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Augmentation & Assistance

QZSS - Japan's New Integrated Communication and Mobile Users

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Over the past several years, leading public and private organizations in Japan have been investigating proposals for developin year, the Japanese government authorized continued work on a concept for a Quasi-Zenith Satellite System (QZSS), or Jun-Te Corporation (ASBC) team, including Mitsubishi Electric Corp., Hitachi Ltd., and GNSS Technologies Inc. (See the sidebar, "Th

If all proceeds as planned, by 2008 the QZSS would provide a new integrated service for mobile applications in Japan based positioning. QZSS's positioning capabilities would, in effect, represent a new-generation GPS space augmentation system, w QZSS is seen primarily as an augmentation to GPS, without requirements or plans for it to work in standalone mode, QZSS ca can be augmented with geostationary satellites in Japan's MTSAT Satellite-based Augmentation System (MSAS) currently und design similar to the U.S. Federal Aviation Administration's Wide Area Augmentation System (WAAS).

This article describes the current overall QZSS concept, design considerations and alternatives including the satellite constell for a differential corrections service.

Market Drivers

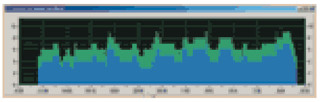
To understand demands for new augmentation systems such as QZSS, one should look at the GPS market in Japan. Today, J services for civil use. The necessity for the new advanced augmentation system came from the spread of civil use of GPS ser land surveying, telecommunications, and so forth.

Approximately two million GPS-equipped car navigation units are sold annually in Japan with a cumulative total of 9,620,000 un annual sales will increase to as many as 2.7 million units per year within the next few years. Currently, about 3.8 million GPS-eq installed base of cell phone users in Japan is 70 million units, equal to about 60 percent of the entire population. This represen annual sale of cellular phone units is about 45 million units per year.

The number of GPS reference stations for synchronizing the CDMA telecommunications infrastructure is 9,000 today and is e market is relatively small - an estimated 1,500 receivers with very low turnover. GPS receivers used in construction number ab

Potentially, railway cars can be equipped with GPS , which could add another 30,000 units.

As one can see, car navigation is the second-largest market in terms of unit volume after cellular phones. The turnover rate fo average unit's life-span doesn't exceed one or two years. But the cellular phone market will not necessarily coincide with the G expressed an intention to provide new-generation cars with an integrated multimedia system, which will function as an office o estimate the potential car navigation market on the size of annual domestic car sales, which is between 4 and 4.5 million. Toda for reliability and availability of positioning service, which at present has some limitations due to the limited satellite visibility typ augment GPS to meet these requirements.



(Click on image for larger view) Figure 1: Simulation of anticipated number of GPS satellites (blue) and QZSS asymmetrical 8-shaped orbit satellites (green) over Tokyo during a 24-hour period at an elevation of at least 30 degrees.

Although QZSS is expected to primarily benefit car navigation users, it will undoubtedly also b well - through the improved visibility, availability, constellation geometry, and corrections servi Tokyo area above 30-degree elevation mask (blue is GPS only, green GPS and QZSS). Figu Shinjuku (Tokyo downtown) district, with the white areas representing obstructed areas in whic position fix. The depicted area is approximately one square kilometer. In the case of GPS-on the total area; for GPS and QZSS (right panel), on 70 percent.

We are also investigating possibilities for improving assisted GPS service for cellular phones through the QZSS, including GPS orbital data, and time.

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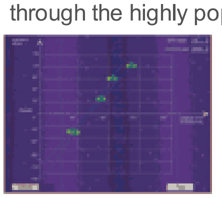
Satellite Constellation

The QZSS constellation will consist of three satellites moving in periodical highly elliptical orbits (HEOs) over the Asia region. T this article depicts an artist's rendering of the QZSS satellite. The big antenna on the top is for S-band communication. The QZ Japan's H-IIA launch vehicle or a similar type of launcher. Satellites will have L-, S-, and Ku-band capabilities (S-band for broad communications, Ku-band for high-speed communications and TT&C).

(Click on image for larger view) The Evolution of the QZSS Project.

