GIRASOLE Receiver Development for Safety of Life Applications

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Abstract. The GIRASOLE Safety of Life Receiver is developed in the frame of the Galileo Joint Undertaking (GJU) Research and Development activities, in the context of the European Commission 6th Framework Programme 2nd call by ALCATEL ALENIA SPACE Italia (AASI), manufacturer leader of advanced, high performance GPS/EGNOS/Galileo receivers for space and safety-critical applications.

Differently from GPS, which relies on an external signal (EGNOS), one of the most appealing features of Galileo is the signal embedded integrity. As this characteristic provides the users with information about the availability and correctness of the Galileo system and signal, Galileo is particularly attractive for all the critical applications that undergo the general name of Safety of Life, or SoL for brevity.

The Safety of Life Services (SoL) are targeted at users who need assurance of service performance in real-time. Typically they are safety critical users, for example Aviation, Maritime and Rail, whose applications or operations require stringent performance levels.

Other applications can be envisaged like emergency and road.

In these types of applications, the receiver plays an important role since is one of the key elements of the safety chain.

The main characteristic of such type of receivers is their capability to detect failures that can come from different sources like the Signal In Space, the environment (ionosphere, troposphere, interference and multipath effects), the constellation etc. and be capable to interpret the integrity information broadcast by the satellites.

In the frame of its 2nd Call, the Galileo Joint Undertaking (GJU) has launched several activities aiming to provide basic technological elements (i.e. receivers) useful for the different services offered by Galileo.

Within this frame, GJU has selected the GIRASOLE project as the one aiming at development of receivers for SoL application. In the framework of the project, Alcatel-Alenia-Space Italia S.p.A. (AAS-I) is leading a Consortium of several companies from eight different countries all over the world.

The GIRASOLE project aims to allow strategic developments of technologies and basic elements of a Safety of life (SoL) Galileo Receiver.

The GIRASOLE system architecture is based on GARDA heritage, a project developed by AASI-Milano under GJU contract (1st call) with the key objective to

build an advanced user receiver prototype, configurable to simultaneously track Galileo/GPS/SBAS satellites, supporting all Galileo frequencies and modulations.

The possibility to have Galileo receivers prototypes available at an early stage will provide benefits for standardization and certification of the receivers within each user communities, while facilitating the market penetration of Galileo.

The receiver processes Galileo signals on the L1, E5b bands and GPS/EGNOS signals on the L1 band. It also provides combined Galileo + GPS Navigation solution, Integrity calculations (HMI, critical satellite prediction and Navigation warning) using Galileo and EGNOS Integrity message, interference and multipath mitigation, support to the use of Local Elements and output raw measurements data of each satellite.

GIRASOLE is conceived to be flexible and easily customized to the user needs in the following applications:

- *Aviation*
- *Maritime*
- *Rail*

The receiver architecture is based on a common core and some specific parts related to the application.

The common core includes: main part of the RF to IF down conversion, HW/SW Signal Processing, Standard Navigation SW, Integrity Processing. The application specific parts include: antenna, RF Front End and filtering and Application dependant HW and SW (e.g. Interfaces.)

1 Introduction and Project Overview

One of the main differentiators of Galileo with respect to GPS and GLONASS is the provision of the integrity information and guarantee of service. These characteristics make systems based on Galileo SoL service suitable to be used in safety related applications where guarantees for integrity and continuity of service are essential.

One of the key elements of the ground components that contribute to the overall system integrity is the receiver, since guarantee for integrity and continuity of service can be achieved only if the user embeds in its equipments Galileo receiver of the Safety of Life class.

There is therefore the need to foster the development of technological elements, like the receivers, for the Galileo SoL service. The GIRASOLE projects aims to provide a comprehensive answer to these needs either in terms of technology development or in term of covering the widest area of the safety critical application.

The main objectives of the GIRASOLE project are:

- Investigation and identification of the main core technologies for Galileo SoL receivers;
- Development of breadboards for the three main safety critical applications (i.e. Aviation, Maritime and Rail) in order to support standardization, foster certification process within each User Community and facilitate Galileo market penetration;
- Allow early availability of receiver prototypes;
- Develop tools useful for SoL receivers development.

