International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-8, Issue-1, Jan 2020 E-ISSN: 2347-2693

An Advanced Target Detection Model for Slow Moving Smaller Target in the Coastal Area

Rajesh B.[1*], Udayarani V.[2], Jayaramaiah G.V.[3]

[1,2]School of Computer Science and Engineering, REVA University, Rukmini Knowledge Park, Kattigenahalli, Yelahanka, Near Border Security Bustop, Bengaluru, Karnataka 560064, India
[3]Dept. of Electronics and Communication, Dr. AIT, Near Jnana Bharathi Campus, Bengaluru, Karnataka 560056, India

Corresponding Author: rajeshbalarama@gmail.com

DOI: https://doi.org/10.26438/ijcse/v8i1.7983 | Available online at: www.ijcseonline.org

Accepted: 15/Jan/2020, Published: 31/Jan/2020

Abstract: Sea clutter in marine surveillance radar makes the task of detecting small targets a very challenging problem In this paper, a better model is been proposed for slow moving smaller target detection. This model initially starts with signal preprocessing to remove the basic noise then a technique called Hanning-Weighted Window Function (HWWF) assisted Time series analysis model with Spatio-Temporal Fourier Transform (STFT) for Time-Frequency analysis is applied, then a space-Time Adaptive Processing (STAP) technique with adaptive weight and filter will be applied to perform small moving target detection under sea clutter, then at last an enhanced Antenna-Pulse-Pair Selection (APS) with Space Spectrum Correlation Coefficient (SSCC) estimation, which has been further processed for the optimal Antenna-Impulse Pair Selection that approximates clutter covariance matrix to achieve enhanced Signal-to-Clutter plus Noise Ratio (SCNR) to achieve computationally efficient STAP for moving target detection This model is proposed for multiple (moving) sea-target detection in sea clutter and jamming probable environment. The overall proposed model will be developed based on impulse radar setup using MATLAB tool Thus, it is well suited for slow moving small target detection under sea clutter for efficient coastal surveillance purposes.

Keywords: Moving Target Detection, Sea-Clutter Environment, STFT, Hanning Weighted Window Analysis; Hanning-Weighted Overlapped Time-Series Analysis, Impulse Radar, Space Time Adaptive Process, Clutter-Suppression, Antenna, Pulse Pair Selection, Coastal Surveillance.

I. INTRODUCTION

Sea clutter is the backscattered returns from a patch of the sea surface illuminated by a radar pulse. Accurate modeling of sea clutter and robust detection of low observable targets within sea clutter are important problems in remote sensing and radar signal processing applications, for a number of reasons identifying small marine vessels, navigation buoys, small pieces of ice, patches of spilled oil, etc. can significantly reduce the threat to the safety of ship navigation; monitoring and policing of illegal fishing is an important activity in environmental monitoring.

Since sea clutter is a type of electromagnetic wave, sea clutter study may also help understand fading and non-Gaussian noise in wireless communications, so that wireless communication channel characterization and signal detection can be greatly improved.

Sea clutter which is decisively dependent on the oceanic events, local weather condition such as wind speed, wind-direction, height of waves, and the grazing angle of radar. In addition, oceanic echoes typically seem to possess sea-spikes that affects efficacy of the target detection systems. It makes target detection more difficult when targets move at low speed and smaller size [1]. Interestingly, it becomes severely infeasible to detect small targets, especially when the grazing angle of radar becomes lower than 3^0 and the target size is smaller than 30m [2]. Under above stated conditions target detection turns out to be highly complicated task; however it is inevitable to ensure precise and continuous target detection. As classical solution, authors [3,4] have modeled sea clutter by means of a stochastic mechanism where varied statistical distributions have been considered to detect target under sea clutter. Employing Constant False Alarm Rate (CFAR) algorithm, authors [5] have detected surface targets with large RCS. However, such approaches can't be suitable for small targets, even with the help of K-distribution [6], which is supposed to be effective to cope up with sea clutter. This is mainly because of the frequent rise in sea spikes and waves dynamism.

