# Target Detection using Binary Coded Sequences

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***Abstract:*** This paper mainly focused on the detection of Radar targets using Binary coded sequences. Cross Ambiguity Function Technique is used as a tool for detection of targets using the Binary coded sequences as a transmitted signal. Cross Ambiguity Function Technique is considered as an alternative technique to identify the presence or absence of target in various scenarios such as single stationary target, multi stationary targets, single moving target, multi moving targets and multi stationary & moving targets.

***Index Terms*–Cross Ambiguity Function, Binary Sequences, Contour Plots.**

## I. INTRODUCTION

Pulse compression radar transmits a long duration pulse which is coded using phase or frequency modulation to achieve a wide bandwidth as well as to meet the requirement of energy for detection. The received echo is processed using a pulse compression filter to yield a narrow compressed pulse that separates closely spaced targets. However, this separation is accomplished at the cost of introducing sidelobes in the matched filter response, which may mask weak targets and possibly prevent their detection altogether. Therefore, in radar applications the pulse compression sequences with high discrimination factor are desired. In this context apart from the good sequences suggested in the literature, Binary sequences with good discrimination factor are proposed in [1-8].

In subsequent sections, since there is no conventional technique available in the literature ,the use of Cross ambiguity Function (CAF) technique is considered to identify the presence or absence of targets in various scenarios are discussed. CAF is computed using binary coded transmitted signal and the received echo signal to demonstrate the detection of targets in different scenarios.

## II. BINARY CODED SEQUENCES

The binary sequence containing N bits represented by a complex signal, can be expressed as

$$S(n) = e^{j\varphi(n)} \qquad n = 1,2,3,\ldots,N \tag{1}$$

where $\varphi(n)$ is the phase of the n[th] bit of a signal. For a binary sequence the number of phases, M = 2 and the phase values are $\varphi(n) \in \{0, \pi\}$ Binary coded signal [1] of length 32,100,200 and 500 are considered to study the detection of targets in various scenarios.

## III. CROSS-AMBIGUITY FUNCTION

The cross-ambiguity function (CAF) describes the response of a radar system to an impulse-like (point) target located at an arbitrary range and Doppler shift. In this sense, the cross –ambiguity function can be thought of as the impulse response of the radar. The ambiguity function is also referred to as the matched-filter response, and the uncertainty function [9]. The cross-ambiguity function is also related to the cyclic cross-correlation function as discussed in [10].

The cross-ambiguity function of radar is a rigorous mathematical description of radar's response to an ideal point target moving at a constant range rate. The cross-ambiguity function is therefore a two dimensional function of range delay and Doppler shift . The cross-ambiguity function $\chi_{xy}(\tau,\nu)$ of the signal $x(t)$ with the signal $y(t)$ is defined as

$$\chi_{xy}(\tau,\nu) = \frac{1}{T_d}\int_{-\infty}^{\infty} x(t)\, y(t-\tau)\, e^{j2\pi\nu t}\, dt \tag{2}$$

where $T_d$ is the duration of the signal $x(t)$, $\tau$ is the time delay between waveforms, and $\nu$ is the Doppler shift introduced by the moving target and $\chi_{xy}(\tau,\nu)$ describe the output of the radar receiver for various values of $\tau$ and $\nu$.

## IV. TARGET DETECTION SCENARIOS

Ambiguity function is in general used for analysis of radar wave forms. However in this work CAF is used for extracting the range and Doppler information of target. The binary sequences of length 100, 200 and 500 are examined for target detection by using cross ambiguity function. Details of the simulation study are presented and various target detection scenarios are tested. All simulations are performed by using MATLAB Programming Language. At these scenarios, following parameters are considered. $f_c$ =Carrier frequency (Giga Hz), $V_{max}$ =Maximum target velocity (m/s), $R_{max}$ =Maximum Range (m), $t_b$ = Sub code Period ( μ s), $f\Delta$=Doppler frequency Resolution (m/s), $R\Delta$= Range Resolution (m), $V\Delta$=Velocity Resolution (m/s).All the simulations are performed taking pulse width133 μ s and the velocity resolution = 37.5m/s. The resolution values are calculated using the following formulae and listed in table 1.

$$\text{Range Resolution } \Delta R = \frac{c}{2B} \tag{3}$$

where B is equal to $\frac{1}{t_b}$ in phase coding and $\frac{N^2}{T}$ for frequency coding.

$$\text{Velocity resolution } \Delta v = \frac{c}{2f_o T} \tag{4}$$

where $f_0$ is the carrier frequency of the waveform.

