Classic Correction of Range Migration Algorithms in SAR Imaging processing

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Abstract

Range Migration plays a most critical role in focusing an image and its correction is the most important procedure in synthetic aperture radar(SAR) image formation.Classic range cell migration correction(RCMC) is realized by Sinc interpolation and it is important to calculate the instantaneous slant range distance between the central phase and the scattering phase in Range-Doppler Algorithm (RDA). The advantages and principle of Sinc interpolation and the basic processing of RCMC will be introduced.

Keywords

SAR imaging processing , RCMC, RDA, Sinc interpolation.

1. Introduction

SAR images of the target scene by two-dimensional compression of the received target scattering echoes. The radar-to-target slant range is the most important parameter in SAR processing and it is also the function of azimuth time. Its variation leads to a phase modulation between different pulses , which is a necessary condition for the SAR to acquire a high azimuth resolution, and it also results in distortion of the target distance, the so-called range cell migration (RCM).[1] Range migration includes range bending caused by relative motion of radar and target and range walking caused by radar slanting distance.When looking sideways, the distance is mainly caused by the bending of the distance. Migration correction is to align the distance migration curve with a straight line parallel to the azimuth direction. The accuracy is within a synthetic aperture time, and the slope distance changes less than half of the distance resolution unit.[2] When the migration distance is large, it will cause the target to defocus and affect the imaging quality. Therefore, the range cell migration correction is an important part of SAR imaging.

The correction of range migration in radar imaging has always been a thorny issue, and the point is how to accurately correct the RCM without unduly increasing the processing complexity. Based on the original RDA algorithm, the Chirp Scaling algorithm, the wk algorithm and the SPECAN algorithm are proposed one after another. It is precisely for different processing of the RCMC that different algorithms are distinguished from each other. RDA initial proposed correction is divided into two kinds, one is the use of Sinc interpolation correction distance correction, the other method is to assume that RCM within a limited area does not change with distance, by linear phase multiplication method to transform. In the following study, different scholars began to compare Sinc interpolation with different interpolation methods, continuously improve the calculation accuracy and speed. The classic RCMC is effective when the radar is moving at a constant speed, but does not work well when the radar speed is not uniform. Some scholars have proposed automatic RCMC to solve the uneven running speed of radar[3, 4].

In this paper, the 16-point Sinc interpolation RCMC is introduced, the principle of Sinc interpolation is introduced in detail, and the specific process of radar imaging is described briefly. Finally, a point RCMC simulation of radar imaging data is simulated.

2. SAR Echo and Distance Model

The spatial relationship of SAR imaging is shown in Fig.1. Let the radar launch a linear FM signal

$$
\begin{aligned}
&S_{pul}(\tau) = w_r(\tau)\cos\{2\pi f_0\tau + \pi K_r\tau^2\} \\
&w_r(\tau) = rect(\frac{\tau}{T_r})
\end{aligned}
\tag{1}
$$

After the demodulated signal (2):

$$
\begin{aligned}
Sr(\tau,\eta) = {} & A_0^{'}W_r(\tau - 2R_{(\eta)}/c)w_a(\eta-\eta_c)*\cos(2\pi f_0(\tau - 2R_{(\eta)}/c) \\
& + \pi Kr(\tau - 2R_{(\eta)}/c)^2 + \psi)
\end{aligned}
\tag{2}
$$

Where: $A_0^{'}$ is the coefficient of the demodulated signal of the echo data, τ is the distance to the time, η is the azimuth time, Doppler center time, Kr is the distance to the frequency modulation rate, c is the wave velocity, λ is the wavelength, R(η) is the target slant distance.

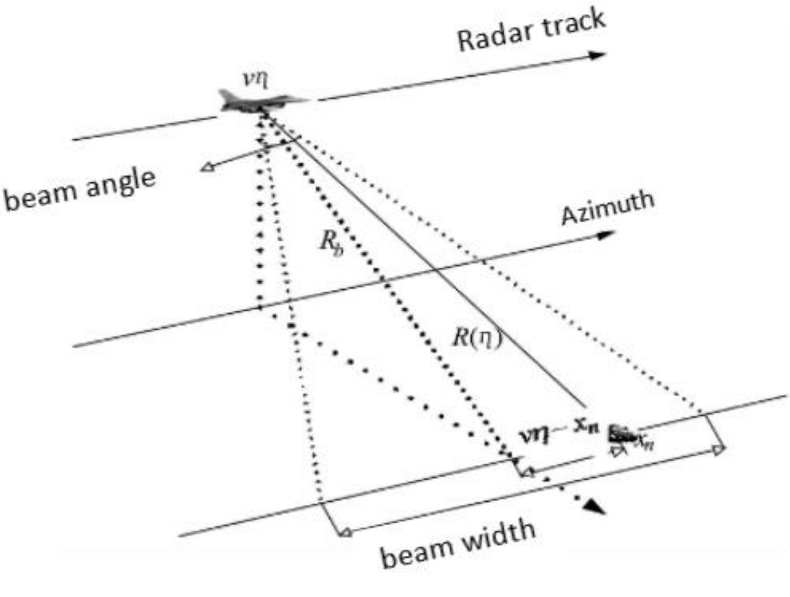

Fig.1 SAR imaging geometry

Zero Doppler: This is a sensor-containing plane perpendicular to the platform velocity vector.

