INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 04.10.2021

Accepted: 18.11.2021

Published: 24.12.2021

Citation: Bhure RKD, Manjunathachari K (2021) Design Of Digital Code Using Trellis Code to Improve Multiple Moving Target Detection in Doppler Radar. Indian Journal of Science and Technology 14(46): 3407-3415. https://doi.org/10.17485/IJST/v14i46.1771

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Design Of Digital Code Using Trellis Code to Improve Multiple Moving Target Detection in Doppler Radar

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Abstract

Objective: Model the digital codes to enhance the detection of desired target in Multi-object environment. **Methods**: This study presents an effective mathematical model using convolution code, Trellis Code, and Quadratic Residue Technique to increases the probability of moving target detection. **Findings**: The proposed digital codes are efficient in detecting and tracking battle-field targets, slow-moving targets (helicopters, fighter aircraft), and fast moving ICBM (Inter-Continental Ballistic Missile). **Application**: The proposed approach can be used in surveillance, defense, and monitoring the weather forecast. It also provides an opportunity for researchers to improve the methodology for fast-moving targets at desired Doppler frequency. **Novelty:** This approach improves the merit factor (MF) of the main lobe and also reduces the amplitude of the side spikes below the threshold limit by creating multiple clear windows at various Doppler ranges. To authenticate the proposed model, a comparison between the proposed model and the existing model is presented. The work has been validated using Mat- Lab.

Keywords: Quad code; trellis coding Technique; Doppler; Mat lab; Side spikes

1 Introduction

Advances in technologies in fighter aircraft, missiles, and ICBMs have forced the Radar and Communication engineering, research community to consistently pay attention to detect and locate the fast-moving targets from the static using extremely sensitive radar receivers which are often inherited with noise. State of artworks mainly uses autocorrelation (Matched filtering) of the received signal with a delayed sample of the input signal to increase the amplitude of the main lobe however this process introduces the side lobe which is the main cause for the loss of energy.

In this paper we initially start with the development of binary codes, to increase the merit factor as well as to improve the SNR of the received signal. However, these approaches are good for stationary targets and slow-moving targets. The main objective is to develop codes that can eliminate the side lobs and improve the merit factor of multiple moving targets. This paper also put much attention to developing the new set of binary codes which helps to create various windows at desired Doppler to detect multiple moving targets with varying Doppler at different ranges.

It is comparatively easy to detect the targets when it is stationary, wherein the sidelobe can be made zero by using complementary codes. The masking of moving targets occurs by the sidelobe as a result of autocorrelation or the Matched filtering that or which hampers the detection of dangerously small fast-moving targets like fighter aircraft, drones, and missiles, etc.

The work done in this paper brings about a conceptual change in the detection process by creating Doppler windows at various frequencies for which detection is easy for the entire range of the radar. These windows can be created at the desired Doppler in which the noise in terms of both frequency and amplitude is very low, this makes the detection process very easy without ambiguity. The ambiguity function at these Doppler frequencies is absolutely narrow both in terms of amplitude and frequency.

Bhure et al and Alotaibi [1,2] presented an approach in which the authors created multiple windows. However in both the techniques side lobes still exist at desired Doppler. Zhang et al [3] presented a novel approach based on Non-homogeneous Signal-Dependent Clutter in which the authors minimize the noise and enhance the SNR. But the approach is not optimum in real-time applications due to its complexity and more delay involved in the detection process.

Binary phase codes [4] were originally developed by Gole and Barker in which the phase elements φi is restricted to 0 or π. The Golay complementary sequences have an enormous effect on the sidelobe masking of targets in several ranges.

Moazzam Moinuddin [5] presented a general approach i.e Multiple Target Detection for High-Resolution Doppler. However, the performance of the system degrades as the auto and cross-correlation of the designed sequence shows an increase in the amplitude of the side lobes.

