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EGNOS Terrestrial Regional Augmentation Networks Based on AIS for River Information Services

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BIOGRAPHY

Marko Jandrisits received his Diploma degree in Interdisciplinary Management from the University of Applied Sciences in Wiener Neustadt in 2001. Since 2000 he is with via donau, the Austrian waterway management agency, where he has been working on positioning and navigation applications in the inland waterway environment. He is member of the board of the Austrian Institute of Navigation and delegate of Inland Navigation Europe (INE) to the European Maritime Radionavigation Forum.
J.C. De Mateo is a Microelectronics Engineer supporting the Galileo Project at ESA in the technical development of test user receivers and ground reference receivers. He was previously involved in the development of simulations tools and signal analyses for Galileo and EGNOS projects.
Günther Abwerzger received his Diploma degree in 2001 and his Doctoral degree in 2004 from Graz University of Technology. Since 2001 he has been employed at TeleConsult Austria GmbH, where he is mainly involved in algorithm and software development for sensor fusion in the context of positioning and navigation applications.

ABSTRACT

Within the ESA Advanced Research Telecommunications program ARTES-5, the project GALEWAT (Galileo and EGNOS for Waterway Transport) aims at introducing EGNOS into River Information Services (RIS) through the Automatic Identification System (AIS), a link that is mandatory for seagoing vessels above 300 GT.

The GALEWAT project comprises several phases: During the initial definition phase, the system architecture and user equipment have been defined in line with standards and international recommendations. This phase was followed by the implementation phase, aiming at developing and setting up the equipment. Finally, the project will be completed by an extensive demonstration phase, which is currently under execution. Up to now, public GALEWAT demonstrations in Vienna (Austria), and Lisbon (Portugal) have been successfully executed. The last demonstration in Constanta (Romania) will take place in fall 2005. These demonstration sites have been chosen to test and demonstrate the GALEWAT system in different environments: river navigation, harbour approach, and open sea operations.

The paper gives a short idea of River Information Services and an overview of the GALEWAT project. The main part concentrates on the presentation of field measurement results, which were collected in Lisbon, to show the performance of the GALEWAT concept. Finally, the paper presents an overview of user feedback resulting from the first two public demonstrations.

INTRODUCTION

Raising the attractiveness of inland waterways as a transport path is a main objective of the European transport policy. However, to achieve this, adequate service quality must be provided to become more competitive against road and rail transport. Hence, a key requirement for the integration of rivers as transport corridor into inter-modal transport chains is the safe, predictable and efficient execution of transport processes.

The key to improve service quality on waterway transports is twofold: On the one hand, there is a strong need for the provision of RIS to support and coordinate traffic and transport management. RIS enable the tracking and optimisation of the logistic transport chain from entering until leaving the waterway transport route. Furthermore, RIS enable vessels to display their own position, as well as the positions of nearby vessels including additional information on an Electronic Chart Display (ECDIS). On the other hand, reliable and accurate navigation information is required for extending the function of RIS from sole Information Systems to trusted navigation aids, increasing the security for man and machine on waterways.

It is well known that GPS as sole-means navigation system cannot meet the safety requirements for many navigation applications, among them also navigation applications on waterways during critical situations (e.g. dense fog). Hence, there is a strong need for additional navigation systems, like the future European GALILEO, to increase the number of available navigation sources for supporting receiver-internal integrity monitoring methods. However, integrity information on existing satellite navigation systems can also be provided by Satellite-Based Augmentation Systems (SBAS), like the European Geostationary Navigation Overlay Service (EGNOS). Nowadays, the incorporation of EGNOS into existing and newly developed RIS is expected to provide sufficient integrity information on the navigation solution, which will subsequently be explained in more detail.

RIS AND AIS

RIS, per definition, base on a concept for harmonized information services to support traffic- and transport management on inland waterways, including the necessary interfaces to other transport modes. This model has been developed within several European research projects in the 3rd and 4th Framework programme for research and development of the European Union [1].