Squint angle: refers to the slope vector and the angle between the zero Doppler plane.

Distance equation model:

$$R^2(\eta) = R_0^2 + V_r^2\eta^2 \tag{3}$$

3. Sinc interpolation principle

With the function f (x), the sampling theorem shows that the discrete sample signal can be reconstructed without distortion under the following two conditions:

The signal is band-limited, that is, the highest frequency of the signal is bounded;

(2) The sampling frequency satisfies the Nyquist sampling rate. The sampling rate of the real signal must be greater than twice the highest frequency of the signal, and the sampling rate of the complex signal must be greater than the bandwidth of the signal[1].

Meet the above conditions, in the baseband case, the recovery signal can be expressed as

$$g(x)=\sum_{i} g(i)\mathrm{sinc}(x-i) \tag{4}$$

Convolution kernel is:

$$\mathrm{Sinc}(x)=\sin(pi*x)/(pi*x); \tag{5}$$

Where g(i) is the sample value of g (x) at x = i. Sinc interpolation principle is the use of rectangular low-pass filter in the frequency domain to extract the fundamental spectrum, then in the time domain and the Sinc kernel convolution. Through the above formula that requires accurate calculation of the point

Value, g(x) need to spread over a myriad of points, but the truth can not be done without countless points. Interpolation kernel length: The requirement is as short as possible for efficiency reasons, but the short-core will bring loss of radiation and phase accuracy and introduce paired echoes. Because of the Gibbs effect caused by the truncation of Sinc, the Sinc interpolated kernels are windowed to further reduce the Gibbs effect. Common window functions include a raised window, Kaiser window. In SAR distance bending correction, and the requirement of precision and computation, 8 point Sinc interpolation is generally used. The number of points in this paper is 16 points.

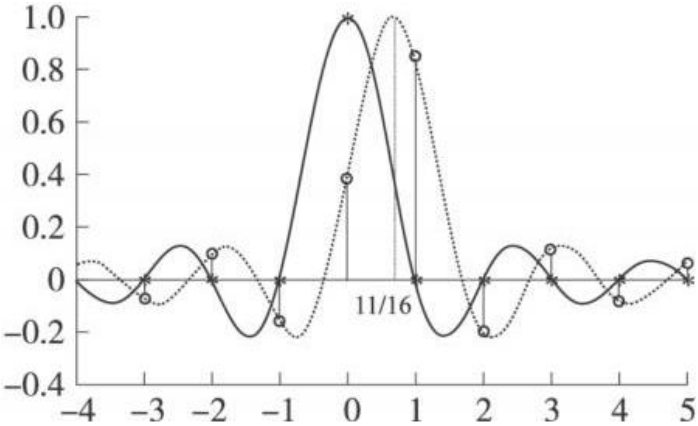

Fig. 2 Sinc interpolation diagram

4. Range cell migration correction processing

SAR echo model and the principle of Fourier transform shows that the same distance from the scattering point of the distance migration curve in the Doppler domain can be used to represent the same curve, the same distance from different directions of the scattering point can be distance migration Move correction[4]. Therefore, the uniform correction distance migration in the range Doppler domain will greatly simplify the computation and complexity. As shown in Fig.3

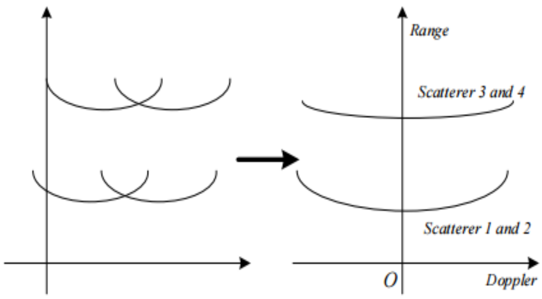

Fig.3 RCM changes from time to Doppler domain

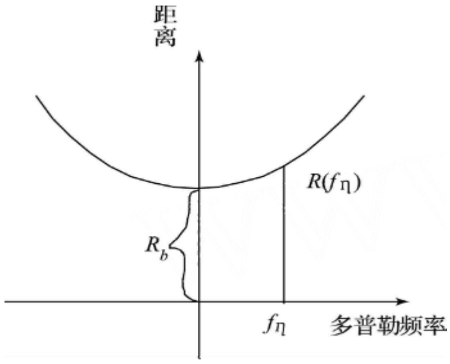

Fig.4 Schematic diagram of excitation Doppler domain

According to the relationship between azimuth and Doppler frequency and azimuth time, the slope distance R(f_η) is a parabola on f_η , as shown in Fig.4.

