PROCEEDINGS

of the Union of Scientists - Ruse

Book 5

Mathematics, Informatics and Physics

Volume 9, 2012

RUSE

The Ruse Branch of the Union of Scientists in Bulgaria was founded in 1956. Its first Chairman was Prof. Stoyan Petrov. He was followed by Prof. Trifon Georgiev, Prof. Kolyo Vasilev, Prof. Georgi Popov, Prof. Mityo Kanev, Assoc. Prof. Boris Borisov, Prof. Emil Marinov, Prof. Hristo Beloev. The individual members number nearly 300 recognized scientists from Ruse, organized in 13 scientific sections. There are several collective members too – organizations and companies from Ruse, known for their success in the field of science and higher education, or their applied research activities. The activities of the Union of Scientists – Ruse are numerous: scientific, educational and other humanitarian events directly related to hot issues in the development of Ruse region, including its infrastructure, environment, history and future development; commitment to the development of the scientific organizations in Ruse, the professional development and growth of the scientists and the protection of their individual rights.

The Union of Scientists – Ruse (US – Ruse) organizes publishing of scientific and popular informative literature, and since 1998 – the “Proceedings of the Union of Scientists- Ruse".

BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 9

CONTENTS

Mathematics

Tsetska Rashkova 7
Grassmann algebra’s PI-properties in matrix algebras with Grassmann entries

Antoaneta Mihova 15
A comparison of two methods for calculation with Grassmann numbers

Mihail Kirilov 21
δ - Characteristic sets for finite state acceptor

Mihail Kirilov 25
λ - Characteristic sets for finite Mealy automaton

Veselina Evtimova 29
Research on the utilization of transport vehicles in an emergency medical care center

Valerij Djurov, Milena Kostova, Ivan Georgiev 35
A mathematical model system for radiolocational image reconstruction of dynamic object with low radiolocational visibility

Informatics

Tzvetomir Vassilev 41
Soft shadows for GPU based ray-tracing

Rumen Rusev, Ana Kaneva 47
Software module for spectral analysis of audio signals

Galina Atanasova, Plamenka Hristova, Katalina Grigorova 52
An approach to flow charts comparing

Valentin Velikov 60
Computer viruses and effectively protection of the home users

Georgi Krastev 66
Nonhierarchical method for clustering

Valentina Voinohovska, Svetlozar Tsankov 70
Corporate presence web site for dental clinic

Metodi Dimitrov 76
Global repository for sequences of robots instructions

Svetlozar Tsankov, Valentina Voinohovska 79
(X)HTML E-handbook in the discipline "Multimedia systems and technologies" for teaching and learning purposes

Physics

Galina Krumova 85
Momentum distributions of medium and heavy neutron-rich nuclei

Galina Krumova 92
Deformation effects on density and momentum distributions of 98kr nucleus

A MATHEMATICAL MODEL SYSTEM FOR RADIOLOCATIONAL IMAGE RECONSTRUCTION OF DYNAMIC OBJECT WITH LOW RADIOLOCATIONAL VISIBILITY

Valerij Djurov, Milena Kostova, Ivan Georgiev

Angel Kanchev University of Ruse

***Abstract**: A mathematical model of a system for reconstruction of aircraft radiolocational image, constructed using modern technology for radiolocational visibility reduction, so called metamaterial, is offered. Linear orthogonal frequency drilling signals and principles of the inverse synthetic aperture radar are used. Images of aircraft F117 are received by software implementation of the mathematic model with horizontal and vertical polarization of the drilling signal. The guidelines for the created model application are indicated for increasing the qality when radiolocation images are restored.*

***Keywords**: Mathematical Model, Orthogonal Signals, Fourier Transformation, Inverse Synthetic Aperture Radar.*

INTRODUCTION

One of the main objectives of radiolocational recognition is to determine the type of the observed object. This can be achieved by radiolocational image reconstruction (RIR) of the observed aircraft. The variety of flying objects and construct decisions for reducing their radiolocational visibility poses challenges to professionals working in radio intelligence. These challenges are greater at objects with low radiolocational visibility because of the use of composite materials and technologies, causing new physical properties and phenomena [11]. Modern technology for reducing the radiolocational visibility is so called metamaterial [3]. This is a matter with certain microscopic structures whereby some specific properties such as negative refraction coefficient, reverse Doppler effect, Cherenkov effect and others are achieved. A mathematical model of approach for RIR of objects filled with metamaterial, is presented. The approach is based on parallel processing of radiolocational information by object, using drilling orthogonal linear frequency modulated signals (OLFMS).