Nieh, et al [6] proposed an Innovative method for Multi-Target Estimation with the help of the Clutter-Suppression Technique for Pulsed Radar Systems. However, the designed method fails to detect multi-moving targets as it is used to detect static targets. Yang. H et.al [7] introduced pulse modulation of Costas frequency hops, using phase codes and complementary sequences. However, the presented approach used Costas signals beyond the orthogonality condition, which requires frequency separation. Therefore, cannot be used to improve the SNR for Moving targets. Touati, et al [8] proposed a technique to improve autocorrelation properties with lower grating lobes for a fixed bandwidth time product. However, in most of the phase codes, the level of the autocorrelation of side lobes decreases when their length is increased. But, the increase in phase code length may not decrease the amplitude of the side lobes which is desired. Hence, increased side lobes lead to decreased SNR, which is not acceptable in multiple moving target detection.

Touati et al [9] proposed Costas codes used to encode the initial Costas pulses. A double-coded Costas signal replaces rectangular pulses with another Costas signal. A double Costas coding approach can be effective in removing grating lobes. In this approach, the authors reduce grating lobes to increase the performance of the system. However, the first side lobe is relatively high and possesses a common problem in the standard LFM waveforms and Costas signals, where the first side lobe is approximately 13:7dB below the main lobe. For Doppler tolerant radar applications, it is not feasible as there is a chance of masking the target due to high amplitude sidelobes. It becomes inefficient for multiple moving Target detection.

Reddy et. al. [10] proposed a model based on Kaiser hamming and Cosh hamming window function to improve the SNR of Mesosphere-Stratosphere-Troposphere (MST). However, this approach only increases the signal power of the main lobe for increasing the merit factor but it also fails to eliminate the effect of side lobes. This happens due to the continuous Doppler change. Hence this approach limits to stationary targets only and cannot satisfy moving targets.

Sindhura et al [11] proposed a wavelet-based model. The authors compared the SNR enhancement of Lower Atmospheric Signals. This approach is efficient to calculate the wind performance in the atmospheric boundary layer (ABL) and minor troposphere. However, this technique puts much attention towards image arrangement of fixed (static) targets only, hence not efficient for optimal use in moving target detection.

Singh et al [12], presented a windowing approach to detect multiple moving targets. This approach is on top of oversampled PTM code by creating a number of windows with respect to desired Doppler's. In comparison with the main window, there are a number of windows one after another, but on some particular Doppler frequencies, the side lobe is above 0.2 dB. However, it increases the merit factor but range resolution gets degraded when multiple moving targets appear below 0.2 dB. Therefore the efficiency of the proposed model may be affected in real-time applications.

Mohammad Reza Mahmoudi et al. [13], [14], [15], presented various approaches based on Cyclostationary (CS) and Almost Cyclostationary (ACS), which are periodically correlated time series models. However, these techniques focus on the difficulties of statistical function estimation, probabilistic characterization, and determining the effect of time sampling. But the efficiency of these models on signal or target detection and source location problems is still ambiguous. Hence existing model may not be the optimum to detect high-speed multiple moving targets.

Rajkumar D bhure et al.[16] proposed Quad Code Sequence Generation using Cyclic Redundancy Technique to enhance target detection in Doppler Rader by using a digital coding technique to reduce the noise of the side lobs below the threshold limit i.e below 0.2 db.

The novelty of this paper uses the Trellis code, in addition to this approach uses equal-weighted hex codes to generate the input sequence for the trellis code to enhance the target detection with respect to desired Doppler. This paper is the extended version of[1] in which extra work has been carried out to improve target detection. The added work has three folds i.e. i) Quadratic Residue Sequence Generation using Trellis Coding Technique (QRSGTCT), ii)Quadratic Residue with '0' change Sequence Generation using Trellis Coding Technique (QRZCSGTCT) iii) Quadratic Residue with '1' change Sequence Generation using Trellis Coding Technique (QROCSGTCT).The codeword of each methodology has been tested with MatLab.

2 Methodology

Bhure et al[1], presented a method to reduce noise in Doppler radar. However, less attention was given towards range resolution and enhancement in the number and size of the windows.

The Design of the methodology applied[1] is given in Figure 1.

