DFMC SBAS: Reception of QZSS L5 SBAS Signal in Europe

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Introduction

• SBAS: Satellite-Based Augmentation System
  – International standard augmentation system primarily for aviation.
    ➢ *International standard by ICAO (International Civil Aviation Organization).*
    ➢ *Transmits Augmentation information from the SBAS satellite.*
      ◆ Augments GNSS in terms of accuracy and integrity.
    ➢ *Current standard: Single-frequency SBAS on L1.*
    ➢ *US WAAS, Japanese MSAS, European EGNOS, and Indian GAGAN.*

• DFMC SBAS: The Second Generation SBAS
  – Dual-Frequency Multi-Constellation SBAS using L5 frequency.
    ➢ *Standardization activities ongoing: Recently defined the baseline.*
  – ENRI has been conducting DFMC SBAS experiment with QZSS L5S signal.

• EU-Japan Joint Experiment
  – Trial of receiving the signal at GSA HQ in Prague next week (March 21-22).
• Monitors consistency of GPS signals on the ground.
• Transmits differential correction and integrity information via SBAS satellite.
DFMC SBAS

• DFMC (Dual-Frequency Multi-Constellation) SBAS
  – The second generation SBAS following L1 SBAS.
    ➢ Using L5 SBAS signal instead L1.
    ➢ Eliminates ionospheric effects thanks to dual-frequency operation.
      ➢ Vertical guidance service everywhere in the coverage.
    ➢ Supports Galileo (and QZSS).
    ➢ Allows non-GEO transmission.
  – Standardization activities ongoing at the ICAO.

• New Feature: Transmission by Non-GEO SBAS
  – DFMC SBAS could be transmitted by non-GEO satellites like QZSS IGSO.
    ➢ Improves availability of SBAS signal by transmission from high elevation angle.
    ➢ Possible solution for applications where GEO signal is likely blocked.
    ➢ Enables SBAS service independent of the latitude of the service area by combination of dual-frequency operation and non-GEO transmission.
Usage of IGSO Satellites

- DFMC SBAS could be transmitted by non-GEO satellites like QZSS IGSO.
- Improves availability of augmentation signals where GEO signal is blocked.
  - Arctic/Nordic regions, mountain area, urban canyon,…
  - Navigating Arctic routes and precise positioning for resource exploration.
  - Note DFMC SBAS is not influenced by ionosphere even in Equatorial regions.
  - Seamless service from Equator to Poles, mountain to urban canyons…

Tyler Reid, ION GNSS+ 2015
Visibility from Nordic Region

- Elevation angles computed from QZS-1/2/4 almanacs.
- QZSS IGSO satellites are visible in Nordic region; Elevation is higher than EGNOS GEO at some Northern location.
Prototype DFMC SBAS

**Prototype DFMC SBAS Developed by Japan**
- The second generation SBAS following L1 SBAS.
  - Eliminates ionospheric effects thanks to dual-frequency operation.
    - Vertical guidance service everywhere in the coverage.
- Electronic Navigation Research Institute, National Institute of Maritime, Port and Aviation Technology has developed the prototype.
  - GPS/GLONASS/Galileo/QZSS-capable dual-frequency SBAS.
  - Compliant with the draft standards of L5 SBAS being discussed at ICAO.
    - Helps validation activities ongoing at ICAO.

**DFMC SBAS Experiment has been Conducted with QZSS**
- The First L5 SBAS experiment with live L5 signal from the space.
  - Using QZSS L5S augmentation signal transmitted from QZS-2, -3, and -4.
- Prototype DFMC SBAS is used for the experiment.
- Began the experiment on 23 Aug. 2017 via L5S signal of QZS-2 IGSO.
  - Now transmitting from QZS-2/4 IGSO and QZS-3 GEO.
Experimental Configuration

- Supports DFMC
- Provides observation in real time
- Operates in real time
- Dual-Frequency
- Supports GPS, GLONASS, Galileo, and QZSS

Uplinks L5 SBAS message stream for transmission

GLONASS
Galileo
BeiDou

GSI (Shinjuku, Tokyo)
ENRI L5 SBAS Prototype
ENRI, MPAT (Chofu, Tokyo)
QZSS C&C
QZSS MCS (Hitachi-Ota, Ibaraki)

QZSS #2, #3, and #4
GEO (QZS-3) + IGSO (QZS-2/4)
Real Time Experiment

- Evaluation of L5 SBAS message generated in real time.
  - Supporting GPS, Galileo, and QZSS in L1/L5 dual-frequency mode.
- Confirmed that L5 SBAS augments multi-constellation of GPS+Galileo+QZSS.
Reception in Nordic Region

- **EU-Japan Joint Experiment**
  - Planned under the Cooperation Arrangement on GNSS.

  Schedule for DFMC SBAS Reception Trial

<table>
<thead>
<tr>
<th>Transmission from</th>
<th>2018 to 2019</th>
<th>2020 to 2022</th>
<th>After 2023</th>
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</thead>
<tbody>
<tr>
<td>QZSS L5S</td>
<td>ENRI receiver</td>
<td>ENRI &amp; Thales Rx</td>
<td>ENRI &amp; Thales Rx</td>
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<tr>
<td>EGNOS V3</td>
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</table>

- **First Step: Reception trial in Prague**
  - Trial of receiving L5S at GSA HQ in Prague next week (March 21 to 22).
  - Using ENRI L5S-capable receiver.

- **Next Step: Reception trial in Nordic Region**
  - Likely in this summer.