DESIGN OF AN AIRBORNE INTERFEROMETRIC SAR FOR HIGH PRECISION DEM GENERATION

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ABSTRACT:

This paper describes the Interferometric SAR (InSAR) of Aero-Sensing, AeS-1. The system AeS-1, being designed and manufactured at Aero-Sensing, will be mainly used for generation of fully geocoded SAR images and Digital Elevation Models (DEM). AeS-1 has a maximal ground resolution of 0.5 m x 0.5 m and a height accuracy of 0.5 m. AeS-1 will have the first tests in August 1996 and will be operational in November 1996. The expected products of the AeS-1-System are presented. Finaly, the results of the DLR SAR, E-SAR, are shown.

1. INTRODUCTION

Aero-Sensing Radarsysteme GmbH is engaged in the field of microwave remote sensing by making use of Synthetic Aperture Radar (SAR) systems on both air- and spaceborn platforms. It is a private enterprise founded in early 1996 by former scientists of the German Aerospace Research Establishment (DLR), who were involved in the design and construction of the E-SAR, the Experimental Airborne SAR-System of DLR.

2. THE INTERFEROMETRIC SAR

The Interferometric SAR (InSAR) of Aero-Sensing, AeS-1, being designed and manufactured at Aero-Sensing, will be mainly used for generation of fully geocoded SAR images and Digital Elevation Models (DEM). The instrument is installed on board a DLR Cessna 207 aircraft, which is a small aircraft, offering the advantage of low costs. The radar will have the first tests in August 1996 and will be operational in November 1996. It operates in the interferometric mode as following:

- operating frequency: 9.6 GHz
- baseline: 1.5 m (orthogonal to line of sight direction)
- system bandwidth: 400 MHz
- ground resolution: up to 0.5 m x 0.5 m
- swathwidth: 1 to 14.8 km
- flight velocity: 60 - 120 m/s
- flight altitude over NN: 1000 to 3500 m

In general, the radar allows an aircraft velocity range between 50 and 200 m/s and a flight altitude range of 100 to 10.000 m over ground.

The preliminary estimation of the height accuracy measurement is around 0.5 m. The navigation system used for SAR motion compensation is composed by a strap-down inertial system, a differential on-line GPS, D-GPS, and a radar altimeter. The Flight Control System of IGI, Aero-Control, processes the data of the navigation units by using Kalman filter techniques and delivers the aircraft motion to the interferometric processor.

Table 1 shows the main imaging configurations of the AeS-1-System. The ground and radiometric resolutions can be set to the following values:
- 0.5 x 0.5 m with 4 looks
- 1.0 x 1.0 m with 8 looks and
- 2.0 x 2.0 m with 16 looks.

The throughput of the processing chain was calculated considering a SGI-Computer with 8 processors and 2 Gbyte RAM.

3. THE INTERFEROMETRIC PROCESSOR

The interferometric processor consists on the SAR processing, interferometric and geocoding chain. The SAR processing chain has full motion compensation capability. The interferometric chain uses a new approach for phase unwrapping (Fornaro et al.,1996). A fusion procedure of strong-filtered and less-filtered unwrapped phases using Kalman filter technique is used (Lanari et al., 1996). These algorithms allow the full automation of the DEM generation process, making the SAR interferometry an attractive tool for topographic purposes. Due to the absolute position accuracy given by the D-GPS, the transformation „phase to height“ and geocoding become straight forward procedures.

AeS-1	Swath Mode				
Parameter	A	B	C	D	E
Spatial Resolution (m)	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0
Height Accuracy (m)	0.5	0.5	0.5	0.5	0.5
Swath Width (km)	1	2	4	7.4	14.8
Radiometric Resolution (dB)	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
Throughput of the Processing Chain (km^2/day)	120	240	480	880	1760

Table 1. Main parameters of the AeS-1-System.

4. PRODUCTS

Due to the high ground resolution and height accuracy, one can have the following products from the AeS-System:

• Fully geocoded DEM's with following parameters:
 - Grid of 0.25 m and height accuracy of 0.5 m
 - Grid of 2.5 m and height accuracy of 0.1 m

• Fully geocoded SAR images, i.e. Orthoimages, with following parameters:
 - Grid of 0.25 m and a geometric distortion less than 0.5 m
 - Grid of 2.5 m and a geometric distortion less than 2.5 m

• Topographical maps in scale of 1:25,000 and larger;
- with contour lines having a spacing of 0.1 m and larger.

• Transformation of SAR products into thematic and topographic maps showing, for example, roads, urban areas, or other area features on the scale of 1:25,000 and larger as well as printed and/or coded data for specific subsequent treatment.

