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Reducing the Effect of Pulsed Noise Jamming on LFM Pulse Compression Radar using 2D CFAR Scheme

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***Abstract* - Pulsed Noise Jammer creates a noise pulse when it receives radar signal, thus concealing any aircraft flying behind it with a block of noise. It degrades the detection performance of Linear Frequency Modulated (LFM) pulse compression radar. In this paper, a proposed Two Dimensional Constant False Alarm Rate (2D-CFAR) scheme is introduced to reduce this effect. The superiority of LFM pulse compression radar using the proposed scheme over the traditional one is validated through the Receiver Operating Characteristic (ROC).**

Keywords: LFM-PC Radar, CA-CFAR, OS-CFAR, 2D-CFAR

1. INTRODUCTION

Pulse compression is an important signal processing technique used in radar systems to reduce the peak power of a radar pulse by increasing the length of the pulse, without making loss in the range resolution associated with a shorter pulse and without affecting the maximum detection range [1]. Modern LFM-PC radar, whose receiver signal processor is shown in Figure 1, supports high Doppler shifts with excellent time side lobe levels [2]. Pulse compression provides radar receiver with a processing gain equals the time- bandwidth product of the transmitted pulse [3].

The coherent integration process in modern LFM-PC radar gives an additional processing gain proportional to the length of the Coherent Pulse Interval (CPI) [4]. Using CFAR processing along with pulse compression and coherent integration enhance the immunity of LFM-PC search radar against jamming [4, 5].

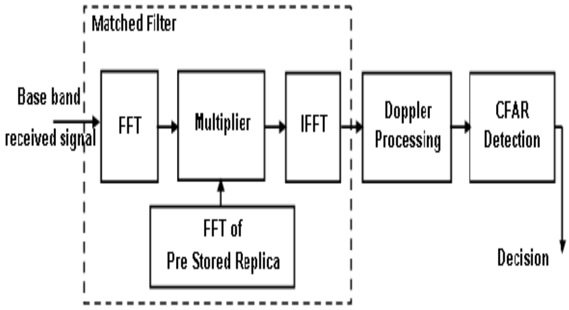

Figure 1 Block diagram of LFM-PC radar receiver signal processor

Pulsed noise jamming is one of the early used jamming techniques against radars [7]. It is located in front of the target. When it receives the victim radar pulses, it generates a noise pulse with the same radar pulse length. This noise pulse causes saturation to the victim radar receiver in this sector, consequently, preventing the target from being detected by the victim radar [8].

Litratrature review about improving the detection performance of LFM-PC under the effect of pulsed noise jamming gives there is a rare work in this branch. In this paper, a proposed scheme of using 2D-CFAR processor against the effect of applying pulsed noise jamming upon LFM-PC search radar is introduced.

The main idea of using 2D-CFAR scheme is analyzed by applying the output data from doppler processing in two dimension CFAR processors , one in the range axis and the other in the doppler axis, and making (OR)ing between the output decision of the two axis .

The detection of LFM-PC radar is evaluated in clear environment and under the effect of pulsed noise jamming added to weather clutter and thermal noise by using the LFM-PC simulation model introduced in [9], and making a comparison by using the proposed 2D-CFAR scheme .

After the introduction, the rest of this paper is organized as follows; in section 2 , traditional one dimensional CFAR (1D CFAR) LFM-PC radar is evaluated in clear environment (noise free) and under interference signals (weather clutter , pulsed noise jamming) . In section 3, a proposed 2D-CFAR based detection scheme for LFM-PC radar is presented and analyzed in clear environment and under interference signals (weather clutter, pulsed noise jamming). Finally, conclusion comes in section 4.

2. 1D-CFAR BASED DETECTION SCHEME IN LFM-PC RADAR

The simulation model derived in [9] of LFM-PC radar is used in the present work. The assumed simulated radar parameters are shown in Table 1. The simulated target range and Doppler are chosen such that the target is totally located in one range cell and one Doppler cell. This prevents the occurrence of range or Doppler straddle [10]. Signals at different nodes of MATLAB simulated model of LFM-PC radar in clear environment are shown in figure (2).