The project Consortium gathers expertise in different fields from several countries all around Europe and world wide. Three main receiver manufacturers, each involved in the development of one specific SoL receiver, are supported by Research Institute and specialized company for the investigation and development of relevant core technologies suitable for SoL receivers.

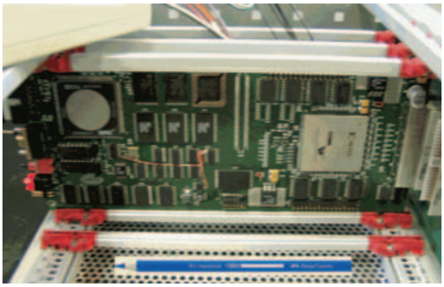
The project baseline approach is constituted by three main elements linked together:

- The main Inputs (SiS ICDs, Standards, External co-ordination activities)
- The main Tasks (Technology Investigation, Requirements definition, Common Platform development, Breadboards development and tests, Final architecture and prototypes)
- The Target Results (consolidated specifications, validated key techniques and components)

Several inputs are foreseen for the projects and among them those coming from the GARDA project (a GJU project under the frame of the 1st Call) have a particular importance. They include studies about the development activities of the Galileo receivers, identification and investigation on some core technologies, development tools and preliminary development activities of a Galileo receiver. All these inputs are taken into account and further deepened within the project.

Three issues of the Receiver Requirements and Specification document will be created: first one on the basis of the input to the project, as described above, a second issue will be released taking into account feedbacks coming from the Core Technologies investigation task and the third and final issue is completed at the end of the project with the feedback from the Breadboard development task.

An important part of the project is the identification and investigation of the main Core Technologies that act as common base for all the SoL applications and



The Garda Prototype.

identification and investigation of technologies specifically related to the targeted SoL applications.

Once identified, they will be analysed by means of the GRANADA SW receiver tool (another heritage of GARDA project) in order to produce solutions and any other indications that will be used as starting point in the Breadboard development task.

Another important concept developed in the frame of GIRASOLE is the Common Platform.

The concept is based on the consideration that the receiver is made of several functions, some of which are common and some others are specific for the three applications.

The Common Platform objective is therefore twofold:

- A way to study and test common core technologies, providing partners with a bench on which main common basic SOL receiver functions can be developed and tested, like the Integrity concept, possibly anticipating problems and solutions to be reflected on final breadboard;
- A way to develop common building blocks shareable among all the three receiver types.

The SoL receivers breadboard development activity derives and is conducted in parallel with the Core Technologies investigation, to which it provides feedback for a better identification, and is aimed to the design and development of a Receiver Breadboard for each of the three identified applications. The breadboards will therefore provide feedback to the Requirements and Specification activity and the Architecture and the Architecture and Building Block definition for the final receiver.

Galileo Simulator test tools are also developed in the frame of the project as elements supporting the receivers development activity.

Based on the above consideration GIRASOLE has several interesting and attractive elements that can be summarized as follows:

- Three GNSS receiver manufacturers are involved in the design and development, thus allowing to exploit different and complementary expertise;

- each GNSS receiver manufacturer is pushed to develop basic technologies for the Galileo system, to be afterwards transferred to other potential users;
- the activities are distributed among different manufacturers and countries, thus allowing a well spread Galileo Safety of Life Service promotion.

1.1 Use of GNSS in Safety of Life Applications

Several applications can be envisaged that require integrity information and continuity of service. The three main areas for safety critical application are identified in the Aviation, Maritime and Rail sectors.

The level of safety provided by EGNOS and Galileo, together with the use of interoperable GPS/Galileo receivers, will grant pilots assistance in all flight phases, from on the ground movement, to take-off, en-route flying, and landing in all weather conditions.

Aircraft separation can be reduced in congested airspace thank to higher accuracy and service integrity, allowing a significant increase in traffic capacity.

