International Committee on Global Navigation Satellite Systems

International Committee on Global Navigation Satellite Systems

Experts Meeting on

Global Navigation Satellite Systems (GNSS) Services

Vienna, Austria

15 - 18 December 2015

Abstracts

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Algeria

Feasibility Study and Site Choice for an EGNOS Station in Algeria

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EGNOS (European Geostationary Navigation Overlay Service) provides data for more accurate positioning with an integrity message that improve the existing services of the GPS system.

This allows to develop a wide range of new applications for different segments such as air navigation, mapping, agriculture, road developments and geolocalisation services.

It consists of several navigation payloads installed on geostationary satellites and more than 40 terrestrial stations networks (RIMS, CMC and NLES) comprising in a geographical area covering Europe and the Mediterranean countries.
Implementing facilities of an EGNOS RIMS (Ranging and Integrity Monitoring Station) ground station in Algeria will provide the corrections made by the system on the Algerian territory, and will certainly offer several advantages, particularly in terms of accuracy, availability, integrity and reliability.

This preliminary feasibility study, using the ESA SBAS Simulator, for the implantation of a RIMS station in Algeria whose latitude would be between 30 ° and 35 ° follows a request from the European Space Agency.

Initially, the sites of Tamanrasset (far south of the country) and El Golea (Centre) were proposed and discussed. If the site of Tamanrasset was considered technically not very favourable for interference reasons (results of the site Survey), the El Golea site, among the ten prospective other sites, present the best technical features and a good coverage of the considered area (for latitude >25 °).

Performances of EGNOS system in Algeria are thus mainly evaluated in terms of precision positioning and integrity, through three parameters: the error of the navigation system, the protection level, and the vertical precision error of the ionospheric grid.

The preliminary results of the feasibility study of the choice of EGNOS RIMS station site in Algeria show that setting up a site in the centre of the Algeria (El Golea) will allow to have a good exploitation of the system and at the same time the expansion of its service area.

Australia

Precise GNSS Positioning -- Not Just a Niche Technology

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We are witnessing the launch of a surge of new navigation satellite systems, with a significant increase in satellites and signals. This heralds the transition from a GPS-dominated era – that has served the precise positioning and navigation disciplines for over 30 years – to a multi-constellation GNSS world. Precise Positioning is becoming mainstream, and the influence of the surveying, geodetic mapping and precise navigation communities will grow as a massive new class of users embrace the new GNSS technology and confront issues such as datums, reference station infrastructure, integrity, value-added services, and new user applications in personal mobility and advanced transport systems.

The first civilian applications of GPS were for geodetic surveying and geodetic science. From those first precise positioning applications of GPS have evolved today's techniques based on carrier phase tracking and relative positioning, in which receivers were deployed on reference stations to provide the datum and to facilitate the mitigation of spatially-correlated measurement biases. The evolution of precise differential positioning techniques during the 1980s and 1990s also led to the establishment of geodetic services that supported global geodesy and precise positioning.

The International GNSS Service (IGS) and the International Earth Rotation and Reference System Service (IERS) are two critical services that continue to provide high quality products. Several technological developments led to the mainstreaming of precise positioning techniques such as "Real-Time Kinematic" (RTK), that are now used for almost all engineering, construction, surveying and machine guidance applications.

In the last years a new Precise Point Positioning (PPP) technique has been under investigation, and several commercial services have been launched. The IGS Real-Time Service is also contributing to the development of real-time geodetic services for science applications such as tsunami warning systems. This presentation examines the implications of PPP for traditional positioning and navigation applications using multi-constellation GNSS, but also speculates on what type of precise positioning technique, and commercial or scientific services, will be used for future precise positioning applications of driverless cars and other advanced Intelligent Transport System (ITS) applications.

Brazil

A joint project of the University of Brasilia and the International Centre for Theoretical Physics on GNSS applications

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During the Final Discussion held in Krasnoyarsk (2015, May 18th-22nd) of the "United Nations/Russian Federation Workshop on the Applications of Global Navigation Satellite Systems (GNSS)", the advice of joint projects and initiatives on GNSS related topics as follow-up of the meeting has been expressed and encouraged. In this context, the Laboratory for Application and Innovation in Aerospace Science (LAICA) of the University of Brasilia (UnB), Brazil, and the Telecommunications/ICT for Development Laboratory (T/ICT4D) of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, have started investigating possibilities for cooperation in the field of Precise Point Position and related ionospheric studies in the region of Brasilia, Brazil. The result has been the project presented here.

LAICA gathers all initiatives developed within the aerospace field at UnB. In the context of GNSS, LAICA has been involved in operations towards the enhancement of the quality of navigation using GLONASS in the Latin-America Region. Since July 2014, it is responsible for the regular operation of the Russian serial laser station «Sazhen-TM-BIS» (IRLS Site Code BRAL, Station # 7407, DOMES# 48081S001, 15.7731 S, 132.1347 W) that was deployed at UnB equiped with the MS-GLONASS double frequency navigation receiver designed for continuous tracking of GLONASS and GPS satellites signals. Furthermore initial tests of other low cost GLONASS receivers for different applications in positioning and tracking are already underway at the UnB. Case studies with low cost uBlox receiver and transmission via APRS made in Brasilia are under evaluation.

On the other hand, the expertise of the ICTP T/ICT4D, located in Trieste (Italy), in the field of ionospheric pure and applied research and Space Weather impact on GNSS performance is well known. ICTP though its T/ICT4D has been involved in research and development ionospheric studies related to the implementation of the EGNOS and GALILEO European navigational systems. For these reasons the centre is in a suitable position to contribute to the type of research proposed in this project.

The main objective of the joint project is to assess the impact of using both GPS and GLONASS constellations instead of stand-alone (GPS or GLONASS) solution for Precise Point Positioning (PPP) in the area around Brasilia. This region is strongly affected by the Ionospheric Equatorial Anomaly (IEA) that implies a highly variable ionosphere. The particular condition of the ionosphere in that geographical area will be investigated using Total Electron Content (TEC) data extracted from the GNSS receiver installed at the UnB, a component of the «Sazhen-TM-BIS» station. Using this receiver, the ionospheric irregularities events affecting the signals in the Brasilia region would be investigated by means of TEC and Rate of Change of TEC (ROT).

The main activities foreseen in the project would be as follows:

- Ionospheric irregularities over Brasilia area (as a function of season and time of day, during disturbed and quiet condition of the ionosphere and its relation to Space Weather events) would be investigated using TEC data derived from the receiver observations.
- The impact of using the combination of GPS and GLONASS on precise positioning would be assessed and compared with the results obtained by using stand-alone (GPS or GLONASS) solutions.
- The observed positioning degradation as a function of ionospheric disturbances would be assessed to characterize the impact of ionospheric phenomena on the GNSS receiver.
- The positioning results in terms of accuracy and the convergence time improvement of the combined GPS and GLONASS data would be evaluated.

China

Status Report on BeiDou International Exchange and Training Center

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The UN Regional Centre (RCSSTEAP) in China was inaugurated on November 17, 2014 at Beihang University. During last year, we have constructed the personnel and system to facilitate the sustainable development of the center.

More than 40 participants are pursuing Mater/Ph.D degrees in RS/GNSS/SmallSat areas in year 2015. Three 10-day training activities are held by the center. We are working with enterprise/industry to offer practice opportunities for participants. International experts are invited to have lectures and courses for these participants. In the next year, we will continue our GNSS Degree program in GNSS, Remote Sensing and GIS, Space Law and Policy areas. Until now, three training program on GNSS technology and applications, Micro Satellite technology and applications, Remote Sensing and GIS applications might be held in Beijing.

