The SARTOM Project;
Tomography for enhanced target detection for foliage penetrating airborne SAR
(First-Year Results)

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Abstract

The SARTOM project addresses a key area of defence interest, namely the detection and identification of targets hidden in foliage. The project includes a program of experimental data gathering, combined with the use of advanced processing techniques designed to extract the maximum amount of information contained in the data: namely SAR Tomography and the analysis of multi-polarimetric and multi-frequency systems, including the area of Polarimetric Interferometric SAR (PolinSAR). The remote sensing system used in the project is the DLR airborne Synthetic Aperture Radar (SAR) system known as E-SAR, which covers X-, C-, L- and P-band.

In this paper we present the results obtained to-date from the flight trials that were conducted in September 2007 at the test site Dornstetten, west of Munich, Germany. The analysis does not yet include the use of tomography but instead investigates the visibility of targets hidden under a range of different foliage covers compared to targets placed in the open.

Keywords: SAR, target detection, foliage, tomography, polarimetry.

I. Introduction

The SARTOM project will employ and assess the value of a range of advanced research techniques to the area of foliage penetrating radar for the detection and classification of military targets; namely SAR Tomography, multi-polarimetric and multi-frequency systems, including the area of Polarimetric Interferometric SAR (PolinSAR).

The project is currently at the beginning of its second year. During the first year, 2006-7, an airborne campaign was conducted with the DLR E-SAR system which successfully obtained data over a range of targets for tomography, polarimetric, interferometric and multi-frequency analysis, including PolinSAR.

For bureaucratic reasons it was not possible to collect data at P band. Plans are underway to obtain permission for P band acquisition during a second campaign during 2007.

During the course of the SARTOM project DLR will assess the use of SAR tomography for localisation of all scattering contributions in a volume, which normally appear superimposed in a conventional two-dimensional image. This greatly extends the potential of SAR, particularly for the analysis of volume structures such as forests.

Vexcel UK and University of Edinburgh propose to carry out parallel data analysis and simulation activities (respectively) to assess the benefits of lower frequencies to target detection beneath foliage. This includes both L band and (if permission is obtained) P band. In 2007-8, initial tomographic analysis will also be carried out using existing experimental SAR tomography software at DLR.

The project will move logically from an assessment of target detection beneath foliate to the characterisation and then classification by the end of the three years.

The SARTOM project will provide a programme of real experimental results and analysis to pave the way for the UK efforts in this area leading to major improvements in new military capabilities.

II. The DLR Airborne E-SAR System

The E-SAR Synthetic Aperture Radar (SAR) system onboard a DLR Dornier DO-228 aircraft operates in 4 frequency bands, X-, C-, L- and P-band. The polarisation of the radar signal is selectable. E-SAR measurement modes include single channel operation, i.e. one wavelength and polarisation at a time, and the modes of SAR Interferometry and SAR Polarimetry. The system is polarimetrically calibrated in L- and P-band. SAR Interferometry is operational in X-band (XTI or ATI). Repeat Pass SAR Interferometry is operational in L- and P-band, especially in combination with polarimetry.

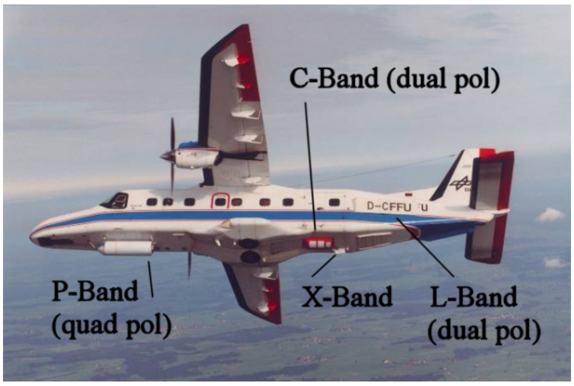

Figure 1: The DLR E-SAR system.

III. SARTOM flight trials campaign

The SARTOM flight trials took place during weeks 39 and 40 in 2006.

