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Anna ŚLESICKA
Polish Air Force University
e-mail: a.slesicka@law.mil.pl; ORCID: 0000-0002-6313-030X

Błażej ŚLESICKI
Polish Air Force University
e-mail: b.slesicki@law.mil.pl; ORCID: 0000-0002-0857-1081

Jacek IWAŃSKI
Polish Air Force University
e-mail: j.iwanski@law.mil.pl

Andrzej TRUSKOWSKI
Polish Air Force University
e-mail: a.truskowski@law.mil.pl; ORCID: 0000-0002-4973-8183

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APPLICATION OF SPACE-TIME ADAPTIVE SIGNAL PROCESSING IN RADIOLOCATION

ZASTOSOWANIE PRZESTRZENNO-CZASOWEGO ADAPTACYJNEGO PRZETWARZANIA SYGNAŁU W RADIOLOKACJI

Abstract

We are currently witnessing a war in Ukraine and in Israel. Analyzing the modus operandi of the warring parties, it should be strongly emphasized that gaining an information advantage on the modern battlefield is a major factor in achieving success in a planned and subsequently conducted military operation. The use of radio-electronic systems, such as radar, for searching, tracking, intercepting and analyzing data from the surrounding reality provides such an opportunity, allowing to assess the potential of the opponent, and often to predict and anticipate his intention, thus ensuring the effective realization of one's own goals. In addition, by equipping radar with state-of-the-art signal processing techniques, the above becomes possible. One of the most modern techniques used in radiolocation is space-time adaptive signal processing technology. The purpose of this article was to analyze space-time adaptive signal processing technology as applied to an airborne radar mounted on a flying platform. The authors applied an analysis of the available literature and carried out computer simulations. In conclusion, the important role played by space-time adaptive

Streszczenie

Obecnie jesteśmy świadkami wojny w Ukrainie oraz w Izraelu. Analizując sposób działania walczących ze sobą stron należy podkreślić stanowczo, że uzyskanie przewagi informacyjnej na współczesnym polu walki jest głównym czynnikiem warunkującym osiągnięcie powodzenia w planowanej i później prowadzonej operacji zbrojnej. Wykorzystanie systemów radioelektronicznych, takich jak radar, do poszukiwania, śledzenia, przechwytu i analizy danych z otaczającej rzeczywistości daje taką możliwość, pozwalając ocenić potencjał przeciwnika, a często przewidzieć i wyprzedzić jego zamiar, zapewniając tym samym skuteczną realizację własnych celów. Dodatkowo wyposażając radar w najnowocześniejsze techniki przetwarzania sygnałów, powyższe staje się możliwe. Jedną z najnowocześniejszych technik stosowanych w radiolokacji jest technika przestrzenno-czasowego adaptacyjnego przetwarzania sygnałów. Celem artykułu było przeprowadzenie analizy technologii przestrzenno-czasowego adaptacyjnego przetwarzania sygnałów w zastosowaniu dla radaru pokładowego zamontowanego na platformie latającej. Autorzy zastosowali analizę dostępnej literatury oraz przeprowadzili symulacje komputerowe.

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signal processing of radar signals on today's battlefield was pointed out.

Keywords: radio warfare, radar, space-time adaptive signal processing, radiolocation, estimation of clutter covariance matrix, radar data cube

Podsumowując, wskazano na istotną rolę, jaką pełni na dzisiejszym polu walki przestrzenno-czasowe adaptacyjne przetwarzanie sygnałów radiolokacyjnych.

Słowa kluczowe: walka radioelektroniczna, radar, przestrzenno-czasowe adaptacyjne przetwarzanie sygnałów, radiolokacja, estymacja macierzy kowariancji zakłóceń, radarowa kostka danych

1. INTRODUCTION

Remote sensing is a technical field that enables situational awareness in both civilian and military applications. Radar systems in this case are sensors responsible for recording and interpreting received environmental signals from targets without being in direct contact with those targets. Space-Time Adaptive Processing (STAP) of signals is a modern signal processing technique used in radar systems. The STAP technique is used to detect targets moving on the ground through a radar system placed on a flying platform. The essence of STAP processing is the detection of a usually weak signal reflected from an target against a background of strong interference[1].

STAP technology has been developed worldwide in fact since the early 1970s[2]. However, it is only in the last decade or so that there has been an increase in the amount of scientific research stimulating the development of STAP signal processing algorithms in the world literature. The development of radio reconnaissance and combat systems, including radars, would not have been possible if it were not for STAP technology[3]. The applications of STAP technology are wide-ranging. This paper focuses on the application of STAP technology to a side looking airborne radar mounted on a flying platform for scanning the ground surface, suppressing interference and detecting slow-moving target.

