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RESEARCH ARTICLE

CHIRP FILTER JAMMING IMMUNITY RESEARCH

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Abstract

The pulse compression technique uses a matched filter to extract an echo signal in the radar's receiver. A model of a matched filter for a chirp signal was synthesized using the Simulink Tool of the MATLAB software. Pulse jamming and chirp jamming signals were feed to the input of the matched filter. The output signals were measured. The matched filter's degree of suppression of these jamming signals was assessed. Conclusions were made about the jamming immunity of a radar operating with a Chirp matched filter.

Introduction:-

Most contemporary radars utilize signal which possesses a big Time-Bandwidth Product(Aleksandrova2001) and (AleksandrovaIvanov2017).

Radars using intrapulse frequency-modulated waveforms may have TBPs of more than 100 up to 10 000. The linear frequency modulated signal (often called "Chirp Signal") is widely used in existing radar systems, especially in the military platform. For a linear frequency modulated waveform the bandwidth can be measured by the difference of the upper $f_{max}$and the lower frequency f_{min}: $B = \Delta f = f_{max} – f_{min}$.
The Time-Bandwidth Product (Levanon2004)is defined as following:

$$TBP = T_{trans}.\ (f_{max} – f_{min}) = T_{trans}.\ B, \qquad (1)$$

where T_{trans} is a length of the transmitted pulse, f_{max} and f_{min} are upper and the lower transmitted frequencies of B - the radar's bandwidth.

The Time-Bandwidth Product of contemporary radars is significantly more than 1 (usually it is within 50 ÷ 10 000).
The correlation properties of linear frequency modulated signals are analyzed by(Nenging1984) and (Korobko2003).
The most essential analytical expressions are presented here to study their properties as counteracting signals.
The absolute integrability (finite energy) of the signal

$$a(t) = A(t)\ .\ \cos\varphi(t), \qquad (2)$$

is a condition for finding the correlation function of any modulated oscillation a(t).
The chirp signal's correlation function is calculated on this basis and ithasthe form shown in Fig. 1.

Jamming signals which possess a high cross-correlation function with radar's transmitted linear frequency modulated signal would be effective to jam this radar (Velkov2004), (Spassov2006).The low jamming efficiency of a noise-like signal on a chirp filter is proved in (Spassov2005), even at very high values of the power spectral density.

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Simulation Setup:
The simulation uses a matched filter for a chirp signal (filter matched to linear frequency modulated signal of the radar) as a part of the radar's receiver. The chirp-matched filter is a functional element of a typical radarreceiver that uses compressed signal (linear frequency modulated signal). Some of the radar's parameters are implemented in the simulation of the chirp filter's operation.

The SIMULINK tool of the MATLAB software was used to create a model of the matched filter for a chirp signal, according to (Spassov2005) and similar to the real matched filter of typical military air defense radar. A simulation of a chirp filter's reaction topulse and chirp jamming signalswas made using MATLAB software. Pulse signals and Linear frequency modulated signals (chirp) were synthesized as a jamming signal. These signals were feed to the input of the matched filter and output signals were measured. The chirp-matched filter's degree of suppression of these types of jamming signals was assessed.The research was made at different ratios of the characteristics of the filter and the jamming signals.

The study of the jamming immunity of a chirp matched filter to jamming signals was done in the following order:
a) A model of an optimal chirp filter matched with the radar's signal was synthesized, and its parameters were determined;
b) Pulse jamming and chirp jamming signals have been selected, and their properties have been determined;
c) Pulse jamming signals have been feed to the input of the matched filter and output signals have been measured;
d) Chirp jamming signals have been feed to the input of the matched filter and output signals have been measured;
e) The obtained results have been evaluated and conclusions have been made.

A 7-element filter was synthesized by parallel connection of standard bandpass filters, delay line in each unit, and adders. The bandwidth and delay time in each unit are selected, optimized, and adjusted according to the general characteristics of the filter and the theoretical requirements defined by (Barton2004) and (Korobko2003). The chirp filter is a dispersion type with a lower cutoff frequency of 57 kHz, a center frequency of 60 kHz, and an upper cutoff frequency of 63 kHz. The matched filter's parameters are selected by the filter's parameters of a typical radar operating with a chirp signal. The functional diagram of the simulation model of the process is shown in Fig. 2 and Fig. 4.

