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# DriveMark – Generation of High Resolution Road Maps with Radar Satellites

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**Abstract:** We report on the ongoing project “DriveMark” which has been started at the DLR Remote Sensing Technology Institute in 2014. It is aimed for high precision (“geodetic”) mapping of the road network using Radar satellites and other remote sensing sensors. With the introduction of corrections for atmospheric and ionospheric path delay as well as solid Earth tides in the determination of the image pixel coordinates of space borne Synthetic Aperture Radar (SAR) we have reached a similar range of absolute geolocation accuracy as possible with the GNSS techniques [Ref 1, 2]. This allows us to produce Ground Control Point (GCP) nets with satellite remote sensing technology in an efficient and global approach. It is not necessary anymore to perform costly in-situ measurements. The GCPs can be used to precisely co-register 3D-road data sets obtained by laser scanner from aircrafts or cars. Furthermore, the fusion of high definition road maps with its absolute coordinates and the surrounding objects gathered by the car sensors can deliver a comprehensive picture where the car is exactly located on the road. This is required for precise navigation in cities as well as for autonomous driving on motorways [Ref 7]. In this paper we focus on the validation for the GCPs which shall be used in the production process of the new high resolution road maps.

**Keywords:** high precision road maps, autonomous driving, navigation, Ground Control Points, Radar satellite, geodetic SAR

## Introduction

Kinematic mapping of the road network with laser scanners suffer from the fact that in urban areas the signal reception from the GNSS satellites can be weak or even distorted. In order to be able to deliver 3D-models of the roads with accurate absolute coordinates it is necessary to make use of Ground Control Points. Their placement, the measurement with a GPS receiver and to collect them again is time consuming, expensive and sometimes impossible. Therefore, we have developed a remote sensing approach which we use to determine the exact position of objects, which can be found at nearly every road in industrial countries.

A ground control point must be clearly visible in the laser scanner data as well in the radar data. It turned out, that the ideal objects are metal poles like from lamp poles, traffic lights and traffic signs. They appear in the Radar image as focussed small dots within one resolution cell, even if the pole is e. g. 20m high. This is caused by the "corner reflector effect" depicted in Figure 1. The microwave beams from the radar satellite return all at the same moment, because they are reflected from the pole and from the ground. All beams have the same running time and get focussed within one resolution cell of the imaging Radar. It is important to notice that also the quality of the ground in front of the pole, especially its smoothness plays an important role.

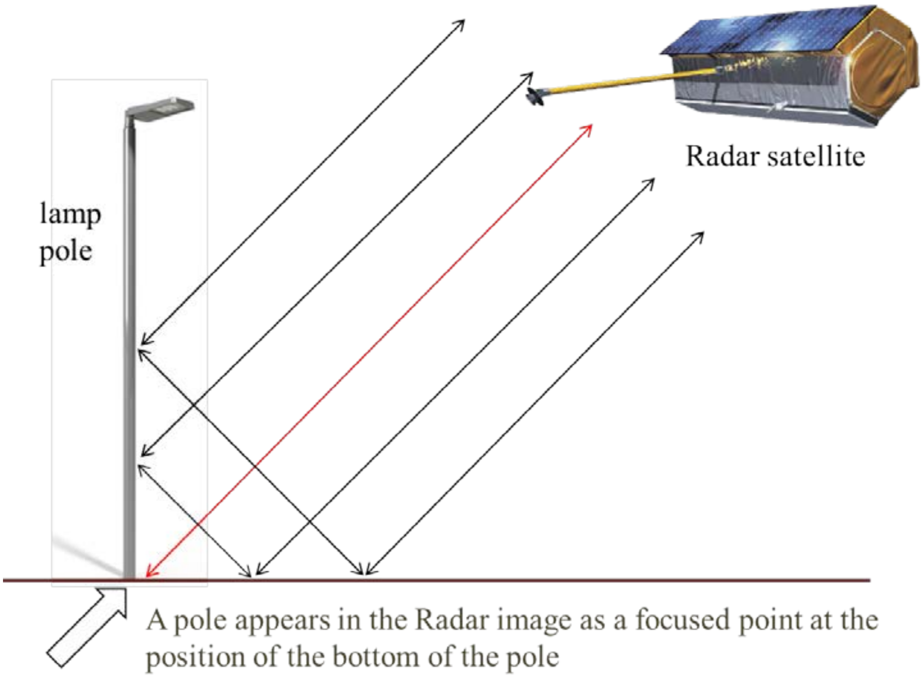


Fig. 1 Pole and ground form a Corner Reflector for the microwaves

**First Results**

We have developed a processing chain which is described in more detail in Ref. 5-6. It performs various corrections on the Radar data and extracts Ground Control Points with 3D-coordinates. In order to validate the accuracy of our system we have acquired more than 100 TerraSAR-X data sets from our test site "Wettzell" near Bad Koetzting / Germany during the last years. The TerraSAR-X "High Resolution Spotlight Mode" with 1m spatial resolution was used. The determination of 3D-Koordinates requires Radar measurements from at least two different orbit positions. For our example we have used three acquisitions obtained with incidence angles of 33, 45 and 54 Grad. For our validation we have chosen lamp poles at the road side with an approximate height of 5m as reference objects (Fig. 2).