The purpose of STAP is to detect the signal coming from a moving target against a background of strong passive and active interference. In the literature, radar interference is divided into passive interference (clutter) and active interference (jammer). On the ground, there are many elements responsible for the existence of passive interference such as immobile terrain obstacles, buildings and the environment. Passive interference, which is the result of electromagnetic wave reflection from stationary terrain obstacles, occurs in the received echo signal and usually almost completely covers the present signal coming from an target that is moving on the ground surface with a non-zero velocity value. The presence of the passive interference component is the result of the Doppler effect, that is, the presence of relative velocity between stationary obstacles and a moving aircraft with radar installed. Sources of active interference are interference transmitters that are targeted means of enemy radio warfare.

1 J.R. Guerci, Space-Time Adaptive Processing for Radar, Norwood, Artech House, 2014, p. 32.

2 I.D. Reed, J.D. Mallett, L.E. Brennan, Rapid convergence rate in adaptive arrays, IEEE Trans. Aerosp. Electron. Syst., vol. 10, no. 6, 1974, p. 853–863.

3 R. Klemm, Space-time Adaptive Processing: Principles and Applications, London: The Institution of Electrical Engineers, 1998, p. 14.

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Therefore, the STAP technique in such a diverse environment is an essential tool for eliminating both types of interference - as can be observed in Figure 1.

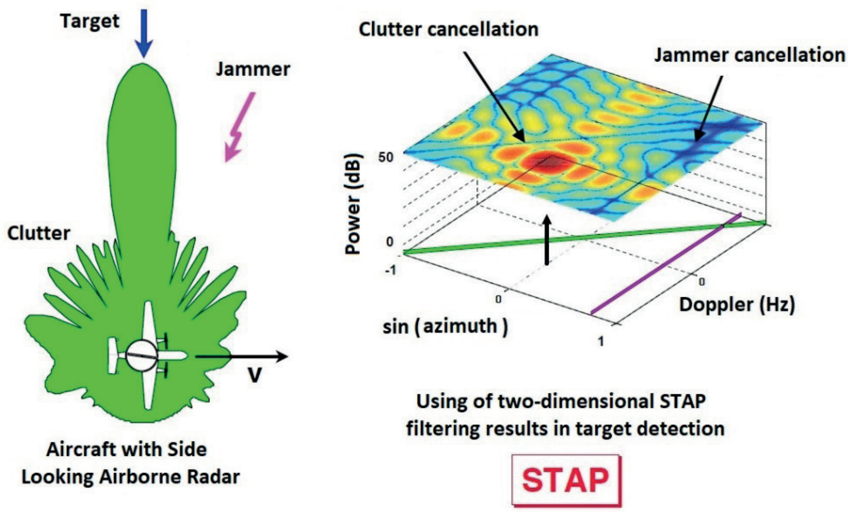

Fig. 1. The idea of STAP
Source: own elaboration based on J.R. Guerci, Space-Time…, op. cit., p. 32.

The purpose of this paper was to introduce STAP technology, discuss the next steps in STAP processing using estimation of clutter covariance matrix with the Sample Matrix Inversion (SMI) algorithm, and present simulation results of applying STAP technology in the MATLAB environment.

Theoretical research methods, such as the analysis and synthesis of information contained in the literature and source materials, as well as the computer simulation method, were used to develop the article.

2. SIGNAL AND RADAR MODEL

To model the geometry of the radar and the flying platform, the scheme shown in Figure 2 was assumed. The target labeled *O* in the figure is located relative to the radar at a distance Rs , the elevation angle between them is θ while the azimuth angle is φ. An aircraft flying at altitude H, travels along a straight line at a constant velocity Va, and the radar placed on it usually has a uniform linear array (ULA) that irradiates the target *O* at an angle α.

Side looking airborne radar usually operates at a carrier frequency f_c derived from the microwave range, transmits a sequence of M coherent pulses of electromagnetic wave with pulse repetition frequency f_r through N antennas, whose mutual distance in an array is d.

The electromagnetic wave pulses reach targets on the ground, which scatter them to varying degrees. Only part of the electromagnetic wave energy is reflected toward the radar antennas mounted on the flying platform.

