Current status of Quasi-Zenith Satellite System

Japan Aerospace Exploration Agency
QZSS Project Team

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I. System Description

**Concept of the QZSS (1/2)**

- QZSS is designed so that at least one satellite out of three satellites exists near zenith over Japan.
- Three satellites are in elliptical and inclined geosynchronous orbits in different orbital planes to pass over the same ground track.
  \[(a=42,164\text{ km}, e=0.06-0.09, i=39-47\text{deg}, \Omega = 120\text{deg} \text{ apart})\]
I. System Description

**Concept of the QZSS (2/2)**

- QZSS can provide a seamless service from high elevation angle.
- Increasing the availability of PNT services in downtown and mountainous areas.
I. System Description

System Architecture

Navigation Signals
L1: 1575.42 MHz
L2: 1227.60 MHz
L5: 1176.45 MHz
LEX: 1278.75 MHz

TWSTFT
Up: 14.43453GHz
Down: 12.30669GHz

Laser Ranging

SLR Site

Monitor Station NW

Time Management Station

TT&C, NAV Message Upload**

Control Station (MCS)

Function distributed in each institute
Timing management, WDGPS correction, etc.

TT&C-NAV Message Uplink Station

User Receiver

QZSS

GPS

GEONET (GSI)

**: S (Up: 2025-2110, Down: 2200-2290MHz) band for LEOP
and C (Up: 5000-5010, Down: 5010-5030MHz) band for Nominal Operation

SLR: Satellite Laser Ranging, TWSTFT: Two Way Satellite Time and Frequency Transfer
I. System Description

**Space Segment - QZS-1 -**

<table>
<thead>
<tr>
<th>Mass</th>
<th>Approx. 1,800kg (dry) (NAV Payload: Approx. 320kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Approx. 5.3 kW (EOL) (NAV Payload: Approx. 1.9kW)</td>
</tr>
<tr>
<td>Design Life</td>
<td>10 years</td>
</tr>
</tbody>
</table>

**Satellite Configuration on Orbit**

- Radiation Cooled TWT
- TWSTFT Antenna
- C-band TTC Antenna
- Laser Reflector
- L1-SAIF Antenna
- L-band Helical Array Antenna
I. System Description

Navigation Payload on the QZS-1
Okinawa is primary TT&C station for nominal operation.
LEOP operation is to be conducted by using JAXA Ground TT&C Network.
I. System Description

Ground Segment (2/2)

QZS-1

Experimental Receiver

Laser Ranging Station

Monitoring Stations

QZSS Tracking Control Stations

Master Control Station

Augmentation Signal Generator

Integrity Information Generator

Data Server

GEONET N/W

Augmentation Signal Generator

Time Management Station

UTC(NICT)

Remote Time Synchronization Ground Equipment

NICT

AIST

ENRI

JAXA

GSI

NAV Signal

NAV Message

TWSTFT

TLM/CMD

Augmentation Signal
## I. System Description

### Planned Signals

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L1-C/A</strong></td>
<td>1575.42MHz</td>
</tr>
<tr>
<td><strong>L1C</strong></td>
<td><strong>Complete compatibility and interoperability with existing and future modernized GPS signals</strong></td>
</tr>
<tr>
<td><strong>L2C</strong></td>
<td>1227.6MHz</td>
</tr>
<tr>
<td></td>
<td><strong>Differential Correction data, Integrity flag, Ionospheric correction</strong></td>
</tr>
<tr>
<td><strong>L5</strong></td>
<td>1176.45MHz</td>
</tr>
<tr>
<td></td>
<td><strong>Almanac &amp; Health for other GNSS SVs</strong></td>
</tr>
<tr>
<td><strong>L1-SAIF</strong></td>
<td>1575.42MHz</td>
</tr>
<tr>
<td></td>
<td><strong>Interoperability with GPS-SBAS</strong></td>
</tr>
<tr>
<td><strong>LEX</strong></td>
<td>1278.75MHz</td>
</tr>
<tr>
<td></td>
<td><strong>Experimental Signal with higher data rate message (2Kbps)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Compatibility &amp; interoperability with Galileo E6 signal</strong></td>
</tr>
</tbody>
</table>

* L1-SAIF: L1-Submeter-class Augmentation with Integrity Function
I. System Description

System Time and Geodetic Reference Frame Standards

- Time scale: QZSST
  - The length of one second is identical to International Atomic Time (TAI).
  - Integer second offset for TAI is the same as GPS, and TAI is 19 seconds ahead of QZSST.
  - Interface with GPS:
    - The SV clocks of QZS and GPS satellites are both controlled with respect to the offset with the GPS time scale (GPST).
    - GQTO: The time scale offset with the GPS is less than 2.0 [m] (95%).

