# Target Detection Using LFM and Costas Sequences

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***Abstract*—This paper presents the target detection in frequency modulated continues wave radars using linear frequency modulated (LFM) and Costas sequences. The magnitude of the cross ambiguity function and its contours for LFM and Costas sequences are computed and plotted as a function of time delay and Doppler frequency shift for various target scenarios and the results are compared.**

***IndexTerms*—COSTAS Sequences, LFM Sequences, Cross Ambiguity Function.**

## I. INTRODUCTION

RADAR (RAdio Detection And Ranging) is an electromagnetic system used for the detection of the targets. It operates by transmitting a particular type of waveform and detects the existence, location and radial velocity of the target from the nature of the echo signal. Radars can be considered in two main categories depending on the type of waveform used in the radar. These are pulsed radar and CW (Continuous Wave) radar. Pulsed radar transmits a relatively short burst of electromagnetic energy whereas CW radar transmits continuously. To extract the target's range and velocity, the transmitted wave is modulated in frequency and the frequency of the return signal from the target is measured. Comparison of the return signal with the transmitted signal can help in the extraction of both the range and the velocity information of the target [1]. There are several techniques to modulate the frequency of a transmitted signal in CW radar. In this paper, LFM and Costas coding sequences are chosen. The competences of linear FM and Costas sequences in frequency modulated CW radars to detect the various target scenarios are compared. In Section 2, the basic concepts of linear FM and Costas sequences are described. Section 3 describes the cross ambiguity function. Section 4 presents the various target detection scenarios.

## II. CW CODING SEQUENCES

The continuous wave coding sequences used in this paper are LFM Sequences and Costas sequences. A LFM signal is one that sweeps linearly from a low to a high frequency. It is designed by concatenating small sequences, each with a frequency that is higher than the last. In general, the Costas sequence of frequencies provides an frequency hopping code that produces peak side lobes in the Ambiguity function, that are down from the main lobe response by a factor of 1/ $N$, where $N$ is the number of frequencies used in the code.That is, the order of frequencies in a Costas sequence or array is chosen in a manner to preserve an ambiguity response with a thumbtack nature (the narrow main lobe and side lobes are as low as possible). The firing order of these frequencies based on primitive roots (elements) of finite fields [2].

## III. CROSS AMBIGUITY FUNCTION

Ambiguity Function (AF), which is a quadratic Time-frequency signal representation (TFR), has been used extensively for investigating the ambiguity properties of the waveform modulation used in various fields such as radar, sonar, radio astronomy, communications and optics. The ambiguity function represents the response of a filter matched to a given finite energy signal when the signal is received with a delay $\tau$ and a Doppler shift $\nu$ relative to the nominal values (zeros) expected by the filter. The Ambiguity Function is defined as

$$|\chi(\tau,\nu)| = \left| \int_{-\infty}^{\infty} s(t)s^{*}(t+\tau)e^{j2\pi\nu t}dt \right| \tag{1}$$

where's' is the complex envelope of the signal. A non zero $\nu$ implies a target moving at a certain radial velocity with respect to radar. Positive $\tau$ refers to round trip delay time when the target is away from the radar by a certain distance [3].

In equation (1), if $s(t)$ and $s(t+\tau)$ are the complex envelopes of the transmitted signal then the resulting equation is the Auto-Ambiguity Function. Auto-Ambiguity Function is used for determining the waveform effects on measurement accuracy, ambiguities in range and velocity, and target resolution. [4].

In (1)if $s(t)$ is the complex envelope of transmitted signal and $s(t+\tau)$ is the complex envelope of the received signal then $\chi(\tau,\nu)$ is called Cross- Ambiguity Function (CAF). Cross-Ambiguity Function may be used for determining the waveform effects in response to the clutter [5]. In this paper, the Cross-Ambiguity Function is mainly used for target detection.

## IV. TARGET DETECTION SCENARIOS

Figs.1-4, (a & b) show the magnitude of cross ambiguity function and (c & d) show contour plots of various target scenarios. In each figure, the delay (proportional to range) and doppler (proportional to radial velocity) are plotted on x-axis and y-axis respectively. In Figs 1-2, (c & d) show the contour plots are showing single stationary and moving target scenarios respectively. In each plot because of the symmetry, the target appears in two quadrants. For convenience, here we consider only left quadrant. In Fig. 1 the target is stationary (zero Doppler shift) whereas range is corresponding to $\tau = 0.00006$ sec. However, in moving target scenario, the target Doppler shift is taken as $v = 1000$m/sec and $\tau = 0.00006$sec, which is evident in Fig. 2.

