Abstract – ION-GNSS 2006

Gate-to-Gate with modernized GPS and Galileo

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Satellite Navigation has become increasingly important in the optimization of the efficiency and safety within the aviation industry. ANASTASIA (**A**irborne **N**ew and **A**dvanced **S**atellite techniques and **T**echnologies in **A S**ystem **I**ntegrated **A**pproach) is a European Commission project within the Sixth Framework Program, with the basic objectives to define and implement future (beyond 2010) communication and navigation avionics based on satellite services, exploiting the multi-constellation and multi-frequency architectures in combination with multiple onboard sensors, to provide a worldwide gate-to-gate service. Included in the objectives are the preliminary development of advanced airborne systems for flight trial evaluation and the dissemination of results for standardisation activities.

Studies have shown that stand-alone Global Navigation Satellite Systems (GNSS – GPS and GALILEO) or stand-alone GNSS augmented by Space Based Augmentation Systems (SBAS) cannot satisfy the demanding performance requirements of Category-II/III approaches or of surface movement. To satisfy these requirements, Ground Based Augmentation Systems (GBAS) are needed. In this paper, the concept of GPS augmented by a GBAS is extended to GNSS configurations consisting of modernized GPS together with at least dual-frequency GALILEO. The most interesting configurations, regarding both performances and institutional aspects, for a combined GPS/Galileo are identified. Performances achievable with these configurations are presented and compared with current proposed performance requirements.

Up to date, performance requirements have only been firmly established for the various phases of flight up to Category-I precision approaches. Two methods have been used to derive the performance requirements for Category-II and III precision approaches: the *Autoland Method* (by RTCA in the USA) and the *ILS Look-Alike Method* (by Eurocae in the European Union). The *Autoland Method* is based on the idea of evaluating the required performance to protect the safety of the landing operation, rather than by extrapolating the equivalent NSE performance from existing ILS specififcations. The *ILS Look-Alike Method* is based upon the concept of matching system performance at the NSE level through linearization of the ILS performance specifications at a given height. Both methods lead to significant discrepancies in the performance requirements, essentially due to the fact that the *Autoland Method* makes use of a mixture of GNSS+GBAS and Aircraft Based Augmentation Systems (ABAS) whilst the *ILS Look-Alike Method considers the use of GNSS+GBAS only*. Both methods are carefully reviewed, the differences highlighted and a viable approach consolidated. Particular emphasis will be placed on the validation of the proposed configurations.

The paper further reports on developments and initial results of the impacts of the new multi-constellation and multi-frequency configuration upon the avionics architecture, for Category-II/III approaches, and for surface movement (taxiing) using the future

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Advanced Surface Movement Guidance and Control System (ASMGCS). The paper looks in detail at modifications required at the software level to enhance performance to the level where Category-III performance requirements determined above can be met.

In this regards, the biggest limitation to the use of GPS augmented by GBAS for Category-II and III precision approaches currently is the integrity risk posed by the ionosphere. The differential nature of GBAS requires Signal-in-Space (SIS) errors between the ground reference receivers and the airborne receiver to be correlated. However, strong ionospheric gradients can significantly decorrelate these SIS errors. In case where dual frequency measurements are used at both reference receiver and airborne levels, these risks can be mitigated. This paper identifies threats for a GBAS using Galileo signals in stand-alone mode or in combination with GPS. Ground monitors and settings are defined to protect the SIS integrity risk monitored by the ground station, especially the integrity risks caused by the ionosphere.

At present, the integrity concept for GPS augmented by GBAS is based upon the computation of protection levels. The probability that these exceed a specified alert limit without providing an alert within a given time frame represents the integrity risk. This integrity concept is reviewed and the possibility of developing alternative concepts for the new GPS/Galileo configurations is investigated. Based upon the performance requirements determined in this paper, integrity and continuity allocation schemes are developed for Category-III approaches.

In line with the gate-to-gate concept, future airborne receivers must be able to satisfy the very stringent performance requirements of taxiing from the runway to the gate and vice versa. Current code-based ranging is limited in its accuracy and it is anticipated that this method cannot satisfy the very stringent performance requirements of ASMGCS. Modernized GPS together with Galileo have increased the potential of using RTK, with preliminary results showing that the initial precise position determination, currently taking up to 15 minutes or more, can be reduced to 6 seconds with an accuracy of 11cm. Existing Real-Time Kinematic (RTK) methods are reviewed and those suitable for ASMGCS identified. Specific research on error modelling focuses on multipath mitigation as the key limiting factor to ambiguity resolution. Integrity and continuity capabilities are investigated. Simulations are proposed to more clearly define data-link requirements for GBAS to support this type of service.