	**Barker sequence**
3	110	110
4	1100	1110 or 1101
5	11010	11101
7	1110100	1110010
11	11101101000	11100010010
13	1111100101000	1111100110101

Table 1 : Barker & Willard codes

The autocorrelation for the Barker & Willard codes with the length N=13 are shown in fig. (1) ,(2) respectively.

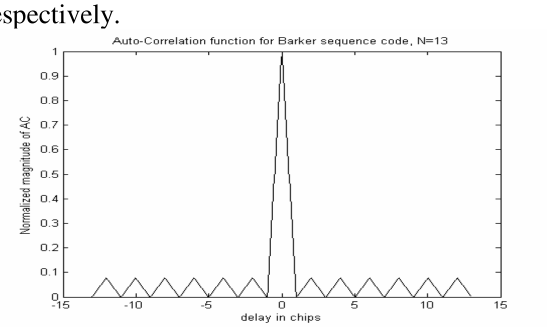

Fig. 1 : Auto-correlation for Barker code, N=13

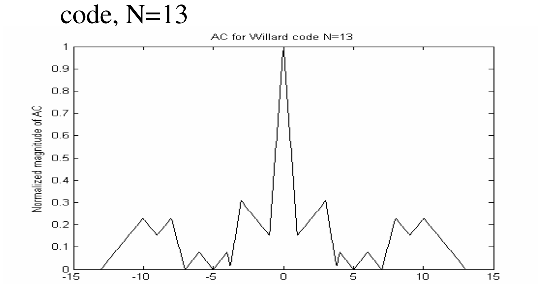

Fig. 2 : Auto-correlation for Willard code, N=13

3.3 Chirp sequences

Chirp signals are widely used in radar applications for pulse compression and were also proposed for use in digital communications by several authors. They refer to creation of such a waveform where an instantaneous frequency of the signal changes linearly between the lower and upper frequency limits. This is graphically illustrated in fig. (3), which presents the two basic types of chirp pulses and their instantaneous frequency profiles [4]:

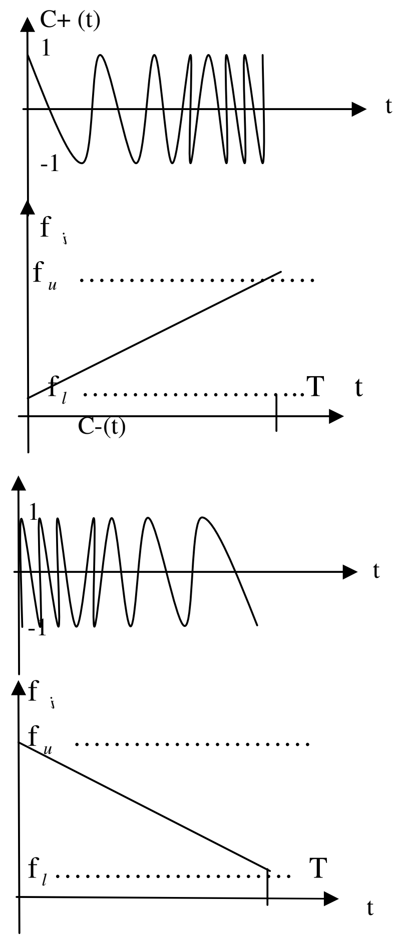

Fig. 3 : Positive and negative chirp pulses and their instantaneous frequency profiles.

We can write a formula defining a complex polyphase chirp sequence for the above single chirp pulse :

$\{ B_n\hat{}(h) \} = (B_n\hat{}(h))$; n=1,2,…,N

where, $B_n\hat{}(h) = \exp(j2\pi b_n)$, n = 1,2,N……..…..(8)

$b_n=(n^2 -nN)/2N^2$ ………..…………...……..…..(9)

and h can take any arbitrary nonzero real value, fig.(4-7) are the auto correlation for the single chirp sequence for N=13,16,32&25 respectively.

