A Realization of QZSS Time Synchronized with UTC(NICT)

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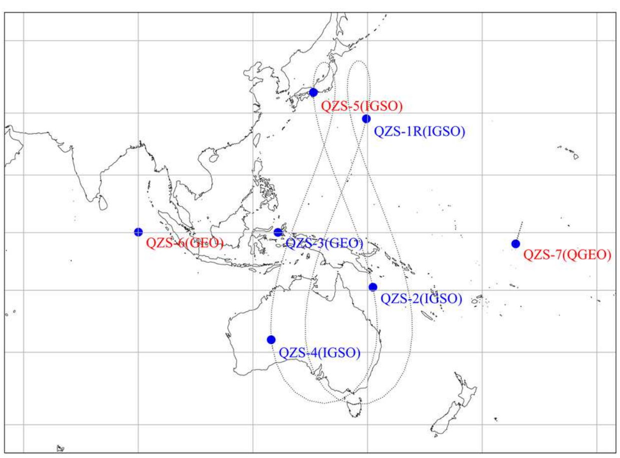
***Summary*—This paper describes a method of realizing QZSST (QZSS time) synchronized with UTC(NICT) in the planned update to a seven-satellite constellation QZSS to maintain PNT services in Japan. We expect uncertainties between QZSST and UTC(NICT) are small enough. Furthermore, we will confirm the realization of QZSST synchronized with UTC(NICT) through a demonstration lasting three years following the launch of the new satellites.**

Keywords*—*QZSS, satellite navigation system, QZSST (QZSS Time), UTC(NICT), time synchronization

I. INTRODUCTION

The Quasi-Zenith Satellite System (QZSS), a Japanese satellite navigation system, is operated with four satellites, master control stations, tracking, telemetry, and command (TTC) stations, and GNSS monitoring stations. QZSS mainly serves positioning, navigation, and timing (PNT) services as GPS complementary [1][2] and GNSS augmentation services [1][3][4][5] for the Asia-Oceania region.

Three additional satellites and an update of the ground segment are planned for QZSS by Japanese fiscal year (JFY) 2024. Fig. 1 shows the satellite constellation and ground track. JAXA is mainly responsible for developing the demonstration system which includes inter satellite ranging and bi-directional ranging between satellite and ground TTC station subsystem shown in Fig. 2 [6] to realize sustained positioning and improve Signal-In-Space User Range Error (SIS-URE) [7].



Four satellites, QZS-2,3,4,1R are operating in orbit; three more (QZS-5,6,7) will be launched by JFY 2024.
Fig. 1. The seven-constellation QZSS Ground Track

QZSST (QZSS time), the system time in QZSS, is used as the reference time of the clock ephemeris in QZSS navigation messages and is synchronized with GPST to maintain interoperability to GPS. Moreover, the UTC parameters in QZSS navigation messages that indicate clock offsets between QZSST and UTC(NICT) generated by National Institute of Communications Technology (NICT) are calculated by GPS common view.

In this paper, we aim to establish QZSST synchronized with UTC(NICT) to maintain PNT services in Japan. Here we show an overview of the demonstration system constructed by JAXA and present the method of realization of QZSST synchronized with UTC(NICT) along with updating to a seven-constellation QZSS.

II. METHODS/RESULTS

QZSS includes navigation satellites equipped with rubidium atomic frequency standards (RAFS) and GNSS monitoring stations a part of which equipped with hydrogen masers. Clock offsets between these clocks at reference points are estimated with navigation signals by orbit and clock estimation.

In the current system, QZSST is synchronized with GPST due to interoperability. The clock offsets which include GPS and QZS SV clock offsets and GNSS monitoring stations' clock offsets are simultaneously estimated relative to temporary reference time calculated by composite clock of some GNSS monitoring stations equipped with stable clocks. The time difference between GPST and the temporary reference time can be calculated by these estimated clock offsets and GPS navigation messages which include clock offsets between GPST and GPS SV clocks. Finally, QZSST is synchronized with GPST by adjusting the time difference between GPST and temporary reference time.

In the demonstration system, some of GNSS monitoring stations are installed at NICT to synchronize QZSST with UTC(NICT). The clock offsets which include SV clock offsets and GNSS monitoring stations' clock offsets are estimated based on temporary reference time. The time difference between UTC(NICT) and temporary reference time can be calculated via the GNSS monitoring stations whose delays are