In the center, we have set up an exhibition hall and a smart classroom. The new type smart classroom can provide more collaborative activities than traditional lecture class. Each one to six participants can gather into a group to solve problems in the room. The signal of all GNSS satellites are received and forwarded to the classroom by the antenna on the top of building. This make the GNSS experiment can be done without coming outside. The participants can use software receiver and other GNSS experiment equipment to analyze the GNSS signal, to test different signal processing algorithms and to complete their courses. The courseware of GNSS principle and visualization tools are published on center's website for worldwide GNSS education. In future, the education cost can be reduced by using such online training/MOOCs methods.

Croatia

Citizen Science for GNSS Performance Monitoring and Assessment

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Citizen Science is a new form of voluntary involvement of lay-individuals in collection of data (observables) with potential of providing new scientific or engineering insight into and understanding of observed processes. With technology becoming more affordable, the lay-individuals around the world increasingly donate money, effort and time in collecting data with potential of later scientific or engineering analysis. Two case scenarios (of the observation processes conducted by amateur meteorologists and ham radio operators) are presented in order to illustrate the potentials, benefits and pitfalls of such activities. Here the Citizen Science approach is proposed as a partial solution for a chronic lack of field data desperately needed for targeted analysis of GNSS performance monitoring and assessment for a number of GNSS-based applications (the mobile ones in particular) that require Quality of Service established by GNSS performance. An honest account of reasonable expectations from such an activity is given, along with the methods and techniques for data cleaning from measurement noise and error, and open-source software-based data processing. Finally, a call for an initiative for a UN ICG-backed international co-operation on establishing standardised procedures for GNSS Citizen Science data collection, storage (with open access), processing and interpretation is presented, with the aim to provide researchers, engineers, business developers, regulators and general public with a framework for impartial GNSS performance assessment based on field data.

This lecture is based on the paper presented at 9th Annual Baska GNSS Conference (Baska, Krk Island, Croatia). Traditionally organised in May, the Annual Baska GNSS Conference addresses the latest and emerging developments in GNSS core PNT, development of resilient GNSS (especially against space weather, ionospheric and jamming effects), signal processing for GNSS receiver design, GNSS alternatives, and GNSS PNT navigation and non-navigation applications (incl. intelligent transport systems, GNSS-R, location-based services, space weather and ionospheric monitoring).

KEY WORDS: CITIZEN SCIENCE, GNSS PERFORMANCE, STANDARDISED PROCEDURE, GNSS APPLICATIONS

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Croatia

Methods and Techniques for Improvement of GNSS Resilience Against Jamming-Spoofing-Meaconing Attacks at the Open Sea

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Satellite navigation has become a public good, with the growing number of navigation and non-navigation applications being established on the technology. Potential threats on GNSS performance and operation have become the increasing concern of developers, operators and users of GNSS-founded systems and services, with the especial emphasis given to malicious artificial attacks, such as jamming, spoofing and meaconing (JSM).

A targeted artificial attack on GNSS performance and operation can cause a considerable material damage and affects lifes. Here the potential consequences of the artificial attack on GNSS performance on the vessel navigation at the open sea are addressed, and a combined technological-procedural mitigation scheme for JMS- resilient GNSS Position, Navigation and Timing (PNT) performance at the open sea is proposed.

Through the technology-supported modifications of navigation procedures a reasonable GNSS Quality of Positioning at the open sea can be achieved, overcoming the potential malicious attack on the vessel in the area with the reduced supporting Information and Communication Technology (ICT) infrastructure. This lecture is based on the paper presented at 8th Annual Baska GNSS Conference (Baska, Krk Island, Croatia).

Traditionally organised in May, the Annual Baska GNSS Conference addresses the latest and emerging developments in GNSS core PNT, development of resilient GNSS (especially against space weather, ionospheric and jamming effects), signal processing for GNSS receiver design, GNSS alternatives, and GNSS PNT navigation and non-navigation applications (incl. intelligent transport systems, GNSS-R, location-based services, space weather and ionospheric monitoring).

KEY WORDS
1. GNSS PERFORMANCE 2. JAMMING 3. SPOOFING 4. MEACONING

GNSS services in Estonia: ESTPOS as a case study

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GNSS permanent station network in Estonia (ESTREF) was established in 2007, various GNSS services were developed shortly after this. Altogether five permanent stations were included to ESTREF network, providing the monitoring and control of the Estonian geodetic system. In 2014-2015 the Estonian GNSS-RTK permanent station network (ESTPos) was developed, consisting now of 27 GNSS permanent stations. Together with establishment of new GNSS stations, GNSS-RTK network solutions were introduced. In the paper the overview of the reconstruction of ESTPos network is given, as well different GNSS instruments, used in different timeframes within the permanent station network are listed. Various GNSS services have been introduced for ESTREF and ESTPos networks, together with demanding needs for the software used and as well for different use cases. For reference frame establishment, all stations of permanent station network have ETRS89 coordinates in national realization EUREF-EST89, computed by Bernese 5.2 software, and verified with different time-series analysis programs. Last but not least, the future insights and cooperation ideas will be introduced.

Finland

Multi-GNSS and deeply-coupled integration of sensors for interference mitigation

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Modern society is becoming more and more dependent on accurate and reliable position, velocity and time (PVT) information acquired using Global Navigation Satellite Systems (GNSS). Unfortunately, GNSS signal is vulnerable to interference. Intentional interference, jamming and spoofing, is rapidly increasing and may cause serious damage if interfering signals are not properly detected and effects mitigated.

Two promising approaches for mitigating the effects of interference are the use of multi-GNSS and deeply-coupled integration of sensors into the GNSS receiver. It is very rare that one jammer could interfere with signals from multiple systems having different frequencies. FGI-GSRx is a Matlab based software defined GNSS research receiver built on an open-source platform and it is used herein for the studies of interference mitigation. At present, the receiver is capable of computing a navigation solution using GPS (L1), BeiDou (B1, B2), Galileo (E1) and GLONASS independently, as well as providing a multi-GNSS solution using all systems. The multi-GNSS solution is able to integrate IRNSS as well.

Deeply-coupled, also referred to as ultra-tight, integration of GNSS and Inertial Navigation System (INS) uses information obtained from the inertial sensors, namely gyroscopes and accelerometers, to aid the GNSS signal processing algorithms. The measurements obtained using INS are not affected by jamming or spoofing and therefore the integration results in a system with enhanced robustness to interference. However, the performance of INS suffers from measurement biases that accumulate to large position errors with time. Typically deep-coupling corrects the above mentioned INS errors using the GNSS signals, but if the jamming continues for a longer time forestalling the use of proper GNSS signals, degradation of the position solution will incur after some period. Visual sensors, i.e. cameras, are feasible instruments for constricting the growth of the errors and are resistant to GNSS jamming. In favorable environments and special camera configuration, camera attitude and translation between consecutive images may be detected. These measurements may further be used for mitigating the errors in INS observations. Deeply-coupled integration of the visual measurements, INS and GNSS will further improve the robustness of the positioning accuracy in situations where the jamming is not only momentary.

This presentation discusses the methods developed at the Finnish Geospatial Research Institute for detecting the presence of a jamming signal and for mitigating its effects utilizing above discussed multi-GNSS and deeply-coupling of sensors. Results from experiments deploying the developed methods and a cheap commercial jammer in a laboratory environment will be discussed.

France

Training on Space Weather in Developing Countries

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In this paper we presented the evolution of the training in Geophysics and Space Weather, mainly in developing countries (Africa and Asia) from the period 1992 until now. The implementation of GPS in many countries allows the development of Space Weather research.

The following points presented are:

The definition of the work (this point changes from one country to another)
The training of students (school and PhD)
The organization of research groups in the various countries
The curricula on Space Weather in the Universities of the different countries
The publications in international scientific journals.