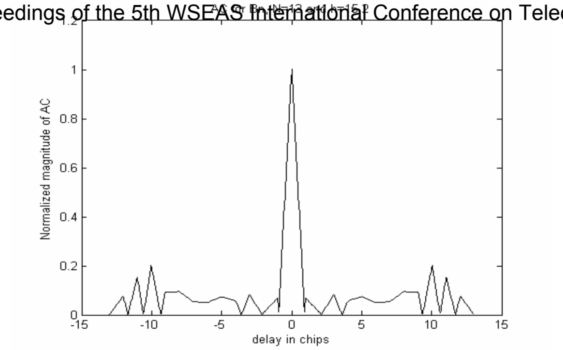

Fig. 4 : Auto-correlation for single-chirp sequence, N=13

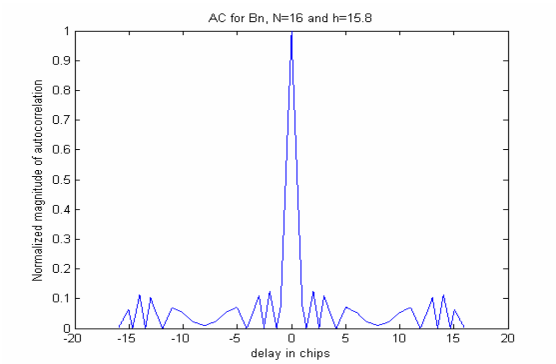

Fig. 5 : Auto-correlation for single-chirp sequence,

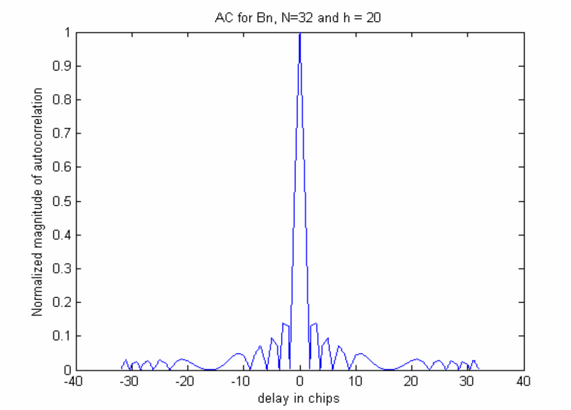

Fig. 6 : Auto-correlation for single-chirp sequence, N=32

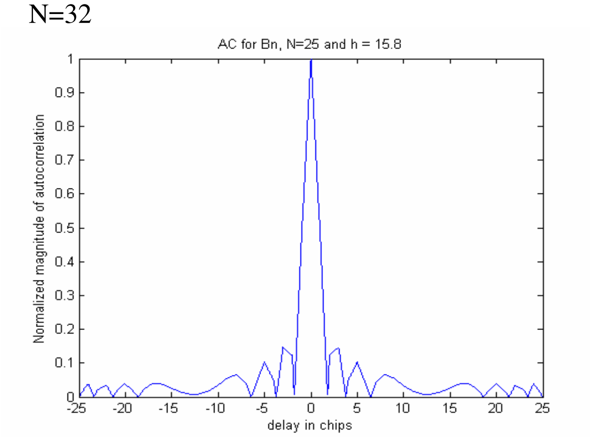

Fig. 7 : Auto-correlation for single-chirp sequence, N= 25

The main advantage of chirp sequences compared to other known sets of sequences, lies in that it can easily generate the set for any given length N, on the other hand, most of the known sets of sequences can be generated only for a certain values of N . The values of parameter h for the sequences can be optimized to achieve :

a) Minimum multi-access interference (MAI) by minimizing the mean square aperiodic cross-correlation (RCC).

b) The best system synchronizability by minimizing the mean square aperiodic auto-correlation (RAC).

c) Minimum peak interference by minimizing the maximum value for the aperiodic CCFs, ACCFmax, over the whole set of the sequences[1].

A pulse is referred to as a chirp pulse of the order s, if and only if the first time derivative of its instantaneous frequency (the angular acceleration) is a step function with the number of time intervals where it is constant is is equal to s :

$$\int_0^T f_i(t)dt = 0 \qquad \text{..............................(10)}$$

Then, such a pulse is called a baseband chirp pulse of the order s.

As an example, a baseband chirp pulse of orders 2&4 are shown in fig.(8)&fig.(9), the presented pulses are symmetrical [1].

