Improved Target Detection in Doppler Tolerant Radar Using a Modified Hex Coding Technique

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Abstract In every corner of the globe, nations want to improve the monitoring mechanism of the country, so that no one can enter their territory in an unwanted manner easily. Well-known equipment, called Radar, is commonly used for monitoring. However, only a small amount of work is done to monitor multiple moving targets in the presence of Doppler. This important issue diverts the attention of the research community away from working on this platform. In the present literature, the merit factor (MF) is improved by increasing the amplitude of the main lobe. However, these particular approaches did not attach more importance to the effects of noise side peaks of fast moving targets. The drawback of noise peaks masks slow-moving targets and cannot be clearly seen by the radar receiver. As a result it reduces the performance of the Doppler radar system. In this paper, an approach is presented which not only improves multiple moving target detection, but also reduces the energy of code generation. This approach is simple and effective in detecting multiple moving targets at the desired Doppler. The presented technique is called Improved Target Detection in Doppler Tolerant Radar Using a Modified Hex Coding Technique. MATLAB is used to formalize the results by simulation.

Keywords Doppler tolerant radar code · Hex code · Multiple moving targets Matlab

1 Introduction

The monitoring of day-to-day activity by a country's surveillance system is an important factor in observing various activities. Radar is the only equipment to monitor such activities in the country. However, the state of art of the work mainly focuses towards the development of immobile object recognition. To achieve the

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goal of target detection probability, several approaches have been presented to improve the merit factor (MF) of the received echo by means of the auto correlation technique. However, these approaches result in noise side peaks which restrict the technique to use in detecting stationary targets and makes it less useful for finding multiple small moving objects as the noise side peaks of the auto-correlated signal as the side peaks of noise in the auto-correlated signal acquire the echoes or noise from many small moving targets. To enhance the current approaches, a variety of constraints such as attitude, altitude, and Range discovery were analyzed. Also for multiple moving target discovery processes, several approaches are being proposed to augment the discovery probability of multiple and moving targets, which requires an array of Doppler filter bank. Current radar for moving and multiple target recognition employs the numerous matchless radiating (k) aerial arrays to acquire an intelligent and sharp autocorrelation reply, and thus the object finding probability is improved. Deviation of the acknowledged constraints is similar to the phase and processing of the acknowledged signal that can execute different operations such as tracking and finding. This result of tracking and finding targets shows the level of autonomy of the transmitted signal, therefore the transmitted signal cannot shift while the acknowledged signal could be shifted more than once, and can be represented by ‘p’ for simplicity. This scheme is able to broadcast unreliable signals from ‘k’ matchless aerials and the received signals are jointly processed subsequent to the acknowledged signal by ‘p’ matchless receiving aerials which results in the enhancement of the accuracy of detection of moving and multiple targets. However, emission by multiple moving aerials results in the need for enormous power, moreover the side noise peaks are more because of acknowledged echoes from the moving and multiple targets. Thus slow affecting targets are masked by these side noise peaks and also the range of the radar is affected by this method. Consequently, power consumption and range presentation is lost with the enhanced probability, and relatively it is not up to the mark. In this paper, multiple moving target detection is upgraded in terms of range and Doppler by using different windowing techniques. The main objective of this paper is to reduce the amplitude of side noise spikes and to increase the amplitude of the main lobe. To achieve this goal we are using windowing techniques to reduce range noise side spikes and make the detection of moving targets much easier. The identified targets can be shown on a Doppler vs. delay plot which arises from the ambiguity function. The key role of this paper is to present a comprehensive detection of moving targets in the presence of Doppler at different ranges. The presented approach is very simple but very affective for multiple moving target detection and also minimizes the transmission power by sending a simple digital code which discords one major portion of the detection process called the range gates. The rest of the paper is organized as follows. In Sect. 2, a literature survey is presented. The proposed approach is discussed in Sect. 3, and the conclusion is given in Sect. 4.

2 Literature Survey

Rafiuddin and Bhangdia [1] presented an approach in which the authors use p1 and p3 series of poly-phase codes along with hyperbolic frequency modulation (HFM). The presented approach enhanced the merit value of the received echo. However, the presented approach increases the delay therefore it cannot fulfill the purpose of moving and multiple target detection. Lewis and Kretschmer Jr. [2] develop an approach in which they proved that in place of poly-phase codes, bi-phase codes can be used to enhance the synchronization of the primary surveillance radar (PSR) by shrinking the bits of the broadcast signal and in that way security can be improved. Also at the same time, the poly-phase codes (i.e. P1 and P2) can be suitably created using a linear frequency modulated waveform technique (LFMWT) on step evaluation. This approach also improves the transmission capacity of the receiver. Lewis and Kretschmer Jr. [3] presented another method using P3 and P4 codes generated by the use of linear frequency modulation waveform (LFMW) to give improved target detection probability when compared with P1 and P2.

