# SBAS Autoland NSE model

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The Instrument Landing System (ILS) is used to guide aircraft on final approach and is by far the most important and frequently used guidance system for landings [EUROCONTROL, 2008]. However this system is both expensive and inflexible because it is only able to provide a straight-in approach trajectory for one runway end, so that multiple installations for one airport are required. The successor of this system is expected to be the Global Navigation Satellite Systems (GNSS) with augmentation systems such as SBAS (Satellite Based Augmentation System) or GBAS (Ground Based Augmentation System). Such system are able to provide safe and reliable guidance with greatly improved flexibility in the definition of approach tracks.

The use of SBAS has been proposed to complement ILS for Autoland CAT-I and CAT-II. No new airport infrastructure implementation will be needed as long as the airport is within the service area. Standalone single-frequency GPS is mostly affected by the ionospheric delay and the satellite clock and ephemeris errors. SBAS is therefore providing to the user, corrections and integrity information for these three error sources. The satellite clock offset and the ephemeris errors, which are the subject of this article are corrected by Fast Corrections and Long-Term Corrections.

The Fast Correction message conveys the PseudoRange Correction (PRC) for each satellite of the current satellite mask. The concerned SBAS message types also contain the UDRE (User Differential Range Error) parameter that expresses a bound on the standard deviation of the correction residual error, providing integrity bounding and used to compute a protection level. The PRC and the computed Range Rate Correction (RRC) are correcting the component of the satellite clock delay that is quickly varying. The Fast Correction is then the sum of the current PRC and the computed RRC multiplied by the elapsed time. The Long-Term Correction conveys the satellite position correction and the slowly varying component of the clock error. These 2 corrections are improving the user position accuracy. In order to quantify this improvement we propose to study the residual clock and ephemeris errors in the position domain.

Currently, WAAS (Wide Area Augmentation System) offers the capability to perform RNAV operations with Localizer Performance with Vertical Guidance (LPV) 200 ft minima at a majority of airports in US National Airspace [FAA, 2015], corresponding to Category I minimum performance defined by ICAO SARPS [ICAO, 2006]. The EGNOS (European Geostationary Navigation Overlay Service) Safety of Life service, established in 2011 to provide LPV capability, will offer the same minima capability in Europe, that is to say 200 ft [AZOULAI, 2012]. WAAS and EGNOS were identified as good candidates for autoland feasibility demonstration [AZOULAI, 2012].

Autoland is an instrument approach and landing operation using precision lateral guidance with minima as determined by the category of operation [ICAO, 2001]. Autoland CAT-I is characterized by a 550m Runway Visual Range (RVR) for a 60m Decision Height (DH). Autoland CAT-II is characterized by a 300m RVR for a 30m DH. Category I precision approach requires a 95 percentile accuracy of 16m in the horizontal plane and of 6m along the vertical axis [ICAO, 2001].

In a previous articles we evaluated the nominal residual clock and ephemeris errors remaining after applying the corrections in the range domain [TESSIER, 2017a] and in the position domain [TESSIER, 2017b], reflecting SBAS accuracy. The methodology and results using 2016 data collections will also be described in this article. The main objective is the residual error modelling for a user of the EGNOS system in the ECAC (European Civil Aviation Conference) area. This study is conducted in the frame of a thesis that is co-financed by the European Space Agency (ESA), AIRBUS OPERATION SAS and ENAC and follows the study of SBAS Autoland feasibility conducted by AIRBUS OPERATION SAS and ENAC [AZOULAI, 2012]. The long-term purpose is to model the SBAS Navigation System Error (NSE) to determine the feasibility of SBAS Autoland CAT-I and CAT-II. The autoland system under test should be fed with an SBAS NSE composed of the nominal residual SBAS clock and ephemeris position error that is modeled in this article, of the nominal residual SBAS ionospheric position error. Then, limit and faulty errors of the SBAS system should also be considered to demonstrate airworthiness requirement for Autoland CAT-I.

In the first part of the paper the methodology used to process the data and to extract the residual clock/ephemeris and ionospheric range errors is described. For the clock and ephemeris range error we are comparing the EGNOS Fast and Long-Term corrections with the final product of the NGA (National Geospatial-Intelligence Agency), while the Ionospheric EGNOS corrections are compared with precise estimation of the slant TEC (Total Electron Content) value provided by UPC (Polytechnic University of Catalonia) for a set of IGS stations in Europe. The range errors models are then briefly presented. From these two range errors models we are then deriving the EGNOS nominal NSE (Navigation System Error) by considering a nominal GPS constellation. As opposed with our expectation the models that we obtained for the range errors are biased which also impact the residual EGNOS position error model. This paper will end on a discussion on those biases, first a study on WAAS daily averaged position errors at WRS (WAAS Receiver Station) will shows that users are experiencing similar biases and then an investigation to determine the error source responsible for those biases.


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