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Target Detection

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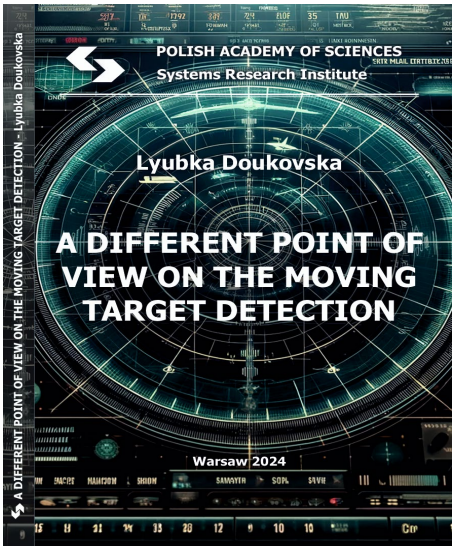

In 2024, the monograph "*A Different Point of View on the Moving Target Detection*" was published by the Systems Research Institute at the Polish Academy of Sciences as part of the series Systems Research, with scientific editor Prof. Olgierd Hryniewicz. The results presented in this book are applicable to solving a wide range of tasks in radiolocation, communications, medicine and other fields of research, processing infrared, ultrasound and other types of sensor signals. The relevance of the book is determined by the currently very modern trends in the design of highly efficient and fully automated systems for processing radar information in the conditions of a priori uncertainty about the targets and interference.

The relevance of the book is determined by the currently very modern trends in the design of highly efficient and fully automated systems for processing radar information in the conditions of a priori uncertainty about the targets and interferences. It consists of 3 chapters and begins with an introduction for the development of new, highly efficient radar information processing algorithms. Modern algorithms require the processing of large data streams using all available information about the observed radar situation.

Chapter 1 discusses an overview of the known methods and algorithms for the detection of moving targets, ensuring the keeping of a constant false alarm rate

(CFAR) in the conditions of an intense noise environment. The advantages and disadvantages of the considered methods and algorithms working in these conditions are indicated. On the basis of the literature review, the need to choose an appropriate structure of the CFAR detector of radar signals against the background of powerful and high-frequency chaotic impulse disturbances is substantiated [1].The mathematical model of the observed target is selected, according to the criteria for evaluating it's effectiveness. The selected algorithms are defined and a composite distribution obtained from the full probability characteristics [2]. The power and probability of appearance of the impulse disturbances are known a priori.

