Antenna Pointing Measurement for Spaceborne SAR Based on Sign-MLCC Algorithm

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1. INTRODUCTION

In order to achieve the best interferometric performance, the on-orbit alignment of the antenna beams [1] of dual-antenna single-pass synthetic aperture radar (SAR) interferometry is a key requirement. Meanwhile, for geosynchronous synthetic aperture radar [2] with the very large slant range from the radar to the mapped area, antenna pointing control system is also required; otherwise, slight deviation of antenna pointing can result in a great variation of the footprint's position.
The antenna pointing control system is based on a combination of AODA and Doppler centroid measurement [1] . The AODA provides solutions for a "coarse" mechanical adjustment, enabling a "fine" electronic steering by means of a Doppler frequency analysis. In this paper, we focus on the antenna pointing measurement using onboard Doppler centroid estimator, to drive pitch and yaw angles to steer the antenna pointing.

2. DESCRIPTION OF SIGN-MLCC ALGORITHM

Multilook cross correlation (MLCC) method [3] , known as a Doppler centroid estimation algorithm for both Doppler ambiguity and fractional PRF part, works better with low contrast scenes such as forests. After upper and lower parts of the available bandwidth of the range-compressed signal are extracted to form two range looks, MLCC computes the average cross correlation coefficient (ACCC) between adjacent azimuth samples for each of the two looks, to determine the Doppler centroid.
Since the processed data are complex numbers, computing ACCC costs much time and memory. A novel Doppler centroid estimation algorithm, called sign-MLCC algorithm, is presented in this paper. After range compression and look extraction, the majority of calculations involved in the estimation are sign comparisons and additions, hence it is suited for real-time application.
The basic idea is to use the arcsine law [4] . Writing a complex number (range-compressed signal) as

$$s(k) = R(k) + jI(k) \,. \tag{1}$$

Then the ACCC of $s(k)$ can be derived as

$$R_s(m) = C \cdot \{[\sin(\frac{\pi}{2} R_{sRsR}(m)) + \sin(\frac{\pi}{2} R_{sIsI}(m))] + j[\sin(\frac{\pi}{2} R_{sRsI}(m)) - \sin(\frac{\pi}{2} R_{sIsR}(m))]\} \tag{2}$$

where C is a constant, and $R_{sXsY}(m)$ $(X, Y = R, I)$ is the sign correlation. Note that the calculation of $R_{sXsY}(m)$ is in essence a matter of counting how often two numbers, shifted m samples (in practice, m=1) in azimuth, have the same sign. Then the difference between the angles of the two coefficients determines the absolute Doppler centroid, the fractional PRF part is derived from the average phase increment of the two looks. The process of sign-MLCC algorithm is shown in Fig. 1.

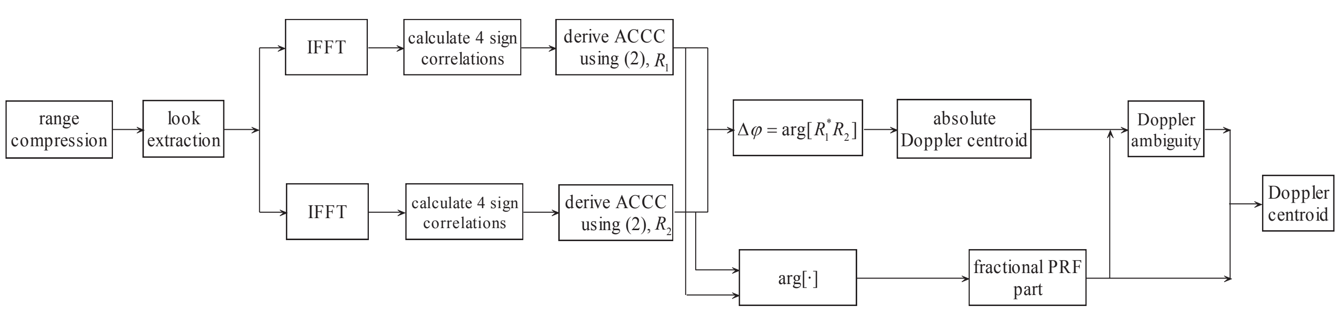

Figure 1. Flowchart of Sign-MLCC Algorithm

It is important to compare the computational load of ACCC between MLCC and sign-MLCC, as shown in Table 1. Consider a range line with 4K samples and 1K samples in each range bin. Assume both the real parts and imaginary parts of complex numbers are single precision.

Table 1. Comparison of Computational Load of Each Range Bin

MLCC			Sign-MLCC		
computation		memory requirement	computation		memory requirement
complex multiplication	1k	64 bits	sign comparison	2k	1 bit
complex addition	1k	64bits	addition	at most 2k	implemented as a counter

3. SIMULATION RESULTS

Assume an X-band spaceborne SAR, and its orbit altitude is 246 km. Two cases of different squint angles are discussed, and the ACCC angle differences between two looks are shown in Fig.2 and Fig.3, respectively.

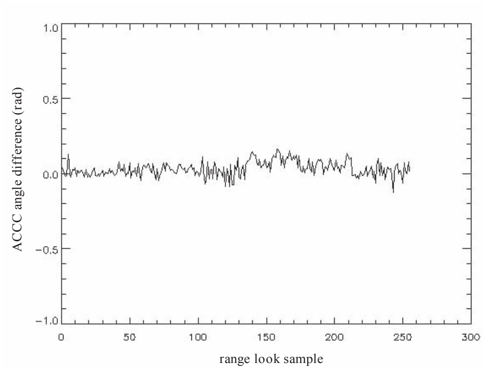

Figure 2. ACCC Angle Difference (squint angle = 1^o)

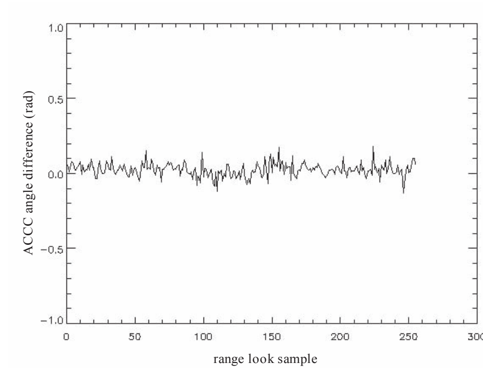

Figure 3. ACCC Angle Difference (squint angle = 2^o)

Table 2. Simulation Results

true value			estimated value		
squint angle	Doppler ambiguity	fractional PRF part	Doppler ambiguity	fractional PRF part	squint angle
1^o	4	786.398 Hz	4	774.390 Hz	0.998^o
2^o	9	-103.483 Hz	9	-139.050 Hz	1.995^o

The simulation results show the validity of the proposed algorithm for Doppler centroid estimation, and furthermore, the antenna pointing measurement. Once processing real data, both the proposed algorithm and global estimate [5] can be used, to make the measurement more reliable.

4. REFERENCES

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