Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

FILTRATION OF THE FMICW RADAR OUTPUT SIGNALS BY THE ADVANCED WINDOWS

L. Rejfek*, N. Chmelařová, L. Beran, P. Chmelař

Department of Electrical Engineering, Faculty of Electrical Engineering and Informatics, Pardubice

Published online: 24 February 2018

ABSTRACT

This paper deals with the special types of windows application on the two dimensional spectrum obtained using the FMICW radar. This processing will improve the signal interpretation for the user. We want to implement this signal processing in our SW for the automatic detection of targets. The obtained results are described in detail with the recommendation for achieving the best processing result. We developed several windows, which can be used, for our algorithm.

Keywords: FMICW radar, 2D spectrum, Spectrum filtration, Target detection, Radar signal interpretation

INTRODUCTION

Interpretation of radar signals is an area with very fast improvement. In the world there are many types of radars for many applications (medicine (Li et al., 2015), meteorology (Yanovsky et al., 2015), air traffic control (Zalabsky and Hnilicka, 2017), safety systems (Krejci and Mandlik), and others.

Our radar is FMICW (frequency modulated interrupted continuous wave). This concept is a combination of pulse radar and FMCW radar. The first mention about these radars in literature started 10 years ago. One of the first references is (Saldana and Martinez, 2007), but these authors do not include many physical factors.

Author Correspondence, e-mail: Lubos.Rejfek@student.upce.cz

doi: http://dx.doi.org/10.4314/jfas.v10i3s.44

The better reference is (Mandlik and Brazda, 2015). A practical application of the FMICW radar for measurement of the Ionosphere is described in (Nozaki, 2009). This radar type has a problem with two dependences of power estimation on distance. The first one is based on the radio communication equation (Pankrac, 2005), which is in all radars. The second one is caused by the FMICW radar principle (Rejfek et al., 2017a).

Systems for an automatic detection of the targets, we described in (Rejfek et al., 2016a) and (Rejfek et al., 2016b). In our algorithms, we are working with the 2D spectrum. In this paper, we described modification of the 2D spectrum by the atypical windows.

FMICW radar

The FMICW radar block diagram is shown in Fig. 1. In this diagram, you can see that the radar is composed from three parts. The first part is the frequency base. This base generates signals for the PIN (switching) diodes. The second part is the transmitter. In this transmitter, the frequency multiplier can be placed before the power amplifier. A benefit of the FMCW and FMICW radars is low transmitted power (no more than a few Watts). The third part is the receiver. Amplifiers can be added in this part. Any type of receiver is composed from many mixers, and the signal is initially processed on the intermediate frequency. Processing of the signals from the FMICW radars is same as in typical FMCW radars. Fig. 2 shows the timing diagram. The signal is transmitted in long pulses. This is represented by the blue color line. The transmitter and the receiver are switched off during the blind zone (protection of the receiver). Only part of the transmitted pulse is available in a received signal. A lost part is represented by the pink color line and a received part is represented by the red color line. The frequency difference is a function of distance.

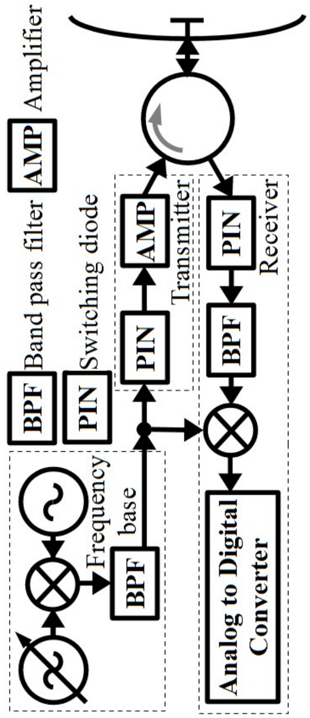

Fig.1. Principal Block diagram of the FMICW radar (Rejfek et al., 2017b)