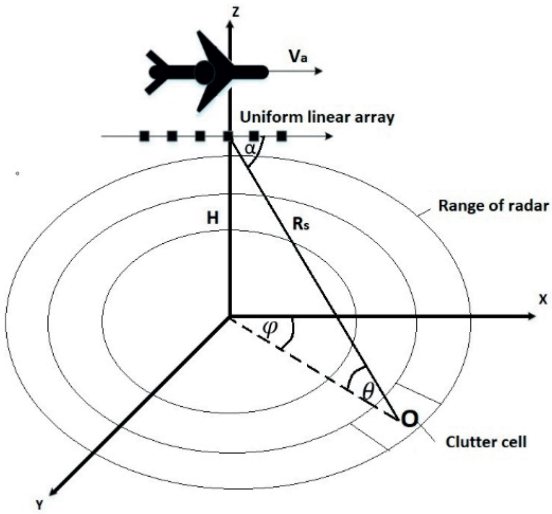

Fig. 2. Scheme of the geometry of the radar and flying platform
Source: own elaboration based on J.R. Guerci, Space-Time..., op. cit.

The received echo is usually represented in the form of a radar data cube. Given the above designations, the radar data cube will consist of composite signal samples collected for M pulses by an N antennas for distance cells from 1 to K. The radar data cube thus described is shown in Figure 3.

The data contained in the kth distance cell, that is, for the kth cross-section of the raw cube, can be represented as a matrix[4]:

$$\boldsymbol{X_k} = \begin{bmatrix} x_{k,1,1} & x_{k,1,2} & \cdots & x_{k,1,N} \\ x_{k,2,1} & x_{k,2,2} & \cdots & x_{k,2,N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{k,M,1} & x_{k,M,2} & \cdots & x_{k,M,N} \end{bmatrix} \tag{1}$$

4 W.L. Melvin, A STAP overview, IEEE Transactions on Aerospace and Electronics Systems Magazine, vol. 19, no. 1, 2004, p. 19–53.

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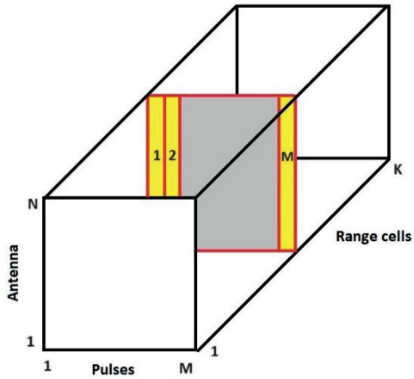

Fig. 3. Radar data cube

Source: own elaboration based on J.R. Guerci, Space-Time…, op. cit.

For further processing, the matrix must be transformed into a vector, which will take the form:

$$\boldsymbol{X_k} = [x_{k,1,1} \quad x_{k,2,1} \quad \cdots \quad x_{k,M,1} \quad x_{k,1,2} \quad \cdots \quad x_{k,1,N} \quad \cdots \quad x_{k,M,N}] \tag{2}$$

Figure 4 shows the steps of transforming the matrix into a vector, where X_k denotes the space-time cross-section of the radar data cube for a given k distance cell, and X_{mk} denotes the spatial cross section for the MTh pulse and the kth distance cell.

The received echo X_k is the sum of the component signals from the target S_k, passive interference C_k, active interference J_k and noise N_k, which is shown below as

$$\boldsymbol{X_k} = \boldsymbol{S_k} + \boldsymbol{C_k} + \boldsymbol{J_k} + \boldsymbol{N_k} \tag{3}$$

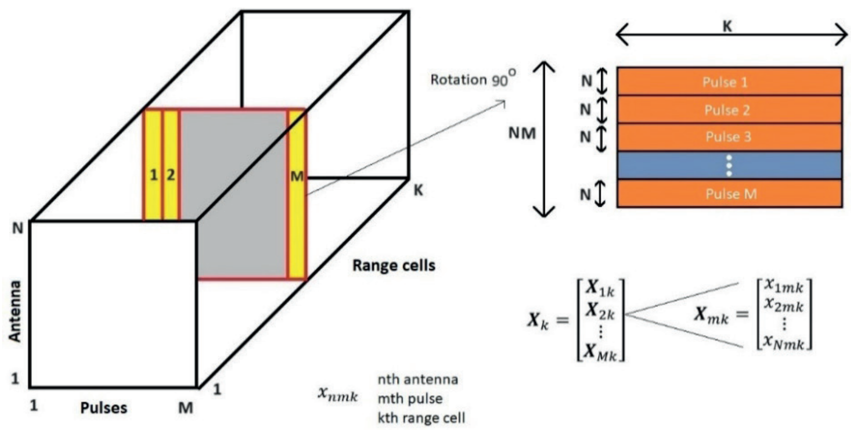

Fig. 4. Rotation of radar data cube

Source: own elaboration based on J.R. Guerci, Space-Time…, op. cit.