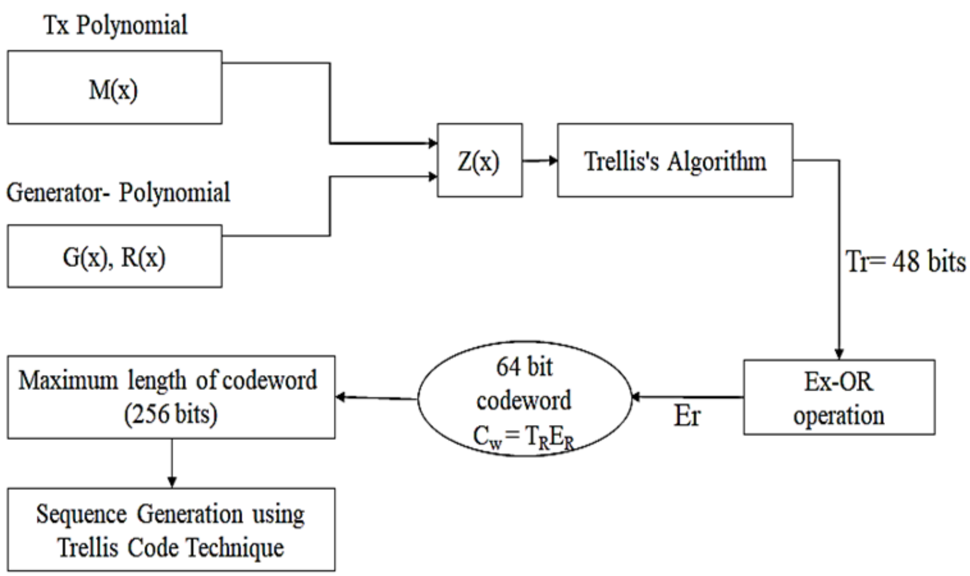

Fig 1. Generation of Trellis Code

The novelty of this work resides in an extensive approach of detecting multiple moving targets at various ranges in presence of Doppler. High-Range resolution radar signal waveforms are presented using Hex Quadratic residue, by changing 0 to 1, and 1 to 0. This concept is reflected in Figure 2.

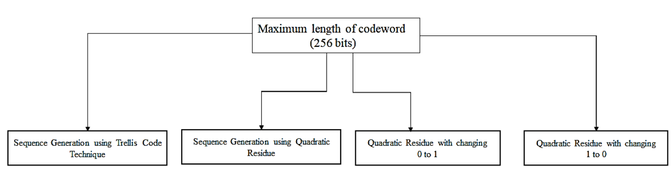

Fig 2. Generation of Quadratic Code

The paper, primarily produces the radar target detection bits by using Trellis Code Technique (TCT) and can be represented as M(x) and G(x)[1].].

$$\mathrm{M(x)} = \prod_{i=1}^{q} c_i \qquad \text{Where C} = 3, \mathrm{q} = 4 \tag{1}$$

$$G(x) = \frac{D_N + W_N}{D_N} \tag{2}$$

Where $'D'_N$ is the first decimal number of M(x) (i.e. 3) and $'W'_N$ is the last decimal number of M(x) (i.e. 12), and the next missing decimal number can be calculated by using [1]

$$R(x) = 2 * G(x) = 2 * 05 = 10 \tag{3}$$

As these two combined expressions G(x), R(x) (i.e. 0101, 1010) and M(x) together considered as input quad code sequence Z(x) for trellis code generation and can be represented as Z(x) [1]

$$Z(x) = [3,\ 5,\ 5,\ 9,\ 10,\ 12] = 0011\ 0101\ 0110\ 1001\ 1010\ 1100 \tag{4}$$

The resultant code word (T_R) was generated by trellis code of length 48 bits [1].

To improve the Merit factor of the received signal, the code length is further increased by the use of EX-OR operation of 'T_R' sequence and can be represented as.

$H_n = k_{m-1} \oplus k_m \oplus k_{m+1}$

Where m=3n+1 and n=0, 1, 2, 3…..7; k_m represents the bits of T_R

The EX- OR Operation of A_R, represented by

A_R = 0 0 1 1 1 1 0 0 1 0 0 0 1 0 1 1

The resultant code word Tc_W of 64 bit can be represented as [1]

$Tc_W = T_R A_R$ =0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 0 1 0 1 1 1 1 0 1 0 1 0 0 1 0 0 0 0 1 0 1 1 1 0 0 1 1 1 1 0 0 1 0 0 0 1 0 1 1