Five types of constellations, which are being considered for QZSS, were registered with the Internationa November 2002. Figure 3 presents the main characteristics for these orbits. We have analyzed mainly t Keplerian parameters. These are a 45-degree inclination with eccentricity of 0.1 (asymmetric 8-shape) a with eccentricity of 0.36 (tear drop shape), corresponding to Type 3 and Type 4/5, respectively, in Figur

Figure 4 demonstrates a satellite distribution for these constellations (types 3 and 4) in the orbital plane. been dropped from consideration due to the frequent satellite maneuvers that would be required to avo through the highly populated geostationary belt. Also this constellation would provide less favorable visibility over the northern



(Click on image for larger view) Figure 4: QZSS constellation deployment of satellites in orbital planes for Type 3 and Type 4 (as described in Figure 3).

As is well-known, Kepler's Second Law of Motion states that a line joining a satellite and the Earth swee time. Therefore, due to the highly elliptical shape of the QZSS orbit, a satellite will linger in the part of the decreases when it goes far from Earth. This will allow the QZSS satellites to spend most of their time ov seen from the elevation graph in Figure 6 (for the asymmetrical figure-8 orbit), a QZSS satellite typically with an elevation above 70 degrees, a performance characteristic from which the term "quasi-zenith" de

To help choose among possible orbits, we looked at the advantages and disadvantages of each orbit fr communication service point of view. For positioning, we used a newly developed simulation tool to ana observability, and their potential for accuracy and ambiguity resolution assistance, taking into account the geometry, and relative speed. (See the sidebar, "A QZSS Simulation Tool.") The simulation tool estima user-to-satellite geometry, satellite-to-network geometry, visibility, and coverage. We also looked at the to find an optimal design, considering visibility and coverage as criteria. We estimate achievable accura location of tracking stations.

Figure 3 depicts the ground tracks for the constellations under consideration and Figure 5 shows five stations of a tracking ne for purposes of simulations. (Because this configuration is not optimal, it will almost certainly not be the final tracking network c be a more probable candidate. This orbit goes about 400 kilometers below the geostationary satellites belt and therefore requ with a symmetrical 8-shape orbit. However, satellites should be monitored for a collision risk at orbit intersections, which is not

The asymmetrical 8-shape orbit also gives better characteristics for positioning service due to superior

(Click on image for larger view) Figure 5: Preliminary location of tracking stations used for QZSS simulation.

ambiguity resolution due to improved satellite visibility, geometry, and azimuth-elevation dynamics, that i azimuth, elevation and visibility graphs for this constellation and sky chart for number 3 and 4 types (fron ephemeris estimation, because of better satellite to monitoring network geometry.

Tracking Network

The accuracy of the system will directly depend upon the accuracy with which one can determine QZSS network has to be constructed. The task is complicated, because the satellite-to-groundstation geometry for a regional network GLONASS.

The QZSS design calls for three types of tracking networks. The first is a part of the control segment and responsible for colle broadcast ephemerides, QZSS satellite clock models, and clock differences to GPS system time. These data will be uploade the navigation message. This network has to have very high integrity. For its geodetic coordinate system, the QZSS will use th (ITRF) or the Japanese Geodetic Datum (JGD-2000), which is linked to ITRF. Apart from this, the system should provide an c including GPS satellite clock corrections. As the next step QZSS also can provide the same functions for GALILEO and GLO GLONASS system time.

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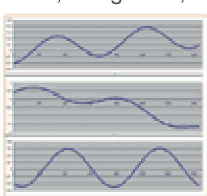
The second network serves to provide enhanced functionality with precise ephemerides. The proposal for this network would e QZSS satellites and a global component with 25 stations to monitor the GPS constellation. The QZSS will use the third networl Japan during the first stage and 10 reference stations outside Japan in Asia. The current plan calls for use of Japan's Geograp GPS reference stations to generate carrier phase corrections. Three or four laser ranging systems will also be used for test ar

The development of this ground network includes selection of the optimal design for tracking station locations. To do this, we station locations. We also have to analyze the proposed network based on the inverse visibility study (satellite to reference sta (based on geometry), and visibility and availability of reference stations for QZSS and for GPS.

