A HIGH ACCURACY METHOD FOR INTERFERENCE FRINGES SUPPRESSION IN SAR DISTRIBUTED TARGETS' RAW DATA SIMULATION

Dazhi Zeng, Hanwei Sun, Tao Zeng, Teng Long

Radar Research Lab, EE Department, Beijing Institute of Technology, Beijing 100081, China

1. INTRODUCTION

Raw signal data are very important in study of SAR system design and imaging algorithms. However, it is indeed difficult to obtain real raw data with variable parameters and special requirements. Thus, simulation has become an inevitable trend [1]. SAR distributed targets' raw data simulation is used for researching motion compensation and phase unwrapping algorithms as well as image matching algorithms. In order to fulfill the simulation, a proper description of geometric and electromagnetic model of targets would be required. A common approach is to use uniform array of discrete targets as geometric model and SAR single-look complex (SLC) image as electromagnetic model of distributed targets [2]. However, interference fringes will be generated in simulated images based on this model, which have large effect on the identification and post-processing of SAR image.

In view of this problem, researchers gives some method on fringes suppression [3], including adding random height in space or random phase on backscatter coefficient of the distributed targets. However, the former method will introduce location error and slant range error in SAR system; the latter method will increase speckle noise twice in simulated image since the inherent speckle noise may already exist in SLC image.

The purpose of this study is to develop a high accuracy method for fringes suppression without introducing additional problems. The main ideal of the method is based on targets' position randomizing and RCS re-sampling via bilinear interpolation. In the following section, we first describe the main theory of SAR distributed targets' raw data simulation, focusing on targets model and signal model. Next, the phenomenon of interference fringes is introduced from a typical simulation. Then, our treatment of fringes suppression is described in detail and an application example is shown to illustrate the availability of the proposed method. Finally, accuracy and computational complexity will be discussed.

2. SAR DISTRIBUTED TARGETS' RAW DATA SIMULATION

2.1. Targets model

Ground targets' backscattering coefficients can be acquired by electromagnetic calculation or experiments [1]. However, computational complex or high cost will be primary problem. Thus, regarding SAR SLC image as the distributed targets' backscattering coefficients is considered as an effective model, since SAR image is a measurement of scene's electromagnetic scattering coefficient in substance. In this model, the regional scene is evenly separated into discrete scatter uniformly, as is shown in Fig.1.

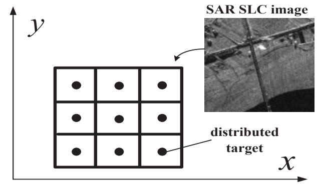


Fig.1. Schematic diagram of scattering model

2.2. Signal model

The high resolution of SAR is obtained through the pulse compression and synthetic aperture. Assume that the backscattering coefficient of a target on the ground is σ, and the distance from the radar platform to the target is $R(t_a)$, where t_a is represents the slow-time. Therefore, the baseband raw signal of the target at the t_a moment can be represented by formula (1), where t denotes the fast-time, f_c is the carrier frequency, $W(*)$ is the rectangular window, k_r is the chirp rate, τ is the pulse width, c is the speed of light, $A(t_a)$ is the amplitude factor calculated by radar equation.

$$s(t_a) = A(t_a)\sigma W\left[t - 2R(t_a)/c\right] \times \exp\left\{-j4\pi f_c R(t_a)/c + j\pi k_r \left[t - \tau/2 - 2R(t_a)/c\right]^2\right\} \tag{1}$$

Considering the targets model above-mentioned, we suppose that the distributed targets' number of the regional scene is N. Based on superposition theorem [4], raw signal of all distributed targets can be obtained through coherent addition of every target's signal, given by formula (2), where $s_i(t_a)$ is the raw signal of the i-th target.

$$S(t_a) = \sum_{i=1}^{N} s_i(t_a) \tag{2}$$

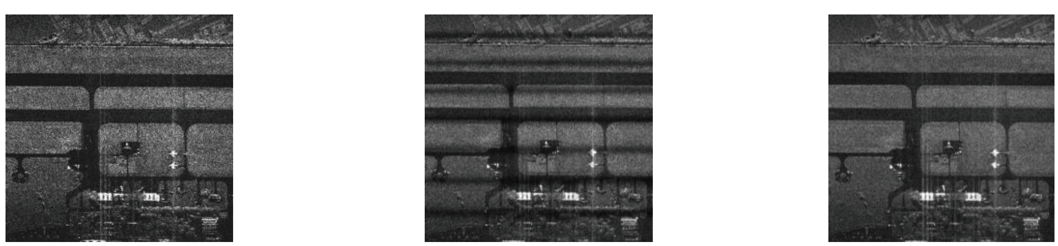
3. INTERFERENCE FRINGES

In this section, raw-data of distributed targets will be simulated with the above models, and processed by Chirp Scaling (CS) algorithm [5] to illustrate this phenomenon of interference fringes directly. The simulation parameters are listed in Table 1.

Table 1. Simulation parameters

wavelength (m)	0.03	platform height(m)	6000	signal bandwidth (MHz)	150
pulse width (us)	4	platform velocity(m/s)	200	sample rate(MHz)	200
PRF(Hz)	800	interval of adjacent points(m)	1.2×0.6	SAR image (pixels)	1024×1024

The input real SAR image and the simulated SAR image are shown in Fig.2 (a) and (b). As we can see obviously that the bright and dark fringes appear in Fig 2(b).