The levels, thresholds, and time values of the parameters of a typical radar operating with compressed signal determine the value of the respective values in the model as follows:
1. The level at the output of the receiving system or the input of the ADC is about 20÷30 mV for radars operating with compressed signal (TBP = $B.T_{trans} >> 1$). A level of 60÷90 mV has been obtained, by taking into account the signal-to-noise ratio 3:1 of the automatic detector's threshold. Therefore, the threshold for comparison and evaluation is fixed at 100 mV. Thus the model's threshold level at the chirp-matched filter's output is 100 mV (for the input power of the tested filters 2.10-4 W accepted in the experiments - normalized amplitude 0.1V on a load of 50 Ω). The amplitude of the jamming signals is normalized to 0.1V at the input of the filter at all of the experiments;
2. A scale of 1000:1 between the real system and the model has been chosen at the time domain, due to a limitation in the software product's speed. The modeling has been performed at the ratio of the parameters between the real radar and the model, shownin Table 1.

Results and Discussions:-
Each simulation experiment has figures with obtained results. The oscillograms and spectrograms of the studies are shown from Fig. 3 to Fig. 6. In each figure a) is the input jamming chirp signal and b) is the response of the filter at the time domain.

Chirp filter's suppression degree to pulse jamming:
The response of a 7-unit chirp matched filter to jamming series of pulses has been researched. The experiment is made according to the structural scheme of the simulation model of the process, shown in Fig. 2, and the series of pulses have a carrier frequency equal to the average frequency of the filter. A continuous pulse series generatoris used as an input signal source.The generator has a pulse duration t = 0,16 ms, a carrier frequency of 60 kHz, a repetition frequency of 100 Hz, and an output amplitude equal to 0.1V. This amplitude is normalized, and it is equal to one division of the scale of the oscilloscope/spectrum analyzer in all experiments. The maximum amplitude is 0.7V, which corresponds to 7 divisions of the scale of the oscilloscope/spectrum analyzer.

Figures 3 a) and b) show the input pulse sequence and the output signal of a 7-element filter matched to a linear frequency modulated signal. The amplitude of the pulses at the input of the filter is normalized to 0.1V. The level of the output signal is about 0.014V. The output signal will not exceed the detector threshold of 0.1V, and the filter suppresses 7 times (16.9 dB) this pulse sequence.

A similar experiment was performed with the same matched filter to a linear frequency modulated signal. The pulse sequence duration is twice longer (τ = 0.32 ms) than the shrunk pulse duration.The input pulse sequence parameters are the same as in Fig. 3. The results compared with the experiment of Fig. 3 are shown in table 2. A comparison of the results shows that the chirp filter better suppresses (17 dBU) pulse interference with a duration comparable to the shrunken pulse (τ = 0.16 ms). Jamming pulses with a duration of two times longer(τ = 0.32 ms) than the compressed pulse are suppressed slightly less (14 dBU), but they cannot exceed the threshold of 0.1 V.

Chirp filter's suppression degree to chirp jamming signals:
The response of a chirp-matched filter to jamming series of pulses has been researched. The next experiments were made according to the structural scheme of the simulation model of the process, shown in Fig. 4.

A next experiment was made. A jamming chirp signal was applied to the filter's input with a frequency deviation B = 57÷63 kHz, which is the same as that of the filter. Figure 5 a) shows the input jamming chirp signal, figures 5 b) shows the output signal of a 7-element chirp filter. The level of the output signal is 0,56V. The output signal exceeds the detector threshold 5,6 times (15 dBU). The filter accumulates 5,6 times chirp jamming signal instead of suppressing it.

The last experiment was made. A jamming chirp signal, applied to the filter input with a frequency deviation B = 59÷61kHz, which is 3 times smaller than that of the filter. Figure 6 a) shows the input jamming chirp signal and Figure 6 b) shows the output signal of a 7-element chirp filter. The level of the output signal is 0,18 V. The output signal exceeds the detector threshold of 1,8 times (5 dBU). The filter accumulates 1,8 times jamming chirp signal instead of suppressing it.

Table 1:- The parameters ratio between the real radar and the model at the modeling process.

Parameters	**Intermediate Frequency IF**	**Transmitted pulse Duration T_{trans}**	**Pulse Repetition Frequency f_{PRF}**	**Compressed pulse Duration τ**	**Repetition Interval Time T_{rep}**
Radar	60 [MHz]	10 [µs]	1 [kHz]	0,2 [µs]	1 [ms]
Model	60 [kHz]	10 [ms]	1 [Hz]	0,2 [ms]	1 [s]

Table 2:- The Chirp matched filter suppression degree for different pulse jamming duration.