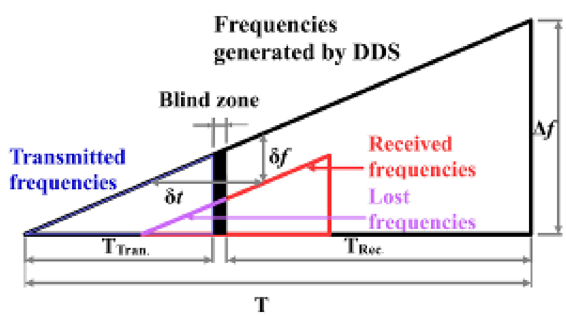

Fig.2. Timing diagram of FMICW radar. (Rejfek et al., 2016a)

An example of the received signal with two strong echoes is shown in Fig. 3. The first target is in the distance of 1000 meters and the second target is in the distance of 2000 meters. From this signal, you can estimate the distance using two methods. The first method estimates the distance from the position of the last sample and the second one uses spectral analysis.

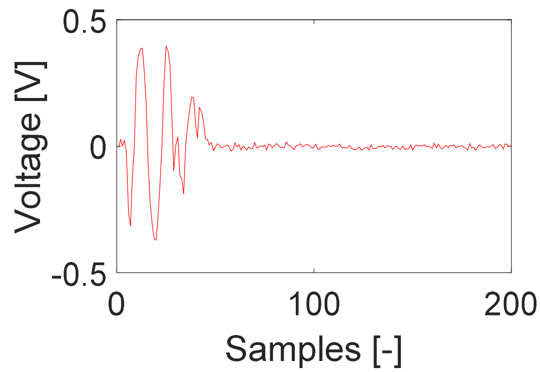

Fig.3. An example of the received signal with two targets in time dimension

Primary signal processing

Primary signal processing is realized using a spectral analysis. Methods for the spectral analysis are separated into two groups. The first methods are non-parametric methods. There is e.g. the Fourier transform. Parametric methods are the second group. Examples are multi signal classification, or auto-regressive models. Auto-regressive models are described in (Tykhonov and Kudriavtseva, 2013). The Fourier transform of the signal with two strong targets is shown in Fig. 4. In the spectrum near to the targets, you can see side lobes. These side lobes are caused by the shape of the echoes.

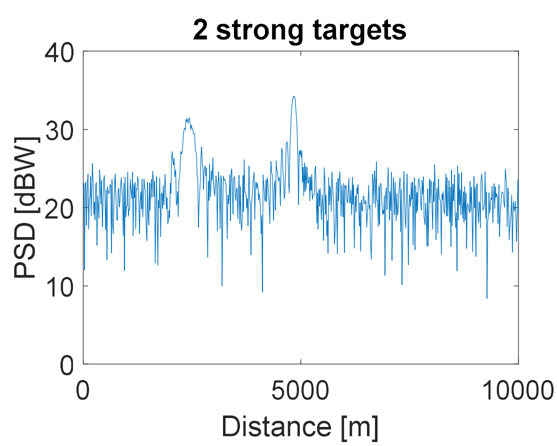

Fig.4. Spectral analysis of the signal with two strong echoes

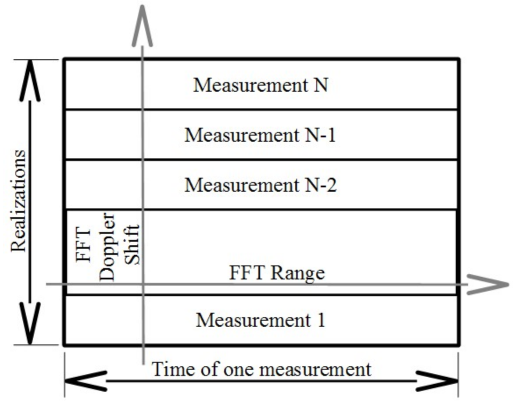

Fig.5. Principle of 2D FFT (Mandlik and Brazda, 2015)

The 2D spectrum is calculated from the square matrix of measurements. One realization of the measurement (in every line and every column) represents time since the start of the realization. In the first step spectra of distances are calculated, and in the second step spectra through realizations are calculated. The principle is shown in Fig. 5 and described in (Mandlik and Brazda, 2015). An example of a 2D spectrum is shown in Fig. 6. Green circles highlight the three weak targets. The shape of the target without noise in the spectrum is shown in Fig. 7. The side lobes are caused by the target distance. Shape of this spectrum is sinus “X” over “X”. It is caused by the shapes of the echoes. For cancelation of the side lobes, another window (e.g. Hamming) can be used, but it is usable only for the FMCW radars. In case of FMICW radar, the window can cancel a short effective part of the signal and we can lose the target. From this shape we can expect that the target has symmetric shape and we can make an estimation, if we see the target, or noise.