**Table.1. Parameters for various target scenarios.**

| Length of Binary Code | $f_c$ (Giga Hz) | $V_{max}$ (m/s) | $R_{max}$ (m) | $t_b$ ( μ sec) | $f\Delta$ (Hz) | $R\Delta$ (m) | $V\Delta$ (m/s) |
|---|---|---|---|---|---|---|---|
| 500 | 30 | 3750 | 20000 | 0.2667 | 7500 | 40 | 37.5 |
| 200 | 30 | 3750 | 20000 | 0.6667 | 7500 | 100 | 37.5 |
| 100 | 30 | 3750 | 20000 | 1.3333 | 7500 | 200 | 37.5 |
| 32 | 30 | 3750 | 20000 | 4.1167 | 7500 | 625 | 37.5 |

**SINGLE STATIONARY TARGET SCENARIO**

Assuming a stationary target situated at 5000 meter away from the radar. i.e. $R$ =5000 m. and $v$ =0 m/s. The transmitted CW signal is coded by using the Binary sequence of length 500, 200,100 and 32 the resulting cross-ambiguity function contour plot with an enlargement around the peak point is shown in Figure 1.a, 1.b, 1c and 1.d respectively. It is measured from the figs.1 that that, the range resolution for sequence length of 500,200,100 and 32 is 40m, 100m 200m and 625m respectively and target is detected at 5000m far from the radar. The resolution values listed in the table 1are verified from fig.1 (a-d). From fig.1 it is observed that, as the sequence length is decreased more sidelobe levels are appeared. In multi target environment high sidelobe levels may lead to ambiguity in detection.

**SINGLE MOVING TARGET SCENARIO**

In this scenario simulation is carried assuming a target at 5000 meter away from the radar moving with a velocity 75m/s. i.e. $R$ =5000 m and $v$=75m/s. The transmitted CW signal is coded by using the Binary sequence of length 500,200, 100, and 32. The resulting cross-ambiguity function contour plots with magnification near the peak is shown in Figure 2a, 2b,2c and 2d respectively .The target situated at 5000m far from the radar moving with a velocity $v$=75m/s. is detected.

**MULTI STATIONARY TARGET SCENARIO**

In this scenario, for the sequence length 500, 200, 100 and 32 the five stationary targets considered for simulation at different locations is as follows.

Sequence Length 500: ($R_1$=5000 m $R_2$ = 5080m $R_3$=5160m $R_4$=5240 m $R_5$=5320 with $v_1 = v_2 = v_3 = v_4 = v_5$=0m/s)

Sequence Length 200 :( $R_1$=5000 m $R_2$ = 5200m $R_3$=5400m $R_4$=5600 m $R_5$=5800 with $v_1 = v_2 = v_3 = v_4 = v_5$=0m/s).

Sequence length 100 :( $R_1$=5000 m $R_2$ = 5400m $R_3$=5800m $R_4$=6200 m $R_5$=6400 with $v_1 = v_2 = v_3 = v_4 = v_5$=0m/s).

Sequence length 32 :( $R_1$=5000 m $R_2$ = 6250m $R_3$=7500m $R_4$=8750m $R_5$=10000m with $v_1 = v_2 = v_3 = v_4 = v_5$=0m/s).

The transmitting signal is coded with binary sequence of length 500,200,100and 32 and the resulting cross-contour plots for the ambiguity function of the transmitted and received radar signal with enlargement around the peak points for the sequence length of 500,200 100 and 32 are shown in figure 3a, 3b, 3c and 3d respectively. It is evident from fig.3a, 3b and 3.6c the targets are detected at chosen locations without any ambiguity. However from fig.3d it is observed that several targets are appeared instead of five targets. When three targets are considered, targets are detected without any ambiguity (not shown in figure). Since the discrimination (D) of 32 bit binary sequence is low the sidelobes near the mainlobe are added up and appeared as several targets instead of five. It is evident from figures 3a to 3d as the sequence length is reduces the sidelobe levels are increased.