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Table 1. Radar and target simulated parameters

Parameters	Value	Unit
Pulse Width	10	μs
Pulse Repetition Interval	1.6	ms
Chirp Bandwidth	7	MHz
Target Range	35	Km
Target Doppler	312.5	Hz
CPI	16	PRI
Radar Processing Gain	30.5	dB

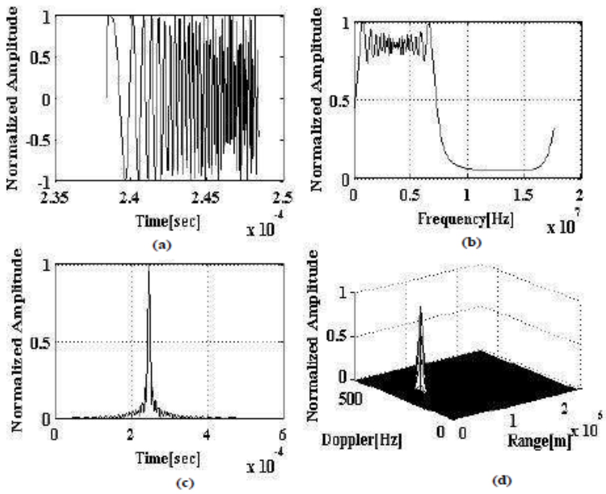

Figure 2 Simulation results at different LFM-PC radar receiver nodes:(a) base band received signal in time domain, (b) spectrum of received signal, (c) time domain matched filter output, and (d) final output after coherent integration and CFAR.

In case of noise and jamming environment, range and Doppler processing outputs are shown in figure (3),and figure (4) respectively for Signal to Noise Ratio (SNR) of 5dB and Jamming to Signal Ratio (JSR) of 5dB. The effect of pulsed noise jamming is clear in range direction. The simulated target at range cell number 3893 is surrounded by a wide interfering area. In Doppler direction, the same target whose Doppler cell number is 9 can be distinguished from its surroundings.

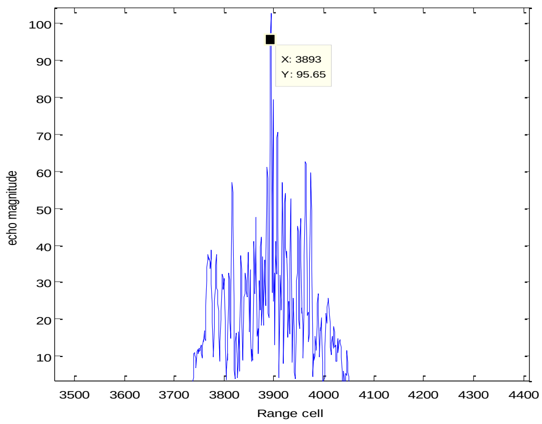

Figure 3 Range-Doppler processing output in range direction

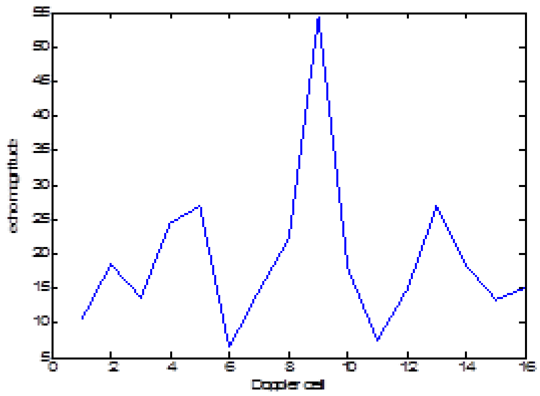

Figure 4 Range-Doppler processing output in doppler direction

Selecting the CFAR type is the first step in evaluating the performance of LFM-PC radar in clear and noise environment using 1D-CFAR detection scheme.

As concluded from [11], the Cell Average (CA)-CFAR processor is optimum choice in homogenous background, while the Order statistic (OS)-CFAR is the optimum choice in non-homogenous background and multiple target situations.