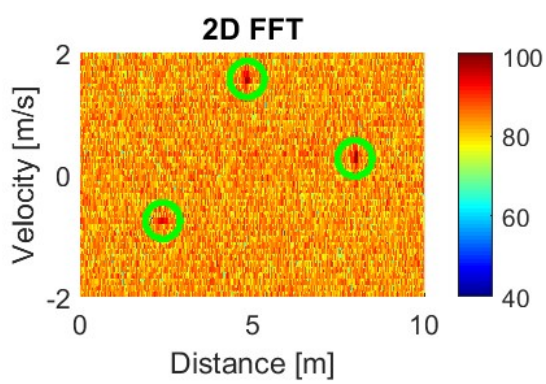

Fig.6. 2D spectrum of the signal with three weak targets

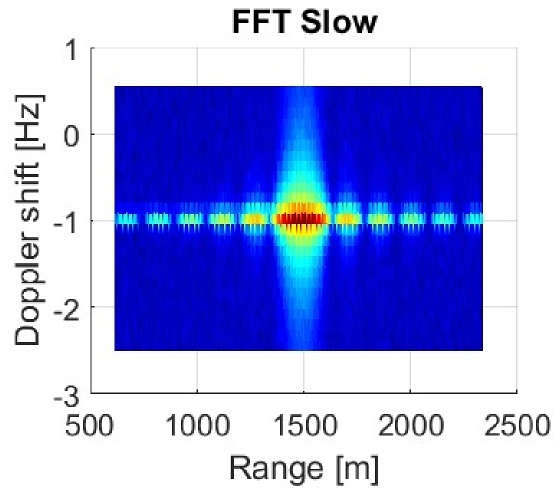

Fig.7. Shape of the echo in the 2D spectrum

Modification of the 2D spectrum

Sometimes it is very problematic to estimate, where we have a target and where we have only a noise. For better representation, we filtered the 2D spectrum by the special windows. These windows were designed for our expected signal shape. These windows are shown in Fig. 8. The windows "a" and "b" are similar; the first one is a cross of ones over the sum of all ones and other values in the rectangle are zeroes. The second one has this cross weighted (maximum is in the middle). These windows were chosen because of an approximate cross shape of the expected signal. The "c" window is a cone, it was chosen because we expected the main lobe to be a cone shape (see Fig. 7). The window "d" was created by the real modification of the signal obtained from the simulation. And window "e" is a simulated signal after dividing of all points by the sum of these points.

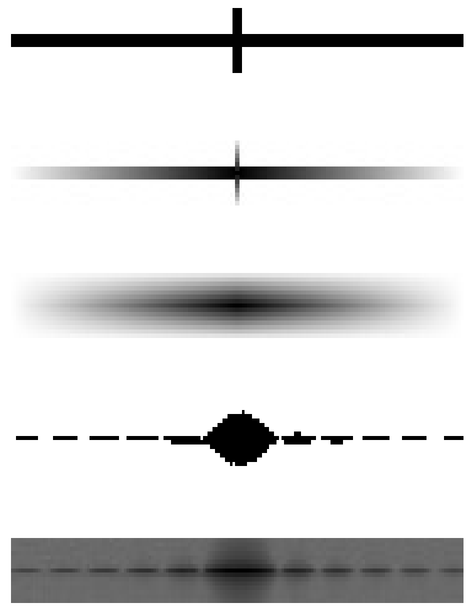

Fig.8. Shapes of the windows for the filtration. ((a) Cross (b) Weighted cross (c) Cone (d) 2D spectrum of the signal echo after thresholding and video-detection (e) Normalized 2D spectrum of the signal echo)

The changes of array during the correlation are problematic. We obtained very bad results near the edge of the array. So we changed the algorithm, the 2D spectrum was extended to the 3x3 spectra matrix. In every cell, we have our original spectrum. After correlation, only a middle part of the new spectrum is used. This is more time demanding, but we obtained better results.

