MFMC GBAS – Flight Trials and Performance Studies

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Multi-Frequency Multi-Constellation GBAS
Why? How?

• Protection against ionospheric gradient threat

• Ionospheric scintillation issues in high/low latitudes

• Weak constellations and required masking may have impact on performance
Motivation

Why?

Large ionospheric gradients and scintillation events can result in significant unavailability of the GBAS

Motivation

How?

• Dual-frequency GBAS can tackle the ionospheric gradient problem

• Multi constellation GBAS can reduce the impact of scintillations on availability

• Quickly growing Galileo constellation (all satellites with E1/E5a)

• Currently 12 GPS Block IIF satellites with L1 and L5 operational, continuous launches all with second frequency
L5/E5a Satellite Status
(12 GPS Block IIF, 14 (9) Galileo)

GPS Block IIF and Galileo status
Performance Metric: Availability

- Represented by protection levels:

\[ VPL_{H,0} = K_{ffnd} \cdot \sqrt{\sum_i \left( s_{vert,i} \cdot \sigma_i^2 \right)} + D_v + b_{other} \]

\[ \sigma_i = \sqrt{\sigma_{gnd}^2 + \sigma_{air}^2 + \sigma_{iono}^2 + \sigma_{tropo}^2 + \sigma_{other}^2} \]

- Need to determine all the necessary parameters for the processing modes

- Analysis of extensive ground and flight data to establish expectable performance models
Data Collection

Airbus A320

Duration: 100 hours A320 since May 2015
6 hours Dornier March 2015

Receiver: Javad Delta
23 Mhz bandwidth
2 correlator spacings

Antenna: Antcom multiband

Dornier DO-228
Towards MFMC GBAS – Performance Assessments

Sigma_{\text{air}}

Elevation in A/C body frame [deg]
Javad Delta Receivers with GPS (L1/L2/L5) + Galileo (E1/E5a) + Glonass + BDS Connected to Leica AR25 choke ring antennas
Evaluating Performance of GPS L5 and Galileo E1/E5a Using Ground Measurements

- Improved performance of the Galileo signals

- RX configuration:
  - 0.1 chips correlator spacing (L1/E1)
  - 1 chip correlator spacing (L5/E5a)

- Multipath and noise on Galileo E1 is lower than on GPS L1, especially at low elevation
  - BOC(1,1) modulation
  - Wider transmission bandwidth

- Galileo E5a shows lower multipath and noise than Galileo E1
  - BPSK(10) signal
  - Higher chip rate
  - Higher signal power

Paper presented at ITM 2015: M-S Circiu et. al – “Evaluation of GPS L5, Galileo E1 and Galileo E5a Performance for Multi Frequency Multi Constellation GBAS”
**Dual-Frequency Dual-Constellation GBAS Flight Trials**

- 4 flights in March 2015 with Dornier DO-228 (6h total)
- Satellite visibility: 5-7 dual frequency (GPS+Gal)

**Charts**

- Single-frequency L5/E5a GPS and Galileo
- Dual-frequency L1/E1+L5/E5a GPS and Galileo
Protection Levels
Contribution of Different Sigma Terms

GPS L1 30s (GAST D)  
GPS L5 30s
Protection Levels
Contribution of Different Sigma Terms

VPL [m] vs Distance to GBAS reference [km]

GPS L1 30s (GAST D) vs GPS L1/L5 100s Ifree
Comparison and Trade-Off Studies
30s Smoothing Constant

- ‘Nominal Performance of Future Dual-Frequency Dual-Constellation GBAS’
  In press, August 2016, IJAE
Comparison and Trade-Off Studies
100s Smoothing Constant

- Nominal Performance of Future Dual-Frequency Dual-Constellation GBAS'
In press, August 2016, IJAE
Conclusions

- Dual frequency and multi constellation GBAS can resolve many of the current GBAS issues

- More data and investigations needed for suitable models covering all aircraft, receivers, antennas etc.

- No solution to all problems

- No defined way ahead concerning different modes

- Trade-off is a difficult task
Thank you for your attention!

Questions?