- Coordinate System: JGS
  - The QZSS coordinate system is known as the Japan satellite navigation Geodetic System (JGS). This coordinate System is operated so as to approach the International Terrestrial Reference System (ITRS).
  - The coordinate system offset with GPS is less than 0.02 [m].
I. System Description

Expected Performance - Service Area -

Minimum Elevation Contour for 3 QZS over 24 hours

* for maximum elevation of visible satellites
I. System Description

Expected Performance - Accuracy -

- The Signal-in-Space (SIS) User Range Error
  - is less than 1.6 m (95%) Including time and coordination offset error.

- User positioning Accuracy
  - defined as positioning accuracy combined GPS L1_C/A and QZSS L1_C/A for single frequency user, L1-L2 for dual frequency user.

<table>
<thead>
<tr>
<th></th>
<th>Specification</th>
<th>Simulation result</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIS-URE</td>
<td>1.6m (95%)</td>
<td>1.5m (95%)</td>
</tr>
<tr>
<td>Single frequency user</td>
<td>21.9m(95%)</td>
<td>7.02m(95%)</td>
</tr>
<tr>
<td>Dual frequency user</td>
<td>7.5m (95%)</td>
<td>6.11m(95%)</td>
</tr>
</tbody>
</table>

- L1-SAIF signal can provide WDGPS correction data, its positioning accuracy is 1m (1 sigma rms) except in cases of large multipath error and large ionospheric disturbance.
I. System Description

Timetable for System Development & Operation

3 months later from the launch (for 1 year) : In Orbit Validation
I. System Description

Development Status - Space Segment -

L-band Antenna Pattern Test
Proto-Flight Model (July 2008)

NAV Payload PFM TVT
(Jan 2009)

Satellite System (Aug 2009)
I. System Description

Development Status - Ground Segment -

Agreements for hosting QZSS MSs.

- **NOAA**
  - National Weather Forecast Office (WFO)
    - MOU (30/09/2008)
- **NASA**
  - Kokee Park Geophysical Observatory (KPGO)
    - LOA (10/10/2008)
- **Indian Space Research Organisation (ISRO)**
  - MOU (24/07/2008)
- **Geoscience Australia (GA)**
  - MOU (TBD)
- **Asian Institute of Technology (AIT)**
  - MOU (18/03/2009)
II. Service Provided and Provision Policies

**Political Back Ground of the QZSS (1/2)**

- Basic Act on the Advancement of Utilizing Geospatial Information (AUGI)
  - August 2007, Basic Act on AUGI entered into force
  - April 2008, Basic Plan for AUGI was approved by the Cabinet (based on Article 9 of the Basic Act on AUGI)
    - QZSS is a key issue and implemented by phased approach;
      - Phase 1: First satellite launch and technology and application demonstration
      - Phase 2: 2nd and 3rd satellite will be launched after assessment of the result of phase 1
- Public-Private-Partnership for Promoting Utilization
  - QZSS project is based on the collaboration between private sector and government
II. Service Provided and Provision Policies

Political Back Ground of the QZSS (2/2)

- Basic Space Law
  - May 2008, Basic Space Law was enacted
  - June 2009, Basic Plan for Space Policy was decided by the Strategic Headquarters for Space Policy
    (chaired by the Prime Minister, based on Article 25 of the Basic Space Law)

- Space-based PNT in the Basic Plan for Space Policy
  - Support six basic Pillars in the Plan
  - Promote highly accurate system such as QZSS and MSAS
  - Create new services in our daily life such as personal navigation systems, with private sector
II. Service Provided and Provision Policies

Organization Structure of QZSS Development & Utilization

Strategic Headquarters for Space Policy, Cabinet

- Ministry of Internal Affairs and Communications (MIC)
- Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- Ministry of Economy, Trade and Industry (METI)
- Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
- Ministry of Foreign affairs (MOFA)