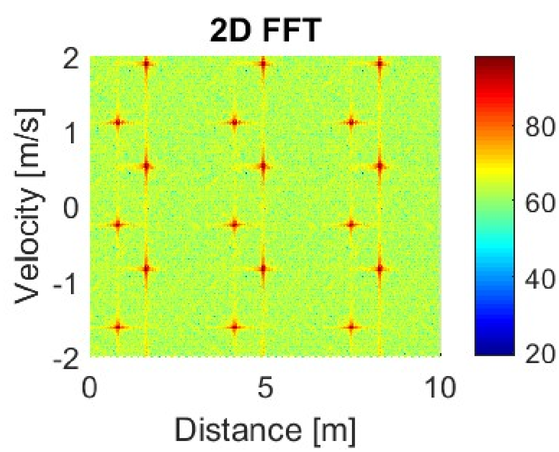

Fig.9. Field prepared for the correlation

RESULTS AND DISCUSSION

The windows evaluation must be realized on the four different types of signals. The first example is composed only from the weak echoes. The second one is composed from strong echoes. The third case is for a signal without echoes, and the forth case is for weak and strong echoes.

The 2D spectra of signal with three weak echoes after correlation with windows are in Fig. 10. From the results, we can say that the last window (e) has unsatisfactory results, but windows (c) and (d) have very good results. Window (c) generates only relevant targets and the window (d) makes a cross at the targets position.

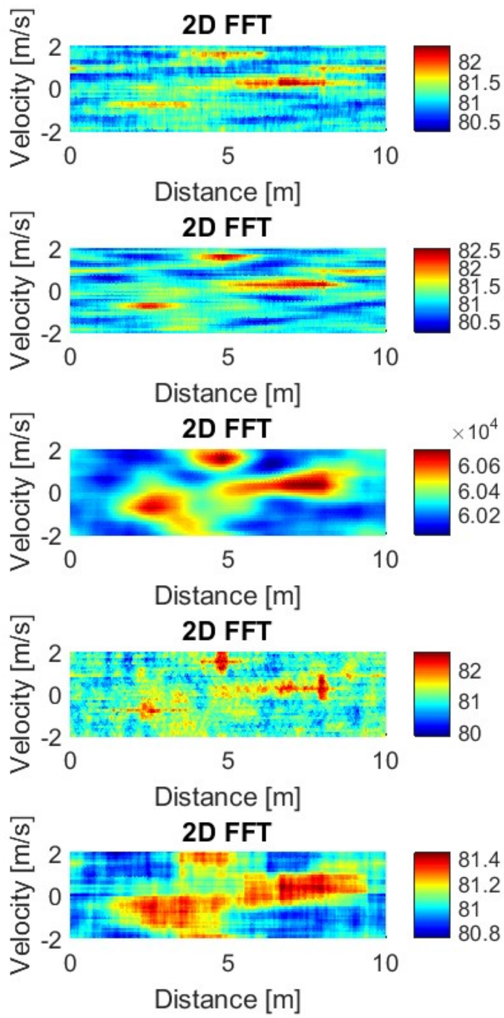

Fig.10. Filtration of the spectrum with three weak targets from figure 6. ((a) Cross (b) Weighted cross (c) Cone (d) 2D spectrum of the signal echo after thresholding and video-detection (e) Normalized 2D spectrum of the signal echo)

The 2D spectrum of the signal with two strong echoes is shown in Fig. 11. From the spectrum, we can see that the strong signal in the spectrum is accompanied by side lobes, and these side lobes can be evaluated similar to the next targets, like in the case of automatic detection (described in (Rejfek et al., 2016b)). Filtrations of this 2D spectrum are in Fig. 12. We can see that all of these new spectra can be used for the target detection. A very important result is shown in Fig. 13. This spectrum was filtered by the cone window (c). The side lobes caused by a strong target were suppressed and they cannot cause problems for the automatic signal analysis. Other windows make only small fluctuations in the 2D spectrum and generation of the false alerts is minimal too.