This localized time-frequency analysis model is often known as Short Time Fourier Transform (STFT) which is also referred as Windowed Fourier Transform (WFT). The predominant feature of the STFT is the confine its time-frequency resolution ability, which is primarily contributed because of the uncertainty principle [7]. In practice, low frequencies are difficult to visualize with short windows, on contrary short pulses can efficiently be identified or detected timely with long windows. To avoid such artifacts, suitable windows are inevitable. Practically, a received radar signal comprises addition of a large number of complex exponentials which can be characterized by means of Fourier spectrum. Our proposed model employs STFT to perform time-frequency analysis of the input signal. The proposed model exploits moving target echo model where echo signal has been analyzed in time-frequency analysis method [8].

Oceanic echoes seem to possess sea-spikes that create significant clutter which makes target detection difficult [9] Furthermore, detection of the multiple targets moving at slow speed becomes even more complicated during sea-clutter, and hence requires optimal clutter suppression model [10]. Jamming situation which is intentionally employed by intruders, in conjunction with sea-clutter can make overall detection process tedious [14]. In such case designing a robust clutter suppression model with jammer resilience and noise-power cancellation can be of vital significance [9-14]. It has been considered as the motivation of the presented research work.

Fourier analysis approaches have been applied for moving target detection [17], the use of both spatial as well as temporal features opens us further scope for enhancement [13][14]. Unlike conventional methods, the use of Space-Time Adaptive Processing (STAP) method because of its ability to process temporal as well as spatial subspace has gained significant attention across academia-industries to perform moving target detection [14-16][18][19][20][21][22-24]. It exhibits combining the different signals and/or allied pulses received from varied antenna-arrays to perform target detection accurately, even under clutter and jamming conditions [13-16]. Functionally, it applies the Clutter-plus-Noise Covariance Matrix (CCM) of the received signal which is processed for whitening before employing any Matched-Filter Detector (MFD). The overall proposed system will be developed using MATLAB tool, while its performance will be examined in terms of Signal-to-Interference-plus-Noise Ratio (SINR), SINR losses, SINR Improvement Factor.

II. RELATED WORK

Considering the complexities caused due dynamic waves, size of the target and sea clutter, Croney et al [25] recommended using clutter de-correlation method that applied fast antenna scanning followed by camera or direct-view storage-tube integration Rodriguez et al [26] proposed the GLRT-based adaptive multi-frame detection scheme for multi-pixel target detection. Authors modeled sea clutter as the channel encompassing Gaussian noise added with the background Gaussian clutter with varying covariance matrix. Authors [27] applied spatial-temporal patches also called frames to obtain the specified target appearance that eventually helped in estimating background clutter. In [28], Haykin et al applied the concept of time-frequency analysis by performing feature extraction and pattern classification to assist small target detection under dynamic background condition. In their approach authors [29] performed time-frequency analysis using Wigner-Ville distribution (WVD) by transforming echoes signal into a time-frequency image (time-varying nature of the received signal's spectral content of the iceberg). In addition, authors applied Hannning window function with Fourier transforms to detect moving object in a sea clutter. It was applied by Baggenstoss et al [30] who assessed different window sizes. The use of Gaussian noise helped detecting pulses of unknown duration, while windowing enabled suppressing multiple radio frequency interference [31]. Undeniably, numerous efforts have been made to detect moving target in sea clutter amongst then STFT based Time-Frequency Analysis (TFA) has performed better. However no significant effort has been made on optimizing selection of STFT parameters to achieve better window analysis which can be significant for time-series analysis, especially for the small moving target detection in sea clutter.

Considering moving target detection issues in sea-clutter, authors [11][12] proposed clutter modeling concept with different statistical distributions. However, non-linearity in clutter amplitude and jamming could not be incorporated using classical statistical modeling method. Additionally, numerous efforts have been made from academician as well as defense sector towards moving object or target detection under sea-clutter. Some of the key efforts were made by employing Spatio-Temporal Fourier Transform (STFT) that enables space as well as time domain analysis of the received signal to detect moving object [32-34]. Due to low range of object floating, numerous targets might undergo undetected, Carretero-Moya et al [35] designed a Radon transform assisted heuristic concept for of low radar cross-section targets detection in sea clutter. Radon transform enabled sequential profile generation to detect small target in sea clutter. Shui et al [36] used three key features from the received signals; relative amplitude, relative Doppler peak height, and relative entropy of the Doppler amplitude spectrum to segment target in sea clutter. To enhance computation, authors [36] applied convex hull learning algorithm. To enhance detection, Duk et al [37] applied Stationary Wavelet Transforms (SWT); however it was well suited for the target detection in medium grazing angle X-band sea-clutter. Panagopoulos et al [38] applied three distinct signal processing techniques, like Signal Averaging (SA), Morphological Filtering (MF) and Time-Frequency Analysis (TFA) to detect target in sea clutter.