Indonesia

Information of Space Weather Effects to GPS/GNSS for Fishermen Activities in Indonesia

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As a develop archipelago country, one of the prime focus sector that needs to developed and improved in Indonesia are fishermen. Navigation systems are very important tools for the activities of fishermen. From small ship to the large vessel, navigation systems are needed for fishing and surveillance activities over the sea. Almost all fishermen have their own GPS receiver to be use as a prime navigation tools and this condition have a positive trends. Unfortunately, by the limitation of the fund of the fisherman, which impact to the GPS receiver instrument that can bought by the fishermen, and also by the limitation of knowledge to use the function of GPS receiver, the effect of space weather conditions could lead some misunderstanding in some situations. Fishermen could not understand for some situation that could appear in their GPS/GNSS receivers when there was a space weather disturbance conditions. Meanwhile, the fishermen in Indonesia could not have any integrity information services of GPS/GNSS, since the augmentation system have not been developed yet. This situation leads LAPAN to support the use of GPS/GNSS receiver by introduce other alternative integrity information format for navigation system due to the space weather effects. Information are globally provide in the Indonesia Space Weather Information and Forecast Services (SWIFtS) form with website address, www.swifts.sains.lapan.go.id and it is forwarded to the fishermen using the Single Side Band (SSB) Radio services. The improvement of the SWIFtS services and also the capability of the researcher to be a bridge information are the homework for LAPAN to provide the useful information that related to the user needs.

Italy

The NeQuick Ionosphere Electron Density Model: GNSS Applications

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NeQuick 2 is the latest version of the NeQuick ionosphere electron density model developed at the Abdus Salam International Centre for Theoretical Physics - Trieste, Italy in collaboration with the University of Graz, Austria. It is a quick-run model particularly designed for trans-ionospheric propagation applications that has been conceived to reproduce the median behaviour of the ionosphere. It allows to calculate the electron concentration at any given location and thus the Total Electron Content along any ground-to-satellite ray-path by means of numerical integration.

In this presentation the diverse model uses and developments will be outlined, with particular focus on the GNSS related applications.

Indeed, a specific version of NeQuick, the NeQuick G, has been implemented by the European Space Agency as the Galileo Single-Frequency Ionospheric Correction algorithm and its performance has been confirmed during "In-Orbit Validation".

Furthermore, the International Committee on Global Navigation Satellite Systems Working Group B has recommended to distribute "the document providing the detailed description of the NeQuick algorithm implemented in Galileo" and to "to assess the performance and usability of a NeQuick ionospheric correction algorithm for the single frequency users similar to the one adopted by Galileo".

Attention will also be given to the assessment studies performed with the model in order to investigate specific effects of the ionosphere on satellite navigation systems. Relevant aspects concerning the implementation of assimilation techniques based on NeQuick and allowing to pass from a "climatological" to a "weather-like" representation of the ionosphere will be finally discussed.

Jordan

Impact of Multipath Error on Availability of Integrity in GBAS Applications

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Background and Motivation:

In a satellite based navigation environment the ground based augmentation system (GBAS) is intended to be used for precision approach from CAT I to III. Standards and developments are available for CAT I. At present there are activities under way on requirements definition and standardisation of GBAS for CAT II/III. Where current GBAS CAT I is limited to GPS only and on L1 single frequency processing, it is recognised that future standards should take also Galileo into account. Galileo provides improved constellation, better signal characteristics and will allow dual frequency processing for safety of life applications. The GBAS CAT II/III high level requirements and the methods for their derivation are under discussion. Of most controversy is the value for the vertical alert limit. Values discussed are between 2.2 and 10m with significant impact on the possible GBAS configurations in terms of the useable satellite constellations, signals and frequency monitoring and processing and the necessary level of error mitigation on equipment level.

A previous study indicated that multipath, especially user multipath, is a limiting factor in achieving CAT II/III requirements with Galileo GBAS as well as with GPS GBAS. The Galileo signals provide new options to mitigate multipath. The previous study gave only some indications on the impact of user multipath. Systematic investigation by a methodical variation of parameters is needed. Investigation of the reasons and mitigation methods is needed as well. This is the major motivations for the master thesis which is titled as "Impact of Multipath Error on Availability of integrity in GBAS Application " and abbreviated as "IMEA-GA" study.

The work was structured along the following two major tasks:

The first task comprises a performance assessment to analyse the necessary level of multipath suppression to reach acceptable availabilities for different levels of requirements namely different vertical alert limits. The analyses was done by means of service volume simulations for GPS and Galileo constellations, taking into account different values for the vertical alert limit, different equipment designators and different numbers of critical satellites.

The second part of the work is concerned with analysis on the reasons for multipath and the methods for multipath mitigation for different signal characteristics of GPS and Galileo. For this a Matlab software was developed. The results of both tasks were validated by comparison of results from other sources which have made similar investigations.

Objectives:

The detailed objectives of the work are as follows:

- ❖ To investigate by means of a simulation tool which degree of multipath mitigation is required (in combination with other parameters impacting the availability of integrity) to achieve CAT II/III requirements with a single constellation on a worldwide level.
- ❖ To investigate the general impact of user multipath on GBAS performance based on a systematic variation of the selected parameters in organized sets:
- Primarily: to show dependency on user multipath by reducing the multipath basic figure by different factors (A, A/2, A/4, A/10)
- To show dependency on number of critical satellites (no, 6, 2, 10)
- To show dependency on constellation (GPS 24, Galileo 27, GPS 29)
- To show dependency on Vertical Alert limits (10m, 5m, and 2.5m).
- To show dependency on Receiver(s) Accuracy Designators GAD/AAD (AA, BB, CB)
- To show dependency on GS/User Receivers Performance (SF, DF)
- ❖ To find parameter-set(s) where CAT II/III can be achieved (or: nearly be achieved) with a single constellation over a global coverage.
- ❖ To find parameter-set(s) where CAT II/III can be achieved (or: nearly be achieved) with a single constellation over a ‘USA only’ coverage and ‘Europe only ‘coverage.
- ❖ To document the user multipath reasons and methods of mitigation.
- ❖ To investigate be means of Matlab software, the improvements of the new BOC modulation scheme over the currently BPSK scheme in terms of code measurement and phase measurement multipath envelopes.
- ❖ To validate all the achieved results with similar outputs of other softwares as much as possible.

Assumptions for the Simulations:

Basic Assumptions:

- ❖ The basic parameters are those parameters that have been used nowadays in the GPS constellation they are derived from the ICAO standards, they are representing the nowadays single frequency parameters using the standard ICAO error models values of A, B, and C letters parameters for the GAD (Ground Accuracy Designator). And the standard values of letter A and B letters for AAD (Airborne Accuracy Designator), And the standard values of A and B for AMD (Airborne Multipath Designator).

- ❖ The hypothesis of fault-free receivers was assumed. And the negligible tropospheric error also, 4 ground station reference receivers and 100 sec convergence time for the smoothing filter.
- ❖ Its assumed to perform the simulation globally.
- ❖ It's assumed that the UDRE error Budget for GPS/GBAS System will be the same as UDRE error Budget for GALILEO/GBAS system during the simulations to be comparable with other studies.
- ❖ It's assumed also to limit the simulations on the vertical alert limit values only due the sensitivity of this parameter in the final approach over the lateral alert limit values.
- ❖ Simulations will be performed for single GNSS constellation only.
- ❖ The mask angle for GPS is assumed to be 5 Degree, and for Galileo will be 10 Degree.

Additional Assumptions

- ❖ The additional parameters are those which have been modified due to the expected improvement of the new GNSS2 world, including the modernized GPS and Galileo constellation as they will use new signal structure (BOC signals), as well as the state of the art technologies that will take place in the domain of UMPE mitigation.
- ❖ Some of those additional assumptions were proposed by the working groups 28 and 62 in EUROCAE publications. They are representing the nowadays dual frequency parameters. The standard ICAO error models will be divided by a factor of 2 for both GAD and AAD parameters.
- ❖ Based on the discussions with experts, its assumed that a reduction of AMD by a factor 4 should be possible. A reduction by a factor of 10 seems to be over optimistic but it is taken into account in the simulation work.

