

GATE: A boon for Galileo

It will allow receiver, application and service developers to perform realistic field tests



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GATE is a ground-based realistic test environment for developers of receivers, applications and services for the future satellite navigation system Galileo. GATE is currently being built-up and as from beginning of 2008 - several years before Galileo becomes fully operational - Galileo signals will be emitted by 6 earth-fixed transmitters in the area of Berchtesgaden, located in the southeast of Germany in the German Alps. This will provide the opportunity for receiver, application and service developers to perform realistic field-tests of hardware and software for Galileo at an early stage. In this way GATE will also support German and European products for Galileo entering the market.

While the motivation of the US ground-based ranging test bed Yuma in the 70's was to prove the concept of satellite navigation, no one doubts that Galileo will work from a conceptual point of view. However, it is still an ambitious

differentiation of the GATE system into the typical sectors Space Segment, Ground Segment and User Segment is not adequate. A division of the GATE system into the four segments - Transmit Segment (GATS), Mission Segment (GAMS), Control Segment (GCS), and the Support Segment - was considered as more adequate. Figure 1 gives an general overview of the system architecture of the GATE infrastructure.

The ground-based transmitters, which are part of the GATE Transmit Segment (GATS), will emit all frequencies foreseen for Galileo. Therefore they have to be flexible in signal generation and adaptive to changes in signal structure. As GATE is a real-time system it is necessary to feed the navigation message in real-time to the transmitters. They are also equipped with stable atomic clocks. The following Figure 2 shows the six envisaged transmitter locations, as well as the transmitter rack and the corresponding transmit antenna.

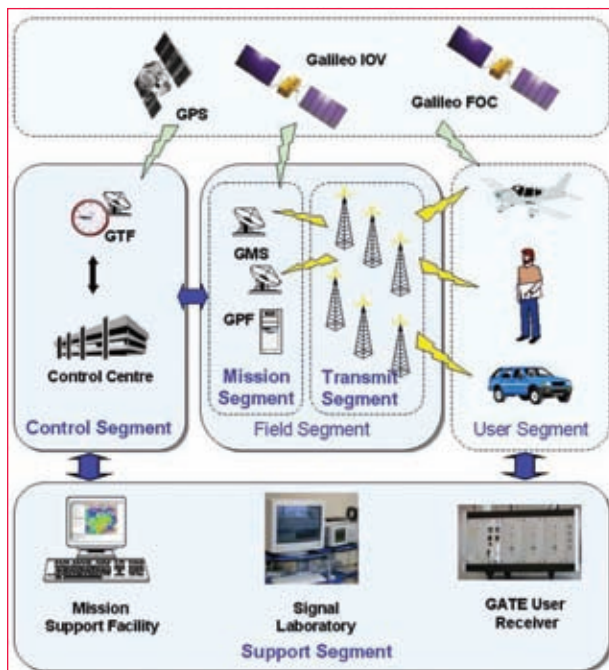


Figure 1: GATE Infrastructure Overview

technological project, introducing a signal structure far more sophisticated than the GPS C/A Code. In fact there are three major mission objectives to be covered by GATE - Signal Experiments, Receiver Testing and User applications.

GATE Infrastructure & Test Area

GATE System Architecture

Differing from real (navigation) satellite missions

The GATE Mission Segment (GAMS) monitors the navigation signals by using two GATE Monitoring Stations (GMS), performs the time synchronisation of all system clocks and generates navigation messages and steering commands to be sent to the six transmitters. The tasks denoted above are mainly performed by the two GAMS core elements, the GATE Processing Facility (GPF) and the GATE Monitor Receiver (GMRx), both developed by IFEN GmbH.

The GATE Control Segment (GCS) includes all the functionality and facilities that are required for the mission control and operation. The main tasks it has to perform are to monitor and control the entire GATE system, to host and operate the control centre, which serves as operational node of GATE including e.g. the mission planning, to host and



Figure 2: GATE Transmitter Locations and Transmitter Rack GATE Infrastructure Overview

provide the GATE system time, and to archive the GATE mission data.