Input pulse duration T_{in} [ms]	0,16	0,32
The average Output amplitude U_{out} [V]	0,014	0,020
The average value of the suppression degree [dBU]	17	14

Table 3:- The Chirp matched filter suppression degree for Pulse Jamming and Chirp Jamming Signal.

Matched Chirp Filter	**Suppression Degree, Mean Value [dBU]**
Pulse Jamming	14 ÷17
Chirp Jamming Signal	**No suppression (Accumulation 5 ÷ 15 dBU)**

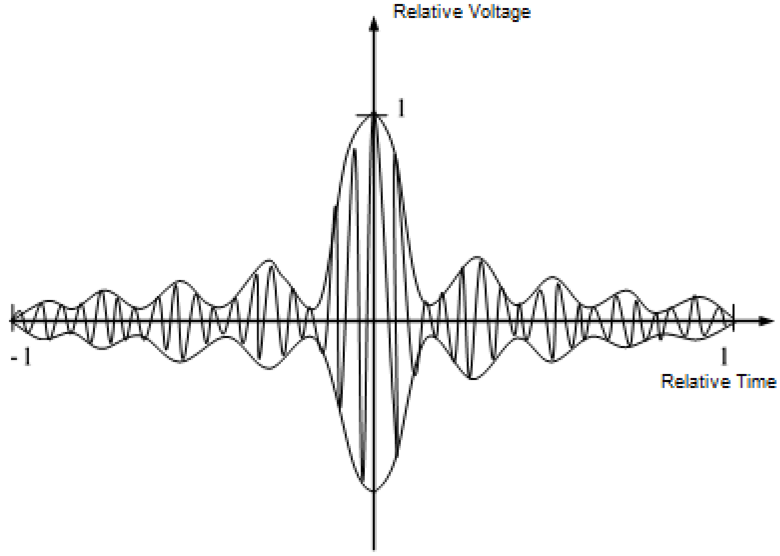


Fig. 1:- The autocorrelation function of a 7-element filter, matched to a linear frequency modulated (chirp) signal.

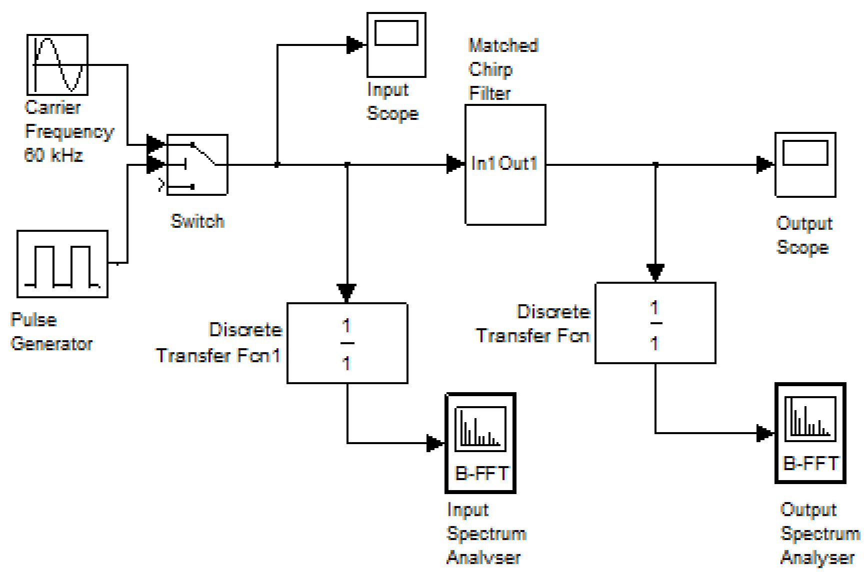
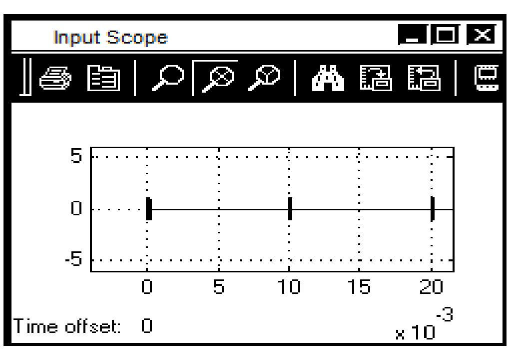


Fig. 2:- The functional diagram of the imitation modeling of the pulse jamming.