Major Results and Findings

Service Volume Simulations:

Global Availability

- ❖ Table 6-33 summarizes the main results on the global average bases, for dual and single frequency and various equipment designators in variation of the multipath performance. The chosen availability targets were 99,99% and 99,75% and three different values for VAL (10m, 5m, 2,5m) values are assumed. Different levels of ground and airborne equipment types were assumed indexed from low level AA to high level CB. For sensitivity analysis reason the number of critical satellites was varied.
- ❖ Availability of GNSS-GBAS increases when the user multipath error decreases

- ❖ Simulations showed significantly improvement of all the selected GNSS constellation availability of integrity in GBAS system after the first level of multipath error mitigation (A/2) in comparison with other mitigation levels.
- ❖ There was strong positive impact on availability in the lower VAL values (2.5m) against visible impact in the middle VAL values (6m) and minor impact in higher VAL values (10m)
- ❖ No significant difference in the way of how different GNSS constellations response to the variation of User Multipath Error levels (UMPE) (A, A/2, A/4, A/10), But more sensitive response of Galileo over GPS performance.
- ❖ DF (Dual Frequency) receivers have higher increment in availability, higher improvement, in both the maximum and the average, than the SF receiver when UMPE decreases.
- ❖ Major availability improvement responses to UMPE error mitigation in CB, BB, types against less improvement responses with lower equipment performance type AA.
- ❖ For a VAL value of 10m a globally averaged availability target of 99.99% and better will be reached in single and dual frequency mode with both constellations with no or moderate multipath mitigation levels.
- ❖ A VAL in the order of 5m with an availability of 99.99% can be reached with Galileo dual frequency and moderate improvements in multipath mitigation. With single frequency Galileo can reach 99.75 %. availability. For the same level with the GPS nominal constellation dual frequency is necessary
- ❖ On a global average bases the availability targets could not be reached for a VAL of 2,5m by means of multipath mitigations only, but may be reached with dual frequency by applying additional means of improvement.
- ❖ The availability plots for GPS and Galileo shows different characteristics which are related to the different satellite constellations. The areas of bad availability for GPS shows spots of different size which are continuously moving over time. In the Galileo case the simulation shows stable stripes parallel to the equator of degreased availability. That’s why Galileo GBAS can have very good availability in certain fix geographical areas, e.g. Europe.

Special simulations over (Europe and USA):

- ❖ Galileo 27 constellation was able to meet VAL requirements of 2,5m of 99,99% or better for an average over Europe only with the given input parameters of the best GBAS equipment configuration of CB-DF, and it was very close (99,404%) over USA. But GPS was not able to meet these requirements.

Analysis on the reasons for multipath and the methods for multipath mitigation:

- ❖ Multipath phenomenon is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths
- ❖ The multipath mitigation methods could be:

- Receiver based methods
- Antenna based methods
- Sitting based methods

❖ The currently used receiver based methods could be correlator based methods or signal structured methods

- The correlator based methods could be the standard correlator: could improve multipath error in magnitude of 80 meters. The narrow correlator : C/A code were reduced to about 8–10 meters. Multipath Estimation Technology (MET): improvement to 50% more than narrow correlator. As well as Multipath Estimating Delay-Lock Loop (MEDLL)., Modified Correlator Reference Waveform (MCRW), Multicorrelator, and Pulse Aperture Correlator(PAC)

❖ The signal structured methods: which are based on the idea of spreading the power over higher frequencies than the Center frequency only. They are : Binary Phase Shift Keying (BPSK), Binary Offset Carrier (BOC), Multiplexed Binary Offset Carrier (MBOC).

Matlab Software:

❖ The outputs of the Matlab software showed:

- The chip spacing and the relative amplitude are the key factors in multipath mitigation in the code tracking loop.
- The relative amplitude is the key factor in decreasing the multipath error in the phase tracking error.
- The future waveform that will be used impact the multipath error in such away that BOC(2,2) has the best performance among all, BOC(1,1) has better performance than the currently used BPSK.
- The increase of bandwidth causes a decrease in the multipath error to a certain limit.
- Type of filter used affects the multipath envelope with ripples.
- Type of filters used will delay the discriminator with internal error, but it can be offset.

❖ This software could be used as a simulating tool for the many purposes:

- Manipulating multipath parameters.
- Manipulating materialization waveforms
- Testing filter types

Validation of Results

❖ The above achieved results were validated by the following action:

- The above achieved availability results were validated by comparison with similar investigations of another source using a different simulation tool. These simulations were done over 35 important airports in both USA and EC. The results are presented to EUROCAE WG-28 in 2005. Differences on comparable results are identified as minor.
- Validation of the Matlab software with similar outputs done by Dr. Braasch [Braasch, ION 59th, 2003].
- Validation of the Matlab software ENAC GPS LABS by Dr. Macabiau.

❖ The work was continuously supervised from both ENAC side in Toulouse-France and Thales ATM side in Stuttgart-Germany.

Kenya

ICAO Global Provisions and REGIONAL Strategy for the introduction

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Today, in the manner of the global aviation community, Africa and Indian Ocean (AFI) Region is facing significant challenges. As demand for air transportation services increase, States are faced with finding solutions to safely increase capacity, efficiency, and access, e.g. to terrain challenged airports. These constraints are largely a result of reliance upon conventional ground-based navigation aids, i.e VOR/DME/NDB/ILS), which limit routes and procedures to the physical locations of ground-based navigation aids. These ground-based systems have served the aviation community well since inception; however, they do not permit the flexibility of point-to-point operations available with procedures based on GNSS to meet the challenges of today and future.
1. International Civil Aviation Organization (ICAO) has legal framework for provisions of GNSS services and each Regional Office developed its implementation strategy mainly in compliance with ICAO technical requirements.

1.1 The purpose of the AFI GNSS strategy is to define an evolution path for replacement of ground-based navigation aids, ensuring that operational and other concerns such as positive cost-benefit are fully taken into account.

1.2 The GNSS strategy assumes availability of GNSS meeting of the specified parameters at every phase of deployment. It does not analyze GNSS systems configuration per se nor the advantages and disadvantages of various strategies.

1.3 By necessity, satellite-based and ground-based navigation systems will co-exist for a period of time. Considering that the operation of a dual system is detrimental to a positive cost-benefit, users and providers will co-operate with the view of reducing the duration of the transition period as much as possible, having due regard for the following principles:

- The level of safety will not be downgraded during the transition;
- GNSS-based service must, before the end of the transition period, fully meet the required parameters of accuracy, availability, integrity and continuity foe all phases of flight;
- During the transition, gradually evolving levels of functionality will be available;
- Operational advantage shall be taken in to consideration the available and capabilities at every step of deployment;
- Methods of application will take into account full consideration of safety considerations of any functional limitations

- Users must be given sufficient advance notice to re-equip before ground-based systems are decommissioned.

2. Evolving Functionality

2.1 Phase I (Short term), up to 2012

This phase allows the use of GNSS as a primary-means of navigation for en-route, and for Non Precision Approach (NPA). Il also allows use of GNSS for TMA. Existing ground infrastructure remains intact.

2.2 Phase II (Medium term) 2013 – 2016

This phase will allow for:

a) En-route phase: sufficient capability to meet en-route navigation requirements everywhere in the AFI Region. GNSS will continue to be used as primary en-route navigation. The same principle will be characterized by a clearly planned transition for the use of GNSS as the primary means for en-route navigation. Navigation aids will not be replaced, subject to consultation with the airspace users.

b) Terminal areas: sufficient capability to meet TMA navigation requirements everywhere in AFI region. GNSS is approved as primary means for TMAs, taking into account technical and legal developments, and institutional aspects.

c) Terminal area VOR/DME/NDB, and Locators not associated with ILS, will not be be replaced during Phase II.

d) Approach and landing phase: sufficient capability for APV1 in the whole AFI Region. ILS will continue to be provided at aerodromes

Note 1: Where the requirements for approach and landing can be met by APV1, ILS CAT I should not be replaced.