To increase the merit factor as well as SNR, the length of the code word is increased by appending the complementary bits of T_{CW}. This process continues till the length of 256 bits code word length approaches. [1]

The following are the approaches reflected in this paper:

2.1 Quadratic Residue Sequence Generation using trellis coding Technique (QRSGTCT)

In this technique, quadratic residue of decimal value of 47 is used to get a maximum change in the current bit positions of the code word generated from trellis code tree. This change of bits will further improve the target detection probability, by acquiring different windows when compared to previous technique [16]. The bit positions, which are affected by quadratic residues of 47 are 1,2,3,4,6,7,8,9,12,14,16,17,18,21,24,25,27,28,32,34,36,37,42 and 47 (table 1). These bit positions are changed with their complementary bits (i.e. 1 to 0 or 0 to 1). Any decimal value can be selected to choose quadratic residue, but here we are choosing 47as decimal value whose quadratic values have been calculated to generate a sequence. The 47 decimal value can change maximum bit position in the sequence to get better performance of target detection.

Bit Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
C_W	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1
quadratic residue of 47	1	2	3	4		6	7	8	9			12		14		16	17	18			21			24
Quadratic residue code word	1	1	1	1	1	0	1	0	1	1	0	1	1	1	0	1	0	1	0	0	1	1	0	0

Bit Position	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
C_W	0	0	1	0	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	1	0	1	1	1
quadratic residue of 47	25		27	28				32		34		36	37					42					47	
Quadratic residue code word	1	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	1

Fig 3. Quadratic residue code word of 47 decimal number

Figure 4 represents the EX-OR operation of 48 bits to generate further 16 bits to increase the length of the codeword upto and compliment the sequence till the length is equal to 256 bits which is the standard length of radar codes [1] EX-OR operation, can be represented as

The quadratic residue of the method is: 1 1 1 1 1 0 1 0 1 1 0 1 1 1 0 1 0 1 0 0 1 1 0 0 1 0 0 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 0 1 0 1 0 1 1 0 0 0 0 0 1 1 1 1 1 0 1 1 1 0

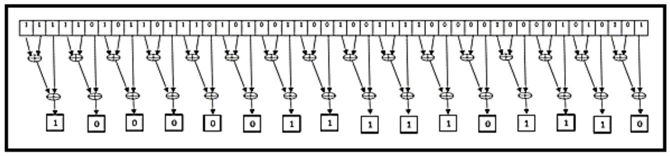

Fig 4. EX-OR operation of 48 bits

Figure 5 depicts relation between Doppler and amplitude variation. It has been observed that more windows (i.e. 3-13, 15-17, 19-21, 23-27, and 31-35) have been created to enhance the target detection in comparison to the QCSGTCT technique.

Figure 6 reflects the range calculation in compared to QCSGTCT technique. It is observed that the QRSGTCT technique provides more clear windows throughout the entire range with respect to desired Doppler frequency (i.e. 3-13, 15-17, 19-21, 23-27, and 31-35).

