NIGCOMSAT-1R SATELLITE-BASED AUGMENTATION SYSTEM(SBAS) TEST BED TRIAL

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Abstract

In October, 2016 China Great Wall Industry Corporation and Spacestar Technology Company Ltd of China entered into cooperative agreement with Nigerian Communications Satellite Ltd on a Satellite-Based Augmentation System (SBAS) performance test and assessment of the Nigerian Communications Satellite (NIGCOMSAT-1R) augmentation System exploiting NIGCOMSAT-1R L Band. This paper examines test bed experimentation conducted in conjunction with partners to validate functional requirements, performance validation of units, sub-systems and systems of both the SBAS payload and ground infrastructure before a pilot project demonstration of capabilities and proof-of-concept nationwide and extension to parts and regions of Africa

Keywords : Augmentation System, NIGCOMSAT-1R, NSAS, Satellite, SBAS, Testbed.

INTRODUCTION OF NIGERIAN COMMUNICATIONS SATELLITE (NIGCOMSAT-1R)

Nigerian Communications Satellite (NIGCOMSAT-1R) is a 9kW quad-band spacecraft built on the DFH-4 satellite platform and is equipped with a total of 26 transponders, including L1/L5 navigation augmentation transponder payloads. The other bands are C, Ku and Ka Band. NIGCOMSAT-1R (N-1R); the insurance replacement for the NIGCOMSAT-1 communication satellite weighing 5 tonnes, N-1R was launched into orbit in December, 2011 and located at 42.5°E in geostationary orbit. Figure 1 provides an overview of the NIGCOMSAT-1R Spacecraft.

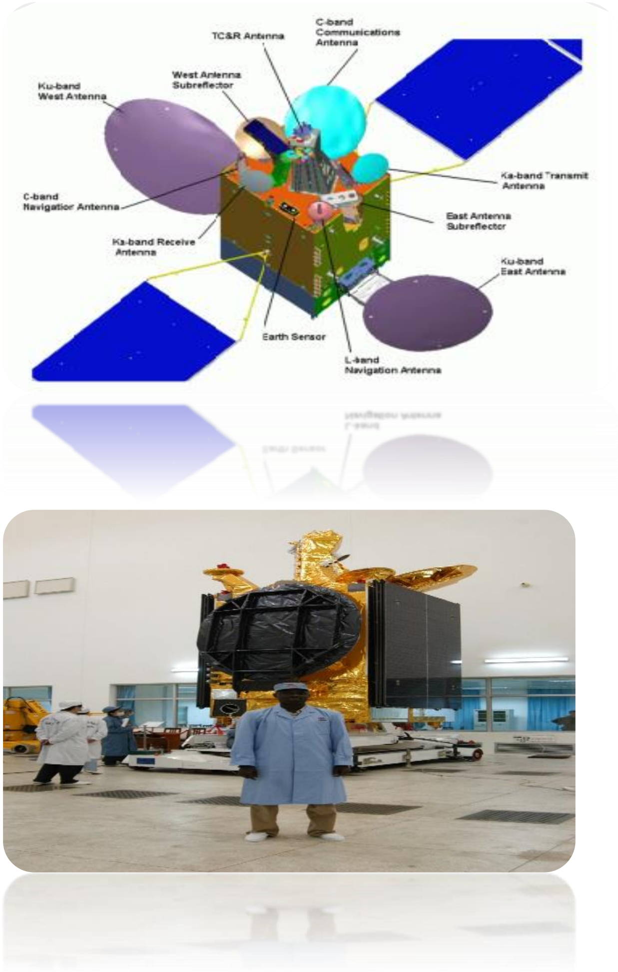

Figure 1: Pictorial view of NIGCOMSAT-1R satellite

NIGCOMSAT-1R L-BAND FPR NAVIGATION OVERLAY SERVICES

The NigComSat-1R Navigation (L-band) payload provides a Navigation Overlay Service (NOS) known as Nigerian Satellite Augmentation System (NSAS). The system augments the Global Navigation Satellite System (GNSS) over Europe and Africa. Dual user frequencies (L1 and L5 frequencies) rather than a single L1 frequency was implemented as a hosted payload on NIGCOMSAT-1R Communication Satellite recognizing its importance and advancement over the single L1 frequency capabilities of the previous GNSS considering the GPS constellation modernization with the additional civil signal on the L5 frequency and the Galileo system.

