HIGH SPEED TARGET TRACKING RADAR SYSTEM BASED ON THE USE OF BPSK SIGNAL AND DIGITAL DOPPLER SHIFT COMPENSATION

Zoran T. Golubičić[a], *Slobodan* M. Simić[b],
Aleksa J. Zejak[c], *Boro* M. Reljić[d], *Svetislav* Marić[e]

[a] Peripolis elektronika, Belgrade, Republic of Serbia,
e-mail: golubicic.zoran@gmail.com,
ORCID iD: https://orcid.org/0000-0003-1698-7017

[b] University of Defence in Belgrade, Military Academy,
Department for MilitaryElectronic Systems,
Belgrade, Republic of Serbia,
e-mail: slobodan.simic@va.mod.gov.rs**, corresponding author**,
ORCID iD: https://orcid.org/0000-0002-6846-4886

[c] R&D Institute, RT-RK Computer based systems,
Novi Sad, Republic of Serbia,
e-mail: aleksa.zejak@rt-rk.com,
ORCID iD: https://orcid.org/0000-0001-5114-2867

[d] R&D Institute, RT-RK Computer based systems,
Novi Sad, Republic of Serbia,
e-mail: boro.reljic@gmail.com,
ORCID iD: https://orcid.org/0000-0002-7660-9854

[e] University of California San Diego, Division of Extended Studies,
La Jolla, CA, USA,
e-mail: smaric@ucsd.edu,
ORCID iD: https://orcid.org/0000-0001-5705-9124

DOI: 10.5937/vojtehg70-36589; https://doi.org/10.5937/vojtehg70-36589

FIELD: Electronics, Telecommunications, Radar technology
ARTICLE TYPE: Original scientific paper

Abstract:

Introduction/purpose: This paper presents a model of a high speed target radar tracking system that is much simpler than the existing ones. The Doppler shift is compensated before signal compression, simultaneously with the modification of the clock signal in the compression filter. This is possible thanks to the development of FPGA technology. The most important for this application are very fast clock control units which enable operation with different frequency references up to 1 GHz with an accuracy far below 1 Hz.

Methods: In this paper, the methodology of mathematical modeling and simulation is used.

Results:The results of the analysis of the most important effects in radars caused by high-speed targets are presented and discussed - target migration through resolution cells and compression filter response distortion due to high target acceleration.

Conclusion: Thanks to flexible RF and signal processing hardware, complex radar processing procedures are not required. The sensitivity of the BPSK signal to the Doppler shift (which is usually considered a disadvantage) can be used to reject targets at a slightly different rate. This system can be used in space debris tracking, airspace target tracking, car driving, etc.

Key words: target migration, FPGA, DDS.

Introduction

High speed target detection and tracking present a serious problem for classical radar systems. A high speed target generates a high Doppler frequency shift in the receiving signal. High Doppler frequency can generate significant losses in the radar compression filter even if the signal with reduced sensitivity to the Doppler shift is applied. A well-known problem is “stop and go”, when a target passes a few range resolution cells during the pulse time. This problem is frequently analyzed in the synthetic-aperture radar (SAR) processing (Tang et al, 2019). The problem is typical for radars operating with very long pulses such as space debris radars (NASA-Handbook 8719.14, 2008). Even if a radar system operates with high radio frequency (RF) power and short pulses, there is a problem with target migration from one pulse to another. These problems are usually resolved by complex radar processing employing banks of matching filters and alignment algorithms (Addabbo et al, 2019; Yang et al, 2017). Complexity in the detection process could be increased by significant target acceleration. It increases the required number of filters in the filter bank and increases the complexity of iterative algorithms. In the case of surveillance radars, such a complex procedure is unavoidable. But, in the case of the tracking radar, the processing method could be adjusted according to the tracked target type. Usually, targets with high velocity have no high acceleration and vice versa. This is the consequence of the target inertial limitations. For example, space targets have high velocity but low acceleration, and drones can have low velocity but high radial acceleration. It means that signal processing in tracking radars could be significantly simplified by adjusting a processing method to a particular target. In this paper, a simple processing method for high speed target tracking is highlighted. In order to obtain enough signal-to-noise ratio (SNR) with limited RF power, a target has to be illuminated long time which causes high target migration during the dwell period. Examples related to space debris radars will support the method applicability (Klinkrad, 2006; Losacco & Schirru, 2019).

