Universal-SBAS:
A Complete Worldwide Multimodal Standard

Cyril Botteron, Y. Tawk, A. Jovanovic, P-A. Farine,
EPFL, Neuchâtel, Switzerland

René Jr. Landry
ÉTS, Montréal, Canada

Mohamed Sahmoudi
ISAE, Toulouse, France

Jean-Luc Issler, Felix Perozans
CNES, Toulouse, France

Veronique Dehant,
ORB, Bruxelles, Belgium

Alessandro Caporali
Department of Geosciences, University of Padova, Italy

Serge Reboul
Univ Lille North of France, Calais, France

ROB Royal Observatory Belgium

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec
École de technologie supérieure

LaCIME

ULCO Université du Littoral Côte d'Opale

LISIC

cnes

Band-Usage of Current and Planned GNSSs

	Band name	B_A1	B_A2	$B_{NA}1$	$B_{NA}2$	$B_{NA}3$	B_A3	B_A4	$B_{NA}4$
	Frequency range (MHz)	1164 -1188	1188 - 1215	1215-1240	1240-1260	1260-1300	1559 - 1591	1591 - 1610	2483.5-2500
MEO GNSS systems (global converage)	GPS (IIF, III-A)	X		X			X		
	GLONASS (current)				X			X	
	GLONASS K-initial		X		X			X	
	GLONASS K-final	X (option)	X		X		X (option)	X	
	GALILEO (current)	X	X			X	X		
	GALILEO 2	X	X			X	X		X (option)
	COMPASS-initial (14 –tbc- 1st SVs)		X			X	X		
	COMPASS-final (15th - tbc- and follow up SVs)	X	X			X	X		X (option)
	GINS	X	X (option)				X (option)		X
Regional GNSS systems	WAAS (current)	X(experiment)					X		
	WAAS-final	X (option)					X		
	MSAS	X (option)					X		
	QZSS	X		X		X	X		
	ETS VIII (experiment)						X		X
	GAGAN	X					X		
	IRNSS	X					X (option)		X
	SDCM						X		
	BEIDOU-1								X
	EGNOS (current)						X		
	EGNOS NG	X (option)	X (option)				X		
	SNAS								
	Malaysian SBAS								
	Korean SBAS								
	PCW	X (option)	X (option)			X (option)	X (option)		

ROB Royal Observatory Belgium
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec École de technologie supérieure
LaCIME
ULCO Université du Littoral Côte d'Opale
LISIC
cnes

Introduction to Universal-SBAS (U-SBAS)

- The worldwide multimodal Universal-SBAS "U-SBAS standard" proposes to extend the current Aeronautical Space Based Augmentation System (SBAS), defined by the RTCA :

  ➔ C/A code; 250 bps; 1575.42 MHz

  - ✓ The current and validated « civil-aviation » standard should be kept into U-SBAS to avoid modification of the existing single frequency SBAS aeronautical receivers.
  - ✓ The U-SBAS standard "encapsulates" the aeronautical SBAS standard, and provides other services not covered by the aeronautical SBAS frame.

➢ U-SBAS aims to be compatible with all the existing and planned regional GNSS systems (and their evolutions) in the world, like IRNSS, QZSS, PCW, BEIDOU-1, WAAS, EGNOS, SDCM, GAGAN, MSAS, PCW ...

  - ✓ U-SBAS could be used in all the regions of the world, by all the civil aviations and other Safety of Life (SoL) users of the world, but also by all other non-SoL users of any countries.
  - ✓ U-SBAS could carry additional channels (signals and messages) to cover the non-aeronautical specific SoL services, and also HPPS, PVT, authentication services, safety services, scientific application services, HPTS, etc.

Proposed Definition and Way Forward

- The international Universal-SBAS multimodal standard should cover systems using GNSS payload overlaying one or several GNSS constellations in MEO:
  - The U-SBAS multimodal payloads would take part of regional GNSS, the related orbits are therefore geosynchronous with a 24 or 12 hour period. They could be GEO, IGSO, EIGSO (*Elliptical and Inclined GeoSynchroneous Orbit: EIGSO*), Tundra, Molnya, …

- One or several SBAS-multimodal system(s) could be the basis and the first step for a future worldwide national or multinational worldwide GNSS system.

- The way forward to use a multimodal worldwide SBAS standard could be for each region to extract « à la carte » from the worldwide U-SBAS multimodal standard:
  - 1, 2, 3 or 4 SBAS frequency(ies) / modulation(s) necessary to cover optimally its needs.

International Names of the RNSS Bands are suggested

B_A1: 1164 -1188 MHz

B_A2: 1188 -1215 MHz

B_A3: 1559 -1591 MHz

B_A4: 1591 -1610 MHz

$B_{NA}1$: 1215-1240 MHz

$B_{NA}2$: 1240-1260 MHz

$B_{NA}3$: 1260-1300 MHz

$B_{NA}4$: 2483.5-2500 MHz

Suggestion :

➢ **at least one of the band of each SBAS multimodal system shall be part of the ARNS bands of the eventual parent GNSS MEO system, to ease the compatibility of the said U-SBAS with the receivers processing the signals of its eventual parent GNSS system**

ROB Royal Observatory Belgium

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec École de technologie supérieure

LaCIME

ULCO

LISIC

cnes

ARNS Frequencies and Modulations (1)

- **Generic frequencies for a future worldwide SBAS standard could cover, for the aeronautical and non-aeronautical SoL and other services like:**
  - ✓ **Aeronautical applications (and covered non-aeronautical SoL applications)**
  - ✓ **HPPS, HPTS, … services with accuracy better than 10 cm; can be SoL or non-SoL**
  - ✓ **Science applications (described later)**
  - ✓ **Integrity of ARNS or non-ARNS channels, …**
  - ✓ **Broadcast of small command messages eventually encrypted by the customers provided with remote platforms having GNSS receivers on board**
  - ✓ **etc …**

f_A1: 1176.45 MHz or close

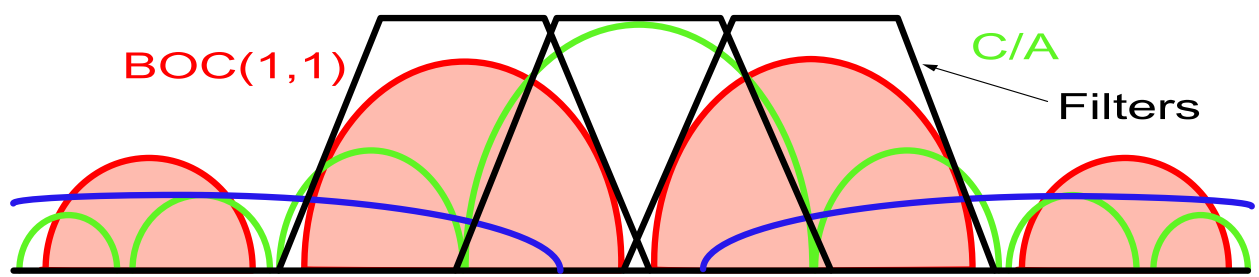
f_A2: in the range 1204 - 1208 MHz preferably 1207.14 MHz or close

f_A3: 1575.42 MHz or close

f_A4: in the range 1604-1608 MHz (TBC)