The system functionality is similar to the European geostationary Navigation Overlay Service (EGNOS), where a number of ground reference stations monitor the GPS satellites' signals and provide their observations to one or more Master Control stations (MCS). An augmentation message is generated by the MCS and two signals, C1 and C5, are transmitted via uplink stations within the uplink coverage areas on the C-band. The navigation payload down converts the C-band signals to L-band, L1 and L5, and broadcasts these signals regionally to users with messages to improve positioning accuracy with integrity.

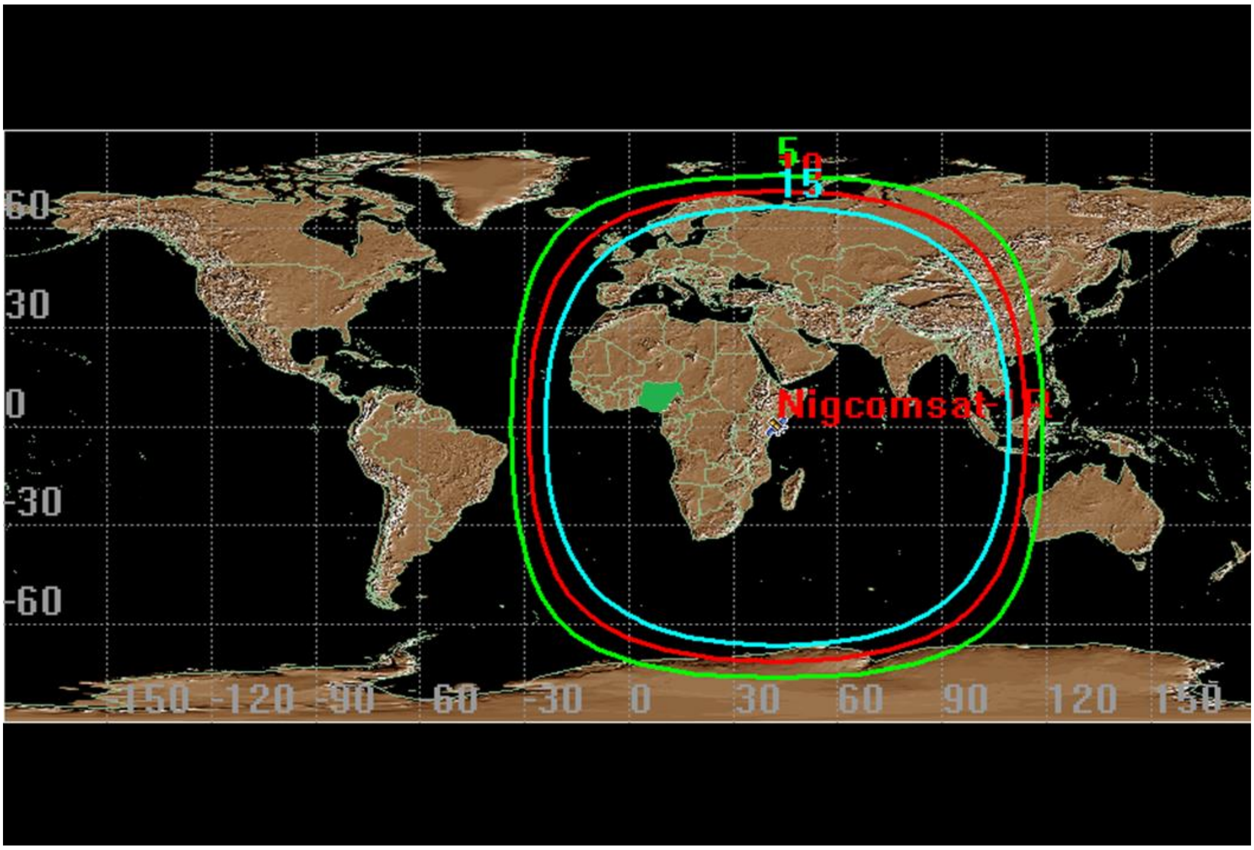

Figure 2: Coverage of NIGCOMSAT-1R Navigation Overlay Services

Figure 2 illustrates coverage of NIGCOMSAT-1R Navigation Overlay Services called Nigerian Satellite Augmentation System (NSAS). The NOS augments the GPS standard positioning service by providing three types of information to users: Ranging information, Differential GPS corrections and Integrity monitoring information (NIGCOMSAT-1R, 2009). The onboard navigation payload has various component redundancies. It is a dual-channel bent-pipe transponder that down-converts two C-band (C1 and C5) uplink signals from a ground earth station to two downlink signals in the two separate bands, L1 and L5. A 4.0 MHz-wide C1 band uplink channel relays in the L1 downlink channel and allows the transmission of the L1 signal while a 20.0 MHz-wide C5 band uplink channel relays in the L5 downlink channel and allows transmission of the L5 signal (1,2,3,4,5 &7).

