Modeling And Simulation of Video Target Echo and Clutter for Phased Array Radar

Xiaohai CUI †, Tao ZENG, Peikun HE‡, Siyu LING
Department of Electronics Engineering
Beijing Institute of Technology
Beijing, People's Republic of China
Phone: +86-10-68915084, Fax: +86-10-68911962
†Email: cuixiaohai@sina.com ‡Email: Hepkn@bit.edu.cn

Abstract

In this paper, we investigate the modeling and simulation of the target echo and clutter echo for phased array radar. In output of the simulator, velocity and distance of a moving target is simulated with delaying video waveform and lineally shifting phase of carrier wave, angel of a moving target is simulated with the angle gain of the antenna. Clutter is used as disturbance.

1. Introduction

In the field of electronic warfare (EW), the development, test, validation, and debugging of radar warning receiver (RWR) hardware and software in the laboratory necessitates the simulation of radar threat signals. This requirement often leads to the development of expensive, high fidelity, radio frequency (RF) simulators. Because they are expensive, they are scarce. They are also often hard to configure, operate, maintain, and relocate. Moreover, they are frequently in heavy demand, and engineers can rarely utilize them for lower priority, everyday design and debugging tasks [1][4].

In this paper, an implementation and simulating method of target reflected signal and clutter in phased-array radar is discussed. In the method, the target reflected signal is generated by the way of coherent video simulation and the Doppler frequency of target is simulated on video. The organization of the paper is as follows. At first, algorithm of the target echo and clutter is providing, then in computer for the synchronization among ballistic trajectory, simulator and radar system, time controlled by HLA.

This simulator all be realized by software based PC, so it has much more flexible and all-purpose than other simulator. The precision and the reality of the simulating video signal are determined by the accuracy of the target models and environmental models. For this reason, the most general and the most complicated work for radar video signal simulating are to establish exact models for the video echoes, and to look for the best effective computing algorithms for generating signal according to echo model.

2. Model of Video Target Echo

For phased array radar, the key problem of simulation of the target echo is real-time target echo by deferent waveform adapting of present radar present wave beam. Generally, phased array radar has following work mode as follow: searching, tracking, binding, and so on. With different work mode, the basic emit signal can be depicted by a general expression for chirp signal.

2．1 Pattern model of radar emit signal

We suppose radar's emit single description

$$S_t(t)=\sqrt{\frac{P_tL_t}{4\pi}}g_{vt}(\theta)\exp(jw_ct)v(t) \tag{1}$$

P_t Is the peak power of radar transmitter; w_c is carried frequency; $g_{vt}(\theta)$ is antenna's gain; L_t is emit total loss; $v(t)$ is complex modulate function, it can be get from: $v(t)=\sum_{k=0}^{N_p-1}\mathrm{Re}\,ct[\frac{t-kT_r}{T_r}]\mu(t-kT_r)\exp(jw_kt)$

(2)

w_k is the increment of the k-th pulse's angle frequency, T_r is Pulse Repeat Interval, $\mu(t)$ is unit function. For chirp signal

$$\mu(t) = \mu_{LFM}(t) = \exp(j\pi bt^2),\ 0 \le t \le T_p \tag{3}$$

b is frequency modulation scanning frequency,

$$\mathrm{Re}ct(t) = \begin{cases} 1,\ t \in (0,1) \\ 0,\ \ other \end{cases} \tag{4}$$

2．2 Pattern model of radar received signal

At time t, we suppose distance between target and radar is $R(t)$, and supposes target's velocity at present time is even. Radar will emit N_p pulses during a DWELL, we suppose

$k = 0,1,2,......,N_{p-1}$, Radar received signal at radio frequency (RF) is

$$r_{RF}^k(t) = S_{RF}^k(t) + C_{RF}^k(t) + n_{RF}(t) \tag{5}$$

$S_{RF}^k(t)$ The radar received target echo from the k-th pulse,

$C_{RF}^k(t)$ is clutter, and $n_{RF}(t)$ is the noise.

Pattern model of radar received target echo

Target echo signal $S_{RF}^k(t)$

$$S_{RF}^k(t) = \sqrt{\frac{P_t L_s}{(4\pi)^3}} \frac{\lambda\sqrt{\sigma}K_{RF}}{R^2(t)}$$
$$\cdot \exp[jw_c(t - \frac{2R_0}{C} - kT_r)]\exp[jw_k(t - \frac{2R(t)}{C} - kT_r)]$$
$$\cdot \exp[j\pi b(t - \frac{2R(t)}{C} - kT_r)^2]\exp[jw_d(t - \frac{2R_0}{C} - kT_r)]$$
$$\cdot \mathrm{Re}ct[\frac{t - \frac{2R(t)}{C} - kT_r}{T_p}] \tag{6}$$

so, the sum signal(Σ), azimuthally difference signal(Δ α)and pitching difference signal(Δ β) can be get. So all signal of target can be generated from only Antenna Gain function.

$$S_{RF\Sigma}^k(t) = G_\Sigma(\theta) S_{RF}^k(t) \tag{7}$$

$$S_{RF\Delta\alpha}^k(t) = G_{\Delta\alpha}(\theta) S_{RF}^k(t) \tag{8}$$

$$S_{RF\Delta\beta}^k(t) = G_{\Delta\beta}(\theta) S_{RF}^k(t) \tag{9}$$

P_t The peak power of radar transmitter; L_s total Loss; σ is RCS of the target, λ is wavelength, K_{RF} is magnify coefficient of the RF filter, C is light speed, w_c is carried frequency, T_r is Pulse Repeat Interval, w_k increments of frequency, w_d is Doppler frequency, b is linear modulation frequency slope.

