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The Analysis of a New Speed Estimation Algorithm

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Abstract. In this paper, based on the feature of high resolution one-dimensional range profile, an effective motion compensation method for Stepped Frequency signal is presented. Firstly, the processing method of stepped-frequency and the response of target moving to range profile is analyzed. Secondly, the function of range profile entropy is presented, and then the theory analysis, math model, and solution method are analyzed in detail. Finally, simulation experiment is designed to prove the accuracy and effectiveness of this methods.

Keywords: Stepped-Frequency; Speed Compensation; Range Profile; Entropy

1 Introduction

Stepped- frequency(SF) signal is the most important pulse compression signal, which is well described in literature [1,2,3] and the technique of inverse discrete Fourier transform(IDFT) is used to get HRRP. But for non-cooperative targets, the radial speed between target and radar contributed influence on phase term, which will make the distortion of HRRP. The impact of Range-Doppler coupling can be eliminated by motion compensation. If the target Speed can be estimated precisely, the target motion can be compensated by removing the phase terms, which is cased by the Speed of target. Thus, many motion compensation methods are presented based on Speed estimation. In literature [6,7], two motion compensation methods based on time domain and waveform entropy are presented, but they have low estimation accuracy in low SNR and is only effective for low-Speed moving targets. In literature [8], an effective algorithm of motion compensation based on SF and Pulse Doppler system is presented, simulation shows that this method had high compensation accuracy and good anti-noise performance. However, it will increase the complexity of radar system.

In conclusion, the motion compensation of moving targets in low SNR is still a key problem for SF signal. Meantime, the project application also should be taken into account. Therefore, in this paper, based on the analysis of range profile, a new motion compensation method is presented. Simulation has proved that this new method has much higher estimation accuracy and lower calculated amount than that used to be, and much easier to be used in project application.

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2 Speed Estimation Method based on Range Profile Entropy

Stepped-frequency radar signal is a group pulse sequence that the carrier frequency increased by the fixed step length, the mathematical formula is shown in formula (1).

$$\Lambda^{\square 1} \quad N1 \; TT \quad 17\pi \; rect \; \frac{t-1}{} \; j2\pi(f+i\square f)t_1 \quad \frac{r}{} \quad \varphi \exp \qquad (1)$$

Where f_0 is the centre frequency, T_1 is the pulse width, T_r is the pulse repetition cycle, Δf is the stepped-frequency value, N is the pulse number.

For a stationary target, the distance is R_0, after I/Q orthogonal frequency mixing of double channel, we can get the complex envelop output of echo signal:

$$G_i \square = \exp\left| j2\pi f_i \left(\frac{2R}{c}\right)\right| \exp(j\varphi_i) \qquad (2)$$

By the concept of entropy, it is easy to understand that entropy is the degree of disorder, the greater entropy value is, and the more disorder range profile is (the worse focus property). And when the range profile is focused, the entropy will have the minimum value. The range profile entropy is defining as follow:

$$E(v) = \sum_{n=0}^{N\square 1} \left| h(l) \log h(l) \right\| \qquad (3)$$

When the radial Speed is estimated and used to compensating the additional phase term, the range profile entropy will decrease. Ideally, when the estimated value is consistent with the real value, the minimum range profile entropy will be obtained. The method of minimum range profile entropy is a closed-loop system with feedback ability. The steps of motion estimation based on minimum range profile entropy are shown as follows:

 Calculate the motion compensation factor by the estimated value of original Speed:

$$p_i = \exp[\; j271.(f_0 i\pi i \frac{v_0 i T r}{c}]$$

 Compensate the echo signal:

$$= G_i p_i \exp[\; j2\pi(f_0 \square \; i \; f) \; 2 \frac{(+R_0 \square\square \square v i T_r)}{c}] \qquad (5)$$

 Make inverse Fourier transform for compensated signal:

$$h(l) = \sum_{i=1} {}_i G' \exp[j2\pi \; N\vartheta \qquad (6)$$

 Calculate the range profile entropy according to formula (6).

 Confirm the next estimated Speed value by a certain optimization method and repeat the steps till the minimum value of range profile entropy is found, and then the final estimated Speed can be gotten.

3 Simulation Experiment

Supposing the parameters of the stepped-frequency signal transmitted by radar is as follows: transmitting frequency f_0=94GHz, step value Δf=4MHz, pulse width T =100ns, repeat cycle T_r=20u, pulse number N=128.

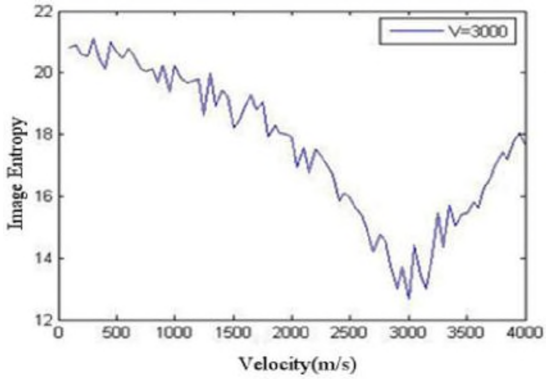
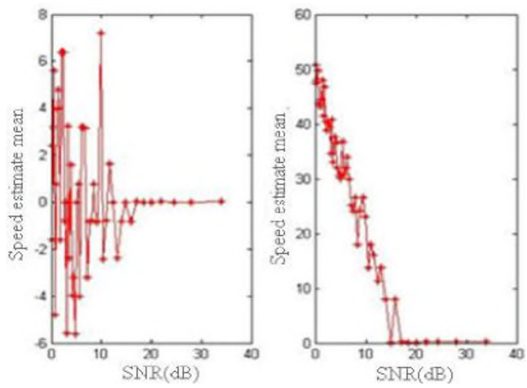


Fig. 1. The characteristic figure of speed estimation



a) The mean error   b) The standard deviation error

Fig. 2. Speed estimation error with SNR

Figure 1 shows the Speed estimation characteristic of minimum range profile entropy method. There is a local minimum value in Speed estimation by minimum range profile entropy method. Therefore, it requires the optimization search algorithm to avoid the local minimum value and restrain itself to the global minimum value. At present, simulated annealing algorithm, genetic algorithm, evolution strategy has the ability to avoid the local minimum value and gradually converges to the global optimal value.

Figure 2 is the Speed estimation error with different signal-to-noise ratio using genetic search algorithm. It is a Monte carol simulation experiment with 1000 times.

Because the signal-to-noise ratio of echo signal is low, the minimum range profile entropy method cannot achieve a fine compensation requirement of phase, but can give a coarse compensation, which is very helpful for the recognition and detection of high-Speed moving target. However, if the signal-to-noise ratio of echo is above 18dB, the compensation accuracy of minimum range profile entropy method can reach the compensation requirements for accuracy.

4 Conclusion

In this paper, a new speed estimation algorithm is presented. According to the discussion above, this method has the global optimal value and local optimal value, so the initial value and the selection of the optimization search method will make a great influence on the estimate effect. In this paper, it uses genetic algorithm, and gets a much better estimate effect. Furthermore, this new method has a much better accuracy in high SNR, which can be used to compensate the HRRP. And, it is more suitable for the engineering application

The next step for further study is looking for simple initial Speed estimation algorithm. It should be ensure to choose the estimated range which can cover the true value, and do not contain local optimal value. Then, the suitable evaluation function and optimization search algorithm should be given. At the same time, it must be reduce the computational complexity and improve the Speed estimation precision.

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