Table 1: Downlink Frequency and Polarization of NIGCOMSAT-1R L-Band Payload.

Channel	Frequency (MHz)	Polarization	Bandwidth (MHz)
L1-Downlink	1575.42	RHCP	4
L5-Downlink	1176.45	RHCP	20

The beam from the downlink L-band navigation antenna is global, ensuring that NigComSat-1R is capable of broadcasting to its coverage area, GEO ranging signals and Satellite Based Augmentation System (SBAS) signals through the L1 and L5 frequencies as depicted in Table 1. The In-Orbit Test (IOT) was used to validate the functional capability of the navigation payload and its readiness for function and purpose. Figure 4 and 5 shows the EIRP results of the re-launched Nigerian Communications Satellite (NIGCOMSAT-1R) in the L1 and L5 signal bands respectively with the colored right-hand bar showing measured results in dBW(6).

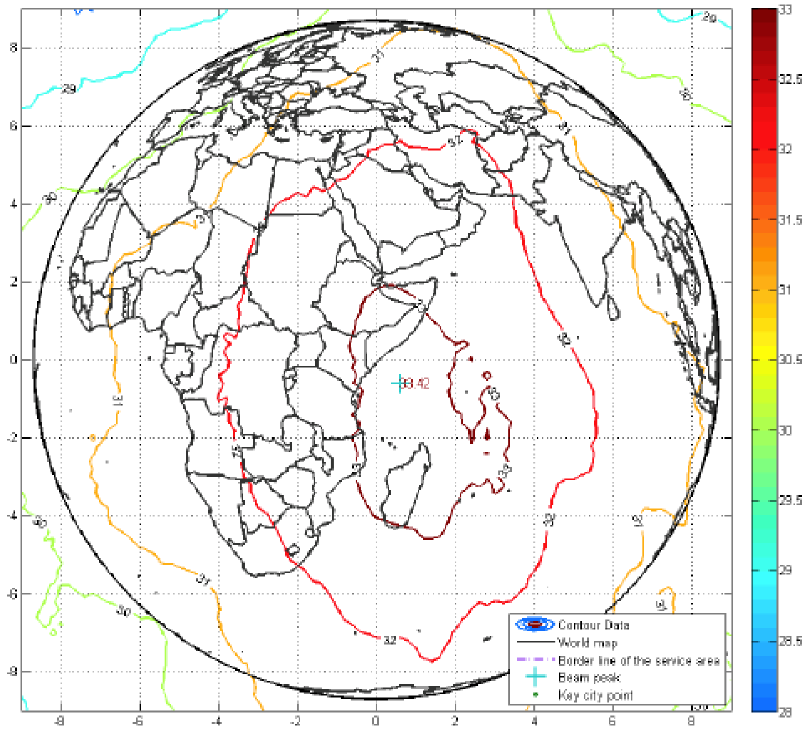

Figure 3: The Downlink coverage beam (L1-Band) of NIGCOMSAT-1R Geo-Navigation Satellite using Dual L-Band Helix Antenna.

