2D UESPRIT SUPERRESOLUTION SAR IMAGING ALGORITHM

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1. INTRODUCTION

In radar imaging, conventional Fourier transform (FT) based image reconstruction techniques result in images with limited resolution and high sidelobes. The range and azimuth resolutions of these algorithms are inversely proportional to the radar waveform bandwidth and to the synthesized aperture size, respectively [1]. But in many practical applications only limited frequency and limited aspect region are available. This leads to radar images with limited resolution. Recently, modern spectral estimation technologies have become a kind of new methods to enhance the image quality by obtaining better space resolution and lower sidelobe [2].

On the basis of the synthetic aperture radar imaging theory, the signal model of SAR imagery is analyzed to be feasible by using superresolution array signal processing methods to improve the SAR image resolution. Generally, SAR systems use linear FM signal as transmitted signal. After imaging processing, SAR image can be represented to be an expression of targets location in slant range, azimuth direction, transmitted signal bandwidth and Doppler bandwidth in azimuth, supporting by a rectangle domain in phase history domain [1]. The SAR image in phase history domain is a band-pass function with a main frequency support domain. Thus, the problem of superresolution SAR imaging is transformed to solve sinusoid harmonic estimation. The paper proposes a 2D Unitary ESPRIT superresolution SAR imaging method, which is classified to parameter methods.

2. SIGNAL MODEL

Based on the theory of synthetic aperture radar imaging, the signal model of SAR imagery is analyzed to be feasible by using data extrapolation methods to improve SAR image resolution in this section. Generally, SAR systems use linear FM signal as transmitted signal. After imaging processing, the form of scene echo can be represented as[1]

$$x\left(t_r,t_a\right)=\sum_{n=1}^{N}\sigma_n Sinc\left[B_r\left(t_r-t_1(R_{r,n})\right)\right]\times Sinc\left[B_a\left(t_a-t_2(R_{a,n})\right)\right]+n\left(t_r,t_a\right) \tag{1}$$

where t_r and t_a represent time in slant range and azimuth direction, respectively; $x_{r,n}$ and $x_{a,n}$ represent targets location in slant range and azimuth direction, respectively; B_{r} and B_a represent transmit signal bandwidth and Doppler bandwidth in azimuth, respectively; N is the number of scatter centers. Transforming (1) into phase history domain, we can see a rectangle support domain in the following expression

$$x\left(\omega_r,\omega_a\right)=\sum_{n=1}^{N}\sigma_n \,\mathrm{Re}ct\left[\frac{\omega_r}{B_r}\right]\otimes \mathrm{Re}ct\left[\frac{\omega_a}{B_a}\right]\times\exp\left(-jt_1(R_{r,n})\omega_r\right)\times\exp\left(-jt_2(R_{a,n})\omega_a\right)+v\left(\omega_r,\omega_a\right) \tag{2}$$

From the expression, we can see that SAR image signal model in phase history domain is a band-pass function with a main frequency support domain. Thus, the problem of superresolution SAR imaging is transformed to evaluate the sinusoid parameters in main frequency support domain.

3. METHODOLOGY

The paper's method exploits the observed data and it's conjugation to extend the efficient data one time, which can increase the estimation accuracy of original ESPRIT. We consider the SAR signal model is a 2D sinusoid signal in 2D frequency field, and the 2D Unitary ESPRIT[5-6] is used to estimate the 2D parameters, which presents the 2D location of targets. Then the backscatter can be obtained by 2D amplitude estimation. Thus the SAR image can be reconstructed. Rewrite the signal model as follow.

$$x(n_1,n_2)=\sum_{p=1}^{D} s_p e^{j\omega_{rp}n_1} e^{j\omega_{ap}n_2} + w(n_1,n_2) \tag{4}$$

Where $x(n_1,n_2)$ is the sample data after preprocessing, $n_1=0,\cdots,N_1-1$, $n_2=0,\cdots,N_2-1$. The range frequency of target p is ω_{rp}, the azimuth frequency of target p is ω_{ap}, and the complex backscatter is s_p. The D target location parameters $\left(\omega_{r,i},\omega_{a,i}\right)_{i=1}^{D}$ are estimated first, and the backscatters are computed using the estimated results of frequency by least square solution.

4. RESULTS

The experiment is carried out using simulated dot targets. Fig.3 is the comparison of the RD imaging method result and the 2D UESPRIT method result.

The actual measured data of X-band airborne SAR is used for validating the method. Fig.4 is the processed results of actual measured data.

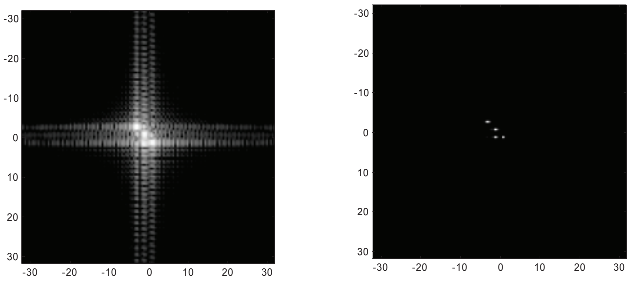

Fig3. (a) Fig3.(b)

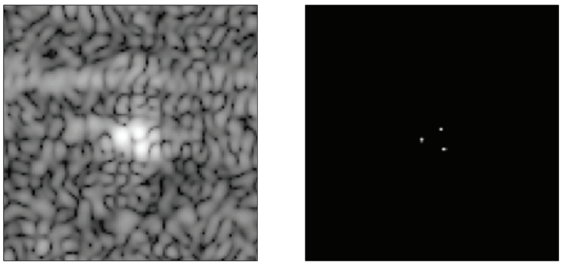

Fig4.(a) Fig4.(a)

Fig.3 Simulation experiment, (a) The result of RD imaging method (b) The result of 2D UESPRIT method

Fig.4 Measured data experiment, (a) The RD imaging method result (b) The 2D UESPRIT method result

4. CONCLUSIONS

The proposed algorithm combines 2D Unitary ESPRIT method and least square method to obtain the targets location and backscatter information based on the SAR signal model. The simulated data and actual measured data are both used to show the validation of the algorithm. Compared with the Fourier method, the proposed algorithm obtains better results.

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