Surface movements and guidance control are application of the aviation sector that can benefit of an improved safety service.

Also helicopters guidance in bad weather conditions can benefit of the Galileo SoL service, thus allowing an improvement in the availability of rescue services (like medical helicopter) and generally in all emergencies management.

A wide variety of vessels moves around the world every day and sea and waterways represent one of the most widely used mean for good transportation. The increased accuracy, integrity, high availability and certified services that Galileo can provide, will improve efficiency, safety and optimization of marine transportations.

Usage of GNSS SoL based equipments can be envisaged in every phase of marine navigation: ocean, coastal, port approach and port manoeuvres, under all weather conditions.

The characteristics of a SoL receiver are ideal for navigation in the open sea and the integrity improve adds confidence in the calculated position of a vessel.

Also inland Waterways Navigation can benefit of precise navigation provided by a SoL receiver. Navigation on rivers and canals needs accuracy and integrity of navigation data as fundamental requirement, especially in critical geographical environments or in bad weather conditions.

The main users of SoL receivers for maritime application are conventional sea and river vessels, i.e., vessels whose navigation is fully regulated by the safety requirements adopted by National Maritime Administrations, namely:

- deep-sea and coasting ships, including cargo ships, tankers, passenger ships and fishing ships;
- sea ships and harbor boats, auxiliary, specialty and service ships, including ice-breakers, floating workshops and floating cranes;
- river ships, including tankers, passenger ships, transport ships, self-propelled auxiliary and specialty ships and boats.

Railway operations can be significantly improved by the use of global positioning systems in terms of navigation accuracy, safety and assistance to the operations.

By integrating the integrity concepts, Galileo will ensure the accuracy and integrity for multi-modal transport applications, thus making user applications more reliable and more accurate.

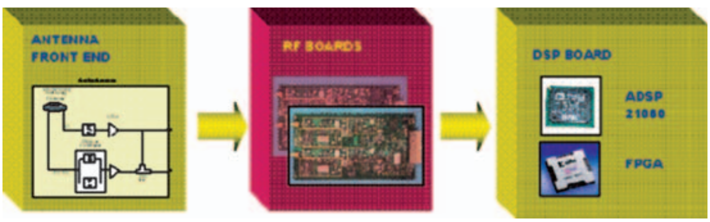
The use of the GNSS signals by the railways represents a technical, industrial and operational challenge. The railways have a consolidated experience using other means of navigation, which may not be ideal, but are well known and familiar to the operators. On the other hand, railways, like other modes, have to cope with a number of new challenges and are under economic pressure to improve and optimize significantly their operations in terms of track occupancy, safety, productivity and customer satisfaction.

The primary objective of the integration of GNSS in the train equipment is to demonstrate the improvement of the train self-capability in determining its own position and velocity, with limited or no support from the track side and to show that the equipment can comply with the European Railway Train Management System (ERTMS) requirements enabling a cost-effective modernization and increasing the efficiency.

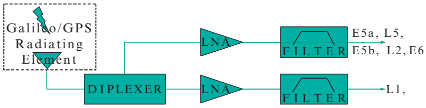
2 Receiver Architecture Overview

The receiver architecture of the AAS-I breadboard is composed of three main modules:

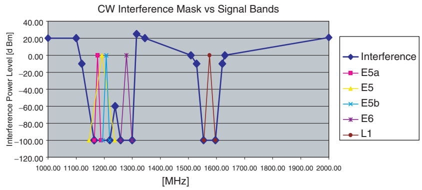
- Antenna and RF Front-end: this is a single element covering both the lower band (E5, E6) and the higher band (L1). The antenna is designed by Satimo targeting the professional/safety-of-life receiver applications. The active section is based on a Low Noise Amplifier and filters providing required amplification with very good noise characteristics.
- RF/IF section: the RF/IF section is in charge of RF signals amplification, RF to IF down-conversion and Local Oscillator synthesis. The down-conversion is based on a single mixing stage, while the final conversion to base band is accomplished after the signal digitization, by the digital channel. The IF signal sampling is also performed within this section, using a high speed ADC and coding the samples on three bits.
- Digital Section: a new proprietary digital channel was specifically designed and developed by AAS-I to process Galileo and GPS signals. The channel, named GALVANI, was designed and simulated through a Simulink design process



Receiver prototype block diagram.