The 'Standortuebungsplatz Dornstetten' training ground of the German army near the village 'Dornstetten' was selected as the trials site (see *Figure 2*). This was selected in order to provide forest of varying density adjacent to open grassland. The site is located about 10km south of the City of Landsberg a. Lech, which is approximately 50km from the DLR research centre Oberpfaffenhofen.

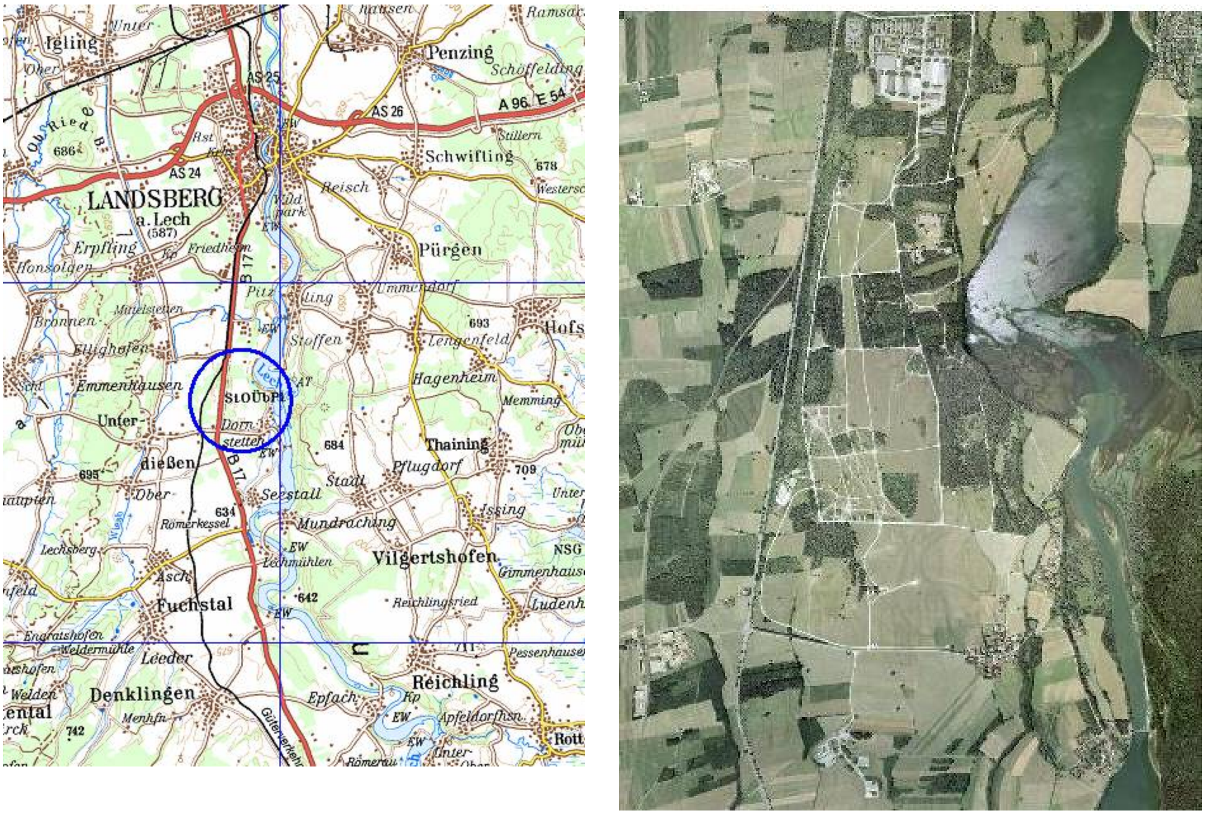

Figure 2: The SARTOM test site 'Dornstetten'. Centre coordinates N 47°59.38', E 10°51.86'.

A range of "typical" military vehicles and idealistic targets were deployed for the flight trial experiments.

Realistic targets:

- Two army trucks of type Magirus Deutz 5to gl with a steel container on the cargo area (*Figure 3*).
- Two army jeeps of type Mercedes Benz 250 GD (also named 'Wolf') (see *Figure 4*).
- One army jeep of type Volkswagen Iltis, which was deployed under netting.