3. Model of Clutter Echo[2]

The clutter suppression is more coming from the earth, weather and sea, so it can be combination from them.

$$C_{RF}^k = C_1^k(t) + C_2^k(t) + C_3^k(t) \tag{10}$$

$C_1^k(t)$ is earth clutter, $C_2^k(t)$ is weather clutter, $C_3^k(t)$ is sea clutter. We only give the weather clutter.

In the following expression, K_{RF} is filter factor, $R_{c2}(t)$ is radial distance between radar and clutter unit, w_{wind} is Doppler frequency contributed by wind speed, $w_{wind} = w_c \frac{2v_{wind}}{C}$, v_{wind} is wind's radial speed, $\tilde{\sigma}_{kc2}(t)$ is complex echo coefficient.

$$C_2^k(t) = K_{RF}\sqrt{\frac{P_t L_s}{(4\pi)^3}\frac{g_{vt}(\theta_{c2})g_{vr}(\theta_{c2})}{R_{c2}^2(t)}}\lambda\widetilde{\sigma}_{kc2}(t)$$
$$\cdot\exp[jw_c(t-\frac{2R_{c2}(t)}{C}-kT_r)]$$
$$\cdot\exp[jw_k(t-\frac{2R_{c2}(t)}{C}-kT_r)]$$
$$\cdot\exp[j\pi b(t-\frac{2R_{c2}(t)}{C}-kT_r)^2]$$
$$\cdot\exp[jw_{wind}(t-\frac{2R_{c2}(t)}{C}-kT_r)]$$
$$\cdot\mathrm{Re}\,ct[\frac{t-\frac{2R_{c2}(t)}{C}-kT_r}{T_p}] \tag{11}$$

4. Computer Simulation

As computer simulation of the echo target and clutter model shown above. Simulator and ballistic trajectory are two federates in RTI; As Figure 1.The RTI software supports a variety of time management policies. Time management services are optional. The RTI provides an optional time management service to simulator gets trajectory information from RTI and keeps synchronization with radar signal processor, the time management has Regulating Federate with Time-Stamp-Order (TSO) and Constrained Federate with Lower Bound Time Stamp (LBTS)[3]. As Figure 2.

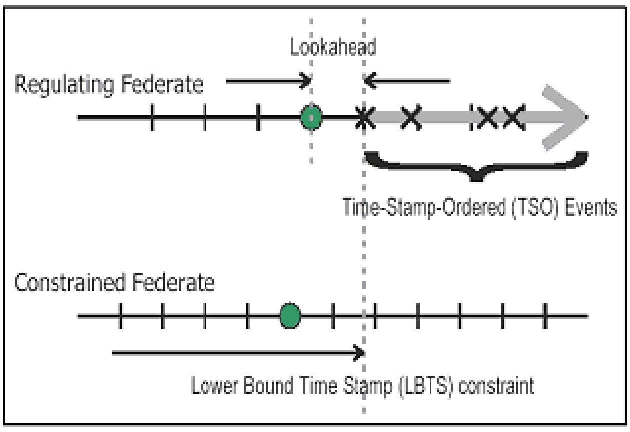

Figure 2.Two-Axis Diagram

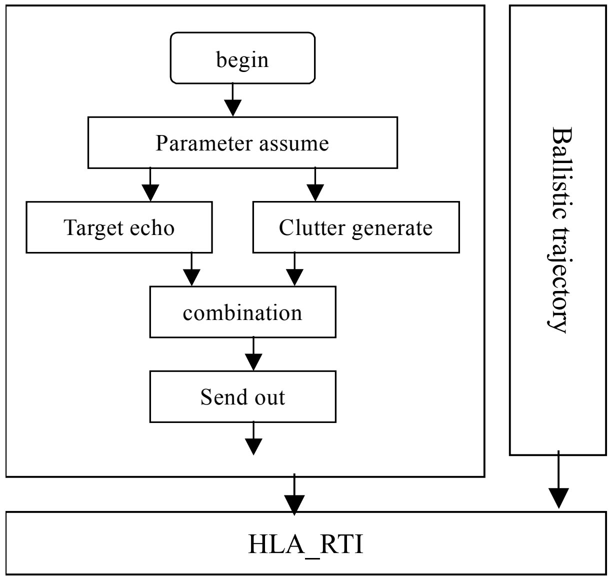

Figure 1.Simulator framework

In the Parameter assume, present radar beam should estimate if target be in the beam.