MATHEMATICAL MODEL OF A SYSTEM FOR PARALLEL PROCESSING OF RADIOLOCATIONAL IMAGE USING DRILLING ORTHOGONAL LINEAR FREQUENCY MODULATED SIGNALS

Signals used in radiolocation depend on the technical, technological and structural characteristics of the radiolocational systems. The choice of them is related to the purpose of the radar observation and the specificity of the observed dynamic object [4,10]. The use of complex signals is dictated by the development of modern technologies (Stealth technologies, plasma cover, metamatter), aiming to reduce the radiolocational visibility of dynamic objects.

Multi-frequency signals as a complex signals with wide base can be also used for obtaining images from objects with low effective reflective surface [2,5,6,9,10]. Radiolocational images of dynamic objects can be realized using: linear frequency modulated signal, linear frequency modulated signal with a step-change of carrier frequency, discrete set of components of the carrier frequency changing by a certain law [1,2].

Tests had been developed for receiving RIR of objects surrounded by Stealth technology [4,7] using drilling linear frequency modulated signals, which don’t give sufficiently good results at objects with metamatter. This determines the necessity of applying different approach with using OLFMS. Modern communication systems use “orthogonal signals” OFDM (Orthogonal Frequency Division Multiplexing) [1,9].

Mathematical models of two parallel working systems with OLFMS appliance, respectively vertical polarized with index (V) and horizontal polarized with index (H) using the theory of inverse aperture synthesis are presented. The two algorithms are combined in one mathematical model.

The object is presented in discrete form as a set of discrete point emitters (m,n), situated in a rectangular Euclid grid $O^{'}XY$ standing at a distance $\Delta X, \Delta Y$, respectively at axes $O^{'}X$ and $O^{'}Y$. It is accepted that the object's geometrical center matches with the beginning of the coordinate system $O^{'}$ [4]. The coordinates of every (m,n)-th pointer emitter ($m=\overline{1,M}$; $n=\overline{1,N}$) in the coordinate system $O^{'}XY$ have the following form:

(1) $$X_{mn} = n\Delta X$$

(2) $$Y_{mn} = m\Delta Y$$

The matrices $[X],[Y]$ are formed with scale $(M \times N)$ and with elements - the values X_{mn}, Y_{mn}. The coordinates of every simple reflector against the coordinate system Oxy are changing during the process of synthesizing the aperture. The law of change is given with a matrix equation [7]:

(3) $$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix} - T_p\left(\frac{N_p^{V(H)}}{2} - p\right)\begin{bmatrix} V_x \\ V_y \end{bmatrix} + A_{tr}\begin{bmatrix} X \\ Y \end{bmatrix},$$

where $p=\overline{1,N_p^{V(H)}}$ is the number of the current drilling impulse for vertical and horizontal polarized frequency,

$N_p^{V(H)}$ is the total impulse number in the sequence for every vertical and horizontal polarized frequency;

x_0, y_0 are coordinates of p. $O^{'}$ in the coordinate system Oxy at moment $p = \frac{N_p^{V(H)}}{2}$;

$T_p^{V(H)}$ is an impulse repetition period for drilling orthogonal signal;

V_x, V_y are speed vector components at corresponding axis;

(4) $$A_{tr} = \begin{bmatrix} \cos(\varphi) & -\sin(\varphi) \\ \sin(\varphi) & \cos(\varphi) \end{bmatrix}$$ - matrix of transformation.