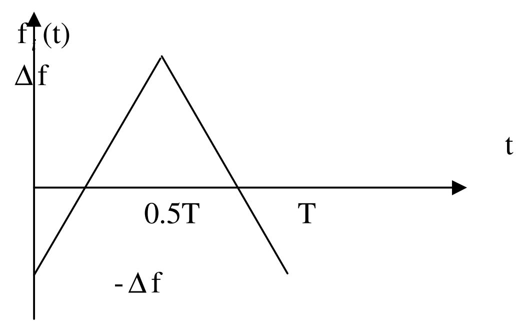

Fig. 8 Example baseband chirp pulses of the order (2)

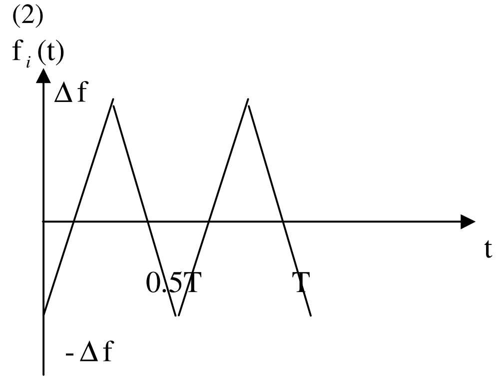

Fig. 9 : Example baseband chirp pulses of the order (4)

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The formula of the elements (d_n) & (q_n) for complex double &quadruple chirp sequences respectively are :

$$d_n=\begin{cases} (2n/N)^2-(n/N), & 0<n \\ (-2n/N)^2+(3n/N)-1, & N/2<n \\ 0, & \text{otherwise} \end{cases} \qquad ....(10)$$

The complex double chirp sequence elements d^n are therefore given by :

$D\hat{}n=\exp(j2\pi h d_n);n=1,2,,N.....(18)$

And corresponding to the chirp pulse of the order 4, the elements q_n are expressed as:

$$q_n=\begin{cases} (4n/N)^2-(n/N), & 0<n \\ (-4n/N)^2+(3n/N)+1, & N/4<n \\ (4n/N)^2-(5n/N)-3/2, & N/2<n \\ (4n/N)^2-(7n/N)-3, & 3N/4<n \\ 0, & \text{otherwise} \end{cases} \qquad ....(11)$$

and the elements of the complex quadruple chirp sequences are given by :

$T_n=\exp(j2\pi h q_n);n=1,2,..,N$ ....(12)

The auto-correlation for the double and quadruple chirp sequences are shown in fig.(10 - 12) for N=16.25.32.

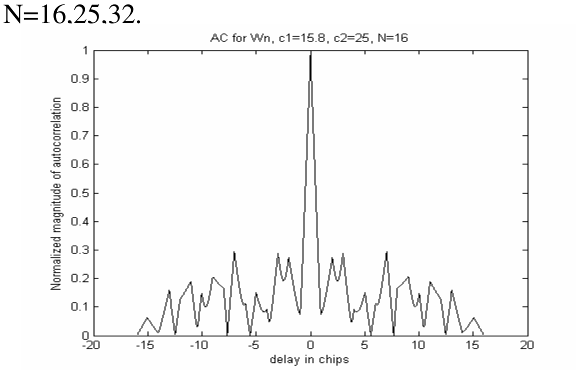

Fig.10 : Auto-correlation for double-chirp sequence, N=16

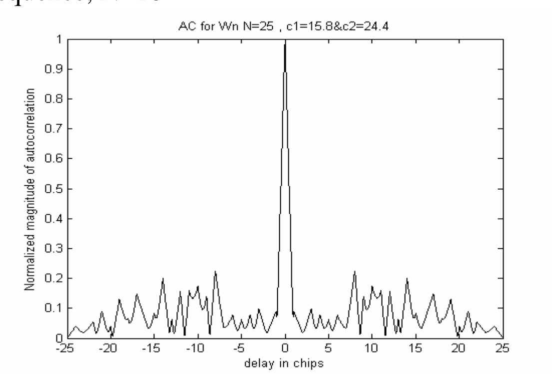

Fig.11 : Auto-correlation for double-chirp sequence, N=25

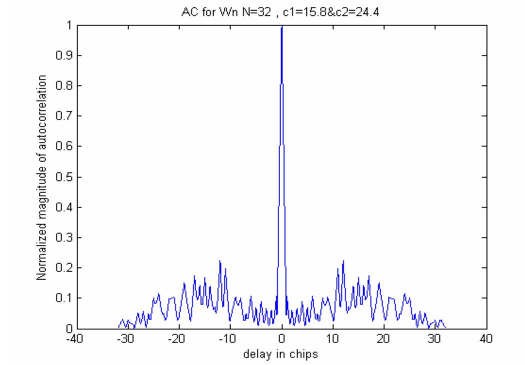

Fig. 12 : Auto-correlation for single-chirp sequence, N=32

Other class of higher order chirp sequences, can be obtained if a superposition of chirp sequences of different order s is used to create the complex polyphase sequence[10].

