PERFORMANCE EVALUATION OF BARKER CODES BY USING NON-SINUSOIDAL WAVEFORMS IN RADAR SIGNAL PROCESSING

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Abstract:

In the Radar signal processing, waveform design plays major role. The target range and Doppler resolution depends on the selection of the waveform. In the waveform design, pulse compression techniques are being implemented for better resolution and accuracy measurements of range and velocity of targets. Hence radar detector requires sophisticated signal processor. Presently, there are so many radar codes are being developed. Barker codes (Bi-phase codes) are being implemented by using sinusoidal waveforms. In this paper, we developed Barker codes by using non-sinusoidal waveforms like Gaussian function. The performances of non-sinusoidal signals are evaluated by using Barker codes(in terms of PSLR,ISLR). By using some performance factor, these two techniques are compared and results are presented.

Keywords- Non sinusoidal waveforms, Barker codes, ISLR, PSLR, Range Resolution.

1. Introduction

In radar applications we generally utilize the reflected “known” signal to detect the existence of a reflecting target. The probability of detection is related to the SNR rather than to the exact waveform of the signal received. A specified matched filter is a linear filter whose impulse response is determined by a specific signal in a way that will result in the maximum attainable SNR at the output of the filter.

The frequency response $H(\omega)$ that will attain maximum SNR at a predetermined delay t_o is given by equation

$$\left(\frac{S}{N}\right)_{\text{out}} = \frac{|s_o(t_0)|^2}{\overline{n_o^2(t)}} \qquad (1)$$

The autocorrelation and ambiguity functions are essential desired tools for performance evaluation of radar signals for stationary and moving targets.

2. Autocorrelation function

The mathematical formula of autocorrelation function for a narrowband complex signal can be represented as

$$R(\tau) = \int_{-\infty}^{\infty} u(t)u^*(t-\tau)dt \qquad (2)$$

u (t) = Transmitted signal;

u (t- τ) = Received signal with time delay τ

Where * denotes the complex conjugate, and the variable τ denotes the delay. In general the radar signal autocorrelation function is defined as the normalized response of a matched filter method to return signal with range rate.

An ideal autocorrelation function is a single spike with no side lobes centre in the range domain. Its physical realization would yield superior target-resolution capabilities and clutter rejection capabilities for radar. Harmuth [1] and Husain [5] have demonstrated that the desired ideal autocorrelation function can be achieved by non-sinusoidal coded waveforms. It is also to attain low PSLR, low ISRL and better range resolution with non-sinusoidal coded waveforms than sinusoidal coded waveforms.

3. Waveform Design

The ideal autocorrelation functions and ambiguity functions in this paper are both sinusoidal and non-sinusoidal waveforms. The autocorrelation for the sinusoidal periodic waveform A Sin(wt) is given by the equation:

ACF= (A^2)/2cos (w*tau)

(3)

A signal that is well suited for the representation of carrier-free electromagnetic signals used in practice for impulse radar and radio communications is Gaussian pulse and it is defined by the time function,

$$\Omega(t) = \frac{E_\circ}{1-\alpha}\big(\exp\{-4\pi[(t-t_\circ)/\Delta T]^2\} - \alpha\exp\{-4\pi[\alpha(t-t_\circ)/\Delta T]^2\}\big), \quad \alpha \neq 1. \qquad (4)$$

The autocorrelation function of the Gaussian Pulse is given by :

$$\Upsilon(t) = \int_{-\infty}^{+\infty} \Omega(\lambda)\Omega(\lambda + t)\, d\lambda = E_\circ^2 \Delta T \sum_{k=0}^{2} I_k \exp\{-a_k[(t - t_\circ)/\Delta T]^2\}, \quad (5)$$

where

$$I_0 = \frac{1}{\sqrt{8}(1-\alpha)^2},$$

$$I_1 = \frac{\alpha}{\sqrt{8}(1-\alpha)^2},$$

$$I_2 = -\frac{\alpha}{(1-\alpha)^2(1+\alpha^2)^{1/2}},$$

$$a_0 = 2\pi, \quad a_1 = 2\pi\alpha^2, \quad a_2 = \frac{4\pi\alpha^2}{(1+\alpha^2)}.$$

In this paper, idealised Gaussian pulse has been considered. The disadvantage of the sinusoidal periodic signal was the presence of large subsidiary peaks in the ambiguity function. Since the peaks are caused by this sinusoidal nature, we can try to eliminate them by using a non-sinusoidal nature.