**MULTI MOVING TARGET SCENARIO**

In this scenario e five moving targets at a range of 5000m/s moving with different velocities are considered for simulation.($R_1$= $R_2$ =$R_3$= $R_4$= $R_5$=5000 m with $v_1$= 0m/s, $v_2$=75m/s, $v_3$= 150m/s, $v_4$ =225m/s $v_5$=300 m/s) .The transmitting signal is coded with binary sequence of length 500,200,100 and 32. The resulting cross-contour plots for the ambiguity function of the transmitted and received radar signal with enlargement around the peak points for the sequence length of 500,200 100 and 32 are shown in figure 4a, 4b, 4c and 4d respectively. It is obvious from fig.4a-c that all the targets are detected at chosen locations without any ambiguity. However from fig.4d it is observed that several targets are appeared instead of five targets. When three targets are considered, targets are detected without any ambiguity (not shown in figure). Since the discrimination (D) of 32 bit binary sequence is low the sidelobes near the mainlobe are added up and appeared as several targets instead of five. It is clear from figures 4 (a-c) that as the sequence length is reduces the sidelobe levels are increased.

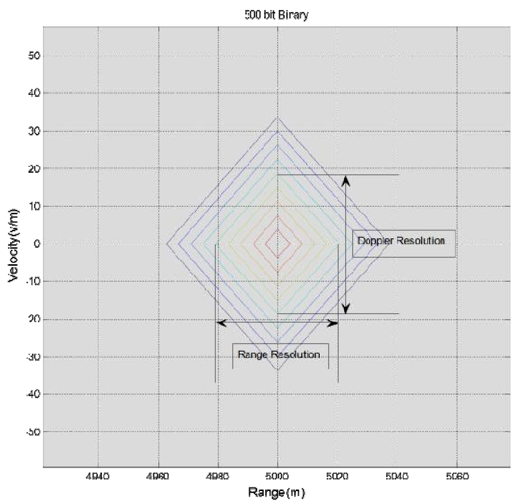


**Fig.1a**

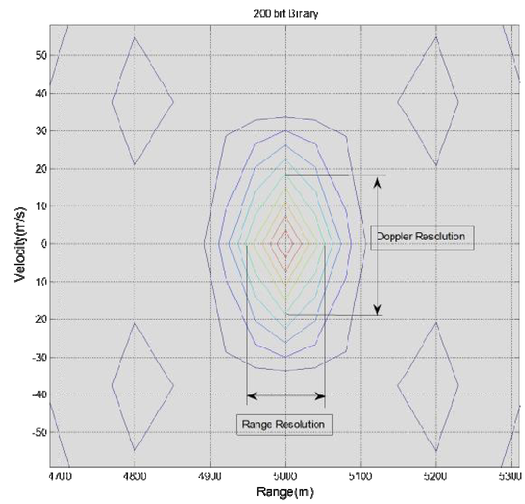


**Fig.1b**

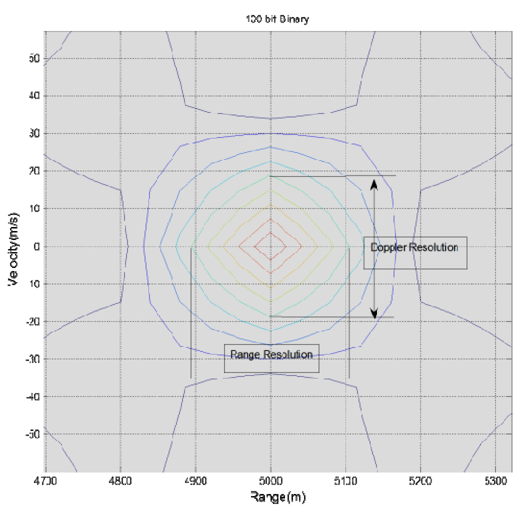


**Fig.1c**

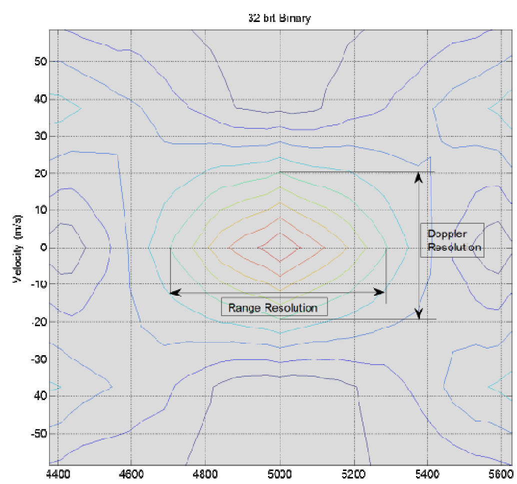


**Fig.1d**

**Fig.1 Single Stationary target scenario.**

**Contour plots of Cross - Ambiguity Function of the transmitted and received signal for Binary sequence.** (R=5000m, $v$=0 $m/$ sec)