Fig. 2: Two of the lamp posts measured in the Arnbrücker Strasse, Bad Kötzting, Germany

In a ground truth campaign the positions of the base of the poles were determined with precise GPS equipment. These were compared with the measurements from the Radar satellite and the calculated differences for the North (in blue), East (in red) and Height (in green) position have been plotted in Fig 3. We have acquired in-situ data from more than 10 objects and performed the Radar satellite measurements over more than two years at our test site in Bad Kötzting / Germany near the Geodetic Observatory of the Federal Agency for Cartography and Geodesy BKG.

The results provided in Fig. 3 cover three different lamp posts over selected periods of time and show a good stability of the measurements. However, not all objects have been able to measure at every satellite snapshot. This is indicated in the plot by solid lines instead of dots for valid measurements. It might be caused by shadowing due to parked cars or heavy snowfall. It shall be pointed out, that also the surroundings of the object which cause microwave reflection (the so called “radar clutter”) plays an important role. Precise measurements can only achieved if the object to be measured is a solitude radar reflector within an area of app. two by two resolution cells. Fortunately, the road surface and pedestrian walkways have very small radar backscatter, so lamp poles, traffic signs and traffic lights are ideal objects for our application.

The radar satellite measurements used to generate the diagrams have been acquired with descending satellite orbits. Several data sets from ascending orbits and from other test sites are also available and need to be analysed. We are confident that we can identify overall offsets which can be subtracted globally in order to reduce the typical error in all three axes to 0,1m. Therefore, the results published in this paper are preliminary and improvements are expected for the near future.