From the setting panel, we can set the Signal Noise Ratio(SNR), Signal Clutter Ratio(SCR). Figure 3 is target echo with only Gauss noise which from external noise and receiver noise. For RCS=1m^2, 60km distance, The SNR=4.37dB. We can test the validity with the pulse compression (Figure 4). We can see the output with target echo and clutter and Gauss noise as figure 5 and pulse compression output as figure 6.

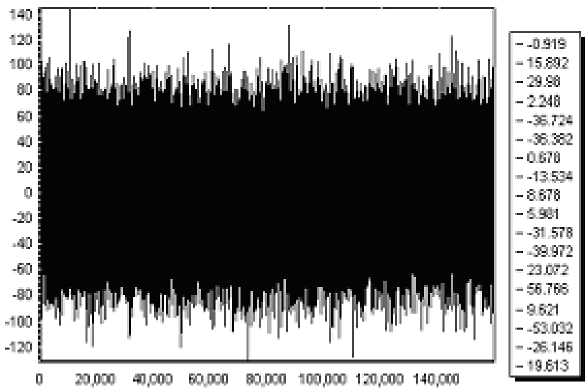

Figure 3. Target echo with receiver noise

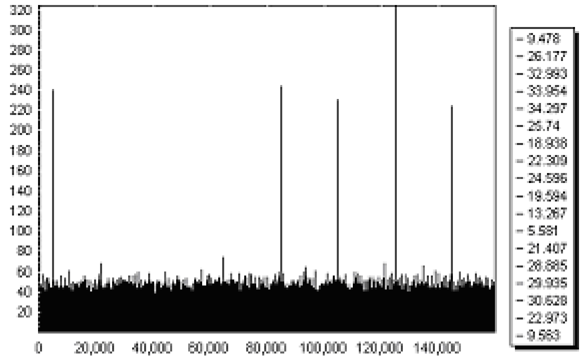

Figure 4. Output after pulse compression

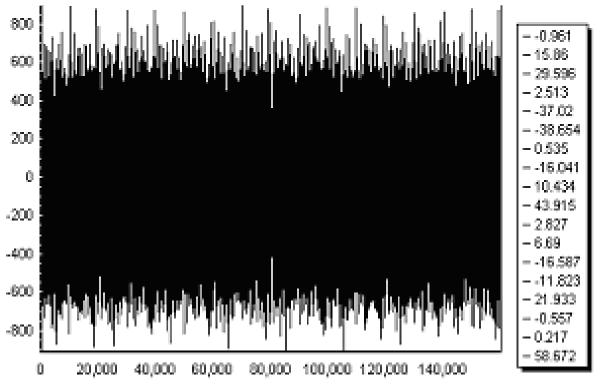

Figure 5.Target echo and Clutter from simulator

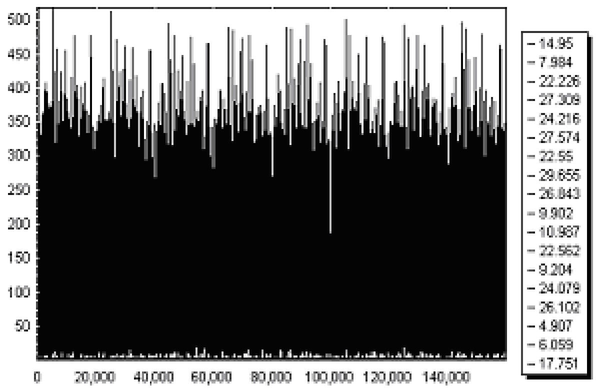

Figure 6.Target echo and Clutter
after pulse compression

5. Conclusion

The design, development, and validation of radar system via radar echo simulator is a very important element, especially for the radar signal processor. Radar echo simulator is suit for different waveform. In this paper, an implementation and simulating method of target reflected signal and clutter in phased-array radar is discussed. In the method, in the computer simulation, the algorithm was realized, the result is tested by pulse compression, the target reflected signal is generated by the way of coherent video simulation and the Doppler frequency of target is simulated on video.

6. References

[1] Douglas W.Olsen, Michael J.Willis. The design of windows-based software for a PC-based, low-cost radar video signal generator. National Aerospace and Electronics Conference, Proceedings of the IEEE v 2 Jul 14-17 1997

[2] Wang Gou-yu, Mathematic Simulating Model of Phased-array Antenna in Multifunction Array Radar, systems engineering and electronic technology. 1999.1

[3] High Level Architecture Run-Time Infrastructure. DMSO RTI 1.3-Next Generation Programmer's Guide Version 3.

[4] Shi Lin, Yang Wanhai, Zhu Haiguang, Yu Jian. Modeling and simulation of space-time two-dimension clutter for airborne phased array radar 2000IEEE