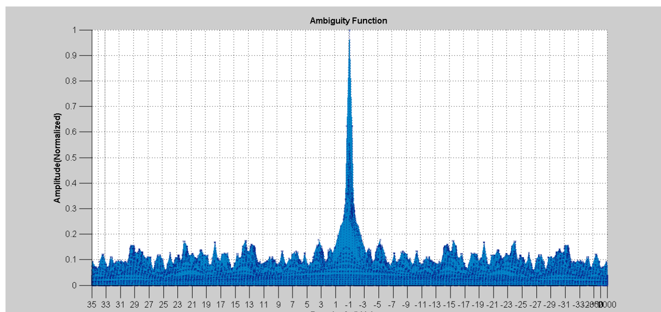

Fig 5. Doppler Vs Amplitude Variation

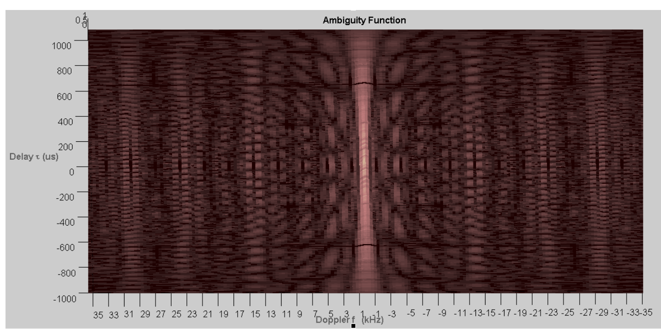

Fig 6. Doppler Vs Delay Variation

2.2 Quadratic Residue with '0' Change Sequence Generation using Trellis Coding Technique (QRZCSGTCT)

The performance characteristics (i.e. Doppler frequency and delay) may be improved further by using QRZCSGTCT method. In this method the changes are incorporated to the bits having weightage '0' in quadratic residue of 48 (Table 2).

The length of the code word is increased in same way as explained in section (i) (Figure 8) represents the EX OR operation.

The Generated Quadratic Residue with only Zero change (QR0) code word of length 64 bits is obtained from EX-OR operation. It can be represented as

QR_0 Code Word: 1 1 1 1 1 1 1 1 1 1 0 1 1 1 0 1 1 1 0 0 1 1 0 1 1 0 1 1 1 1 1 1 0 1 0 1 1 0 1 0 0 1 0 1 0 1 1 1 1 1 1 0 0 1 1 0 0 1 0 0 0 1 1 1

Figure 9 represents the ambiguity function. It is been observed that, all the four huge windows is created with respect to the Doppler frequency (.3-7,11-23, 25-27, and 31-35) whose amplitude lies below 0.1. Moreover, further refinement at various

Bit Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
CW	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	1	0	1	1	1
bit positions ofquadratic residue of 47	1	2	3	4		6	7	8	9			12		14		16	17	18			21			24	25		27	28				32		34		36	37					42					47	
Quadratic residue code word	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	1	0	0	1	0	1	0	1	1	1

Fig 7. Quadratic Residue code word with '0' change only

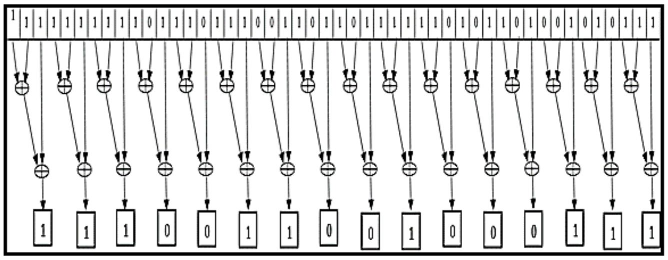

Fig 8. EX-OR Operation of 48 bits

Doppler frequencies are performed to create windows with respect to range (Figure 11).

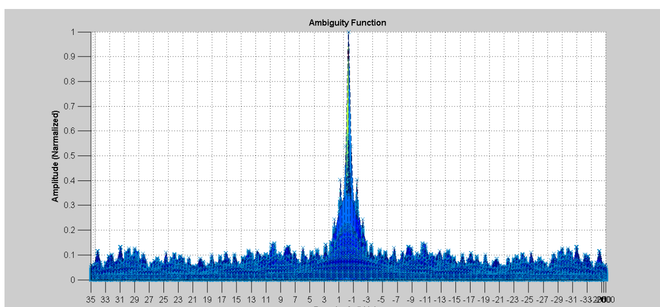

Fig 9. Doppler Vs Amplitude Variation

2.3 Quadratic Residue with '1' change Sequence Generation using Trellis coding Technique (QROCSGTCT)

In this approach, different changes in the sequence can be obtained, which gives further improvement in windows at various Doppler's that is 2-8, 12-20, 24-35. Using this method, the changes are made only to those bits of quadratic residues of '48' whose weight is '1' (i.e. '1' changes to '0') (table 3).

Bit Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
C_W	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	1	0	1	1	1
bit positions ofquadratic residue of 47	1	2	3	4		6	7	8	9			12		14		16	17	18			21			24	25		27	28				32		34		36	37					42					47	
Quadratic residue code word	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1

Fig 10. QuadraticResidue code word with '1' change only

The designed 48 bits, by the use of modified by EX-OR operation of three consecutive bits(Refer Figure 11) to make the length of the codeword 64 bits.