The technical basis for RIS, e.g. in Austria, is provided by a fast short-distance radio data communication between ships, as well as between ships and shore, for the autonomous exchange of ship-related information like name, position, dimension, and other transport-related data. Based on this data exchange, the visualisation of traffic information on an electronic nautical chart, the so-called Tactical Traffic Image (TTI), is enabled. The TTI supports the skipper in his nautical manoeuvres, as well as the authorities, which are responsible for supervising the traffic. Figure 1 illustrates the system concept of a RIS, showing the main communication interfaces. As the figure displays the Austrian realization of a RIS, the abbreviations indicating authorities also refer to Austrian governmental bodies.

The communication layer for RIS in Danube countries is based on an Automatic Identification System (AIS) infrastructure, a standard, which was developed by the International Telecommunication Union (ITU). It is recommended and supported by the International Association of Lighthouse Authorities (IALA), and became mandatory until 2004 for all high sea vessels over 300 GT within the SOLAS-Convention (Safety Of Life At Sea) of the International Maritime Organization (IMO). It is a ship-borne radio data system exchanging static and dynamic ship data between ships and between ship and shore stations. [2]

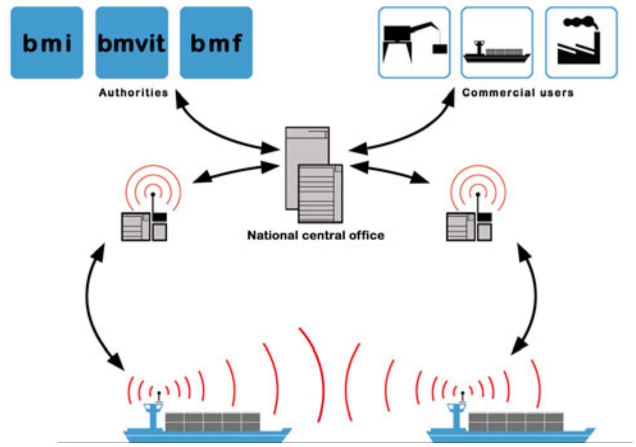

Figure 1: System concept of RIS

AIMS OF GALEWAT

The GALEWAT project, funded by the European Space Agency (ESA), is conducted by a consortium of partners operating in the fields of waterway operation and management, navigation, maritime electronics, telecommunication, and IT industries. The project aims at the realization of a first step towards the introduction of EGNOS and finally GALILEO into the upcoming RIS all across Europe.

Among others, the following topics are subject to the GALEWAT project:

- Identification of user requirements related to AIS and EGNOS service parameters for transport efficiency as well as safety related value added services within RIS. Investigation of the user acceptance according to value added services in the inland waterway, coastal shipping, and harbour navigation domain.
- Replacement of conventional RIS local differential GPS (DGPS) stations by direct reception of the EGNOS signal in shipboard transponders, making the country-wide or trans-European implementation of RIS much simpler and less costly.
- Bridging outages of the EGNOS signal in space (SIS) by retransmitting the EGNOS differential corrections and integrity data via AIS base stations in areas without direct EGNOS reception (mountainous terrain, under bridges etc.).
- Analysis and validation of EGNOS, integrated into the AIS transponder concept, being capable to meet the user and service requirements. This task is performed by theoretical work as well as through demonstration projects across Europe.

GALEWAT CONSORTIUM

The GALEWAT project is carried out by a consortium composed of via Donau (Austria), responsible for the overall project coordination and execution of the public GALEWAT demonstration in Vienna (Austria). In the project, via donau represents the authority, and a service provider for RIS; Kongsberg Seatex AS (Norway), mainly responsible for the ship and shore equipment provision and installation; TeleConsult Austria (Austria), responsible for assessing the safety of the GALEWAT system, providing a geodetic reference system, supporting the field measurements evaluation, and demonstration execution in Constanta (Romania); and INOV (Portugal), responsible for software development, i.e., performance monitor software and web interface for the external segment, field measurements evaluation, and demonstration execution in Lisbon. The GALEWAT project is supported by the European Space Agency (ESA), and is executed within their Advanced Research Telecommunications program ARTES-5.

