Automatic Generation and Error Analysis of High-Precision DEM Derived from Airborne Dual-antenna Interferometric SAR Data

SUN Zhongchang¹,², GUO Huadong¹, JIAO Mengmei³, HUANG Qingni¹,²
1. Center for Earth Observation and Digital Earth, Chinese Academy of Sciences, Beijing 100012
2. Graduate School of Chinese Academy of Sciences, Beijing 100039
3. Beijing Explo-Tech Engineering Corp, Beijing 100190
Email: zhongchang26@126.com

1. INTRODUCTION

As an advanced earth observation technology, airborne interferometric synthetic aperture radar (InSAR) has become an important tool for rapidly deriving three-dimensional topographic maps, especially in the tropics, mountainous and Polar Regions [1-3]. From the early 1990’s, airborne InSAR has been increasingly applied for the measurement of the earth’s topography and demonstrated the capability to generate high-precision digital elevation models (DEMs) in practice [3-8].

Over the last decade, the airborne InSAR systems TOPSAR, EMISAR, DO-SAR, IFSARE, E-SAR, AeS-1, STAR-3i and OrbiSAR-1 have demonstrated the capability to derive DEMs of land surface from radar images, with high spatial resolution and a height accuracy in an order of magnitude of meters [2][9][10]. In China, the Experimental Airborne InSAR System is the first Chinese single-pass InSAR system developed successfully by Institute of Electronics, Chinese Academy of Sciences (IECAS) in 2004 [11]. In 2005, the airborne X-band dual-antenna InSAR system is designed successfully by East China Research Institute of Electronics Engineering (ECRIEE), with a ground resolution up to 1m×1m and a height accuracy excelled in 5m in mountain area [12]. As an international advanced airborne InSAR system, the system can avoid time de-coherence existing in airborne single-antenna InSAR system or space-borne radar system, which has great advantage in topographic mapping. This paper describes how high-precision DEMs are derived from the airborne dual-antenna InSAR data, and quantificationally analyses the DEM error.

2. DATA PROCESSING

In this section, data processing of DEM generation is described (as shown in Figure 1), including complex image registration, phase flattening, phase filtering, phase unwrapping, antenna eccentricity correction, absolute phase estimation, parameter calibration, height derivation and geo-coding. In order
to improve the precision, the antenna eccentricity correction and parameter calibration based on Least Square Method (LSM) are proposed.

![Diagram](image)

Fig.1 The data processing flowchart for DEM generation using airborne dual-antenna InSAR data

### 3. THEORETICAL ERROR ANALYSIS

Based on airborne dual-antenna InSAR bore-sight model, section 3 summarizes the main factors which affect accuracy of DEM in airborne dual-antenna InSAR data processing, including platform height, slant range, phase, baseline length, baseline angle, the center Doppler frequency and carrier aircraft attitude (pitch angle, yaw angle, roll angle and carrier aircraft velocity), and analyses the error of those factors. Then, the paper mainly analyses the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM error (height error and point error). As shown in Figure 2, the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM height error is given.
Fig.2 the quantitative relationship between the platform height, baseline length, baseline angle, look angle and DEM error.

4. EXPERIMENT AND ACCURACY ANALYSIS

In the section 4, the experimental data used is airborne dual-antenna X-band InSAR single-look complex (SLC) image pairs (spatial resolution is 2m×2m). The processing results are derived and analyzed. The Figure 3 shows the DEM generated from the airborne dual-antenna InSAR data. The measured ground control points (GCPs) are used to validate the DEM precision. The root mean square error of height of DEM is \(\pm 2.584m\) (as shown in Figure 4) and the mean square error of a point of DEM is \(\pm 3.547m\), which meet the requirements of 1:50000’s DEM accuracy. The airborne InSAR system provides the new technique for large area topographic mapping.

Fig.3 the DEM derived from airborne dual-antenna InSAR data

Fig.4 The elevation error statistics graph between the GPS elevation and InSAR elevation
REFERENCE