$$R_{rd}(f_\eta) = R_0 + \frac{\lambda^2 R_0}{8V_R^2} f_\eta^2 \tag{6}$$

The relationship between the bending distance and the number of sampling units ΔR at each f_η is:

$$\Delta R = \frac{\lambda^2 R_0}{8V_R^2} f_\eta^2 \tag{7}$$

After sampling the SAR echo is a discrete matrix s (m, n), 1≤m≤Na, 1≤n≤Nr, Na is the azimuth sampling points, Nr is the distance sampling points.

$$s(n,m) = A \times \exp\left\{ -j\frac{4\pi R(n)}{\lambda} \right\} \times p_r\left(m - \frac{2R(n)}{c}\right) \tag{8}$$

To correct the curvature caused by the slant distance, we need to estimate the value of s (m, n + Δn) from the original data s (m, n), which is an interpolation problem along the distance. First we get the Doppler domain signal:

$$s(f_n, m) = A \cdot \exp\left(-j\frac{4\pi R_0 D(f_n)}{\lambda}\right) \cdot p_r\left(m - \frac{2R_0}{cD(f_n)}\right) \tag{9}$$

Where : $D(f_n) = \sqrt{1 - \left(\frac{\lambda f_n}{2v}\right)^2}$, The final RCMC is obtained from (10).

$$s_{rcmc}(f_n, m) = \sum_{k=-n/2+1}^{n/2} s(f_n, m-k) \cdot \operatorname{sin}c\left(\frac{2R_0}{cD(f_n)} \cdot f_s - floor\left(\frac{2R_0}{cD(f_n)} \cdot f_s\right) - k\right) \tag{10}$$

Where fs is the fast time sampling rate, and floor (x) is the nearest integer solution to x. c is the speed of light, k is the interpolated kernel length.

5. SAR imaging process

5.1 Radar raw data

"Raw Data" means the data received by the radar system. The data is first demodulated to baseband so that the distance from the frequency domain center is set to zero.

$$\begin{aligned} s_o(\tau,\eta) &= A_o w_r[\tau - 2R(\eta)/c] w_a(\eta - \eta_c) * \exp\{-j4\pi f_0 R(\eta)/c\} \\ &* \exp\{j\pi K_r (t - 2R(\eta)/c)^2\} \end{aligned} \tag{11}$$

In the simulation, our parameters are set in the following table. Table 1 is the signal parameter, and Table 2 is the radar parameter. According to these parameters, we can get the result of our simulation.

Table 1 Signal parameters used in simulation

parameter	C	Nr	Fs	Na	PRF
value	3.e8	2002	24.e6	2041	1700

Table 2 Radar parameters used in simulation

parameter	R(η)	Ra	V	Rsa	Sample
value	30.e3	10.d3	7100	0.0	801

The Ra is the radar height and Dsa is the radar squint angle ,sample is the sampling point of azimuth and range.

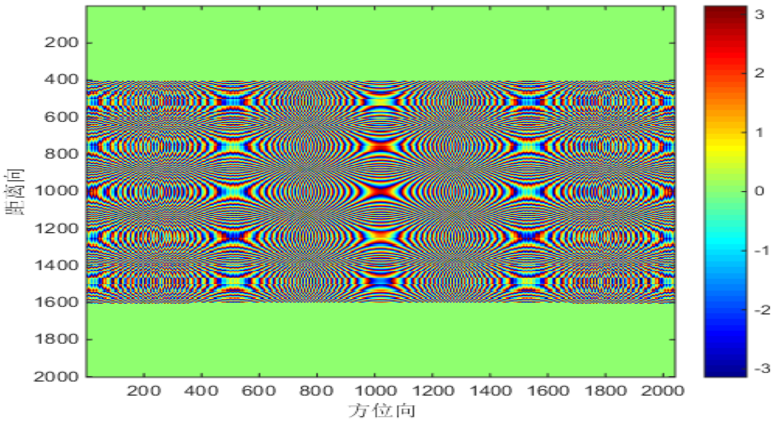

Fig. 5 Radar raw data simulation

5.2 The realization of distance compression

Do Fourier Transform (FFT) for distance and azimuth, and allow distance compression after multiplying the processed signal by compression factor.