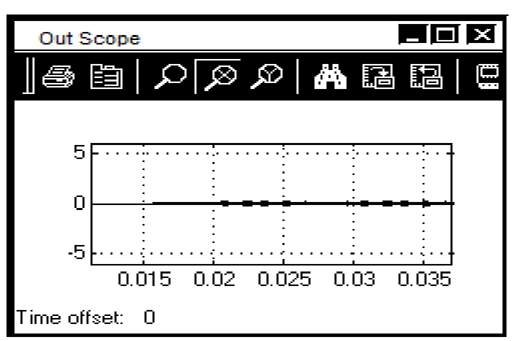


Fig. 3 a):- The pulse jamming at the input of the chirp filter, **Fig. 3 b):-** The signal at the output on the filter.

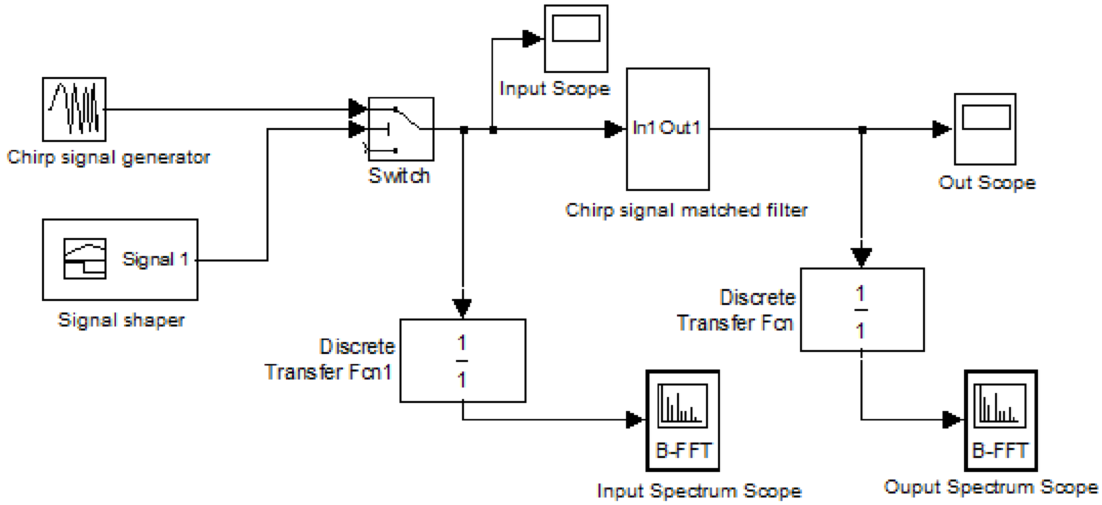
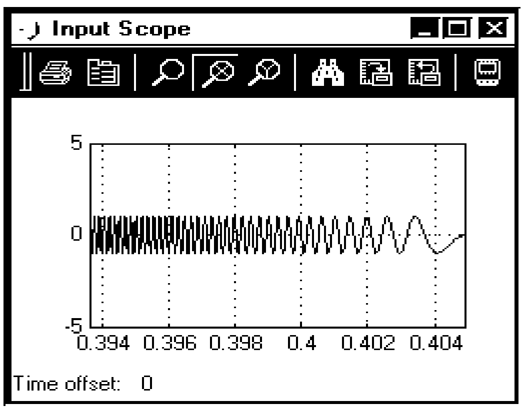


Fig. 4:- The functional diagram of the imitation modeling using chirp jamming signals.



