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TARGET DETECTION USING CROSS AMBIGUITY FUNCTION

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Abstract ***Detection of multiple radar targets with high probability of detection or low false alarm rate is a challenging task. In this paper an efficient cross ambiguity function technique for Polyphase and Discrete frequency coded Radar signal is used to detect the multiple targets with high probability of detection in different scenarios like i) targets have same speed but at different ranges ii) targets have different speeds but at same range iii) targets have different speeds and different ranges.***

Key Words: *Cross Ambiguity function, Pulse compression, Target detection.*

1 INTRODUCTION

Pulse compression technique is used to detect the target with high range resolution. Pulse compression technique allows the radar to utilize a long pulse to achieve large radiated energy and simultaneously obtaining the range- resolution of a short pulse. Theoretically, in pulse compression, the code is modulated onto the pulsed waveform during transmission. At the receiver, cross ambiguity function is used to achieve a high range and Doppler resolution. Range-resolution is the ability of the radar receiver to identify nearby targets. The good pulse compression code have low autocorrelation sidelobes. Pulse compression codes like: Binary, Polyphase and Discrete Frequency Codes(DFC) are widely used in radar[1-7].

2. Polyphase coded Radar signal is used to detect the multiple targets. Polyphase signal have larger main lobe-to-peak sidelobe ratio. The aperiodic autocorrelation function (ACF) of sequence S of length N is given by

$$|A(K)| \le 1, \qquad 1 \le |K| \le N-1 \quad \ldots\ldots(1)$$

If all the sidelobes of the ACF of any polyphase sequence are bounded by

$$S_m = \exp\left\{2\pi i.\frac{m}{M}\right\} =: \exp(i\phi_m) \qquad 0 \le m \le M-1 \quad \ldots(2)$$

then the sequence is called a generalized Barker sequence or a polyphase Barker sequence. The binary Barker can be regarded as a special case of polyphase Barker sequences, if the sequence elements are taken from an alphabet of size M, consisting of the M^{th} roots of unity. In this paper Six and Eight phase and DFC sequences are synthesized and demonstrated[3,4,6].

3. DFC SEQUENCE SETS FOR RADAR SYSTEMS

The DFC sequence with good autocorrelation properties is used to detect the multiple targets. Consider a DFC sequence set consisting of N frequency-hopping sub-pulses, each of sub-pulses has time duration t_b and modulated with a distinct frequency. The complex envelope of DFC waveform can be represented as[7-9]

$$S(t) = \sum_{n=1}^{N} P_n(t) e^{j2\pi fnt} \quad \ldots(3)$$

Where

$$P_n(t) = \begin{cases} \frac{1}{t_b}, & (n-1)t_b \le t_b \le nt_b \\ 0, & \text{otherwise} \end{cases} \quad \ldots(4)$$

and fn is the coding frequency of sub-pulse n of the waveform. The coding frequency sequence $\{f_1, f_2, f_3, \ldots, f_N\}$ is restricted to be a permutation of $\{0, \Delta f, 2\Delta f, \ldots (N-1)\Delta f\}$, and Δf is normally chosen to satisfy $\Delta f = 1/t_b$. The coding frequency sequence $\{n_1\Delta f, n_2\Delta f, n_3\Delta f, \ldots n_N\Delta f\}$.

The periodic Auto-Correlation Function (ACF) of sequence s(t) should have the good autocorrelation property, and mathematically defined as,

$$A(s,\tau) = \frac{1}{N_t}\int_t^{s} S(t)S^*(t-\tau)dt \begin{cases} = 1, & \tau = 0 \\ = 0, & |\tau| > t_b \end{cases} \quad ..(5)$$

Where, $A(s,\tau)$ is the aperiodic autocorrelation function of the coding sequence s(t). Therefore, to design a DFC sequence used in radar communication system, we needs to construct a sequence satisfying the requirements in above equation.

4. CROSS AMBIGUITY FUNCTION

The radar signal detection actually based on the ambiguity function and cross ambiguity function rather than autocorrelation and cross correlation functions. The ambiguity function of transmit waveform specifies the ability of the sensor to resolve targets as a function of delay (τ) and Doppler (ν). The ideal transmit signal would produce an ambiguity function with zero value for all non-zero delay and Doppler (i.e., a "thumbtack"), indicating that the responses from dissimilar targets are perfectly uncorrelated. It is well known that if the ambiguity function is sharply peaked about the origin, then simultaneous range and velocity resolution capability is good. Ambiguity Function has been used to assess the properties of the transmitted waveform as regards to its target resolution, measurement accuracy, ambiguity, and response to clutter and effect of Doppler[2,5].