4 Proposed sets of polyphase sequences

As shown in section(3), the single, double and quadruple chirp sequences (B_n,D_n&T_n) have good correlation properties, if a superposition is used to obtain other two sets of chirp sequences which are :

$W_n=\exp(j2\pi(c_1 b_n+c_2 d_n))$ ....(12)

$Q_n=\exp(j2\pi (c_1 b_n+c_2 d_n+c_3 q_n))$ ....(13)

Where , $b_n = (n^2 -nN)/2N^2$

$$d_n=\begin{cases} (2n/N)^2-(n/N), & 0<n \\ (-2n/N)^2+(3n/N)-1, & N/2<n \\ 0, & \text{otherwise} \end{cases}$$

$$q_n=\begin{cases} (4n/N)^2-(n/N), & 0<n \\ (-4n/N)^2+(3n/N)+1, & N/4<n \\ (4n/N)^2-(5n/N)-3/2, & N/2<n \\ (4n/N)^2-(7n/N)-3, & 3N/4<n \\ 0, & \text{otherwise} \end{cases}$$

The new sets of polyphase sequences obtained by multiplying these chirp sequences by other sequences which have good aperiodic correlation properties as follows :

4.1 Chirp – sequence multiplying by other binary sequences

In this paper Barker and Willard sequence codes are used. As a result of the multiplication process, other polyphase sequences obtained with different phases. Multiplying the single chirp polyphase sequence (B_n) by Barker code, the correlation properties are better than multiplying (B_n) by the Willard code, but the double chirp (W_n) by Willard has better correlation properties than that of (W_n) by Barker code, as shown in the fig.(13-20).

In order to compare different sets of spreading sequences, a standard or quantitative measure needed for the judgment, they are based on the correlation functions of the set of sequences, since both the level of multi-access interference and synchronization amiability depend on the cross-correlation between the sequences and the auto-correlation functions of the sequences, respectively[4] :