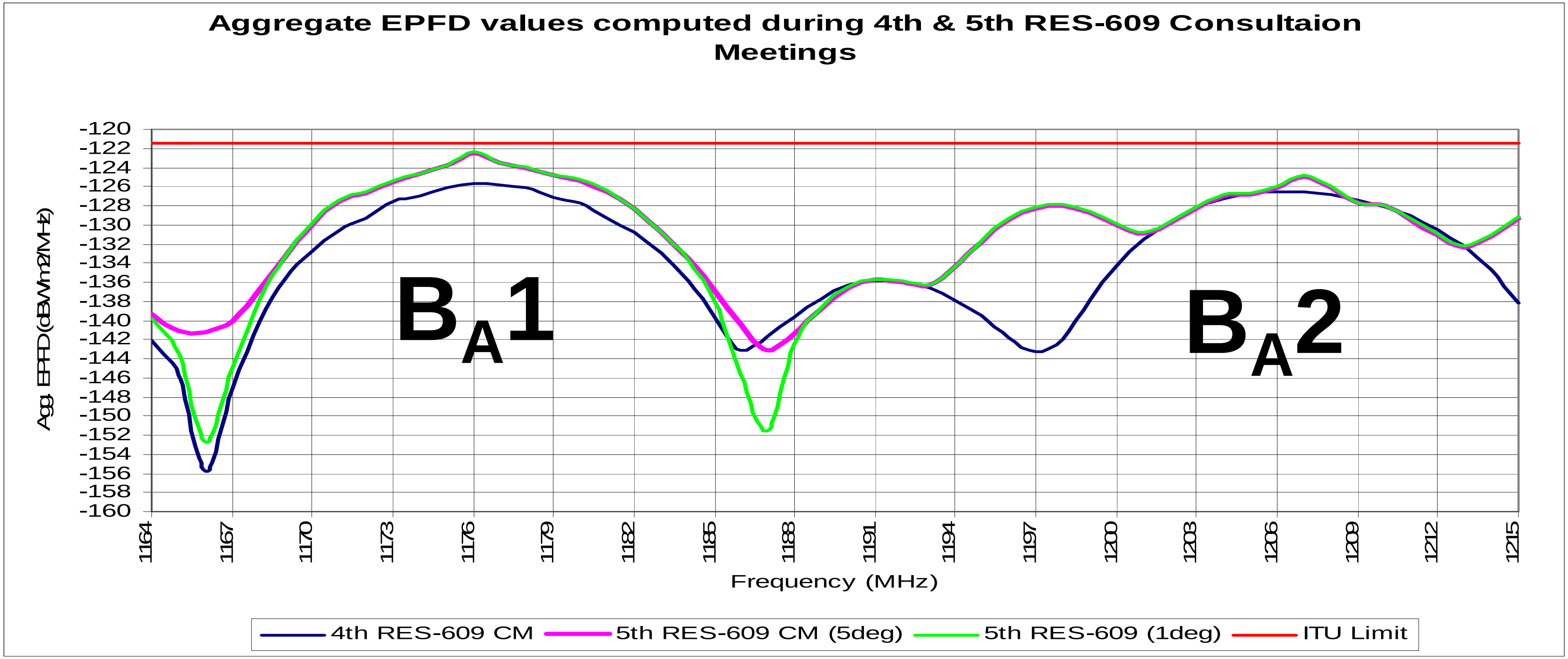
ARNS Frequencies and Modulations (2)

- **Modulations for a future U-SBAS standard could be, for the SoL and other services:**
  - **At f_A1:** **QPSK(10) or QPSK(2) or QPSK(1) (or BOC to cope with PFD limit mentioned later on) or equivalent with time multiplexing**
  - **At f_A2:** **QPSK(1) or QPSK(2) or QPSK(4) or QPSK(5) or QPSK(10) or equivalent with time multiplexing**
  - **At f_A3:** **BPSK(1) [legacy] eventually multiplexed with BPSK(1) or MBOC(6,1,1) or BOC(1,1)**



  - **At f_A4:** **MBOC or BOC(1,1) or QPSK(0.5) or QPSK(1) or QPSK(2) or ?**

PFD Limit in the Lower ARNS Bands



- **PFD limit in the 1164-1215 MHz band (-121.5 dBW/m2/MHz) agreed at UNO/ITU level, in order to protect the aeronautical ground navigation aids like DMEs from armful interference coming from the GNSS systems.**
- **GNSS operators which would create an overpass of the PFD limit, would take the responsibility of endangering the ARNS ground services in these bands.**

Royal Observatory Belgium
ROB
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec
École de technologie supérieure

Non ARNS Frequencies and Modulations (1)

- Non ARNS frequencies and modulations can be useful for future multimodal SBAS, for:
  - ✓ HPPS, HPTS, … services providing a positioning accuracy better than 10 cm
  - ✓ Science applications (described later)
  - ✓ Non- SoL applications (integrity of non-ARNS channels, …)
  - ✓ Broadcast of small command messages uncrypted by the customers provided with remote platforms having GNSS receivers on board
  - ✓ Etc …

$f_{NA}1$: 1227.60 MHz or close

$f_{NA}2$: in the range 1240-1260 MHz ; preferably 1248,06 MHz

$f_{NA}3$: 1278,75 MHz or close

$f_{NA}4$: 2491 MHz or close

Royal Observatory Belgium

ROB

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec
École de technologie supérieure

Non ARNS Frequencies and Modulations (2)

o**Modulations for a future U-SBAS standard could be, for the non-ARNS frequencies:**

- **At $f_{NA}1$: BPSK(1) assuming time multiplexing of pilot and data channels**
- **At $f_{NA}2$: QPSK(2) or QPSK(4) or QPSK(5) or ?**
- **At $f_{NA}3$: QPSK(2) or QPSK(4) or BPSK(5) or QPSK(5) assuming data/pilot time or phase multiplexing**
- **At $f_{NA}4$: QPSK(1) or QPSK(1.23) or QPSK(2) or QPSK(4) or … ?**