The application of matching filter banks or complex iterative algorithms is suitable for off line signal processing. Otherwise, extremely high power numeric processing machines are required. The proposed simplification is applicable not only for space control radars (which are a representative example in this paper) but also for other radars utilizing long pulses. The examples are high resolution radars for autonomous vehicle guidance (when two close vehicles have to be separated by different speed) or military purpose (when a plane has to be separated from a lunched missile). All these systems require real time signal processing with reasonable hardware resources. Sometimes, problems with high Doppler frequency do not have origin only in high speed but in high frequency (millimeter wave radar for autonomous navigation) and wide bandwidth (required high resolution in the slant range). Independently of the origin, high Doppler frequency and wide bandwidth cause the received signal compression and target migration problems that should be resolved in real time.

A common tracking radar employs linear frequency modulated (LFM) signals. An LFM signal is known as a Doppler resistive signal. But, this signal is also sensitive to “stop and go” effects and a compression filter should be based on the bank of matching filters. However, the binary phase shift keying (BPSK) modulation is known as the Doppler sensitive modulation and requires a high number of matching filters inside the filter bank. In the case of the tracking radar, the velocity of the target is known (with some uncertainty) and the advantage of the LFM modulation is not significant. On the other hand, the BPSK matching filter structures intended for wideband signals are significantly simpler (than the LFM matching filter) because they do not need hardware multipliers. In the case of the tracking radar, the BPSK Doppler sensitivity should be exploited for non-tracked target rejection. In the next section, a fast target tracking method based on the BPSK radar signal is presented. Critical Doppler uncertainty is simply resolved by using target speed measurement and appropriate signal processing techniques avoiding requirements for the filter bank.

Proposed radar configuration

A simplified block schematic of the proposed tracking radar is presented in Fig. 1. A radar signal is digitally generated at the low intermediate frequency (IF) frequency and up-converted by two fixed local oscillators(LO) to the output frequency. The input signal is down-converted by the same LO to the low IF frequency that is similar to the frequency of the digitally generated Tx signal. The difference is in the Doppler shift.

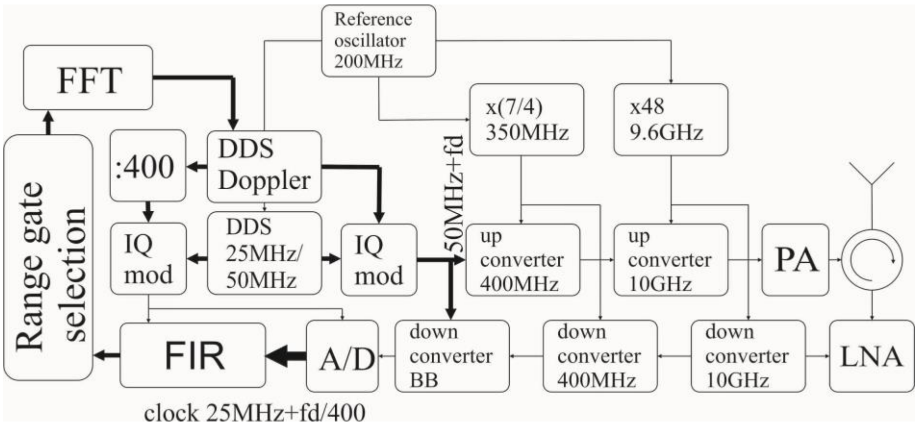

Figure 1 – Simplified block schematic of the tracking radar
Рис. 1 – Упрощенная блок-схема РЛС слежения
Слика 1 – Упрошћена блок-шема радара за праћење

This signal is down-converted to baseband (BB) by the LO signal generated by the direct digital synthesis (DDS). The frequency of this signal corresponds to the IF frequency of the receiving signals i.e. the baseband signal has no Doppler component. The baseband signal without a Doppler component is compressed by the standard finite impulse response (FIR) filter. Because the complete signal spectrum suffers from the high Doppler shifting, the bit rate in the BPSK signal is changed. For that reason, the FIR filter clock has to be modified. In the Rx mode, the DDS has to generate a new clock with the offset respectively to the Tx signal bit rate:

$$f_{clk}^{offset} = f_{doppler} * \left(\frac{f_{clktx}}{f_o}\right) \tag{1}$$

where $f_{doppler}$ is the measured Doppler frequency, f_o is the output central frequency, and f_{clktx} is the generated chip rate. This offset has to compensate for pulse stretching or extension caused by the Doppler effects.