• Detailed measurement of the extent of local or area flooding to assist in the avoidance and/or protection from high water, representation of flood containment areas as well as cartographic representation of other environmental catastrophies and their chronological development.

• Update of geographical, topographic, land use, or other data banks and comparison between present and historical (also optical) data.

• Classification and representation of land surface as well as of vegetation and its change over time.

• Volume calculations of trash dumps, land fills, coal heaps, and other such areas.

• Measurements of the flow velocity of rivers and canals to an accuracy of 0.1 m/s with the along track interferometry technique.

• Evaluation of optimum sites for telecommunication stations

5. RESULTS

First results of the interferometric processor were obtained by processing the interferometric data of the E-SAR (Horn, 1994). The E-SAR, designed and manufactured in DLR, is a research tool to elaborate SAR related problems concerning both system performance and data analysis. The instrument is installed on board a DLR Dornier DO-228 aircraft. At the present the radar is operational in P-, L-, C- and X-bands with selectable vertical or horizontal polarizations.

Fig. 1 shows a C-band image with 2 x 2 m resolution. A small river and some trees can be seen very clear.

Fig. 2 shows a geocoded image with 3 x 3 m resolution. The E-SAR flight measurement and the processing of the slant range image were produced by DLR under contract for the Remote Sensing Laboratories (RSL) of the University of Zürich. The geocoding was then performed by RSL. A topographic map in the scale 1:25.000 is now being derived from this image.

Fig. 3 shows the terrain modell of a trash dump in Germany. The height accuracy was measured and is better than 20 cm.

6. REFERENCES

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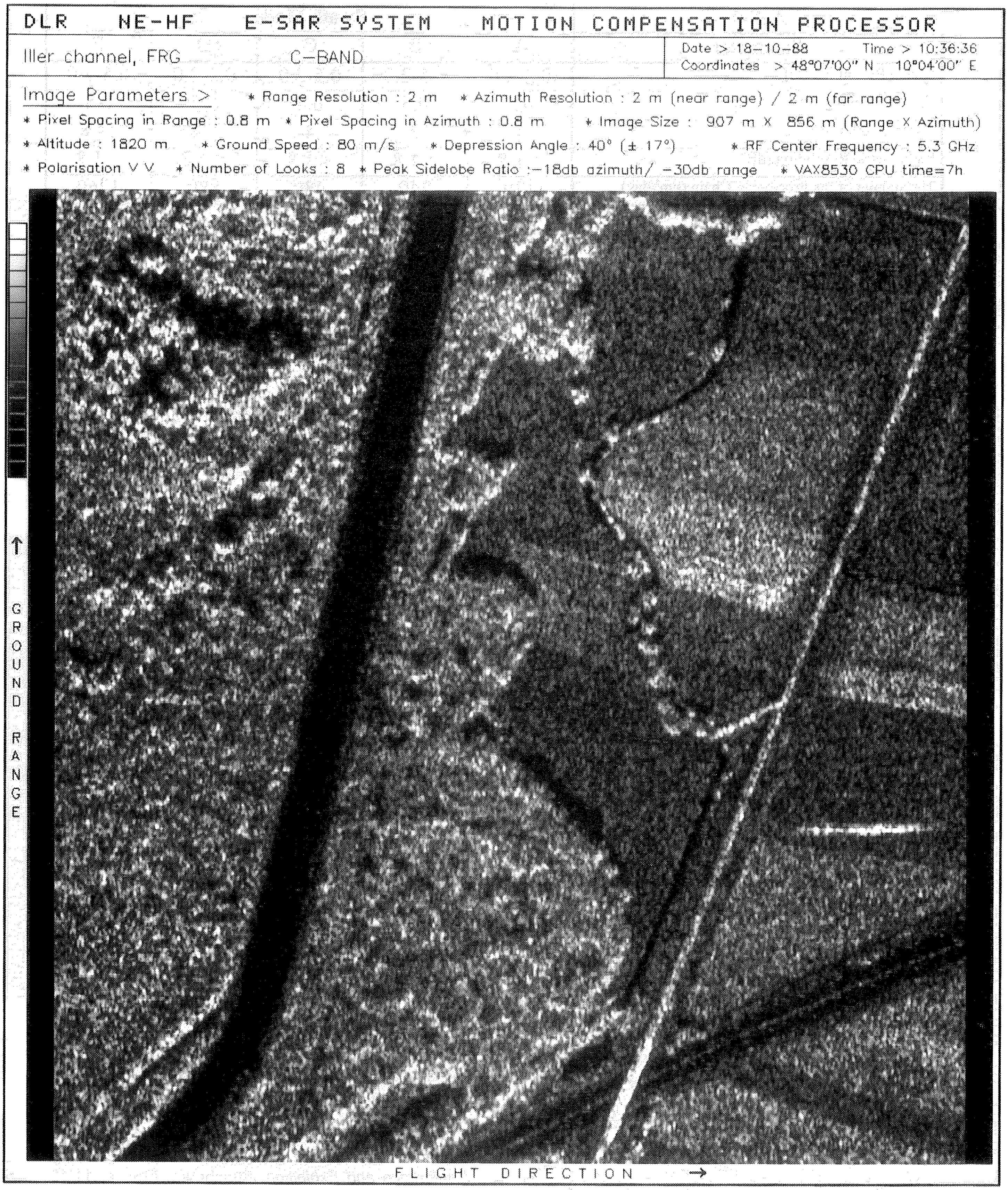