Kretschmer Jr. and Lewis [4] proposed an another approach using a set of codes called P3 and P4 codes to enhance the signal-to-noise ratio and they also demonstrated that such codes are more capable of getting a better response in terms of target detection probability when compared to other codes of the poly-phase family. But in the presence of Doppler these codes showed a very poor response of probability of target detection. Lewis [5] proposed a technique, known as the sliding window technique (SWT), to reduce the noise peaks which are caused due to the range-time noise spikes produced. However the presented approach is inadequate to decrease the noise spikes up to a certain level, and as a consequence has finite appliances in Doppler tolerant radars. Kretschmer Jr. and Welch [6] offered a technique in which they used autocorrelation of poly-phase codes to remove the noise elements that are present with the signal. But the presented approach fails to locate high velocity targets in the occurrence of Doppler, because autocorrelation of poly-phase codes creates noise spikes at close to zero Doppler. As a result, this approach is unsuitable for moving and multiple target discoveries. This particular approach also begins with the use of an amplitude weighting function (AWF) utilizing poly-phase codes to reduce noise spikes on the receiver side. However, there is an extra power loss in the method and merely an inspection on correlating the sending and the receiving power at source and destination respectively is made.

Sahoo and Panda [7] proposed a compaction window approach to decrease the effect of the noise peaks in Doppler tolerant radars. However, the presented approach increases delay and thus fails to create a larger window or enhance the capacity of windows to recognize the moving and multiple targets exactly. Singh et al. [8] proposed coding technique to enhance the size of the window in which they used Hex coding to enhance the probability of moving and multiple target detection. Though due to huge mathematical complexity it devours extra power and boosts delay, therefore it is valid to distinguish slow moving targets only. Singh et al. [9] proposed a method called the matrix coding technique (MCT), where no doubt the number of windows are greater in number in comparison with the existing approaches to obtain an obvious image of the present position of the moving target. But this approach is restricted to find immobile and sluggish targets only, because the duration of the calculated code vector is less and this reduces the merit factor (MF) of the auto-correlated signal and results in side noise peaks approximately around zero Doppler.

In this paper, a technique called Improved Target Detection in Doppler Tolerant Radar Using a Modified Hex Coding Technique is proposed. This technique improves the probability of target detection by creating multiple numbers of windows with respect to the desired Doppler. It also improves the merit factor of the auto-correlated signal and reduces the power consumed by the received echo.

3 Proposed Approach

In the present approach, equal weighted binary hex codes from 0 to 15 are considered, which are divisible by 3 (such as 3, 6, 9 and 12) and can be represented in the binary system as 0011, 0110, 1001 and 1100 given as

$$H_c = \prod_{k=1}^{j} Pk \tag{1}$$

where H_c is an equal weighted hex code, P = 3 and $1 \le j \le 4$.

The concatenation binary series of H_c can be represented as below

0 0 1 1 0 1 1 0 1 0 0 1 1 1 0 0

A matrix N × N can be obtained by taking the above series as the first row and column of the matrix. The other elements of the matrix can be developed by using ex-or operation shown in the equations

$$R_{22} = R_{12} \oplus R_{21} \tag{2}$$

$$R_{23} = R_{21} \oplus R_{13} \tag{3}$$

$$\cdots\cdots$$

$$\cdots\cdots$$

$$R_{2n} = R_{21} \oplus R_{1n} \tag{4}$$

Generalizing the above, we get,

$$R_{n(n-1)} = R_{n1} \oplus R_{1(n-1)} \tag{5}$$

and

$$R_{nn} = R_{n1} \oplus R_{1n} \tag{6}$$

where R is the radar matrix.

Matlab finds its use in image processing as it is feasible and holds good for testing of the algorithm as it is a growing database with in-built libraries. In this approach, matlab is used to simulate the results by transmitting the matrix blocks and detecting the moving targets masked in the noise at the desired Doppler. Figure 1 shows the Doppler frequency v/s normalized amplitude when a binary matrix of equal weighted hex code (see Table 1) is transmitted. From the figure we observe two clear windows from 8 to 12 kHz and from 14 to 40 kHz where we can easily detect the target as the amplitude of the noise peaks is much lower than the threshold limit, i.e. 0.2 (as per the literature).