Knowing the Doppler shift at the central frequency, the target velocity could be estimated with high accuracy. Knowing the target velocity, a prediction of the target migration could be performed. This prediction enables a right selection of the pulses participating in the coherent signal integration. So, the key parameter that has to be measured is the target radial velocity.

Although this architecture seems simple, there are a few reasons why it is not widely applied in practice. The digital generation of wideband radar signals at IF frequency was limited by the FPGA (Field programmable Gate Array) maximum clock and the FPGA numeric capacity. The DDS were usually realized as separate devices with limitation in the configuration speed. It was limited by the accumulator word length and the frequency resolution. The FPGA clocks were limited by the one clock manager circuit. New FPGA circuits operate with clocks up to 1GHz permitting different references to difference clock manager, simultaneously achieving an accuracy that is far below 1 Hz. Doppler shifts can be compensated before signal compression, simultaneously with compression filter clock modifications. In this way, methods utilizing filter banks and signal oversampling (few tenths of time) are avoided.

Signal processing is divided in two consecutive phases. The first phase is velocity determination. After that, the down converter and the filter matched to the Rx sequence will be configured in real time and target migration from pulse to pulse will be determined. In accordance with the calculated values, a coherent or non-coherent integration process could be performed.

Velocity (Doppler) measurement

The first phase in the tracking process has to be target velocity measurement (this measurement should be performed simultaneously with angular measurement and tracking). For this measurement, the radar should transmit and receive non modulated pulses. The received signal should be sampled and the FFT (Fast Fourier Transform) of the received signal should be performed. Because the pulse is long in time, the main part of energy should be concentrated around the Doppler frequency. A component from the pulse modulation will be present, but the energy of these components should be below the carrier component. A simple frequency analysis can highlight the carrier (Doppler) frequency. The dwell time has the main influence on the precision of the frequency measurement.

The resolution of the Doppler frequency *Δf* can be determined as:

$$\Delta f = \frac{1}{\tau_{ill}} \Rightarrow \Delta v = \frac{c * \Delta f}{2 f_0} = \frac{c}{2 f_0 \tau_{ill}} = \frac{\lambda_0}{2 \tau_{ill}} \tag{2}$$

where τ_{ill}presents the target illumination time (dwell time), Δv is the velocity resolution, *c* is the speed of the light and λ_0 is the transmission signal wavelength. If the number of pulses during the dwell time is *N*, the maximum uncertainty in the target position should be:

$$\Delta l = N * PRI * \Delta v = N * PRI * \frac{\lambda_0}{2\tau_{ill}} \tag{3}$$

where PRI is the pulse repetition interval. If Δr is the range resolution, then:

$$\Delta l \ll \Delta r \tag{4}$$

As an example, a space debris radar with 10ms long pulse and 6m range resolution cell integrates 32 pulses with the PRI of 25ms (duty factor 40%). It means that the dwell time is 0.8s. The frequency resolution is 1.25Hz. The velocity uncertainty for a 10GHz radar should be 0.019m/s. The uncertainty in the target position for the dwell time should be 15cm. Since the received signal is a pulse amplitude modulation (PAM) signal, the obtained spectrum will have components at both sides of the carrier signal. The carrier peak presents the received Doppler frequency and the frequency of the other component depends on the PRI and the pulse time. An example of the spectrum of the 400kHz Doppler shift is presented in Fig. 2 (left).

The diagram in Fig. 2 (right) presents a zoomed part of the full span when components at 40Hz (25ms PRI) exist. The highest component presents the carrier (Doppler) frequency. The presented spectrums are without noise. In practice, the noise floor minimum 20dB below the maximum components is desirable.

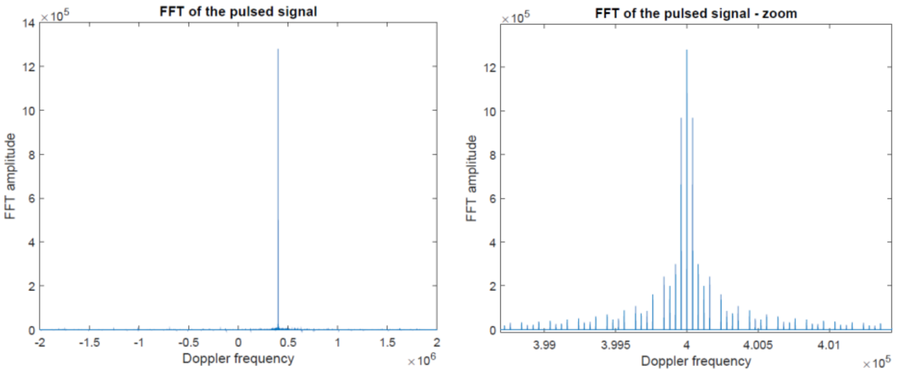

Figure 2 – Spectrum of the pulsed signal modulated with the Doppler frequency
Рис. 2 – Спектр импульсного сигнала, модулированного доплеровской частотой
Слика 2 – Спектар импулсног сигнала модулисаног Доплеровом фреквенцијом