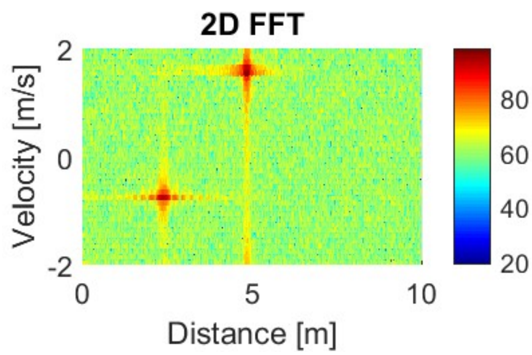

Fig.11. 2D spectrum of the signal with two strong targets

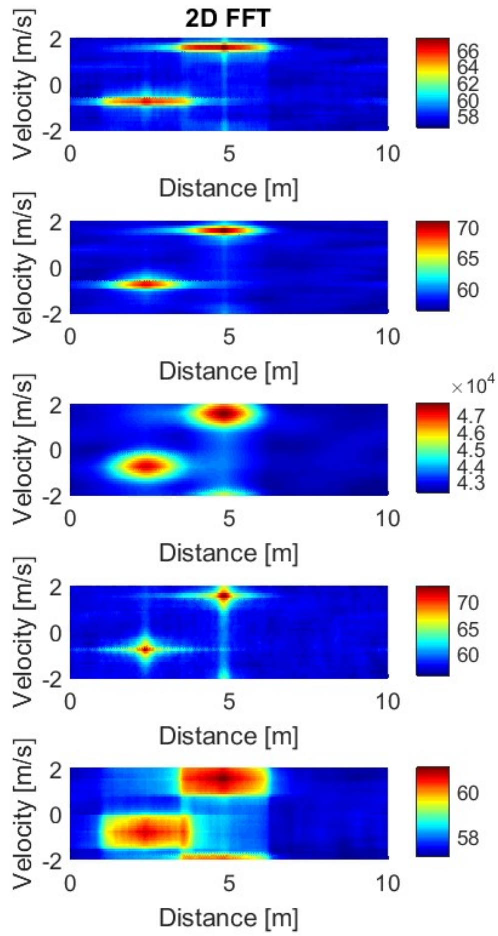

Fig.12. Filtration of the spectrum with three weak targets from figure 11. ((a) Cross (b) Weighted cross (c) Cone (d) 2D spectrum of the signal echo after thresholding and video-detection (e) Normalized 2D spectrum of the signal echo)

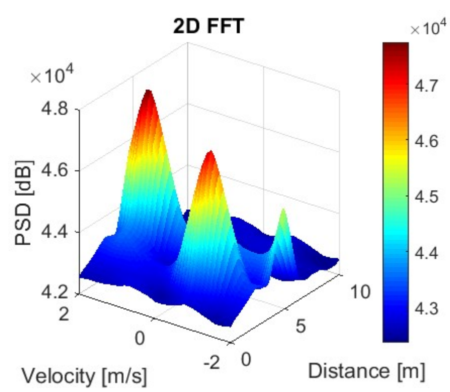

Fig.13. 2D spectrum filtered by cone window

The third tested variant is the signal analysis without any echoes. The 2D spectrum of this signal is in Fig. 14. The filtration of this spectrum is shown in Fig. 15. From these figures, we can estimate that false alerts are generated only for the windows (c) and (e). After processing by the algorithm described in (Rejfek et al., 2016b), it was validated that these two filtered 2D spectra were processed wrongly.