During Phase II, the implementation of Long-term GNSS will be developed.

2.3 Phase III (Long term) 2017 onwards:

It is assumed that more constellations of navigation satellites will be available to support GNSS as the primary means of navigation from en-route to CAT I operations. CAT I by SBAS or GBAS will be available in those locations where analysis of historical MET data or traffic characteristics justifies the requirement. Other requirements will be met by ground-based augmentation system (GBAS).

During Phase III, ILS CAT I will not be replaced, subject to consultation with users. Where CAT II/III ILS requirements have been confirmed, these facilities will remain unless technical evolution then demonstrates that the requirement can be supported by GBAS or SBAS.

3. The strategy will be reviewed periodically. In particular, it will be reviewed and updated at the beginning of each planning phase to ensure continuous relevance in support of the global ATM operational concept, taking into account technological evolution and developments in the field of GNSS.

4. AFI SBAS implementation criteria:

- Availability of conclusive cost-benefit analysis;
- Full compliance with ICAO technical requirements (Standards and Recommended Practices);
- Agreement between stakeholders on pre-implementation cost benefit analyses on case by case basis;
- Application of the users pays principle across all sectors (SBAS users).

National authorities shall prevent cross-subsidization of non-civil aviation users of SBAS. The area of air transport studies have shown that civil aviation will significantly benefit from the GNSS services. These benefits include improved navigation safety and efficiency, significant saving in terms of distance (and so of time) flown (so saving in fuel consumption, less likelihood of diversion and reduced CO2 emission.

Performance studies of the GNSS receivers with carrier phase measuring in dynamic mode

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GNSS receivers together with reference systems are being widely used in many sectors [1][2]. In nowadays use of GNSS receivers in dynamic mode (e.g. computerized control of agricultural machinery) are getting more common. To ensure the reliability of GNSS RTK measurements in dynamic mode it was necessary to test it somehow. Main difference between measurements in static and dynamic mode is that in dynamic mode there can be only one measurement at one point [3] and there is no reference point on which the accuracy of measurements can be tested as it can be done in static mode.

To test the accuracy in dynamic mode original method was used. To determine the accuracy of GNSS RTK measurements in dynamic mode two GNSS receivers and Bentley software were used. During the measurements distance between both receivers was constant and thereby it could be used as reference value for accuracy determination.

Measurement processing showed that RMS of the measurements in 80% of cases in dynamic mode is 10mm or less if velocity of movement is 30km/h or less and the cycle ambiguity of carrier phase measurements remains solved. These results prove that GNSS RTK measurements can be used in dynamic mode with high accuracy as well as in static mode.

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Latvia

State GNSS base station Network development and applications

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Global navigation satellite system augmentation system Latpos has been established 2005. There are 25 permanent base stations installed. GNSS applications with RTK data stream has been increased and now there are surveyors, precise agriculture, forestry, road construction machinery and maritime.

Case studies on UAV started with data stream up to 20 Hz. High resolution 3D images produced. More and more copter drones with 3D photogrammetric data analysis has been used and RTK data is required. RTK positioning gives opportunity create photographs and process data with coordinates without trespassing object for marking coordinate points.

GNSS base station real time Data streams should reach users with no delay. Mobile data transfer has been used more and more often by surfing internet and listening radio and this affects GNSS RTK users. There are no priority on data flow for GNSS positioning services. GNSS base station network LatPos will be upgraded to receive and process Galileo signals for best performance.

Base stations will be densified to reach performance for measuring heights about 2 cm in real time. Maritime applications for measuring sea bottom also requires RTK coordinates with 2 cm level to perform precise scanning jobs. As base stations could not be installed in sea and long radio waves must be used to create communications for baselines longer than 25 km. Water surface did not affect RTK FIX position time achievement. Only data connection could not be established longer than 25 km. To improve measurement quality, information of ionospheric activity will be available for users in field. Local ionospheric maps of Latvia will be generated near real time and available on mobile device applications.

Morocco

Capabilities and Potentialities of Implementation of GNSS Precise Point Positioning (PPP) in Morocco

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Precise point positioning (PPP) is an approach able to provide position solutions at centimeter to decimetre level by combining the precise satellite positions and clocks with a dual frequency GNSS receiver. If single-frequency receivers are used, the ionospheric correction must be provided. There are many reference stations observing the satellites and calculating the precise orbits and clocks. As a result, PPP gives a precise and robust position solution.

In this work, a comparison is first made between PPP and the double-difference Real Time Kinematics (RTK) positioning. Then, the results of the PPP technique are assessed based on field experimentations. To conduct a comprehensive study of the various parameters influencing the accuracy of the PPP, we proceeded to the evaluation and the analysis of the influence of these parameters on the positioning error in the case of a dual-frequency receiver and the case of a single-frequency receiver. Then, we conduct an assessment of the impact with code measurement, and using the combination of the code and the phase measurement.

We also tested the direct influence on the determination of the pseudo-range. To do this, we used the observations of the Moroccan permanent stations and data from some geodetic and surveying projects in the city of Rabat, Morocco.

The last part of this study will discuss the possibility and the benefits for the national operators to implement a global solution for Geodetic and surveying needs especially to support the creation and the densification of geodetic networks, and for the cartographic and cadastral missions.

Key Words : GNSS, Precise Point Positioning (PPP), Geodesy, RTK, Ionosphere.

Morocco

The state of space techniques in African French speaking: Bottleneck and Future Perspective

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The Regional African for Space Sciences and Technology Education in French Language, affiliated to UN (CRASTE_LF), has developed since 2010 a training program of and dissemination of space techniques in several French-speaking countries in Africa by participating in the European projects FP7 (GEONetCab, EOPOWER and IASON) in collaboration with ISESCO. These activities aim to promote the use of space technologies, including GNSS, for examples: organizing of the postgraduate courses on GNSS and workshops of GNSS application (ISWI), during the last five years, the CRASTE-LF conducted 19 activities in 9 African countries to benefit 1,300 experts, users and stakeholders from thirty countries.

The CRASTE-LF has also conducted an inquiry into the state of the use of space technologies in the African French-speaking countries, through questionnaires sent to experts, African policymakers and potential users, and organized Round Tables on the issue with the present's participants in 19 activities. This has allowed Map view the main factors that hinder the progress of space technology in the Region (materials means, administrative and technical issues, internet connection etc...) and to have perspective by encouraging creation of specialized networks and development of Geoportals for data sharing.

Nepal

Capacity-building for GNSS Education in Nepal

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Global Navigation Satellite Systems (GNSS) is the emerging technology in the recent years. Its application is important in the field of research as well as in development issues. Nepal has limited work in this field; the first priority should go to the capacity building. The formal education is very limited. Nepal has recently introduced some course and is in the process of opening new courses in collaboration with international universities as well as organization. Tribhuvan University, Institute of Engineering, Pashchimanchal campus is proposing the master level programme curriculum in the field of Geomatics and proposed the GNSS as an elective course. Application of GPS in land use mapping for the classification on land use policies is an ongoing project research.

Cadastral mapping of entire Nepal was completed in 1996 using graphical survey with plane table technique, derived information from the existing maps now are outdated and do not fulfil the needs of the general public. Survey Department under the Ministry of Land Reforms & Management, Government of Nepal now has to adopt an appropriate innovative approach for cadastral mapping in the country in order to meet the growing public demands on reliable land information system, to provide speedy land administrative services as well as for overall development of the country. With continual research and development into GPS, the techniques and systems developed have become more reliable, cheaper and more productive, making GPS more attractive for a range of surveying solutions including cadastral mapping.

