# Results of the MultiNav Project with Focus on H-Field Antenna Measurements

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## 1 Introduction

Within the MultiNav project procedures were developed to integrate several navigation sensors. Project partners are the Geodetic Institute of Dresden University of Technology (TUD) and Telematica e.K. Linden. An essential task of TUD focuses on the development of basic algorithms for real time software for GNSS receivers as well as the test and validation of those.

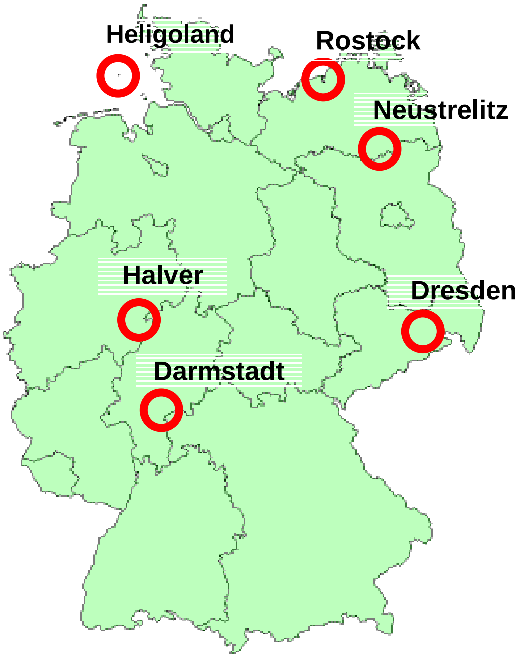


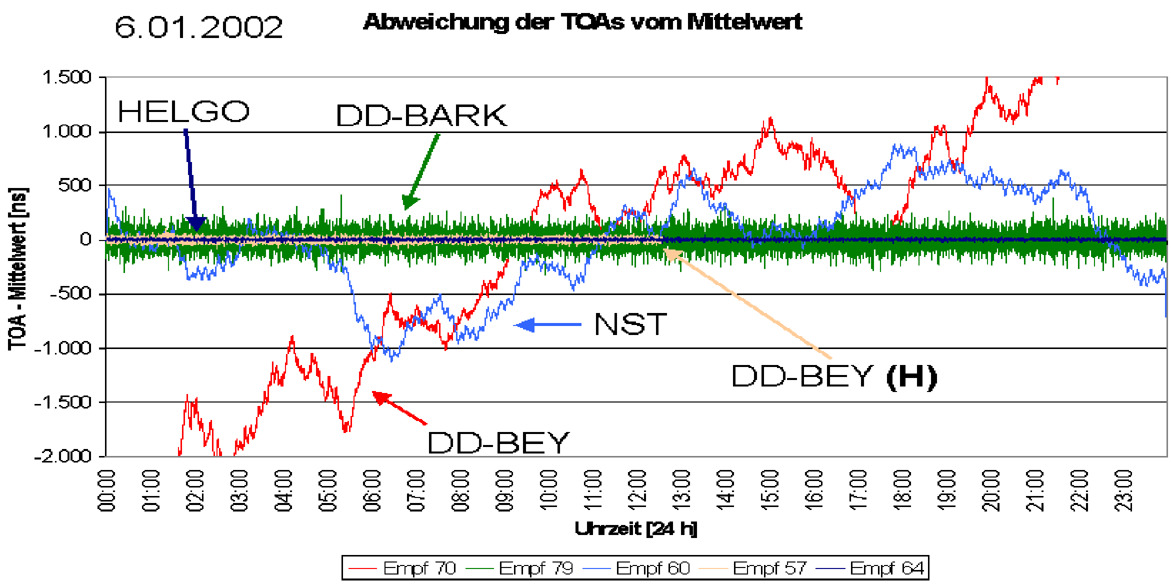

**Figure 1: Test measurement sites**

One of the main topics is the examination of LORAN-C signal reception. Numerous LORAN-C measurements with LOCUS SatMate 1000 E-field as well as with a state-of-the-art SatMate 1020 H-field receiver were carried out. Measurement sites for both, stationary and mobile tests have been conducted from well covered areas near Frankfurt/M. (Darmstadt), near Cologne (Halver) and on the isle of Heligoland to the outside region of the LORAN-C coverage area in Dresden, Neustrelitz[1] and Rostock. (Figure 1)