Idealistic targets:

- Two 20ft steel containers representing large uniform structures.
- Four 150cm corner reflectors serving as master ground control points (CR02, CR07, CR10, CR13).
- Two sets of two 149cm corner reflectors in tomographic SAR configuration (CR11H, CR11T, CR12H(c), CR12T(c), where H denotes 'high' and T 'low'), one set up under canopy.
- Two 149cm corner reflectors at approx. the same range, one placed under canopy (CR03, CR04(c)) (see *Figure 5*).
- Two 70cm corner reflectors, one placed under canopy (7001(c), 7002) (see *Figure 5*).

During field visits all target positions were defined (measurements by handheld GPS) and marked (aluminium sticks, rope). With the targets in place the positions were measured again using DGPS to the best possible precision with the exception of the containers and vehicles. Those were measured simply by handheld GPS. The quality of the measurements was degraded in the forest.

DLR organised the target deployment in two stages to allow for controlled change detection investigations (*Figure 6*).

Figure 3: Army truck with steel container on cargo area.

Figure 4: Army jeep 'Wolf'.

Figure 5: CRs in the forest (left: 150cm; right: 70cm.

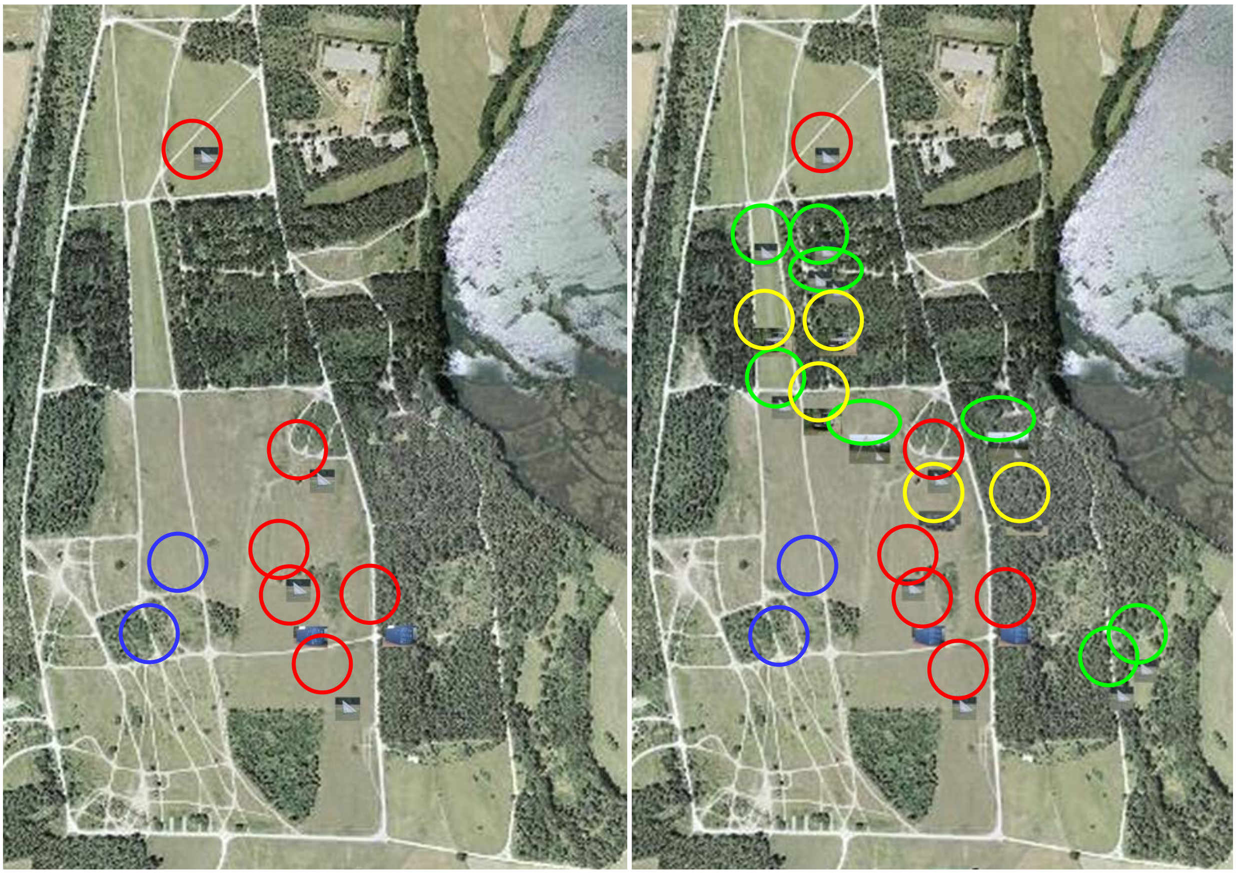

Figure 6: Target deployment (left: stage 1, right: stage 2); red circles: basic targets, yellow: army vehicles, green: added corner reflector targets, blue: targets of opportunity - decommissioned armoured vehicles.

IV. Container analysis

The following example shows the container in open site (Cont1) and forest site (Cont2) in L-HH.

Open site (Cont1)

Measured deviation of Cont1 from nominal position [east, north]:

Day1: -1.87, -1.75 m (detected)
Day2: -0.87, -1.75 m (detected)
Day3: 0.25, -1.12 m (detected)

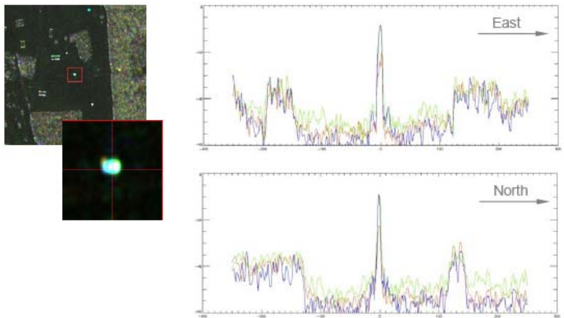

Figure 7: Containers - Open Site. Survey, zoom and profiles of Cont1 in L-HH, R-G-B=day1-day2-day3

Forest site (Cont2)

Measured deviation of Cont2 from nominal position [east, north]:

Day1: -8.62, -1.12 (detected)
Day2: -8.25, -1.12 (detected)
Day3: (not detected)

The measured deviation is due to the imprecise nominal target position.

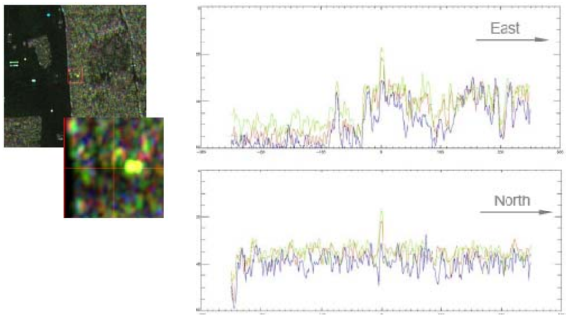

Figure 8: Containers – Forest Site. Survey, zoom and profiles of Cont2 in L-HH, R-G-B=day1-day2-day3

Container discussion

The containers in the forest can be detected using L-band HH or VV polarisation. The container in cross polarisation HV or VH is only seen in the open site but not in forest due to low back-scatter. Assisting with the detection is the fact that the container in forest has been placed in broadside. Other orientations may lead to decreased backscatter such that the container in forest disappears. Furthermore, it can be observed in the profiles that the open site container exceeds the forest backscatter by 20 dB which is a necessary precondition for detection in forest. This 20 dB advantage shrinks down to 10 dB when the container is under foliage cover, but still suffices for target detection.

V. Standard Geometry versus Grazing Angle Geometry

Grazing angle SAR geometry is generally not of advantage for target detection but might be considered for military purposes. Disadvantages include:

- longer shadows
- longer wave propagation through forest.