3. STAGES OF STAP PROCESSING

Figure 5 shows the subsequent stages of STAP processing. The red color indicates the key processing stage, which is the estimation of the clutter covariance matrix. In the literature, two types of methods for estimating the clutter covariance matrix should be distinguished - statistical and non-statistical.

Until the late 1990s, STAP algorithms were based on statistical methods for estimating the clutter covariance matrix. A very popular method, which later often served as a reference for new methods, was the Sample Matrix Inversion (SMI) method. The SMI method was used in this article.

A breakthrough in scientific research on the development of methods for estimating interference covariance matrices was the work of , which presented for the first time a new type of non-statistical methods for estimating clutter covariance matrices - Direct Data Domain (D3) methods, often referred to by the acronym D3.

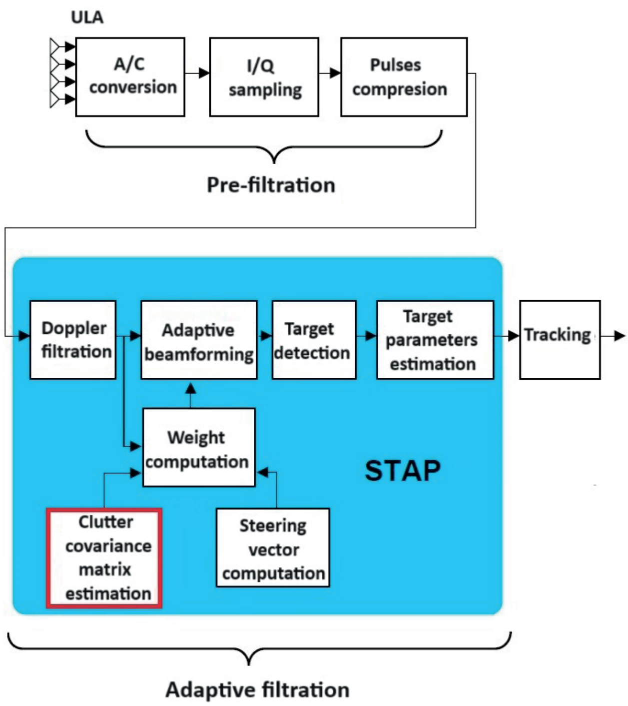

Fig. 5. STAP processing steps

Source: own elaboration based on J.R. Guerci, Space-Time..., op. cit..

Subsequently, research on statistical methods for estimating clutter covariance matrices was discontinued, which seems appropriate, given the drawbacks with which they were characterized. The main ones include the need to access a huge amount

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of training data contained in distance cells, which was not infrequently difficult to meet. In the following years, efforts were made to introduce improvements to D3 methods by eliminating the disadvantages that occurred, which caused phenomena such as difficulties in detecting an target against a background of inhomogeneous interference or mistaken detection of target[5].

A completely different approach turned out to be a method for estimating the clutter covariance matrix based on knowledge of the terrain scanned by the radar or the targets present. The new type of non-statistical methods was called KA-STAP (Knowledged-Aided STAP)[6].

In recent years, it is important to note a new research direction in the development of non-statistical methods for the estimation of clutter covariance matrices. In the literature of this article you can find a whole series of scientific papers on the use of sparse recovery algorithms in STAP[7].

The authors of this paper are the developers of both a statistical[8] method for estimating the clutter covariance matrix and a non-statistical[9] one.

The first step in STAP processing is to determine the steering vector $S(f_{sp}, f_d)$ for each target. This vector is the Kronecker product of the steering vector in the time domain $S_t(f_d)$ and the steering vector in the spatial domain $S_{sp}(f_{sp})$. The steering vector in the time domain is shown as[10]:

$$\boldsymbol{S_t}(f_d) = e^{j2\pi(M-1)f_d} \tag{4}$$

where f_d is the Doppler frequency shift, which is expressed as:

$$f_d = \frac{2 \cdot V_r}{\lambda} \tag{5}$$

where V_r is the radial velocity between the target and the radar. The steering vector in the spatial domain is given as:

$$\boldsymbol{S_{sp}}\left(f_{sp}\right) = e^{j2\pi(N-1)f_{sp}} \tag{6}$$

where f_{sp} is the spatial frequency, which is expressed by the relation:

$$f_{sp} = \frac{d}{\lambda}\cos(\alpha) \tag{7}$$

5 K. Sun, Y. Meng, Y. Wang, X. Wang, Direct data domain STAP using sparse representation of clutter spectrum, Signal Processing, vol. 91, no. 9, 2011, p. 2222–2236.

