Московский физико-технический институт (Россия)
Интерколледж, Ларнака (Кипр)
Средиземноморский институт прикладных наук (Кипр)
Национальный Космический Центр (Ирландия)

engineering
&telecom

II Международная конференция
«Инжиниринг & Телекоммуникации – En&T 2015»

ТЕЗИСЫ ДОКЛАДОВ

18–19 ноября 2015

Москва/Долгопрудный
МФТИ
2015

УДК 004ю82+621.39
ББК 32.318+32.94(06)
М43

II International Conference «Engineering & Telecommunication En&T 2015». November 18-19, 2015. Book of Abstracts. – Moscow– Dolgoprudny: MIPT, 2015. 392 p.

Editors: E. Pavlyukova, Z. Suroegina, L. Uzhinskaya

All rights reserved

© Federal State Autonomous Educational
Institution of Higher Professional Education
"Moscow Institute of Physics and Technology
(State University)", 2015

ISBN 978-5-7417-0581-0

9 785741 705810

СОДЕРЖАНИЕ*

** Полное содержание см. в конце издания.*

Цель эксперимента состояла в определении возможности обнаружения и распознавания малоразмерных объектов (с размерами 0,05...1 м), расположенных на поверхности земли и скрытых под покровом травы или листьев.

Полученные экспериментальные данные использовались для формирования РЛИ путем их обработки с помощью разработанных алгоритмов и программ. Параметры СЧМ сигнала и условия проведения эксперимента позволили получить РЛИ с разрешением (0,15 *м* × 0,15 *м*), что соответствует числу точек (N_x=378)×(N_y=667) при размере зоны обзора 56,7 *м* × 100 *м*.

Проведено детальное сравнение синтезированного радиолокационного изображения (РЛИ) с фотографией места эксперимента. Результаты натурного эксперимента показали возможность обнаружения и распознавания малоразмерных объектов от 20 *см*, даже в условиях расположения их в траве и кустах.

Литература

1. Гаврилов К.Ю., Игонина Ю.В., Линников О.Н., Панявина Н.С. Оценка разрешающей способности по дальности при использовании сигналов со ступенчатой частотной модуляцией // Информационно-измерительные и управляющие системы. 2015. № 5. Т. 3.

2. Чапурский В.В. Избранные задачи теории сверхширокополосных радиолокационных систем. М.: Изд. МГТУ им. Баумана. 2012.

Ivan Garvanov, Christo Kabakchiev, Vera Behar, Magdalena Garvanova
Vehicle University of Library Studies and Information Technologies, Sofia,
Sofia University, IICT-BAS, Sofia, BULGARIA

TARGET DETECTION USING A GPS FORWARD-SCATTERING RADAR

Abstract: *The Global Positioning System (GPS) allows the accurate positioning of an object using satellite signals. There are a lot of applications of this technology in many scientific fields all over the world. The paper focuses on scientific issues related to new application of GPS technology using the effect of Forward Scattering (FS)* *of electromagnetic waves to detect targets by their GPS radio shadows. The aim of the paper is to make experimental studies of GPS radio shadows of vehicle targets irradiated by GPS signals and to develop algorithm for automatic detection of the shadows of these targets. In this paper, we offer an original approach for using of CFAR techniques for detection of moving targets from GPS radio shadows.*

Keywords: *Global Positioning System (GPS), Forward Scattering (FS), Constant False Alarm Rate (CFAR) detector, signal processing.*

1. Introduction

Historically, radar and communications networks are the oldest networks. They have evolved independently, i.e. have solved various problems. The difference is that the radar network consists of distributed sensors, where both transmitter and receiver are in the one and the same position in the radar. Communication networks are constructed from a sequence of remote transmitters and receivers. This principle of multistatic radars, i.e. radars with different positions of receivers and transmitters, underlies the so-called radar networks using *Forward Scattering Radio Techniques.*

Currently Russia is the world's largest manufacturer of FS radar barriers for protection in air and space (Barrier-E, Delta, Periscope, etc.), and is a leader in this research area. These systems are extremely popular due to the ability to detect small moving objects and air targets produced by the stealth technology.