[1] maintained by the German Aerospace Centre (DLR)

## 2 Stationary Tests

Figure 2 shows the variation of static Time of Arrival (TOA) measurements (transmitter Sylt, chain 7499) on Heligoland, in Neustrelitz and at three sites on the roof of buildings of the TUD. Two receivers (DD-BEY and NST) behave deviant from the usual variation: Some kind of interference is detected – a condition which lasts for days or weeks and may vanish from one moment to another. No relation of those unsystematic behaviour to external noise sources were observed. This effect is under evaluation at the moment in co-operation with the receiver manufacturer.



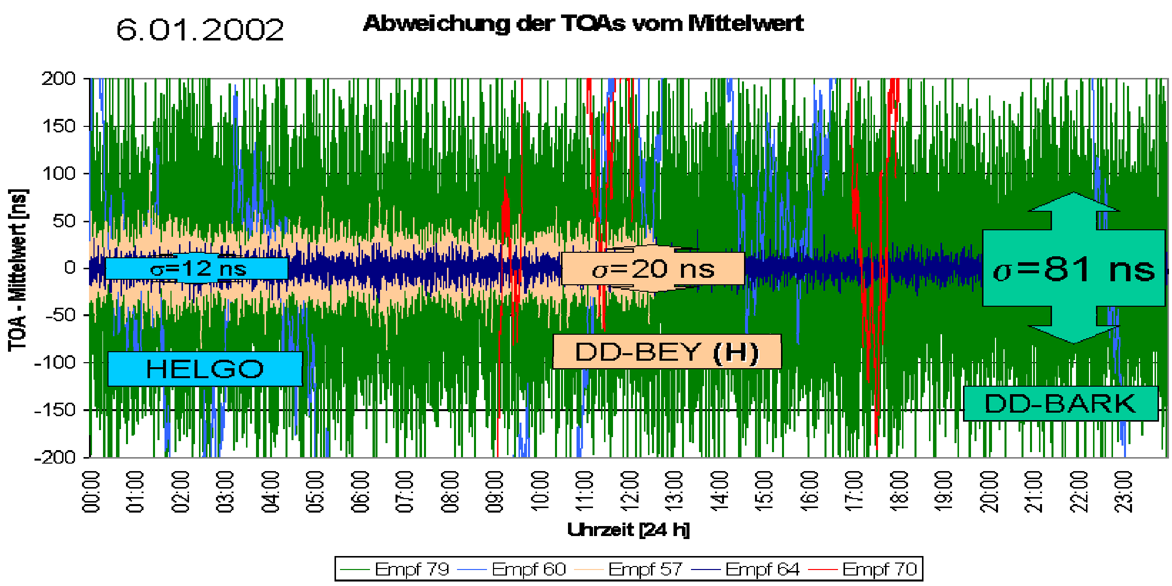




**Figure 2: Averaged TOA measurements at different sites for Transmitter Sylt, 24 hours, 5-sec-intervals (upper graphics); Zoom into a larger scale, with (1σ) standard deviations[2] (bottom graphics)**

The standard deviations (1σ) of the other receiver's measurements give an impression of the improvement gained by the H-field antenna. For the test in Dresden σ of the H-field measurements became smaller by factor 4 compared to the E-field

[2] 10 ns time error means 3 m range error

values. It is still two times the σ (E-field) calculated from data collected on Heligoland. These are about 12 ns and demonstrate the potential of present LORAN-C receivers in a well covered area[3] (Figure 2, above).

