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TESTING AND MEASURING GNSS PARAMETERS

Abstract

This paper describes the consistent preview of the testing and measuring GNSS parameters. The Measuring and testing GNSS requires three essential components: aircraft with flight crews, procedures or navigation aid requiring validation, and a Flight Inspection System (FIS). A Global Navigation Satellite System (GNSS), as a source of position information available worldwide is considered as a key enabler to future navigation.

INTRODUCTION

The Global Navigation Satellite Systems (GNSS) have changed the face of navigation dramatically in recent years, in that they can give an accurate and instant readout of position almost anywhere in the world. The implementation of GNSS-based services offers an opportunity to rationalize conventional navigation aids and radar. The Measuring and testing GNSS requires three essential components: aircraft with flight crews, procedures or navigation aid requiring validation, and a Flight Inspection System (FIS). With each component comes its own particular set of issues. Flight crews must be trained and current in the airframe. The airborne platform must be certificated, maintained, and operated. The flight inspection system consists of complex avionics equipment and software. Before a procedure can be flight inspected, flight inspection criteria must be developed and implemented. The main focus in this paper will be on the airborne platform, the flight inspection system and incorporating developing technologies. [2,6]

1. PROCEDURES FOR MEASURING AND TESTING GNSS

The flight validation is a flight assessment of a new or revised instrument flight procedure to confirm that the procedure is operationally acceptable for safety, fly ability and design accuracy, including obstacle assessment and database verification, with all supporting documentation. Includes flights performed with Simulators (except desktop software simulators).

The flight evaluation is a validation flight of an instrument flight procedure with an aircraft.

The flight inspection is an operation of a suitable equipped aircraft for the purpose of calibrating ground based NAVAIDS or monitoring/evaluating the performance of Global Navigation Satellite System (GNSS).

The ARINC 424 is a standard by which a navigation database is created to interface with an airborne navigation computer (i.e., FMS, GPS receiver, etc.). The navigation database will provide paths and termination points for the navigation computer to follow. [4]

1.1. Aircraft Requirements

The aircraft avionics configuration must be appropriate to support the procedure to flight measuring. Flight Inspection of RNAV Standard Instrument Departure (SID), airways, and Standard Terminal Arrival Route (STAR) may be accomplished with any flight inspection aircraft capable of the procedure's ARINC 424 path and terminators. RNAV approach charts provide separate minima for Lateral Navigation (LNAV), Lateral and Vertical Navigation (LNAV/ VNAV), LP, LPV, and RNP. Inspection of an RNAV procedure with vertical guidance requires an appropriately equipped flight inspection aircraft. Flight inspection of a LNAV approach procedure (without vertical navigation) may be accomplished with any flight inspection aircraft capable of the procedure's ARINC 424 path and terminators. [4]

1.2. Pre flight preparation

Prior to departure for a flight check the flight inspector is responsible for the flight inspection system serviceability, calibration and that the calibration will remain current for the expected duration of the check. All relevant data must be obtained to enable the execution of the flight check. This data may include:

– facility information and status,
– type of check required,
– survey data.

The Ground reference station is deployed in accordance with the Flight Inspection System Manual published at University of Žilina. A detailed ATC briefing shall be conducted in accordance with the University of Žilina ATC briefing pack. [5]

1.3. The flight inspection system warm up time

During normal operation of the Flight Inspection System (FIS), all parameters except Received Signal Level (RSL) are within operating tolerances immediately after the system is powered on. RSL parameters are within operating tolerances after 45 minutes. The flight inspector ensures that RSL parameters are not used prior to 45 minutes of the Flight Inspection System has been powered on. The flight inspector has to check correct operation of the system fans prior to conducting the flight check. An audible check is satisfactory.

Fig. 1. The Ground reference station at the Zilina airport. [5]

1.4. The flight inspection system temperature/RSL

All parameters measured by the Flight Inspection System are within operating tolerances over an ambient temperature range of 10°C to 30°C. All parameters except RSL are within tolerances over an ambient temperature range of 10°C to 45°C. The flight inspector has to check the aircraft cabin temperature to ensure operation within the specified temperature range. The cabin temperature has recorded on the relevant run sheet and also recorded on the final flight check report. The flight inspection system is calibrated at -70 dBm. At signal levels above -50 dBm the flight inspector should be aware that errors may be present and thus limit use of the FIS at RSL above -50 dBm. [5]

1.5. The flight check

During the flight check the flight inspector organizes a run list that will enable the aircraft and crew to measure and record the required parameters. The number and type of runs will depend on the type of check being conducted and will be selected from the flight check procedure. The flight check procedure document provides guidance and instructions:

– The flight profile to be executed.
– Parameters to be measured.
– Tolerances to be applied.
– Data to be recorded.
– Reference to the flight check recording.