**a) Binary sequence of Length 500** **b) Binary sequence of Length 200**
**c) Binary sequence of Length 100** **d) Binary sequence of Length 32**

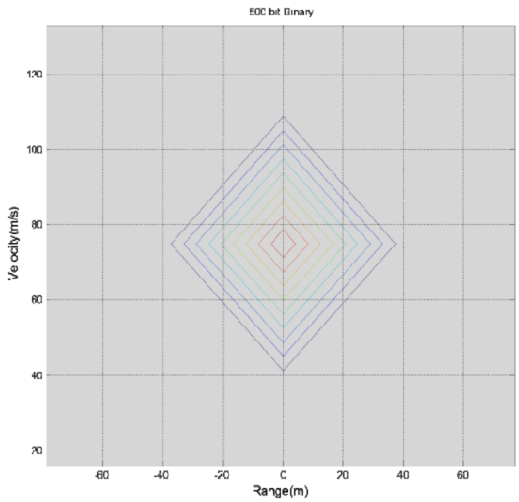


**Fig.2a**

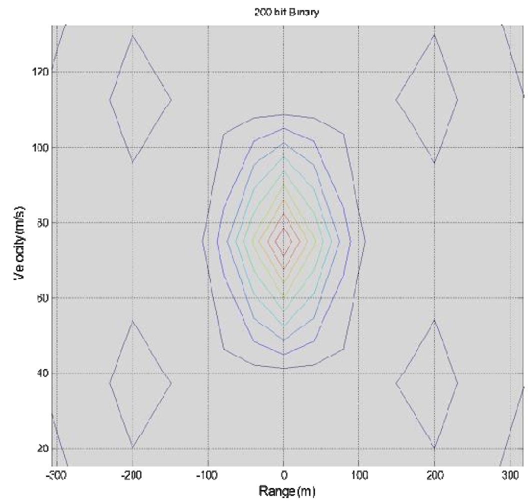


**Fig.2b**

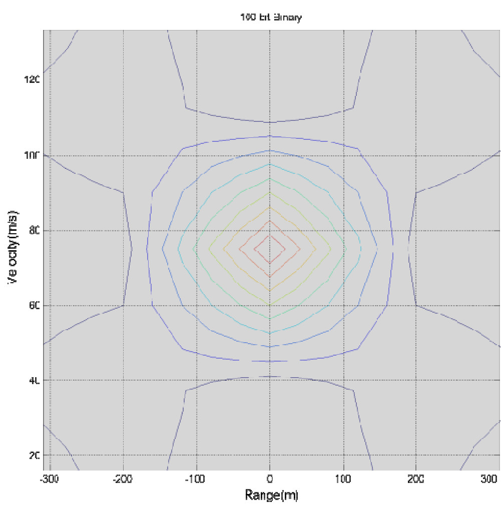


**Fig.2c**

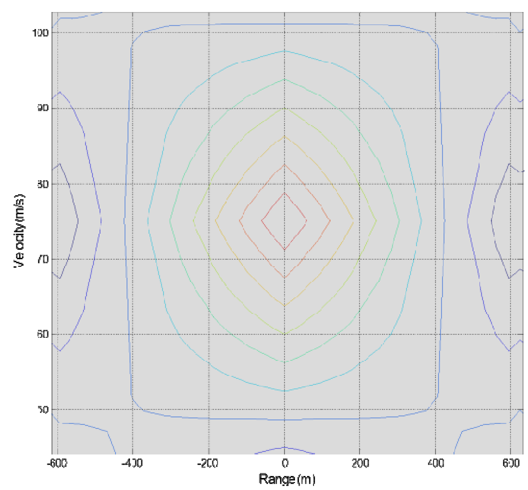


**Fig.2d**

**Fig.3 Single moving target scenario**

**Contour plots of Cross - Ambiguity Function of the transmitted and received signal for Binary sequence.**
(R=5000m, $v$ =75 $m$/ sec)

**a) Binary sequence of Length 500** **b) Binary sequence of Length 200**
**c) Binary sequence of Length 100** **d) Binary sequence of Length 32**