GALEWAT SYSTEM CONCEPT

As shown in Figure 2, the GALEWAT system is composed of several segments:

- Ship segment: The ship segment consists of 5 ships that are equipped with AIS transponders; one of the ships is equipped with the so-called “extended ship equipment”. The extended ship equipment is able to output position fixes in various modes of operation (i.e. GPS stand alone, GPS augmented by EGNOS from direct Signal-in-Space (SIS), GPS augmented by EGNOS from re-transmission over AIS, and GPS augmented by IALA DGPS). During a data analysis, the outputs from the extended ship equipment allow to compare and evaluate the performances of the various positioning modes. All other ships are equipped with “standard ship equipment”, i.e., AIS transponders including GPS receivers with DGPS option. The task of these ships is mainly to provide additional targets for the TTI to show the benefits of RIS.
- Shore segment: The shore segment mainly comprises 2 AIS base stations that are also able to receive the EGNOS SIS and to broadcast re-formatted EGNOS information through the AIS data link.
- Regional segment: The regional segment consists of terminals, located e.g. nearby the locks. The terminals are connected to several shore elements to gather tactical traffic information of the area (e.g. for local traffic management).
- Operator segment: The operator segment can be represented by a national control center (e.g. used by the Supreme Shipping Authority) storing all traffic information provided by the RIS in a large database.
- External segment: The external segment consists basically of a web interface where external users (e.g. logistics service providers) can retrieve relevant traffic information of the area.

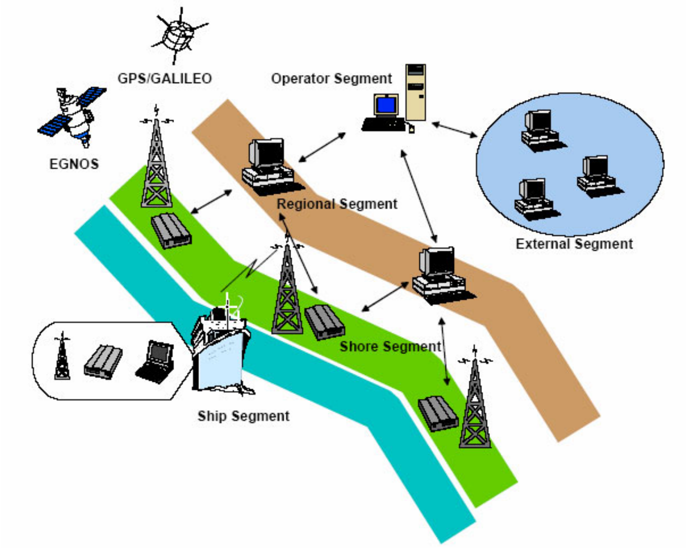

Figure 2: GALEWAT system concept

EGNOS OVER AIS

As already mentioned, one special feature of the GALEWAT system concept is the EGNOS over AIS principle. This is, EGNOS information is received at shore stations, re-formatted, and again broadcast over the AIS communication link.

When analyzing the potential use of EGNOS for inland waterways, the question of signal availability is a critical issue. Due to the environment along the shoreline of the rivers/canals, the danger of losing line-of-sight to the EGNOS satellites is quite high. Obstacles could be terrain, buildings, bridges, or other technical structures (e.g. in harbor areas, locks, etc.).