6 H. Jeon, Y. Chung, W. Chung, Clutter covariance matrix estimation using weight vectors in Knowledge--aided STAP, IET Electronics Letters, vol. 53, no. 8, 2017, p. 560.

7 W. Zang, Reduced dimension STAP based on sparse recovery in heterogeneous clutter environments, IEEE Trans. on Aerospace and Electronics Systems, vol. 56, no. 1, 2020, p. 785.

8 A. Ślesicka, B. Ślesicki, A. Kawalec, A new statistical method for determining the clutter covariance matrix in spatial-temporal adaptive processing of a radar signal, Sensors, vol. 23, no. 9, 2023, p. 4280.

9 A. Ślesicka, A. Kawalec, An application of the orthogonal matching pursuit algorithm in space-time adaptive processing, Sensors, vol. 20, no. 12, 2020, p. 3468.

10 W.L. Melvin, A STAP overview, IEEE Transactions on Aerospace and Electronics Systems Magazine, vol. 19, no. 1, 2004, p. 19–53.

Finally, the steering vector can be represented as[11]:

$$\boldsymbol{S}\left(f_{sp}, f_d\right) = \boldsymbol{S_t}(f_d) \otimes \boldsymbol{S_{sp}}(f_{sp}) = \begin{bmatrix} 1 \cdot 1 \\ e^{j2\pi f_{sp}} \cdot 1 \\ e^{j2\pi 2 f_{sp}} \cdot 1 \\ \vdots \\ e^{j2\pi(M-1)f_{sp}} \cdot 1 \\ 1 \cdot e^{j2\pi f_d} \\ e^{j2\pi f_{sp}} \cdot e^{j2\pi f_d} \\ \vdots \\ e^{j2\pi(M-1)f_{sp}} \cdot e^{j2\pi(N-1)f_d} \end{bmatrix} \tag{8}$$

where the symbol ⊗ stands for Kronecker product.

The next step is to determine the clutter covariance matrix. For this purpose, the distance cell under test k is divided into N_c cells of clutter. It is also assumed that the clutter for a given distance cell is a superposition of the signal coming from each clutter cell. Hence, the clutter covariance matrix, active interference and noise for a given cross-section of the radar data cube is given respectively as[12]:

$$\boldsymbol{R}_c = E\{\boldsymbol{C}_k \boldsymbol{C}_k^H\} = \sigma^2 \sum_{i=1}^{N_c} CNR \boldsymbol{S}_i\left(f_{sp}, f_d\right) \boldsymbol{S}_i^H\left(f_{sp}, f_d\right) \tag{9}$$

$$\boldsymbol{R}_j = E\{\boldsymbol{J}_k \boldsymbol{J}_k^H\} = I_M \otimes \sigma^2 JNR \boldsymbol{S}_j\left(f_{sp}, f_d\right) \boldsymbol{S}_j^H\left(f_{sp}, f_d\right) \tag{10}$$

$$\boldsymbol{R}_n = E\{\boldsymbol{N}_k \boldsymbol{N}_k^H\} = \sigma^2 I_{MN} \tag{11}$$

where σ is the power of the interference source, CNR is the clutter to noise ratio (CNR) measured in decibels, JNR is the jammer to noise ratio (JNR) measured in decibels, $\boldsymbol{S}_i(f_{sp}, f_d)$ is the steering vector of a particular jammer cell, $\boldsymbol{S}_j(f_{sp}, f_d)$ is the steering vector of a particular active interference source, while I_M and I_{MN} denote the unit matrix of dimension $M \times M$ and $M \times N$, respectively. Hence, the covariance matrix of the sum of interference and noise is given by the relation:

$$\boldsymbol{R_k} = \boldsymbol{R_c} + \boldsymbol{R_j} + \boldsymbol{R_n} \tag{12}$$

By determining the steering vector and the covariance matrix of the sum of interference and noise, determine the vector of weights:

$$\boldsymbol{w_k} = \varepsilon \cdot \boldsymbol{R_k^{-1}} \cdot \boldsymbol{S}\left(f_{sp}, f_d\right) \tag{13}$$

where ε is a scalar, $\boldsymbol{R_k^{-1}}$ is the inverse covariance matrix of the sum of noise and interference. $\boldsymbol{S}(f_{sp}, f_d)$ is the steering vector for one target to be detected. In practice, both $\boldsymbol{R_k^{-1}}$ and $\boldsymbol{S}(f_{sp}, f_d)$ are unknown.