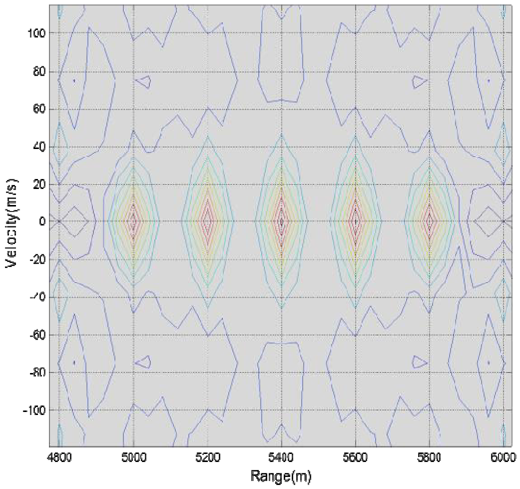


**Fig.3a**

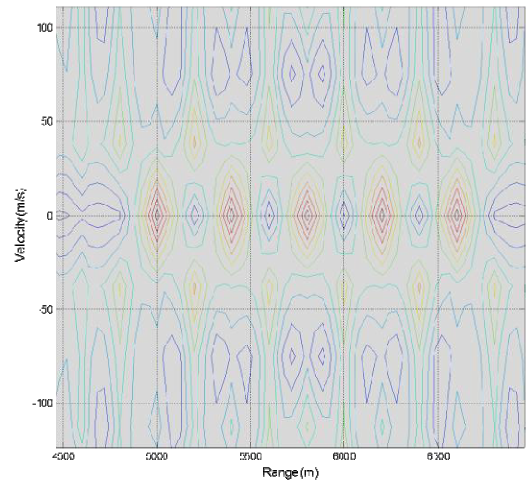


**Fig.3b**

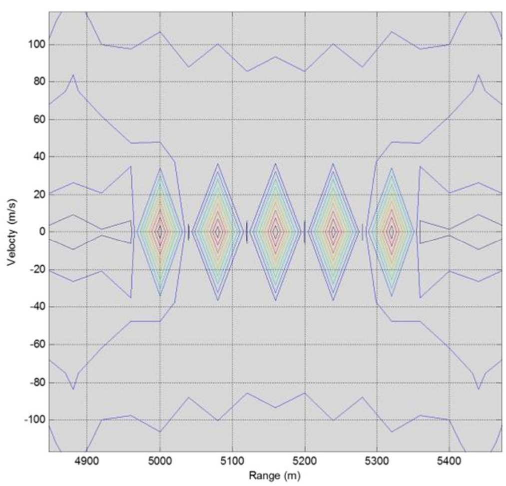


**Fig.3c**

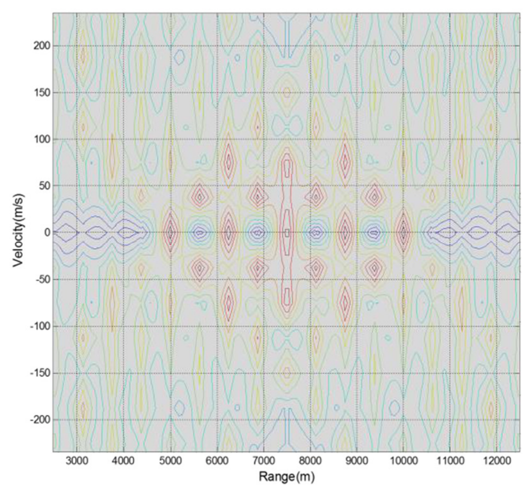


**Fig.3d**

**Fig.3Multi Stationary Target Scenario**
**Contour plots of Cross - Ambiguity Function of the transmitted and received signal for Binary sequence.**

**a) Binary sequence of length 500:**
($R_1$=5000 m $R_2$ = 5080m $R_3$=5160m $R_4$=5240 m $R_5$=5320 with $v_1= v_2= v_3= v_4 = v_5=$0m/s)

**b) Binary sequence of length 200:**
(R1=5000 m $R_2$ = 5200m $R_3$=5400m $R_4$=5600 m $R_5$=5800 with $v_1= v_2= v_3= v_4 = v_5=$0m/s).

**c) Binary sequence of Length 100:**
(R1=5000 m $R_2$ = 5400m $R_3$=5800m $R_4$=6200 m $R_5$=6400 with $v_1= v_2= v_3= v_4 = v_5=$0m/s).

**d) Binary sequence of Length 32:**
(R1=5000 m $R_2$ = 6250m $R_3$=7500m $R_4$=8750m $R_5$=10000m with v1 = v2 = v3 = v4 = v5= 0m/s).