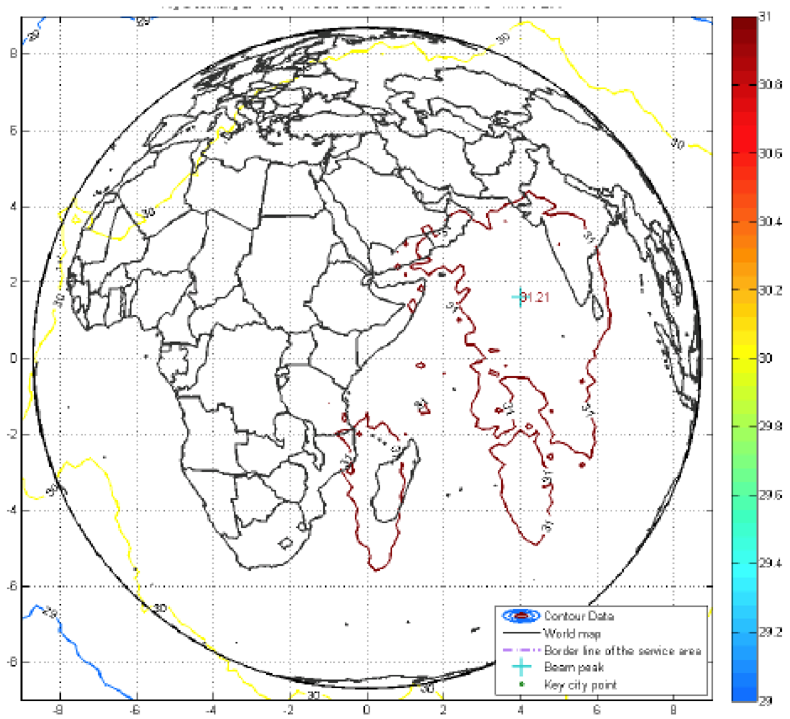

Figure 4: The Downlink coverage beam (L5-Band) of NIGCOMSAT-1R Geo-Navigation Satellite using Dual L-Band Helix Antenna.

DISCUSSION OF NIGERIAN SATELLITE AUGMENTATION SYSTEM (NSAS) TESTBED TRIAL.

A test bed experimentation was conducted in conjunction with partners to validate functional requirements, performance validation of units, sub-systems and systems of both the SBAS payload and ground infrastructure before implementing a nationwide pilot project as a demonstration of capabilities and proof-of-concept for Africa countries and regions. One reference station situated at Abuja Ground station was used for the functional tests. The workflow of the system architecture is as depicted in figure 5. The system collects GPS monitoring station data to generate satellite ephemeris, ionospheric correction, integrity parameters, and broadcasts augmented information through GEO satellite; Nigcomsat-1R.

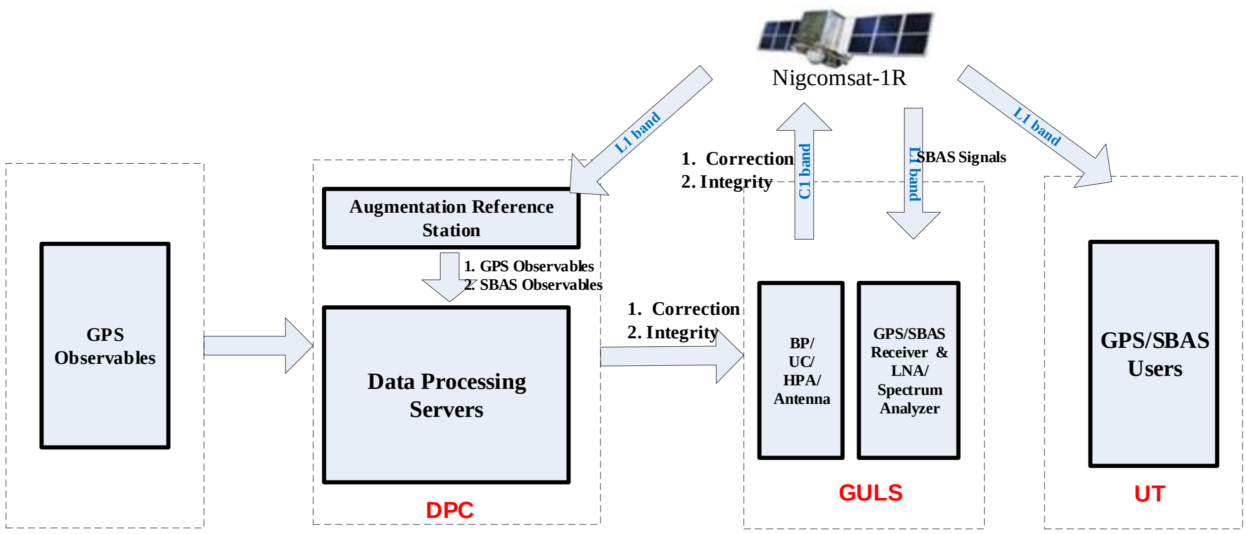

Figure 5: Workflow of the System Test Architecture.