Undeniably, numerous efforts have been made to detect moving target in sea clutter amongst then STFT based TFA has performed better. However no significant effort has been made on optimizing selection of STFT parameters to achieve better window analysis which can be significant for time-series analysis, especially for the small moving target detection in sea clutter. Though, above discussed approaches intended to achieve better clutter suppression and target detection; however majority of the existing approaches either focus on clutter suppression or Doppler analysis based target detection. On contrary, in contemporary conditions it is inevitable to detect moving target irrespective of size while assuring optimal clutter suppression, jamming attack-resilience even with low computational cost and training impulses. These gaps and allied scopes have been considered as the motive for this research work.

III. PROBLEM FORMULATION

In this paper the problem the model has be proposed in two different levels for slow moving smaller target detection which are explained below as part A and B respectively.

Part: A
The efficient Hanning Weighted Window Function (HWWF) model to be developed in conjunction with STFT to perform Hanning-Weighted Overlapped Time-Series Analysis (HWOTSA) to detect slow moving target detection in sea clutter, the use of orthonormal transformation also called rotation enabled Hanning Window Analysis to use suitable STFT parameters and statistical test across the windows to achieve better accuracy of the target detection. HWOTSA assisted STFT in conjunction with the Probability Distribution Function Projection, Pulse Position Modulation (PPM) over extracted features enabled accurate slow moving target detection in sea clutter

Part: B
Space-Time Adaptive Processing (STAP) technique with adaptive weight and filter for better target detection and also to use enhanced Antenna-Pulse-Pair Selection (APS) strategy to reduce or approximate the Clutter-plus-Noise Covariance Matrix (CCM) so as to achieve computationally efficient STAP, followed by Space Spectrum Correlation Coefficient (SSCC) with optimal CCM to suppress clutter subspace, noise and jammers to help optimal moving target detection under sea clutter

IV. OUR CONTRIBUTION

This research the predominant emphasis is made on achieving slow-moving target detection in sea clutter. Based on the literature survey we understood the research gaps for slow moving smaller target detection is with the current methods or models are not showing the better results, in this paper we are proposing the better model which may through a better results after implication of this.

Unlike conventional moving target detection schemes with Doppler filters which employs uniform motion targets, in this proposed model the focus is made on detecting moving target under sea clutter and noise conditions (say, under low SNR, spectral divergence conditions). Majority of the classical approaches are confined due to its inability to perform multi-component signal processing, especially under non-linear movement conditions and signal-backscattering.

These model also focus on augmenting major steps of moving target detection under sea-clutter condition including signal acquisition and time-frequency analysis, STFT parameter optimization for better time series analysis and signal projection analysis (say, statistical process or Probability Density Function (PDF) based signal analysis and detection).

The overall proposed system shall been realized in following key phases:
1. Echo Demodulation and Time-Frequency Spectrum Reconstruction
2. Doppler-Shift Information mapping to the Time-Frequency Conversion
3. Hanning-Weighted Window Function (HWWF) assisted STFT for Time-Frequency analysis
4. Signal strength assessment per window for Target Hypothesis construction and detection.

Considering the inevitable significance of a robust signal processing technique for radar signal detection this research primarily emphasizes on designing a novel and enhanced model, especially designed for moving object detection in sea clutter, which often undergoes significant interferences and clutter conditions. In addition, realizing the contemporary oceanic threats caused due to malicious intruders and respective activities such as jamming this research intends to design a robust signal processing technique which could achieve optimal object detection even under noise, interference, clutter and jamming conditions. Literatures reveal that unlike classical Fourier transform based approaches, the use of STAP can be of great significance to achieve optimal object detection even under aforesaid conditions. With this motive, in this paper a novel Adaptive STAP (ASTAP) model is developed that focuses on achieving optimal detection, clutter suppression and jamming resilience. This as a result can achieve optimal performance for real-time coastal surveillance using Pulse Doppler Radar (PDR) system. In our proposed sea-object detection model, we have obtained spatial spectrum correlation coefficient (SSCC) that characterizes the disparity between the target and the nearest cluster information or Fourier basis, also called clutter subspace. In addition, we introduce a novel Antenna Pulse Selection (APS) model that gives rise to the space time (spatio-temporal) configuration, which eventually enhances signal-to-clutter-noise ratio (SCNR) for better detection accuracy.