Receiver Breadboard Antenna and RFFE Block Diagram



Breadboard interference rejection mask.

and ported to VHDL for implementation on a Xilinx Virtex II FPGA. The digital section includes an Analog Devices ADSP21060 that runs all the acquisition signal processing and tracking loops software. Digital channels can be flexibly configured as Single Frequency Channels (SFC) including data and pilot signals or as complex Multi-Frequency Channels (MFC), each handling multiple Galileo carriers.

2.1 Antenna and RF Front End

The antenna breadboard design has been driven by the following concepts: phase centre stability, minimization of multi-path and overall phase error, minimization of antenna size, suppression of unwanted out-of-band signals and minimization of manufacturing costs.

The antenna is a broadband element covering the L1 and E5 and E6 bands. It is based on a patch element, and includes the input RF filter (interference mitigation), based on a custom made diplexing element. The LNAs are physically located in the antenna envelope and provide two separate outputs feeding the RF/IF board. Band separation is achieved through a diplexer with reasonable rejection slope and low losses to be trade-off with the overall antenna performance. The additional separation of the E5 bands is better accomplished after the LNA.

2.2 RF/IF Section

The design of RF/IF section includes the hardware for two complete (L1, E5b) signal paths with identical architecture. Each path is in charge of generating the Local Oscillator signal, mixing the incoming RF signal to Intermediate Frequency, according to a properly defined frequency plan, providing the signal amplification, filtering and, finally, digitizing the IF signal.

The down-conversion is based on a single mixing stage, while the final conversion to base-band is accomplished after the signal digitization, by the digital channel.

Reconfigurable PLLs, image filters, IF filters and digitally controlled AGCs are located in each signal branch.

The IF signal sampling is also performed within this section, using a high speed ADC. The ADCs used are AD9480 with a maximum resolution of 8 bit at 250 Msps, which also provide LVDS outputs suitable for signals transfer to the Signal Processing. The digital samples are coded using three bits and the sampling frequency of the ADC is 95 Msps: this sampling frequency has been selected adopting standard precautions against aliasing and excess signal loss.

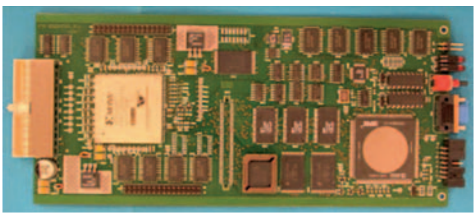
The frequency plan has been studied considering spurious frequency suppression. This means that harmonics or non-harmonics related to the clock generation and mixing process must be kept under control and possibly located in non dangerous frequency regions. The Local Oscillators phase noise is kept under tight control. The frequency synthesizer has been designed with the goal of achieving best phase noise performances.

The master oscillator is a standard 10 MHz clock and the choice of 70 MHz as IF frequency has allowed the use of standard SAW filters.

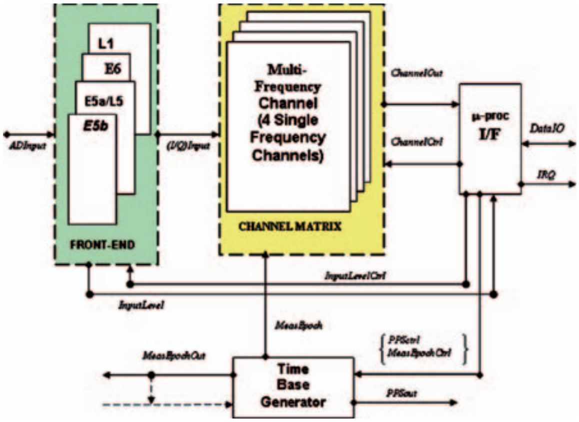
2.3 Digital Section and Channel Correlators

The Digital Signal Processing board is a re-programmable computing platform for high data-throughput signal processing Galileo/GPS applications. The module is able to process an entire Galileo/GPS digital channel acquired via LVDS Interface. The digital channel (called GALVANI) main functionalities have been implemented on a Virtex-II XC2V8000 FPGA, while signal processing algorithms run on Analog Device DSP 21060 SHARC. The board is also equipped with SPI and RS232 connectors: the former is used to connect an external memory card useful for testing purposes, while the latter to download data from the on board DSP and communicate with the user interface program.