Royal Observatory Belgium

ROB

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec

École de technologie supérieure

LaCIME

ulco

LISIC

cnes

Frequencies and Modulations: Additional Remarks

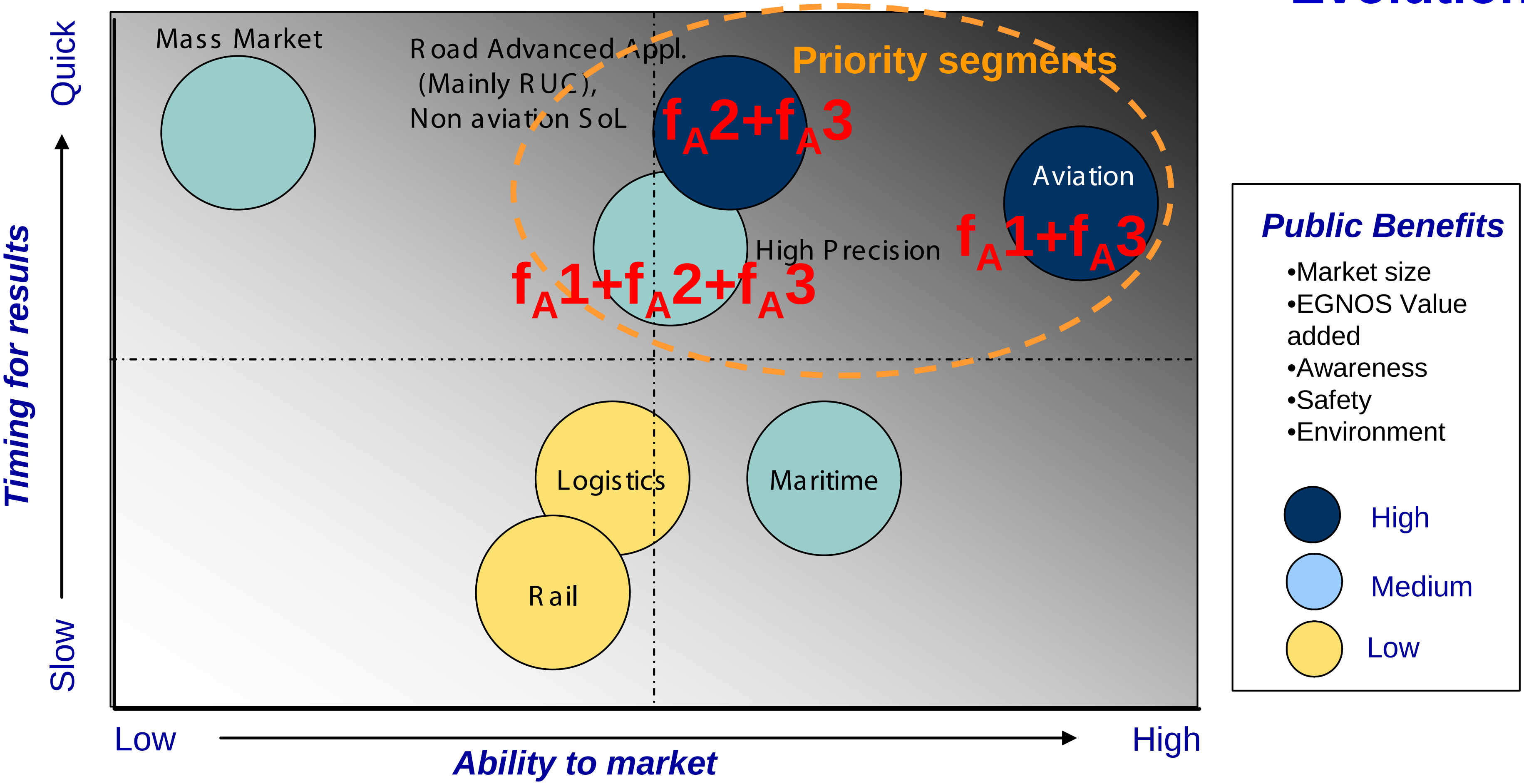
- The goal of the multimodal SBAS standard would be to reduce as far as possible the number of standardized modulations per frequency:
  - A limited number of remaining modulation per frequency (1, 2 or 3 for example) should be acceptable.
  - In most of the non-commercial space radio link standards, like in the Consultative Committee for Space Data Systems (CCSDS) the number of standardized modulations per application band is generally 2 or 3 or 4.
  - The suggested U-SBAS is therefore in line with the international normalisation logic, and the technological evolution trends, which goes toward digital and flexible GNSS receivers.

- It is important not to exclude any regional GNSS system from the future complete multimodal worldwide U-SBAS standard
- It is as much important to avoid proliferation of possible signals beyond such a worldwide frame.

Royal Observatory Belgium

Université du Québec
École de technologie supérieure

Full signal of a U-SBAS system - Example of EGNOS Evolutions



Possible services / signals matching plan of EGNOS evolutions

Nota Bene : 2 tri-frequency future EGNOS payloads have been ordered by Europe

ROB Royal Observatory Belgium
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec École de technologie supérieure
LaCIME
ULCO
LISIC
cnes

Examples of Applications for Multimodal U-SBAS
Science and precise positioning (1)

- The « fix » and "permanent" aspect of a geostationary satellite above the earth surface, or the « quazi –fix» and "permanent' feature of a Tundra-like or a IGSO orbit is very interesting for science applications:
  - like ionospheric observations and related earthquake signatures, and also very accurate positioning or timing for instance.

- For ionospheric sciences, to benefit from a "fix" our "quasi-fix" "control point" in the ionosphere allows calibration of ionospheric tomographic and cartographic applications.
  - Such "quasi-fix" triple or quadriple frequency RNSS "satellite → station" links allows to perform fine monitoring of low temporal variations of the ionosphere coming, for instance, from gravity wave having diverse causes, like sismic or tsunaminic origins. An ionospheric earthquake potential precursor can be monitored accurately without discontinuity during several days thanks to geostationary multifrequency signals complementing signals coming from MEO satellites.
  - These at least tri-frequency links allows to measure and correct accurately the second order terms (term in 1/f3) of the ionosphere.

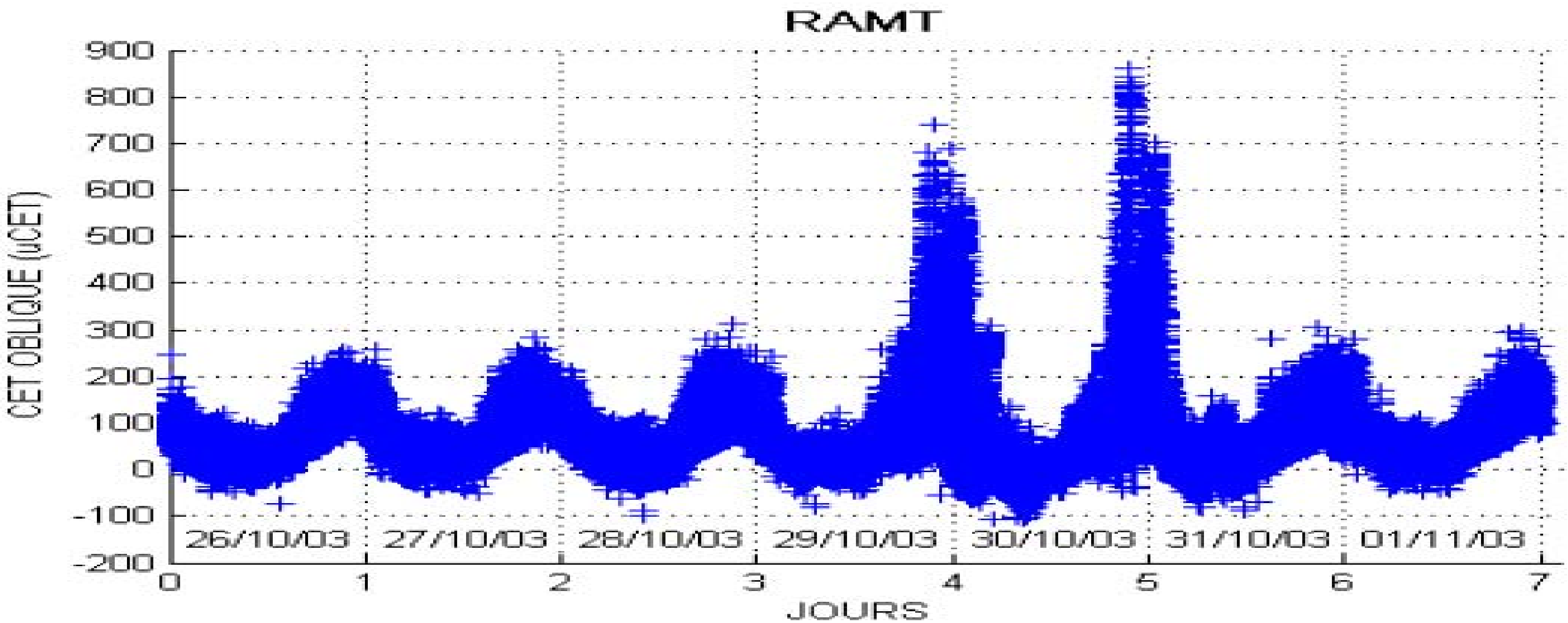
Royal Observatory Belgium ROB

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec École de technologie supérieure

lacime ulco LISIC cnes

Effect of ionospheric storms on HPPS and HPTS (1)