The STAP processor is a linear filter, so ultimately the STAP processor is designed to remove noise and detect the target. The relationship describing these actions is given as[13]:

$$Y_k = \boldsymbol{w_k^H} \cdot \boldsymbol{X_k} \tag{14}$$

11 Ibidem.
12 W.L. Melvin, A STAP overview..., op. cit.
13 Ibidem.

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where Y_k is the resulting scalar. The symbol H denotes the composite transpose of the given matrix.

The problem of the target's missing steering vector is solved by using a test grid[14]. This article uses a statistical method to determine the clutter covariance matrix based on the Sample Matrix Inversion (SMI) method[15].

The final step in STAP processing is to define and verify hypotheses about the presence or absence of the desired target. Hypotheses are defined as:

$$H_0: \boldsymbol{X_k} = \boldsymbol{C_k} + \boldsymbol{J_k} + \boldsymbol{N_k} \tag{15}$$

$$H_1: \boldsymbol{X_k} = \boldsymbol{S_k} + \boldsymbol{C_k} + \boldsymbol{J_k} + \boldsymbol{N_k} \tag{16}$$

where H_0 denotes the hypothesis of the absence of the target, and H_1 denotes the alternative hypothesis. The value of ε being a scalar in the weight vector relation (13) can be determined by knowing the surrogate control vector $\boldsymbol{v}_{s-t}$ and the inverse covariance matrix of the sum of interference and noise $\boldsymbol{R_k^{-1}}$, as:

$$\varepsilon = \frac{1}{\sqrt{\boldsymbol{v}_{s-t}^H \boldsymbol{R_k^{-1}} \boldsymbol{v}_{s-t}}} \tag{17}$$

The test statistic for the presence of a target is given as[16]:

$$\eta = \frac{\left|\boldsymbol{v}_{s-t}^H \boldsymbol{R_k^{-1}} \boldsymbol{X_k}\right|^2}{\boldsymbol{v}_{s-t}^H \boldsymbol{R_k^{-1}} \boldsymbol{v}_{s-t}} \tag{18}$$

The given test statistic is characterized by the property of Constant False Alarm Ratio (CFAR). As a result, the actual two-dimensional map of the test statistic was obtained, being the output of the STAP filter.

Finally, the obtained value η is compared with the accepted decision threshold value γ. The situation when $\eta < \gamma$ means no target, otherwise the target has been detected.

4. SIMULATIONS AND TEST RESULTS

In order to confirm the relevance of using space-time adaptive processing of radar signals, computer simulations were carried out in the MATLAB environment. An environment in which an target was placed at a given location was simulated, and the occurrence of clutter and jammer in the form of an interference transmitter was simulated.

A radar system of 10 antennas operating at 10 GHz was assumed. The distance between the antennas was chosen to be equal to half the wavelength, in this case 0.015 m. The radar was mounted on a flying platform moving along the axis of the antennas at a constant speed equal to 230 m/s at an altitude of 1000 m. For such an

[14] Ibidem.

[15] A. Ślesicka, Application of the orthogonal matching pursuit algorithm to determine the clutter matrix in space-time adaptive signal processing, Doctoral thesis, Military University of Technology, Warsaw, 2021, p. 100.

[16] W.L. Melvin, A STAP overview..., op. cit.

assumed value of velocity and pulse repetition frequency, the value of the parameter β is equal to 1. The value of the target's radar cross-section was set equal to 1 m^2.

Table 1. Target, clutter and jammer parameters

Parameter	**Values**
Velocity vector of target [x, y, z]	[20 m/s, 30 m/s, 30 m/s]
Location of target	x = 900; y = 1100; z = 0
Target's radar cross section	1 m^2
Jammer transmitter power	115 W
Location of jammer [x, y, z]	x = 1900; y = 2900; z = 0
Noise	White Gauss noise

Table 2. Radar parameter

Parameter	Values
Radar operating frequency	10 GHz
Wavelength	0.03 m
Sampling frequency	6 MHz
Pulse duration	33 µs
Pulse repetition frequency	30 kHz
Number of pulses	8
Range	5000 m
Number of antennas	10
Distance between antennas	0.015 m
Transmitter power	6.5 kW
Gain	25 dB
Height	1000 m
Platform velocity	230 m/s

A frequently used model of heterogeneous forest-covered terrain, referred to in the MATLAB environment as the gamma model, was adopted as clutter. In addition, an jammer transmitter was placed in the field. The above tables show the target, interference and radar data, respectively.