- National Institute of Information and Communications Technology (NICT)
- Japan Aerospace Exploration Agency (JAXA)
- National Institute of Advanced Industrial Science and Technology (AIST)
- Geographical Survey Institute (GSI)
- Electronic Navigation Research Institute (ENRI)
- Satellite Positioning Research and Application Center (SPAC)
Satellite Positioning Research and Application Center (SPAC) was established in 5 February 2007 approved by the Ministers associated with QZSS research and development (MEXT, MIC, METI and MLIT) to promote navigation satellite technology application and consequential geo-spatial information utilization (http://www.eiseisokui.or.jp/en/)
II. Service Provided and Provision Policies

- GPS interoperable signals, L1 C/A, L2C, L5 and L1C, are to be provided on the basis of no direct user fee.

- GPS performance enhancement signals, L1-SAIF and LEX, charging policy is under examination.
II. Service Provided and Provision Policies

**Interface Specification for QZSS**

- Describes Not only SIS ICD but also SPS, CONOPS for design of receiver and applications
  - System architecture of whole QZSS
  - Signal structure and specifications
  - Service performance properties
- Close relationship with GPS IS Documents
- All users can download **freely** from JAXA’s web site
  - Both Japanese and English versions are available.
- Ver. 1.0 was released in June 2008.
  - IS-QZSS ver. 1.1 has been released in August 2009.
  - It is available on following web site.

[http://qzss.jaxa.jp/is-qzss/index_e.html](http://qzss.jaxa.jp/is-qzss/index_e.html)
Compatibility is a mandatory requirement to share same frequency bands among multi GNSS systems without harmful interference.

QZSS complies with the international rule and consensus.

- ITU Radio Regulation
- ICG definition
Interoperability is **NOT mandatory**, but **highly desirable** in the users’ point of view.

There exists some levels for the interoperability among GNSS depending on each application.

- Each applications have different allowable levels.
  - For instance, High end precise positioning users can allow combining usage of CDMA and FDMA signals.

QZSS will try to achieve as higher levels of interoperability as possible, for all user communities including low-cost receivers

- L1 and L5 with GPS, Galileo, COMPASS, as well as future GLONASS CDMA signals
- L2C with GPS
- LEX with Galileo
III. Perspective on Compatibility and Interoperability

Requirements for Securing High Level Interoperability

- Same RF properties
  - Center Frequency, Bandwidth, Spectrum
  - PRN code family
- Same Message structures
  - Message rate, Error Correction method, Frame length,
    Message contents and their definitions
- Same Time and Geodetic reference
- Same Max/Min User Receiving Power
  - need for better availability and geometry without increasing
    noise floor, i.e. degrading ranging accuracy.
  - QZSS may have some exemption due to its eccentricity.
  - It can be accepted with the direction or general principal, but
    appropriate and achievable URP range for each system are to
    be investigated.
- The above requirement should be provided in open technical
  descriptions for users such as;
  - Interface Specification
  - Performance standard
Commitment of Service Performance

- Performance standard will be described in IS-QZSS document after enough evaluation through actual operation will be implemented.
  - Moderate specification values are to be written in the document during the first step, followed by the appropriate values during the next step, obtained from operation's experience.

- JAXA will monitor the performance of the QZSS and report periodically in web site, as to whether the described performance is matched.

- As for providing commitment, careful discussion is to be requested.
To discuss future joint development and experiment for multi GNSS use in Asia Oceania region
To feed back the experiment result to discussion on interoperability
Official announcement will be issued soon at
  • http://www.multignss.asia

Multi-GNSS
  • More Stars, Signals, Frequencies
  • Increasing coverage, availability
  • Better Geometry
  • Higher accuracy
  • More reliable, robust performances

New Applications
IV. Summary

- QZSS is a Japanese regional Space-based PNT System
  - Enhance GPS capability
  - High level interoperability with GPS
- QZSS is being developed by step by step manner
  - First satellite (QZS-1) will be launched in Summer of 2010
- Proto-Flight test of QZS-1 has been conducted.
- The User Interface document, IS-QZSS ver. 1.1 is available on [http://qzss.jaxa.jp/is-qzss/index_e.html](http://qzss.jaxa.jp/is-qzss/index_e.html).

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