Existing satellite radio Navigation system (GPS, GLONASS, Galileo, Compas) are space-based systems, the operation of which is not dependent on weather conditions. These systems global navigation are widely used for operational navigation. They allow globally to determine the exact coordinates and speed of moving objects and perform precise coordination in time. A major problem in the processing of GPS signals is the low signal-to-noise ration and the availability of different types of interference in urban environments. Protecting GPS receiver from various disturbances in urban environments is the topical scientific field in the world. Although in recent years this technology deeply enters in the domestic and social life of the modern society, the scientists still actively works on the development of new applications of the GPS technology. It is known that the presence of other objects on the path of propagation of GPS signals results in a loss of signal in the GPS receiver, i.e. radio shadow.

The topicality of the paper is that it proposes to use the information contained in radio shadow from different objects to develop new applications of the GPS technology. This research aims to demonstrate the feasibility of the Forward Scattering GPS system of detecting road vehicles in urban environment by their GPS radio shadows. The results presented in this article show that from GPS radio shadows of different objects can be extracted information for positioning and classification of moving objects; for accurate assessment of the geographic location of fixed objects by method triangulation in systems for transport management, security of zones, subsequent identification of the detected objects from digital geographical maps.

2. Principles of Forward Scattering Radar

In bistatic radar, one of the factors affecting the electromagnetic field strength and pattern at the receiver is the angle that the target makes to the transmitter and receiver, this angle is called the bistatic angle. When the bistatic angle is equal or near 180°, the radar system is referred to as FSR system [1], as shown in Figure 1. At forward scattering, the presence of a target will partly block the signal wavefront from the transmitter. This blocking yields a hole in the wavefront, known as the target shadow.

Fig. 1. Forward scattering radar [1].

FSR has been known for a long time and the main literature devoted to forward scattering radiolocation is given in [2, 3]. Earlier publications regarding forward scattering were devoted to estimating the RCS of an object at forward scattering. The paper by Hiatt, Siegel and Weil [4] published in 1960 provides a theoretical analysis and experimental results to prove that RAM coatings do not have any effect for forward scattering when applied on highly conductive objects that are larger than the carrier wavelength. Later the advantages of FSR became known, including the increase in the RCS of the object at forward scattering. The subsequent work of Glaser's [5] presented a fast and simple approach for estimating the effective forward scattering RCS for different targets at various operating frequencies. Chesnokov and Krutikov [6] then confirmed experimentally that the RCS at forward scattering is bigger than in the monostatic case by 30–40 dB depending on the carrier frequency. Blyakhman and Runova [7] discussed target detection and estimating detection zones at forward scattering. They showed that the detection zone of a FSR depends on object type and its' flight trajectory. They calculated the bistatic RCS of the objects related to the XY Cartesian co-ordinates for estimating the detection zones. Gould, Orton and Pollard [8] stated that detection is always lost at zero Doppler. This area is known as a 'dead zone' as shown in Figure 2. They also state that the detection performance could be limited by: Maximum signal handling capability of the receiver; Transmitter close to carrier noise dominating front and noise at low Doppler and reducing detection capability; Transmitter stability (Doppler spreading on both direct and wanted signal); High pass filtering to remove/reduce the direct signal and clutter to prevent or reduce spectral leakage when Doppler processing.

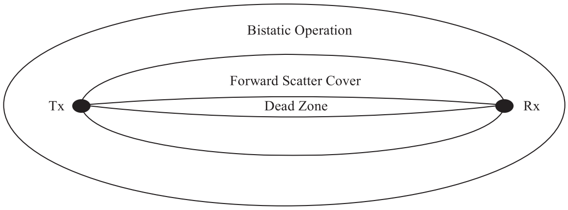

Fig. 2. FSR performance [8].

To track and estimate a moving object at forward scattering, Blyakhman, Ryndyk and Sidorov [7] proposed an algorithm which is based on maximal likehood. The proposed algorithm was tested by using the full-scale field test and gives a sufficiently accurate measurement. They have also shown that the proposed algorithm can find trajectory parameters using parameters Doppler frequency and returned signal bearing. Gould, Orton and Pollard [8] have developed a tracking algorithm based on an extended Kalman filter. They display the target co-ordinate in a normal XY cartesian co-ordinates. Their results confirm the ability of FSR for the detection and tracking of a small jet target.