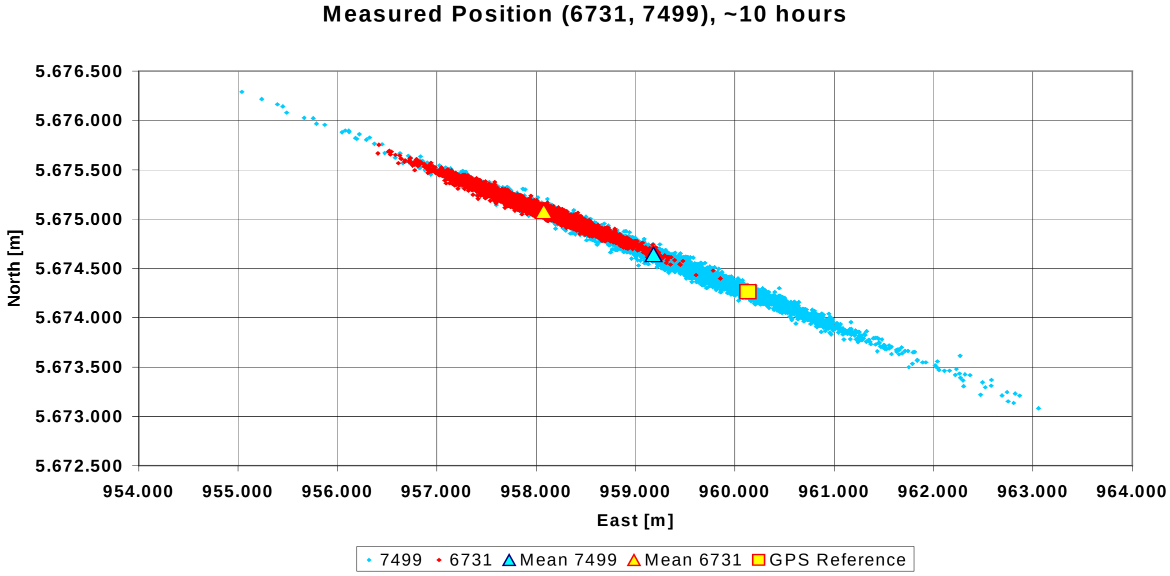



**Figure 3: Scatter-plot of positions calculated by SatMate 1020 in Dresden, 10 hours, 5-sec-intervals**

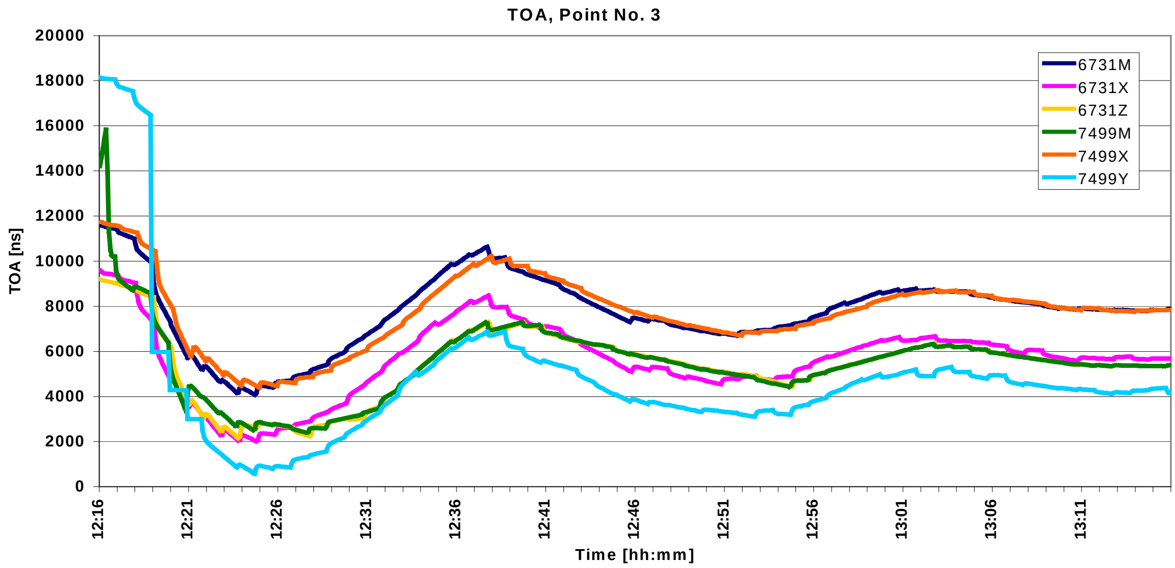



**Figure 4: Start-up effects of SatMate 1020 at a static test (Reduced TOAs of 6 observed stations)**

Regarding the positions computed by the receivers the typical cigar-like shape of the scatter-plot is manifested which is a clear indication of unfavourable geometry for LORAN-C at the location Dresden. Figure 3 shows positions calculated by the H-field receiver from Sylt chain (7499) and Lessay chain (6731). Values vary some kilometers along the Northwest – Southeast axis (extremely bad geometry at coverage limit). The variance in the Southwest – Northeast axis is in the range of 100 meters (reasonable geometry at coverage limit). The latter comes closer to the

[3] Heligoland is less than 100 km afar from Sylt

expected performance (10m to 30m) of an optimised LORAN-C stations network (2 to 3 more stations in Central Europe).

Compared with nearby E-field measurements a reasonable improvement of the H-field antenna could be observed.

Figure 4 demonstrates that an initialisation phase of approximately 45 minutes is necessary to get stable measurements. This duration is distinctly longer than expected and can be seen as another indication that currently available LORAN-C receivers are designed for stationary applications and are not optimised for dynamic positioning purposes.

Meanwhile various companies started such design / development activities and first prototypes are expected to be available for further testing in the near future.