As a result of the simulation, a sequence of 8 pulses was transmitted through the antenna array, with a pulse repetition frequency equal to 30 kHz and a pulse duration equal to 33 µs. Then, the signal reflected from the target but also clutter from the ground surface, the interference signal from the transmitter and noise on the receiving side were received.

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Figure 6 shows the values of received signals by the radar's antenna array as a function of range, after transmitting the first pulse. At this stage, the received signals form a data cube of three dimensions (number of distance cells x number of pulses x number of antennas), which has not yet been processed by the STAP algorithm. As a result, the radar, against a background of strong interference, is unable to indicate the location of the target. As can easily be seen, the radar erroneously indicates that the target is at a distance of 1000 meters from the radar.

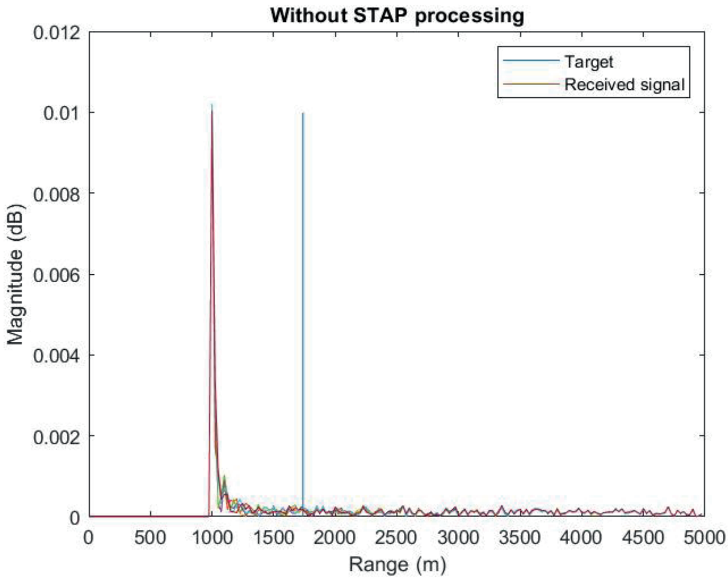

Fig. 6. Values of received signals by the radar antenna array as a function of range, after transmitting the first pulse before STAP processing

Source: own elaboration based on J.R. Guerci, Space-Time..., op. cit.

Figure 7 shows the values of received signals by the radar's antenna array as a function of range, after transmitting the first pulse. However, this time, the raw data was subjected to STAP processing by implementing the STAP algorithm in the MATLAB environment. As can easily be seen, the radar correctly indicates that the target is at a distance of about 1700 meters from the radar in a straight line.

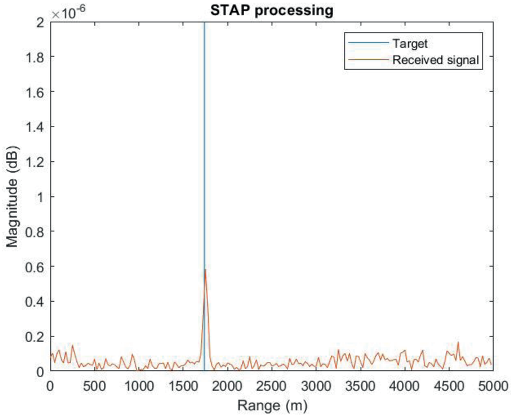

Fig. 7. Values of received signals by the radar antenna array as a function of range, after transmitting the first pulse after STAP processing

Source: own elaboration based on J.R. Guerci, Space-Time..., op. cit.

Figure 8 also shows the values of received signals by the radar antenna array as a function of range, after transmitting the first pulse, but on the spatial-temporal plane. As can be seen, both clutter and jammer occurs at virtually every Doppler frequency. This is due to the movement of the flying platform and the non-zero value of the Doppler frequency shift between the platform and stationary terrain objects. In addition, the exact location of the target is plotted to show the extent to which the signal value from the target is obscured by unwanted interference.