The use of GPS signals as a passive radar system is becoming increasingly popular as an alternative to radar systems. The idea to apply a GPS L1 receiver to FSR for air target detection is discussed in [9]. Some experimental results of a GPS L1 receiver concerning the detection of air targets are shown and discussed in [10]. A possible algorithm for air target detection in a GPS L5-based FSR system is described in [11], and the detection probability characteristics are calculated in [12] in case of low-flying and poorly maneuverable air targets in the urban interference environment. GPS L1 FSR system is researched in [13-16] for detection of FSR shadows from stationary ground objects. Target detection is indicated if the signal integrated from some satellites exceeds a predetermined threshold. In this paper, a passive FSR system, similar to the GPS L1 FSR system, in which GPS satellites are exploited as non-cooperative transmitters, is studied. The aim of this study is to verify the possibility to detect FSR shadow of moving ground targets when GPS satellites are located at small elevation angles as shown in Figure 3. The paper investigates the possibility of extracting useful information from the radio shadow. The obtained experimental results can be used to develop software applications to a GPS receiver that could measure traffic movement, target velocity and target classification.

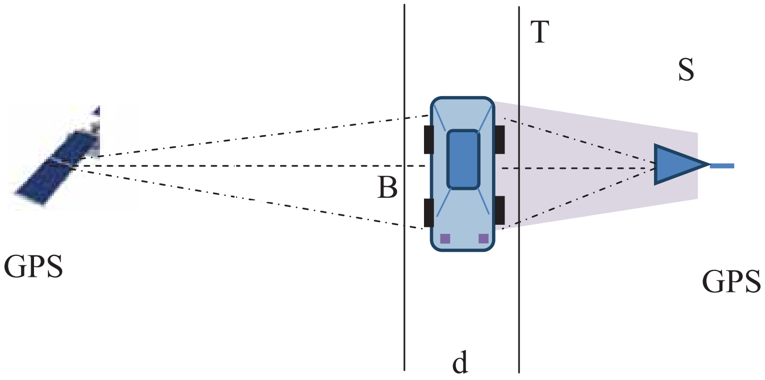

Fig. 3. Forward Scattering GPS topology i.e. when bistatic angle is ≈180°.

3. Experiment dEscription

The purpose of the experiments is to verify that with a small and omnidirectional commercial GPS antenna is possible to record differences in GPS shadows of moving targets. In this experimental study, the GPS L1-based recording system consists of two types of GPS receivers. The first GPS receiver (Antaris AEK-4R) will be used to determine the location of the satellites while the other software GPS receiver (GNSS_SRR) will be used to record and store GPS signals from different targets (Figure 4).

Fig. 4. Experimental equipment and Experiment topology.

In the registration of shadows from vehicles are selected satellites located on the horizon. In scenario, the conditions for the occurrence of FS-GPS effect are guaranteed. The scenario includes moving targets and stationary-based GPS-FS system that records FS shadow of cars moving on the road (Figure 5). The GPS receiver is positioned from the one side of the road and records the signal from GPS. For recording are selected such visible satellites, which are located at low elevation angles and form a baseline (between satellite and receiver) perpendicular to the road, in order to form the FS effect. During the experiment are recorded the satellite signals when a car move on the road.

Fig. 5. GPS-FS scenario.

4. SIGNAL PROCESSING

The general block-scheme of a possible algorithm for FSR shadow detection is shown in Figure 6 [9, 17].

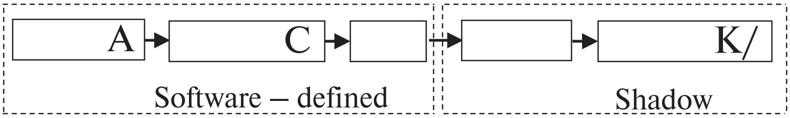

Fig. 6. The general block-scheme of signal processing for target detection and parameter estimation used in a passive GPS based FSR system.

According to this block-scheme, several visible GPS satellites are acquired and tracked over the complete duration of recorded signals. We consider the case when the acquisition and tracking algorithms of a GPS receiver are implemented in MATLAB. The absolute values of the I_p component at the output of the Code & Carrier tracking block are then integrated during N milliseconds. These integrated output signals from M satellites are additionally summed in order to improve SNR before detection. Target detection is indicated if the signal integrated from M satellites exceeds a CFAR detection threshold. In such a system, the signal integrated at the output of the Code & Carrier tracking block (message bits) of a GPS receiver can be used for detection of the FSR shadow created by moving targets.