The distance to each point (m,n) of the object space, for every p-th impulse from the sequence of drilling impulses is determined by the equation:

(5) $$R_{mn}(p) = \sqrt{x_{mn}^2(p) + y_{mn}^2(p)}$$, where $p=\overline{1,N_p^{V(H)}}$ [4].

Analytical record of the sequence of pulses in the drilling complex type of vertically and horizontally polarized signal is represented by the equation:

(6) $$s^{V(H)}(t) = A_s^{V(H)} \exp[j(\omega^{V(H)}t \pm \mu^{V(H)}t^2)],$$

where $A_s^{V(H)}$ is the amplitude of the emitted orthogonal signal, $\omega^{V(H)} = 2\pi f^{V(H)}$ is the circular frequency, $f^{V(H)}$ - the main carrying impulse frequency for the corresponding polarization, t - the current time, $\mu^{V(H)} = \frac{2\pi\Delta F^{V(H)}}{T^{V(H)}}$ - the variation rate of frequency modulation, $\Delta F^{V(H)}$- the frequency deviation, $T^{V(H)}$- the pulse duration at corresponding polarization.

The number of needed impulses $N_p^{V(H)}$ for realization of resolution at azimuth ΔL is given using the formula [4,7]:

$$N_p^{V(H)} = \frac{0.5\lambda R}{\Delta L T^{V(H)}{}_p V \sin(\beta+\varphi)}, \tag{7}$$

where λ is wavelength, $N_p^{V(H)}$- drilling impulse repetition period for the corresponding polarization, R- traverse distance to the object's mass center at a moment $p = \frac{N_p^{V(H)}}{2}$.

Each of the point emitters from object space reflects radiation pulse using the law

$$\hat{s}_{mn}^{V(H)} = A_{mn}^{V(H)} \exp[j(\omega^{V(H)}(t-\tau_{mn}^{V(H)}) \pm \mu^{V(H)}(t-\tau_{mn}^{V(H)})^2)], \tag{8}$$

where $A_{mn}{}^{V(H)}$ is amplitude of the reflected signal at corresponding polarization by (m,n)-th simple reflector; $\tau_{mn}^{V(H)}(p) = \frac{2R_{mn}^{V(H)}(p)}{c}$ - delay time of the reflected signal by the (m,n)-th simple reflector at vertical and horizontal polarized signal; $c = 3.10^8[m/s]$ - spread speed of electromagnetic energy.

The duration of the reflected impulse for orthogonal signals in general case can be described by the expression:

$$T_p^{V(H)} = T^{V(H)} + (\tau_{\max}^{V(H)} - \tau_{\min}^{V(H)}) \tag{9}$$

By putting $T^{V(H)} = k\Delta T^{V(H)}$ and $\tau_{\max}^{V(H)} - \tau_{\min}^{V(H)} = l\Delta T^{V(H)}$, where $k = \overline{1, N_k{}^{V(H)}}$, $l = \overline{1, L}^{V(H)}$, impulse time discretization is realized . Equation (9) has the following look:

$$T_p^{V(H)} = k\Delta T^{V(H)} + l\Delta T^{V(H)} \tag{10}$$

The current discrete time t, for which the reflected impulse is elapsing, is given with the expression:

$$t = \tau_{\min}^{V(H)} + k\Delta T^{V(H)} + l\Delta T^{V(H)} \tag{11}$$

The sum of all complex values of the reflected signals by all point emitters from every p-th impulse and every k-th time discrete for orthogonal signals is given with the expression:

$$\hat{S}_{kp}{}^{V(H)} = \sum_{m=1}^{M}\sum_{n=1}^{N} \hat{s}_{mn}{}^{V(H)} \tag{12}$$