PSLR is defined as ratio of peak cross correlated side lobe to peak output of matched filter

$$PSLR = \frac{1}{R_0^2}\left(\max_{k \neq 0} |R_k|\right)^2 \quad (6)$$

When the filter is matched, $R_0^2 = N^2$

ISLR is defined as :

$$ISLR = \frac{1}{R_0^2}\sum_{k \neq 0} R_k^2 \quad (7)$$

Range resolution is the ability to distinguish two or more targets that are very close in range. In this paper, range resolution value is attained for ideal matching conditions.

4. Barker codes

Barker codes are popular codes in radar applications. Barker codes are being implemented in existing technology. Originally, the Barker codes were designed as the sets of M binary phases yielding a peak-to-peak side lobe ratio of M. Although it was only proved that no binary Barker codes exist for 13< M <1 and that no binary Barker codes exist for all odd M >13. In Barker and other phase-coded signals, the instantaneous phase switching causes extended spectral side lobes.

Table: Barker Codes

length	code
2	+−, ++
3	++−
4	+−++, +−−−
5	+++−+
7	+++−−+−
11	+++−−−+−−+−
13	+++++−−++−+−+

5. Simulation Results:

The Autocorrelation and Ambiguity plots for Barker code of lengths 5, 7 using sinusoidal and non-sinusoidal (e.g.: Gaussian) waveforms plots are simulated and results have been given from following figures. These plots will determine PSLR, ISLR and Range Resolution.