It is well know that the constant false alarm rate (CFAR) detector with binary or non-coherent integration with fixed reference window is usually used for detection of a point target with a known size in conditions of a clutter with unknown power [18-20]. The standard one dimensional CA CFAR processor has been realized. It has a fixed length of the tested and the reference windows. The sample from the test resolution cell x_0 is compared with adaptive detection threshold H_D=VT where V is the noise level estimation and T is the scale factor. The detection is declared if the sample x_0 exceeds the detection threshold. Difference between standard and our CFAR processor is the big distance between the test cell and the two reference window. It is necessary because one of the reference windows slides on the azimuth data, and then when it slides on the target the samples of the target mask himself. We use the distance between the sliding windows equal to the half cells of the biggest target.

K/M-L is a non-parametric detection of the package of binary signals with unknown length. When the target size is unknown, ordinary for the automatic detection of the binary pulses is used the approach for batch detection for the estimate of the beginning and finish of plot of target, and after that is estimated the size of plot. This algorithm uses two non-parametric tests: The pulse train detection is declared if the M-binary integration exceeds the digital threshold K. The criteria for fix of the beginning package are simultaneously the criteria of the detection, in this detector. The fix of a finish of the target package is declared if the last L-binary integration is zero. This approach is used for detection of the pulse package with unknown length.

5. Experimental results

GPS receiver is located on one side of the road at a height of one meter from the ground. The position of the visible satellites and the intensity of the incoming signals from them are shown in Figure 7 and 8.

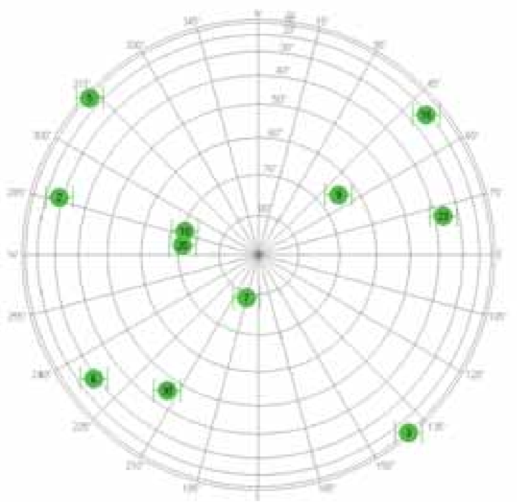

Fig. 7. Satellite constellation.

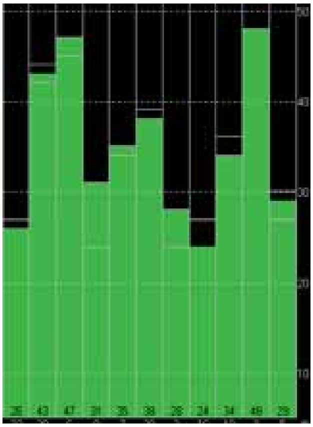

Fig. 8. Acquisition results.

It can be seen that during this experiment several satellites are visible, one of which with number 3 creates the best conditions for the occurrence of the FS effect. It is the most low on the horizon and the car crosses the baseline "satellite – receiver" at the angle of about 90 degrees. To detect radio shadows of moving targets the averaging algorithm is used with an interval of integration 200 ms. Figure 9 shows the bits of the navigation message of the satellite 3 and radio shadows of moving car and bus. Figure 10 demonstrates the GPS radio shadows of two moving targets (a car and a bus).

After the invert signal, we applied CFAR signal processing. CA CFAR detector is used to detect the single pulse. The specificity of the received signal leads us to choose the parameters of the detector as follows: the number of reference cells is 6, the distance between the test cell and the reference window is 10 cells (on both sides of the test cell), and for K/M-L algorithm we use K=1, M=2, L=2. Several steps of work of our algorithm for target detection in time domain are shown in Figures 11 and 12.

6. Conclusions

This research aims to demonstrate the feasibility of the Forward Scattering GPS system of detecting road vehicles in urban environment by their GPS radio shadows. Detection of moving targets by using GPS radio shadows can successfully be used for radio barriers, classification and identification of moving objects.