For example, we used our simulation software and Bernese GPS postprocessing software to analyze whether the tracking-sta accuracy. We simulated the asymmetrical figure-8 QZSS orbits. Using a disturbed orbit as an initial guess for orbit estimation the basis of simulated measurements from the given network of reference stations (as shown in Figure 2) with decimeter-leve

The simulation verified the QZSS orbit's observability from the given tracking network. GPS ephemerides had been fixed to Ir an attempt to improve GPS orbits using the QZSS regional network gives less-accurate results in comparison with IGS orbits. track, along-track, radial) for QZSS satellites over a 12-hour period.



(Click on image for larger view) Figure 7: Error components (from top: cross-track, along-track, radial) of estimated QZSS satellite position for 12-hour data arc. (Vertical scale in meters.)

The QZSS project will require international cooperation in order to provide places to locate tracking stati precise ephemeris estimation is expected to be done in cooperation with NASA's Jet Propulsion Labor

A Matter of Time

The quality of QZSS differential corrections depends partly on the type of time synchronization, the qua ground control segment. QZSS System Time will be aligned to the Japan UTC (CRL). QZSS navigation directly or through UTC (USNO). Depending on the eventual QZSS implementation, the navigation mess correction can be broadcast. Clock accuracy and the data processing burden will vary as a function of th

As part of the overall QZSS test program, QZSS time comparison equipment, developed by the Comm ETS-VIII and evaluated. This equipment will provide time comparison, using two-way time transfer (TW equipment will be used in QZSS to assist time synchronization.

Different options for satellite clocks under consideration now. Use of high-accuracy atomic clocks would allow the system to o emergencies, such as earthquakes, in which uploads from ground control were unavailable. It will also provide the capability to A system based on low-accuracy clocks has no prototypes but basically could work in a similar fashion to pseudolites, for exa satellite clocks also will be a factor in the determination of QZSS satellite lifespan, the requirement for which is 12 years.

Differential Correction Service

In considering the QZSS differential correction service, we should highlight the differences from the WAAS-like MTSAT (multi-
(MSAS). In terms of ranging service, QZSS will provide better geometry and more frequencies, which will allow direct estimatio
signal modernization, in which case civil codes with higher chip rates than the L1 C/A-code will be available on L2 and L5 in the
and therefore provide potentially better service.

Differences also exist between QZSS and MSAS in the way corrections are generated. The QZSS will have dissimilar content
QZSS will be generated differently, partly because many more reference points will be available in Japan. MSAS ionospheric
density of reference stations.

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As with ionospheric corrections, QZSS will use a dense local grid for the tropospheric correction, rather than the global model
generate more accurate atmospheric corrections by giving more weight to actual observations instead of modeling. These cor
QZSS will use the same grid data for all frequencies and for code and carrier phase corrections. In the Asian region outside Ja

On the other hand, QZSS will not need the same high integrity level as MSAS, which has design requirements for safety-of-life
would be difficult, taking into account the different infrastructure, onboard satellite clocks, constellation dynamics relative to mo
MSAS for safety-critical missions, but instead can provide more high-accuracy and diverse services.

Using the unique advantage of a very dense GeoNet reference station network in Japan, we are conducting a feasibility study
grids. Apart from the grid data, the RTK corrections will incorporate one or several data streams from artificially created refere
real reference station, an ARS can provide data for a satellite which is not visible from the receiver location. To remove orbital
transmitted to the user. The QZSS corrections from two sub-streams (one includes ionospheric corrections, another – orbital)
sufficiently to allow users to implement conventional RTK approaches.

Conclusion

An Advanced Space Business Corporation team including MELCO, Hitachi, NTS and GNSS Technologies, is currently working
which then will be submitted to related governmental institutions. A definition study will continue approximately until June of 200
specified.

Acknowledgements

The availability analysis over 3D map was performed using software developed by the laboratory of Prof. R. Shibasaki. The au
discussions and the preparation of cooperation with JPL. We would also like to acknowledge Mr. Bryan Townsend for participa
of Astronomical Institute of Bern University for practical discussions on precise orbit estimation.

Manufacturers

The signal-availability analysis in Figure 2 was done using 3D DiaMap by Mitsubishi Corporation. Figures 1, 3, 4, 6, and 7 were
Technologies Inc., Tokyo, Japan, developed by the first author.

Some network RTK software modules and libraries for ionospheric and tropospheric corrections for G-Sim and the QZSS-RT
Inc., Calgary, Alberta, Canada.

We also used an STR 4760 GPS simulator from Spirent Communications, Paignton, UK.

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