Due to the lack of sufficient manpower progress is not achieved as desired. So capacity building issues are important and we have to open the new courses and conduct formal academic as well as trainings in GNSS by the Pashchimanchal Campus, Institute of Engineering, Tribhuvan University.

Nigeria

Simultaneous Observations of EGNOS and GPS Amplitude Scintillations over Equatorial Africa

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We simultaneously observed EGNOS and GPS amplitude scintillations over equatorial Africa. Data, over the current solar cycle (SC 24) were obtained from three GNSS stations, namely Addis Ababa (Lat 9.03^{o}N, Lon 38.77^{o}E, Mag. Lat 0.18^{o}N), Ethiopia, Nairobi (Lat 1.16^{o}S, Lon 36.80^{o}E, Mag. Lat 10.65^{o}S), Kenya and Ile-Ife (Lat 7.33^{o}N, Lon 4.34^{o}E, Mag. Lat 2.04^{o}S), Nigeria. In order to suppress multipath effects, we imposed 30o elevation masking on the data, with principal interest on S4 _ 0.5 (~ 10 dB). Scintillations were majorly localized within the hours of 2200–2400 LT.

On a monthly basis, April and October recorded the highest occurrences of scintillation, and June recorded the lowest. Seasonally, the highest occurrences of scintillation were recorded in equinoxes, and the lowest in June solstices. On a yearly scale, scintillations recorded the highest occurrences in 2012, and the lowest in 2009. Large proportions of the observed scintillations were localized within the northern sky of the cities. Finally, we observed that during active days of scintillations, EGNOS signals also scintillated correspondingly with GPS signals.

The EGNOS scintillations commenced around local sunset terminator to form plateaus that vanished around local midnight. However, these events were mostly at low levels of scintillation with few cases of S4 $\geq$ 0.5.

Pakistan

Disaster Monitoring and Management with Unmanned Aerial Systems Utilizing Global Navigation Satellite Systems

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Pakistan is one of the most disaster prone countries in the world. The damage caused by disasters varies depending upon geographical location, climate severity and above all, the types of disasters. The disasters can be mitigated and losses can be minimized with efficient monitoring and management.

Unmanned Aerial Systems (UAS) can be deployed using GNSS as navigation technique for monitoring and management of disasters. UAS are very dynamic and are capable of providing high resolution imagery by flying at lower altitudes as and when required. The data from UAS along with the satellite imagery can be used to generate multi-layered GIS maps of the disaster-struck areas. UAS has been found very economical in comparison to current domestic approach in response to various disasters in which manned helicopters are used to capture the images of the affected areas which is quiet expensive.

The proposed system will employ GNSS technology for position determination and way point navigation of the disaster-struck area. The system will be capable to hover, track desired way points and provide visual feedback to the base station.

Presentation will discuss applications of UAS and GNSS technology for monitoring and rescue activities in various situations of disaster.

Peru

The Use of Satellite Technology in Air Navigation Services in Peru

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The paper discusses the importance of satellite technology in air navigation services at international and national level in Peru, such as VSAT, Global Navigation Systems (Global Navigation Satellite System - GNSS) and Automatic Dependent Surveillance (Automatic Dependent Surveillance - ADS), which have become very important for air traffic services. In that sense, this paper presents the benefits to civil aviation in Peru and the South America (SAM) Region.

1) VSAT Networks
CORPAC as an air navigation services provider of Peruvian state, has a satellite node that is part of the Regional Satellite Network called REDDIG which consists of 16 nodes, which has been operating since 2003 to now, providing aeronautical communications services: ATS (voice) channels and messaging AFTN / AMHS. Now, it has been running the migration/renewal of the satellite network to expand new services and capabilities to automate air traffic services in the SAM Region.

Also CORPAC is implementing its own satellite network; as the first phase of the project since 2012 have been implemented nationwide satellite nodes, the date is in the process of implementing the second phase consisting of 17 new nodes, making a total of 25 satellite nodes distributed nationwide. On this network aeronautical fixed and mobile communications are provided; surveillance and radar data and GNSS navigation, it is estimated that the network is fully implemented by 2016.

Both, VSAT satellite networks are operating in the C band, the satellite segment provider is INTELSAT.

2) GNSS Navigation Systems
As a global navigation system in the SAM Region was a regional project sponsored by ICAO called "Regional GNSS Augmentation Test (CSTB)":

- Improved testing capabilities GNSS (CSTB) based on American Augmentation Systems WAAS (space) / LAAS (ground-terrestrial).
- The architecture consisted of test equipment installed in Brazil, Chile, Panama, Argentina, Bolivia, Colombia, Honduras and Peru.
- Developed technical expertise in satellite navigation technologies and augmentation systems
- Modeling and Research on the effects of the ionosphere on GNSS in the SAM Region.

As a result of this project the following existing conclusions:

- Research / develop algorithms to mitigate the equatorial ionospheric conditions (low latitude).
- Use dual-frequency (L1 and L5 frequencies) as a solution for severe solar storms, ionospheric scintillation and threats.
- Collect and analyze operational performance of a SBAS augmentation system (space) or GBAS (ground) in the region.
- Nowadays, Brazil is developing a GBAS system and plans to extend it to the SAM Region.

3) Automatic Dependent Surveillance (ADS)
It is broadcast by aircraft of its position (latitude and longitude), altitude, speed, aircraft identification and other information obtained from the onboard systems. All ADS position messages comprise an indication of the quality of data allowing users to determine if the data are good enough to support aerial surveillance.

The position, speed and related aircraft data are usually obtained from the GNSS system aboard the aircraft. The current inertial sensors by themselves do not provide data required accuracy or integrity. Some aircraft utilize an integrated GNSS and inertial navigation indicators to provide position, speed and quality of data for transmission ADS system. There are 02 types of ADS: ADS-B (Broadcast) and ADS-C (Contract).

Because its coverage and links are satellite (GNSS), the ADS nicely complements the current radar information giving coverage to remote areas, low level flight and oceanic areas, which is integrated with the radar data.

For safety, the ADS-B / C data can be used for monitoring purposes from automated collision avoidance (TCAS) aircraft systems. This function is an additional benefit for States implementing ADS-B coverage / C in their areas of responsibility.

Current Status of the ADS Surveillance in the SAM Region and Peru:

- Now, all SAM Region has surveillance radar (ground sensors).
- Today, many states are in the stage of studies and tests of ADS-B, noting that Brazil has implemented ADS-C stations in your area of oceanic control.
- Today, around Peru are 07 S mode Radar systems, 01 S mode Radar and 01 Radar system PSR / MSSR in Lima.
- Today, there is an ADS-B system in Pisco that is not yet integrated with the radar data. This system was initially used as Test, later it will be integrated into the ACC Lima.

Long-Term (2015 - 2025) according to ICAO, the current Radars system will be replaced by ADS-B / C systems.

Peru

Analysis and Simulation of GNSS for Peru

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Peru is a small country with mountainous and variable relieves that requires a reliable GNSS service, sometimes only one GNSS is not enough to receive a desired quality of signal, and requires the combination of an additional GNSS to increase the performance. The use of two or more GNSS systems can provide a faster and more accurately reception of data, regardless of the type of work or environment.

The BeiDou (BD) navigation system currently in service only for the Asian continent is planned to become globally available and complete deployed by 2020, representing an additional alternative in GNSS services that could increase the quality of service in small countries.

The dilution of precision (DOP) is a measure of the fortress of satellite geometry and is related to the distance between the satellites and their position in the sky. The DOP can increase the effect of the error in measuring distance to the satellites.

A simulation had been carried out considering a complete deployment of the BD system and the GPS GNSS, where the considered parameters for this simulation are the satellites visibility and the DOP values.

