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THIRTEENTH AIR NAVIGATION CONFERENCE

Montréal, Canada, 9 to 19 October 2018

COMMITTEE A

Agenda Item 2: Enabling the global air navigation system
2.2: Integrated CNS and spectrum strategy

GNSS IMPLEMENTATION PHASE 1 - MONITORING

(Presented by the Republic of South Africa)

EXECUTIVE SUMMARY

This paper presents an overview of the global navigation satellite system (GNSS) monitoring system programme planned for the Republic of South Africa.

1. INTRODUCTION

1.1 In preparation for the roll-out of ground-based augmentation system (GBAS) the accuracy of the GNSS signals currently received at ten selected airports or sites (FAOR, FACT, FABL, FALE, FAPE, FAGG, FAUP, FAPP, FAMM and FAEL) will be remotely monitored for accuracy, consistency and reliability. This will be done through the establishment of GNSS receiver sites at these locations and a central monitoring computer. In the event that satellite-based augmentation system (SBAS) is, in the future, supported by the South African Aviation Industry the information from these monitoring receivers will be essential to establish a safety of life system.

1.2 The current core constellation (Global Positioning System (GPS) and Global Orbiting Navigation Satellite System (GLONASS)) is unable to provide accuracy, availability, continuity and integrity to achieve precision approach and landing. The GNSS monitoring receivers at the identified sites will collect information from the core constellations to determine the level of accuracy, availability, continuity and integrity from these satellites and these will be used to develop error correction models, these receivers will also be used to collect data to enable the drawing up of ionospheric models of South Africa.

1.3 Air Traffic and Navigation Service (ATNS) has initiated plans to transition from its present conventional navigation and landing system to a GNSS based system using signals provided by a combination of the two core constellations namely GPS and GLONASS.

1.4 There have been expressions of concern regarding the robustness of this plan and whether the risks to a dependency upon GNSS have been adequately addressed. In response to this concern, ATNS has found the need to determine the reliability of the GNSS signals currently received at ten selected airports or sites which will be remotely monitored for integrity, accuracy, consistency and reliability. This will be done through the establishment of GNSS receiver sites at these locations.

2. DISCUSSION

2.1 Global Navigation Satellite Systems (GNSS) are subjected to errors induced by ionospheric activity. Ionospheric delays affect the speed of microwave signals differently depending on their frequency, a characteristic known as dispersion, delays measured on two or more frequency bands can be used to measure dispersion, and this measurement can then be used to estimate the delay at each frequency.

2.2 The principal source of the dispersion comes from the total electron content (TEC) in the ionosphere, along the line of sight from the satellite to the receiver. Because it is difficult to measure the TEC along the line of sight, instead a prediction can be made using a simplified model of the ionosphere.

2.3 This model assumes that the ionosphere is a thin, uniform-density shell about the earth, located near the mean altitude H of maximum TEC (approx. 350 km). Using geometry, a slant intersection with this shell model can be determined and a vertical TEC measurement inferred. The intersection between line of sight and this shell is called the ionospheric pierce point (IPP). Its perpendicular projection onto earth's surface is called sub ionospheric point. The effects of the ionosphere can be devastating: solar storms can cause widespread power blackouts, disrupt navigation systems and radio communications, and destroy the payloads on commercial satellites. GPS and GLONASS broadcasts timing codes and data on two frequencies, L1 and L2. The magnitude of the ionospheric effects on GPS measurements is dependent on the signal frequency and the level of ionospheric activity. The ionosphere may also cause intermittent signal fading, in severe cases causing losses of availability. We need a model to reduce these errors. The ionospheric model broadcast by GPS corrects for only 50% of the delay, and this is now the largest error source in a GPS and GLONASS error budget.

2.4 Much of the delay caused by a signal's trip through our atmosphere can be predicted. Mathematical models of the atmosphere take into account the charged particles in the ionosphere and the varying gaseous content of the troposphere. On top of that, the satellites constantly transmit updates to the basic ionospheric model.

2.5 A GNSS receiver must factor in the angle each signal is taking as it enters the atmosphere because that angle determines the length of the trip through the perturbing medium. Another way to get a handle on these atmosphere-induced errors is to compare the relative speeds of two different signals. This "dual frequency" measurement is very sophisticated and is only possible with advanced receivers.