Matching filter configuration

Knowing the target speed, the LO frequency and the compression FIR filter clock should be adjusted in accordance with the Doppler shift. The DDS generating the measured Doppler frequency can modulate (shift) the LO carrier. The chip frequency is always generated as a fraction of the LO carrier frequency i.e. this frequency will be shifted for the carrier frequency shift divided by a constant fraction. Knowing the Doppler frequency f_d, and knowing the ratio between the carrier frequency and the chip frequency, a new chip frequency (the FIR filter clock) can be calculated as:

$$f'_{chip} = \frac{f_0 + f_d}{\frac{f_0}{f_{chip}}} \quad T'_{chip} = \frac{1}{f'_{chip}} \tag{5}$$

where f_{chip} is the frequency of the PN chip clock in the Tx signal and f'_{chip} is the frequency of the PN chip clock in the Rx signal. It means that the FIR filter has to change the clock frequency in accordance with the relation given above. For example, if the carrier frequency is 10GHz, and the symbol frequency is 25MHz, the symbol frequency presents the 1/400th part of the carrier frequency i.e. the symbol frequency is generated by the carrier frequency divider 1:400. If the carrier shift is 400kHz, the symbol rate is changed 1 kHz. It means that if the LO frequency of the DDS is shifted from 50MHz to 5040kHz, the symbol frequency will be shifted from 25000kHz to 25001kHz. A new symbol frequency is the frequency fed to AD converters and FIR filters. Other processing parts of the matching filter are the simplified FIR filters (Golubičić et al, 2013; Simić et al, 2013) easily incorporated in the low-cost FPGA circuits. A simplified schematic is presented in Fig. 3. It is clear that the filter has a simple structure without hardware multipliers. During 10ms, 250000 chips of 40ns will be compressed by the FIR filter.

Fig. 4 (left) presents the FIR filter response when the filter is perfectly matched to the receiving signal Doppler frequency. Fig. 4 (right) shows how the filter response drops when it is non-matched to the Doppler shift. According to the diagrams, the filter has to be matched to the Doppler frequency with the range of ±10Hz.

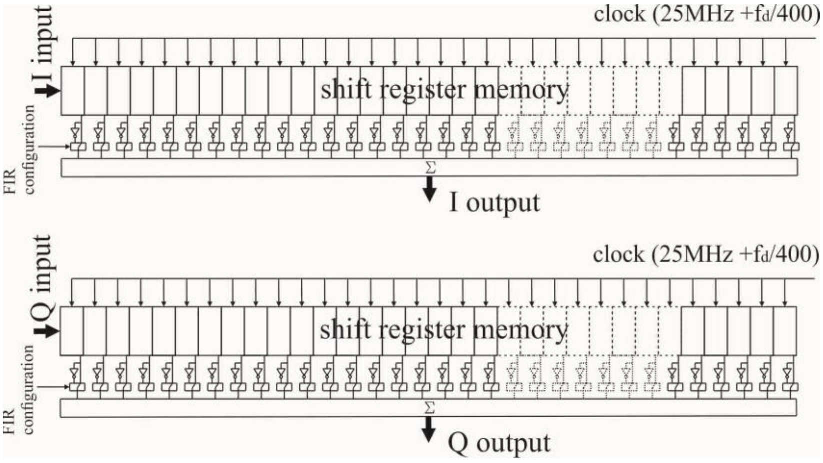

Figure 3 – Simplified schematic of the BPSK compression filter
Рис. 3 – Упрощенная схема фильтра сжатия BPSK
Слика 3 – Упрошћена шема BPSK компресионог филтера