A simulation of operation of a GNSS over the territory of Peru was focused on the operation of the GPS system only, and the combined BD/GPS system, where the results show that using a combined system based on the BD/GPS gives a better result in terms of number of satellites visibility and DOP values.

The satellites visibility for the BD/GPS option has been increased by compared to a sole GPS system, and the DOP values for the BD/GPS became better than the sole GPS system.

Following the result of simulation, a viable alternative for Peru in the near future is to consider more than one GNSS, which gives a better operation services by improvement of quality of the signal received.

Philippines

Philippine Active Geodetic Network (PageNET) in Support of the Surveying Community

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National Mapping and Research Information Authority

The Philippines thru NAMRIA has been a participant to the various workshops on the applications of GNSS sponsored by UNOOSA in Beijing, China last 4-8 December, 2006; in Prague 24-25 September 2010; then in Vienna 12-16 December 2011 and lastly in Rome 4-5 May 2012. Since then, the agency's awareness of the benefits of satellite navigation technology has increased.

With the revival of the Philippine Reference System of 1992 Project (PRS92) in 2007, NAMRIA has invested on the establishment of permanent stations in the country as part of the Geodetic Network Development. The permanent stations, called Philippine Active Geodetic Network (PageNET) supports the densification of geodetic control points and all types of survey in the country. Since 2007, thirty (30) stations have been established all of which have been aligned/tied to the ITRF and the coordinates are monitored daily using Bernese Software. The PageNET plays a fundamental role in NAMRIA's strategic plan to modernize the national geodetic system (NGS) by year 2020. It is also one of the agency's contributions to the development of a sustainable global geodetic reference frame as called for by the United Nations General Assembly through Resolution No. 69/266 of 26 February 2015 (A Global Geodetic Reference Frame for Sustainable Development).

NAMRIA thru PageNET has been an active participant/contributor in various local and international endeavors utilizing GNSS, most especially for geodetic applications. It has provided support to various applications such as zero order network observation (namria modernization of NGS); crustal deformation studies (phivolcs); real-time kinematic surveys (practitioners); water utilities mapping (maynilad); hazard mapping/3D modelling(UP-DREAM project); airborne gravity and GNSS/Leveling survey (namria modernization of NGS); UAV survey project (SRDP); and ionosphere monitoring studies by ICAO thru CAAP. In terms of international cooperation, we have always participated in the APRGP campaigns and lately the APREF. The station PTAG has been inducted to the IGS network on April 2010. It will also be collocated with the proposed location of monitoring station of QZSS of the Japanese Aerospace Exploration Agency's Multi-GNSS Monitoring Network (MGM-Net) Project and the Reseau GNSS pour l'IGS et la Navigation (REGINA) Project. We also share our PageNET data with Geoscience Australia for the improvement of geodetic infrastructure in the Asia Pacific Region. For the next five years, we plan to densify the PageNET stations for crustal deformation studies and a complete Network – RTK coverage nationwide; Capability building for NAMRIA personnel; Promote the use of the PageNet in the country; and Continued cooperation with international and regional campaigns.

Russian Federation

On development of recommendations applicable to radio monitoring for the purposes of interference environment estimation in the radio frequency bands of GNSS

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Practical measurements and estimations of spectral occupancy in the radio frequency bands of GNSS help to detect interfering events to GNSS signal propagation and reception.

Interfering signals and high level of electromagnetic noise background adversely affect on the quality of navigation.

Aspects of interference detection and mitigation for GNSS signal propagation and reception must be particularly worked out. The area of focus must include questions of national law, methodical aspects, technological aspects, practical activity applicable to interference monitoring and mitigation of impact, aspects of international cooperation regarding this problem within a framework of ITU and ICG.

Some Recommendations concerning radio monitoring should be elaborated within a framework of ICG to the benefit of development of this concept for the purposes of interference estimation in the frequency bands of GNSS.

Such Recommendations should represent basis for strategy and technological approach in detecting interferences for GNSS signal propagation and reception, mitigating its’ impact and deactivation. Recommendations should help along effective practical activities in this area.

In that context Recommendations concerning radio monitoring in the frequency bands of GNSS should include:

- definitions applicable to goals and tasks of radio monitoring;
- recommendations concerning radio monitoring arrangement and planning;
- recommendations concerning equipment and systems of radio monitoring;
- recommendations concerning execution of necessary measurements;
- recommendations concerning secondary processing of measuring results;
- recommendations concerning interference detection and integral estimation of interference environment;
- recommendations concerning cooperation in this field.

Recommendations should take account of peculiar properties of satellite navigation systems, special aspects of operation in the frequency bands of GNSS, satellite navigation systems sensitivity to electromagnetic noise level and interfering emission level.

The goals of radio frequency radio monitoring in the frequency bands of GNSS should be aimed at supporting stable non-interference operation of navigation satellite systems by precise detection of interferences for GNSS signal propagation and reception and its deactivation.

The list of radio monitoring duties should include:

- duties of operation in the frequency bands of GNSS: - monitoring of GNSS frequency bands; - GNSS frequency bands occupancy estimation; - emission detection in the frequency bands of GNSS;

- duties of operation with detected emissions and signals in the frequency bands of GNSS: - pattern analysis and identification of emissions and interference sources in the frequency bands of GNSS; - measurements of emission and interference parameters; - interference source location; - interference sours recognition; - estimation of the level of interferences impact on navigation satellite systems;

- duties of operation with interference sources, initialization of procedures focused on decreasing of interference impact and its deactivating.

Efficiency of crucial task solution of interference detection is directly linked with used monitoring techniques. Any monitoring and interference environment estimation technique is based on an object model designed in this technique. Monitoring object model directly determines configuration of monitoring facilities and operating procedures.

It is reasonable to consider spatial distribution of emissions in the frequency bands of GNSS as the base for the model in case of GNSS frequency bands monitoring.

Spatial distribution of emissions in the frequency bands of GNSS is determined by spatial distribution of radio facilities and other sources of emissions in the frequency bands of GNSS.

Spatial distribution of emissions in the frequency bands of GNSS is estimated by the level and direction of coming emission energy in azimuth and elevation angle at a point of estimation (monitoring) during radio monitoring planning and carrying out. A collection of measurement results received during such measurements forms complete collection of initial data for solving all the problems in interference monitoring at the point of measurement.

For the cases of emission analysis and detection of interferences from terrestrial emission sources:

- especial spectral diagrams of all-round azimuthal view are constructed basing on the results of secondary processing of spectral measurements. Diagrams present data on total energy impacts at the point of estimation according to the azimuth and elevation angle of energy arrival in the frequency bands of GNSS. The centers of the diagrams correspond with the points of measurements.

For the cases of emission analysis and detection of interferences from air-based and space-based emission sources:

- especial semi-sphere diagrams of energy impact view with the center at the point of estimation are constructed based on the results of secondary processing of spectral measurements. Diagrams present data on total energy impacts at the point of estimation according to the azimuth and elevation angle.

Diagrams determine aggregated integral energy characteristics of impacts taking into account direction of emission energy arrival in the frequency bands of GNSS.

The diagrams mentioned serve to determine informative criteria of interference detection and direction of energy flow arrival.

Such methodological approach could be used for elaboration of some practical recommendations on specifications of necessary equipment, lists of measuring tasks, measurement planning, secondary measuring results processing for the purposes of interference environment estimation in the frequency bands of GNSS.

Implementation of the pointed methodological approach allows to make integrated informative estimations of interference environment in the frequency bands of GNSS, to determine and help to avoid interfering emissions without undue delay, to hold activities to prevent their negative impact.