A $S^{V(H)}(k,p)$ matrix is formed with elements the partial sums $\hat{S}_{kp}{}^{V(H)}$, where $k = \overline{1, N_k{}^{V(H)}}$, $p = \overline{1, N_p{}^{V(H)}}$. The matrix is the discrete record of the complex trajectory signal, reflected by the object for the whole period of aperture synthetizing using drilling orthogonal signals:

$$S^{V(H)}(k,p) = \sum_{m=1}^{M}\sum_{n=1}^{N} A_{mn}{}^{V(H)} \exp\left[j\left[\omega^{V(H)}\left(t-\tau_{mn}{}^{V(H)}(p)\right) \pm \mu^{V(H)}\left(t-\tau_{mn}{}^{V(H)}(p)\right)^2\right]\right] \tag{13}$$

The discrete values of the complex trajectory signal form the matrix $S^{V(H)}(\bar{k},p)$

(14) $$S^{V(H)}(\bar{k},p)=\sum_{m=1}^{M}\sum_{n=1}^{N}A_{mn}{}^{V(H)}rect[t-\tau_{mn}{}^{V(H)}(p)]\,\mathrm{x}\,B^{V(H)}$$, at

(15) $$\begin{aligned}B^{V(H)}&=\exp\{j[\omega^{V(H)}(\tau_{\min}{}^{V(H)}(p)+\bar{k}\Delta T^{V(H)}-\tau_{mn}{}^{V(H)}(p))\pm\\&\pm\mu^{V(H)}(\tau_{\min}{}^{V(H)}(p)+\bar{k}\Delta T^{V(H)}-\tau_{mn}{}^{V(H)}(p))^2]\}\end{aligned},$$

where $\bar{k}=\overline{1,N_k{}^{V(H)}+L^{V(H)}(p)}$; $p=\overline{1,N_p{}^{V(H)}}$,

(16) $$rect[t-\tau_{mn}{}^{V(H)}]=\begin{cases}1, & 0\le t-\tau_{mn}{}^{V(H)}\le T^{V(H)}\\ 0, & t-\tau_{mn}{}^{V(H)}<0\\ 0, & t-\tau_{mn}{}^{V(H)}>T^{V(H)}\end{cases}$$

The rectangular function limits the time duration for each reflected impulse, so that it does not exceed the duration of the impulse itself. For each *p*-th reflected impulse, multiplication of the complex matrix elements $S^{V(H)}(\bar{k},p)$ by complex-conjugate transmitted signal is accomplished.

(17) $$\overset{*}{S}{}^{V(H)}(k,p)=S^{V(H)}(\bar{k},p)\exp[-j(\omega^{V(H)}t\pm\mu^{V(H)}t^2)],$$

where $t=k\Delta T^{V(H)};k=\overline{1,N_k{}^{V(H)}}$; $\bar{k}=\overline{(\frac{L^{V(H)}}{2}+1),(N_k{}^{V(H)}+\frac{L^{V(H)}}{2})}$, $p=\overline{1,N_p{}^{V(H)}}$

After proper transforming equation (17) has the following look:

(18) $$\overset{\bullet}{S}{}^{V(H)}(k,p)=\sum_{m=1}^{M}\sum_{n=1}^{N}A_{mn}{}^{V(H)}rect[k\Delta T^{V(H)}-\tau_{mn}{}^{V(H)}(p)]\,\mathrm{x}\,C^{V(H)}$$, where

(19) $$C^{V(H)}=\exp\{j\left[\begin{aligned}&\omega^{V(H)}(\tau_{mn}{}^{V(H)}(p)-\tau_{\min}{}^{V(H)}(p))\pm\mu^{V(H)}(\tau_{mn}{}^{V(H)}(p)-\tau_{\min}{}^{V(H)}(p))^2+\\&+2\mu^{V(H)}k\Delta T^{V(H)}(\tau_{mn}{}^{V(H)}(p)-\tau_{\min}{}^{V(H)}(p))\end{aligned}\right]\}$$

By applying the discrete Fourier transform to the orthogonal sum of harmonic signals $\overset{\bullet}{S}{}^{V(H)}(k)$ it is possible to achieve a result in the frequency area, reflective and dependent by the differences in the time delay of signals from different point emitters. This transformation realizes distance compression of the complex trajectory signal and obtains information about the spacious situation of the point emitters in different remoteness bands towards the radiolocation station.