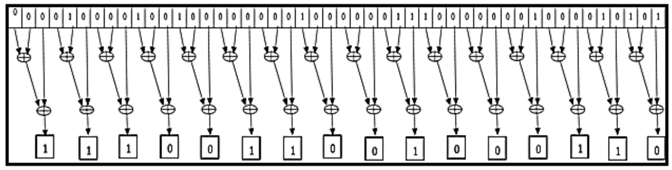

Fig 11. Doppler Vs Delay Variation

The required Quadratic Residue code word with one change (QR_1) of length 64 bits can be represented as (48 nornal bits appended with 16 bits from EX-OR operation):

QR_1 Code word: 0 0 0 0 1 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 1 0 0 1 1 0 0 1 0 0 0 1 1 0

Figure 12 represents the ambiguity function. From the figure it is observed that 03 huge windows have been created (i.e. 2-8,12-20 and 23-35) to monitor the target with respect to Doppler, whose amplitude lies below the 0.1, which is further refined at various Doppler frequencies to create windows with respect to range (Figure 13).

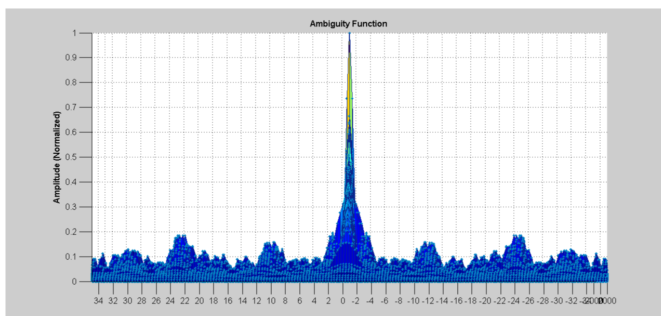

Fig 12. Doppler Vs Amplitude Variation

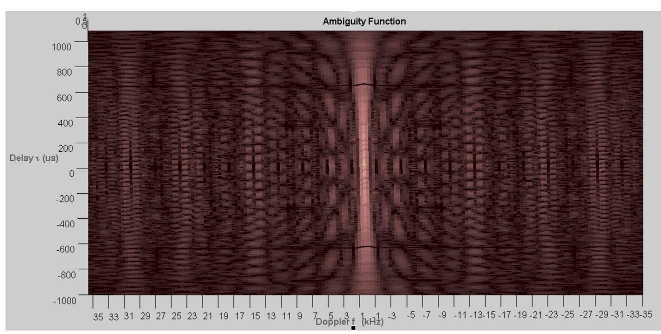

Fig 13. Doppler Vs Delay Variation

3 Results and Discussion

The present approaches are compared with previous work [1,16] and other existing approaches such as Doubly coded Costas [9], Minimum Peak Sidelobe code [14], and R K Singh code [12]. Figure 14 represents the variation of Doppler Vs Noise Amplitude (normalized) of the existing approaches.

The comparative analysis of these approaches is represented in table 4. From the table, it can be observed that the amplitude of noise peaks in the existing approaches are more when compared to the proposed approach. As a result, these side spikes of the noise will create obstruction in detecting the weak echoes coming from the multiple slow-moving targets. Hence, the small targets are masked by slow-moving comparatively big targets as a result of more amplitude inside spikes than the detectable limit. The novelty of the proposed model is to minimize the noise side peaks and thereafter enhancing the probability of target detection in Doppler by more window creation.