Rwanda

Effects of Solar radio bursts on GPS derived TEC: an analysis of some recent events

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Solar transients events such as Coronal Mass Ejections (CMEs) and solar flares represents the cause of various aspects of space weather and its impact on modern man made technological system. Such solar transients are often associated with solar radio bursts, particularly of type II which , at ground level can be detected by the CALLISTO solar spectrometer. The later instrument has recently been installed in the premises of the University of Rwanda, Kigali and fully operational since July 2014. This study aims at characterizing some particular solar bursts as detected by our instrument. Further, the present study will investigate ionospheric response associated with detected transients events using GPS derived TEC data. The characteristics and comparison of response trends are done using high, mid and low latitude GPS receiver stations.

Spain

The Use of Satellite Navigation in Aviation: Towards a Multi-Constellation and Multi-Frequency GNSS Scenario

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ISDEFE

Satellite navigation is becoming a cornerstone of civil aviation. According to the International Civil Aviation Organisation (ICAO), satellite navigation is based on core constellations as well as the so-called augmentation systems: Aircraft-Based Augmentation System (ABAS), Satellite-Based Augmentation System (SBAS) and Ground-Based Augmentation System (GBAS). The whole set of elements is referred to as Global Navigation Satellite System (GNSS).

GNSS is not only used for navigation but also for surveillance and time synchronization. Therefore, GNSS is truly a Communications, Navigation and Surveillance (CNS) element satisfying the needs of aviation users.

Aircraft fly following specific rules of the air that can be either visual (VFR) or instrument flight rules (IFR). When flying IFR, GNSS supports the navigation functions along the whole flight profile: departure, en-route, arrival and instrument approach. Concerning the latter, which is the most demanding phase of flight from the navigation point of view, GNSS is able to support instrument approach operations with lateral as well as those with both lateral and vertical guidance down to low decision heights above the runway.

With regard to the avionics on-board the aircraft, most of them are currently equipped with basic GPS (ABAS) receivers whereas the uptake of the corresponding SBAS and GBAS augmentation avionics is increasing.

Although the future Multi-Constellation and Multi-Frequency (MCMF) GNSS scenario will enhance the performances and the robustness of GNSS, there are a number of institutional and technical challenges that need to be sorted out.

On one hand, States should ideally avoid institutionally-driven requirements or limitations on the use of GNSS elements. However, although this should certainly be the ultimate goal, it is currently recognised that States in reality do preclude and/or mandate some specific constellations within their airspaces, and will continue to do so for a long time. To cope with this situation, ICAO has proposed to assess practical solutions for MCMF avionics to automatically select or deselect a given constellation to navigate seamlessly over airspaces where constellations are either mandated or precluded.

On the other hand, concerning the technical challenges, it is key to ensure compatibility and interoperability of core constellations and augmentations as well as to mitigate the GNSS vulnerabilities.

The necessary Standards and Recommended Practices (SARPs) and guidance material are being developed in order to accommodate other constellations such as GLONASS, Galileo and BeiDou that will eventually operate in multiple frequency bands.

With regard to the vulnerabilities, GNSS signal disruption has the potential to affect multiple aircraft over a wide area. In this regard, MCMF GNSS will help mitigate interferences. Nevertheless, disruption cannot be completely ruled out, and therefore Air Navigation Service Providers (ANSPs) must be prepared to deal with potential loss or degradation of GNSS signals.

The disruption of GNSS signals will require the application of realistic and effective mitigation strategies. There are three principal methods, which can be applied in combination:

- Taking advantage of on-board equipment, particularly Inertial Navigation Systems (INS);
- Taking advantage of conventional navigation aids, such as Distance Measuring Equipment (DME) and Instrument Landing System (ILS), and radar; and
- Employing procedural (aircrew and/or Air Traffic Control) methods.

By adopting an effective strategy using one or more of the identified methods, ANSPs and aircraft operators will not only ensure safe aircraft operations in case of GNSS outages, but will also discourage intentional interference attempts by reducing the operational impact of interference.

Moreover, there are research studies, e.g. in the frame of SESAR 2020 that will address the need for and feasibility of an Alternative Position, Navigation and Timing (A-PNT) system. A-PNT could be implemented through enhancing existing technologies (DME, INS hybridization), new technologies (Multilateration, LDACS, Secondary surveillance radar mode N, etc.) or their combinations.

This paper will focus on the value of GNSS to satisfy aviation users’ needs, the status of GNSS avionics as well as on the challenges raised by the future MCMF GNSS.

Ukraine

The Current State and Prospects of the Positioning and Timing and Navigation System in Ukraine

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Ukraine has developed the Positioning and Timing and Navigation System using the signals of GPS and GLONASS global navigation satellite systems (GNSS). The State Space Agency of Ukraine is System's Customer. The system has been developed on the basis of standards adopted by the European project EUPOS.

The System continuously provides corrective information via the Internet, allowing users in real time to achieve positioning accuracy at 1 m across Ukraine, submeter level at a distance of 150 km from the control and corrective stations (CCS) of the ground network, and centimeter-level accuracy within 20 km zone around each of the CCS.

Currently the System, which operates in the mode of trial operation, uses information from 10 stations belonging to different governmental, scientific and commercial organizations.

Users of the System are governmental authorities, governmental scientific and industrial enterprises, commercial enterprises and individuals performing coordinate measurements using satellite navigation devices.

According to the plans of the National Space Program of Ukraine the consolidation of network stations to 100 units will take place in the coming years. This will allow to perform precision navigation and geodetic measurements across Ukraine with centimeter accuracy in real-time.

United States of America

Solar Cycle 24's Effects on WAAS

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Solar Cycle 24 will go down in history as one of the lowest solar cycles in over a hundred years. Now in its declining phase, Cycle 24 peaked in April 2014 with a smoothed sunspot number maximum of about 115, making it the smallest sunspot cycle since Cycle 14 which had a maximum of 64 in February 1906 (http://solarscience.msfc.nasa.gov).

Generally, near the peak of a solar cycle we see a significant increase in the number of space weather events such as solar radio bursts, solar flares and coronal mass ejections (CMEs). These events can affect the performance of ground- and space-based technological systems, with results ranging from minor digital upsets to severe power grid disruptions that can cause loss of service to millions. For Global Navigation Satellite System (GNSS) users, space weather events can ultimately degrade ranging measurements affecting the performance and availability of many applications that are built into our modern daily lives.

For aviation augmentation systems such as the Wide Area Augmentation System (WAAS) and the European Geostationary Navigation Overlay Service (EGNOS), geomagnetic storms that result from solar flares and CMEs are the most threatening of solar events. This was demonstrated in October 2003 when a series of large X class solar flares induced coronal mass ejections that generated loss of availability of the WAAS Approach with Vertical Guidance (APV) service for many hours over the entire service volume. Similar effects were seen in response to other large solar flares and CMEs in November 2003 and in November 2004. Solar Cycle 23 certainly provided challenges and direction for improvement and development of future augmentation systems. Although WAAS and EGNOS have responded to Cycle 24 space weather events with degraded availability of vertically guided approach services, the systems have not been confronted with geomagnetic storms of the intensity seen in earlier solar cycles. One of the reasons is that the Cycle 24 geomagnetic storms are weak, even though the number of solar flares and CMEs haven't dropped off very much. Scientists have suggested that reduced pressure currently present in the heliosphere have weakened the magnetic field inside the CMEs resulting in milder geomagnetic storms (*Gopalswamy et al. 2014*).

In this paper, we will review the characteristics, frequency and magnitude of the space weather events of Solar Cycle 24. We will discuss the methodology used by WAAS to detect geomagnetic storms and we will illustrate the impact these storms have had on WAAS and EGNOS system performance. Finally, we will look to the future with a glimpse of the scientific predictions for Solar Cycle 25, expected to peak between 2022 and 2025. Solar cycle 24 was the third cycle in a trend of diminishing solar cycles leading some scientists to believe that Cycle 24 could be even smaller than the current Cycle.