Ionospheric Scintillation Effects on GPS Measurements

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Ionospheric Scintillation Effects on GPS Measurements

• EPSRC funded project
  - Study effects of ionospheric scintillation and of North/South TEC gradients in Northern Europe and mid-latitudes (UK) by
    - Investigating impact on GPS applications
    - Assessing impact on GPS accuracy, integrity and availability

• 3 years duration

• IESSG with collaborators:
  • Thales Geosolutions Group Ltd
  • Trinity House Lighthouse Service
  • University of Calgary
Work Packages

WP1 Establishment of a scintillation observing GPS network
   Using an array of GPS scintillation monitors
   Co-located with dual-frequency receivers

WP2 Develop data processing and archiving strategies

WP3 Assess impact on EGNOS

WP4 Assess impact on Maritime DGPS

WP5 Assess impact on different receiver technologies

WP6 Application to other satellite systems

Also: Form data base for future (next solar maximum)
   Develop warning & mitigation mechanisms ?
The Monitoring Network

- Thales SkyFix Europe Network
- North South Distribution (red ellipses)
- GPS Iono Scintillation Monitors
- Co-located with 2-freq receivers
Ionospheric Scintillation Monitor

- GPS Silicon Valley GSV 4004
- Dual Frequency 12 channel NovAtel OEM4 card
- Stable ovenized crystal oscillator
- Wide bandwidth to insure that all spectral components of amplitude and phase scintillation are measured (50 Hz raw data)
- Logs and Outputs Statistics of Phase and Amplitude Scintillation (60 seconds data)
- Also outputs TEC and dTEC

The monitor can also track one SBAS satellite (e.g. EGNOS or WAAS)
Experimental IESSG Interactive Scintillation Plots Web Interface

Plot Parameters

Size: 500
Station: Hammerfest

Datasets
- PH11
- PH15
- PHI60
- PHI60
- Elevation
- S4corr
- dTEC60
- dTEC15
- dTEC30
- dTEC45

Limits: date-time
- start: 0 SEP, time: 00:00
- end: 0 SEP, time: 24:00
- y max: 2.0
- y min: 0.0

Satellites: plot all
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
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- 28
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- 30
- 31
Experimental IESSG Interactive Scintillation Plots Web Interface
Stations with Dual-frequency/Scintillation Data

- Ny Alesund (79N 12E)
- Tromso (70N 19E)
- Bronnoysund (65N 12E)
- Lerwick (60N 01W)
- Bergen (60N 05E)
- Nottingham (53N 01W)
- Hammerfest (71N 23E)

- Station with dual frequency Data
- Station with Scintillation Data (current monitoring network, part of Thales SkyFix Network)
Dual-Frequency Model Residuals

Bernese software

24 Hrs, 30 sec dual-freq data from Nottingham

All Satellites

08 Jun 1997
Low of the Solar Cycle

02 Apr 2001
Peak of the Solar Cycle
(major Geomagnetic Storm)
Correlation of TEC residuals with Phase Scintillation (Iono Storm Apr 2001)

Phase Scintillation Data for PRN 10, starting at 22:00 UT on 01 Apr 2001
Correlation of TEC Variations, GPS Positioning Errors and Hourly Standard Deviation of Geomagnetic Field

Lerwick 31 March 2001

TEC Variations at Lerwick

GPS 3D Positioning Errors at Lerwick

Hourly Stdev of Geomag Field from Lerwick
Spatial Analysis of Phase Scintillation
07 September 2002
North-South Gradient in TEC Change
Iono Storm Nov 2001

Lat 79° N
Long 12° E

Lat 70° N
Long 19° E

Lat 60° N
Long 01° W

Lat 53° N
Long 01° W

04 Nov 05 Nov 06 Nov 07 Nov 08 Nov
TEC Change Observed at Tromso and Hammerfest on 7 November 2001

Tromso - IGS 2-freq data processed with Bernese

Hammerfest - output data from GSV4004
Lerwick Nov 01 - Correlation of TEC Variations, GPS Residuals, Phase Scintillation (Bergen) and Hourly Standard Deviation of Geomagnetic Field

TEC change per 30 seconds

Dual Frequency residuals

GPS 3D position Residuals

Phase Scintillation (at Bergen)

Hourly Standard Deviation of geomagnetic field (Lerwick Observatory)

All satellites plotted
L2 Data Loss for Different Receivers at Lerwick and Sumburgh, 4 to 8 Nov 01

4th - 8th November 2001 - Sumburgh Head (TRIMBLE SSI) LERWICK (ASHTECH ZX11)

Lerwick K Index - Time

% of observations with No L2

Lerwick K Index Total Sigma for 4 to 8 Nov 2001

Hourly Standard Deviation of Geomagnetic Field
North-South vs East-West Baseline
DGPS (4 to 8 Nov 01)

DGPS Solution at Girdleness from Flamborough - Hourly 2drms (m)

2drms error (whole period) = 3.5m

DGPS Solution at Lynas from Flamborough - Hourly 2drms (m)

2drms error (whole period) = 2.66m

North-South

East-West
Improvement with the EGNOS Corrections on a North/South Baseline (4 to 8 Nov 01)

DGPS Solution at Girdleness from Flamborough - Hourly 2drms (m)

EGNOS Corrections applied at both ends
(SVs without correction in solution, min 4 SVs)

2drms error (whole period) = 2.57m
However....

2drms error (whole period) = 2.85m

Only 4 SVs with corrections covered by EGNOS grid

2drms error (whole period) = 2.57m

Additional 3 SVs, even without EGNOS correction, improve solution

However...
Possible Development of Warning Mechanisms

Prediction of Scintillation Levels with WBMOD (Wide Band Model)

- Based on climatological models of global distribution of ionospheric irregularities + propagation theory
- Developed by NorthWest Research Associates Inc.
- Inputs: location, day of the year, local time, SSN, Kp
- Relevant outputs: S4 and Phase RMS (SPHI)
- Predictions based on the L1 GPS frequency
Correlation of TEC Changes with hourly standard deviation of Geomagnetic Field, WBMOD prediction and Data Loss, Lerwick, 4 to 8 November 2001

Hourly Standard Deviation of Geomagnetic Field

TEC changes

Predicted Phase Sigma (99% percentile)

Percentage of L2 loss on a semidebellss GPS receiver
Correlation of WBMOD phase and amplitude scintillation predictions with DGPS and EGNOS user 2drms - Trondheim, 4 to 8 Nov 2001

Mean Predicted Phase Scintillation

Mean Predicted Amplitude Scintillation

DGPS Solution at Trondheim from Oslo - Hourly 2drms (m)

2drms error (whole period) = 4.30m

EGNOS Correction applied at both ends
(SVs without correction in solution, min 4 SVs)

2drms error (whole period) = 3.69m