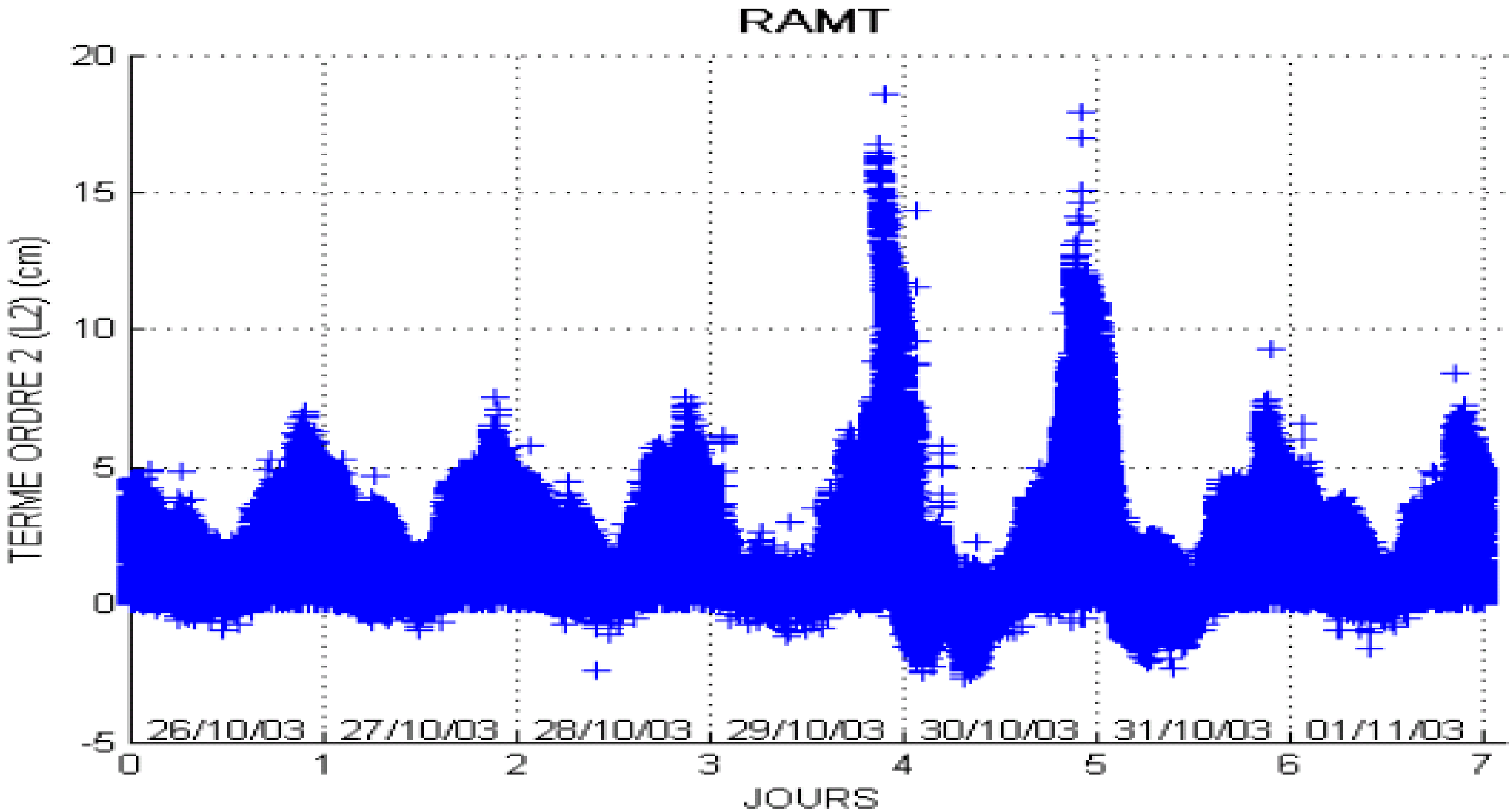
Oblical Total Electronic Content at RAMT station (USA), during a ionospheric perturbation

Day of October-November 2003	26/10	27/10	28/10	29/10	30/10	31/10	01/11
Ap index	10	15	20	189	162	93	91

Value of the planetary magnetic Ap during one week in October 2003

Royal Observatory Belgium ROB
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec École de technologie supérieure
LACIME
ULCO
LISIC
cnes

Effect of Ionospheric Storms on HPPS and HPTS (2)

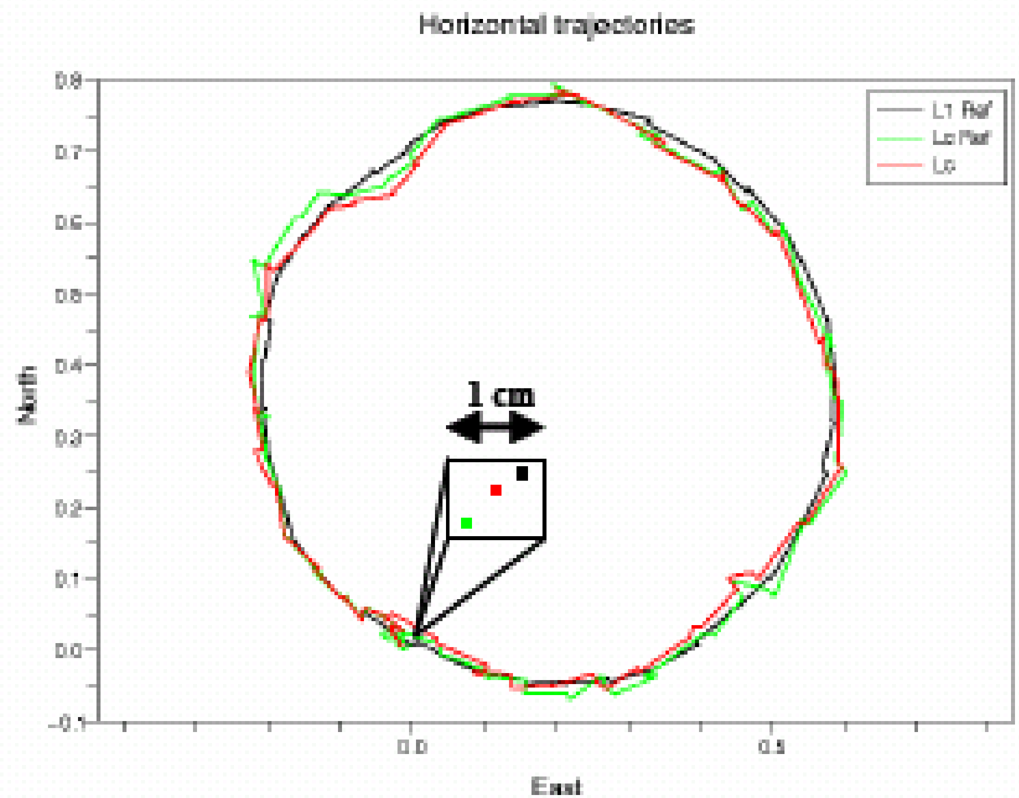


Ionospheric 2nd order pseudorange term at f_{NA}1 GPS frequency calculated for the RAMT station