V. CONCLUSION

Hanning Window Analysis has emerged as a potential approach for STFT based signal analysis as it can solve the problem of time and frequency resolution that typically depends on the width of window function used to estimate STFT. Improper window size selection could cause inaccurate detection results. Unfortunately significant effort is made to alleviate aforesaid issues, which are significant to perform small moving target detection in sea clutter. Considering it as motivation, in this paper we performed a time-series analysis by exploiting efficacy of Hanning-Weighted time-series analysis or processing windows. The proposed model enables window analysis output for all samples (at certain predefined window size) to convert into other window size by means of rotation, which is also called Ortho-normal linear transformation. This approach enabled the selection of optimal window sizes and statistical test across the windows to assist better target detection. The fact that the conventional STAP method requires high space as well as temporal subspace (impulse) information also called training impulse to perform detection, at first spatial spectrum correlation coefficient (SSCC) estimation has to be performed that enabled an optimal Array-Pulse Pair Selection (APS). Consequently, it resulted into low dimensional array-impulse requirements to perform further clutter suppression and the target detection. Such value additions enabled proposed method to achieve time-efficient multiple targets detection under sea-clutter and jamming probability. Noticeably, this research employed convex optimization concept along with an enhanced clutter covariance matrix information which enables target detection more efficiently. The use of SSCC enhanced Signal-to-Clutter-Noise Ratio (SCNR) output which eventually strengthened clutter suppression and hence more effective target detection under clutter and jamming conditions.

REFERENCE

[1] H. W. Melief, H. Greidanus, P. van Genderen, and P. Hoogeboom, "Analysis of sea spikes in radar sea clutter data," IEEE Transactions on Geoscience and Remote Sensing, vol. **44**, no. **4**, pp. 985–993, **2006.**

[2] S. Panagopoulos and J. J. Soraghan, "Small-target detection in sea clutter," IEEE Transactions on Geoscience and Remote Sensing, vol. **42**, no. **7**, pp. 1355–1361, **2004.**

[3] A. Parthiban, J. Madhavan, P. Radhakrishna, D. Savitha, and L. S. Kumar, "Modeling and simulation of radar sea clutter using K-distribution," in Proceedings of the International Conference on Signal Processing and Comm. (SPCOM '04), pp. **368–372**, Bangalore, India, December **2004.**

[4] Y. Norouzi, F. Gini, M. M. Nayebi, and M. Greco, "Noncoherent radar CFAR detection based on goodness-of-fit tests," IET Radar, Sonar & Navigation, vol. **1**, no. **2**, pp. 98– 105, **2007.**

[5] K. Siddiq and M. Irshad, "Analysis of the cell averaging CFAR in weibull background using a distribution approximation," in Proceedings of the 2nd International Conference on Computer, Control and Communication (IC4 '09), pp. **1–5**, Karachi, Pakistan, February **2009.**

[6] L. Jingsheng, W. Wenguang, S. Jinping, and M. Shiyi, "Chaosbased target detection from sea clutter," in Proceedings of the IET International Radar Conference, pp. 1–4, Guillin, China, April **2009.**

[7] Kabakchiev, K., Daniel, L., Gashinova, M., et al.: 'Radar parameters influence on the clutter in maritime forward scatter radar'. 2014 11th European Radar Conf., Rome, Italy, 8–10, pp. **113– 116,** October **2014.**

[8] G. Davidson and H. D. Griffiths, "Wavelet detection of low observable targets within sea clutter," in Proc. IEE Conf. Radar 2002, IEEE Conf. Publ., vol. **490**, Edinburgh, U.K., , pp. 238–242, **2002**