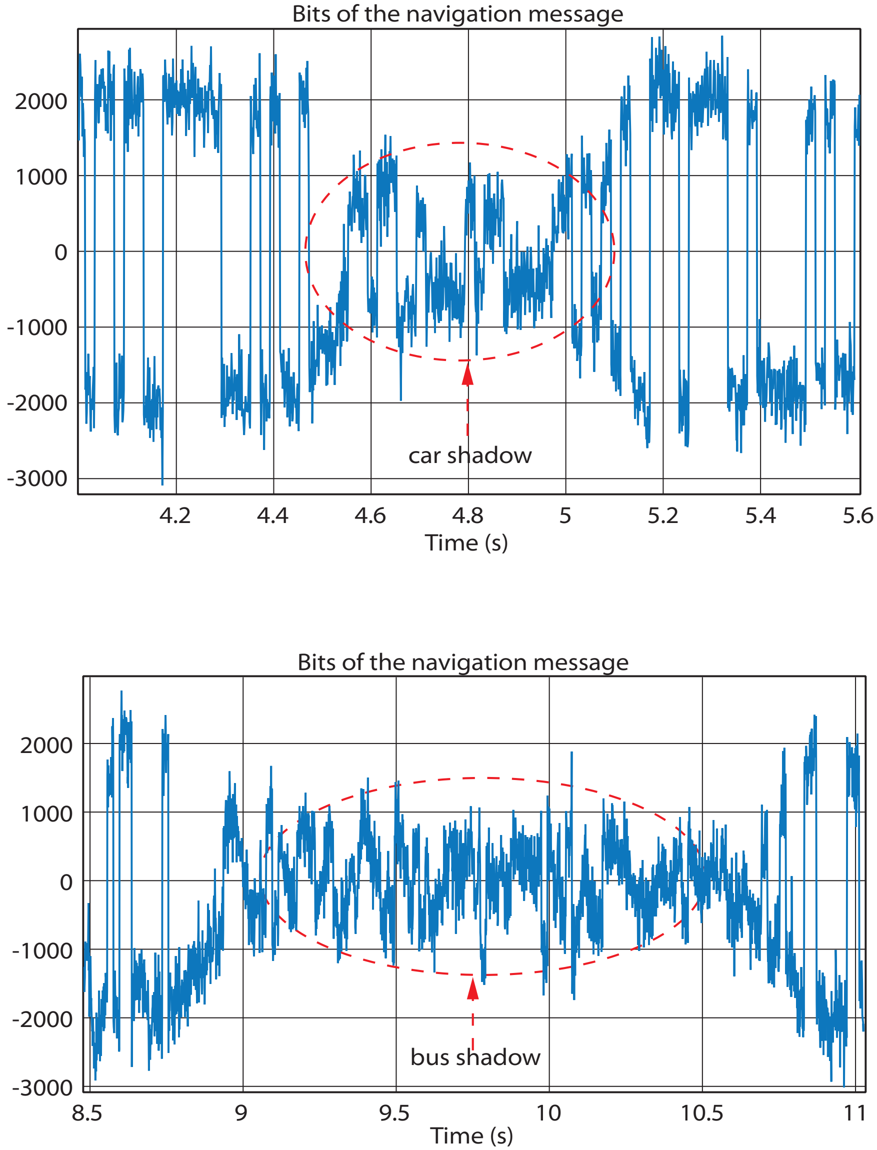

Fig. 9. Radio shadows from a car and a bus (bits).

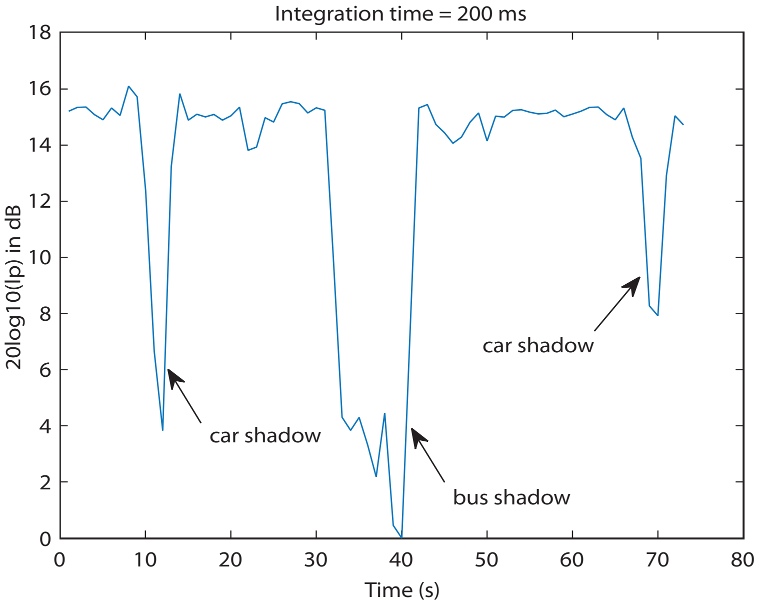

Fig. 10. Radio shadows from a cars and a bus (integrating signal).