The functional requirements covers generation of SBAS messages, coding of SBAS messages in accordance with the Radio Technical Commission for Aeronautics (RTCA) 229D standard, GPS Single Point Position (SPP), SBAS Single Point Position (SPP), SBAS Precise Point Position (PPP) and SBAS L-band alarm function, while the general performance requirements validation were as follows:

i. Coding format: RTCA, 250 bps;

ii. GPS SPP accuracy: Horizontal (H)<3.0m,Vertical (V)<4.0m;

iii. SBAS SPP accuracy: Horizontal (H)<1.5m,Vertical (V)<2.0m;

iv. SBAS PPP accuracy: H<0.3m,V<0.4m;

Some of the test results among others show that the SBAS system operates normally, is stable and meets all design functions and performance requirements. On December 12, 2017, a single-frequency terminal and a dual-frequency terminal were used in the Abuja reference station to perform single-frequency and dual-frequency SPP and PPP positioning performance tests. The Klobuchar ionosphere model estimation was used for the single-frequency; SPP while ionosphere-free combination was used for the dual-frequency PPP. GPS SPP is a single-point positioning using basic navigation, SBAS SPP is a wide area differential correction mode, and SBAS PPP is a precise single-point positioning using SBAS augmentation information (8).

Figure 6 shows both the tracking graph and Skyplot of the GNSS and SBAS signal-in-space including the NIGCOMSAT-1R Augmentation Signal on Pseudo Random Noise (PRN) Code 147 known as Nigerian Satellite Augmentation System (NSAS)

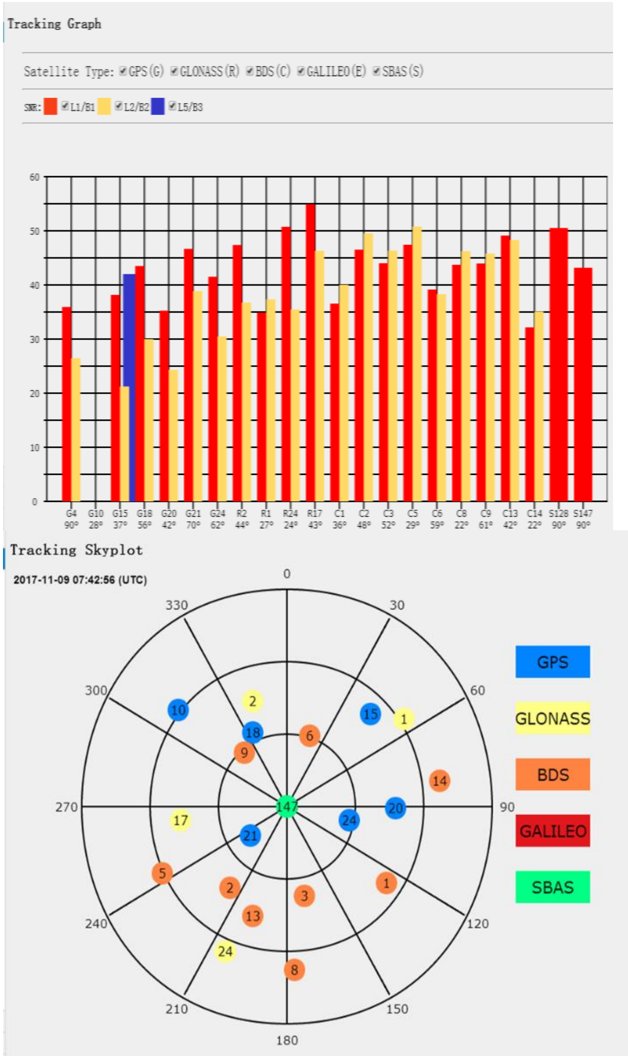

Figure 6: Tracking Graph of GNSS and SBAS signals (G=GPS, R=GLONASS, C=BDS, S147=Nigerian SBAS)