Royal Observatory Belgium
ROB
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec
École de technologie supérieure

U-SBAS application: Precise positioning better than 10 cm in real time

- Receiver: Septentrio PolarX2
- Circular motion (80 cm diameter)
- Validated by comparison with differential positioning with the TLSE station (100 m baseline)



all solutions agree to 1 cm RMS

Accuracy close to 1 cm provided by PPP-WIZARD using GPS signals at $f_{NA}1$ and f_A3 frequencies.

PPP-WIZARD : PPP With Integer Zero-difference Ambiguity Resolution Demonstration

ROB Royal Observatory Belgium

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec
École de technologie supérieure

LACIME

ULCO

LISIC

cnes

Conclusions

We have presented contributions to the multimodal worldwide SBAS standard, proposed to be named Universal-SBAS (U-SBAS) :

- ✓ **Giving international names for RNSS bands and related frequency, suggesting some modulations, (data rates, coding, messages,…)**
- ✓ **Some service, multi-constellation message, payload, signal multiplexing and ranging issues are also discussed (see also back up slides).**
- ✓ **The U-SBAS standard is compatible with SoL and non-SoL services, including very precise and robust positioning / timing, and SBAS-related very accurate scientific applications for instance.**
- ✓ **All the regional GNSS systems like QZSS, IRNSS, WAAS, SDCM, PCW, EGNOS and its multifrequency evolutions, BEIDOU-1, etc …, are compatible with the proposed U-SBAS standard.**

  - ➢ **Study of the U-SBAS standard in a IGC frame is proposed**

Back up slides

Some informations on some GNSS systems (1)

- **In USA**, GPS is the leading GNSS system in the world. A signal option in $B_{NA}3$ at 1278 MHz was sometimes mentioned for GPS 3 evolutions and this band has been filed by the USA. L/S-band frequency was selected for low-cost radio development (commercial wireless technology) in a GPS II F Search And Rescue (SAR) low cost design study involving a 2.4 GHz downlink.
- **In Russia**, government supports development of GLONASS/GPS receivers and promote mandatory equipping governmental users with combined GLONASS/GPS receivers. More than 10 types of on board GLONASS/GPS receivers are developed in Russia for civil aviation, and several GLONASS/GPS/GALILEO simulators are manufactured in Russia. Civil aviation authorities in Russia have initiated mounting these receivers on board spacecrafts. The GLONASS-K bands filled by the Russian Federation at ITU in BA2 are close to approximately 1196-1212 MHz.
- **In India**, GAGAN is an SBAS system, using dual frequency B_A1 and B_A3 payloads, the next to be launched being on board GSAT-4R, GSAT-8 and GSAT-9 geostationary satellites [40]. The IRNSS (Indian RadioNavigation Satellite System) will have B_A1 and $B_{NA}4$ as core frequency bands. The core IRNSS constellation will be made of 3 geostationary satellites, and 4 IGSO satellites.

Some informations on some GNSS Systems (2)

- **In China**, for the 2013-2016 period, the Chinese Aeronautical Association (CAAC) considers employing navigation services from Compass, and conducting tests with Compass. For the period 2017-2025, the CAAC will use GNSS based on multilateral cooperation, including consideration of using Compass satellite navigation system. The CAAC plans to equip the aircrafts for general aviation with GNSS navigation system. The multi-constellation GNSS receivers compatible with Compass will be the preferred navigation system for future general aviation.
- China also made a CAPS-V1 navigation experiment, using a telecom repeater of retired satellites originally on GEO orbit and now in SIGSO (Slightly Inclined GeoSynchroneous Orbit), to test BOC and BPSK navigation signal performances. The used frequencies are close to 3.8 GHz and is not in a RNSS band for the CAPS-V1 experiment.
- **In Europe**, the GNSS constellations generally preferred for future aeronautical navigation are GPS and GALILEO, and a symmetrical situation is expected in the USA. A frequency evolution is related to the B_A1/B_A2 band extension decided on ARTEMIS GEO spacecraft replacement, and on another GEO spacecraft

Some Informations on some GNSS Systems (3)

- **In Japan, the MSAS system planned an expansion of the used BA3 band width portion for the future. QZSS will not only transmit in B_A3 band C/A and MBOC navigation signals, but also a third signal, named SAIF (Sub-meter class Augmentation with Integrity Function), compatible with ICAO SARPs.**
- **QZSS will have the advantage to transmit on four frequencies to cover a wide variety of services.**
- **The ETS VIII geostationary satellite provide a navigation in time experiment using navigation PN codes in B_A3 and $B_{NA}4$ bands.**
- **In Malaysia, an SBAS system is under study, for a development phase planned between 2011 and 2015.**
- **In Korea, the development of a GNSS Augmentation System also have been studied.**
- **In Canada, the development of a GNSS Augmentation payload on board 2 “Polar Communication Weather” satellites is also studied. The targeted orbit is Molnya. The current payload specifications includes B_A1, B_A2 and B_A3 bands.**

Payload and Ranging Issues (1)

- **The interest of using transparent repeaters came originally from several needs:**
  - **To rent or build a payload while the coding, PN-codes, and message structure of the SBAS signal(s) weren't finalized**
  - **To minimize complexity of the space segment, even if the impact is a complex ground segment**

- **The transparent payloads face however several inconveniences :**
  - **The servo-loop of the long loop through the Navigation Land Earth Station (NLES) and transparent payloads creates non-Gaussian phase noise which decrease the accuracy of the carrier phase measurements**
  - **The code/carrier divergence at the output of the payload is not perfect, and fluctuates with time**
  - **The code phase itself has some extra-residual errors**
  - **On board the satellite, the signal pass through a reception antenna and a transmission antenna, this situation being more complicated to keep signal quality during spacecraft attitude manoeuvres, than with a single transmitting antenna**
  - **It is also more complicated to keep the long loop signal quality during spacecraft orbital manoeuvres, than with an on board signal generation**
  - **The phase noise of the on board oscillator involved in the transparent repeater is generally higher than in the case of generative navigation payloads**
  - **…**

Payload and Ranging Issues (2)

