Interference Information System and Interference Local Protection

IIS-ILP

Project Abstract

(IISILP-IFEN-ABS)

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Prepared by:	IIS-ILP Team IFEN / FAFU	Date: 2010-03-26	*Signatures on original and final versions only*
Checked by:	B. Ott ISS-ILP Project Manager	Date: 2010-03-26	*Signatures on original and final versions only*
Authorized by:	B. Ott ISS-ILP Project Manager	Date: 2010-03-26	*Signatures on original and final versions only*
Approved by:	J. Samson IIS-ILP Technical Officer	Date:	*Signatures on original and final versions only*

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1. SCOPE OF THE IIS-ILP PROJECT

Interference is of major concern to Satellite Navigation in general and Galileo in particular. As the Navigation Signal is weak when received by a receiver on Earth (i.e. max. -152 dBW for Galileo E5 and E6), it can be interfered easily by signals of other sources. It can be observed that:

- GNSS L1 band at 1575.42 MHz is within the ITU band 1559-1610 MHz in which also aeronautical navigation services are operating
- GNSS E5 band at 1176.45 MHz [E5a] and at 1207.14 MHz [E5b] is within the ITU band 1164-1215 MHz in which also aeronautical navigation services are operating,
- GNSS E6 band at 1278.75 MHz is within the ITU band 1240-1300 MHz in which also Earth exploration satellite services, radiolocation services, radars, space research transmissions and radio-amateur communications are operating.

The maximum level of interference which can be expected in E5 or E6 can be significantly higher1 than the maximum level of interference in L1.

The objective of the IIS-ILP activity has been the study of interference mitigation techniques for satellite navigation. Within this activity, the feasibility of the two basically independent concepts has been assessed:

- The Interference Information System (IIS)
- The Interference Local Protection (ILP)

The IIS is a computer-based expert tool that uses stored information about potential interference sources and theoretical receiver algorithms to predict the effect of the interference sources on the performance of a generic GNSS receiver. The tool considers the geographic locations of interference transmitter and GNSS receiver and the terrestrial propagation characteristics.

Applying spatial variations to the tool, GNNS receiver impact of interference can be predicted over user-defined service volumes.

In a single-point query mode, the tool allows to provide real-time information on predicted levels of interference to a GNSS receiver at any location within the coverage volume and thus supports adaptive interference mitigation strategies implemented within that receiver.

In the frame of the IIS-ILP activity, the IIS interference prediction software and the adaptive GNSS receiver interference mitigation have been designed, implemented and validated, at different stages, in laboratory and real-world measurement setups.

The ILP is a mechanical structure integrated with a GNNS reference station antenna that alleviates the power of unwanted RF signals arriving at the antenna. The structure works similar to well-known choke-rings, but is optimized for interference coming in horizontally from transmitters located at - roughly - the same altitude as the reference station antenna.

In the frame of the IIS-ILP activity, a downscaled prototype ILP structure has been designed, built and validated by measurements in an anechoic chamber.

2. INTERFERENCE IMPACT ANALYSIS

The analysis of the effects of potential interference sources on the performance of typical GNSS receivers has been assessed in this activity by following in parallel a theoretical approach and an empirical approach.

While the theoretical approach has concentrated on studying the expected degradation of typical GNSS receivers according to existing theoretical models, the empirical approach has underlined all those aspects that are receiver specific. Then a comparison of the results delivered by both approaches has been carried out and conclusions have been drawn.

With the knowledge obtained in the theoretical and empirical analysis, software algorithms have been implemented to mitigate the effect of interference on the receiver.

The results that have been derived by theory have been be compared to real measurements based on the software receiver (Ipex SR) and GNSS signal generator.

3. INTERFERENCE INFORMATION SYSTEM - IIS

A database containing geo-referenced interference data has been designed, developed and implemented. Data covering the area of Southern Bavaria and neighboring territories from different sources have been fed into the database.

The SVS tool has been designed to investigate the impact caused by interference on receiver performance over geographical areas. The service volume simulation is implemented on the basis of IFEN's GSPF tool and library. Some new algorithmic models have been implemented to add the required functionality to the GSPF library.

The actual interference effect processing is performed by MATLAB functions that have been provided by FAFU-GN. The MATLAB functions are essentially the same that have been used for the analysis described above.

The SVS performs the assessment over a configured geographical area and grid. For every grid point, the interference environment will subsequently be received from the IIS database. The grid-based interference results are generated in a standard GIS format. Any GIS tool can be used to import these files and perform further evaluation, overlay with maps, and so forth.

For validation of the SVS and the GNSS receiver interference impact prediction, an extensive measurement campaign has been performed More than 40 separate data logging sessions have been recorded and evaluated, each between 15 minutes and several hours long. The raw data logged amount to approximately 800GB, mainly due to the size of the Software Receivers IF samples.

In summary it can be stated:

- The interference mitigation approaches "notch filtering" and "Wavelet based interference mitigation" have been implemented and successfully proven their performance in standalone operation mode in laboratory and real-world validation.
- The database supported mitigation approach has been implemented and shown to be of limited value in terms of performance and processing time.

- The implemented interference database has been shown to provide received interference power levels accurate to below 3 dB in good cases, but significantly inferior prediction performance in difficult cases.
- It has been shown that it will be of significant effort to fill an operational interference database with complete and accurate and up-to-date information on interference sources of interest.
- The algorithms applied to predict the effects of interference on receiver performance parameters, while being basically correct and valid; have been shown to be of limited accuracy for real-world receivers under certain severe conditions (i.e. ill described interference).

4. INTERFERENCE LOCAL PROTECTION - IMLP

After carrying out numerical analysis and simulations, it was decided to manufacture the IMLP as a scaled model with foam walls and commercially available pyramidal absorbers on top. The outer wall was intended to be covered with conducting material in order to block lateral interferers. The absorbers, type Hyfral APM, are removable and temporarily fixed using hook-and-loop tape. Inside the structure additional absorbers can be installed. The outer diameter of 57 cm for the model's outer wall (60 cm ground plane maximum) corresponds with roughly 4.6 m of the real Galileo IMLP.

The interference blocking performance has been determined with the help of gain measurements. It has been shown that the gain measurement is well (more than 20 dB) above the system's noise floor. The protection equipment leads to a lower ripple in the whole elevation range and between -60 degree and 60 degree elevation the gain changes only insignificantly. At 90 degree elevation angle (horizon) the signals are attenuated by 10 to 15 dB.

It was determined by the measurements that the structure will be effective not only against interference signals, but also against multipath signals from reflectors at or below antenna altitude. Therefore during the activity the ILP designation was extended to an Interference and Multipath Local Protection - IMLP.

In summary it can be stated:

- The IMLP construction offers superior protection compared to other investigated shields.
- The focus of further work should imply the reduction of the IMLP size.
- For fixed services the development of lossy material (concrete, e.g.) should be taken into account.
- A complete radome protection from weather should be strived for.
- The structure's shape might probably be optimized with the help of an extremely simplifying 2-D simulation, which would have to be developed during further work.