The reference block diagram of the GALVANI chip is sketched in the figure: it is made up by a matrix of processing elements referenced as Digital Channel (DC). Each DC is a flexible processing unit that can be configured and controlled to demodulate and track any channel of the Galileo signal, including both pilot and the data sub-channels. Indeed the DC matrix is controlled and configured by a software routine running on DSP core in order to implement acquisition and tracking algorithms and symbols demodulation. A DC can also be referred to as a Single Frequency Channel (SFC) to highlight that each processing element is dedicated



Digital signal processing board.



Digital channels architecture.

to a single channel on a particular Galileo carrier. In line with this notation, a collection of 4 DC, one for each carrier, is referred to as Multi Frequency Channel (MFC), and it is the basic unit which can track all the signals from a Galileo satellite.

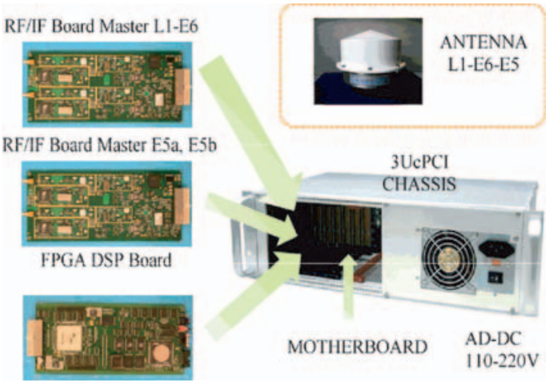
By properly programming the DSP it is possible to reconfigure each DC realizing a flexible reuse of the FPGA resources. Within the FPGA a dedicated micro-processor interface is also needed to interface the internal signal processing with the DSP.

2.4 Application Breadboards

In the framework of GIRASOLE, AAS-I has developed an integrated Galileo/GPS/EGNOS breadboard receiver for on-board train safety-critical applications.

The receiver processes the Galileo signals on the L1 and E5b bands and the GPS/SBAS signals on the L1 band. The receiver baseline is to use E5b and L1 for Safety of Life Service. In future configurations, to allow also dual-freq GPS L1-L5 measurements, the receiver may be configured with an additional E5a/L5 RF path. The Rail breadboard receiver performs the following main functions:

- Search visible Galileo/GPS/ SBAS SVs and allocate HW channels to SVs on the basis of predefined strategies;
- Acquire and Track Galileo/GPS/ SBAS specified signals;
- Maintain Code Lock and Carrier Lock, demodulate and decode data messages and recover Navigation Data from each received GNSS satellite;
- Implement interference and multipath mitigation techniques at the most appropriate level (HW or signal processing);
- Perform position, time and velocity calculation with GPS, Galileo and/or a combination of GPS + Galileo SVs in view;



Receiver breadboard functional architecture.

- Use calculated position information to establish geometrical line of sight information of each acquired GNSS satellite with respect to the receiver platform and predict a tracking list of visible satellites;
- Perform integrity related calculations (xPL, HMI, Critical Satellites Prediction and Navigation Warning) to alert the user in case of integrity risks;
- Provide raw measurements data for each GNSS satellite in lock;
- Monitor receiver health status;
- Allow receiver control by the user through its Command & Control interface.

In addition, the following features are under investigation:

1. the Rail SoL Receiver capability to accept, at its serial interface port, pseudorange measurement correction data from a trackside Local Reference Station, in order to perform a code-based local-precision positioning solution,
2. the Rail SoL Receiver capability to accept, at its serial interface port aiding data from an inertial measurement unit (including three axis acceleration and angular rates) in order to propagate position/velocity and satellites predictions in conditions of no visibility (tunnels), to aid satellites acquisition/reacquisition and to perform additional data integrity checking.

