

AN UNFOCUSED SAR APPROACH TO IMPROVE AZIMUTH RESOLUTION OF DUAL-FREQUENCY POLARIZED SCATTEROMETER(DFPSCAT) Postprint

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Abstract

For the spaceborne scanning pencil-beam scatterometer, the azimuth resolution is low that could not meet the demands. Based on the motion of platform and the scanning rules of the spaceborne scatterometer, this paper takes an unfocused SAR approach to improve the Azimuth Resolution.

Full Text

Preamble

AN UNFOCUSED SAR APPROACH TO IMPROVE AZIMUTH RESOLUTION OF DUAL-FREQUENCY POLARIZED SCATTEROMETER (DFPSCAT)

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1. ABSTRACT

For spaceborne scanning pencil-beam scatterometers, the azimuth resolution is too low to meet mission requirements. Based on the platform motion and scanning characteristics of spaceborne scatterometers, this paper proposes an unfocused SAR approach to improve azimuth resolution.

Index Terms—scatterometer, unfocused SAR, Doppler, azimuth resolution

2. INTRODUCTION

The Water Cycle Observation Mission (WCOM) proposes an X-Ku band dual-frequency polarized scatterometer (DFPSCAT) with relatively high resolution and a 1000 km swath for mapping snow water equivalent and freeze-thaw processes [1]. Retrieval of snow water equivalent is highly complex, and retrieval errors become substantial in mountainous snow regions when the resolution exceeds 10 km, necessitating a resolution of 2-5 km [2]. Spaceborne scanning pencil-beam scatterometers can provide high signal-to-noise ratio (SNR) despite shorter dwell times, and offer the advantage of covering a much larger area than SAR systems.

DFPSCAT will employ pulse compression using linear frequency modulation along the elevation direction, providing range resolution of approximately 50 m ($B = 5$ MHz) and 25 m ($B = 10$ MHz). Given the resolution requirement of 2-5 km, the measurement area could theoretically be resolved into as many as $2000 \div 50 = 40$ or $5000 \div 50 = 100$ separate elements, each constituting an independent sample and corresponding to a normalized-measurement standard deviation of and $1/10$ [3]. To achieve improved resolution along the azimuth direction, the system will utilize an unfocused synthetic aperture technique that exploits the Doppler effect to synthesize a longer aperture, combined with super-resolution reconstruction through azimuth oversampling.

3. SYSTEM PARAMETERS

To achieve both high-accuracy backscattering coefficient measurements and relatively high-resolution snow water equivalent retrievals, DFPSCAT system parameters must represent a compromise between these two objectives in the system design.

The unfocused SAR method should not be used when the azimuth angle is less than 35 degrees; alternative methods such as resolution reconstruction are employed in these cases. At the far swath, the azimuth footprint corresponds to a Doppler bandwidth of approximately 20 kHz, while at the near swath this corresponds to about 10 kHz, thus requiring a minimum PRF of 20 kHz to unambiguously resolve the scene in azimuth [4].

To achieve high azimuth resolution, the antenna rotation rate should be designed to be small while still satisfying the no-gap coverage requirement for the footprint. Key system specifications are summarized in Table 1 .

Table 1: System Parameters - Frequency: 9.6 GHz, 14/17 GHz - Bandwidth: 5 MHz / 10 MHz - Polarization: HH, VV, HV/VH - Antenna dimension: 1.5 m \times 0.3 m - Raw resolution: 50 m (elevation) \times 15 km (azimuth) - Resolution after processing: 2-5 km

4. BASIC PRINCIPLE

Based on the echo signal characteristics of the target, the secondary phase term of the Taylor series expansion of the echo equation can be utilized to ensure coherent accumulation without correction.

When the secondary phase term is no more than $\pi/2$, the coherent accumulation time should satisfy:

Where θ is the angle between the satellite nadir point and antenna direction and α is the azimuth angle. When the phase center error is sufficiently small such that targets do not migrate through resolution cells, the general objective of this method is to maintain a stable beam sharpening ratio across different azimuth angles. This can be achieved through two approaches: (1) varying the PRF according to azimuth while keeping the number of accumulated pulses constant, or (2) varying the number of accumulated pulses according to azimuth while maintaining a constant PRF. $2201/(1\cos\theta)\sin\alpha \leq \text{PRF} \leq 2201/(1\cos\theta)\cos\alpha$

Considering practical implementation, the second method is typically employed, using constant PRF and rotation rate while varying the number of accumulated pulses according to azimuth. The number of accumulated pulses can be approximately equal to the number of echoes from one beamwidth. Since each target has a different radial velocity relative to the radar, each echo within the beam may have a different frequency of arrival. A set of narrowband filters, with center frequencies corresponding to the echo frequencies, can accomplish Doppler frequency division. The specific filter bandwidth selection is based on system parameters and resolution requirements. Key factors affecting the unfocused synthetic aperture method include: (1) system parameters, (2) Doppler centroid estimation, (3) phase center accuracy, and (4) maintaining a constant sharpening ratio at different azimuth angles.

The quality of the unfocused SAR approach is closely associated with the accuracy of Doppler centroid estimation, which influences target location and Doppler centroid frequency. DFPCAT can measure not only HH/VV and HV/VH polarizations but also phase information, making the phase center accuracy critically important.

5. SIMULATION

Based on beam sharpening ratio requirements, we simulated the relationship between beam sharpening ratio and azimuth angle for different PRF values, as shown in Figure 1 [Figure 1: see original paper]. The beam sharpening ratio increases with PRF, indicating that the PRF should be sufficiently large. The allowable coherent accumulation time selection is illustrated in Figure 2 [Figure 2: see original paper] under the condition that coherent accumulation is permitted for a bandwidth of 5 MHz.

As discussed above, an antenna rotation rate of 4 rpm combined with a PRF of 300 Hz produces approximately 4500 pulses during one rotation. The number

of coherent accumulation pulses is four, as shown in Figure 3 [Figure 3: see original paper], which satisfies the requirement of achieving 2-5 km resolution after processing.

6. CONCLUSION

This paper introduces an unfocused SAR processing method that can achieve azimuth resolution enhancement without employing full SAR technology. Simulations demonstrate that this approach is feasible for engineering implementation and can effectively improve azimuth resolution.

7. REFERENCES

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