- **But, time has passed, and the interest of using transparent payloads vanish if some guidelines which could be implemented in the U-SBAS standard are taken into account:**
- **The on board NSGU (Navigation Signal Generation Unit) is compatible with :**
  - **1a) SoL and non-SoL modulations mentioned above, or finally the modulations which could be finally retained in the Universal-SBAS standard**
  - **1b) U-SBAS SoL and non-SoL data rates to be defined in the U-SBAS standard**
  - **1c) Every type of navigation message and related coding, including high performance coding like LDPCCC. This means that the message and the related coding(s) are elaborated outside the standardized SBAS NSGU**
  - **1d) On board memories implemented in the NSGU allows storing any type of periodical PN code, with a maximum length which has to be defined in the U-SBAS standard.**
  - **1e) The NSGU design will have to be compatible with user defined features related to potential SBAS authentication services**
  - **1f) The NSGU is driven by a rubidium clock for instance or at least an Ultra Stable Oscillator (: quartz USO), thus allowing the SBAS ground segment to upload not so often clock coefficient describing the on board clock drift. Of course, if a scientific experiment involving stable clocks in orbit take part of the mission, such a clock (“cold atom”, “optical”, etc) could be added.**

Payload and Ranging Issues (3)

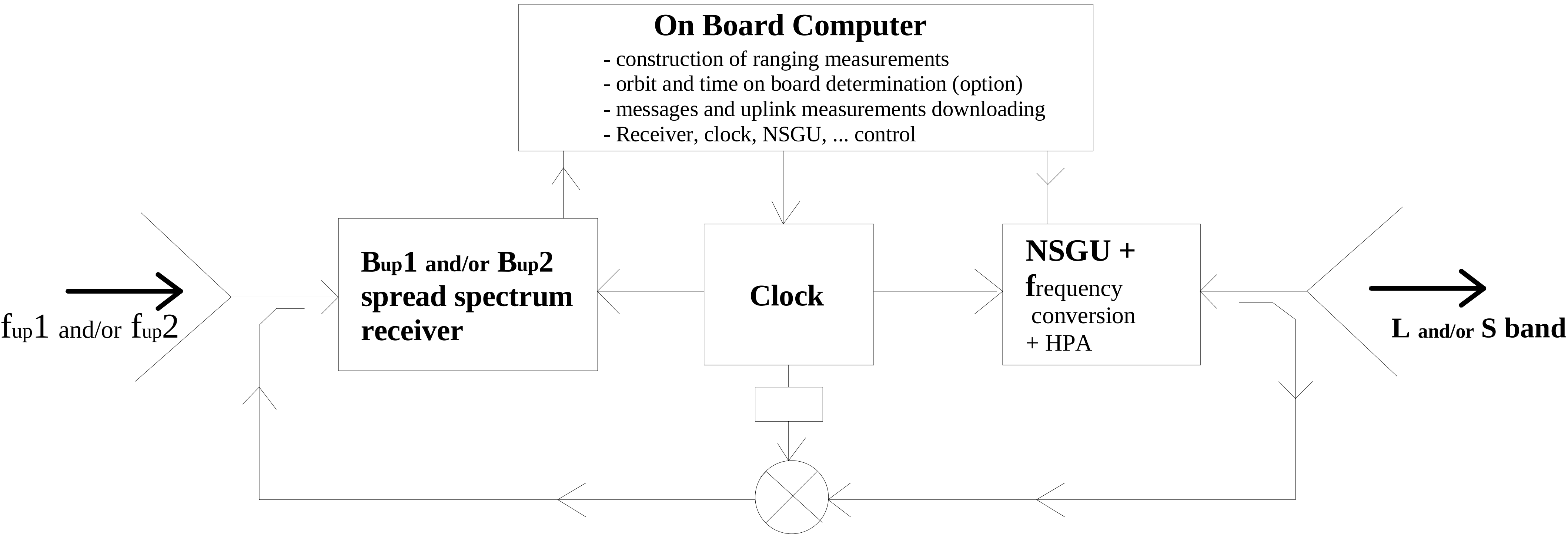
o**With on board NSGU, the message and coding upload ground segment is simplified:**

- **2a) In the case of a proprietary satellite, the on board NSGU receive the navigation/integrity/HPPS/… message and the coding from the On Board Computer (OBC), itself receiving these informations from the standard Telecommand station of the used high altitude satellite (GEO, IGSO, Tundra, etc). There is no need anymore of specific NLES (Navigation Land Earth Stations) anymore.**
- **2b) In the case of a multimodal SBAS payload offered for rental by a satellite operator, this operator has also to provide (in addition to the NSGU) an on board receiver, to collect the navigation/integrity/HPPS/… message and coding coming from a small station replacing the NLES, using one of the 2 RNSS uplink bands standardized at ITU:**

  $B_{up}1$ = 1300-1350 MHz (L band, quite large), or $B_{up}2$ = 5000-5010 MHz (C band, not so large). RNSS C band Bup2 uplink multichannel receivers have already been developed for GALILEO, QZSS and other GNSS programs. RNSS L band Bup1 uplink multichannels receivers has also already been manufactured, for GEO missions, to provide significant performance improvement by the introduction of pseudolite-tracking and message demodulation capability at fup1 frequency (fup1 = 131x10.23 = 1340,13 MHz), these receivers being able to simultaneously track fup1 and f_A3 C/A data-modulated signals.

ROB Royal Observatory Belgium
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec École de technologie supérieure
LaCIME
ulco
LISIC
cnes

Possible U-SBAS Payload Architecture



Rx-Tx Calibration loop

Royal Observatory Belgium
ROB
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec
École de technologie supérieure
LACIME
ULCO UNIVERSITÉ DU LITTORAL CÔTE D'OPALE
LISIC
cnes

Science and Precise Positioning (2)

- The U-SBAS multifrequency issue is not only important for science or operational ionospheric applications, but also for operational precise positioning applications, specially the ones targeting an accuracy better than 10 cm, thanks to HPPS coefficient broadcasting in BA2 or BNA3 for instance. Moreover, 3-frequency links allow for better retrieving of the second order term variations, in order to better observe tropospheric delays variations for meteorological or climatologic applications.
- Such links also allows to measure the polarization of the signals received, and therefore the Faraday effect, linked like the second order terms, to the terrestrial magnetic field.
- Maintaining a terrestrial reference frame at a level that allows the determination of global sea level changes at the sub-millimeter per year level, pre-, co-, and post-seismic displacement fields associated with large earthquakes at the sub-centimeter level, timely early warnings for earthquakes, tsunamis, landslides, and volcanic eruptions, as well as the monitoring of mass transport in the Earth system at the few Gigatons level will be possible in the future.
- In real time, safety services could also involve surveillance of earthquake and tsunaminic events through centimetric monitoring of the ionosphere thanks to "fixed" paths between the geostationary multimodal SBAS satellites and a network of MEO+SBAS GNSS receivers [64]. For instance, QZSS, in association with other GNSS systems observable from Asian regions, will be used for a "disaster management" experiment

