RESULTS AND ANALYSIS OF HYBRID BISTATIC SAR EXPERIMENTS WITH SPACEBORNE, AIRBORNE AND STATIONARY SENSORS

Ingo Walterscheid, Thomas Espeter, Christoph Gierull, Jens Klare, Andreas Brenner, Joachim Ender

FGAN-FHR
Neuenahrer Str. 20, 53343 Wachtberg, Germany
Tel: +49 228 9435-372, Fax: +49 228 9435-618, E-mail: walterscheid@fgan.de

1. INTRODUCTION

A bistatic synthetic aperture radar (bistatic SAR) is a promising and useful supplement to a classical monostatic SAR system. Using a bistatic SAR system, where transmitter and receiver are spatially separated, additional information of a scene will be provided, because the scattering characteristics of objects depends on the line of sight vector to the transmitter and receiver. Therefore, the image analysis and classification will be improved using appropriate bistatic configurations. Another advantage of bistatic SAR is the potential cost reduction achievable by using for instance one already existing transmitter and one or several passive receivers, which are usually much cheaper than the expensive transmit unit. An important application of bistatic SAR systems is single-pass interferometry with large baselines to get significantly improved height resolutions. The spatial separation of the active and passive part of a radar has also the advantage of reduced vulnerability for military applications. The passive and possibly unmanned receiving platform could operate close to the theater of operation, whereas the active transmitter is located in a safe stand-off range, e.g. on a satellite or stratosphere aircraft.

To validate these advantages, the first experiment with a spaceborne transmitter and an airborne receiver took place in the mid-nineties in the USA. Due to technological problems and lacking bistatic SAR image processors the interest tapered-off afterwards until the proposal of an interferometric cartwheel in 2000 [1]. Recently, many bistatic experiments have been conducted and different processing algorithms to focus bistatic SAR data have been proposed [2, 3, 4, 5].

The first bistatic experiments at FGAN-FHR took place in 2003 and have already been described in detail in [6]. This paper describes newer bistatic SAR experiments of FGAN-FHR and presents image results. These experiments have been conducted in 2007 and 2008 with FGAN-FHR's airborne multi-channel SAR system PAMIR [7] and a stationary ground sensor as well as PAMIR and the German radar satellite TerraSAR-X. The paper also analyzes the scattering behavior of objects in the bistatic case in contrast to monostatic data acquisition as well as results from a scene acquired with different bistatic configurations.

Additionally, results of similar bistatic SAR experiments conducted at DRDC [1] Ottawa will be presented and discussed. In contrast to the FGAN setup, here the transmitter was located on an aircraft while the receiver was mounted on a tower.

2. BISTATIC SAR EXPERIMENT WITH THE AIRBORNE SENSOR PAMIR AND A STATIONARY TRANSMITTER

Several hybrid bistatic SAR experiments have been conducted with a stationary X-band transmitter and PAMIR as receiver on board a Transall C-160. The reasons for these experiments are manifold. First, we wanted to acquire bistatic SAR data of a translational variant configuration to verify our developed SAR processors. Second, it is necessary to analyze SAR data with non-synchronized oscillators, which is often the case for bistatic SAR with transmitters of opportunity (e. g. TerraSAR-X and PAMIR). Third, we wanted to analyze bistatic SAR images of the same scene, acquired for different flight trajectories and bistatic angles. The paper explains the data acquisition and presents the image results.

3. BISTATIC SPACEBORNE/AIRBORNE SAR EXPERIMENT WITH TERRASAR-X AND PAMIR

FGAN and ZESS (University of Siegen) used the "Pre-Launch Announcement of Opportunity" for the scientific use of TerraSAR-X to propose several hybrid bistatic SAR experiments with TerraSAR-X as transmitter and PAMIR as receiver. The

[1] Denfence Research and Development Canada

first of these experiments took place in July 2008. TerraSAR-X operated in a sliding spotlight mode and illuminated a scene of 5 km x 10 km. The incidence angle at the scene center was 47°. The airborne platform, a Transall C-160, flew at an altitude of 3300 m with a velocity of 95 m/s on a nearly parallel trajectory with respect to the satellite. PAMIR operated in a right looking strip-map mode. The variable yaw angle was compensated by the electronically steerable antenna. The incidence angle at the scene center was 70° which resulted in a bistatic angle of about 23° in the middle of the data take. PAMIR has been adapted to receive the direct and reflected TerraSAR-X signal. To acquire the data in a pulse operation mode, a reliable synchronization system has been realized. The paper describes the hardware setup including the pulse synchronization system and discusses the data acquisition of the direct as well as the reflected TerraSAR-X signal. The processing steps and first image results will be presented.