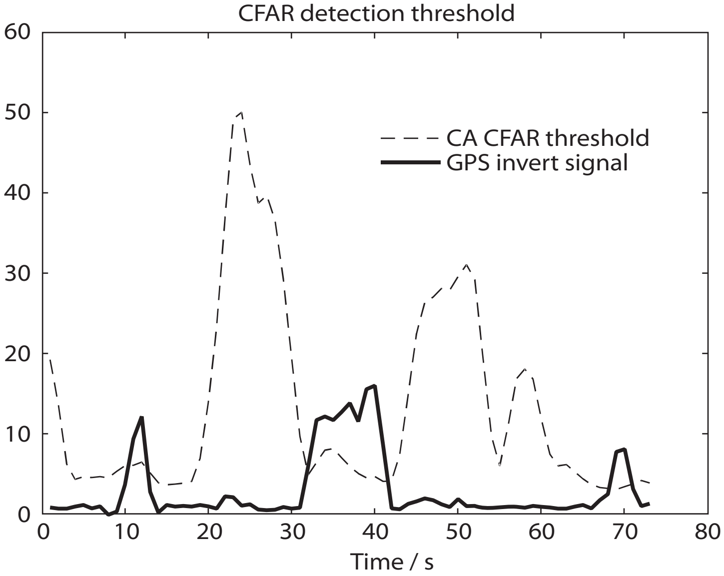

Fig. 11. Invert signal and CFAR threshold.

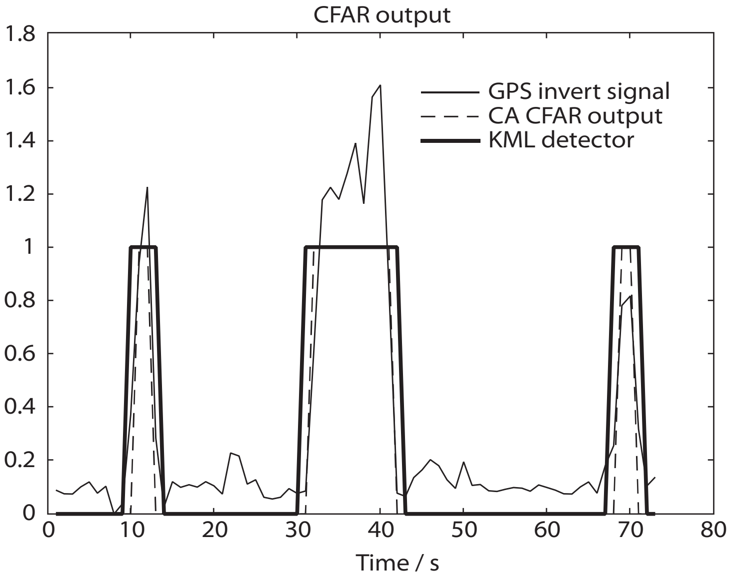

Fig. 12. Target detection.

Acknowledgment

This work is partly supported by the projects DFNI-T-02/2014 and NIP-2015-08/2015.

References

[1] Cherniakov M., (ed.), "Bistatic Radar: Principles and Practice", Wiley & Sons, 2007.

[2] Willis N.J., 'Bistatic Radar', Technology Service Corporation, 1995

[3] Skolnik, M., 'Radar Handbook', McGraw-Hill Book Company, New York, 1990, pp. 2-B

[4] Hiatt, R.E., Siegel, K.M., Weil, H., 'Forward Scattering of Coated Objects Illuminated by Short Wavelength Radar', Proceeding IRE, Sept, 1960, pp. 10—11.

[5] Glaser, J.I., 'Bistatic RCS of Complex Objects Near Forward Scatter', IEEE Transactions on Aerospace and Electronic System, Vol.AES-21, No.1, January 1985, pp. 70—78.