Ambiguity function $|\chi(\tau,\nu)|$ represents the time response of a filter matched to a given finite energy signal when the signal is received with delay τ and a Doppler shift ν relative to the nominal values (zeros) expected by filter. It can be defined as

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

5. RESULT ANALYSIS

In this paper six phase, eight phase and DFC codes are used to detect the target in different scenario using ambiguity function. The matched filter results are very sensitive to the Doppler frequency (ν) in the radar echoes due to target movement. It can be seen that the output signal amplitude is not significantly reduced (signal loss < 3 dB) if the Doppler frequency is less than 0.5/T, i.e.

$$|\nu| T < 0.5$$

where T is the signal time duration equal to Nt_b, where t_b is the duration of sub pulse. Therefore, if above condition is satisfied, the Doppler effect on the processing result is negligible; otherwise, the correction processing must be conducted. A simple way to minimize the Doppler effect is to select the signal time duration such that the above condition is satisfied for all expected target speeds.

5.1 Target detection using polyphase sequence

In this paper target detection for six phase sequence of length of 36 is shown through contour and ambiguity function plots in fig(1-3). The range of the target is calculated using formula, Range =velocity of light x delay/2

5.2 Targets moving with different speed but at same range

In this scenario the two targets moving with different speed of V= 400km/h and 1800 km/h but at the same range of 9 Km are detected using cross ambiguity function, simulated results are presented through Contour and ambiguity function plots in fig(4,5).

5.3 Targets moving with same speed but at different range

In this scenario the two targets moving with same speed of V= 600km/h but at different range of 9 Km and 11 Km respectively are detected using cross ambiguity function, Simulated results are presented through Contour and ambiguity function plots in fig(6,7).

5.4 Targets moving with different speed with different range

In this scenario the five targets moving with different speed of V= 100Km/h, 500Km/h, 1000Km/h, 1600Km/h, 3000Km/h respectively but at different ranges of 7 Km, 3 Km, 12 Km, 9 Km, 0 Km respectively, simulated results are presented through Contour and ambiguity function plots in fig(8,9).

In result analysis the plots which are generated with different conditions has very low probability of error in detection.

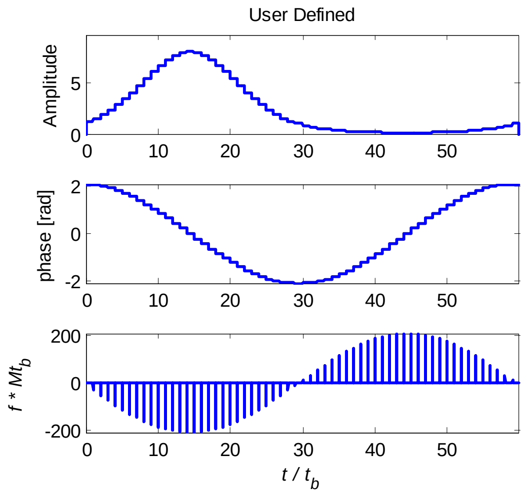

Fig: 1 Signal structure of 6-phase of length 37

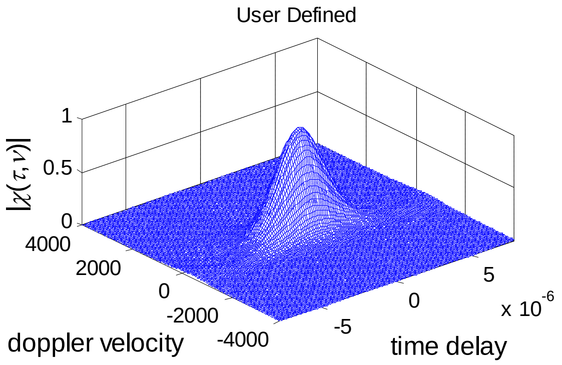

Fig: 2 Ambiguity diagram of 6-phase sequence of length 37

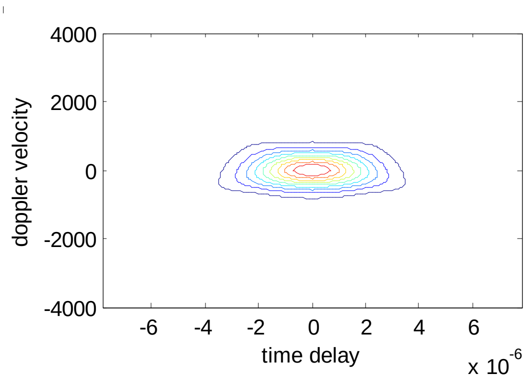

Fig: 3 Contour diagram of 6-phase sequence of length 37

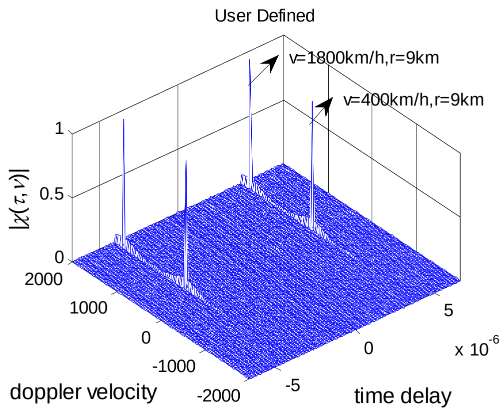

Fig: 4 Ambiguity diagram of detection of targets at same range with different velocity

