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Performance Amelioration of Standard Variants of Adaptive Schemes Operating in Heterogeneous Environment

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Abstract—The ruggedness of emerging single adaptive approach that performs well in all types of operating conditions has led to the development of composite adaptive strategy. In this regard, the fusion of particular decisions of single adaptive schemes through suitable fusion rules can provide a better final detection. Particularly, the fusion of cell-averaging (CA), ordered statistics (OS) and trimmed-mean (TM) procedures can enhance the overall detection performance. Our goal in this paper is to analyze this developed model when the operating environment is heterogeneous. A χ^2-distribution with two- and four-degrees of freedom is assumed for the fluctuation of primary and secondary extraneous targets. A closed form processor performance is derived for single pulse detection. The results show that for the non-homogeneous background the new approach is more practical. Particularly in multitarget situations, it exhibits higher robustness as compared to the CA, OS, or TM architectures. Additionally, the novel strategy has a homogeneous performance that surpasses performance of the classical Neyman-Pearson (N-P) detector, which can be employed as a yardstick for the analysis of different techniques in the CFAR world.

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1. INTRODUCTION

The emission of electromagnetic waves and collection of returned echos excited by objectives within its exploration area for detecting the nearby targets of interest and discarding those that do not relate to a particular application represent the mission of the radar. For the same goal, some objectives, such as clouds, can be considered as targets for some applications (related to meteorology) and as spurious signals (with respect to warfare) for others. In this regard, echo signals produced at the ground surface, sea surface or atmospheric masses are considered as interference and called clutter.

The magnitude of the clutter signal cannot be deduced by purely deterministic mechanisms. Therefore, its modeling requires the use of statistical techniques. On the other hand, the operating environment of modern radar systems has many sources of noise, and there are unwanted signals, which are artificially agitated from other sources of radiation. These undesirable signals can occupy the radar display fully and make targets very hard to follow.

In such type of systems fitted out with automatic detection circuits, an adaptive threshold sensing element, which has the feature of spontaneously regulating its sensitivity in accordance with the variation of interference power, must be employed for the purpose of sustaining a fixed rate of false alerts. A processor with this feature is called constant false alarm rate (CFAR) detector.

For this type of signal detection, the threshold of detection is established by estimating the level of local background noise power from the reference cells and multiplying it by a scaling factor, the value of which depends on the required rate of false alarm. The CFAR strategy is a pivotal element in radar receivers for detecting targets in their surveillance zone where the parameters of the statistical distribution of clutter are either unknown or non-stationary.

In this category of signal detection, the envelope detector output represents the input of the CFAR circuit, which is sampled in the range cells. These cells establish what is known as reference window. For this window, increasing the size of its elements can result in an enhancement of the chance of detection. It is clear

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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REFERENCES

1. A. R. Elias-Fusté, A. Broquetas-Ibars, J. P. Antequera, and J. C. M. Yuste, "CFAR data fusion center with inhomogeneous receivers," *IEEE Trans. Aerosp. Electron. Syst.* **28**, No. 1, 276 (1992). DOI: 10.1109/7.135453.
2. D. Ivkovic, M. Andric, and B. Zrnic, "Nonlinear fusion CFAR detector," in *Proceedings International Radar Symposium* (2015). DOI: 10.1109/IRS.2015.7226305.
3. M. B. El Mashade, "Monopulse detection analysis of the trimmed mean CFAR processor in nonhomogeneous situations," *IEE Proc. - Radar*, *Sonar Navig.* **143**, No. 2, 87 (1996). DOI: 10.1049/ip-rsn:19960324.
4. L. Zhao, W. Liu, X. Wu, and J. S. Fu, "A novel approach for CFAR processors design," in *IEEE National Radar Conference - Proceedings* (2001), pp. 284–288. DOI: 10.1109/nrc.2001.922992.

5. Y. Hu and J. Liang, "CFAR decision fusion approaches in the clustered radar sensor networks using LEACH and HEED," *Int. J. Distrib. Sens. Networks* **2015**, 1 (2015). DOI: 10.1155/2015/987526.
6. S. López-Estrada and R. Cumplido, "Fusion center with neural network for target detection in background clutter," in *Proceedings of the Mexican International Conference on Computer Science* **2005**, 189 (2005). DOI: 10.1109/ENC.2005.21.
7. M. B. El Mashade, "Analysis of Cell-Averaging based detectors for x2 fluctuating targets in multitarget environments," *J. Electron.* **23**, No. 6, 853 (Nov. 2006). DOI: 10.1007/s11767-005-0067-0.
8. W. Q. Wang, *Radar Systems: Technology*, *Principles*, *and Applications* (Nova Science Publishers, Inc, 2013).
9. M. B. El Mashade, "Analytical performance evaluation of adaptive detection of fluctuating radar targets," *Radioelectron. Commun. Syst.* **56**, No. 7, 321 (2013). DOI: 10.3103/S0735272713070017.
10. D. Ivkovic, B. Zrnic, and M. Andric, "Fusion CFAR detector in receiver of the software defined radar," in *Proceedings International Radar Symposium* (2013).
11. D. Ivkovic, M. Andric, and B. Zrnic, "Nonlinear fusion CFAR detector," in *Proceedings International Radar Symposium* **2015-August**, 481 (2015). DOI: 10.1109/IRS.2015.7226305.
12. D. Ivkovic, M. Andric, and B. Zrnic, "A new model of CFAR detector," *Frequenz* **68**, No. 3-4, 125 (2014). DOI: 10.1515/freq-2013-0087.
13. Y. Xu, C. Hou, S. Yan, J. Li, and C. Hao, "Fuzzy statistical normalization CFAR detector for non-Rayleigh data," *IEEE Trans. Aerosp. Electron. Syst.* **51**, No. 1, 383 (Jan. 2015). DOI: 10.1109/TAES.2014.130683.
14. D. Ivkovic, M. Andric, and B. Zrnic, "Detection of very close targets by fusion CFAR detectors," *Sci. Tech. Rev.* **66**, No. 3, 50 (2016). DOI: 10.5937/str1603050i.
15. M. B. El Mashade, "Performance Predominance of a New Strategy for CFAR Processors over the N-P Model in Detecting Four Degrees of Freedom $\chi 2$ Fluctuating Targets," *Radioelectron. Commun. Syst.* **61**, No. 9, 377 (2018). DOI: 10.3103/S0735272718090017.
16. J. R. Machado-Fernández, N. Mojena-Hernández, and J. de la C. Bacallao-Vidal, "Evaluation of CFAR detectors performance," *Iteckne* **14**, No. 2 (2017). DOI: 10.15332/iteckne.v14i2.1772.
17. J. R. Machado-Fernández and J. D. la C. Bacallao-Vidal, "Cell averaging CFAR detector with scale factor correction through the method of moments for the log-normal distribution," *Cienc. e Ing. Neogranadina* **28**, No. 1, 27 (May 2017). DOI: 10.18359/rcin.2408.
18. M. B. El Mashade, "Heterogeneous performance analysis of the new model of CFAR detectors for partially-correlated $\chi 2$-targets," *J. Syst. Eng. Electron.* **29**, No. 1, 1 (Feb. 2018). DOI: 10.21629/JSEE.2018.01.01.
19. H. Wang, Z. Tang, Y. Zhao, Y. Chen, Z. Zhu, and Y. Zhang, "Signal processing and target fusion detection via dual platform radar cooperative illumination," *Sensors* **19**, No. 24, 5341 (Dec. 2019). DOI: 10.3390/s19245341.