The latter most likely to prevent the target from being detected because more obstacles appear in line-of-sight. Cont2 demonstrated a dramatic loss in the ability of target detection with grazing angle geometry.

However, grazing angle geometry may enhance target-background contrasts for targets placed in the open.

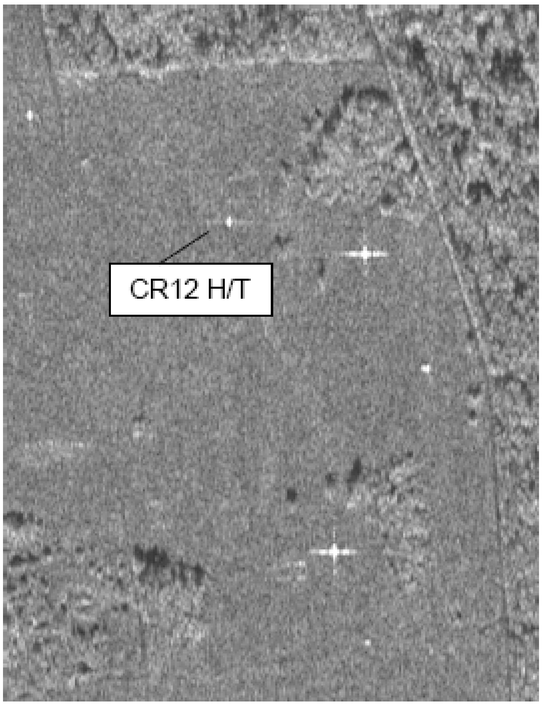

Figure 9: Container Standard Geometry. X-HH.

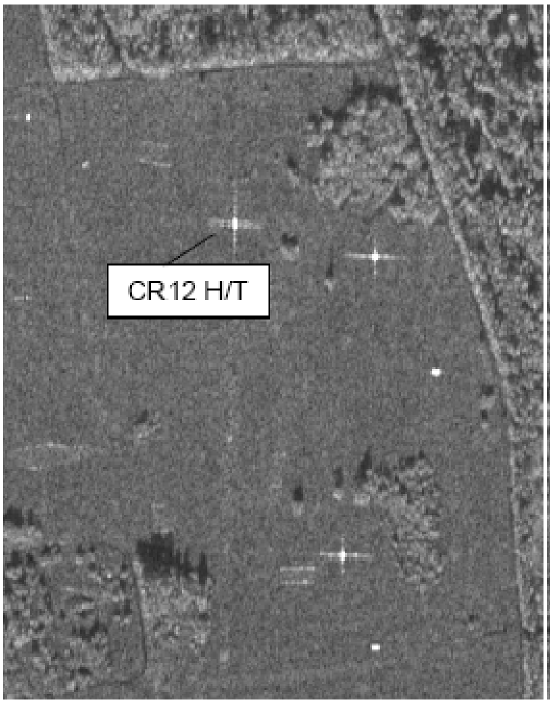

Figure 10: Container Grazing Angle Geometry. X-HH. The target appears as double-CR. The overall image is darker than the standard geometry but the target is brighter.

VI. Conclusions

Beside corner reflectors, it was only the containers among the real targets which could be detected under foliage – and only in L-band co-polarisation (HH and VV).

Trucks and Jeeps could not be detected in any frequency band (X,C,L) however we believe that P-band would perform better.

Grazing angle geometry may enhance the target-to-background radiometric contrast for targets placed in the open but due to the shallow angle and correspondingly longer signal run time through foliage it is less suitable for the detection of targets hidden under foliage.

Corner reflectors proved to be the easiest targets to be detected under foliage. Their detection mainly depends on the optimal corner elevation angle (depending on standard or grazing angle geometry) and obstacles in line-of-sight.

As expected, L-band (the longest available wavelength in SARTOM so far) in co-polarisation (HH and VV) is the favourable frequency-polarisation combination (among X, C, L-band) for the detection of targets hidden under foliage.

VII. Acknowledgements

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