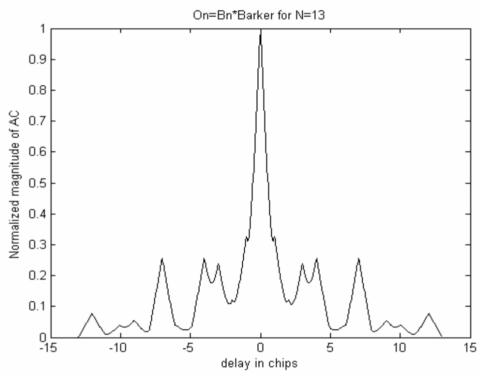

Fig. 13 : Auto-correlation of Bn*Barker sequence, N=13

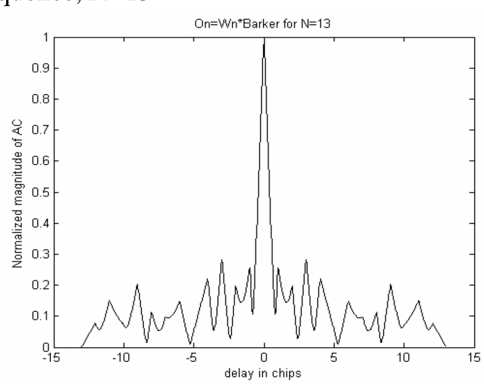

Fig. 14 : Auto-correlation of Wn*Barker sequence, N=13

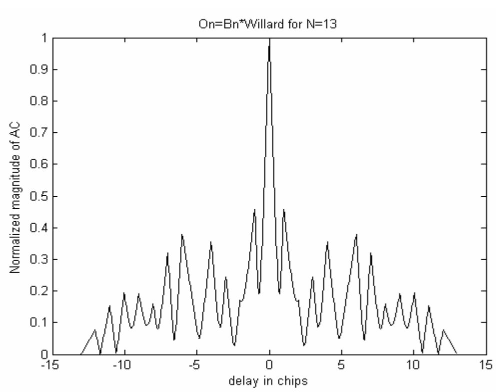

Fig. 15 : Auto-correlation of Bn*Willard sequence, N=13

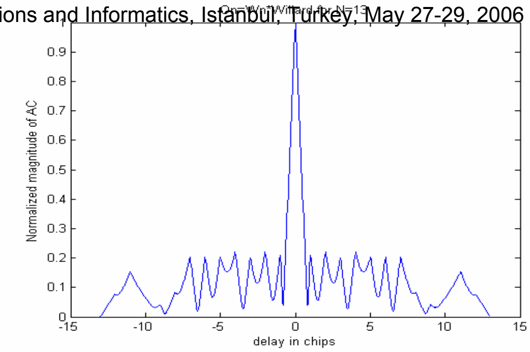

Fig. 16 : Auto-correlation of Wn*Willard sequence, N=13

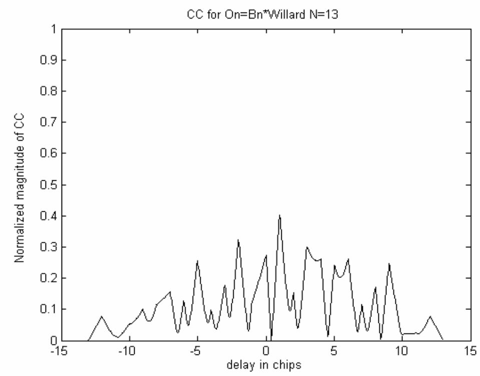

Fig. 17 : Cross-corelation between two Bn*Willard sequences,N=13

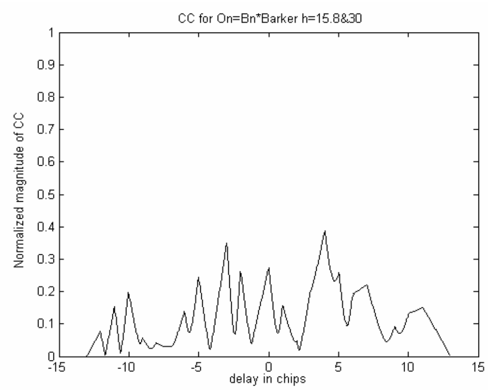

Fig. 18 : Cross-corelation between two Bn*Barker sequences,N=13

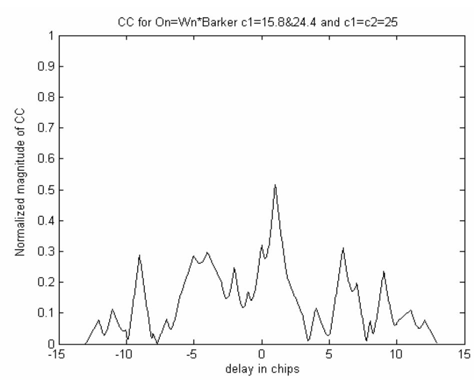

Fig. 19 : Cross-correlation between two Wn*Barker sequences, N=13

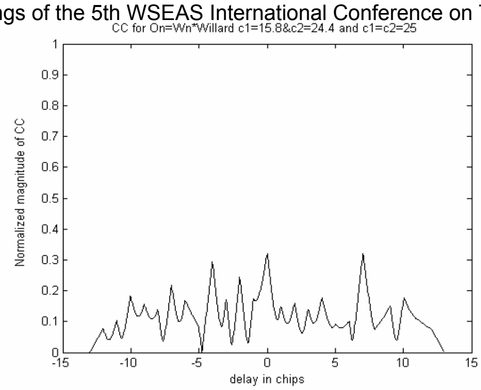

Fig.20 : Cross-correlation between two Wn*Willard sequences, N=13

4.3 Results tests and discussion :

As shown in the figures, the auto-correlation of each sequence has main lobe and sidelobes, the main lobe is for zero delay and the sidelobes for delay not zero, for any sequence, the sidelobes must be as small as possible, and for the cross-correlation, the peak must be as small as possible between any two sequences, in the results it is shown that the auto and cross correlation for each previous and the proposed sets of the sequences, the best sets of sequences is that sequence that has best correlation properties, smaller sidelobe peak in the auto-correlation and smaller peak of the cross-correlation.

5 Conclusions

In this paper, new method to design sets of orthogonal polyphase sequences introduced. The method is based on utilizing a polyphase chirp sequence, the complex coefficients obtained from the superposition of baseband chirp sequences and other sequences like Barker And Willard binary sequences. The resultant polyphase sequences can be optimized to achieve desired correlation properties of the set. As shown in the figures, a single chirp-Barker polyphase sequence has better correlation properties than a double chirp-Barker polyphase sequence, on the other hand, the double chirp-Willard polyphase sequence has better correlation properties than a single chirp-Willard polyphase sequence. Further on, one can apply the method proposed in this paper with the sequences mentioned in (4), i.e. instead of Barker or Willard binary sequence codes, other binary or non-binary (polyphase) sequences can be modified using chirp pulses.

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