Figure 1. C-band image of the E-SAR with 2 x 2 m resolution.

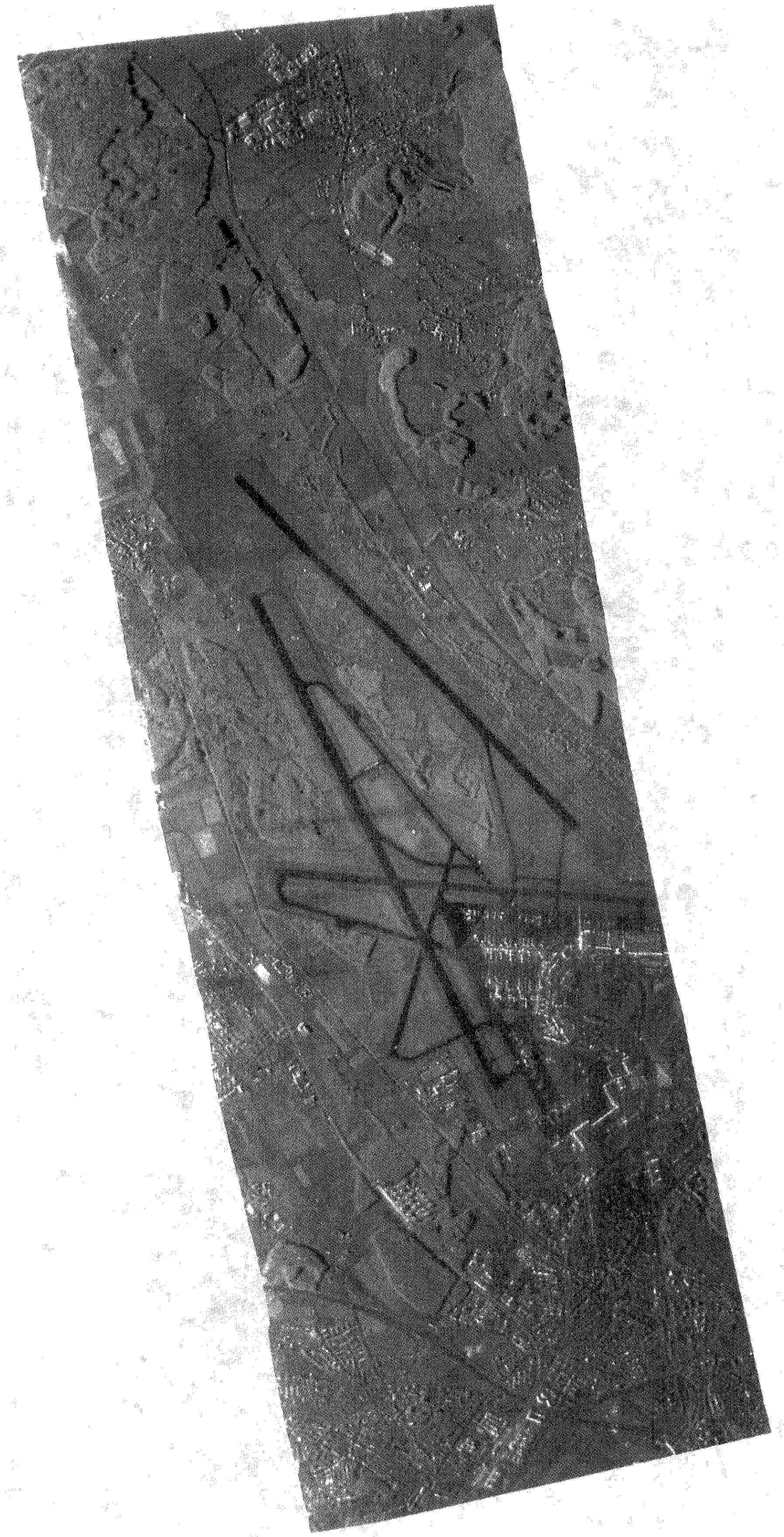

Figure 2. Geocoded E-SAR Image of the Zürich Airport Area (produced under contract for RSL, University of Zürich).