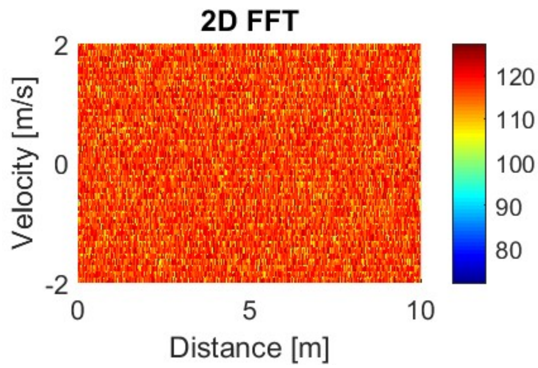

Fig.14. 2D spectrum of the noise

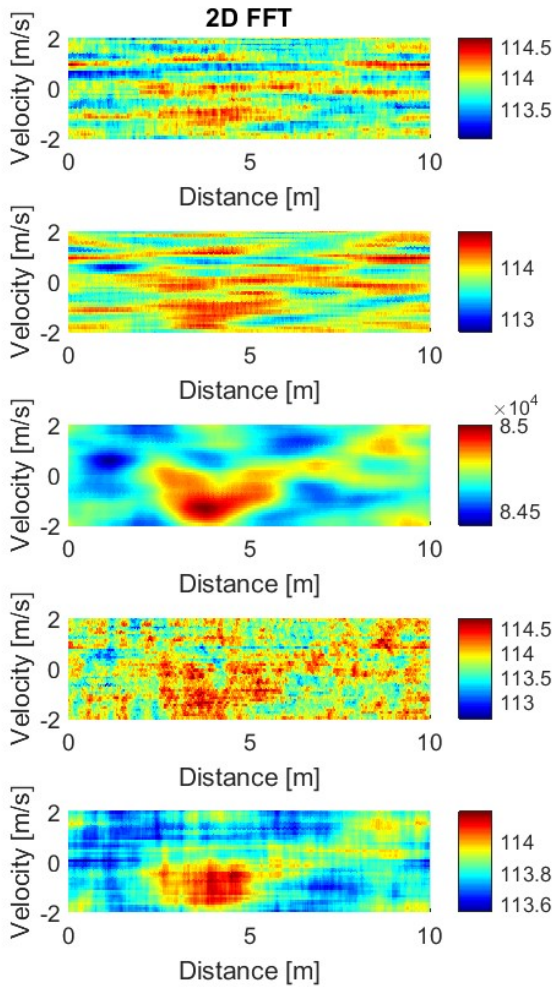

Fig.15. Filtration of the spectrum with three weak targets from figure 14. ((a) Cross (b) Weighted cross (c) Cone (d) 2D spectrum of the signal echo after thresholding and video-detection (e) Normalized 2D spectrum of the signal echo)

The last tested variant is the signal processing with strong and weak echoes. This is shown in Fig. 16. Used windows are weighted by the cross and the 2D spectrum of the signal echo after thresholding and video-detection. The 2D spectra are results after the threshold according to the algorithm described in (Rejfek et al., 2016b). In the last part, the original 2D spectrum is placed. The pink circles highlight echoes in the original spectrum and the green circles highlight position of the targets in the threshold 2D spectra. Other windows were not used for unsatisfactory results (cone and normalized 2D spectrum of the signal echo) and similar results (cross and weighted cross – weighted cross is only used). From the results, we can see that the all targets are detected.

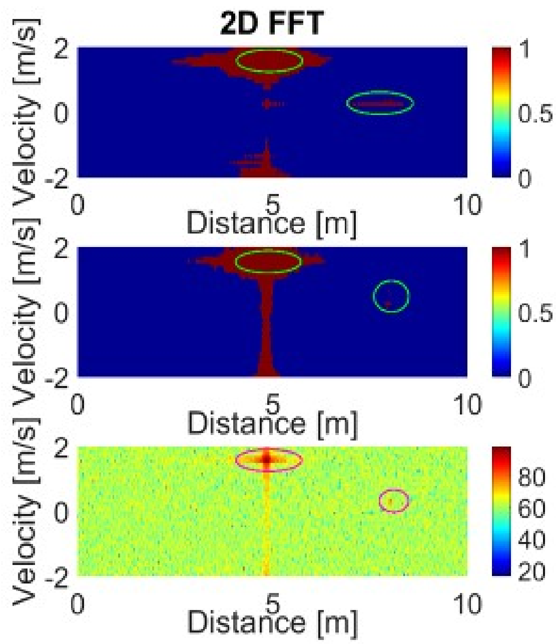

Fig.16. Evaluation of the strong and weak target in one signal. ((a) Weighted cross (b) 2D spectrum of the signal echo after thresholding and video-detection (c) Original 2D spectrum)

CONCLUSIONS

In this paper, we described a system for the filtration of the 2D spectrum. We tested five windows for 2D spectrum filtration. The best window, according to our testing, is the 2D spectrum of the signal echo after thresholding and video-detection. The next possibility is using more windows combinations and comparing results.