So, in the present work, the performance of LFM-PC radar using 1D-CFAR detection scheme is evaluated in case of using CA-CFAR or OS-CFAR in range detection.

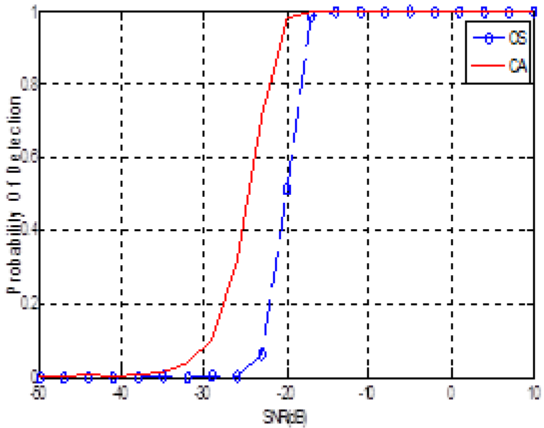

Figure 5 ROC curves for LFM-PC radar in clear environment at $P_{fa}=10^{-6}$ by using CA or OS CFAR in 1D-CFAR scheme

As shown in figure (5), when working in homogenous environment, the CA CFAR is the better processor can be used rather than the OS one. The CA-CFAR loses its benefit of high performance when transferring the environment from homogenous to non-homogenous environment when compared with the OS-CFAR as shown in figures (6), (7), and (8). When increasing JSR, the probability of detection goes down for both CFAR processors. So, the interest of the present work is to overcome this problem.

Referring back to figure (3) and figure (4), it is clear that the target can be discriminated easily in Doppler domain than in range domain. So, a proposed 2D-CFAR scheme is proposed and evaluated in the next section based on this result.

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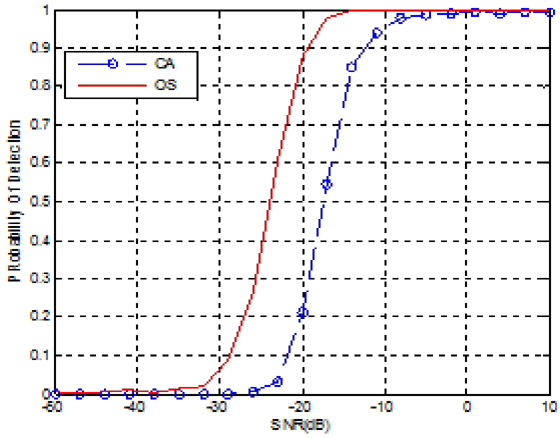

Figure 6 ROC curves of the LFM-PC radar at Pfa = 10^{-6} under pulsed noise jamming at JSR= -5dB by using CA or OS CFAR in 1D-CFAR scheme

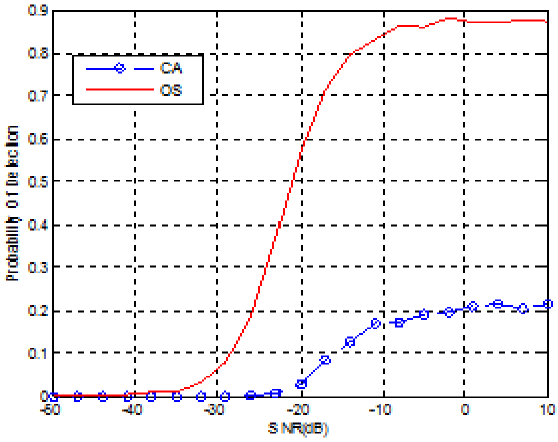

Figure 7 ROC curves of the LFM-PC radar at Pfa = 10^{-6} under pulsed noise jamming at JSR= 0 dB by using CA or OS CFAR in 1D-CFAR scheme

