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MULTI-PLATFORM, MULTI-FREQUENCY SAR CAMPAIGN WITH THE F-SAR AND MIRANDA35 SENSORS

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ABSTRACT

Multi-platform campaigns open up new opportunities and allow a comparison and analysis of SAR signatures of the same area at different frequency bands and incident angles. In this paper, we make use of two different sensor systems: DLR's pulsed F-SAR operating at X-, C- and L-band, and FHR's frequency-modulated continuous-wave (FMCW) MIRANDA35 operating at Ka-band. Main goals of the campaign include the comparison of high-resolution polarimetric signatures at different frequency bands, change detection, synchronized acquisition of ground moving targets and air-moving target indication (AMTI) experiments. We present the planning and implementation of the campaign and first results of the data processing.

Index Terms— multi-frequency, multi-platform, MTI, SAR signatures, synthetic aperture radar.

1. INTRODUCTION

Multi-platform, multi-frequency airborne SAR experiments are complex and logistically challenging. Thus, many studies rely on satellite SAR data, either by using various sensor systems (e.g. [1]) or one of the newly established SAR constellation missions (e.g. [2]). Fewer studies make use of multi-platform airborne data at similar frequencies, which, however, are often non-simultaneously acquired ([3], [4]). In this paper, we present an experiment in which two different sensor platforms recorded the same test areas either simultaneously or only slightly shifted in time (minutes to a maximum of 2 days), covering a frequency range from the low-frequency L-band to the high-frequency Ka-band. The systems used are the pulsed F-SAR system of DLR ([5]) and the FMCW MIRANDA35 system of FHR ([6]). Here, we focus on three different experiments that were conducted within the multi-platform campaign: (1) polarimetric acquisitions of the same test site, (2) acquisition of moving targets for ground moving target indication (GMTI) and inverse SAR (ISAR) and (3) the acquisition of the signature of one platform in the beam of the other (AMTI).

In the following, we present both, the campaign setup (flight planning and logistic challenges) in chapter 2 and first processed images of some experiments in chapter 3. In chapter 4, we conclude with a brief discussion and an outlook.

2. CAMPAIGN SETUP

The multi-platform (F-SAR & MIRANDA35) experiments took place in southern Germany.

2.1. Sensors & test sites

2.1.1. F-SAR sensor

The F-SAR system ([5]) is a multi-frequency, pulsed SAR system. For our campaign, it was operated at 9.6 GHz (X-band), 5.3 GHz (C-band) and 1.325 GHz (L-band). It transmitted signals with bandwidths of 384 MHz in X- and C-band and 150 MHz in L-band and pulse repetition frequencies (PRF) ranging from 0.946 to 7.57 kHz. The system is fully polarimetric and in addition, allows for interferometric data acquisitions. Details of the F-SAR system are summarized in the left column of Tab. 1.

2.1.2. MIRANDA35 sensor

The MIRANDA35 system ([6]) is a miniaturized FMCW SAR system operating at 35 GHz (Ka-band) with a bandwidth of 300 MHz to 1.5 GHz at a PRF between 1 and 7 kHz in our experiments. The system has two receiving channels and can be flown either in a dual-polarimetric mode with cross-polarized antennas mounted or in a hybrid along- and cross-track interferometric configuration with co-polarized antennas mounted. The system is operated from a ground control station (GCS) via a direct data link to the platform. Key parameters of the sensor are summarized in the right column of Tab. 1.

2.1.3. Test sites

The experiments took place in southern Germany in the municipalities of Kaufbeuren, Memmingen and Friedrichshafen. All test areas for the joint multi-platform experiments are illustrated in Fig. 1. Details of the planning and main objectives are described in chapter 2.2.

Fig. 1: Multi-platform test sites in South Germany.

	F-SAR	MIRANDA35

Carrier Frequency	X, C, S, L, P	Ka
Bandwidth [MHz]	Up to 760 @ X	Up to 1500
Polarization	Fully polarimetric	VV, VH (optional)
Waveform	Pulsed	FMCW
PRF [kHz]	0.946 to 7.57	1 to 7
Platform velocity	~90 m/s	~35 m/s
Max. flight altitude	Up to 6000 m	Up to 2500 m
Look direction	Right looking	Left looking

Tab. 1: Overview of the key characteristics of F-SAR and MIRANDA35.