The main tasks of the GATE Support Segment (GSS) finally comprise the appropriate preparation, i.e. simulation and planning, of the GATE experiments with dedicated software tools, as well as the provision of the GATE User Terminals equipped with a combined Galileo/GPS receiver.

GATE Test Area Berchtesgaden / Germany

The GATE test area is located in the region of Berchtesgaden in the very south-eastern part of Germany / Bavaria. The service area is depicted in the maps shown in FIG. 8 below. The GATE test area, which is roughly limited by the imaginary connection lines between the signal transmitters, has a size of about 65 km², while the GATE core test area, as marked in Figure 3 below on the right hand side, is about 25 km². The two monitoring stations are located at an exposed position quite centric within the GATE test area. As it can be seen from fig. 3 below, Berchtesgaden is surrounded by high mountains rising up to over 2000 m. The

establishment of the GATE transmitters on well exposed positions allows for the emission of the GATE signals with average elevation angles between 10 to 15 degrees from a user's point of view located within the GATE test area.

Positioning performance in the GATE test area

Static field tests

At the "GATE central point", which is located quite in the centre of the core test area, all transmit stations (GTS) are visible and HDOP and VDOP values are very good for the GATE service area. Therefore the positioning accuracy obtained is very favourable in the vicinity around this point. The Figure below shows the positioning performance at the GATE central point for a static receiver in the three different GATE modes.

The receiver was installed in a van with the GATE user antenna on the top of the van. The van was parked beside the road at a reference mark, which had been surveyed with a precision of 10 cm.

The experiment was performed in the GATE Base Mode and Extended Base Mode as well as in Virtual Satellite Mode, where the GATE/Galileo signals are simulated as they were transmitted from orbiting satellites. In fact of course the signals are transmitted by the earth fixed transmitters, so that signal fading and multipath effects, due to building and the landscape, are still present. The viewgraphs in Figures 4 show the position solutions on L1 frequency. The observation time for the static measurements was about 5 to 10 minutes for each GATE mode. The GATE position accuracies ($\sqrt{2} \sigma$) for these measurements are below 10 m for all three modes.

Dynamic field tests

Several tracking / positioning tests with the GATE system under dynamic conditions with a speed of up to 100 km/h were performed. The standard dynamic tests cover low dynamic conditions with an averaged speed of about 30 to 50 kilometers per hour. A sample track of a test drive in the EBM mode is presented below in the left-hand figure. High dynamic tests can only be performed at a section of the road B20, which passes the eastern part of the GATE area in north/south direction, where a good visibility of the GATE transmitters is available. The road B20 is the only one in the GATE area where it is allowed to drive at 100 km/h. As starting point a dedicated position at the roadside was selected where all 6 GATE transmitters could be tracked well. After a short time of static positioning with all 6 signal sources – to make sure that the GATE receiver is in a well-defined starting position with stable tracking – the test car was accelerated rapidly up to a velocity of more than 90 km/h.

The sample results of a test drive in the GATE mode VSM are presented in fig. 5.

The dynamic positioning tests of the GATE receiver with Galileo signals in the GATE test area gave proof of the operational capability as well as the performance of the receiver and the whole system also under dynamic conditions in all three GATE modes. This was evaluated not only for the receiver in uniform motion but also particularly with regard



Figure 3: GATE Service Area Berchtesgaden / Germany (core test area marked in red, transmitters marked as red dots) and view into the GATE test area