3 Core Technologies

3.1 Integrity

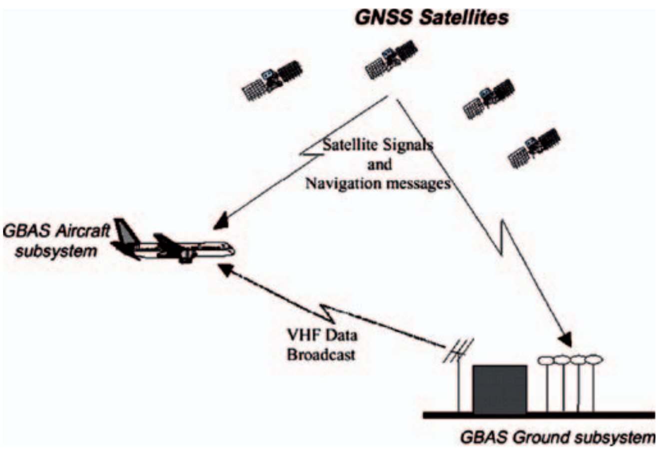
Integrity is a key issue in satellite navigation for safety-of-life applications. Integrity is a measure of the trust which can be placed in the correctness of the information. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation. The integrity performance is specified by means of three parameters:

- ***Integrity risk***
  This is the probability during the period of operation that an error, whatever is the source, might result in a computed position error exceeding a maximum allowed value, called **Alert Limit**, and the user be not informed within the specific time to alarm.
- ***Alert limit***
  This is the maximum allowable error in the user position solution before an alarm is to be raised within the specific time to alarm. This alarm limit is dependent on the considered operation, and each user is responsible for determining its own integrity in regard of this limit for a given operation following the information provided by GNSS SIS.
- ***Time-to-alert***
  The time to alert is defined as the time starting when an alarm condition occurs to the time that the alarm is displayed at the user interface. Time to detect the alarm condition is included as a component of this requirement.

The integrity capabilities of the Girasole receiver consist of the Galileo SoL service integrity messages, the RAIM, the SBAS integrity messages and the GBAS integrity messages.

The integrity concept introduced by Galileo is innovative and has the aim to provide the user with a more powerful mean to check the integrity of the system. Integrity concepts have been established and optimized for present Space Based Augmentation Systems (SBAS) like WAAS (Wide Area Augmentation System) or EGNOS (European Geostationary Navigation Overlay System) according to their required performances in terms of availability, integrity, and continuity.

The performance requirements for Galileo are one order of magnitude more demanding compared to these present systems and therefore a new integrity concept, based on the established approaches, has been developed.



GNSS/GBAS system overview.

In the frame of Girasole project, the concept of multisystem integrity has been addressed with the purpose to establish a link between two generations of GNSS, to find the best way to integrate the Galileo and EGNOS integrity information into a new multi-system integrity algorithm and then to identify the implications in the use of the additional information provided by different RAIM schemes.

The integrity concepts have been investigated in the frame of Girasole specific environments; because of the military prime nature of navigation satellite systems, integrity requirements were first defined only in the avionic environment. As these systems were intended to be used also for civil purposes, it became necessary to extend the requirements also for the other applications. So, at the present, the requirements are standardized only for aviation, while for maritime and rail environment they are recommended values. Furthermore, while in the aviation both vertical and horizontal parameters have to be considered (3D-analysis), in maritime and rail the analysis is focused only in the horizontal plane (2D-analysis). In particular for rail environment the parameter to be controlled is the along-track position, that is the distance of the train along the railway path from a fixed point (1D-analysis).