[6] Chesnokov, Y.S, Krutikov, M.V., ‘Bistatic RCS of Aircrafts at the Forward Scattering’. Radar, 1996. Proceedings, CIE International Conference of 8-10 Oct. 1996, pp. 156–159

[7] Blyakhman, A.B., Ryndyk, A.G., Sidorov, S.B., ‘Forward scattering radar moving object coordinate measurement’, Radar Conference, 2000. The Record of the IEEE 2000 International, 7-12 May 2000, pp. 678–682

[8] Gould, D.M., Orton, R.S., Pollard, R.J.E., ‘Forward Scatter Radar Detection’, RADAR 2002, 15–17 Oct. 2002, pp. 36–40

[9] Koch, V., R. Westphal, “New approach to a multistatic passive radar sensor for air/space defense”, IEEE AES Systems Magazine, pp. 24–32, November 1995.

[10] Suberviola I., I. Mayordome, J. Mendizabal, “Experimental results of air target detection with GPS forward scattering radar, 2012, In IEEE Geoscience and Remote Sensing Letters, vol. 9, no. 1, pp. 47–51, January 2012.

[11] Behar V., Chr. Kabakchiev, “Detectability of Air Target Detection using Bistatic Radar Based on GPS L5 Signals”, Proc. IRS’2011, Leipzig, 2011, pp. 212–217.

[12] Behar V., Chr. Kabakchiev, H. Rohling, “Air Target Detection Using Navigation Receivers Based on GPS L5 Signals”, Proc. of ION GNSS’ 2011, Portland OR, 2011, pp. 333–337.

[13] Kabakchiev Chr., I. Garvanov, V. Behar, H. Rohling, “The Experimental Study of Possibility for Radar Target Detection in FSR Using L1-Based Non-Cooperative Transmitter”, Proc. of IRS’13, Dresden, Germany, 2013, pp. 625–630.

[14] Kabakchiev Chr., I. Garvanov, V. Behar, H. Rohling, A. Lazarov, “The Experimental Study of Target FSR Shadows Detection using GPS signals”, Proc. of the Third International Symposium on Radio Systems and Space Plasma, Sofia, Bulgaria, 2013, pp. 64–73.

[15] Kabakchiev Chr., I. Garvanov, V. Behar, P. Daskalov, H. Rohling, “Moving Target FSR Shadow Detection using GPS signals”, Proc. of the Third International Conference on Telecommunications and Remote Sensing (ICTRS 2014), 26–27 June, 2014, Luxembourg, ISBN 978-83-931525-3-7, pp. 34–40.

[16] Kabakchiev Chr., I. Garvanov, V. Behar, “Study of Moving Target Shadows using Passive Forward Scatter Radar Systems“, Proc. of the International Radar Symposium – IRS’14, Poland, Gdansk, June 16-18, ISBN 978-83-931525-3-7, pp. 345–348, 2014.

[17] Borre K., D. Akos, N. Bertelsen, P. Rinder, S. Jensen, “A Software-Defined GPS and Galileo Receiver: Single-Frequency Approach”, Birkhäuser, Boston, MA, 2006.

[18] Garvanov, I., Chr. Kabakchiev, “One and Two Dimensions CFAR Processors in the Presence of Strong Pulse Jamming”, Cybernetics and Information Technologies, (ISSN 1311-9702), Volume 2, № 1, pp. 58–72, (2002).

[19] Garvanov, I., Chr. Kabakchiev, “Sensitivity of CFAR Processors Toward the Change of Input Distribution of Pulse Jamming”, Proc. of IEEE – Int. Conf. on Radar “Radar 2003”, pp. 121–126, (2003).

[20] Garvanov I., “Forward Scattering Radar. Principles and applications”, Sofia, Bulgaria, “Za bukvite”, ISBN 978-954-2946-45-8, pp. 117, 2012, (in Bulgarian).

Доброжанский А.П., Зайцев Г.В., д.т.н., Литвинов Д.М., Цыпин И.Б., к.т.н.,
ПАО «НПО «Алмаз», г. Москва

СИСТЕМА ЦИФРОВОЙ ОБРАБОТКИ СИГНАЛОВ МНОГОФУНКЦИОНАЛЬНОГО РАДИОЛОКАТОРА

Ключевые слова: *радиолокационные сигналы, цифровая обработка сигналов, архитектура вычислительных устройств.*

Центральной частью многофункционального радиолокатора (МФР) является система приема и обработки сигналов. Параметры этой системы во многом определяют характеристики МФР. Применение цифровых методов обработки сигналов позволяет применять различные алгоритмы обработки в разных режимах работы МФР, существенно улучшает характеристики и упрощает процесс настройки аппаратуры. Построение ап-