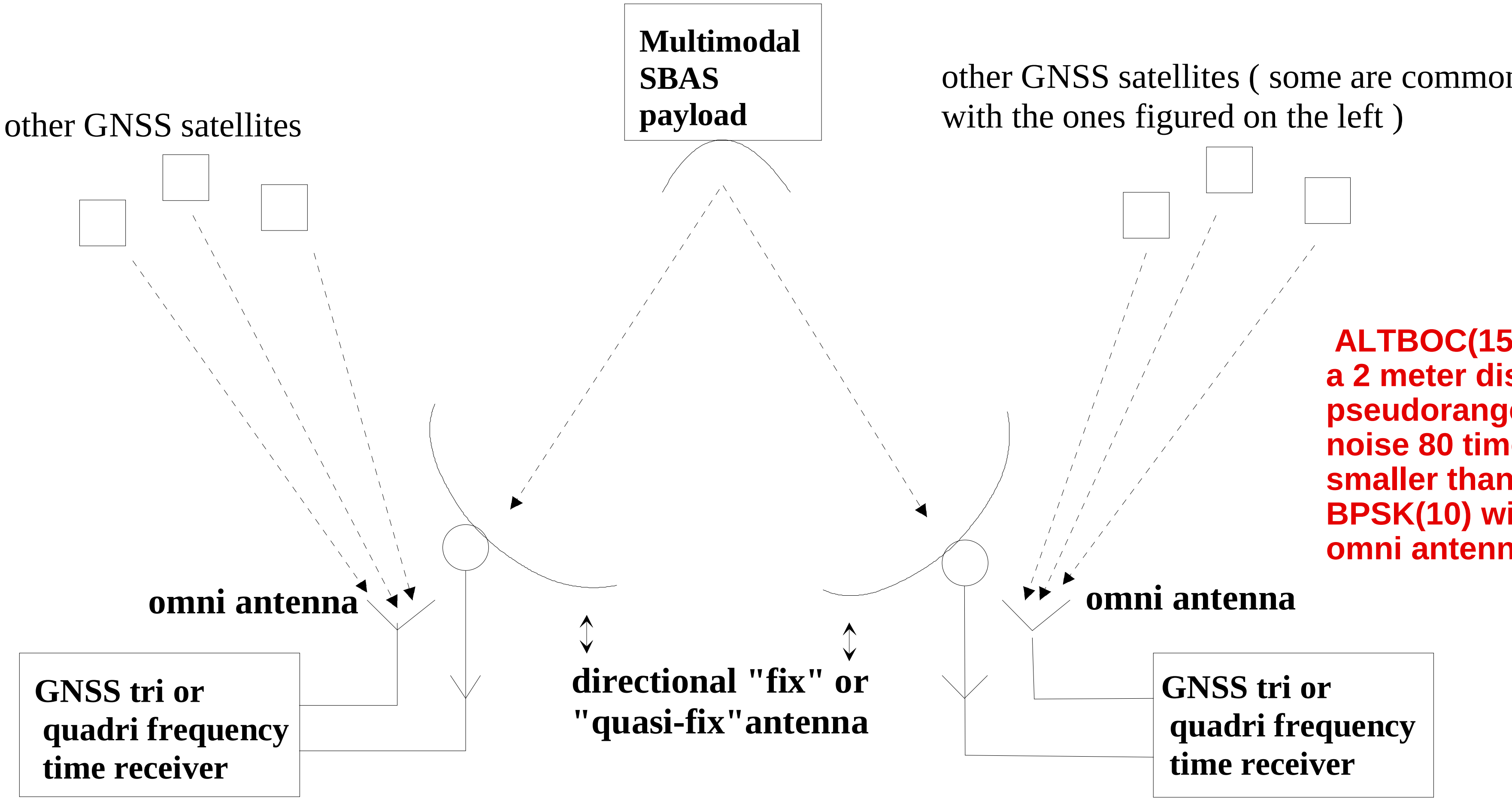
Exemple of application for multimodal U-SBAS : Robust and secured positioning

o**An adversary can influence the commercial location information, *loc*(*V*), a node *V* calculates and compromise the node operation. Adversary could jam/spoof the receiver.**

o**In the case of a fleet management system, an adversary can target a specific truck. First, the adversary can use a transmitter of forged GNSS signals that overwrite the legitimate GNSS signals and are received by the victim node (truck) *V* . This would cause a false *loc*(*V*) to be calculated and then reported to the fleet center, essentially concealing the actual location of *V* from the fleet management system. Once this is achieved, physical compromise of the truck (e.g., breaking in the cargo, hijacking the vehicle), is possible with reduced or no ability for the system to detect and react in time.**

- **SBAS systems can provide security for the scenario mentioned above and many others, providing secure distribution of the location and time such that the adversary is not able to emulate the positioning system. They can be used to provide to those systems additional security needed for the distribution of changing cryptographic parameters (between mobile nodes as in the VANETs – Vehicular Mobile Ad-Hoc Networks). Applications of VANETs are Safety-related applications, such as collision avoidance, cooperative driving, and traffic optimization.**
- **By using different modulations on different frequencies, jamming risk of the satellite receiver can be reduced for the receiver using signal diversity successfully.**