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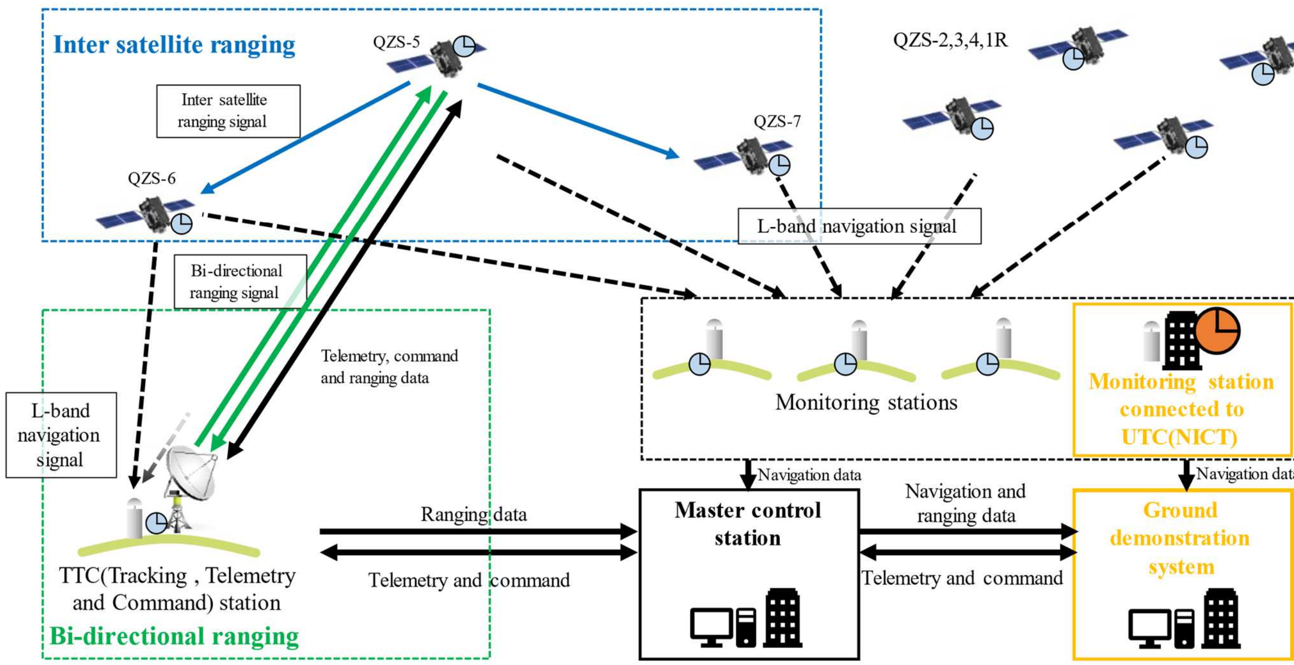

Fig. 2. The overview of demonstration system

calibrated in advance like [8]. Fig.3 shows the delay model. The calibration results are obtained by time interval counter, network analyzer and Common Clock Difference (CCD) between NICT and JAXA receivers. Finally, QZSST is synchronized with UTC(NICT) by adjusting the time difference between UTC(NICT) and temporary reference time with calibration results.

In addition, the target of synchronization is selectable for UTC(NICT) or GPST in this demonstration system. We plan to synchronize QZSST with GPST in the normal operation due to interoperability. However, if we need to change the target, QZSST is gradually adjusted from GPST to UTC(NICT) without service interruption and degrading SIS-URE.

III. DISCUSSION/INTERPRETATION

The specifications related to QZSST are time synchronization accuracy and UTC parameter accuracy. The time synchronization accuracy is needed within 50ns (95%). Additionally, UTC parameter accuracy is also needed within 40ns (95%). We expect the uncertainties of the calibration and orbit and clock estimation are small enough against these specifications from results of system design. We will verify these specifications with Fig.2 through a demonstration lasting three years following the launch of the new satellites.

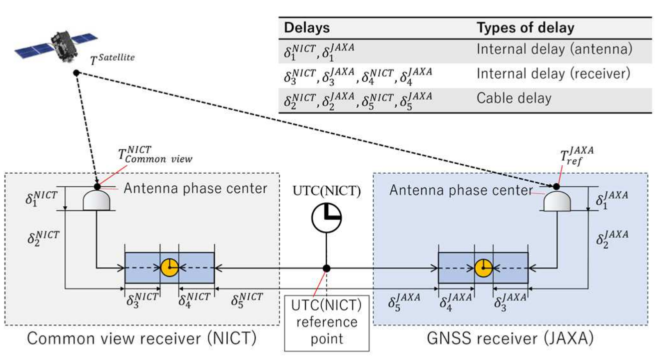

Fig. 3. The delay model for calibration

IV. CONCLUSIONS

This paper described a method of realizing QZSST synchronized with UTC(NICT). We expect the uncertainties are small enough against the specifications. Finally, we will confirm the realization of QZSS time synchronized with UTC(NICT) through a demonstration lasting three years following the launch of the new satellites.

REFERENCES

[1] Cabinet Office Government of Japan, "Quasi-Zenith Satellite System Performance Standard (PS-QZSS-003)," 2022.

[2] Cabinet Office Government of Japan, "Quasi-Zenith Satellite System Interface Specification Satellite Positioning," Navigation and Timing Service (IS-QZSS-PNT-005), 2022.

[3] Cabinet Office Government of Japan, "Quasi-Zenith Satellite System Interface Specification Sub-meter Level Augmentation Service (IS-QZSS-L1S-004)", 2019.

[4] Cabinet Office Government of Japan, "Quasi-Zenith Satellite System Interface Specification Centimeter Level Augmentation Service(IS-QZSS-L6-005)," 2022.

[5] Cabinet Office Government of Japan, "Quasi-Zenith Satellite System Interface Specification Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning (IS-QZSS-MDC-001)," 2022

[6] Y. Yoshimura, I. Takahashi, Y. Horikawa, E. Myojin, A. Matsumoto (JAXA), H. Hashimoto, K. Ohara, M. Nishio (NEC), "Developmental Status of Precise Ranging Payload of QZS-5/6/7," Proceedings of the Space Sciences and Technology Conference, 2022, JSASS-2022-4136-1I07.

[7] K. NUMATA, National Space Policy Secretariat, Cabinet Office, Japan, "Status Update on the Quasi-Zenith Satellite System (QZSS)," Sixteenth Meeting of the International Committee on Global Navigation Satellite Systems (ICG), 2022.

[8] Ryuichi Ichikawa, Tadahiro Gotoh, Takehiko Tanabe and Masami Yasuda "Internal delay calibration at NMIJ", NICT and AIST, Koganei Tokyo and Ibaraki Tsukuba, August. 2022