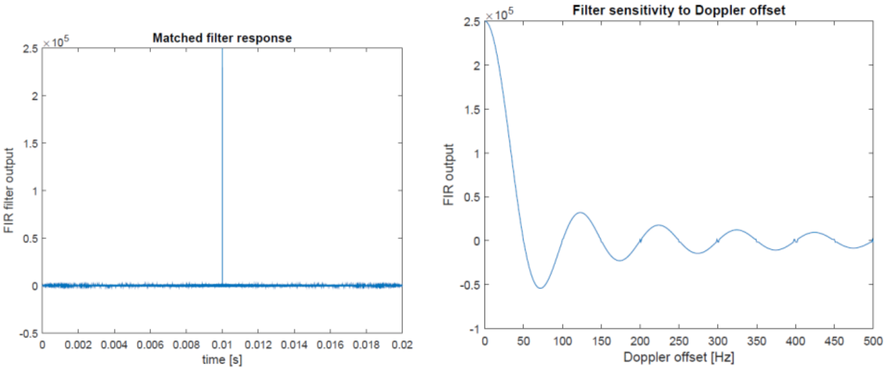

Figure 4 – Matching filter characteristics
Рис. 4 – Характеристики согласованного фильтра
Слика 4 – Карактеристике прилагођеног филтера

Main effects of high speed targets on the radar tracking system

Due to high target speed, the range between the radar and a target varies during the coherent processing interval (CPI). Because of that variation in the range, not all the echo signals from the target appear in the same range cell. This is called target migration through range cells. Equally, a high acceleration of the target causes that the Doppler frequency is also spread over multiple cells and this is called the Doppler cell migration.

Effect of target migration

The problem of target migration is presented in Fig. 5. Because the velocity of the target is high, the distance between the target and the radar should be different from one pulse to another. In that case, the pulses from the same range gates could not be used in the integration process. The solutions for this problem were usually analyzed for the LFM radars operation (Li et al, 2009).

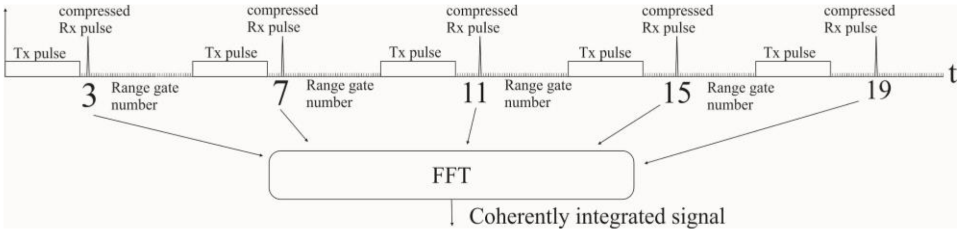

Figure 5 – Target migration between pulses
Рис. 5 – Миграция цели между импульсами
Слика 5 – Миграција циља између импулса

This radar has a problem with the range gate coupling and cannot exploit velocity knowledge. In the proposed method, this is not the case. The range gate of the returned signal (from one target) will be changed from one pulse to another. As a consequence, signals from different range cells have to be included in the integration process. The selection of the range gates that participate in one integration process is determined by the target velocity. When the target velocity is known, the migration of the target from one pulse to another could be predicted.

$$\varDelta_{lp} = v * PRI \qquad \varDelta_{lp}^2 = \varDelta_v * PRI \tag{6}$$

where v is the target speed, $\varDelta_{lp}$ is the difference in the distance between the radar and the target in successive pulse repetition intervals, $\varDelta_v$is the uncertainty of the target speed, and $\varDelta_{lp}^2$ is the uncertainty of the target position. For example, the target migration between pulses with the target speed of up to 8000m/s and the PRI of 25ms could be between 0m and 200m i.e. between 0 and 34 range gates. The uncertainty in the position between two pulses (if $\varDelta v$ is 0.019m/s) could be 0.5mm. It means that a prediction of the target migration could be very accurate. The uncertainty in the target position during the dwell time of 0.8s is 15cm. Since the uncertainty of the velocity, compared with the range resolution cell, is low, a prediction of the range gate migration should be simple. Theoretically, there is a possibility that the migration distance coincide with the integer number of the range cell distance. In that case, it is not clear which range cell contains the target. But, because this point is predictable, two series of range cells can be formed. The sum or the FFT should be performed over both pulse series.

The number of the range cells that has to participate in the FFT calculation should be found as

$$N = floor\left(v * PRI * \frac{n}{\Delta r}\right) \tag{7}$$

where n is the number of the Tx pulses and Δr is the range resolution. Taking into account the maximum and minimum velocity, different N vectors could be established, providing all possible range cell combinations. Fig. 6 illustrates target migrations through the range cells, starting from the first two range cells. The linear lines present possible target velocities. It is clear that, for the second range cell, there is ambiguity at the 8th Tx pulse, and it is necessary to integrate this pulse with two different sets.

