Geographical Situation Monitoring Applications Based on MiniSAR

Xuejing Shi[1,2](✉), Gang Huang[2,3], Ming Qiao[4], and Bingnan Wang[4]

[1] Chinese Academy of Surveying and Mapping, Beijing 100830, China
XuejingShi@163.com, SHJ_shixuejing@163.com
[2] Beijing GEO-Vision Tech. Co., Ltd., Beijing 100070, China
GangHuang@163.com
[3] College of Resource Environment and Tourism, Capital Normal University, Beijing 100048, China
[4] Institute of Electronics, Chinese Academy of Sciences, Beijing 100190, China
MingQiao@163.com, BingnanWang@163.com

Abstract. For rapid development and wide application of UAV, high-resolution imaging radar suitable for UAV is more and more requirement. Miniature Synthetic Aperture Radar (MiniSAR) can be equipped with medium/low altitude UAV platform, which applies to the remote sensing tasks in hazardous and harsh conditions. Thus, it plays a pivotal role in geographical situation monitoring. The merit of high-performance MiniSAR is light weight, low-cost, low power consumption. Moreover, it has high resolution, interferometric and fully polarimetric imaging capabilities. Currently this paper does introduce the hardware components, system functionality and property of MiniSAR. The system is employed for the flight testing in Jishan County of Shanxi to achieve fully polarization and interference SAR imagery with 0.3 m resolution. Considering the fact that the fully polarization SAR imagery contains abundance of ground target's backscattering characteristics, it can be available for terrain classification, crop monitoring and other fields. For the SAR interferometry, DSM and DOM are obtained after phase unwrapping, block adjustment and other interference processing. Finally, the accuracy is verified using checkpoints. The result meet the requirements of topographic mapping at a scale of 1:5000. The applicability of MiniSAR system in the application of geographic condition monitoring is verified.

Keywords: MiniSAR · POLSAR · InSAR · DSM · DOM

1 Introduction

At present, geographical situation as the one of important status of national economy, represents the development of China's social economy and the progress of science and technology [1]. Due to the vastness of China, there are many regions need fast and dynamic geographic information service and response. Optical remote sensing is hardly meet the requirements of the rapid response in the difficult areas of special climatic conditions. Synthetic aperture radar (SAR) with the all-day and all-weather observation characteristics is a significant technical support to improve the capability of response

H. Yuan et al. (Eds.): GRMSE 2016, Part I, CCIS 698, pp. 350–355, 2017.
DOI: 10.1007/978-981-10-3966-9_40

and promote the remote sensing and geographic information industry. The miniature SAR (MiniSAR) that developed by Chinese Academy of Sciences Institute of electronics is a high performance system of synthetic aperture radar for low altitude flight platforms. It is small, light and low power consumption. The diversity of microwave remote sensing information are accessed flexibly and low-cost by MiniSAR that can be employed in unmanned and small light manned aircraft platform [2, 3]. This again is an important future development direction, with potential applications across many areas, including geographical situation monitoring.

2 MiniSAR System Introduction

MiniSAR system, which operates in the Ku-band, owns fully polarimetric mode and interference mapping function so that it can obtain abundant information of the ground objects and geographic data. As more SAR have been launched they have facilitated available application of polarization and interference technology in geographical situation survey, which represents one of the most challenging and active areas of development at the current time. Less than 2 kg of the radar host and the whole system is less than 6 kg, therefore it can be carried in all kinds of light aircraft and equipped with UAV that load platform above 6 kg. Naturally, the assignment data collection of airborne remote sensing radar can be executed easily by MiniSAR system with all-weather, multi-polarization, multi-function. A novel solution is provided in monitoring of difficult geographical conditions.

The hardware of MiniSAR system include radar host, IMU, GPS antenna, RF transceiver antenna, polarization switching switch, power supply batteries, cables and other related equipment. The main role of the radar host is to generate excitation signals, and accept the radar echo signal from the receiving antenna for fast gathering and high-speed storage; IMU mainly provides motion compensation for MiniSAR imaging; the action of GPS supplies GPS Data for PCS module; the function of RF transceiver antenna is to transmit and radiate the output of the microwave power of the transmitter to the ground, then, the echo signals of the ground targets are received through the feeder to the receiver, which is transmitted to the receiver via the feeder. MiniSAR system specifications are shown in Table 1.

Table 1. MiniSAR system specifications

Name	Interference pattern	Polarization mode
Maximum flying height	1500 m	1900 m
Center frequency/bandwidth	14.5 GHz/600 MHz	
Beam center angle	45°	45°
Polarization mode	Single polarization	Full polarization
Interference baseline	1 m	/
Maximum mapping bandwidth	1.2 km	1.4 km
Polarization isolation	Better than 25 dB	
Weight	≤5 kg	
Power consumption	≤65 W	

Here we present a brief discussion of the work flow of flight test by MiniSAR. (1) Route planning, flight routes are designed according to the mapping area and parameters of radar. (2) Data playback and POS processing, radar echo data are being played back to the local hard disks. (3) Quality inspection, checking the information is overwritten and fast imaging processing, and the data quality is evaluated. (4) Imaging processing, fine imaging of full resolution into SLC data. (5) Polarization synthesis, a pseudo color imagery is created by pauli synthesis after polarization and radiation calibration of full polarimetric data. (6) Interference processing, the DSM and DOM are generated after registration, filtering, phase unwrapping, joint scaling, geocoding and other steps.