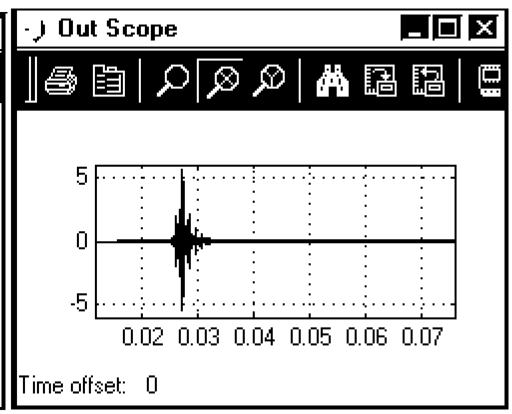
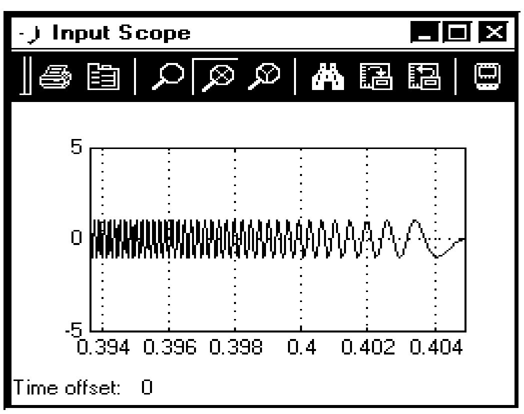


fig. 5 a):- The chirp jamming signal at the input. **fig. 5:b):-** Thesignal at the output on the filter



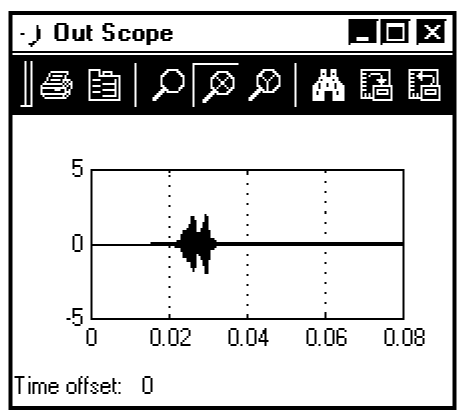


fig. 6 a):- The chirp jamming signal at the input. **fig. 6b):-** The signal at the output on the filter.

Conclusion:-

The following conclusions have drawn from the research of the suppression degree of the chirp filter jammed by pulse sequence and a chirp signal:

1. The chirp-matched filter suppresses a jamming pulse sequence. This filter better suppresses (17 dBU) jamming pulses with a duration equal to the shrunken pulse (τ = 0.16 ms), than suppresses (14 dBU) jamming pulses with a twice longer duration (τ = 0.32 ms).

2. The filter, matched to the radar's linear frequency modulated signal does not suppress the input chirp jamming signal but also accumulates it. The degree of accumulation is proportional to the coincidence of the deviation of the jamming signal with the complex amplitude-frequency characteristics of the filter.
3. The chirp matched filter accumulates input chirp jamming signals from 1.6 to 5.6 times (4÷15 dBU), and its output signals willexceed the threshold of the automatic detector several times. The amplitude of the output signal depends on the deviation value of the chirp jamming signal.
4. The chirp-matched filter is more vulnerable to chirp jamming signals than to jamming pulse sequence from an energy point of view. This is a result of the longer time for matching the spectra and phase ratios of jamming chirp signals with the frequency band of the optimal filter of the receiver.

The acquired results would be used to design jamming devices to improve the jamming of military surveillance radars operating with chirp signals.

References:-

1. Barton, D. K. (2004), Radar System Analysis and Modeling, Artech House, ISBN 9781580536813.
2. Nenging, L. (1984),Formulas for assessing the capabilities of radar to combat countermeasures, Proc., Pt. F., №4, July, vol.131.
3. Korobko, I. (2003), Radio systems (system design), (in Bulg. lang.), Corv., Press, Sofia.
4. Levanon N., Mozeson, E. (2004), Radar signals, Wiley&Sons.
5. Spassov S.I., Zdravkov Z. I. (2006), Research of the effect of phase manipulated jamming signals on filters of radar receivers, (in Bulg. lang.), Proc. FMI-Shumen Univ., vol. II, pp. 141-147.
6. Velkov, V., Spassov, S.I., (2004), Development of the radar suppression factor equation at the jamming process, (in Bulg. lang.), October, Proc. Nat. Mil. Acad., Sofia, vol. I.
7. Aleksandrova K. G., Bulgarian army radar's modernization to achieve operational interoperability with NATO member'sarmies, (2001), (in Bulg. lang.), Proc. Nat. Mil. Acad., Sofia.
8. Aleksandrova K. G., Ivanov I., (2017), Multiband multifunction radars, (in Bulg. lang.), Proc. Nat. Mil. Univ., Aviation Faculty, D. Mitropolia.