4. BISTATIC SAR EXPERIMENT WITH AN AIRBORNE TRANSMITTER AND STATIONARY RECEIVER

Most (if not all) recently demonstrated experimental bistatic SAR images have been acquired using rather steep incidence angles, resulting in relatively short synthetic aperture times of only a few seconds. DRDC Ottawa has embarked on a project to demonstrate the feasibility of long-range airborne bistatic SAR with submeter resolutions. As part of an experiment in spring 2006 a stationary receiver was mounted ontop a 25 m tall tower while the transmitter was located on a maneuvering aircraft in a distance to the scene of about 30 km. Due to the shallow incidence angles a major challenge includes the development of technology to achieve adequate phase stability between both local oscillators over long periods (1-2 min). In order to avoid a direct link between transmitter and receiver to establish phase coherence DRDC Ottawa uses highly stable 'free-running' crystal oscillators [8].

In this paper, the impact of uncompensated phase noise on the image quality will be discussed and the experimental setup presented. Furthermore, the functionality of the phase noise compensation unit will be demonstrated for the first time based on experimental bistatic SAR images.

5. ANALYSIS AND COMPARISONS OF THE BISTATIC IMAGE RESULTS USING ALSO MONOSTATIC SAR AND OPTICAL IMAGES OF THE SCENE

The image results will be analyzed with regard to shadows, RCS, layover effects or scattering behavior in urban as well as rural areas. Significant differences in contrast to monostatic SAR images are discussed. Additionally, a comparison with optical images helps to understand some scattering phenomena.

6. REFERENCES

[1] D. Massonet, "Capabilities and limitations of the interferometric cartwheel," *IEEE Trans. Geosci. Remote Sens.*, vol. 39, no. 3, pp. 506–520, March 2001.

[2] I. Walterscheid, A. Brenner, and J. Ender, "Geometry and system aspects for a bistatic airborne SAR-experiment," in *EUSAR 2004*, Ulm, Germany, May 2004, pp. 567–570.

[3] G. Yates, A. M. Horne, A. P. Blake, R. Middleton, and D. B. Andre, "Bistatic SAR image formation," in *EUSAR 2004*, Ulm, Germany, May 2004, pp. 581–584.

[4] P. Dubois-Fernandez, H. Cantalloube, B. Vaizan, G. Krieger, R. Horn, M. Wendler, and V. Giroux, "ONERA-DLR bistatic SAR campaign: planning, data acquisition, and first analysis of bistatic scattering behavior of natural and urban targets," *IEE Proc.-Radar Sonar Navig.*, vol. 153, pp. 214–223, 2006.

[5] J. Sanz-Marcos, P. Lopez-Dekker, J. J. Mallorqui, A. Aguasca, and P. Prats, "SABRINA: A SAR bistatic receiver for interferobetric applications," *IEEE Geosci. Remote Sens. Lett.*, vol. 4, no. 2, pp. 307–311, April 2007.

[6] I. Walterscheid, J. Ender, A. R. Brenner, and O. Loffeld, "Bistatic SAR processing and experiments," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 10, pp. 2710–2717, October 2006.

[7] A. R. Brenner and J. Ender, "Demonstration of advanced reconnaissance techniques with the airborne SAR/GMTI sensor PAMIR," *IEE Proc. Radar Sonar Navig.*, vol. 153, no. 2, pp. 152–162, April 2006.

[8] C. Gierull, C. Pike, and F. Paquet, "Mitigation of phase noise in bistatic SAR systems with extremely large synthetic apertures," in *EUSAR 2006*, Dresden, Germany, May 2006.