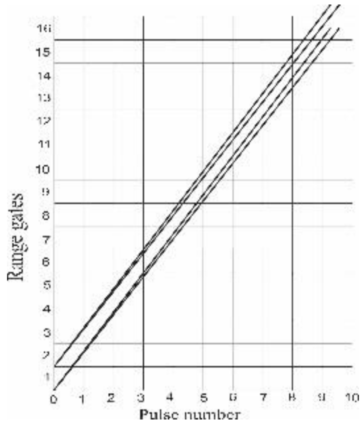

Figure 6– Target migrations through the range cells
Рис. 6 – Миграция цели по ячейкам диапазона
Слика 6 – Миграција циља кроз резолуционе ћелије

Acceleration effect

In theory, target velocity is not always constant. Because of that, a compression filter is not always matched to target velocity. But, in practice, the correlation function is not sensitive to real acceleration values, as it is shown in Fig. 7 that presents the correlation function for the (non-matched) Doppler velocity up to ±200Hz and the acceleration of $\pm 200 Hz/s^2$. For the 10GHz radar, it corresponds to the realistic velocity of ±5m/s and the acceleration of $\pm 5 m/s^2$ when a 10ms pulse is applied (Murray et al, 2019).

But, at very high accelerations, significant distortion in the response of the compression filter is evident. Fig. 8 presents the FIR filter outputs for target accelerations up to 500m/s^2 (±360Hz/s^2). In that case, the matching filter has to include acceleration (even the third order phase function) (Jin et al, 2019; Chen et al, 2019).

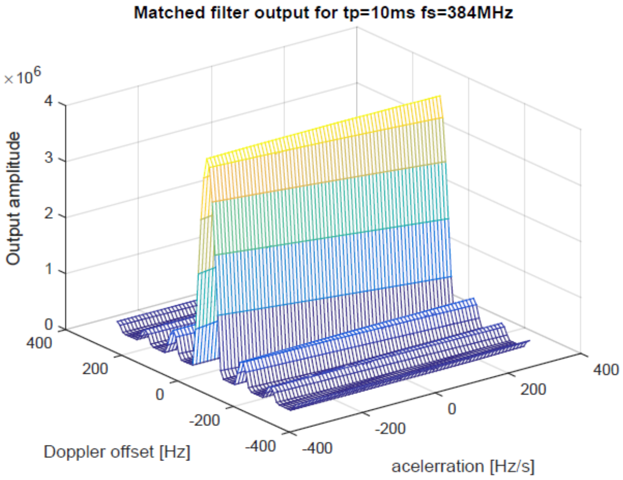

Figure 7– FIR filter outputs for different velocities and accelerations
Рис. 7 – Выход КИХ-фильтра при различных скоростях и ускорении
Слика 7 – Излаз из FIR филтера при различитим брзинама и убрзањима

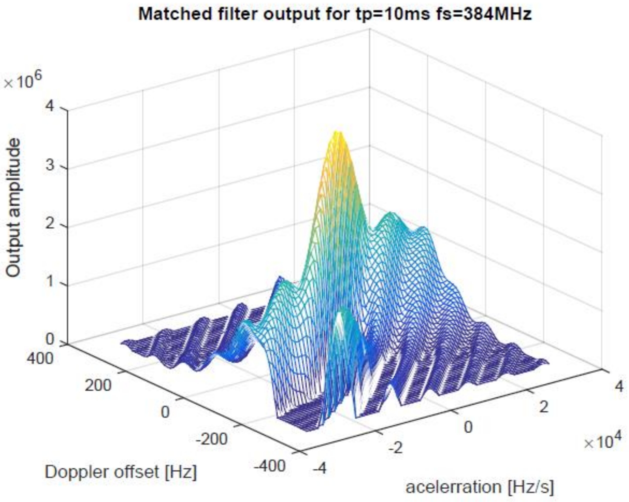

Figure 8– FIR filter outputs for different velocities and high accelerations
Рис. 8 – Выход КИХ-фильтра при различных скоростях и сильном ускорении
Слика 8 – Излаз из FIR филтера при различитим брзинама и великим убрзањима

Conclusion

Thanks to the flexible RF and processing hardware, the tracking radar does not need complex processing procedures with unknown target positions and velocities. Radars operating with long pulses (in order to compress high energy) can measure target speeds and positions alternatively employing the obtained data from one measurement to facilitate the other. The sensitivity of the BPSK signals to the Doppler shift (usually mentioned as a disadvantage) could be used for the rejection of targets with slightly different velocity. This system can find application in space debris tracking, aerial target tracking, automotive car driving, etc.