Very accurate time/frequency transfer using U-SBAS+MEO 1-way common views

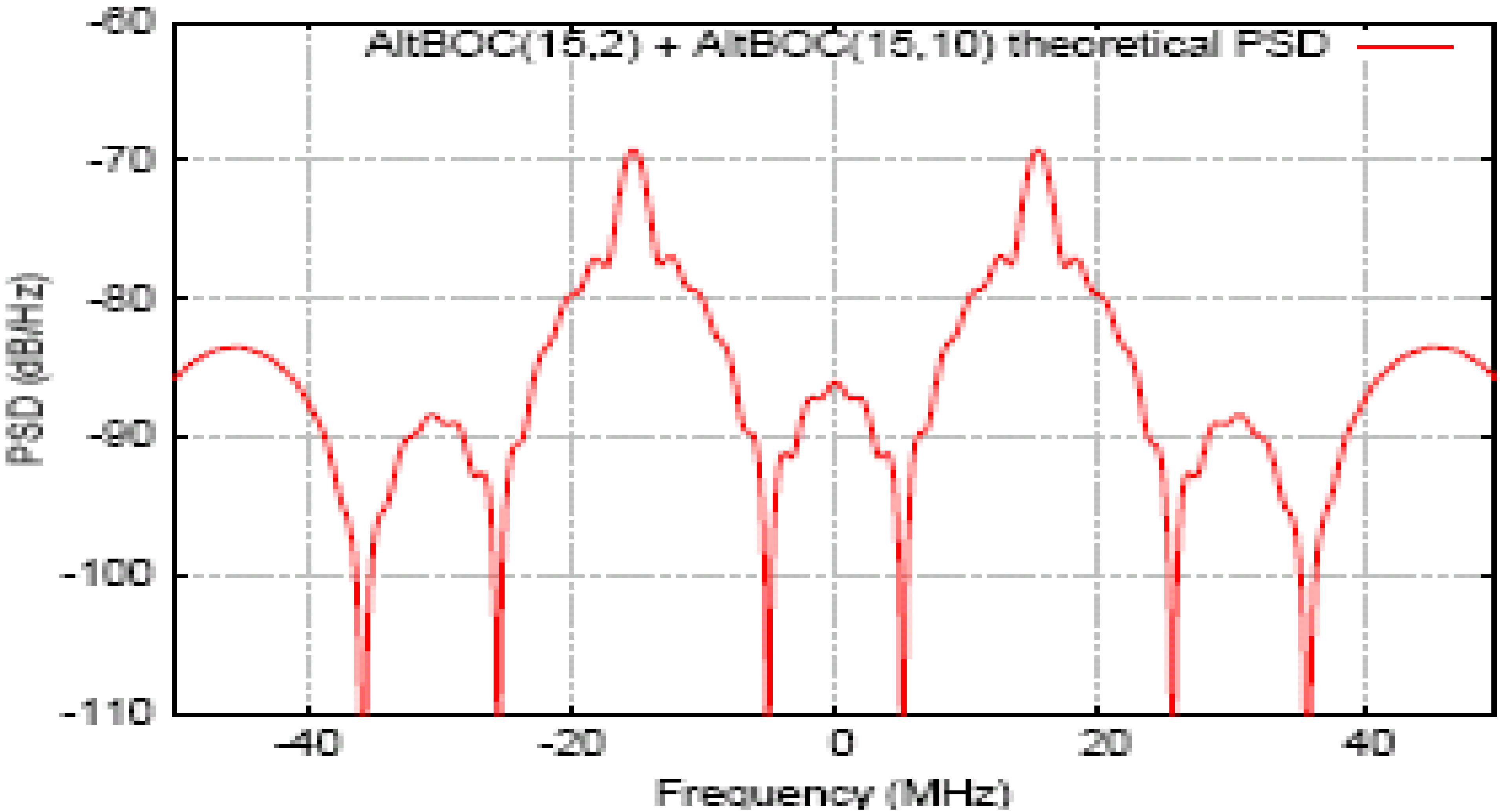


ALTBOC(15,10) with a 2 meter dish gives a pseudorange thermal noise 80 times smaller than a BPSK(10) with an omni antenna

ROB Royal Observatory Belgium
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec École de technologie supérieure
LaCIME
ULCO
LISIC
cnes

Very good accuracy offered by ALTBOC(15,x) modulations, for precise and or science applications, even when using standard omnidirectional GNSS antennas

AltBOC(15,10)-pilot + AltBOC(15,2)-data



Royal Observatory Belgium
ROB
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Université du Québec
École de technologie supérieure
LISIC
cnes

For more detailed information and references, see:

U-SBAS paper in Proc. 52nd International Symposium ELMAR 2010, Zadar, Croatia, Sept. 2010

Universal-SBAS: A Worldwide Multimodal Standard

Jean-Luc Issler[1], Felix Perozans[1], Y. Tawk[2], A. Jovanovic[2], Cyril Botteron[2], P-A. Farine[2], René Jr. Landry[3], Mohamed Sahmoudi[4], Veronique Dehant[5], Alessandro Caporali[6], Serge Reboul[7]

[1]Centre Spatial de Toulouse, CNES, Toulouse, France
[2]Ecole Polytechnique Fédérale de Lauzanne, Neuchâtel, Switzerland
[3]École de Techologie Supérieure, Montréal, Canada
[4]Institut Supérieur AErospatial, Toulouse, France
[5]Observatoire Royal de Belgique, Bruxelles, Belgium
[6]Department of Geosciences, University of Padova, Italy
[7]Univ Lille North of France, Calais, France
Email: jean-luc.issler@cnes.fr

***Abstract*—This paper describes a generalisation of the aeronautical GNSS Space Based Augmentation System (SBAS) air interface, in a true worldwide multimodal standard named Universal S-BAS. Examples of usages of this multifrequency future standard are presented in the area of science and precise positioning, timing, security, robust positioning, maritime and reflectometry applications.**

Keywords : SBAS, GPS, GLONASS, GALILEO, COMPASS, GINS, Science, Precision, U-SBAS, EGNOS, NSGU, frequency, WAAS, QZSS, IRNSS, SDCM, PCW, ionosphere, GNSS

I. INTRODUCTION

Several studies have been done or have been started in order to extend the current aeronautical Space Based Augmentation System (SBAS), called DO-229D Minimum Operational Performance Specification (MOPS) SBAS standard mainly defined by the US Radio Technical Commission for Aeronautics (RTCA, Inc) corporation, Sub-Committee 159, Working Group 2. The SBAS message is transmitted by geostationary satellites using a modulation scheme similarly to GPS wherein the same Gold code family, chipping rate, BPSK modulation of the same GPS carrier frequency of 1575.42 MHz with the difference being that a 500 bps bit stream is also modulated instead of the 50 bps data stream as in GPS. The 500 bps data stream is symbol bits which encode a 250 bps SBAS data stream, containing messages such as satellite integrity and differential corrections. These messages are documented in Appendix A of RTCA/DO-229D, which also serves as the Signal-In-Space (SIS) Interface Control Document (ICD) for SBAS. RTCA/DO-299D has been adopted by ICAO and has become the ICAO aeronautical SBAS standard. As an international standard, aeronautical SBAS can be adopted by any state. Aeronautical SBAS main purpose was to provide near real-time GNSS integrity world-wide. That concept evolved to also providing differential corrections and optionally a ranging signal. In addition, every aeronautical SBAS service provider has the ability to certify and then designate his service for Safety-of-Life (SoL) service. Once certified as a SoL service, the respective aeronautical SBAS service provider would also transmit the appropriate messages and data indicating that the particular transmission (and data) can be used for SoL applications. Data within the aeronautical SBAS message indicate over which regions the differential messages can be used. Aeronautical SBAS is capable of supporting LPV (Localizer with Precision Vertical) approaches to about 66 meters minimums. These are CAT-I ILS equivalent approaches. For further technical details, the reader is referred to the RTCA/DO-229D MOPS.

The idea of the worldwide multimodal Universal-SBAS (U-SBAS) standard is that it could be used in all the regions of the world, by all the civil aviations of the world, but also by all other types of non-aeronautical Safety of Life (SoL) users, and in-addition by non-SoL users of any countries. The worldwide multimodal U-SBAS standard could carry additional channels (signals and messages) to cover the non-aeronautical specific SoL services, and also High Precision Positioning Services (HPPS), Position Velocity Time (PVT) authentication services, safety services, scientific application services, High Precision Timing Services (HPTS), etc. Since the aeronautical and non-aeronautical SoL services would be carried out by the U-SBAS multimodal worldwide standard, the privileged bands addressed by this standard should be a priori all the ARNS/RNSS bands (Aeronautical Radio Navigation Service/Radio Navigation Satellite Service), that is 1164-1215 and 1159-1610 MHz. This standard shall be open to (and compatible with) GPS/WAAS (Wide Area Augmentation System), GLONASS/SDCM (System of Differential Correction and Monitoring), GALILEO/EGNOS (European Geostationary Navigation Overlay Service), COMPASS, QZSS/MSAS, IRNSS/GINS/GAGAN (Indian Radio Navigation Satellite System/Global Indian Navigation System/GPS And Geo Augmented Navigation), and potential other GNSS systems using L band. Backward compatibility with the current and validated L1-C/A SBAS aeronautical standard should be mandatory to avoid modification of the existing single frequency SBAS receivers. The services including robust governmental cryptography would be excluded from the SBAS multimodal worldwide standard. The multimodal worldwide U-SBAS standard is suggested to be elaborated at international worldwide level. As in the field of

Click on the paper to read it !

ROB Royal Observatory Belgium

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Université du Québec
École de technologie supérieure

LACIME

ulco UNIVERSITÉ DU LITTORAL CÔTE D'OPALE

LISIC

cnes