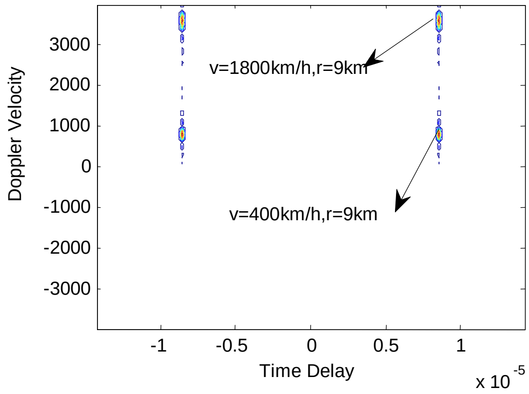

Fig: 5 Contour diagram of detection of targets at same range with different velocity

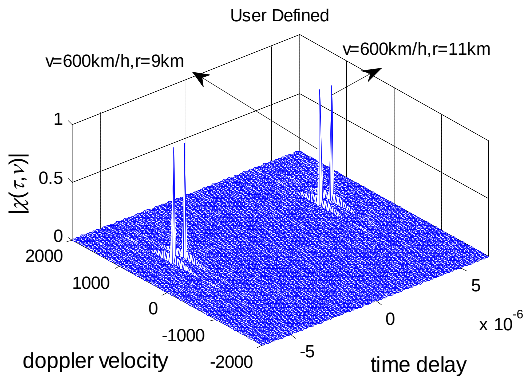

Fig: 6 Ambiguity Diagram of detection of targets at different range with same speed

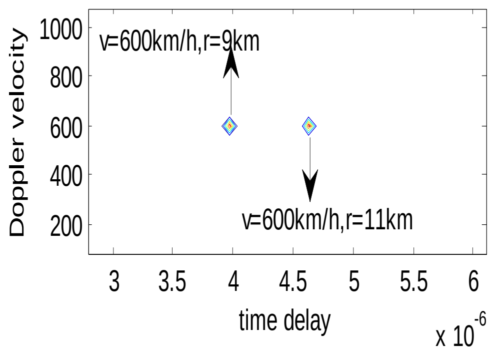

Fig: 7 Contour plot of detection of targets at different range with same speed

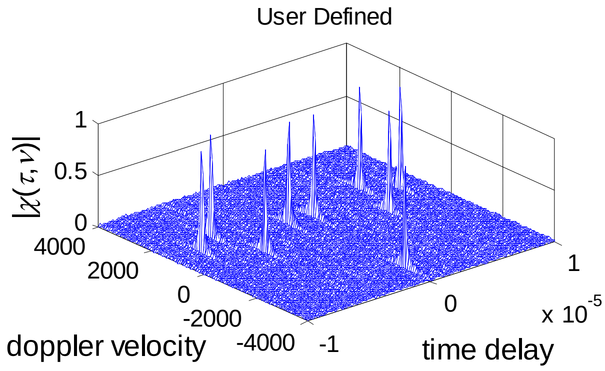

Fig: 8 Ambiguity diagram of detection of targets at different range and speed

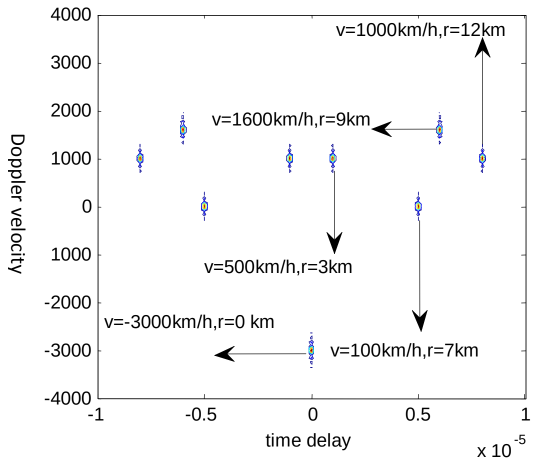

Fig: 9 Contour plot of detection of targets at different range and speed

6 CONCLUSION

In this paper we have synthesized sequences using Modified Genetic Algorithm and these sequences are used for detection of multiple targets in different scenarios with very low probability of errors.

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BIOGRAPHY

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