References

Addabbo, P., Orlando, D. & Ricci, G. 2019. Adaptive Radar Detection of Dim Moving Targets in Presence of Range Migration. *IEEE Signal Processing Letters*, 26(10), pp.1461-1465. Available at: https://doi.org/10.1109/LSP.2019.2936650.

Chen, J., Jin, K., Yu, S., Lai, T. & Zhao, Y. 2019. Radar Coherent Detection for Maneuvering Target Based on Product-Scaled Integrated Cubic Phase Function. *International Journal of Antennas and Propagation*, 2019(art.ID:8691903). Available at: https://doi.org/10.1155/2019/8691903.

Golubičić, Z., Simić, S. & Zejak, A.J. 2013. Design and FPGA implementation of digital pulse compression for band-pass radar signals. *Journal of Electrical Engineering*, 64(3), pp.191-195. Available at: https://doi.org/10.2478/jee-2013-0028.

Jin, K., Lai, T., Wang, Y., Li, G. & Zhao, Y. 2019. Coherent Integration for Radar High-Speed Maneuvering Target Based on Frequency-Domain Second-Order Phase Difference. *MDPI electronics*, 8(3), art.ID:287. Available at: https://doi.org/10.3390/electronics8030287.

Klinkrad, H. 2006. The Current Space Debris Environment and its Sources. In: *Space Debris. Springer Praxis Books.*Berlin, Heidelberg:Springer. Available at: https://doi.org/10.1007/3-540-37674-7_2. ISBN: 978-3-540-37674-3.

Li, J., Liu, H. & He, Z-S. 2009. A practical method for range migration compensation in chirp radar. *Progress In Electromagnetics Research M*, 7, pp.15-28. Available at: https://doi.org/10.2528/PIERM09022302.

Losacco, M. & Schirru, L. 2019. Orbit Determination of Resident Space Objects Using the P-Band Mono-Beam Receiver of the Sardinia Radio Telescope. *Applied Science*, 9(19), art.ID:4092. Available at: https://doi.org/10.3390/app9194092.

Murray, J., Miller, R., Matney, M. & Kennedy, T. 2019. Orbital Debris Radar Measurements from the Haystack Ultra-wideband Satellite Imaging Radar (HUSIR): 2014-2017. In: *International Orbital Debris Conference (IOC)*, Sugar Land, TX, Document ID:20190033902, Patent Number:IOC6133, December 9-12 [online]. Availble at: https://ntrs.nasa.gov/citations/20190033902 [Accessed: 20 February 2022].

-NASA-Handbook 8719.14. 2008. *Handbookfor limiting orbital debris*. Washington, DC: NASA-Handbook [online]. Availble at: https://explorers.larc.nasa.gov/APMIDEX2016/MO/pdf_files/NHBK871914.pdf[Accessed: 20 February 2022].

Simić, S., Zejak, A.J. & Golubičić, Z. 2013. Hardware implementation of DIRLS mismatched compressor applied to a pulse-Doppler radar system. *Microprocessors and Microsystems*, 37(4-5), pp.381-393. Available at: https://doi.org/10.1016/J.MICPRO.2013.04.001.

Tang, S., Guo, P., Zhang, L. & Lin, C. 2019. Modelling and Precise Processing for Spaceborne Transmitter/Missile-Borne Receiver SAR Signals. *Remote Sensing*, 11(3), art.ID:346. Available at: https://doi.org/10.3390/rs11030346.

Yang, S., Li, Y., Zhang, K. & Liu, J. 2017. A Signal Processing Algorithm Based on 2D Matched Filtering for SSAR. *Mathematical Problems in Engineering*, 2017(art.ID:4047983). Available at: https://doi.org/10.1155/2017/4047983.