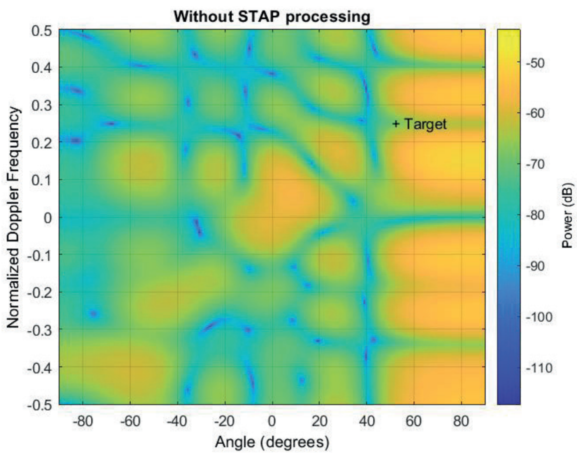

Fig. 8. Values of received signals by the radar antenna array as a function of range, after transmitting the first pulse before STAP processing on the spatial-temporal plane

Source: own elaboration based on J.R. Guerci, Space-Time..., op. cit.

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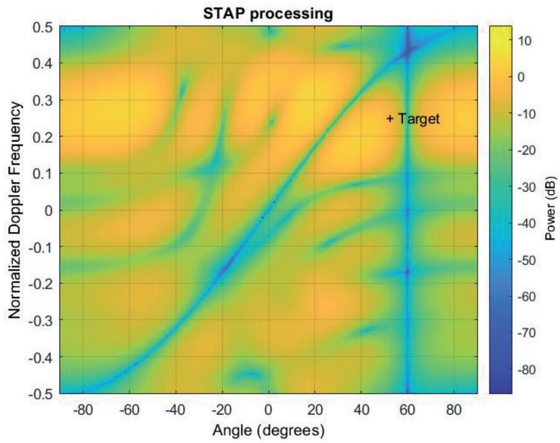

Fig. 9. Values of received signals by the radar antenna array as a function of range, after transmitting the first pulse before STAP processing on the spatial-temporal plane

Source: own elaboration based on J.R. Guerci, Space-Time…, op. cit.

Figure 9 shows the values of received signals by the radar antenna array as a function of range, after transmitting the first pulse, on the spatial-temporal plane. In the figure in question, two characteristic areas of blue color can be seen, that is, with the lowest value of signal power specified in decibels. The first area stretching vertically along the entire set of Doppler frequencies for an azimuth of about 60° indicates the complete elimination of active interference radiated by the jammer transmitter.

The second blue area extends along the diagonal of the graph. According to the research literature, this marks the clutter ridge. Again, the proposed STAP algorithm removed the components that are cluuter, as evidenced by the aforementioned blue area with the smallest signal value along the diagonal of the graph.

Table 3 summarizes the results of the above simulation. The direct distance of the radar to the target was 1737 meters, which directly translated into the elevation angle of the radar relative to the target (-35.13°).

Table 3. Simulation results

Parameter	Values
Azimuth of the radar relative to the target	50.71°
Radar elevation relative to the target	-35.13°
Radar-target distance	1737 m
Accidental radar-target relative velocity	112.87 m/s
Doppler frequency shift radar-target	7530 Hz
Normalized Doppler frequency	0.2512

The execution of the simulation was guided by two goals. The first goal was to comprehensively implement the STAP algorithm and environment together with a flying platform with radar designed to detect the target, as well as eliminate non-uniform interference. The second goal was to recreate the environment as close to real as possible. This was due to the lack of research done practically. The precise target data obtained lead us to believe that it is expedient to use space-time adaptive signal processing algorithms in airborne radars.

5. SUMMARY – CONCLUSIONS

The article is devoted to the analysis of space-time adaptive signal processing.

First, the theoretical basis of STAP processing and the individual steps of the classical SMI STAP processing algorithm are presented. Next, a critical analysis of previous and currently used methods of estimating of the clutter covariance matrix was made. Statistical and non-statistical methods were compared. The area of research development of current STAP methods was indicated. Finally, the essence of using STAP processing was experimentally verified on the basis of computer simulations.

The article identified the latest technical solutions in the field of digital processing of radar signals, which include space-time adaptive processing. The use of radio-electronic systems such as on-board radar, equipped with the latest STAP algorithms, can be a key tool for searching, tracking, intercepting and analyzing data from the surrounding reality, allowing to assess the potential of the enemy, and often to predict and anticipate his intention, thus ensuring the effective realization of their own goals.

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