2.6 All the proposed sites are inside an aerodrome and shall comply with the requirements listed in ICAO Annex 14 — *Aerodromes* and Doc 8168, *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS), both Volume I — *Flight Procedures* and Volume II — *Construction of Visual and Instrument Flight Procedures*. The contractor will coordinate with ATNS and South African Civil Aviation Authority (SACAA) to submit an obstacle evaluation request and have it approved before the installation of the antenna on the site.

3. CONCLUSION

3.1 On the basis of the above, the Conference is invited to:

a) take note of the current initiative on GNSS monitoring in South Africa; and

b) request ICAO, States and organizations to support the implementation of the GNSS monitoring system in South Africa.

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APPENDIX

GLOSSARY OF TERMS

Coarse/Acquisition (C/A) code – is modulated on L1 only and provides relatively inaccurate (coarse) positions compared with the precise code.

Constellation – A group of coordinated artificial satellites.

Cycle Slip – is a discontinuity in a receiver's continuous phase lock on a satellite's signal. A power loss, a very low signal-to-noise ratio, a failure of the receiver software, a malfunctioning satellite oscillator can cause a cycle slip. It can also be caused by severe ionospheric conditions.

Dual-Frequency Receiver – A receiver that detects and records both L1 and L2 signals.

Elevation Mask – An angle above the horizon below which satellite signals are ignored by the receiver. A low elevation mask may result in less accurate positioning because of increased susceptibility to multipath. A high elevation mask may result in more accurate positioning, but with a decrease in satellite availability.

Ephemeris – A set of coefficients used to calculate the orbital position of a satellite as a function of time. Ephemerides can generally be classed as post-processed or predicted. The post-processed ephemeris is determined after observations are made of the satellite and is an estimate of the satellite's position in the period of the observations. The predicted or “broadcast ephemeris” for a satellite is obtained by extrapolating its post-processed orbit for a few days into the future.

Epoch – The time that elapses between recording observations. Epochs are typically 1, 5, 10, 30 or 60 seconds. Some GNSS receivers can be configured to record data at higher rates for special applications. Although it may seem counterintuitive, high data rates (such as 1 second) can be detrimental when processing static observations, resulting in overly optimistic statistics and sensitivity to erroneous measurements at the start of a session. (Static observations are best processed at a 10 to 30 second interval.)

Global Navigation Satellite System (GNSS) – Various operational and proposed satellite positioning systems, including the U.S. Global Positioning System (GPS), the Russian Global Navigation Satellite System (GLONASS), the European Union Galileo, and others.

Ionosphere – A thin region of the atmosphere between 50 and 1500 km above the surface of the earth, containing free electrons, positive atoms, and molecules called ions. The free electrons cause delays and advances in the pseudoranges and carrier phases, respectively, depending on the carrier frequency and the total electron content (TEC) or density of free electrons.

L1 – (1575.42 MHz): is modulated with the navigation message, coarse-acquisition (C/A) code and encrypted precision P(Y) code, plus the new L1C on future Block III satellites.

L2 – (1227.60 MHz): is modulated with the Precision P(Y) code, plus the new L2C code on the Block IIR-M and newer satellites.

L5 – (1176.45 MHz): A result of the GPS Modernization project, a proposed signal that will provide ranging codes and other navigational data. L5 is also proposed for use as a civilian safety-of-life (SoL) signal.

Multipath – Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Multipath is one of the dominant sources of error in GNSS positioning. Causes of multipath include reflective terrestrial objects in the vicinity of the receiver, such as metal surfaces, buildings and trees.

NTRIP – Networked Transport of RTCM via Internet Protocol is a protocol for streaming differential GPS (DGPS) data over the Internet in accordance with specification published by RTCM.[5] Ntrip is a generic, stateless protocol based on the Hypertext Transfer Protocol HTTP/1.1 and is enhanced for GNSS data streams.

Precise (P) Code – is modulated on both L1 and L2. The P-code is modulated at a higher frequency than the C/A-code with the result that P-code positions have finer spatial resolution (higher precision) than C/A-code positions.

RINEX – Receiver Independent Exchange Format is a data interchange format for raw satellite navigation system data.

Single-Frequency Receiver – A receiver that measures L1 signals (only).

Station – A combination of a GNSS receiver and antenna setup at a single location

Troposhere –The troposphere is the lowest portion of Earth's atmosphere, containing the majority of the atmosphere's mass. In the context of GPS, the troposphere can be considered to extend from the surface of the earth to an effective height of about 40 km. The portion of the troposphere in which all weather occurs extends to a height of about 14 km. Variations in the state of the troposphere cause delays in the pseudoranges and carrier phases, independent of the frequency of the carrier.

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