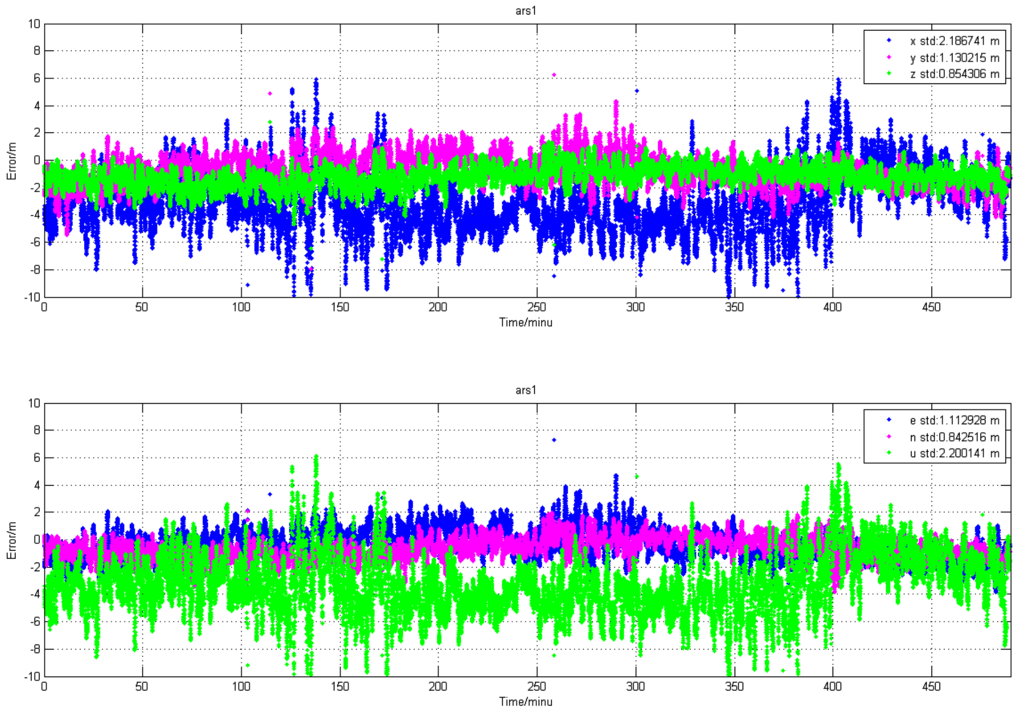

Figure 7: Graphic GPS Single-Frequency SPP Test Result in both Horizontal/Vertical Dimensions and E-N-U Coordinates.

NIGCOMSAT-1R SBAS Dual Frequency Precise Point Positioning(PPP) yielded the following position data results X<0.25m, Y<0.20m Z < 0.09m; E<0.18m N<0.07m, U<0.27m; H<0.19m V<0.27m as shown in figure 8 and 9 respectively, which met test performance criteria.

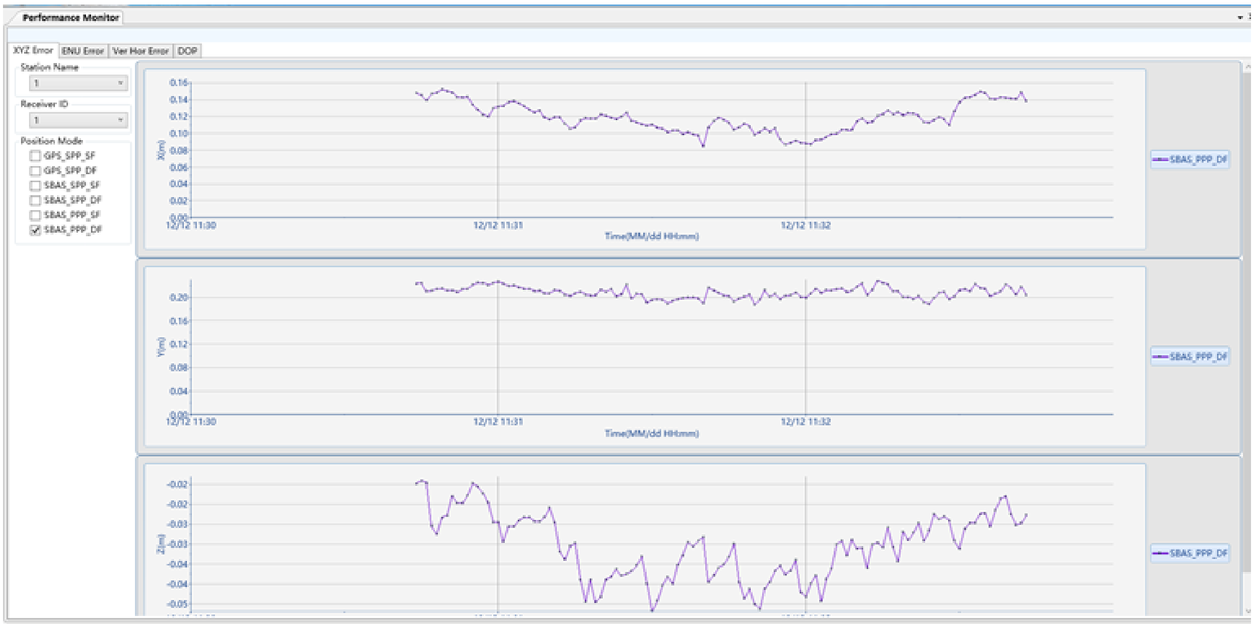

Figure 8: NIGCOMSAT-1R SBAS Dual-Frequency PPP Test Result in X-Y-Z Coordinate System