## 3 Mobile Tests

Test campaigns with different measurement equipment and altered installations / configurations were carried out in several environments.

First intense kinematic trials were carried out in the port area of Rostock. The equipment used for the test only differed slightly from that used in another campaign a couple of months before. Nevertheless deeper investigations were necessary to recognize and minimize disturbing influences of the recording devices, power supply and the car itself. As a result the uninterruptible power supply (UPS) was identified as a source of interference to the H-field measurement.

Another measurement campaign was carried out in co-operation with the ZIV[4] in rural environment (with some power lines crossing and villages along the way) near Frankfurt.

Following aspects come out of Figure 5: As expected the longer TD averaging interval causes a smoother shape of the route plot. Details of the track (corners etc.) get lost. Contrary to GPS the LORAN-C signal was available for the entire way. The characteristic offset between the LORAN-C and GPS trajectory is caused by not applying ASF corrections. Again, H-field measurements obviously provide a performance improvement compared to E-field (not shown).

The antennas were mounted on the roof of a car with only little possible interference sources. Comparable results were obtained on a professionally equipped bus.

Further tests were performed using a train of the private railroad company Schleifkottenbahn in Halver (Figure 7). Its track routes through a couple of narrow valleys, tunnels and timbered canyons – impenetrable to GPS and quite a challenge for LORAN-C.

While the H-field test under reservations approximates the true track there is no similarity visible for the E-field antenna.