2.2. Main objectives, flight planing and logistic setup for each test site

2.2.1. Kaufbeuren (AMTI)

The Kaufbeuren test area served for the AMTI experiments. With F-SAR actively acquiring SAR data and MIRANDA35 with its highly precise navigation system (GPS and inertial measurement unit, IMU) as passive target, it is one of the first air-to-air SAR experiments of its kind. Two flight tracks were designed: one linear, where F-SAR with a higher platform speed (~90 m/s) is passing MIRANDA35 flying parallel to F-SAR but on a lower flight level with a platform speed of ca. 35 m/s. Additionally, one circular track was designed, where F-SAR was circulating around an aim point with a radius of 2.78km and thus constantly illuminating an area with a diameter of 1.3km at the flight level of MIRANDA35. MIRANDA35 stayed during the acquisition time in the pre-defined circular airspace on the ascribed flight level. For the planning, on the one hand the receive gates of F-SAR had to be configured to make sure the MIRANDA35 platform is sampled correctly. On the other hand, the timing of the linear flight track had to be calculated and coordinated between the pilots of the platforms to make sure that MIRANDA35 is in the beam of F-SAR close to the center of the acquisition. Additionally, a Luneberg lens was installed in the cockpit of the ultra-light platform of MIRANDA35 to guarantee a strong radar cross section of the AMTI target (see also Fig. 2). The main objective for the later data analysis is to focus the SAR signature of MIRANDA35 in the F-SAR data.

Fig. 2: Luneberg lens installed in the cockpit of the MIRANDA35 platform for the AMTI experiment.

2.2.2. Memmingen (mainly GMTI)

The Memmingen test area served for GMTI experiments and change detection applications. Several flight tracks were planned for both platforms over the airport and a highway intersection close to Memmingen. Note that for GMTI experiments and due to the opposite looking directions of the F-SAR and MIRANDA35 antennas, the flight tracks had to be flown accordingly. I.e. the platforms were flying on parallel lines, but with an offset in the direction of illumination to obtain simultaneous SAR data of the area of interest. The test area was recorded very close in time (max. a few minutes apart) but, unfortunately, due to unexpected airspace restrictions over the airport of Memmingen only a small subset of the GMTI experiment could be acquired. An analysis of whether and if so, how much of the recorded data is suitable for GMTI applications will follow later.

2.2.3. Friedrichshafen (polarimetric signatures and ISAR)

The Friedrichshafen test area is well suited for the analysis and comparison of polarimetric signatures of F-SAR and MIRANDA35 as the area exhibits forests, agricultural land, urban and industrial infrastructure as well as a harbor on the lake. Additionally, Lake Constance allows for ISAR experiments: on the one hand a scheduled car ferry (Meersburg-Constance) with a predefined route and on the other hand ferries of opportunity cruising around the harbor of Friedrichshafen. Several flight tracks over Friedrichshafen and surrounding areas were planned in the way that the illumination geometry of F-SAR and MIRANDA35 are comparable for polarimetric analysis. For F-SAR the flight pattern also featured a repeat-pass tomographic pattern with non-linear flight tracks, especially interesting for forested areas. The ferry Meersburg-Constance was acquired in circular spotlight mode for F-SAR and in linear stripmap mode for MIRANDA35. Originally, it was foreseen to do the acquisition simultaneously in time which would have been specifically interesting for the ISAR experiments. However, due to the unavailability of the MIRANDA35 platform on the scheduled acquisition day, the MIRANDA35 data were recorded with a time shift of 2 days. For polarimetric signatures, this time difference has most likely a negligible influence given the very dry and warm weather conditions during the campaign. Unfortunately, the SAR data of the ISAR experiment of the ferry Meersburg-Constance are less meaningful due to the larger time shift in the acquisitions. The analysis of the data is currently ongoing.

Fig. 3: Full-polarimetric SAR images of Friedrichshafen / Lake Constance with the F-SAR sensor. From top to bottom: X-, C- and L-band. Red: power of the even-bounce; blue: power of the odd-bounce; green: power of volume scattering.

Fig. 4: Dual-polarimetric SAR images of Friedrichshafen / Lake Constance with the MIRANDA35 sensor.