3 MiniSAR Mapping

3.1 Survey Area

The flight test of MiniSAR was conducted in November, 2015. The survey area is located in Jishan County. The east-west direction of the zone is about 3.5 km and there is about 5.5 km from north to south. The terrain is dominated by hills and partly mountainous, the highest elevation of 470 m in the region and the minimum altitude of about 320 m. Here we set up six flights in this zone, and overlap between the strips at arte of 30%.

3.2 Full Polarization Mapping

Polarimetric SAR (Polarimetric SAR, POLSAR), as the frontier imaging radar in recent years, which can obtain richer target signatures information than single polarimetric SAR system and open up possibilities for POLSAR remote sensing applications. So it has unattainable advantages of the single polarimetric SAR in analyzing, extracting and inversion of the polarimetric scattering characteristics of ground objects [4].

Data acquisition of dual-channel mode is utilized in the miniature POLSAR system. It adopt the full-polarization antenna and the polarized switch, which is needed to switch the H/V polarization mode to obtain HH, HV, VH and VV four kinds of polarimetric signals. The test of full polarization mapping was carried out. The aircraft flight with 1500 m altitude, 45° side view angle and the viewing angle of 21°. A plurality of corner reflectors is arranged in the middle strip of the survey area. There are two sets of polarization scalers, each group contains dihedral reflector of 0°, dihedral reflector of 45°, trihedral corner reflector, meanwhile, other triangular reflectors are adopt to make polarimetric calibration. The image is processed to obtain exquisite polarization image with the accuracy of 0.3 m after data playback. As shown in Fig. 1.

In order to facilitate the visual interpretation of radar images, the pauli synthesis is available for usage of polarization image to construct a pseudo color image. As shown in Fig. 2, the farmland, roads, waters, residential areas can be distinguished clearly. Obviously, the sophisticated fully polarized images of MiniSAR would be offered the vital sources of data for urban monitoring, resource census, land use and land cover [5].

Fig. 1. HH polarized image

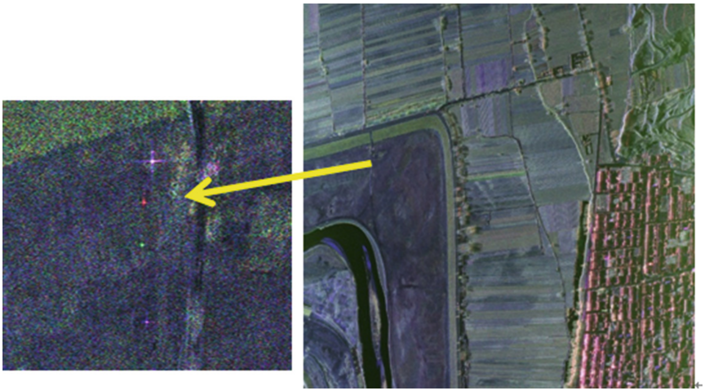


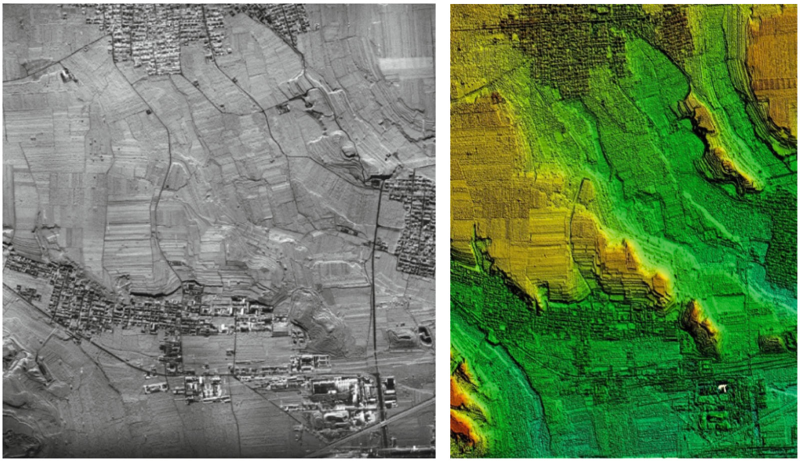
Fig. 2. Pauli synthesis of MiniSAR image (the purple point is trihedral reflector, red point is dihedral reflector of 0° and green point is dihedral reflector of 45°) (Color figure online)

3.3 Interference Mapping

The gray-scale images and terrestrial three-dimensional information can be get after imaging and interferometric processing of Synthetic Aperture Radar Interferometry (InSAR) data [6].