[4] Zentrum für integrierte Verkehrssysteme Darmstadt; Dr. Jörg Pfister

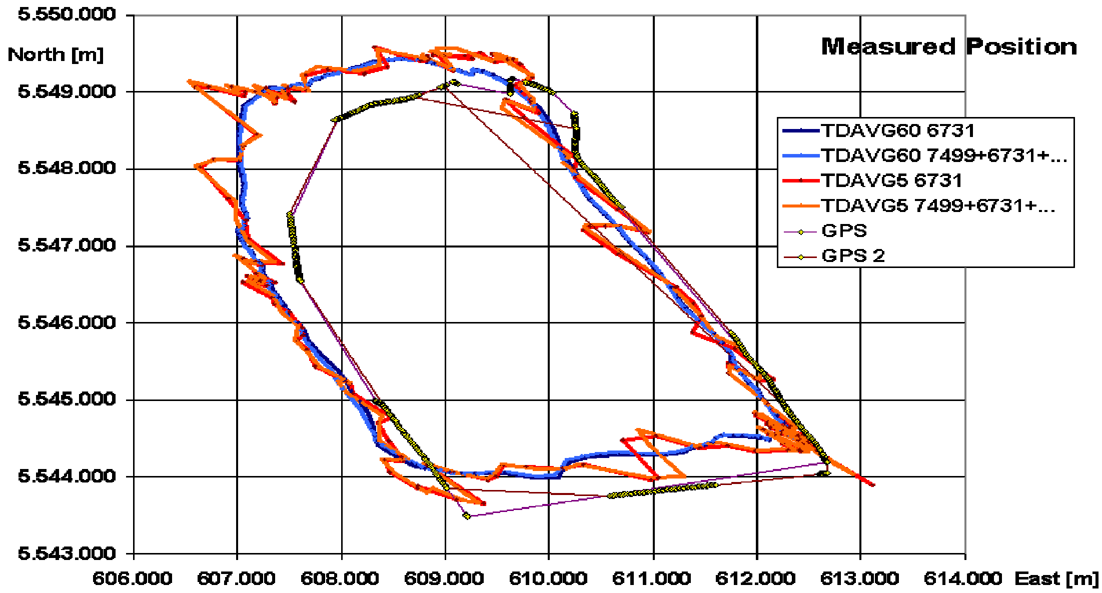



**Figure 5: H-field measurements, TD averaging 5 sec vs. 60 sec**

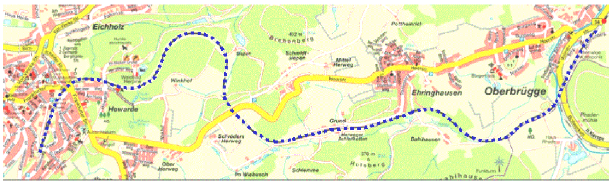



**Figure 6: Route of the Schleifkottenbahn**

**Figure 7: Train of the Schleifkottenbahn, H-field- and E-field antenna mounted on the waggon, GPS mounted on the driving cab**

## 4 Conclusions

Receivers which will be optimised for dynamic positioning and navigation services are under development at the moment. The current commercially available LORAN-C receivers are primarily designed for static time synchronisation applications.

Using these receivers for the trials and testing performed by TUD the following issues could be identified:

- **Effects of external devices.** The use of an UPS unit was identified as a source of interference. Mobile phones were switched off during the tests as their disturbing power right aside the H-field antenna was recognized. Other influences did not come out that clear. The diesel engine of the train or the car ignition may cause disturbances. For these reasons receiver manufacturers are asked to clearly state in their manuals how and where antennas have to be mounted and which precautions against possible interference have to be taken.
- **Receiver Output.** Clear specifications of receiver output data are necessary. Receiver internal determination of co-ordinates with respect to different chain

configurations needs to be known. The relation between a particular TOA output and its corresponding point of time of arrival has to be specified. Applied filtering and averaging algorithms need to be specified and explained in their function.

- **Additional Secondary Factors.** In the figures shown in this paper no ASF corrections have been applied. As these effects represent a considerable source of deviation they have to be considered in operational applications.

**The manufacturers are asked to** find solutions for these aspects. For mass market applications the receivers do not only have to become smaller, but also easier to use. Shielding against external electromagnetic fields or the compensation for those influences has to be improved.

**From Geodetic point of view** a raw data output is needed and the way of the signal within the receiver should be explained comprehensively. For an integration of LORAN-C with GPS on the level of raw data a solution has to be provided to determine pseudoranges from LORAN-C measurements.

Problems demonstrated do not condemn the LORAN-C system principle.

The work showed difficulties of the current commercially available receiver technology which is developed for static time synchronisation use and is adapted to electro-magnetic conditions in Northern America.

In Europe there are a lot of additional interference sources while the strength of the signals is much weaker due to the fragmentary coverage.

Two or three additional transmitter stations in Europe would result in an important improvement of the LORAN-C coverage and hence it’s signal and performance quality.

Efforts will be undertaken to decrease the susceptibility to failure and to determine the extension of those perturbations which are difficult to quantify or which can not be modelled.

There are good reasons to look forward to new developments on the receiver market. Smaller, cheaper and mainly less error-sensitive devices can revitalise the LORAN-C community and initiate new technological and political impulses.