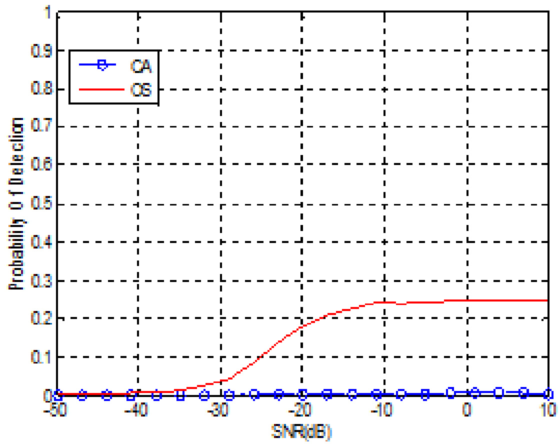

Figure 8 ROC curves of the LFM-PC radar at Pfa = 10^{-6} under pulsed noise jamming at JSR= 5 dB, by using CA or OS CFAR in 1D-CFAR scheme

3. A PROPOSED 2D-CFAR BASED DETECTION SCHEME IN LFM-PC RADAR

The idea of the proposed 2D-CFAR scheme in LFM-PC radar based on applying one CFAR processor in range direction and another CFAR processor in Doppler Direction and logically (OR)ing the two results. Two schemes are tested; the first scheme is CA-CFAR in range direction and CA-CFAR in Doppler direction. This proposed scheme is called (CA-CA) scheme. The second one is OS-CFAR in range direction and CA-CFAR in Doppler direction and called (OS-CA) scheme. Table 2 shows the main parameters of the two proposed schemes used in this section, and by using the same radar model used above in 1D-CFAR schemes.

Table 2 The main parameters of the proposed 2D-CFAR schemes

Scheme type	Range window size	Doppler window size
CA-CA	24	8
OS-CA	12	8

Firstly, ROC curves of the two schemes are evaluated in clear environment. As shown in figure (9), the performance of the two schemes is the same. Also, it is the similar to that of the 1D CFAR scheme.

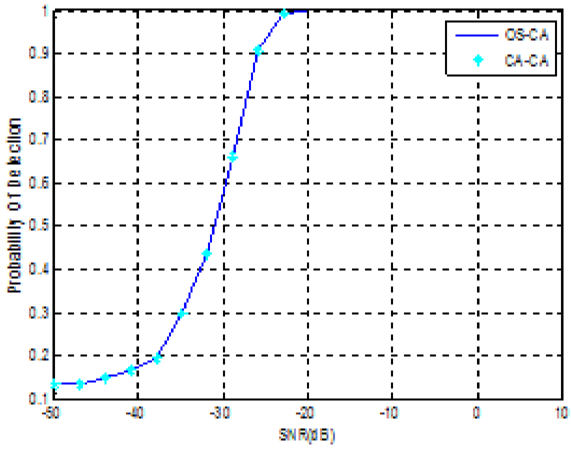

Figure 9 ROC curves of the LFM-PC radar at Pfa= 10^{-6} in clear environment by 2D-CFAR processors

Figure (10) through figure (12) show the improvement in detection performance of the LFM-PC radar under jamming conditions by using the proposed schemes over the traditional one. The main reason for improvement is the application of the CFAR processor in Doppler Direction. For example, at JSR = 5 dB, and
SNR = -20 dB, the probability of detection of both the two proposed schemes is 88%, while it is zero for the traditional scheme with CA-CFAR, and 18% for OS-CFAR. Figure (13) shows a comparison between the performance of LFM-PC radar under the effect of pulsed noise jamming using all the studied CFAR for the 1D and the proposed 2D-CFAR schemes. The superiority of the proposed 2D-CFAR schemes is clear. For simplicity in hardware implementation, the CA-CA scheme is preferred.

6. CONCLUSION

In this paper, a proposed 2D-CFAR scheme is applied in LFM-PC radar instead of the traditional 1D-CFAR scheme to reduce the effect of pulsed noise jamming which imposes a non-homogeneous background in range direction to conceal the target. The proposed scheme improves the performance because of the second CA-CFAR processor in Doppler direction which is combined with that of the CA-CFAR in range direction. At JSR=5dB, and SNR=-20 dB, the proposed scheme achieved P_d =88% compared to P_d=0% for 1D CA-CFAR or P_d =18% for 1D OS-CFAR.