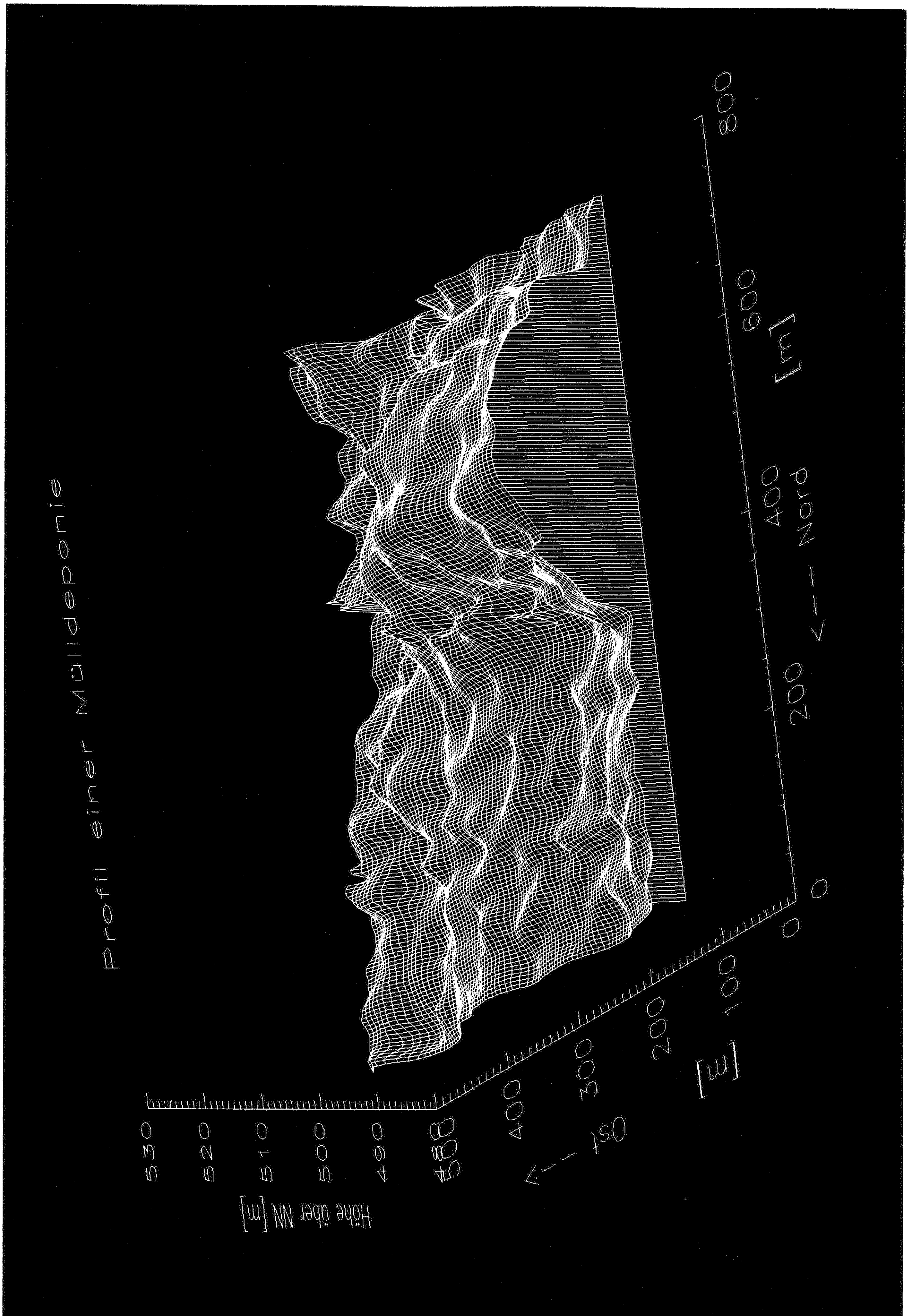

Figure 3. Terrain Model/Profile of a trash dump derived from interferometric E-SAR data.