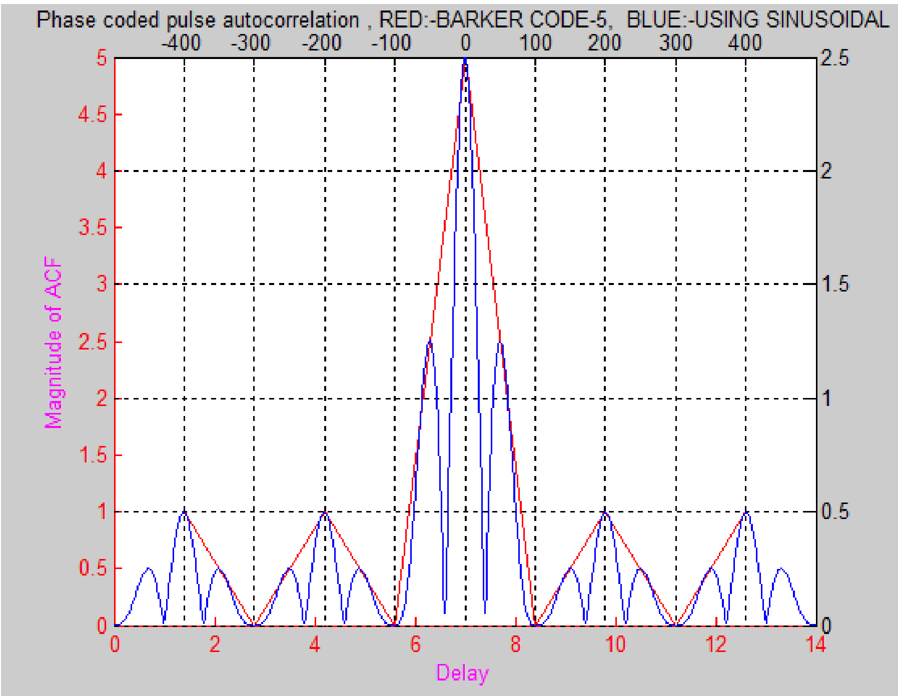

Fig 1(a) Phase coded autocorrelation plot of Barker-5 for sinusoidal signal

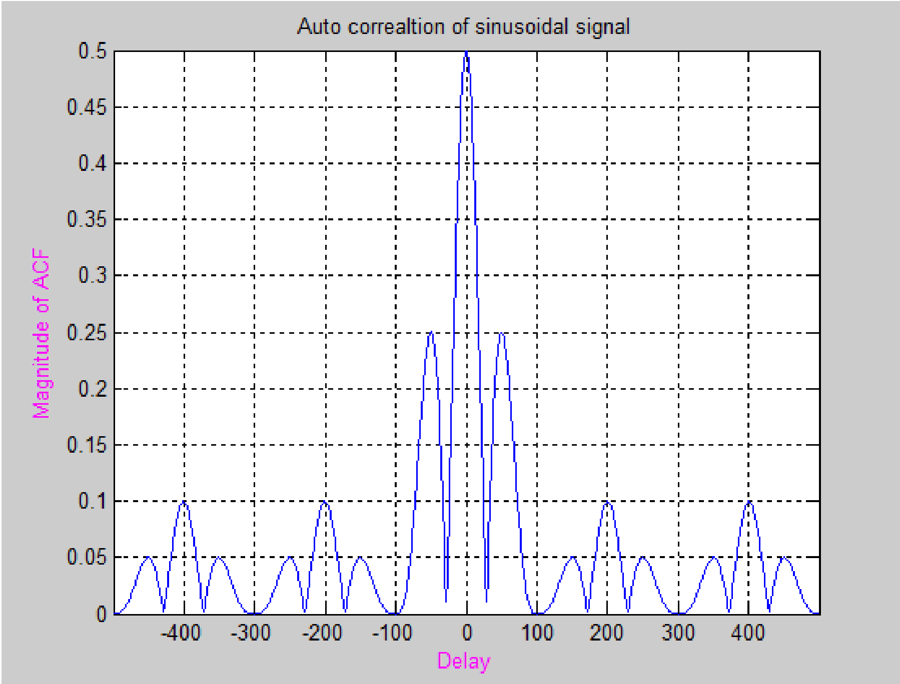

Fig 1(b) Autocorrelation plot for sinusoidal signal

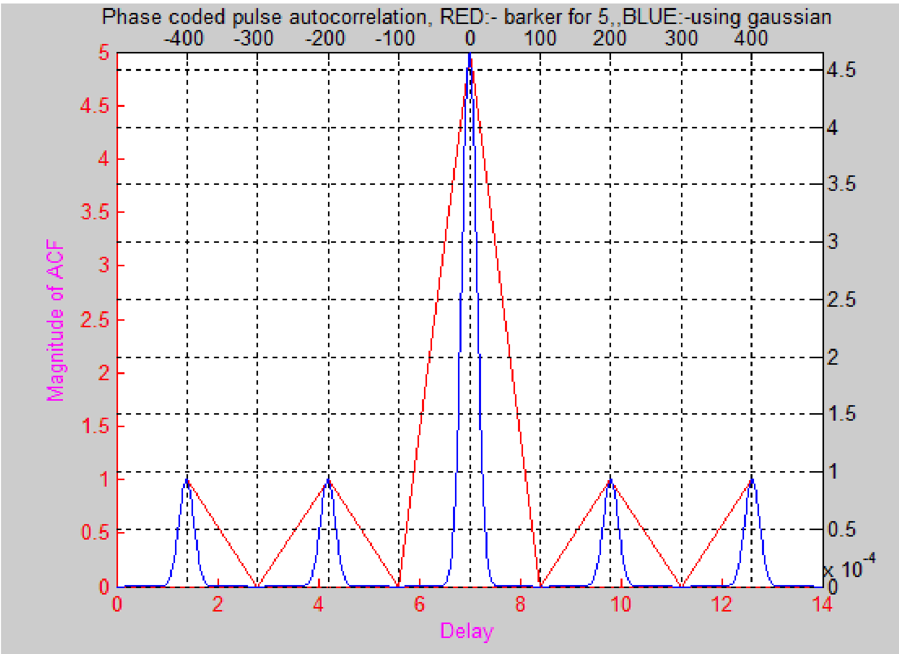

Fig 1(c) Phase coded autocorrelation plot of Barker-5 for Gaussian signal

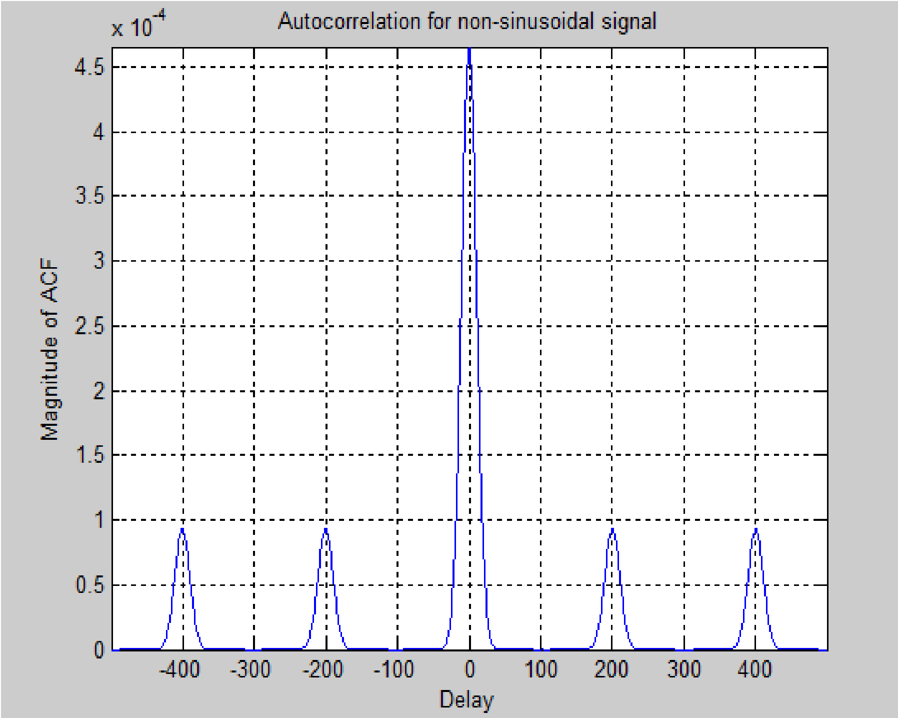

Fig 1(d) Autocorrelation plot for Gaussian signal

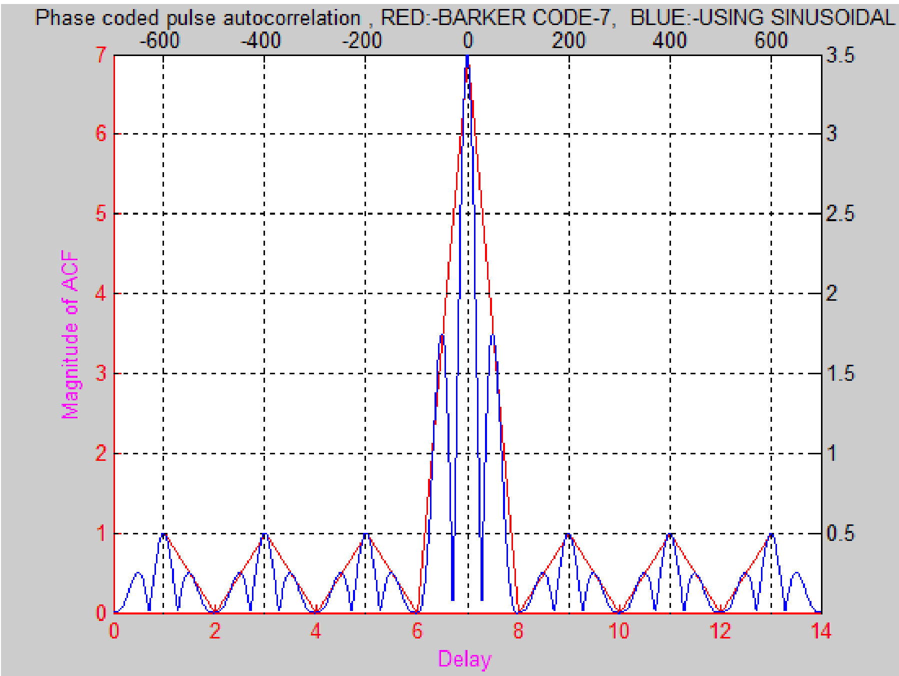