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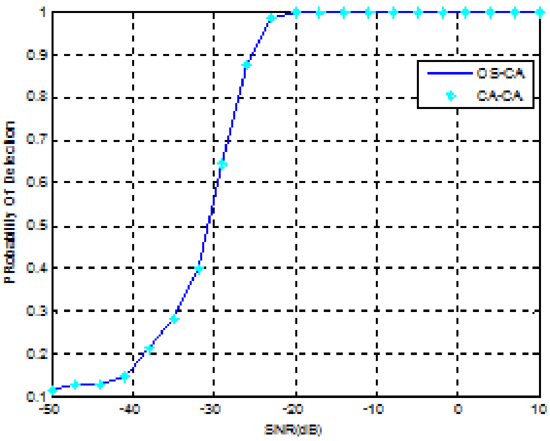

Figure 10 ROC curves of the LFM-PC radar at Pfa= 10^{-6} under pulsed noise jamming at JSR=-5dB by 2D-CFAR schemes

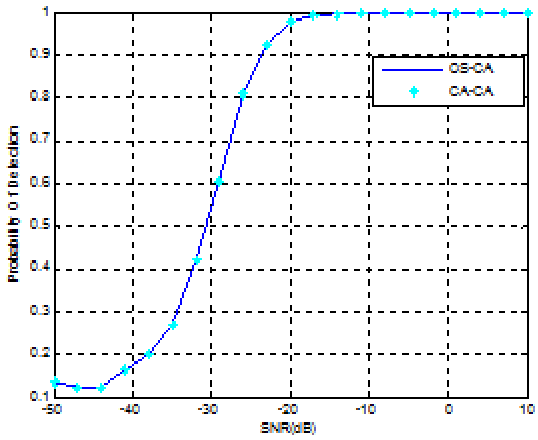

Figure 11 ROC curves of the LFM-PC radar at Pfa= 10^{-6} under pulsed noise jamming at JSR=0 dB by 2D-CFAR schemes

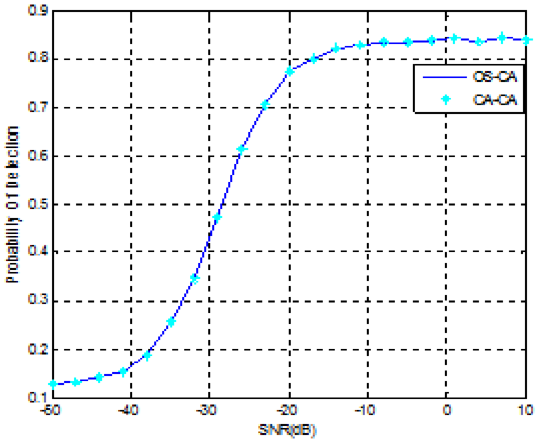

Figure 12 ROC curves of the LFM-PC radar at Pfa= 10^{-6} under pulsed noise jamming at JSR=5 dB by 2D-CFAR schemes

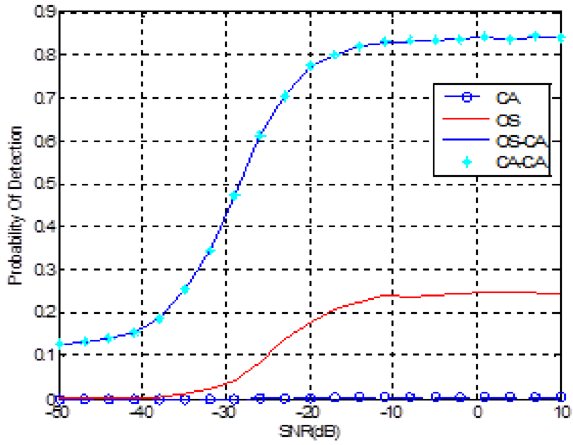

Figure 13 ROC curves of the LFM-PC radar at Pfa= 10^{-6} under pulsed noise jamming at JSR=5 dB by all cases of CFAR schemes

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