[9] H. W. Melief, H. Greidanus, P. van Genderen, and P. Hoogeboom, "Analysis of sea spikes in radar sea clutter data," IEEE Transactions on Geoscience and Remote Sensing, vol. **44**, no**. 4**, pp. 985–993, **2006**

[10] S. Panagopoulos and J. J. Soraghan, "Small-target detection in sea clutter," IEEE Transactions on Geoscience and Remote Sensing, vol. **42**, no. **7**, pp. 1355–1361, **2004.**

[11] A. Parthiban, J. Madhavan, P. Radhakrishna, D. Savitha, and L. S. Kumar, "Modeling and simulation of radar sea clutter using K-distribution," in Proceedings of the International Conference on Signal Processing and Comm. (SPCOM '04), pp. **368–372**, Bangalore, India, December **2004.**

[12] Y. Norouzi, F. Gini, M. M. Nayebi, and M. Greco, "Noncoherent radar CFAR detection based on goodness-of-fit tests," IET Radar, Sonar & Navigation, vol. **1**, no. **2**, pp. 98– 105, **2007**

[13] Ward, J.: 'Space-time adaptive processing for airborne radar'. Tech. Rept., ESC-TR-94-109, Lincoln Laboratory, December 1994

[14] Klemm, R.: 'Principles of space-time adaptive processing' (The Institution of Electrical Engineers, **2002**).

[15] Melvin, W.: 'A STAP overview', IEEE Aerosp. Electron. Sys. Mag., , **19**, (**1**), pp. 19–35, **2004.**

[16] Guerci, J., Goldstein, J., Reed, I.: 'Optimal and adaptive reduced-rank STAP', IEEE Trans. Aerosp. Electron. Syst**.,** , **36**, (**2**), pp. 647–663, **2000.**

[17] V. Duk, L. Rosenberg and B. W. Ng, "Target Detection in Sea-Clutter Using Stationary Wavelet Transforms," in IEEE Transactions on Aerospace and Electronic Systems, vol. **53**, no**. 3**, pp. 1136-1146, June **2017.**

[18] Aboutanios, E., Mulgrew, B.: 'Hybrid detection approach for STAP in heterogeneous clutter', IEEE Trans. Aerosp. Electron. Syst., , **46**, (**3**), pp. 1021–1033, **2010.**

[19] Degurse, J.-F., Savy, L., Marcos, S.: 'Reduced-rank STAP for target detection in heterogeneous environments', IEEE Trans. Aerosp. Electron. Syst., **50**, pp. 1153–1162, **2014.**

[20] Aboutanios, E., Mulgrew, B.: 'Heterogeneity detection for hybrid STAP algorithm'. Radar Conf., 2008. RADAR'08, pp. **1–4,** May **2008.**

[21]Bidon, S., Besson, O., Tourneret, J.-Y.: 'Knowledge-aided STAP in heterogeneous clutter using a hierarchical Bayesian algorithm', IEEE Trans. Aerosp. Electron. Syst., **47**, pp. 1863–1879, **2011.**

[22]Yang, Z., de Lamare, R., Li, X.: 'Sparsity-aware space-time adaptive processing algorithms with l1-norm regularisation for airborne radar', IET Signal Process., **6, (5),** pp. 413–423, **2012.**

[23]Yang, Z., De Lamare, R., Li, X.: 'L1-regularized STAP algorithms with a generalized sidelobe canceler architecture for airborne radar', IEEE Trans. Signal Process., **60**, pp. 674–686, **2012.**

[24] Ward, J.: 'Space-time adaptive processing with sparse antenna arrays'. Thirty-Second Asilomar Conf. on Signals, Systems & Computers, 1998, vol. **2**, pp. 1537–1541, **1998.**

[25]J. Croney, A. Woroncow and H. Salt, "Detection of surface targets in sea clutter by shipborne radar," in *Electronics Letters*, vol. **5**, no. **24**, pp. 619-621, 27 November **1969.**

[26]M. Rodriguez-Blanco and V. Golikov, "Multiframe GLRT-Based Adaptive Detection of Multipixel Targets on a Sea Surface," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. **9**, no. **12**, pp. 5506-5512, Dec. **2016.**

[27]G. Hennessey, H. Leung, A. Drosopoulos and P. C. Yip, "Sea-clutter modeling using a radial-basis-function neural network," in *IEEE Journal of Oceanic Engineering*, vol. **26**, no. **3**, pp. 358-372, July **2001.**

[28]S. Haykin and T. K. Bhattacharya, "Modular learning strategy for signal detection in a nonstationary environment," in *IEEE Transactions on Signal Processing*, vol. **45**, no. **6**, pp. 1619-1637, June **1997**.