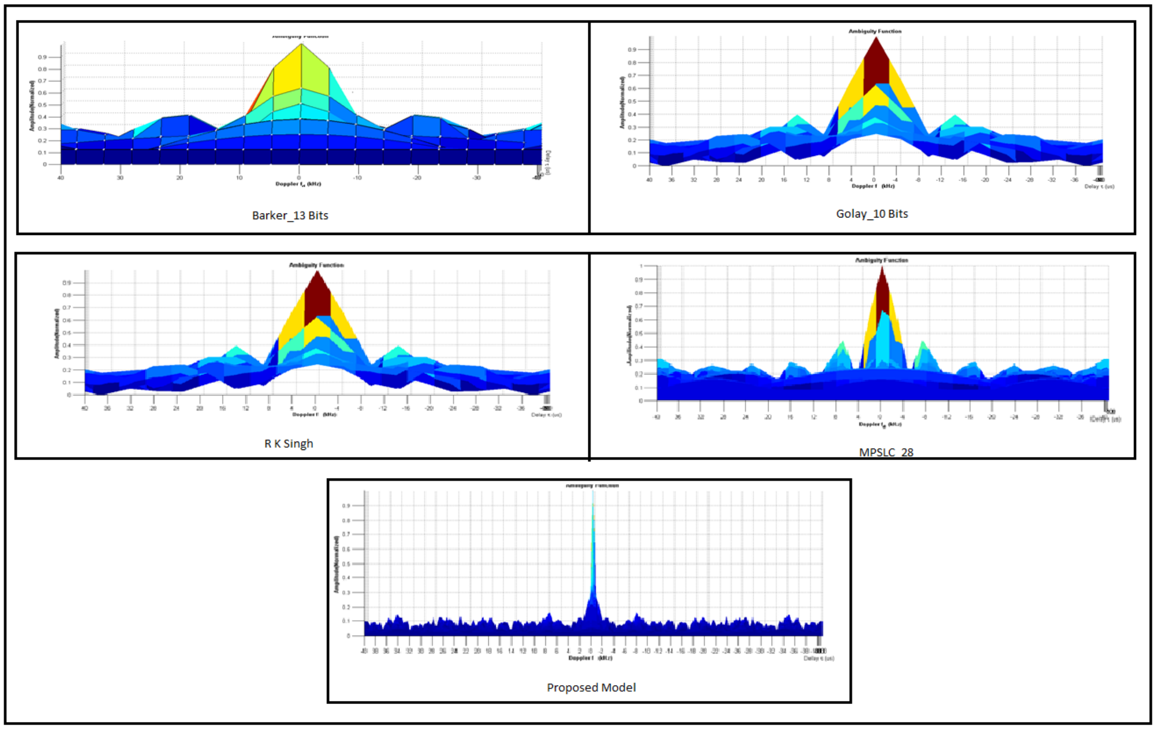

Fig 14. Doppler Vs Noise Amplitude Variation

Comparative analysis of noise peaks is reflected in Table 1

Table 1. Comparative Analysis of Noise Peaks

Doppler/Peaks (KHz)	Amplitude of Noise peaks					
	BC_13	MPC_28	GC_10	RK_C	RDB_C	Proposed approach (refer figure 10)
0	1	1	1	1	1	1
9	0.4	0.37	0.45	0.38	0.05	0.05
14	0.28	0.28	0.32	0.33	0.08	0.05
17	0.38	0.18	0.3	0.34	0.1	0.08
19	0.35	0.27	0.29	0.28	0.06	0.05
23	0.25	0.24	0.34	0.24	0.07	0.06
28	0.2	0.24	0.31	0.22	0.09	0.07
33	0.27	0.25	0.46	0.19	0.01	0.065
40	–	0.3	0.38	0.2	0.09	0.09

Figure 15 shows the graphical representation of Table 1. From the figure it has been clearly observed that the noise peaks of the proposed approach has much lower than the existing approaches.

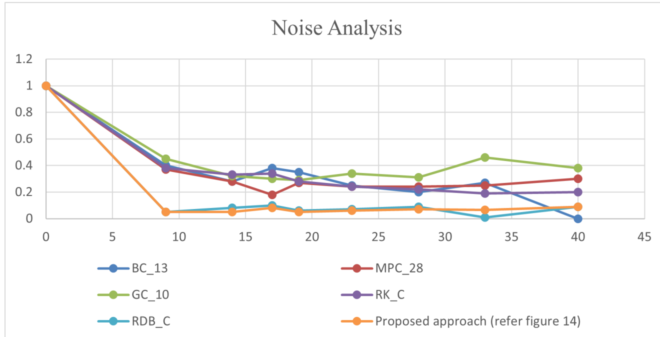

Fig 15. Noise Vs Doppler

4 Conclusion

The presented approach can improve the probability of multiple moving target detection by creating huge number of clear windows. The presented approach is effective in detection of the present position of the target with respect to range and Doppler frequency. It is also reflected that the integration of all above presented approaches will give the clear information about the moving targets from 0 to 35 KHz Doppler frequency which is the practical frequency of detection process. The presented approach reduces the amplitude of side lobs below 0.1db, which is very faithful and effective development in target detection in Radar engineering.

