Development of an Efficient Processor for SIRAL SARIn Mode

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Abstract: Recently, ESA (European Space Agency) has launched CryoSAT-2 for polar ice observations. CryoSAT-2 is equipped with a SIRAL (SAR/interferometric radar altimeter), which is a high spatial resolution radar altimeter. Conventional altimeters cannot measure a precise three-dimensional ground position because of the large footprint diameter, while SIRAL altimeter system accomplishes a precise three-dimensional ground positioning by means of interferometric synthetic aperture radar technique. In this study, we developed an efficient SIRAL SARIn mode processing technique to measure a precise three-dimensional ground position. We first simulated SIRAL SARIn RAW data for the ideal target by assuming the flat Earth and linear flight track, and second accessed the precision of three-dimensional geopositioning achieved by the proposed algorithm. The proposed algorithm consists of 1) azimuth processing that determines the squint angle from Doppler centroid, and 2) range processing that estimates the look angle from interferometric phase. In the ideal case, the precisions of look and squint angles achieved by the proposed algorithm were about -2.0 μdeg and 98.0 μdeg, respectively, and the three-dimensional geopositioning accuracy was about 1.23 m, -0.02 m, and -0.30 m in X, Y and Z directions, respectively. This means that the SIRAL SARIn mode processing technique enables to measure the three-dimensional ground position with the precision of several meters.

Key Words: CryoSAT-2, SIRAL, SAR, Interferometry, Altimeter.

1. Introduction

Generally, a radar altimeter system has been used to measure altitude. It can accurately measure the altitude of sea level within several centimeters as well as prevent the crash of an aircraft on the ground by detecting the altitude during take-off and landing. The radar altimeter of TOPEX/Poseidon which finished its mission in 2006 measured the height of sea level with an accuracy of about 3.3 centimeters at an altitude of 1,366 km (Ganachaud et al., 1997). Its measurements provided useful information for marine activities by making it possible to understand thermal expansion and flow of seawater. However, as the radar altimeter measures only the distance between an aircraft and the Earth surface from the
travel time of a radio wave with a wide beam width of the altimeter, it is difficult to estimate an accurate land surface height from the radar altimeter.

On April 8th, 2010, the CryoSAT-2 satellite, which was launched by the ESA to investigate the glaciers of the Polar regions, was equipped with a new concept radar altimeter sensor named SIRAL (SAR/interferometric radar altimeter) which was developed by Thales Alenia Space. It has been known that the principle of the Poseidon altimeter made it possible not only to detect complicated topography such as the seashores of the North Pole, but also to measure the changes in the thickness of glaciers within centimeters (Wingham, 2002). In addition, SIRAL sensor has two remarkable characteristics in comparison to a radar altimeter. One is that operation modes differ according to the features of the Earth surface, and another is that high PRF of 17.8 kHz during a burst is used for SIRAL sensor. As to SIRAL, three modes of LRM (low resolution mode), SARM (synthetic aperture radar mode) and SARInM (synthetic aperture radar interferometric mode) are in operation (Rostan, et al., 2001; Phalippou et al., 2001). The LRM has the same principle to the radar altimeter, and SARM mainly is used to detect glaciers which have the characteristics of high reflectance but low backscattering by high surface scattering. The PRF (pulse repetition frequency) of the SARM is about 10 times higher than the LRM, and then the along-track resolution of the SARM is largely improved. The SARInM uses the interferometric phase obtained by two receivers. The look angle to LOS (line-of-sight) direction can be estimated from the phase difference between two antennas, and the accurate three-dimensional location is achieved by the estimated look angle (Rey et al., 2001). As shown in Fig. 1, the signals returned from the closest ground surface are acquired by the two receivers simultaneously. The baseline between two sensors causes the phase difference ($\Delta \phi$) between two signals, and the across-track ground distance $\Delta y$ can be calculated from this phase difference (Cullen, 2002). Another characteristic of the SIRAL sensor is to improve the along-track resolution largely. The SARM and SARInM modes transmit and receive 64 pulses in one burst with high PRF of 17.8 kHz (see Fig. 2). This high PRF of SARM and SARInM lead to the improved along-track resolution (Wingham et al., 2006).

In this study, an efficient signal processing algorithm was proposed to measure a precise three-dimensional ground position from an interferometric radar altimeter, which is the SARIn mode of SIRAL sensor. This algorithm includes 1) range processing that determines the slant range distance from the range resolution improved by a chirp signal and that estimates the look angle from an interferometric phase, 2) azimuth processing that determines the squint angle from the Doppler centroid. This method enables to precisely measure the three-dimensional position of the nearest target from the RAW data of SIRAL SARIn mode that improves the azimuth and the range resolutions by using high PRF and SAR interferometry. To validate the performance of the