The procedure can also be used as a run sheet for the flight inspector to record facility specific information, measured parameters and cross reference to the flight check recording. The flight inspector is responsible for:

– Checking of correct fan operation.
– Filtering is set to automatic.
– Ensuring that all profiles, tests and recordings are completed with consideration to the type of check being undertaken i.e. Commissioning, Annual, Routine.
– Site data width is to be adjusted to actual value measured at the beginning of each check.
– Glide slope back set is to be calculated using the coordinate calculator.
– Calculation and application of tolerances.
– Any localizer modulation above 60% is to be investigated. Data shall be extracted and a normalized plot produced.
– Position quality 3 is required for all Instrument landing system (ILS) recordings except coverage and clearance recordings. Position quality 1 or 2 is satisfactory for all other recordings.
– Mean width recordings should be made at the discretion of the flight inspector. This will be required when poor course structure causes poor correlation with mean width recordings.
– Reporting all required data.
– Production of the flight check report.

Additional flight inspector duties that facilitate efficient of flight check include:

– Effective liaison with the airport operator and technical staff.
– Monitor flight technical error to ensure that the average track accuracy is within an average of 15Microamps.
– Efficient air/ground communications.
– Explanation of reports.

Fig. 2. Airborne and ground equipment AT-940 with spectral analyzer and selective millivolt meter.

1.6. Post flight

On the completion of the flight check mission is the flight inspector responsible for:

– Reporting any flight inspection system faults.
– Updating FIS log if required.
– Updating the central data base for any new or updated site data.
– Archiving the flight check report both electronically and in hard copy.
– Production of the flight check report in a timely manner and ensure that the site data file relevant on the day of check is appended to the report.
– Obtaining a review of the flight check report.
– Issuing the report to the facilities operator.

1.7. Flight Check report

On the completion of the flight check mission shall the flight inspector produce the flight check report to the standard prescribed in this manual including the following considerations: all recordings shall be printed and included as part of the report. Recordings shall not include raw course deviation indicator (CDI) or Aircraft position traces. The report shall include the actual site data record pertaining to the facility being inspected. The flight check report is checked by another qualified and current flight inspector prior to release.

1.8. GNSS procedure Validation Software

The detailed operation of the WinFis™ software is discussed, including control of the system, cockpit CDI setup, recording Flight Inspection data and interpreting the results of the automatic analysis.

Tab. 1. Recorded and displayed parameter for validation procedures in WinFIS software.

Parameter	Description
Bearing to Waypoint	Bearing in magnetic and true degrees to next waypoint in procedure
Segment Length	Length of segment in nautical miles
Offset Begin/End	Guidance offsets in horizontal and vertical planes at beginning and end of segment
SV	Number of SVs in position solution
Altitude Begin/End	Altitude of flight inspection aircraft at beginning and end of segment
Max/Min Altitude	Maximum and minimum aircraft altitudes in segment
Average Climb/Descent Rate	Average climb/descent rate of aircraft in segment given in feet per minute
Gradient	Climb/descent gradient in percent for segment
Max FTE	Maximum flight technical error in horizontal and vertical planes for segment
Avg Gnd Speed	Average ground speed of aircraft in segment
Max Gnd Speed	Maximum ground speed of aircraft in segment
Avg PDOP	Average PDOP in segment
Min SVs	Minimum SV count in segment
Samples	Number of data samples in segment

2. MEASURING PARAMETERS FOR GNSS

Recording of GNSS parameters during the flight test is not required for NPA. However, the parameters in Tables 1 and 2 can support analysis of GNSS signal anomalies or interference encountered.