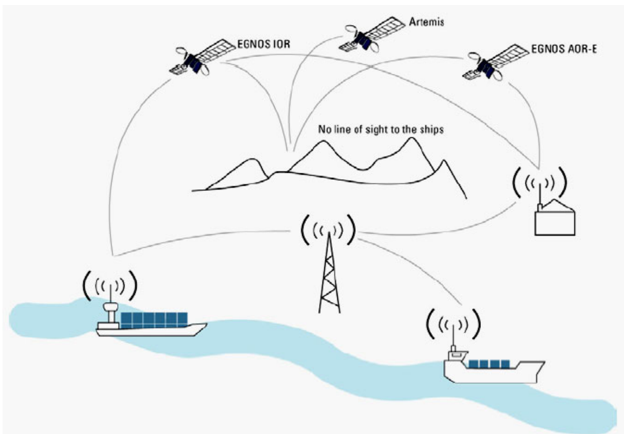

Figure 3: EGNOS over AIS principle

In order to complement the direct line-of-sight reception and considering the capacity of AIS [3,4], the GALEWAT project uses transponders that can also receive the EGNOS message from an AIS base station, which tracks the EGNOS geostationary satellites on shore. Parts of the EGNOS message received on shore are then converted into AIS message type #17, which is defined by the AIS standard. This message is retransmitted from the AIS base station to all AIS mobile units (transponders) within the coverage area in order to increase the availability of EGNOS information (Figure 3). Hence, navigation accuracy and integrity calculated by the AIS mobile units can considerably be improved.

LISBON MEASUREMENTS AND PUBLIC DEMONSTRATION

The second GALEWAT measurement campaign and public demonstration was carried out between March and June 2005 in Lisbon (Portugal). The ferry "Campolide", owned by the Transtejo Company (Figure 4), was provided for carrying the extended GALEWAT ship equipment. During normal ferry operations, the GALEWAT team was able to carry out measurements. These measurements mainly aimed at evaluating the GALEWAT system performance for inland waterway applications.

Figure 4: Ferry boat used for the measurements in Lisbon

Different pieces of data were recorded on shore and onboard. Furthermore, using a pair of geodetic GPS receivers, a reference solution was computed in kinematic mode with a horizontal position accuracy better than 20 cm CEP (Circular Error Probable). Onboard, the Ship Performance Monitor (SPM) recorded data provided by the extended ship equipment including, among others, time stamp, position latitude, and position longitude for each available positioning mode (GPS stand alone, GPS augmented by EGNOS from SIS, GPS augmented by EGNOS over AIS, and GPS augmented by IALA differential corrections. Even a weighted solution (WDGPS), i.e., a weighted mean computed over all modes of positioning was output by the extended ship equipment and recorded). In addition, heading data provided by the heading sensor was also recorded onboard.

The analysis of performance during the test campaign was focused on:

- The visualization of the vessel movement (trajectory, heading, course, speed, and height graphs).
- The analysis of horizontal accuracy by means of the computation of northing and easting errors for the different positioning systems. Furthermore, HDOP and number of satellites used for navigation were considered for the evaluations.
- The analysis of integrity by means of the computation of the, Horizontal Protection Level (HPL) from the North/East variances and covariance. The integrity risk allocated to this application was according to [5], 10^{-5} per 3 hour resulting in a Kh value (HPL=Kh* σ) of 5.6 [6].

MEASUREMENT RESULTS

This section presents a subset of the measurement results, obtained for kinematic vessel operations. The measurement data was collected during normal operation of the Transtejo ferry "Campolide". The measurements were carried out on 6 May 2005. EGNOS information was continuously received from AOR-E (PRN 120).

Figure 5 shows scatter plots showing the position differences from the reference trajectory (i.e., the position error), and Figure 6 shows the position error plotted over time.