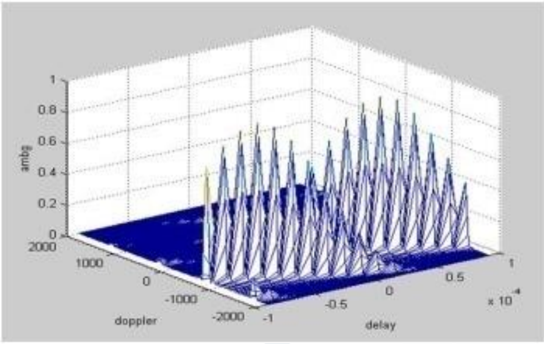



Fig.1a CAF of LFM

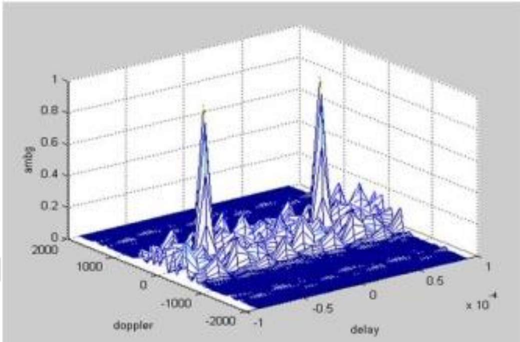



Fig.1b CAF OF COSTAS

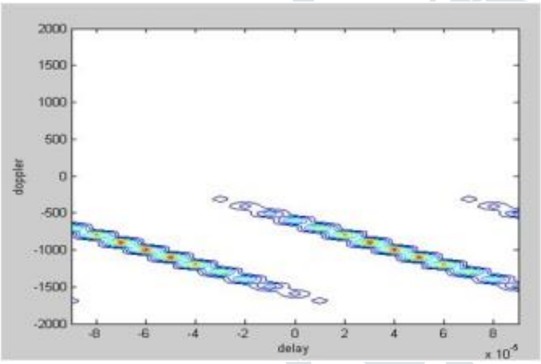



Fig.1c Contour plot of LFM

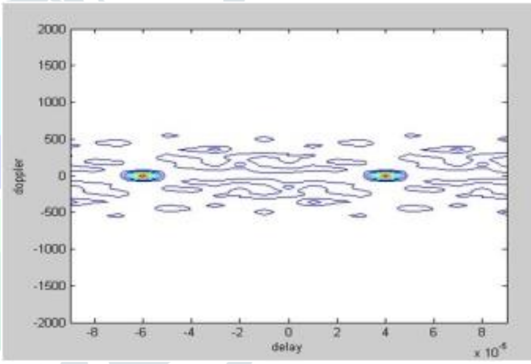



Fig.1d Contour plot of COSTAS

**Fig. 1 Stationary single target scenario with τ=0.00006sec.**

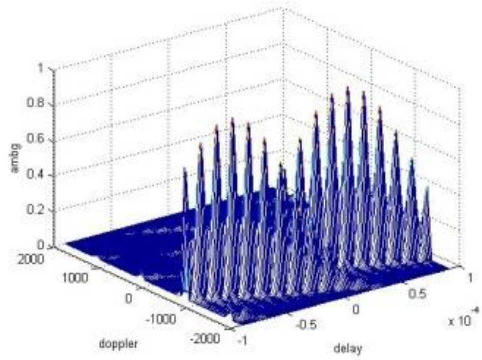



Fig.2a CAF of LFM

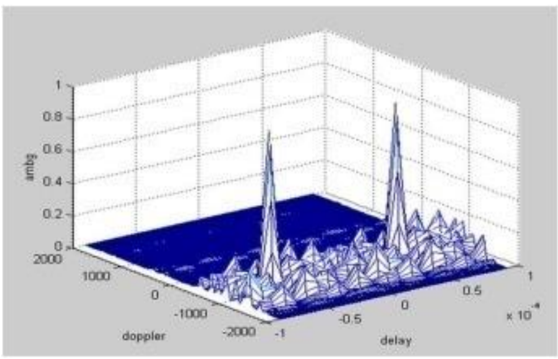
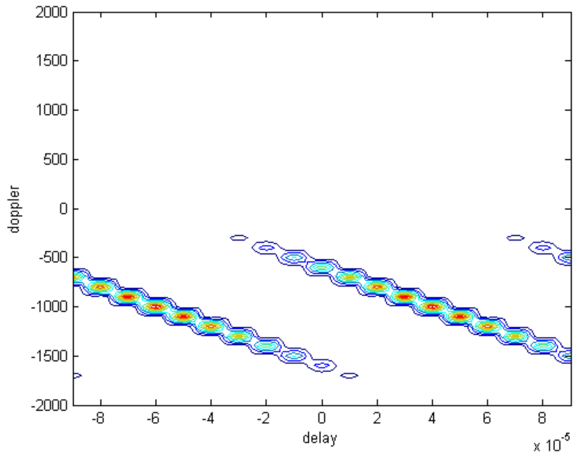



Fig.2b CAF OF COSTAS



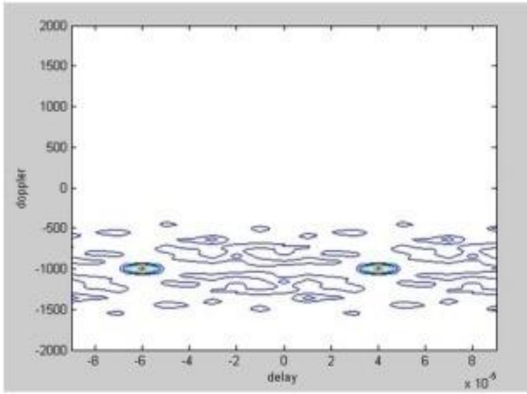
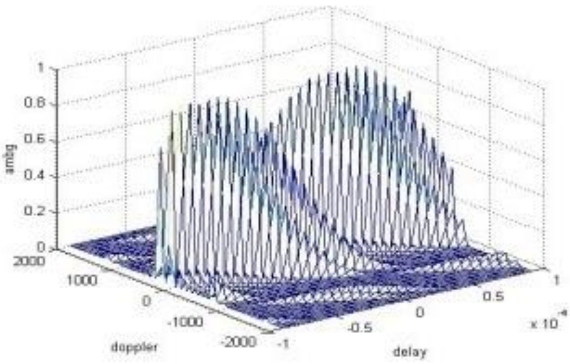




**Fig.2c Contour plot of LFM** **Fig.2d Contour plot of COSTAS**

**Fig. 2 Moving single target scenario with $v$=1000 m/sec $\tau$=0.00006sec.