The work mode of interference MiniSAR selected dual-channel acquisition. In this test, the selected antennas is a pair of HH single-channel and a fully polarized antenna that is used as a single-polarized. The two antennas installed in the wing of the aircraft are employed to acquire the basic processing data that two SAR images in the same area, while the interference image is created by calculating the phase difference of the two SAR images [7]. Eventually, the terrain elevation data is generated through phase unwrapping, joint calibration and other related handling.

This interferometry test with aviation altitude 600 m, side view angle of 60°, the baseline length of 0.5 m. There are six corner reflectors are arranged in the pilot site, and four scalers are selected as control points for block adjustment. The block adjustment technology of InSAR can not only reduce the demand for control points, but also improve the accuracy of the coordinates of the connection point and the integrity of the regional network [6, 8]. It largely improves the precision of interferometry. Figure 3 shows the results of interferometry.



(a)DOM (b)DSM

Fig. 3. The results of interferometry

To verify the accuracy of interferometry, in addition to the 4 control points, the other two points are used as check points in the six corner reflectors arranged in the survey area. While more check points of the required to do accuracy analysis are selected. In the figure, 17 feature points measured by GPS. As shown in Table 2, the results of the MiniSAR interferometric mapping meet the requirements of 1:5000 national standard accuracy, but it is closer to 1:2000 than those of the national standard accuracy requirements of hilly areas (Table 3). Selecting feature points artificially, what makes it difficult is the complexity of SAR imaging. The plane accuracy is not particularly high since the man-made factors. However, due to the choice of checkpoints are in flat terrain where the accuracy of elevation is relatively high.

Table 2. MiniSAR interference mapping accuracy

Point class	Error in plane (m)	Elevation error (m)
Control point	0.32	0.37
Corner reflector checkpoint	0.37	0.34
Spike checkpoint	1.44	0.44

Table 3. The national standards accuracy of hilly areas

Mapping scale	Point class	Error in plane (m)	Elevation error (m)
1:2000	Control point	0.6	0.26
	Checking point	1.0	0.4
1:5000	Control point	1.5	0.8
	Checking point	1.75	1.0

4 Conclusions

In this paper, the hardware composition and function index of MiniSAR system are described. The flight test of full polarization and interference mode is carried out. Interferometry achieves the positional precision of DSM and DOM at scale of 1:5000 in the case of sparse control points. It can realize important geographic information industry such as basic surveying and mapping, land-based monitoring, geographical situation survey and so on. Next we will further improve the accuracy of MiniSAR mapping and promote the continuous progress of MiniSAR to more miniaturization, more low power consumption, lower cost, higher resolution. It provides a broader space and prospects for the effectively application of MiniSAR in geographical situation monitoring.

Acknowledgments. This work was supported by the subject that Study on Air-ground integration of Holographic three-dimensional Data Acquisition and Demonstration Area Experiment, Chinese Academy of Surveying and Mapping, and National High Technology Research and Development Plan, under grant 2013AA092105.

References

1. Wang, J., Qiao, M., Wei, Y.: Geographical situation monitoring applications based on the UAV airborne SAR. Geomat. Spat. Inf. Technol. **39**(5), 61–64 (2016). HeiLongjiang
2. Wang, Y., Liu, C., Zhan, X.: An ultrafine multifunctional unmanned aerial vehicle SAR system. J. Electron. Inf. Technol. **35**(7), 1569–1574 (2013)
3. De Wit, J.J.M., Meta, A., Hoogeboom, P.: Modified range-Doppler processing for FM-CW synthetic aperture radar. IEEE Geosci. Remote Sens. Lett. **3**(1), 83–87 (2006). IEEE Press, New York
4. Lu, L., Zhang, J., Huang, G., Su, X.: Land cover classification and height extraction experiments using Chinese airborne X-band PolInSAR system in China. Int. J. Image Data Fusion **7**(3), 282–294 (2016). Taylor & Francis, Abingdon
5. Xie, L., Zhang, H., Liu, M., Wang, C.: Identification of changes in urban land cover type using fully polarimetric SAR data. Remote Sens. Lett. **7**(7), 691–700 (2016). Taylor & Francis, Abingdon
6. Yue, X., Han, C., Dou, C.: Mathematical model of airborne InSAR block adjustment. Geomat. Inf. Sci. Wuhan Univ. **40**(1), 59–63 (2015). The University of Wuhan, Wuhan
7. Pieraccini, M., Luzi, G., Atzeni, C.: Terrain mapping by ground-based interferometric radar. IEEE Trans. Geosci. Remote Sens. **39**(10), 2176–2181 (2001). IEEE Press, New York
8. Huang, G., Yang, S., Wang, N.: Block combined geocoding of airborne InSAR with sparse GCPs. Acta Geod. Cartogr. Sin. **42**(3), 397–403 (2013). Surveying and Mapping, Beijing