Threats of Ionosphere on GNSS an general overview of CIGALA and CALIBRA Projects

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Presentation Outline

• Threats of Ionosphere on GNSS
  o Ionosphere effects and scintillation

• CIGALA & CALIBRA Projects
  o The team, objectives and realizations
  o Network

• Preliminary results & comments
Threats of Ionosphere on GNSS

• Ionosphere is the main source of errors for GNSS single frequency users;

• For GNSS dual frequency users, the first order effects are eliminated; 2nd order can be modeled (Marques, Monico & Aquino (2011) GPS Solution);

• For GNSS single frequency users, a model may be used (Ionex files from several agencies, Klobuchar or NeQuick models, and others)
Effects such as ionospheric scintillations, caused by time-varying electron density irregularities in the ionosphere that occur more often at equatorial and high latitudes regions, in particular during solar maxima, may cause problems such as:

- signal power fading,
- phase cycle slips,
- receiver loss of lock, etc.,

Such effects degrade the position quality provided by the satellite navigation systems (GNSS). This problem is still to be solved!
Ionospheric scintillation (IS) is caused by time-varying electron density irregularities in the ionosphere that occur more often at equatorial and high latitudes and during solar maximum.

IS may degrade the quality of GNSS positioning and navigation.
Ionospheric Scintillation

- The reliance on GNSS, especially by countries with large territorial coverage, has increased, and IS may be a potential problem for reaching the predicted annual global market for GNSS of about €300bn by 2020.
Impact of IS on GNSS

Threats from Ionospheric Scintillation

- Precise positioning
- Safety-critical applications

Ionosphere

Plasma perturbations

GNSS Satellite

GNSS Receiver

signal fluctuations

Impact of IS on GNSS

Precise positioning

Ionosphere

Plasma perturbations

GNSS Satellite

GNSS Receiver

signal fluctuations
Latin America GNSS Demands

- Off-shore
- Precision Agriculture
- High Accuracy Positioning
- Aerial Navigation
- Rural Cadastre (Brazil – accuracy better than 50 cm – 1 sigma)
- ...

MundoGEO #Connect, Latin America 2014, São Paulo, 9th May 2014
Precise Agriculture demands 24h of RTK Service

Mendonça; Monico; Motoki (2012)
Degradation in the Absolute Positioning

Silva; Monico; Marques (2012)
The Threat to GNSS

- **Current strong reliance on GNSS signals and receivers**
  - Solar maximum was expected to pose serious threats to GPS
  - Signals may be corrupted
  - Services may have outages
  - How will Galileo signals be affected?

- **Modeling ionospheric scintillation essential to develop countermeasures**

GPS scintillation event associated with sudden TEC changes (Brazilian receiver)
CIGALA and CALIBRA Projects
CIGALA

• CIGALA (Concept for Ionospheric Scintillation Mitigation for Professional GNSS in Latin America)
  
  o Funded by European Commission (EC) in the framework of the FP7-GALILEO-2009-GSA (European GNSS Agency)

  o The aims were to analyze the ionospheric scintillation effects, to know its causes and to develop new approaches to be developed in multi-frequency GNSS receivers
CIGALA Partners
CIGALA

• CIGALA Project was finalized on February 2012 (two year of duration)

• But the GNSS network composed of 8 GNSS IS monitoring stations continued collecting data

• It consists of a very useful database for monitoring the ionosphere in Brazil
CIGALA Network
CALIBRA

- Following CIGALA, the CALIBRA project was approved
- CALIBRA (Countering GNSS high Accuracy applications Limitations due to Ionospheric disturbances in BRAzil)
- KoM was on November 2012 and will end on February 2015.
• It was also funded by the European Commission in the framework of the FP7-GALILEO-2011-GSA activity

• It aims to develop new algorithms (and improve existing ones) that can be applied to high accuracy GNSS techniques in order to tackle the effects of ionospheric disturbances
  o Mainly on PPP and RTK
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<td>Market needs &amp; user requirements</td>
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<td>Underlying causes of scintillation and new models for signal propagation and tracking perturbations</td>
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<td>Deployment of specialised network of multi GNSS ionospheric monitoring receivers</td>
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Main Objectives / Review

• Identify and describe vulnerabilities of GNSS carrier phase based techniques and reliant services/applications to ionospheric disturbances

• Establish metric and characterise ionosphere related effects degrading applications – RTK, NRTK and PPP in particular
  o In terms of accuracy, integrity and availability

• Develop local empirical models for TEC climatology and scintillation
Main Objectives / Review

• Develop new algorithms for ‘cleaner’ observable to enable improved positioning performance
• Implement algorithms on SSN receivers
• Carry out application specific field tests, e.g. static, dynamic, offshore, etc.
• Validate and fine tune algorithms
Method

UNESP

GNSS Problem Characterisation

WP100

Underlying Geophysics Assessment and Modeling

INGV

WP200

Application Algorithm Development

WP300

Algorithm Implementation

WP400

Test and Validation

WP500

Final Product
Dissemination of results and awareness to the project and its impact on the attractiveness of Galileo for the user community in Brazil and consequently in Latin America.
CIGALA/CALIBRA Partners in Brazil
CIGALA/CALIBRA Partners in Brazil

Agro – Pastoril Paschoal Campanelli S/A
To allow the experimental evaluation of the plasma drift velocity under scintillation scenario by applying algorithm such as cross-correlation function of the GNSS signal amplitudes using 50Hz data.
GNSS-SP Network - URTKN

Rede GNSS-SP
UNESP RTK Test Area

Track 1 – Partial Obstruction
Track 2 – Several Obstructions
Track 3 – No Obstruction
Track 4 & 6 – Partial Obstruction & Multipath
Track 5 & 7 – Multipath
UNESP RTK Test Area

- High accuracy leveling
UNESP RTK Test Area

• High accuracy GNSS and Total Station Positioning
Preliminary Results

• The deployed CIGALA/CALIBRA Network
• ISMR Query and Visualization Tool for parameters like S4, SigmaPhi, LockTime and so on, with more than two years of data
• High accuracy GNSS market surveying
• Ionospheric short term empirical forecasting model
• Ionospheric model with gradients
• A filtering method developed to improve GNSS receiver data quality
Preliminary Results

• Receivers with capability of working under moderate to strong scintillation
• Algorithm for IS mitigation on RTK and PPP
• Data from several field tests
• Data from the Micro Test Area
• Data from PA tests on dynamic environment
• UNESP RTK Test area for IS and ordinary surveying tests
• And much more…
Questions?
(Perguntas?...)