Towards each of the matrix columns of the demodulated complex trajectory signal $\overset{\bullet}{S}{}^{V(H)}(k,p)$ is applied discrete Fourier Transform [6] which has the following look:

(20) $$\tilde{S}{}^{V(H)}(k,p)=\sum_{q=1}^{N_K}\overset{\bullet}{S}{}^{V(H)}(q,p)\exp[\frac{-j2\pi(q-1)(k-1)}{N_k{}^{V(H)}}],$$

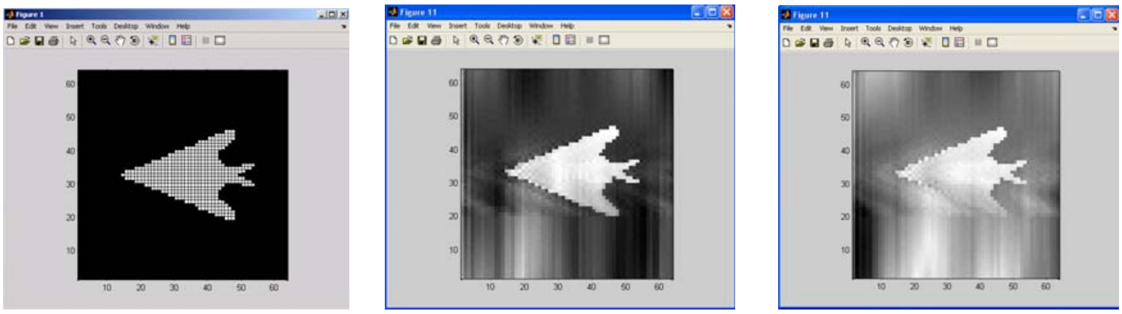
where k is the element number bypassing the rows for first strobe, $k=\overline{1,N_k{}^{V(H)}}$, $p=\overline{1,N_p{}^{V(H)}}$.

An image reconstruction is completed by Discrete Fourier Transform, applied towards the rows of the matrix $\tilde{S}{}^{V(H)}(k,p)$ (component compression of the signal path in azimuth).

$$\overset{\approx}{S}^{V(H)}(k,p)=\sum_{r=1}^{N_p}\tilde{S}^{V(H)}(k,r)\exp\left[\frac{-j2\pi(r-1)(p-1)}{N_p^{V(H)}}\right], \tag{21}$$

where $k=\overline{1,N_k^{V(H)}}$, $p=\overline{1,N_p^{V(H)}}$, q and r are sum indices with corresponding values $q=\overline{1,N_k^{V(H)}}$, $r=\overline{1,N_p^{V(H)}}$.

Based on the developed mathematical models, software applications are created in Matlab environment [8]. Standard and reconstructed images of a F117 object, at vertical and horizontal drilling polarized signals are presented on Fig.1. The results show the correctness of the developed models. It gives the opportunity on parallel work of the two algorithms in system for restitution of RIR, information for the observed radiolocation object to be supplemented aiming to raise the quality of the reconstructed image of the object covered with metamaterial and Stealth technology.



a) b) c)

Fig. 1. Standard image (a), reconstructed image at vertical polarization (b) and reconstructed image at horizontal polarization (c) of F117 object.

REFERENCES

[1] Joo, A., Ney da Silva, Marcello de Campos. Spectrally Efficient UWB Pulse Shaping with Application in Orthogonal PSM COPPE. Fed. Univ. of Rio de Janeiro, Communications, IEEE Transactions, Feb. 2007,Volume: 55, pp. 313-322.

[2] Karakasiliotis A. V., A. D Lazarov, P. V. Frangos. Two – Dimensional (2-D) ISAR Signal Modeling and Imaging for Stepped Frequency Modulation. Signal Processing, IET, 2008, Vol.2, Issue 3, pp.277-290.

[3] La Recherche, Mai 2006, № 396, RFID Technologic.