Tab. 2. GNSS parameters

Parameter	Definition	Purpose
Cross track distance	The across track distance computed by the GNSS receiver or FMS with GNSS sensor.	Provides a continuous record of the total system error component perpendicular to the desired track segments.
Active way-point	The active way-point identifier.	Gives a continuous indication of the active way-point.
Distance to active way-point	Distance to the active way-point in nautical miles.	Provides a continuous record of the GNSS receiver computed distance to the active way-point.
Bearing to active way-point	Bearing to the active way-point.	Provides a continuous record of the GNSS receiver computed true bearing to the active way-point.
No. of satellites visible	The number of space vehicles visible to the GNSS sensor.	Continuous indication of the satellites in view.
No. of satellites tracked	The number of space vehicles being tracked by the GNSS sensor.	Continuous indication of those satellites for which a range solution is being tracked.
Carrier-to-noise density ratio	The carrier-to-noise density for each satellite visible to the GNSS sensor.	Continuous indication of received C/N0 from each satellite. Useful for investigating interference problems.
HDOP	Horizontal dilution of precision.	Continuous indication of the geometric dilution of the GNSS position accuracy in the horizontal plane.
RAIM alarm	Indicator of lost GNSS signal integrity as computed by the GNSS receiver/sensor RAIM algorithm.	Continuous indication of RAIM alarm status. Can be used to investigate loss of RAIM occurrences along with other inputs such as HDOP, HFOM, aircraft attitude

		(roll, pitch and heading) and satellite carrier-to-noise.
Date and time	GNSS UTC date and time.	Provides an accurate time for each GNSS position solution to be compared to a reference system.
GNSS position	Present position latitude and longitude.	Provides a continuous indication of the GNSS position.

Tab. 3. Flight test system parameters

Parameter	Definition	Purpose
XTKER	The across track error. Derived by calculating the position difference between the GNSS and the positioning system, and then extracting the vector component that is 90 degrees from the track heading.	Provides a continuous record of the NSE (Navigation System Error) component perpendicular to the desired track.
ATKER	The along track error. Derived by calculating the position difference between the GNSS and the positioning system, and then extracting the vector that is in the direction of the track heading.	Provides a continuous record of the NSE component in the direction of the desired track.
WPDE	Way-point displacement error is the vector sum of the XTKER + ATKER.	Can be calculated for the point at which the position reference system indicates the aircraft is abeam the way-point being checked. Includes known errors inherent in the measurement system used.
Positioning system position data	Precise position of the GNSS antenna relative to the position system reference frame.	Provides a continuous record of the GNSS antenna position.
Positioning system status	Operational status of the positioning system.	Provides continuous indication of the operational status of the position reference system.

Tab. 4. Interference parameters

Parameter	Definition	Purpose
RAIM warning flag	Receiver Autonomous Integrity Monitoring is able to detect excessive pseudorange errors.	Cannot discriminate between interference, shading, multipath and other anomalies.
Receiver interference flag	Some GNSS receivers are equipped with an interference detection capability.	Detects interference by monitoring of the amplitude distribution (e.g. signal is buried in the noise, therefore amplitude has Gaussian distribution, amplitude distribution is distorted by interference signal).
C/N or C/N_0	Signal to Noise or Signal to Noise density ratio, indicates quality of signal.	C/N or C/N_0 will be degraded during reception of an interference signal. To detect degradation value of C/N, or C/N_0 has to be compared with undisturbed value of satellite with same elevation angle. Attitude of aircraft has to be taken into account.
Spectrum analyzer measurements	Spectrum analyzer equipment can be used to monitor the input to the GNSS receiver for signal levels which exceed the receiver interference protection criteria as specified in GNSS SARPs.	This measurement is dependent on achieving a measurement noise threshold in the area of -153.5dBW for GPS non-precision approach, -150.5dBW for GPS precision approach.

The potential for interference exists to various extent in all radio navigation bands. As with any navigation system, the users of GNSS signals must be protected from harmful interference resulting in the degradation of achieved navigation performance.

Current satellite navigation systems provide weak received signal power – meaning that an interference signal can cause loss of service at a lower receiver power level than with current terrestrial navigation systems. Interference exist wherever the GNSS signal is authorized for use. However the GNSS is more resistant to misleading navigation errors from interference signals than current terrestrial radio navigation systems.

CONCLUSION

The implementation of GNSS-based services offers an opportunity to rationalize conventional navigation aids and radar. The pace of rationalization will depend on the level of GNSS avionics equipage, on airspace and procedure development and on the vulnerability risk assessment.

Avionics equipments are more complicated by the stage-by-stage approach to implementation, by the advent of new features. For example the multiple frequencies (GPS, Glonass, Galileo), and by the addition of new GNSS elements. The EU states need to work closely with operators to develop a coordinated strategy and a plan that is practical and achievable from both ANS providers' and aircraft operators' perspectives. This process must identify all of the avionics requirements to meet PBN, ADS-B and the requirements of any other systems.

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