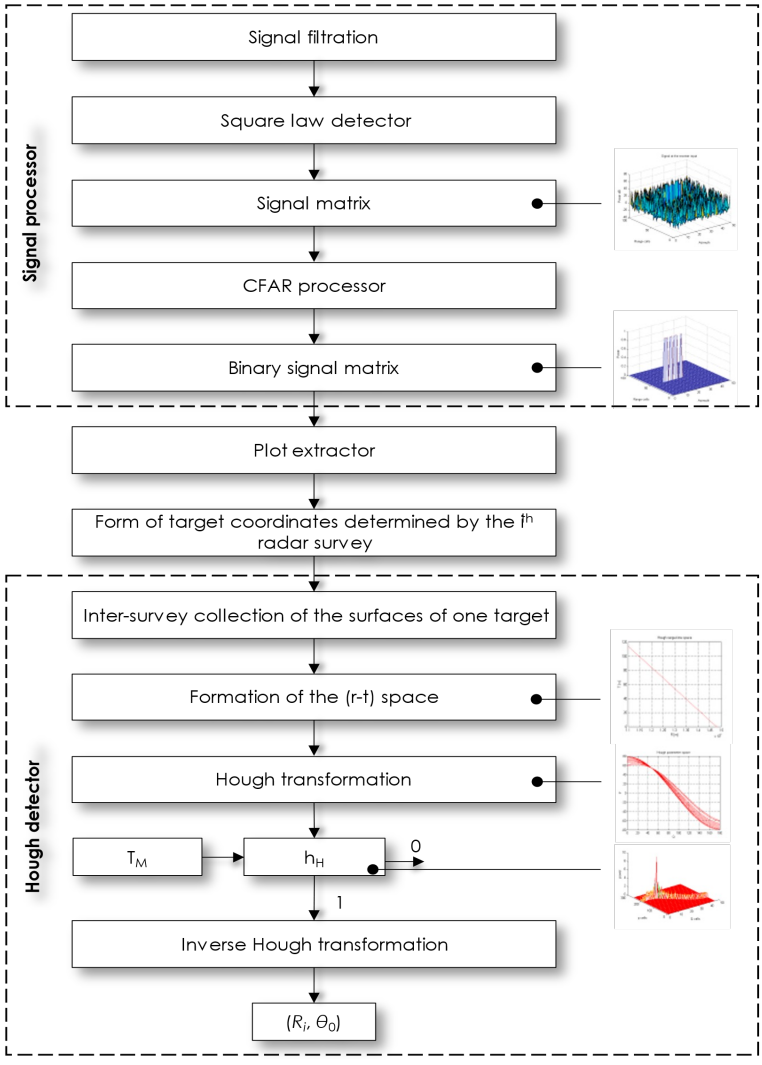

Fig. 1. The structure of the Hough detector

An analysis of the known applications of the Hough transform of signals in various fields of science was carried out. The block diagram of the algorithm of an adaptive Hough detector with binary data accumulation in the parameter space, including two stages of signal processing, is shown on Figure 1. The limited number of publications showing the effectiveness of the application of the Hough transform of radar signals in the task of detecting moving targets indicates the need for a thorough analysis of the field [3, 4, 5].The necessity of using various new combinations of known algorithms for simultaneous detection of trajectories and signals from the targets using Hough transformation in the conditions of pulse disturbances is substantiated. A statistical approach was used in the synthesis and analysis of signal processing algorithms. The behavior of a Hough detector, synthesized for white Gaussian noise, in the conditions of an intense flow of randomly appearing impulse disturbances was investigated [6, 7, 8].

The results obtained show the strong influence of impulse disturbances on its operation. In this practically real and unexplored situation, it does not support the false alarm probability and degrades the probability of detection of the target trajectory. This necessitates the use of different types of signal processors that ensure the keeping of a constant false alarm rate before applying the Hough transform under conditions of intensive pulse jamming.

Chapter 2 presents studies of conventional radar detectors for moving targets operating under conditions of Poisson or binomial flow of intense randomly arriving impulse interference. The considered structures of detectors ensure the keeping of a constant false alarm rate (CFAR) with the one-dimensional or two-dimensional signal processors in the conditions of an intense noise environment.

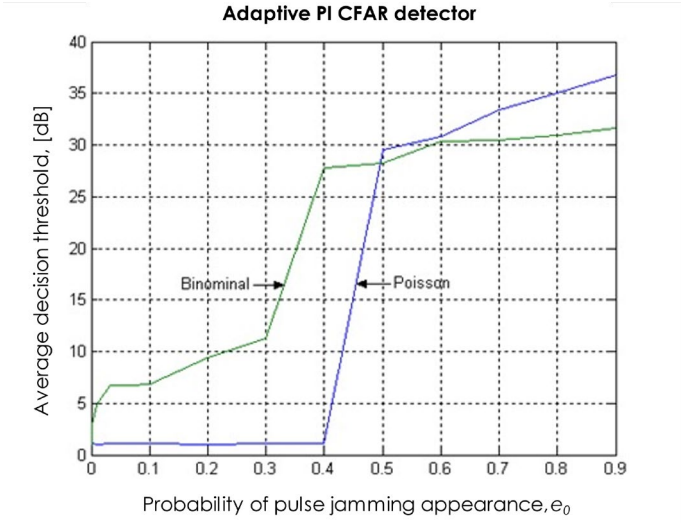

Fig. 2. Average detection threshold of an adaptive CFAR detector, for Poisson and binomial interference

The methodology for evaluating the performance of the considered signal detectors is proposed based on the use of the performance criterion of CFAR detectors, mean detection threshold [1, 9]. The performance of the detectors in keeping a constant false alarm probability is evaluated using probabilistic characterization techniques, signal-to-noise ratio and mean detection threshold. The problem is considered from several aspects, seeking a near-optimal solution for a fixed threshold, proposing solutions with an adaptive threshold. Optimal detection thresholds are found under Poisson and binomial flow conditions of randomly arriving impulse interferences. The average detection threshold of an adaptive CFAR detector with incoherent accumulation for Poisson or binomial impulse interference flow is shown on Figure 2.

The adaptive CFAR detector with incoherent signal accumulation has the lowest average detection threshold of the detectors studied for the given input situation. This is due to the fact that it uses a censoring procedure to remove the influence of the pulse interference in both the reference window and the tested cell. In the presence of interference with a relatively low probability of appearance, the censoring procedure of the adaptive CFAR detector with non-coherent clustering succeeds in removing the influence of the noise interference. It has been shown that the use of censoring and interference-adaptive techniques leads to a significant reduction of the losses expressed in terms of signal-to-noise ratio.

Chapter 3 investigates different structures of the Hough detectors, where a constant false alarm rate is guaranteed to be kept using the application of one-dimensional and two-dimensional signal processors operating under randomly arriving impulse interference conditions. In order to improve the detectability of the useful signal in the presence of a stream of high-intensity randomly arriving impulse interference, the influence of censoring and adaptive techniques applied in the detection process of the observed target is also investigated in the structure of the Hough detector. The considered Hough detectors are compared through their average detection thresholds. The optimal values of the binary decision rule in the Hough parameter space are determined for the considered Hough detectors [10, 11, 12]. Figure 3 shows the values of the threshold constants (the binary decision rules) in the Hough parameter space.