РАДИОЛОКАЦИОННАЯ СИСТЕМА СЛЕЖЕНИЯ ЗА ВЫСОКОСКОРОСТНЫМИ ЦЕЛЯМИ, ОСНОВАННАЯ НА ИСПОЛЬЗОВАНИИ СИГНАЛА BPSK И ЦИФРОВОЙ КОМПЕНСАЦИИ ДОПЛЕРОВСКОГО СДВИГА

Зоран Т. Голубичич[а], *Слободан* М. Симич[б],
Алекса Й. Зеяк[в], *Боро* М. Реич[в], *Светислав* Марич[г]

[а] Периполис электроника, г. Белград, Республика Сербия

[б] Университет обороны в г. Белград, Военная академия,
департамент военного электронного инжиниринга,
г. Белград, Республика Сербия, **корреспондент**

[в] Институт РТ-РК, г. Нови-Сад, Республика Сербия

[г] Калифорнийский университет в Сан-Диего, отделение расширенных
исследований, г. Ла-Хойя, Калифорния, Соединенный Штаты Америки

РУБРИКА ГРНТИ: 47.49.29 Радиолокационные системы, станции,
78.25.16 Вооружение и техника ракетных войск,
78.25.17 Вооружение и техника войск ПВО
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: В данной статье представлена модель радиолокационной системы слежения за высокоскоростными целями, которая намного проще существующих. Доплеровский сдвиг компенсируется перед сжатием сигнала одновременно с модификацией тактового сигнала в компрессионном фильтре. Это стало возможным благодаря развитию технологии FPGA. Важнейшими факторами в ее применении являются сверхбыстрые блоки управления тактовой частотой, которые *позволяют работать с различными опорными частотами до 1 ГГц, с точностью намного ниже 1 Гц.*

Методы: В данной статье используется методология математического моделирования и ситуационного моделирования.

Результаты: В статье представлены и обсуждены результаты анализа наиболее важных радиолокационных приемов, касающихся высокоскоростных целей и миграции цели через ячейки разрешения и искажения отклика фильтра сжатия вследствие сильного ускорения цели.

Выводы: Благодаря гибкому оборудованию радиочастотной обработки и обработки сигналов нет необхдимости в сложных процедурах обработки радиолокационных данных. Чувствительность сигнала BPSK к доплеровскому сдвигу (что обычно считается недостатком) может быть использована для отклонения целей с отличающейся скоростью. Данная система может быть использована при отслеживании космического мусора, слежении за целями в воздушном пространстве, управлении транспортным средством и пр.

Ключевые слова: миграция цели, FPGA, DDS.

РАДАРСКИ СИСТЕМ ЗА ПРАЋЕЊЕ ЦИЉЕВА ВЕЛИКИХ БРЗИНА ЗАСНОВАН НА УПОТРЕБИ BPSK СИГНАЛА И ДИГИТАЛНОЈ КОМПЕНЗАЦИЈИ ДОПЛЕРОВОГ ПОМАКА

Зоран Т. Голубичић[а], *Слободан* М. Симић[б],
Алекса Ј. Зејак[в], *Боро* М. Рељић[в], *Светислав* Марић[г]

[а] Периполис електроника, Београд, Република Србија

[б] Универзитет одбране у Београду, Војна академија,
Катедра војноелектронског инжењерства, Београд, Република Србија,
аутор за преписку

[в] Институт РТ-РК, Нови Сад, Република Србија

[г] Калифорнијски универзитет у Сан Дијегу, Одсек за проширене студије,
Калифорнија, Ла Хоја, Сједињене Америчке Државе

ОБЛАСТ: електроника, телекомуникације, радарска техника
ВРСТА ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: У овом раду представљен је модел радарског система за праћење циља велике брзине који је знатно једноставнији од постојећих. Доплеров помак се компензује пре компресије сигнала, истовремено с модификацијом сигнала такта у компресионом *филтеру. То је могуће захваљујући развоју FPGA технологије. За ову примену најважнији су веома брзи блокови за контролу такта, који омогућују рад с различитим референцама фреквенција до 1 GHz, са тачношћу много испод 1 Hz.*

Методе: Коришћена је методологија математичког моделирања и симулација.

Резултати: Представљени су и разматрани резултати анализе најважнијих ефеката у радарима које изазивају циљеви великих брзина – миграција циља кроз резолуционе ћелије и изобличење одзива компресионог филтера услед великих убрзања циља.

Закључак: Захваљујући флексибилном RF и хардверу за обраду сигнала, радару за праћење нису потребне сложене процедуре обраде. Осетљивост BPSK сигнала на Доплеров помак (обично се помиње као недостатак) може се искористити за одбацивање циљева с мало другачијом брзином. Овај систем може наћи примену у праћењу свемирског отпада, циљева у ваздушном простору, при вожњи аутомобила итд.

Кључне речи: миграција циља, FPGA, DDS.

Paper received on / Дата получения работы / Датум пријема чланка: 22.02.2022.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 18.03.2022.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 20.03.2022.