(a) Original image (b) Result without fringes suppression (c) Result with proposed method

Fig.2. Simulation results

4. SUPPRESSION OF INTERFERENCE FRINGES

The reason for such fringes is that: all targets are uniformly distributed in the space and the interval of adjacent targets is equivalent to the resolution of system, thus the raw signal phase of every target is relatively fixed. When they are coherently superimposed, the bright-dark interference fringes are generated. The theory of array antenna can be used to explain this phenomenon [3] that the reception model of SAR is similar to the radiation model of sparse antenna array, interference fringes are introduced as a result of the coherent superposition among received signal.

4.1. Method of interference fringes suppression

Since the interference fringes are caused by the uniform alignment of distributed targets, we present a suppression method to break the regular state of distributed targets based on introducing random position changes of targets slightly and re-sampling backscattering coefficients with new positions from original SAR image through interpolation. Then SAR raw data will be generated with new positions and backscattering coefficients of targets. There are many image re-sampling algorithms [6] among which bilinear interpolation algorithm is our choice due to its compromise between efficiency and precision.

4.2. Processing procedures

According to the proposed method, we illustrate the procedures of distributed targets' raw data generation in Fig.3.

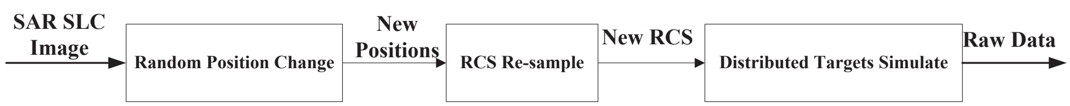


Fig.3. Processing procedures

Firstly, a SLC image is separated into discrete scatter uniformly, facet by facet. Next, new positions of facets are achieved by random position changes slightly. Then, new RCS of each facet is re-sampled from original SLC image based on new positions. Finally, new positions and RCS are both used for distributed targets' simulation.

4.3. Application example

In this section, an application example will be given according to the proposed method. The simulation parameters have been listed in Table 1. We set [-0.05m, 0.05m] as maximum random variation of targets' location and utilize CS processing for imaging. The simulation result is shown in Fig.2 (c). We can find that interference fringes disappear compared with Fig.2 (b) and it is very close to the original image (Fig.2 (a)) with high definition. Hence, the proposed suppression method is proved to be valid.

5. PERFORMANCE DISCUSSING

5.1. Method accuracy

In this section, quantitative analysis will be given to discuss the method precision. We consider computing correlation coefficient between simulated image and original image. In order to facilitate description, the suppression method proposed above together with the random phase method will be compared. Correlation coefficient is given by formula (3), where $s_1(u,v)$ is simulated image, and $s_2(u,v)$ is original image. The analysis results are displayed in Table 2. Considering the results, simulated image using the proposed method is much more close to the original image, which illustrates the high accuracy of the proposed method.

$$\rho = \frac{\sum_u \sum_v \left| s_1(u,v) s_2^*(u,v) \right|}{\sqrt{\sum_u \sum_v \left| s_1(u,v) \right|^2} \cdot \sqrt{\sum_u \sum_v \left| s_2(u,v) \right|^2}} \tag{3}$$

5.2. Computational complexity

Let us look at the computational complexity of the new suppression method. We compare the computational time of positions randomization and RCS re-sampling between different sizes of SLC image, when a personal computer with an Intel Core Duo processor at 2.33GHz is used. Table 3 shows the time result, which indicates that the computational complexity of the proposed method could be supported by personal computer easily.

Table 2. Precision comparison result

Method	Correlation Coefficient
Random Phase	0.80907
Proposed	0.995545

Table 3. Computational time result

SLC Image Size(Pixels)	Time (seconds)
512×512	2.59
1024×1024	9.26
5120×5120	220

6. CONCLUSION

SAR raw data simulation has been an important way to verify rationality of system parameters and reliability of imaging algorithms. However, interference fringes will be caused in SAR images when simulating distributed targets' raw data with uniform model of targets. These fringes bring large effect on the identification and post-processing of SAR image. Aiming to interference fringes suppression with high accuracy, a new method based on random position changes and the RCS re-sampling of the original targets has been presented with detailed procedures, accuracy and computational complexity discussion. A few application examples illustrate potential uses in the field of SAR raw signal simulation.

7. REFERENCES

[1] G. Franceschetti, M. Migliaccio, D. Riccio, SARAS: A Synthetic Aperture Radar(SAR) Raw Signal Simulator[J], IEEE Trans. Geoscience and Remote Sensing, 30(1), 110-123, 1992.

[2] Zhang, S., Long, T., Zeng, T., Ding, Z.: Space-borne Synthetic Aperture Radar Received Data Simulation Based on Airborne SAR Image Data. J. Advances in Space Research 41, 1818–1821, 2008.

[3] JIANG Bi-tao, ZHANG Yun-hua, JIANG Jing-shan. The Interference Phenomenon and Its Explanation in SAR Imaging Simulation of Point-Targets[J]. Remote Sensing Technology and Application, 2007,(2).

[4] Klaus, F.: "SiSAR: Advanced SAR Simulation", SPIE Proceedings European Symposium on Satellite Remote Sensing II, Paris, France, 1995.

[5] R.K. Raney, H. Runge, R. Bamler, etc, Precision SAR Processing Using Chirp Scaling[J], IEEE Transactions on Geoscience and Remote Sensing, 32(4), 786-799, 1994.

[6] H C Andrew, B R Hunt. Digital image restoration, Prentice-Hall Inc, Englewood Cliffs, NJ, 1997.