Quadratic residues are widely used in acoustics, graph theory, cryptography, etc. Quadratic residues are used to get a clear window for detecting the moving targets which are masked in the side lobes. A quadratic residue of 15 is taken as it is close to 16 (the total number of bits in the presented approach) and odd values provide a greater number of changes than even values.

$$Q_r(15) = \{1, 4, 6, 9, 10\}$$

where Q_r is the quadratic residue.

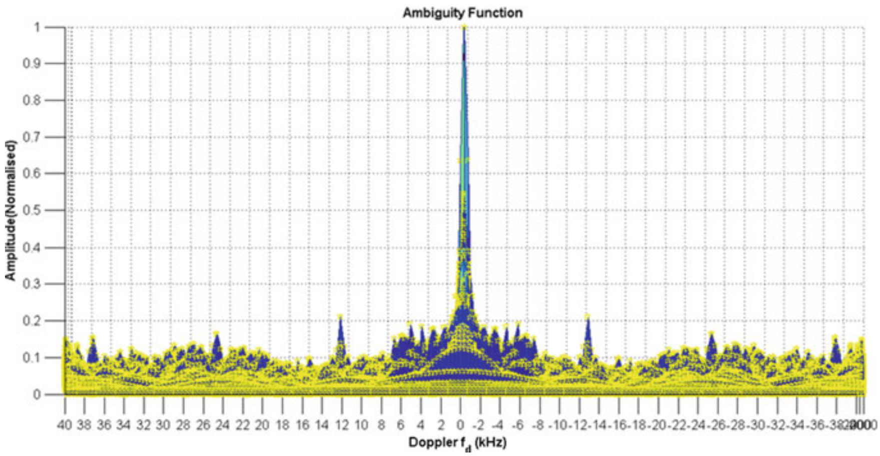

Fig. 1 Ambiguity function of the table

Table 1 Binary matrix of equal weighted hex code

0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0

Table 2 New code with zeros and ones changed

Equal weighted hex code word	0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
Quadratic residue of 15	Q1 ↓			Q2 ↓		Q3 ↓			Q4 ↓	Q5 ↓						
New code with zeros and ones changed (C_{01})	1	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0

Where C_{01} is the code generated after the zeros and ones change

Consider the positions of $Q_r(15)$ in Eq. (1), 16 bits are generated by complementing the binary digits present at positions 1, 4, 6, 9 and 10 as depicted in Table 2.

A matrix of 16 × 16 is obtained (shown in Table 3) by taking C_{01} as first row and column of the matrix and rest of the elements in the matrix are generated in the same manner as Eqs. (2)–(6) and Table 1.

Figure 2 shows the normalized amplitude v/s Doppler frequency graph by transmitting binary matrix of equal weighted hex code with ones and zeros changed (Table 3) which has two clear windows, at 7 kHz to 11 kHz and 14 kHz to 34 kHz, respectively.

Similarly, we can generate C_1 and C_0 codes (shown in Tables 4 and 6) by changing only ones and only zeros in the binary code of Eq. (1) and developing their respective matrix as given in Tables 5 and 7.

Table 3 Binary matrix of equal weighted hex code with ones and zeros changed

1	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
1	1	0	0	0	0	0	1	1	0	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	1
1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	1
1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0

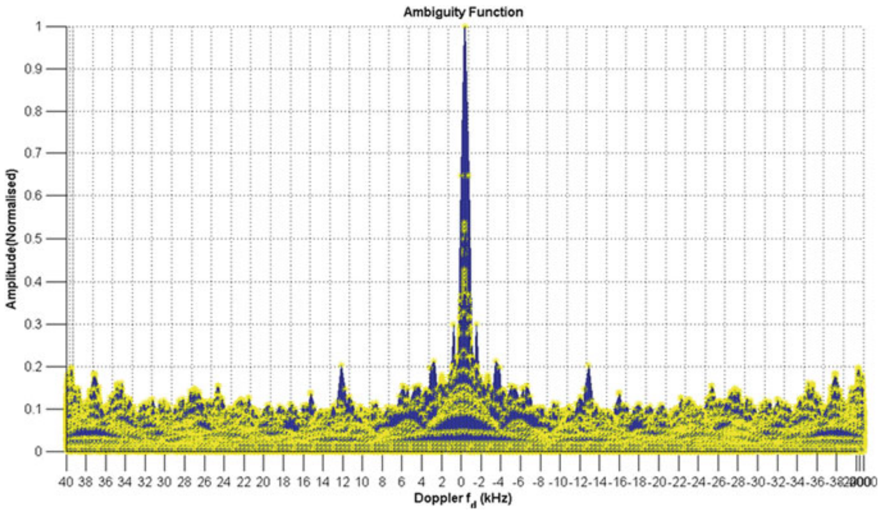

Fig. 2 Ambiguity function of Table 3

Figure 3 shows the ambiguity function received after transmitting a binary matrix of equal weighted hex code with ones changed (Table 5) to detect multiple moving targets. From Fig. 3 we can observe one small window from 7 to 11 kHz and a huge window from 14 to 34 kHz.