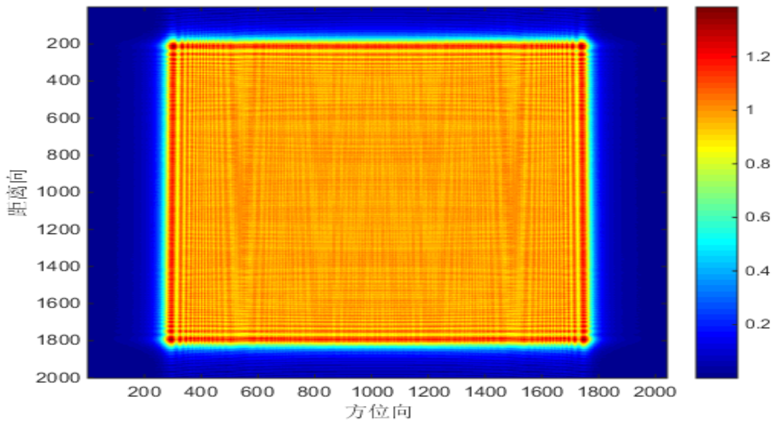

Fig. 6 Distance compressed data simulation

5.3 Azimuth FFT

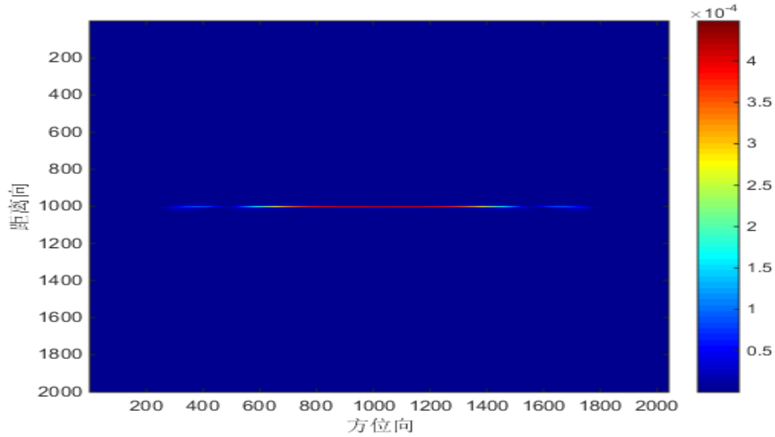

Fig. 7 Azimuth Fourier transform data simulation

5.4 RCMC

It can be seen from Fig. 7 that the image is not a straight line along the azimuth direction, but the image has obvious straightening changes after we finished the distance correction. This also realizes our RCMC process.

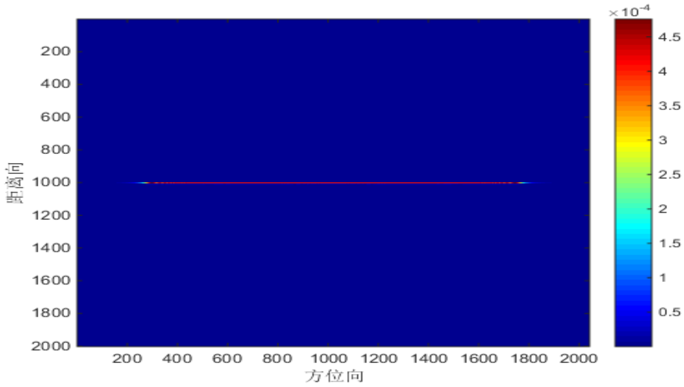

Fig. 8 Simulation of data after migration

5.5 Azimuth compression and azimuth inversion

The final step of the azimuth compression and azimuth up the inverse change, and finally got a point image, the magnified image can clearly see the side lobe of the target.

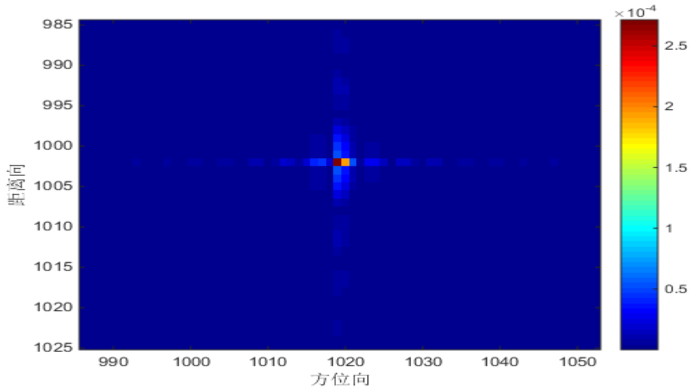

Fig. 9 The final compressed data

6. Conclusion

Through the study of the specific problems of SAR imaging, a lot of related literature about RCMC are consulted, and finally the RCMC based on sinc interpolation is realized. The simulation results are given by combining Fortran and Matlab, and the signal parameters and radar parameters are constantly adjusted to make the results more perfect. Next, we can compare the effects of different interpolation based on RCMC, and we can solve the problem that how to implement the RCMC process when the speed of radar is uneven.The remaining work can then be further studied.

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