References

1) Bhure RD, Chari KM, Ahmad SJ. DDTRCSTCT: Design of Doppler Tolerant Radar Code to Increase SNR Using Trellis Code Technique. *Lecture Notes in Networks and Systems*. 2018;p. 261–268. doi:10.1007/978-981-10-8204-7_27.
2) Alotaibi M. Low noise moving target detection in high resolution radar using binary codes. *EURASIP Journal on Advances in Signal Processing*. 2021;2021. Available from: https://asp-eurasipjournals.springeropen.com/articles/10.1186/s13634-020-00716-0.
3) Zhang J, Du Y, Yan H. Code Design for Moving Target-Detecting Radar in Nonhomogeneous Signal-Dependent Clutter. *Mathematical Problems in Engineering*;2020. doi:10.1155/2020/7609547.
4) Pace PE, Ng CY. Costas CW frequency hopping radar waveform: peak sidelobe improvement using Golay complementary sequences. *Electronics Letters*. 2010;46(2):169–169. doi:10.1049/el.2010.2209.
5) Moinuddin MM, Y MR, Pasha IA, Naveed SA, Kishore KL. Multiple Target Detection for High Resolution Doppler Radar. *International Journal of Engineering and Technology*. 2011;3(5):497–504. doi:10.7763/ijet.2011.v3.276.
6) Nieh JY, Cheng YP. Innovative Multi-Target Estimating with Clutter-Suppression Technique for Pulsed Radar Systems. *Sensors*. 2020;20(9):2446–2446. doi:10.3390/s20092446.
7) Yang H, Zhou J, Wang F, Zhang Z. Design and analysis of Costas/PSK RF stealth signal waveform. *IEEE CIE International Conference on Radar*. 2011. doi:10.1109/CIE-Radar.2011.6159782.
8) Touati N, Tatkeu C, Chonavel T, Rivenq A. Phase Coded Costas Signals for Ambiguity Function Improvement and Grating Lobes Suppression. *2013 IEEE 78th Vehicular Technology Conference (VTC Fall)*. 2013;p. 1–5. doi:10.1109/vtcfall.2013.6692362.
9) Touati N, Tatkeu C, Chonavel T, Rivenq A. Doubly coded costas signals for grating lobes mitigation. *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*. 2013;p. 481–485. doi:10.1109/pimrc.2013.6666184.
10) Ravi D, Reddy K, Anuradha B. Improved SNR of MST Radar Signals by Kaiser-Hamming and Cosh-Hamming Window Functions. *Journal of Engineering Research and Applications*. 2015;5:32–38.
11) Sindhura S, Reddy SN, Kamaraj P. Comparison of SNR Improvement forLower Atmospheric Signals Using Wavelets. *I International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*. 2015;4. doi:10.15662/IJAREEIE.2015.041022.
12) Singh RK, Rani DE, Ahmad SJ. RSBHCWT: Re-Sampling Binary Hex Code Windowing Technique to Enhance Target Detection. *Indian Journal of Science and Technology*. 2016;9(47). doi:10.17485/ijst/2015/v8i1/105952.
13) Reza MM. Mohsen Maleki "A new method to detect periodically correlated structure. *Comput Stat*. 2016. doi:10.1007/s00180-016-0705-z.
14) Reza MM. Testing the difference between spectral densities of two independent periodically correlated (cyclostationary) time Series models. *Communications in Statistics - Theory and Methods*. Available from: https://doi.org/10.1080/03610926.2018.1472776. doi:10.1080/03610926.2018.1472776.
15) Reza MM. . Available from: https://doi.org/10.1016/j.dsp.2019.102597. doi:10.1016/j.dsp.2019.102597.
16) Bhure RD. Quad Code Sequence Generation using Cyclic Redundancy Technique to Enhance Target Detection in Doppler Rader. *Journal of Electrical Engineering &Technology*. 2020;15:2745–2757. doi:10.1007/s42835-020-00519-1.