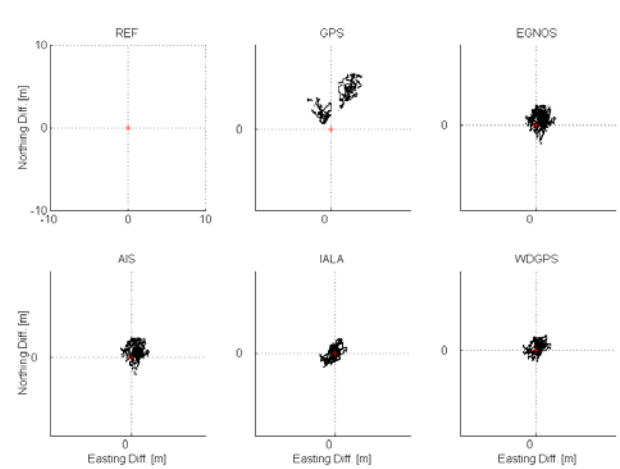

Figure 5: Scatter plots, position error

As expected, GPS in stand-alone mode shows poor performance and also some outliers, which can be seen in both figures. GPS/EGNOS from SIS compared to GPS/EGNOS from AIS shows nearly identical behavior, which also could be expected as they both use the same source of differential pseudo range corrections for position computation. However, there is a slight difference: In GPS/EGNOS from SIS positioning mode, the pseudo range corrections are being computed directly within the extended ship equipment using the complete EGNOS information. In GPS/EGNOS from AIS mode, the pseudo range corrections are being computed on shore, re-formatted into a certain AIS message, and submitted to the vessel.

Table 1 shows some numbers representing statistical accuracy and availability results. The availability of each system was 100% for these trials, i.e., each system has provided a position solution every second throughout the measurement period. Compared to the previous demonstrator in Vienna [7], IALA signals were available, and the obtained GPS/IALA position solution could be compared with the EGNOS operational system. In general, the differential accuracies of EGNOS and IALA were proved to be comparable (1.6 vs. 1.2 m position error at 95% confidence level) and were significantly improving GPS performance (accuracy improvement factor of 3.2 vs. 4.2). The main differences observed between the test environments of Vienna and Lisbon is, that no blockage of the EGNOS SIS was observed in Lisbon justifying less the need to complement EGNOS with AIS. This observation requires to be confirmed in the river to open sea environment in the course of the GALEWAT demonstration in Constanta (Romania)

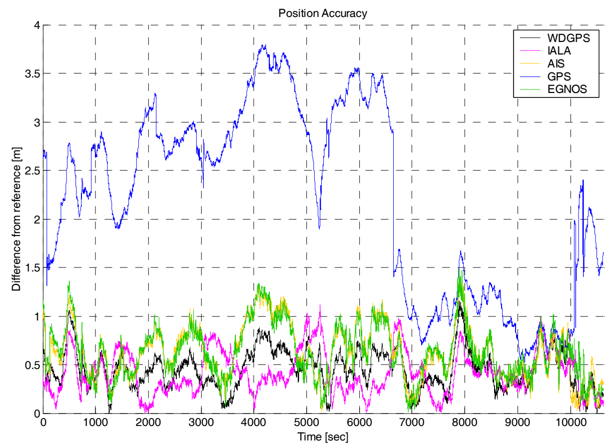

Figure 6: Time series, position error

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Position Accuracy	GPS	GPS/EGNOS from SIS	GPS/EGNOS over AIS	GPS/IALA
Position Mean (m)	2.05	0.47	0.47	0.11
Position std. dev. (m)	1.27	0.51	0.50	0.46
Pos. mean + 1.731 * RMS (95.00%) (m)	5.12	1.64	1.62	1.15
Epochs considered	10629	10629	10629	10629
Availability of position fix (%)	100	100	100	100

Table 1: Numerical results, position accuracy and availability

Figure 7 shows time series of the HPL, as obtained from accuracy information provided by the extended ship equipment. Note that only in case of GPS/EGNOS from SIS and GPS/EGNOS over AIS, the time series represent the HPL in its original sense. In case of GPS stand-alone or IALA DGPS corrections, the graph can only represent a kind of horizontal position error with high confidence, but not integrity, as the underlying performance is missing. A numeric data evaluation proved that there was no integrity violation (i.e., position error derived from reference trajectory >= HPL) from any system during the measurement period of some 10600 seconds.