[4] Lazarov, A. D., Ch. Minchev. “Spectral 2D Image reconstruction in ISAR with linear frequency modulated signal“. Processing of the 20th Digital Avionics Systems Conference, Daytona Beach 2001.

[5] Wang,X.B., X.Y.Zheu, T.Y.Cui, Y.B.Tao, H.Lin. High-Resolution Inverse Synthetic Aperture Radar Imaging Based on the Shooting and Bouncing Ray Methods Millimeter Waves, 2008. GSMM 2008. Global Symposium, IEEE, pp.1–3

[6] Yanan, Li, Y.Fu, X.Li. An ISAR Imaging Method for Multiple Moving Targets Based on Fractional Fourier Transformation. Radar Conferense, 2009, IEEE, pp.1-6.

[7] Джуров В. Алгоритъм за възстановяване на радиохолографско изображение на обект с ниска ефективна отразяваща повърхност със сложна аеродинамична форма. Сборник научни трудове от Втора юбилейна международна научна конференция “50 години от полета на Ю. Гагарин”, Шумен, 2011, том 1. с.117-121.

[8] Дьяконов, В., В. Круглов. MATLAB анализ, идентификация и моделирование систем, Санкт-Петербург, 2002.

[9] Зеленский, В. К, А. А. Ксендзук, А. В. Кравченко, В. Ф. Лукин, В. В. Кравченко. Цифровая обработка сигналов и изображений – М.: ФИЗМАТЛИТ, 2007, 544 с.

[10] Лазоренко, О. В., Л. Ф.Черногор. Сверхширокополосные сигналы и физические процессы, методы анализа и применение. Радиофизика и астрономия, 2008, Том 13, №3, с.270-322.

[11] Мусатова, М. М. Разработка и исследование алгоритмов обнаружения локационных объектов с помощью сверхширокополосных сигналов в поглощающих средах. Диссертация, Таганрог, 2007, с. 218.

CONTACT ADDRESSES

Pr. Assist. Valerij Djurov, PhD
Department of Electrical Engineering
Angel Kanchev University of Ruse
8 Studentska Str., 7017 Ruse, Bulgaria
Phone (+359 82) 888 629
E-mail: vdjurov@yahoo.com

Pr. Assist. Milena Kostova, PhD
Department of Algebra and Geometry
Angel Kanchev University of Ruse
8 Studentska Str., 7017 Ruse, Bulgaria
Phone.(+359 82) 888 453
E-mail: mpk@mail.bg

Pr. Assist. Ivan Georgiev
Department of Numerical Methods and Statistics
Angel Kanchev University of Ruse
8 Studentska Str., 7017 Ruse, Bulgaria
Phone (+359 82) 888 725
E-mail: igeorgiev@uni-ruse.bg

МАТЕМАТИЧЕСКИ МОДЕЛ НА СИСТЕМА ЗА ВЪЗСТАНОВЯВАНЕ РАДИОЛОКАЦИОННО ИЗОБРАЖЕНИЕ НА ДИНАМИЧЕН ОБЕКТ С НИСКА РАДИОЛОКАЦИОННА ЗАБЕЛЕЖИМОСТ

Валерий Джуров, Милена Костова, Иван Георгиев

Русенски университет „Ангел Кънчев”

***Резюме**: Представен е математически модел на система за възстановяване на радиолокационно изображение на самолет, конструиран чрез съвременна технология за намаляване на радиолокационната забележимост - т. н. метаматерия. Използвани са линейно честотни ортогонални сондиращи сигнали и принципите на обратния апертурен синтез. Получени са изображения на самолет F117 чрез софтуерна реализация на математическия модел при хоризонтална и вертикална поляризация на сондиращия сигнал. Посочени са насоките за приложение на създадения модел за повишаване качеството при възстановяване на радиолокационни изображения.*

***Ключови думи:** Математически модел, Ортогонални сигнали, Преобразуване на Фурие, Обратен апертурен синтез, Метаматерия, Радиолокационно изображение.*

ISSN 1314-3077

9 771314 307000