Red: power of the VV channel; green: power of the VH channel; blue: ratio of the power the VV and VH channels (VV/VH).

Fig. 5: Dual-polarimetric SAR images of the ferry Meersburg-Constance with the MIRANDA35 sensor (left) and optical image (right).

3. PRELIMINARY RESULTS

Processing of the first images shows some preliminary polarimetric signatures for a linear stripmap acquisition over Friedrichshafen: fully polarimetric F-SAR X-, C-, and L-band Pauli decomposed images are illustrated in Fig. 3 while dual-polarimetric MIRANDA35 Ka-band RGB images are shown in Fig. 4. Note that the elevation beam width is smaller and flight altitude is lower for MIRANDA35 explaining the narrower slant range of the image. Also, note that the color coding and image geometry of the F-SAR and MIRANDA35 images is different at the current stage. Images from F-SAR were processed in radar geometry by an extended-omega-K method [7], while those from MIRANDA35 were processed in map geometry with a time domain back-projection method [8]. At the conference, we will show results of the eigen-decomposition [9] to analyze the different scattering mechanisms, for both F-SAR and MIRANDA35. For F-SAR, the polarimetric analysis will be performed using (1) the images from all channels and (2) the images from the VV and VH channels only. Fig. 5 shows a first image of the car ferry with MIRANDA35 and the corresponding optical image. An in-depth analysis of the processing of MIRANDA35 and F-SAR data including initial ISAR results will be presented at the conference. Also first insights into the AMTI experiment are expected to be ready for the final conference.

4. DISCUSSION & OUTLOOK

A multi-platform, multi-frequency campaign with DLR's F-SAR and FHR's MIRANDA35 sensor was successfully flown. Some smaller challenges in the coordination led to the fact few date-sets could not be recorded simultaneously but shifted in time. Nevertheless, many of the aspects of the campaign provide highly innovative data-sets including the AMTI experiment, simultaneous GMTI data and polarimetric SAR signatures from two different airborne platforms. The

data processing is still in an early stage and only some aspects can be touched on in this paper. Nevertheless, preliminary results and the acquired data promise interesting findings of the multi-platform, multi-frequency campaign in the future.

5. REFERENCES

- [1] Jiang, H., Zhang, L., Wang, Y., & Liao, M., "Fusion of high-resolution DEMs derived from COSMO-SkyMed and TerraSAR-X InSAR datasets". *Journal of Geodesy*, 88(6), pp. 587-599, 2014.
- [2] Thompson, A. A., "Overview of the RADARSAT constellation mission". *Canadian Journal of Remote Sensing*, 41(5), pp. 401-407, 2015.
- [3] Huang, W., Sun, G., Ni, W., Zhang, Z., & Dubayah, R., "Sensitivity of multi-source SAR backscatter to changes in forest aboveground biomass". *Remote Sensing*, 7(8), pp. 9587-9609, 2015.
- [4] Zink, M., Olivier, P., & Freeman, A., "Cross-calibration between airborne SAR sensors". *IEEE Transactions on Geoscience and Remote Sensing*, 31(1), pp. 237-245, 1993.
- [5] Reigber, A., Jäger, M., Fischer, J., Horn, R., Scheiber, R., Prats, P., & Nottensteiner, A., "System status and calibration of the F-SAR airborne SAR instrument". *IEEE Int. Geoscience and Remote Sensing Symposium (IGARSS)*, pp. 1520-1523, 2011.
- [6] Stanko, S., Johannes, W., Sommer, R., Wahlen, A., Wilcke, J., Essen, H., Tessmann, A., & Kallfass, I., "SAR with MIRANDA - millimeterwave radar using analog and new digital approach", *8th European Radar Conference (EURAD)*, pp. 214-217, 2011.
- [7] Reigber, A., Alivizatos, E., Potsis, A., & Moreira, A., "Extended wavenumber-domain synthetic aperture radar focusing with integrated motion compensation". *IEE Proceedings-Radar, Sonar and Navigation*, 153, pp. 301-310, 2006.
- [8] Soumekh, M., *Synthetic aperture radar signal processing*: New York: Wiley, 1999.
- [9] Lee, J. and Pottier, E., *Polarimetric radar imaging: from basics to applications*: CRC press, 2009.