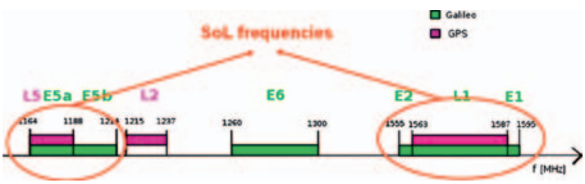
3.2 Interference

It well known that a GNSS receiver is in principle vulnerable to several types of interference, which can lead to a complete signal disruption. This is an intrinsic feature of this type of receiver, because of the way it extracts the pseudorange information from the SIS (Signal in Space), and to the very low SIS power.

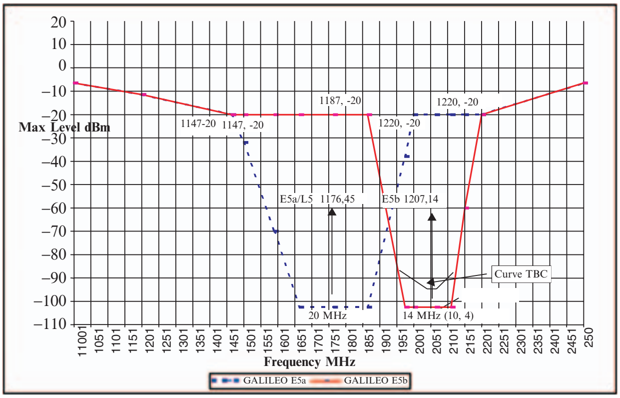
Hence, it becomes of main interest to evaluate the possible impact of potential interferences in bands of interest and in particular in the Galileo frequencies SoL bands, illustrated in Figure.

Among different transportation system scenarios, the railway environment represents a source of new developments incorporating different advanced radio systems that supports Automatic Train Control (ATC) and Automatic Train Protection (ATP). There are different kinds of interferences that could disturb a GNSS receiver in train applications and they are related with the environment in which the receiver operates. A classification of main potential interference sources is presented:

- Unintentional Electromagnetic Interference (EMI) sources from devices strictly related to railway environment.
- Unintentional EMI sources from high-voltage transmission lines.



Galileo frequency bands.



E5 band interference mask for avionic receiver.

- Unintentional RF disturbances that probably could interfere in GNSS receiver but not necessarily related to railway environment. These could be indicated in higher harmonics of out-of-band interferers as Continuous Wave (CW) or Wide Band (WB) interferences, or in-band interferers as Ultra Wide Band (UWB).

For GNSS civil aviation application, the standard received signals and interference environment applicable to the GNSS receivers are defined in the aviation standards issued by ICAO, Eurocae and or RTCA. These are defining the minimum equipment applicable environmental conditions by referring to dedicated sections of ED 14 D (Europe) or D0 160 C (US) documents. Additional constraints are set by the aircraft manufacturer depending upon more detailed installation conditions.

In Maritime environment, there are a lot of electric, electronic and radio equipments on the vessel board, which are the sources of the electromagnetic radiations. Vessel external environment is more propitious for electromagnetic compatibility (EMC) as shipborn not connected to power cable supply and communication, which can perceive interference signals. Even in harbour, where many shipborn systems don't work in fact or theirs work is forbid, unlikely find oneself nearer then 500 m from permanent commercial or industrial interferers, or then 1 km from transmitter.

Out of band and secondary radiation values are regulated in accordance with ITU recommendations. Special department controls level of these radiations. But there is a risk of appearance of such interferences and it can be an object of additional investigations in ship-borne equipment (which is not included in conventional, required for IMO approval) interference chart compiling.

3.3 Multipath Mitigation Techniques

Multipath is the phenomenon whereby a non-direct signal arrives at the receiver antenna. Non-direct signals makes the tracking loops to detect the maximum correlation power in a different instant than that corresponding to the isolated direct signal. Since this error source is the main contribution to the pseudorange measurement error and cannot be removed by local or wide area augmentations, a multipath mitigation strategy at the antenna (HW) or signal processing (SW) level must be included in the receiver.

Taking classical multipath mitigation techniques used in GPS as baseline, new techniques have been investigated in the frame of Girasole project taking profit of the Galileo signal characteristics (E5 wideband, or BOC modulations) to develop new multipath mitigation algorithms.