**

Similarly, in multi-target scenarios, both stationary as well as moving targets are considered in Figs. 3-4. Fig. 3 shows the multi stationary targets, Target 1 is taken with $\tau$ =0.00008sec and target 2 with $\tau$ =0.00006sec., and Fig 4 shows the multi moving targets with Target: 1( $\tau$ =0.00008sec, $v$=1500 m/sec), and Target: 2 ( $\tau$ =0.00006sec, $v$=1000 m/sec). The positions of each targets corresponding to their values can be clearly seen in the case of Costas contour plots but not in LFM contour plots. It can also be observed that the sidelobe levels are larger in the case of LFM .This clearly shows that the detection capabilities of Costas sequences are better than LFM sequences.



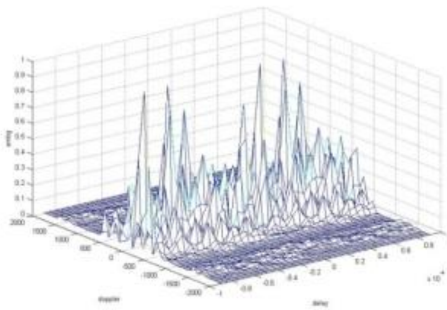
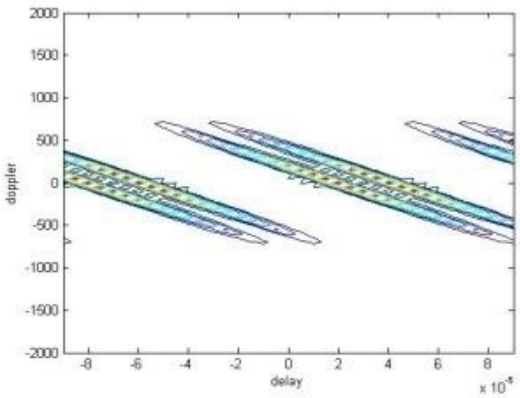