The proposed solution will be used for an implementation of our algorithm for the signal analysis with unknown number of targets, which is described in (Rejfek et al., 2016b). It was validated by the experiments presented in this paper. The best advantage of this step is integration into our algorithm, it reduce the number of false alerts caused by the side lobes of the strong echoes.

In the future we want to use these windows for target symmetry detection. The described windows transform the targets to the symmetric objects in the spectrum. This is important for the weak targets, which are represented only by the small points in the 2D spectrum.

Very surprising for us was that the window based on the real shape of the received echo has the worst results. Contrary to expectations, the best results are for the window which is based on the thresholding of the real echo shape. We can notice that after some modification of this shape, we can obtain excellent results in the future. But in this time, this modification is unknown, if it even exists.

ACKNOWLEDGMENT

The research was supported by the Internal Grant Agency of University of Pardubice, the project No. SGS_2017_030.

REFERENCES

KREJCI, T. and MANDLIK, M., 2017. Close vehicle warning for bicyclists based on FMCW radar, *2017 27th International Conference Radioelektronika.*

LI, C., CHEN, W., LIU, G., YAN, R. and XU, H., 2015. A noncontact fmcw radar sensor for displacement measurement in structural health monitoring. Sensors (Switzerland), 15(4), pp. 7412-7433.

MANDLIK, M. and BRAZDA, V., 2015. FMICW radar simulator, *Proceedings of 25th International Conference Radioelektronika, RADIOELEKTRONIKA 2015* 2015, pp. 317-320.

NOZAKI, K., 2009. FMCW lonosonde for the SEALION project. Journal of the National Institute of Information and Communications Technology, 56(1-4), pp. 287-298.

PANKRÁC, V. Elektromagnetické pole. ČVUT FEL, Katedra Elektromagnetického Pole, 2005. Přednášky. doi: http://www.old.elmag.org /lib/exe/fetch.php/wiki:user:pankrac:x17tep:prednaska_11_12.pdf

SALDAÑA, R. R., MARTÍNEZ, P. F. "FMICW TECNIQUES APPLIED TO A Ka BAND SAR ON BOARD UAV." (2007).

REJFEK, L., FISER, O., MATOUSEK, D., BERAN, L., CHMELAR, P., 2017a, Correction of Received Power for Doppler Measurements by FMICW Radars, Proceedings Elmar - International Symposium Electronics in Marine, pp. 107-110.

REJFEK, L., FISER, O., MATOUSEK, D., BERAN, L., CHMELAR, P., 2017b, Sensitivity Analysis of PCDR35 Radar, Proceedings Elmar - International Symposium Electronics in Marine, pp. 111-114.

REJFEK, L., MOŠNA, Z., URBÁŘ, J. and KOUCKÁ KNÍŽOVÁ, P., 2016a. System for Automatic Detection and Analysis of Targets in FMICW Radar Signal. *Journal of Electrical Engineering,* 67(1), pp. 36-41.

REJFEK, L., MOŠNA, Z., BERAN, L., FIŠER, O. and DOBROVOLNÝ, M., 2016b. Automatic detection of the unknown number point targets in FMICW radar signals. International Journal of Advanced and Applied Sciences.

TYKHONOV, V.A., KUDRIAVTSEVA, N.V., "Improving the resolution capability of the parametric power spectrum density on the base of an additive linear prediction process," Proceedings of 23rd International Conference, RADIOELEKTRONIKA 2013 2013, pp. 416-419.

YANOVSKY, F.J., OUDE NIJHUIS, A.C.P., KRASNOV, O.A., UNAL, C.M.H., RUSSCHENBERG, H.W.J. and YAROVOY, A., 2015. Turbulence intensity estimation using advanced radar methods, *2015 European Radar Conference, EuRAD 2015 - Proceedings* 2015, pp. 141-144.

ZALABSKY, T., HNILICKA, T., 2017, An Antenna Array Synthesis for Large Vertical Aperture Antenna for Secondary Surveillance Radar, Proceedings Elmar - International Symposium Electronics in Marine, pp. 119-122.

How to cite this article:
Rejfek L, Chmelařová N, Beran L, Chmelař P. Filtration of the fmicw radar output signals by the advanced windows. J. Fundam. Appl. Sci., 2018, *10(3S), 521-535.*