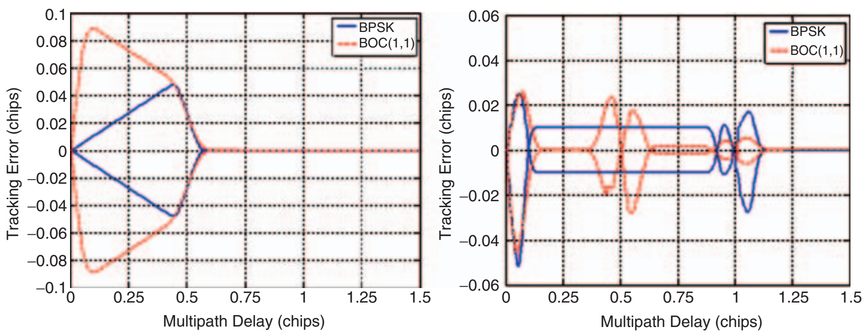
In order to be able to efficiently mitigate multipath and interference one has to drop classical methods which are based on correlator techniques. This also comprises to partly leave classical synchronization architectures which give astoundingly good performance, while not being designed for severe multipath scenarios like urban environments. New methods and architectures need to be introduced to the field of navigation in order to enhance quality of TOA (time-of-arrival) parameter estimation.

Different methods have been proposed to track a GNSS signal in presence of multipath propagation, mitigating the errors induced by it. These techniques can be classified according to the approach used as reported in the following.

Discriminator Based Techniques. These algorithms rely on DLL to track the signal. However, in presence of multipath the shape of the ACF is distorted, and some error appears in the estimation of the code delay. This kind of techniques tries to modify the discriminator function to reduce the error.

Tracking Error Compensation Algorithms. These techniques are based on the concept of Multipath Invariance (MPI), which states that there exist regions or properties of the ACF that do not vary as a function of the multipath. Knowing the position of these regions, the tracking loop solution can be corrected by the difference between the measured and ideal position.

Multipath Estimation Techniques. In the *A-Posteriori Multipath Estimation* (APME) technique, the tracking is done in a conventional narrow correlator DLL that achieves low noise. The multipath error is estimated in an independent module



Multipath error profile for E1/E2 slope and Early/Late slope technique.

using the signal amplitude measurements. The use of *Kalman filtering* for tracking the time delays in CDMA systems is an approximation to the minimum variance estimator when the observation sequence is nonlinear in the state variables. In this case, the state variables are the multipath complex coefficients, multipath delays and Doppler shift. Some adaptive filtering techniques have been applied to multipath mitigation: in this approach the adaptive filter (RLS, LMS . . .) is used for estimating the multipath delay profile, which is subtracted from the measured correlation function of the signal with the code. The *Maximum Likelihood (ML) Estimation Techniques* family of algorithms try to cancel the multipath interference subtracting from the correlation function of the estimated contribution of the multipath. Within this class of algorithms lay the MEDLL, Deconvolution Methods, Subspace-Based Algorithms, Quadratic Optimization Methods, Teager-Kaiser (TK) Operator-Based Algorithms. *Wavelet Filtering* is a kind of multi-resolution analysis that gives simultaneously time and frequency information of a signal sequence. It can be applied to non-stationary signals, as the case of satellite navigation systems signals. The signal is passed through a series of high pass and low pass filters to analyze the signal at multiple resolution.

4 Conclusions

One of the main differentiators of Galileo with respect to GPS and GLONASS is the provision of the integrity information and guarantee of service. These characteristics make systems based on Galileo SoL service suitable to be used in safety related applications, where guarantees for integrity and continuity of service are essential. There is therefore the need to foster the development of technologies that will allow the receiver to meet the safety-critical requirements of several applications ranging from aviation to rail, maritime and emergency services. The Girasole project is the step towards this definition and development. The Girasole project is also keeping a tight link with other on-going safety-critical application development programs so that the Galileo SoL receiver could be used as a basic element in future generation safety-critical transport systems.

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