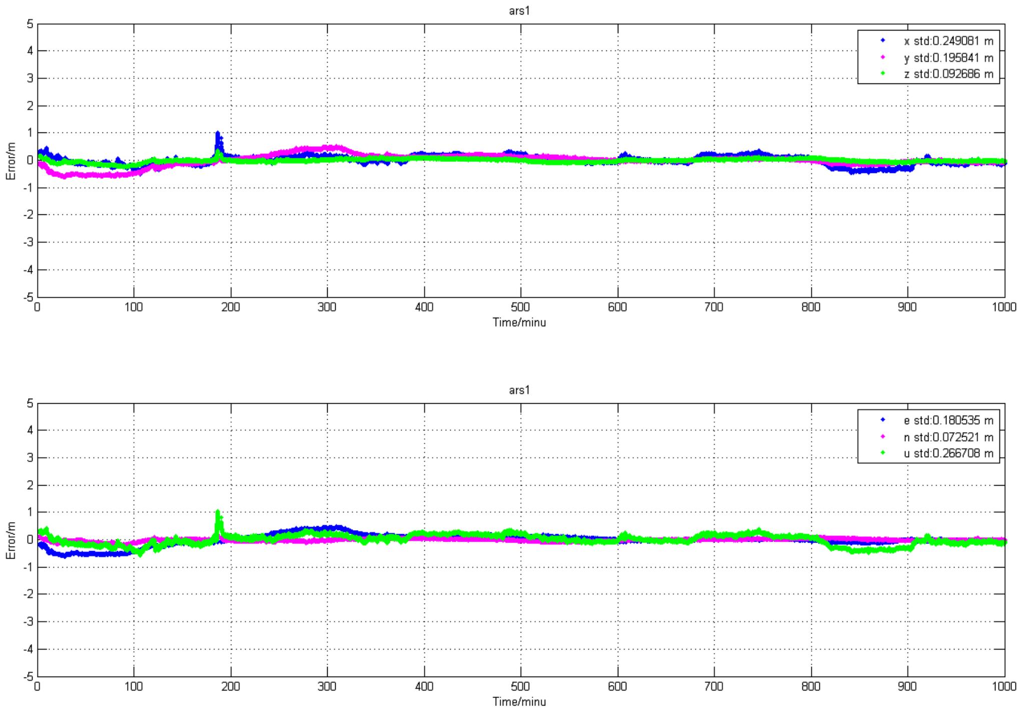

Figure 9: NIGCOMSAT-1R SBAS Dual-Frequency PPP Test Result in both Horizontal /Vertical Dimensions and E-N-U Coordinates.

The SBAS System Reliability Test

In order to evaluate the system reliability, SBAS messages of week 1977 were analyzed. The types of broadcast information include eight types: 0, 1, 2, 3, 4, 25, 29, and 30. In theory, the total SBAS message should be 606800, and the real received SBAS message is 606780, 20 SBAS messages were lost based on the test criteria. Thus, data loss rate is 0.0033%.

CONCLUSION

The test bed analysis of signal-in-space capability with very high availability has been demonstrated on pseudo random noise code 147, by NIGCOMSAT Ltd in conjunction with partners meeting the overall objective of commencing nation-wide pilot project as a demonstration of capabilities and proof-of-concept for Africa countries and regions including test performance in conjunction with ASECNA (The Agency for Aerial Navigation Safety in Africa and Madagascar).

Test results confirm design functionality compliance and performance criteria however, system positioning accuracy will achieve better precision after full deployment of ground infrastructure, after which aviation sector application tests and functionality will begin. The certification plan in compliance with the International Civil Aviation Organization (ICAO) will follow as soon as a second Geo-Satellite is launched on the NigComSat-2 satellite presently work-in-progress to support continuity. It is important to note that commercial aircraft are five times more likely to have an accident flying a non-precision approach than flying a precision approach as reiterated by the Flight Safety Foundation.

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