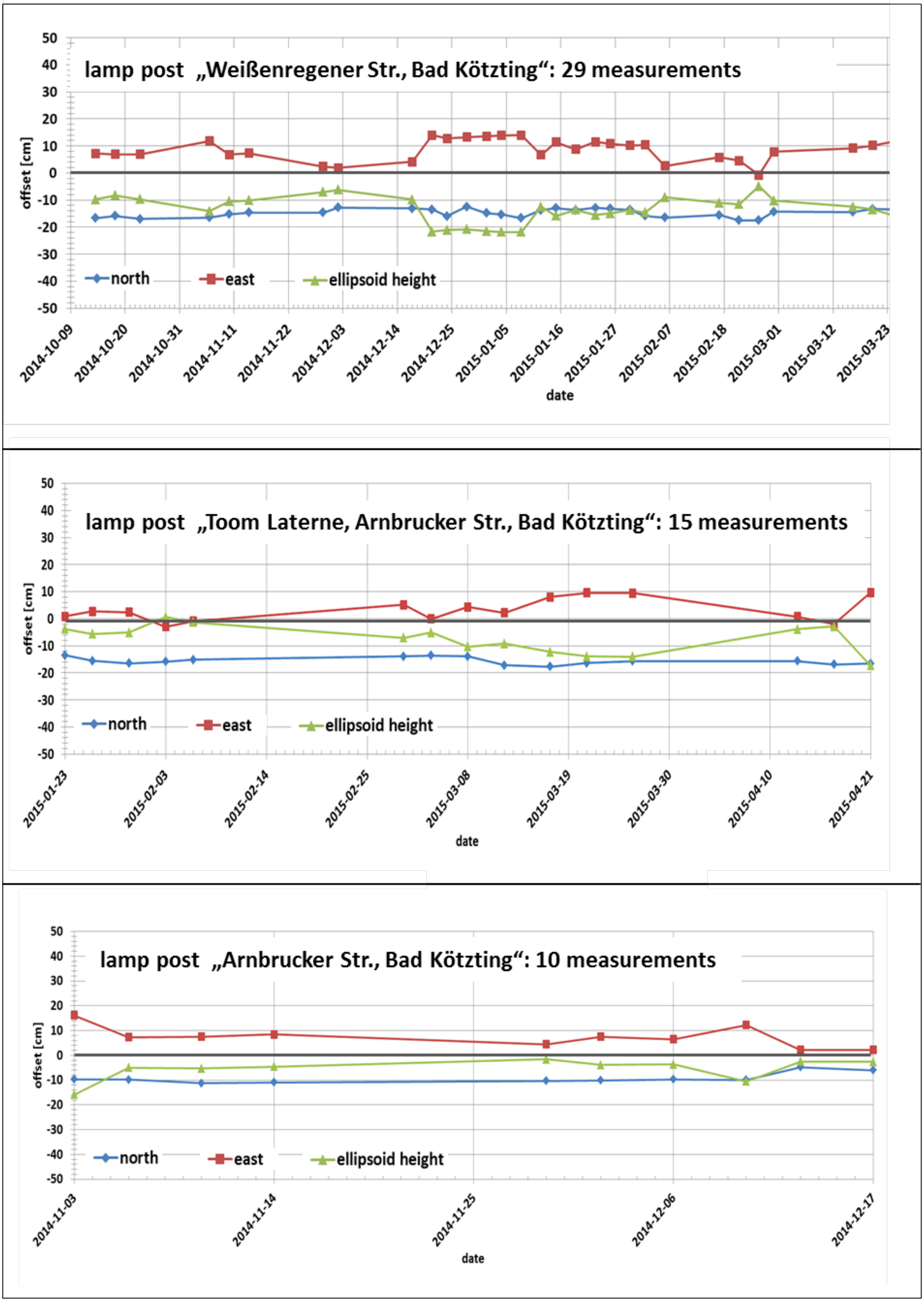


Fig. 3 Difference between GNSS in-situ and Radar satellite measurements of three objects

**Outlook: GCPs for Landmark Navigation**

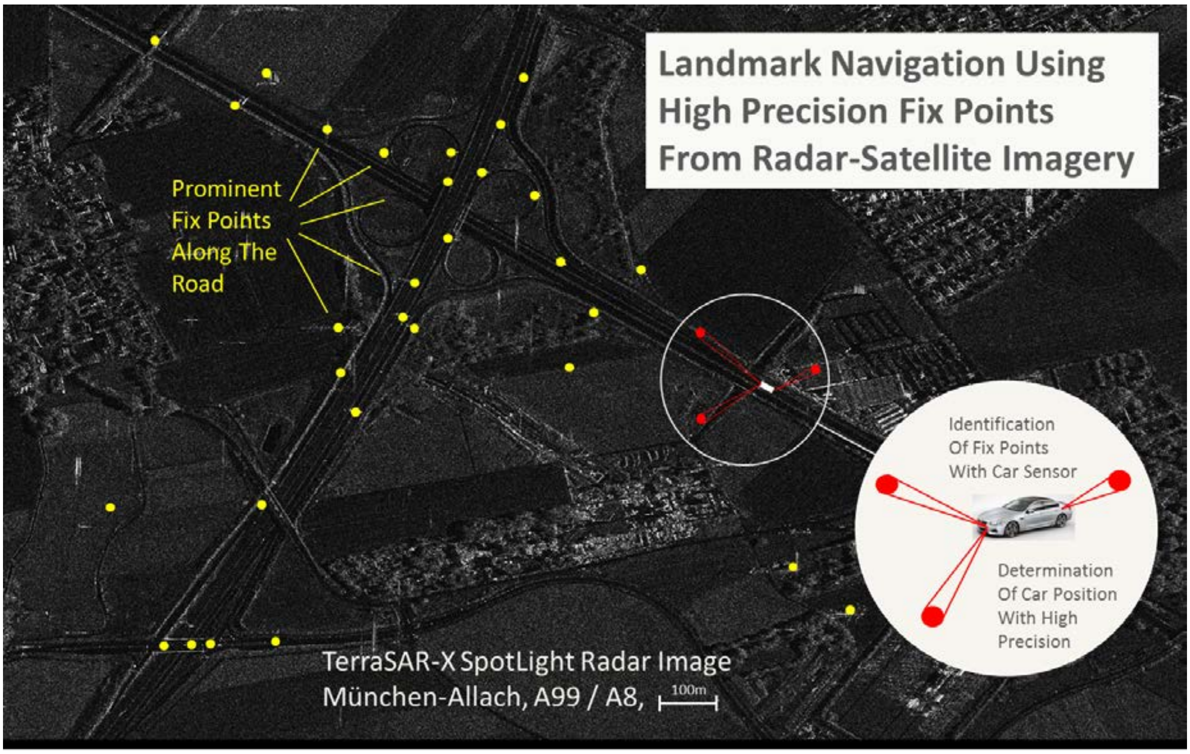


**Fig. 1 Ego-Positioning of a car using radar fix points ("DriveMarks") and on-board sensors**

The black and white image of Fig. 1 was obtained by the TerraSAR-X radar satellite and covers the intersection of A8 and A99 west of Munich / Germany. Point like features which act as Ground Control Points, coloured in yellow and designated "Fix Points" may be used as landmarks for triangulation with the car sensors [Ref 7]. This approach allows for GNSS independent self-positioning of cars.

**Summary**
TerraSAR-X can deliver for suitable objects global absolute coordinates in X, Y and Z with a precision in the 0.10m range. Suitable objects are typically solitary lamp poles or traffic signs on the road side and the coordinates are provided for the base of the mast. These positions can be used as Ground Control Points to co-register aerial images or laser scanner data..

**Acknowledgement**
Many thanks to the surveying company Patrzek which has performed very accurate ground truth in-situ measurements in our test sites.

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