Various new structures of Hough detectors working together with one-dimensional and two-dimensional CFAR signal processors have been synthesized, ensuring the maintenance of a constant false alarm probability under conditions of intense impulse interference. Using the method of numerical experimentation, the probabilistic characteristics of the obtained structures in the conditions of randomly arriving impulse interference with Poisson and binomial law of appearance and Rayleigh fluctuation of the amplitudes were investigated. The sensitivity of the probabilistic characteristics of a Hough trajectory finder, operating in the conditions of an intense binomial flow of randomly arriving

impulse interference, to the change of the disturbance parameters, using an averaging CFAR processor with subsequent binary accumulation in the tested cell, was investigated. It is shown that the use of a two-dimensional binary CFAR processor significantly increases the detection quality.

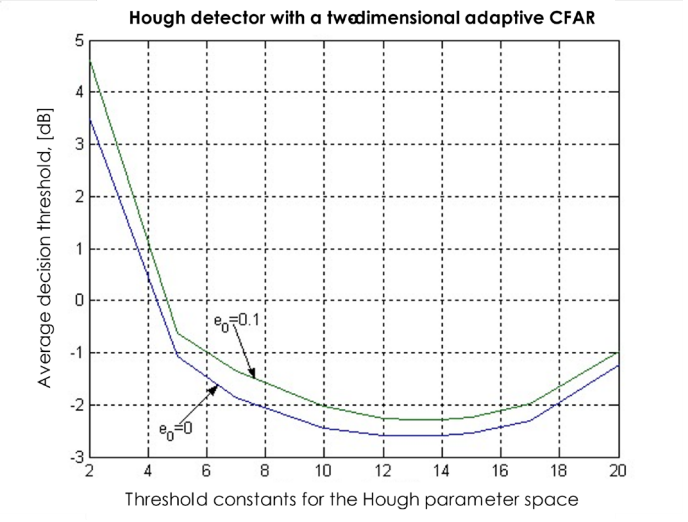

Fig. 3. Optimal values of threshold constants for the Hough parameter space with a two-dimensional adaptive CFAR processor with non-coherent accumulation

The performance of a Hough trajectory finder with a binary CFAR processor with a censoring procedure in the reference window is investigated. The hypothesis proposed in this book, that the use of censoring techniques increases the efficiency of the considered detectors by about 5 [dB], in the conditions of an intense binomial flow of randomly arriving impulse interference, has been confirmed [13]. The dependence of the probabilistic characteristics of a Hough trajectory finder with a two-dimensional adaptive CFAR processor with non-coherent accumulation, performing censoring of the reference window and the tested cell, in relation to the change of the probability of appearance of impulse disturbances, is investigated [14]. This structure is shown to be of the highest efficiency for the Poisson flow case of randomly arriving impulse interference. A comparative analysis of the performance of different Hough detectors' structures of trajectories and signals, which use one-dimensional and two-dimensional CFAR signal processors in their detection algorithm, is performed [15]. It is proposed that a Hough detector with a two-dimensional adaptive CFAR processor with non-coherent accumulation be used as the most efficient for operation in the environment of intense randomly arriving impulse interference with a Poisson distribution of appearance frequency. With a high probability, it is assumed that it will be most effective also in the conditions of a binomial flow of randomly arriving impulse interference.

The purpose of the book is to synthesize and investigate various approaches, methods and algorithms for detecting and determining the parameters of moving targets, providing a constant false alarm rate in the conditions of intense pulse jamming, as well as to evaluate the effectiveness of the newly obtained structures.

Today, the task of detecting moving targets in an environment of intense randomly impulse disturbances of intentional origin is of high priority. In modern communication and radar systems, the task of detecting and estimating signal parameters (i.e., estimating spatial coordinates) is fundamental. It is solved under different statistical uncertainty of the signal and disturbance parameters, i.e. under various types of signals and disturbances. Corresponding member Lyubka Doukovska's monograph is about the task of joint detection and estimation of the parameters of a moving target with the application of the Hough transform, using data for single or packet reflected signals from radar targets in the conditions of randomly arriving impulse interference, has been further developed. This is a very dynamic scientific field, in which artificial intelligence methods are rapidly developing, and this is the next challenge for the monograph's author [16, 17].

Finally, I would like to thank the publisher the Systems Research Institute at the Polish Academy of Sciences for their very good judgment in terms of the substantive monograph and proven professionalism in selecting the manuscripts for publication.

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