[29]J. Gao, Z. Lin and W. An, "Infrared Small Target Detection Using a Temporal Variance and Spatial Patch Contrast Filter," in *IEEE Access*, vol. **7**, pp. 32217-32226, **2019.**

[30]P. M. Baggenstoss, "On the Equivalence of Hanning-Weighted and Overlapped Analysis Windows Using Different Window Sizes," in *IEEE* Signal Processing Letters, vol. **19**, no. **1**, pp. 27-30, Jan. **2012**.

[31] Li and Y. -. Lin, "Receiver window designs for radio frequency interference suppression in DMT systems," in IET Signal Processing, vol. **3**, no. **1**, pp. 33-39, January **2009**.

[32] J. Gao, Z. Lin and W. An, "Infrared Small Target Detection Using a Temporal Variance and Spatial Patch Contrast Filter," in *IEEE Access*, vol. **7**, pp. 32217-32226, **2019**.

[33] P. M. Baggenstoss, "On the Equivalence of Hanning-Weighted and Overlapped Analysis Windows Using Different Window Sizes," in *IEEE* Signal Processing Letters, vol. **19**, no. **1**, pp. 27-30, Jan. **2012.**

[34] Li and Y. -. Lin, "Receiver window designs for radio frequency interference suppression in DMT systems," in IET Signal Processing, vol. **3**, no. **1**, pp. 33-39, January **2009**.

[35] J. Carretero-Moya, J. Gismero-Menoyo, A. Asensio-Lopez and A. Blanco-del-Campo, "Application of the radon transform to detect small-targets in sea clutter," in IET Radar, Sonar & Navigation, vol. **3**, no. **2**, pp. 155-166, April **2009**.

[36] P. Shui, D. Li and S. Xu, "Tri-feature-based detection of floating small targets in sea clutter," in IEEE Transactions on Aerospace and Electronic Systems, vol. **50**, no. **2**, pp. 1416-1430, April **2014.**

[37] V. Duk, L. Rosenberg and B. W. Ng, "Target Detection in Sea-Clutter Using Stationary Wavelet Transforms," in IEEE Transactions on Aerospace and Electronic Systems, vol. **53**, no. **3**, pp. 1136-1146, June **2017**.

[38] G. Xiong, C. Xi, D. Li and W. Yu, "Cross Correlation Singularity Power Spectrum Theory and Application in Radar Target Detection Within Sea Clutters," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. **57**, no. **6**, pp. 3753-3766, June **2019.**

AUTHORS PROFILE

Shri. Rajesh B is currently pursuing his PhD studies at REVA University working as Assistant Professor at Bengaluru Dr. B R Ambedkar School of Economics, Bangalore. He obtained his B.Sc. degree in Electronics and Computer Science in the year 2010 from Mysore University and M.Sc. degree in Computer Science from Mysore University, Karnataka, in 2012. He has 7 years of teaching experience, his main research focus on trends in Radar signal processing, Image Processing, Data Analysis and Pattern Recognition.

Dr. Udaya Rani V currently working as Associate Professor in School of Computer Science and engineering, REVA University, Bangalore. She received Ph. D. from Mother Teresa University. She has 12 years of teaching experience. She has published 2 research articles in International journals. She has presented 9 research paper in international conference and 4 papers in national conferences. Her areas of interests are Data Mining, Networks, Genetic Programming.

Dr. G. V. Jayaramaiah currently working as Professor in Electronics and Communication Engineering department at Dr. Ambedkar Institute of Technology, Bangalore. He received B.E. (Electrical engineering), and M.E. (Power Electronics) from Bangalore University, in 1990 and 1994 respectively and Ph.D from Indian Institute of Technology, Bombay (IIT-B) in April 2008.