Table 2 shows the performance availability as derived from application-specific Horizontal Alert Limits (HAL). If the HPL is below the HAL, the system performance for the specific application can be met. When the HPL exceeds the HAL, the required performance for the application cannot be met.

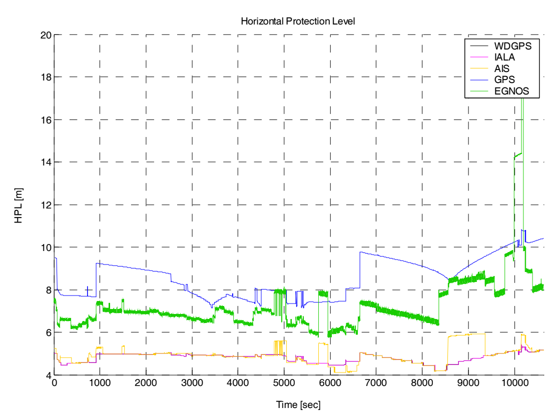

Figure 7: Time series, Horizontal Protection Level (HPL)

It can be seen in the table that none of the positioning modes could be used for applications requiring a HAL of 2.5 m during these trials. Applications requiring a HAL of 10.0 m could partially be served by the positioning modes under investigation, and finally, every mode of positioning was able to fulfill the performance requirements for applications requiring a HAL of 25.0 m. The measurement trials therefore provided a first proof that the system is suitable for maritime operations with 25.0 m of integrity alarm limit, i.e. ocean and coastal navigation, as well as approach to harbor.

Performance availability (HPL<HAL)	GPS	GPS/EGNOS from SIS	GPS/EGNOS over AIS	GPS/IALA
HAL (m)	2.50			
Success (%)	0.00	0.00	0.00	0.00
HAL (m)	10.00			
Success (%)	91.94	98.03	100.00	100.00
HAL (m)	25.00			
Success (%)	100.00	100.00	100.00	100.00

Table 2: Performance availability

USER FEEDBACK

During the public demonstration in Lisbon, the participants were asked to fill in a questionnaire. The results from that opinion poll were intended to give a feedback about user needs to the GALEWAT project team. In total, 26 filled in questionnaires were returned from the audience. As a summary of the results, the majority of potential users (i.e., 65%) is aware that GPS as sole means navigation system is not sufficient for safety-critical vessel operations. Additionally, they agree that a GALEWAT-like system (i.e., GPS augmented by EGNOS) enhances the service performance of safety-related operations compared to the current situation (65%). However, not all potential users could imagine to actually using a GALEWAT-like system, as they are not entirely convinced of the benefits, or as they prefer to rely on IALA DGPS. Furthermore, the majority of users would neither accept higher purchase costs of a GALEWAT-like system compared to traditional equipment, nor any service fees, even when considering potential benefits of such a system.

CONCLUSIONS

This paper provides field measurement results obtained from measurements in Lisbon (Portugal) carried out in spring 2005 using EGNOS signals. GPS augmented by EGNOS from SIS has proven to be a good candidate for maritime and inland waterway safety-critical applications with required accuracy below 10 m, high system availability, and protection level below 25 m. Further, it has been confirmed that the use of AIS to broadcast EGNOS data is not introducing any significant degradation of performance compared to the EGNOS performance directly obtained with the SIS. Differential accuracies achieved with local area dGPS (IALA) and EGNOS are comparable, which opens the door to the introduction of EGNOS into the maritime community, either as a complementary system when IALA is not available (e.g. Vienna) or as system that can easily be integrated within the AIS/IALA infrastructure (EGNOS over AIS with RTCA to RTCM data conversion). EGNOS coverage over Lisbon harbor resulted to be very good. Indeed, compared to the Danube environment of Vienna, no loss of the signal in space was observed during the test campaign, avoiding the need to complement EGNOS with AIS.

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