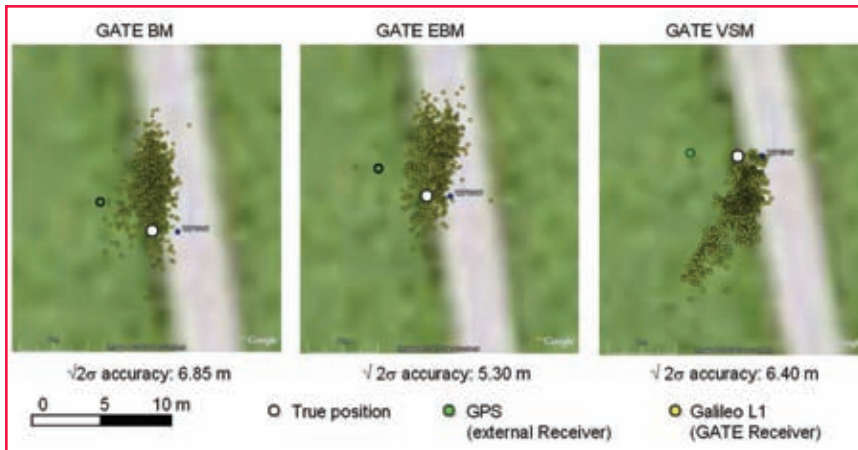


Figure 4: Galileo position estimates in BM, EBM and VSM at the GATE central point, Map© Google

to significant accelerations of the receiver. The acceleration values during the relevant parts of the test runs were in the range from about 15 to 20 seconds for speeding up from 0 to about 100 km/h. Also under these conditions regular Galileo position updates were obtained. Slight outages in the position solution, as seen in Figures 6 are the result of a conventional epoch by epoch data processing of the GATE User Terminal Software. For estimation of the position solution a standard least-squares approach is used to get unfiltered solutions for each single epoch. A Kalman-Filter or dead-reckoning algorithm as it is implemented in common low cost GPS receivers would smooth such outliers in the position solution. For the position estimates illustrated in this paper even no carrier smoothing was applied to smooth the pseudo-ranges obtained from the code measurements from only data channels. Hence, any degradation of the measurements' quality due to e.g. signal

shading, as it is the case in the wooded part of the road in the fig. 5, strongly effects the quality of the position solution.

Regarding the illustrated tests in this paper it should be pointed out, that in all operational modes of the GATE system the receiver has at maximum six GATE transmit stations in view. Due to the vegetation and housing in the GATE test area and the low elevation angles of the transmitters in view at the user receiver position, shading of lines of sight to the transmitters occurs very often, while moving through the test area. Position outliers are often caused due to heavily degraded HDOP values, especially in VSM mode, when the remaining (not shaded) lines of sight represent a satellite constellation where the satellites and the user form a polyhedron with a very small volume (e.g. the satellites are situated nearly in one line from the users point of view). To a certain extent such scenarios can be evaded by an elaborate configuration of the



Figure 5: Sample track of dynamic GATE positioning in EBM (left) and VSM (right), Map© Google

virtual satellite constellation to be applied. However, it is not possible to completely avoid such cases, because this would result in too frequent PRN switches of the transmitters. A PRN switch will decrease the number of potential available measurements at least for the time that is needed to receive the whole navigation message of the "new" satellite (at least 50 seconds for F/Nav and 15 seconds for I/Nav messages).

Conclusions

GATE is a terrestrial test environment for developers of Galileo (Galileo/GPS) receivers, applications and services. The test range is situated in the region of Berchtesgaden/Germany. GATE is currently running in trial operation and will be fully operational soon. The terrestrial test bed is considered to be a necessary intermediate step for Galileo from laboratory into orbit in terms of realistic RF signal transmission. It will not only support signal validation by providing valuable data but also provide insight in building a ranging system, simply by building it. This contributes to mitigate risks in the development of Galileo. Currently further tests and optimisations with respect to environmental conditions are being performed.

GATE will provide the opportunity for receiver, application and service developers to perform realistic field-tests of hardware and software for Galileo at an early stage, i.e. several years before the full operability of Galileo. And last but not least, GATE will allow full end-to-end testing of unmodified / commercial Galileo receivers. For further information on GATE please refer to the official project homepage <http://www.gate-testbed.com>.

Acknowledgments

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