Fig 2(a) Phase coded autocorrelation plot of Barker-7 for sinusoidal signal

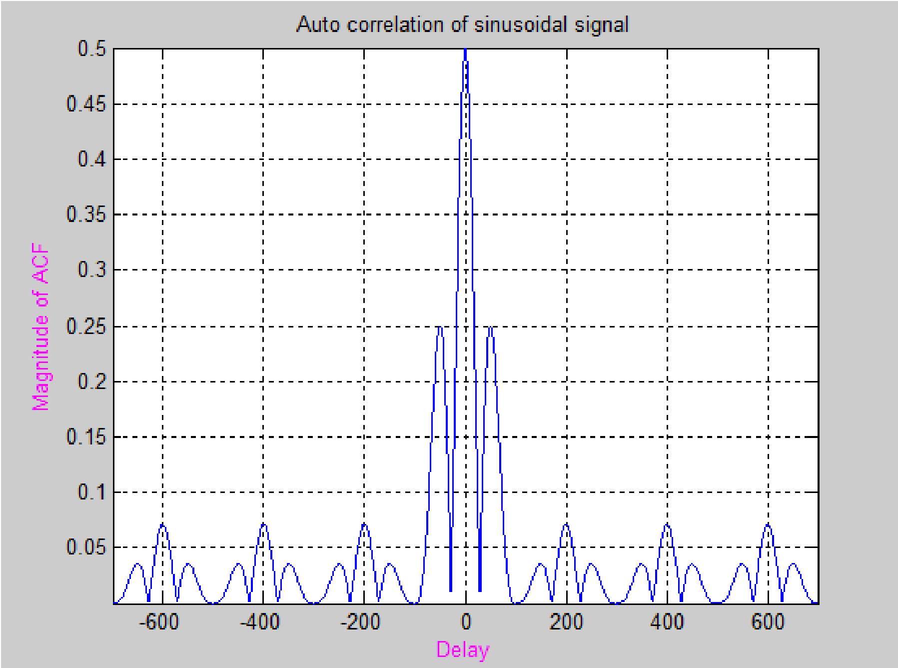

Fig 2(b) Phase coded autocorrelation of Barker-7 for sinusoidal signal

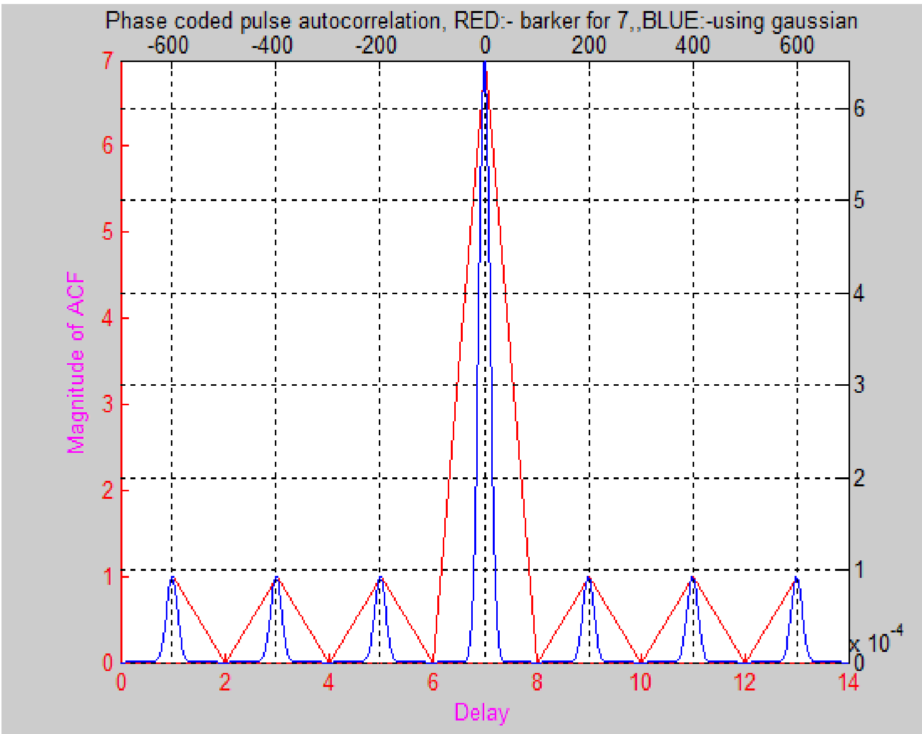

Fig 2(c) Phase coded autocorrelation plot of Barker-7 for Gaussian

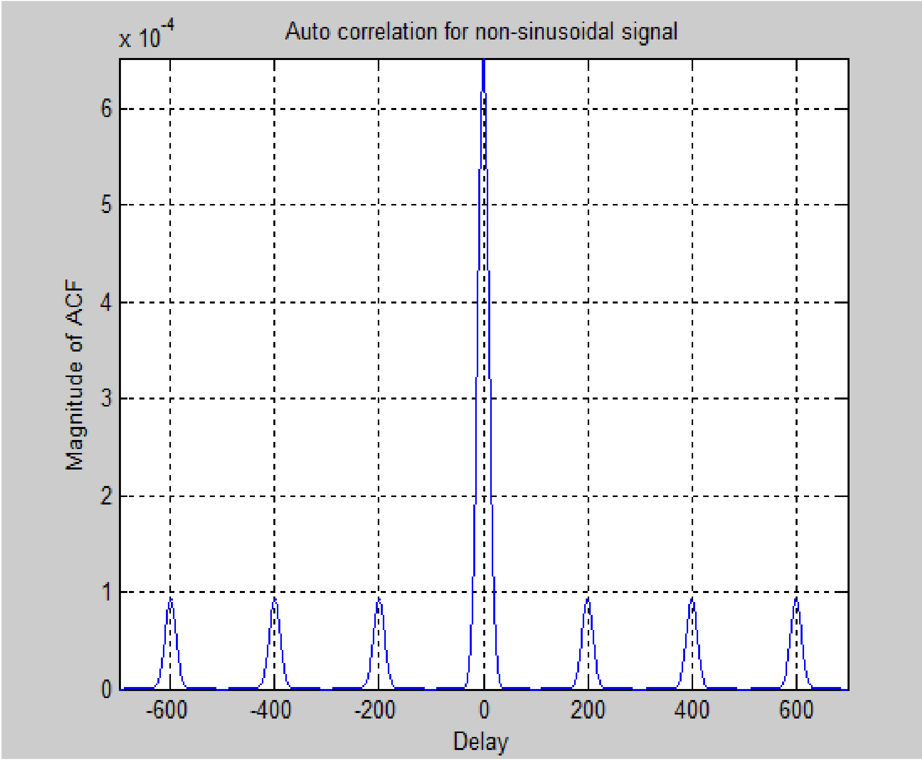

Fig 2(d) Magnitude plot for Auto correlation for non-sinusoidal

PARAMETER	SINUSOIDAL	NON-SINUSOIDAL
PSLR(**dB**)	**-13.79**	**-13.79**
ISLR(**dB)**	**-7.95**	**-7.95**
RANGE RESOLUTION(cm)	**39**	**25.5**

Table (1) comparision of sinusoidal and non-sinusoidal for Barker code-5

PARAMETER	SINUSOIDAL	NON-SINUSOIDAL
PSLR(**dB)**	**-16.90**	**-16.90**
ISLR(**dB)**	**-9.12**	**-9.12**
RANGE RESOLUTION(cm)	**39**	**27**

Table (2) comparision of sinusoidal and non-sinusoidal for Barker code-7

6.Conclusions:

From the results, it is evident that Barker codes using non-sinusoidal signals show better performance than sinusoidal waveforms. The plots of non-sinusoidal waveforms having large main peak value and less side lobe levels. Large peak values generate higher energy levels which are advantageous in detecting the targets with high accuracy. The table shows that PSLR and ISLR and better Range Resolution for better target detection.

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