Table 4 New code with only ones changed

Equal weighted hex code word	0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
Quadratic residue of 15	Q1 ↓			Q2 ↓		Q3 ↓			Q4 ↓	Q5 ↓						
New code word with only ones changed C_1	0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0

Where C_1 is the code generated after the ones have been changed

Table 5 Binary matrix of equal weighted hex code with ones changed

0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	1	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	1	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
1	1	0	1	1	1	0	1	1	1	1	0	0	0	1	1
1	1	0	1	1	1	0	1	1	1	1	0	0	0	1	1
1	1	0	1	1	1	0	1	1	1	1	0	0	0	1	1
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0
0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0

Table 6 New code with only zeros changed

Equal weighted hex code word	0	0	1	1	0	1	1	0	1	0	0	1	1	1	0	0
Quadratic residue of 15	Q1 ↓			Q2 ↓		Q3 ↓			Q4 ↓	Q5 ↓						
New code word with zeros changed only C_0	1	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0

Where C_0 is the code generated after the zeros have been changed

The ambiguity function simulation result in Fig. 4 gives a clear windows from Doppler frequency 5 to 11 kHz and from 13 to 40 kHz.

Table 7 Binary matrix of equal weighted hex code with zeros changed

1	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
1	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0
0	0	1	1	0	1	1	0	1	1	0	1	1	1	0	0

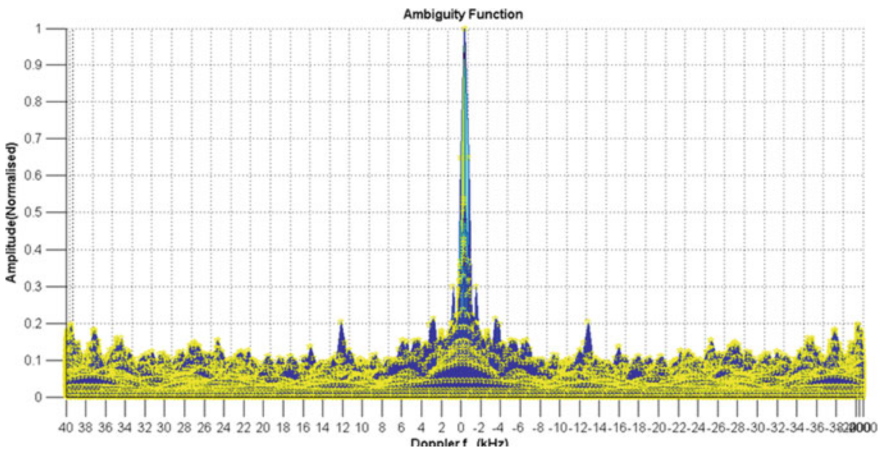

Fig. 3 Ambiguity function of Table 5

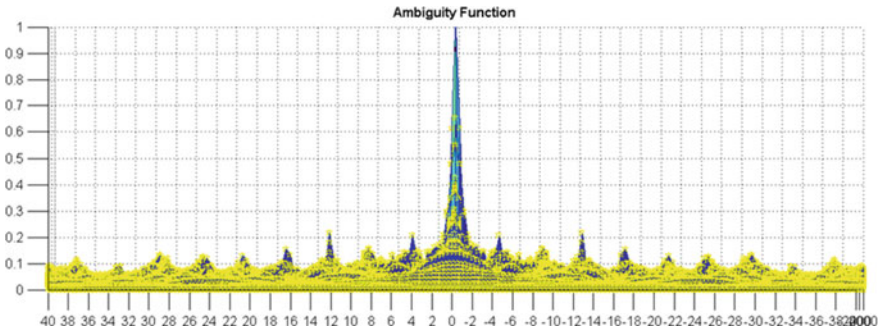

Fig. 4 Ambiguity function of Table 7

4 Conclusion

In this paper, a simple binary matrix coding approach is presented using a quadratic residue technique to detect multiple moving targets simultaneously. In this approach multiple clear windows are created with respect to the Doppler in order to obtain accurate information about multiple moving targets. This approach is more effective and simple. The approach is validated by simulation results obtained using MATLAB.

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