**Fig.3a CAF of LFM** **Fig.3b CAF OF COSTAS**



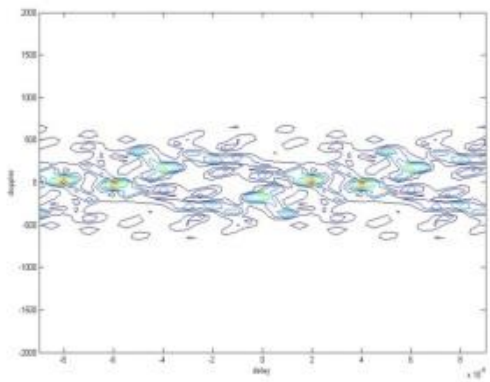



**Fig.3c Contour plot of LFM** **Fig.3d Contour plot of COSTAS**

**Fig. 3 Stationary multi target scenario with Target.1 $\tau$ =0.00008sec, Target: 2 $\tau$ =0.00006sec**

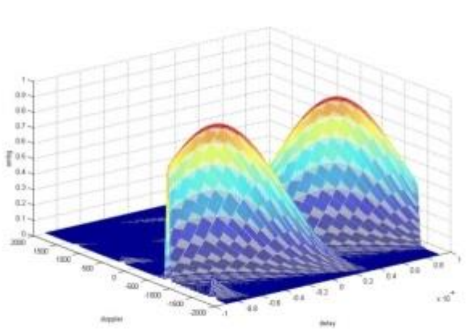


**Fig.4a CAF of LFM**

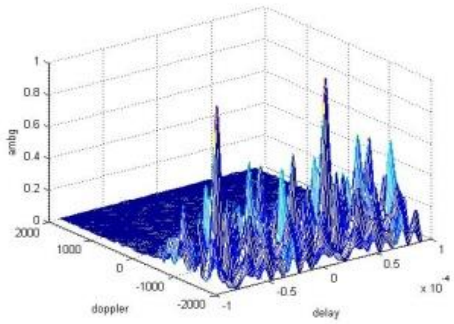



**Fig.4b CAF OF COSTAS**

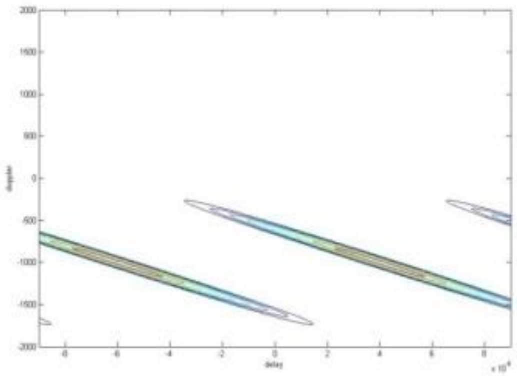


**Fig.4c Contour plot of LFM**

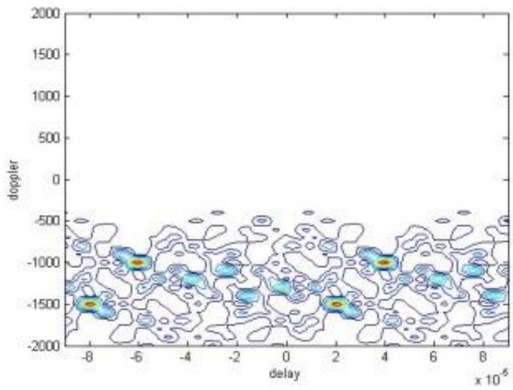



**Fig.4d Contour plot of COSTAS**

**Fig. 4 Moving multi target scenario with Target: 1( $\tau$ =0.00008sec, $v$=1500 m/sec)**
**Target: 2 ( $\tau$ =0.00006sec, $v$=1000 m/sec)**

## V. CONCLUSIONS

This paper mainly focuses on the use of CAF technique for the target detection capabilities of LFM and Costas coding sequences. From the simulation results it is observed the LFM code is much simpler to implement when compared to the Costas code. It is also noted that for the same design parameters, the linear FM coding provide higher side lobe levels than COSTAS , which are all very important factors in multi-target detection especially when the targets are very close either in range or velocity. High side lobes obviously increase the false alarm rate in the radar applications. Therefore the better detection capabilities of Costas sequences when compared with LFM sequences are reinforced through the CAF technique

## REFERENCES

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