Reception tendency of Quasi-Zenith Satellite System (QZSS) L1S ” disaster crisis report” signal

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Abstract We conducted an experiment to verify that if the positioning signals of the Quasi-Zenith Satellite System (QZSS) were being received (outputted from the receiver), the ”disaster crisis report” signal would also be received (outputted from the receiver). We observed whether there were any differences in the reception characteristics when using Spresense and MAX-M10S for receiving the ”disaster crisis report” signal broadcasted in the L1S band of QZSS. For our experimental study, we prepared two units each of Spresense and MAX-M10S. We used the same accessories, such as antennas, for both devices, with the exception of the chips themselves. In our experimental study, the results showed that when using MAX-M10S, there were no disruptions in the output of positioning signals. However, there were disruptions in the output of the ”disaster crisis report” signal. On the other hand, when using Spresense, not only were there disruptions in the output of the ”disaster crisis report” signal, but there were also disruptions in the output of the positioning signals.

Keywords navigation satellite signal; missing communication; reception test

1 Introduction

We are planning to utilize the ”disaster crisis report” signal broadcasted in the L1S band of QZSS to provide a service for guiding evacuations to the affected individuals during large-scale disasters where the regular communication infrastructure is disrupted. GNSS (Global Navigation Satellite System), represented by GPS (Global Positioning System) developed by the U.S. Department of Defense, is known for providing information services to determine the location of receivers. GNSS broadcasts not only positioning information but also time information, making it promising for utilization during the critical period following a disaster. In particular, the aim is to deliver evacuation instructions for the immediate aftermath of a severe disaster in areas where the regular communication infrastructure is likely to be disrupted. In order to deliver evacuation instructions to affected individuals during the critical period following a disaster, we collaborated with officials responsible for Galileo, the European GNSS, and jointly developed a dedicated message structure[1].

This initiative aims to utilize QZSS, the Japanese positioning satellite system, for the distribution of evacuation instructions. Galileo and QZSS have nearly identical communication bands for broadcasting towards their respective ground stations. Figure 1 illustrates this by diagrammatically representing the wireless transmission bands of Galileo in the upper section and QZSS in the lower section, depicting the communication between the satellites and the ground[2]. Let’s focus on the highlighted portion, the second from the bottom on the left side, labeled as ”L1 Downlink” in Figure 1. From the ground station on the lower right, Galileo utilizes the frequency band of 1559MHz to 1591MHz, represented as the E1 band, using the C-band to broadcast evacuation instructions during the critical period as an Early Warning Service (EWS). Similarly, in QZSS, the frequency band of 1560MHz to 1590MHz, indicated as the L1 band, is used to broadcast evacuation instructions as a Disaster and Crisis (DC) report. By jointly developing the messaging system for delivering evacuation instructions during the critical period, it has become possible to broadcast the same evacuation instructions from both the QZSS’s DC Report (Disaster Crisis Report) and Galileo’s EWS (Emergency Warning Service) positioning satellite systems. The mechanism for obtaining positioning information involves the receiver of each system receiving signals from multiple positioning satellite systems orbiting the Earth. The receiver then performs calculations such as triangulation and other algorithms to derive the output as the location information. On the other hand, the signals for the evacuation instructions during the critical period that we aim to deliver through QZSS and Galileo are currently not distributed by other positioning satellite systems. Therefore, in this study, we specifically aimed to verify through experimentation that if the positioning signals are being received (outputted from the receiver), the DCReport signal of QZSS can also be reliably received (outputted from the receiver).

This paper takes the following structure. Section 2 presents a review of previous studies that provide the background leading up to the experiments described in this paper. Section 3 outlines the experimental specifications for the current study, while Section 4 presents the experimental results. Section 5 discusses the findings and presents future plans. Furthermore, throughout this paper, the term ”DCReport signal” will be used to refer to the signal utilizing QZSS’s DCReport.

2 RELATED WORKS

There is a report[3] on the reception of the DCReport signal. The DCReport signal used in this report is generated according to the message format developed jointly by Japan and Europe for delivering evacuation directives. [3] discovered that there are instances where the DCReport signal cannot be received despite the reception of positioning signals. Here, the term ”reception of positioning signals” refers to the condition where the message begins with GQGSV, followed by satellite numbers, elevation and azimuth angles, and the C/No (Carrier-to-Noise) ratio being specified in the output. Currently, the ground stations of QZSS have implemented a broadcasting pathway for the DCReport signal, which is designated as MT43 and is used to broadcast disaster information provided by the Japan Meteorological Agency every 4 seconds. In the absence of specific disaster information, MT63 is broadcasted instead. Therefore, the DCReport signal is outputted from the receiver every 4 seconds, while the positioning signal is outputted every second. In reference to[3], they conducted an experiment where the DCReport signal, generated according to the previously mentioned message format developed jointly by Japan and Europe, was broadcasted for a certain period. The experiment took place from August 20th to 23rd, 2019, between 10:00 in the morning and 17:00 in the evening. Reception records were reported during repetitive round trips on the approximately 10 km coastal roads of Omori Route 1 and Shimohama Route in Noshiro City, Akita Prefecture, Japan (as shown in Figure 2), using both walking and driving modes. Despite being in an environment where the positioning signal was received and outputted by the receiver every second,

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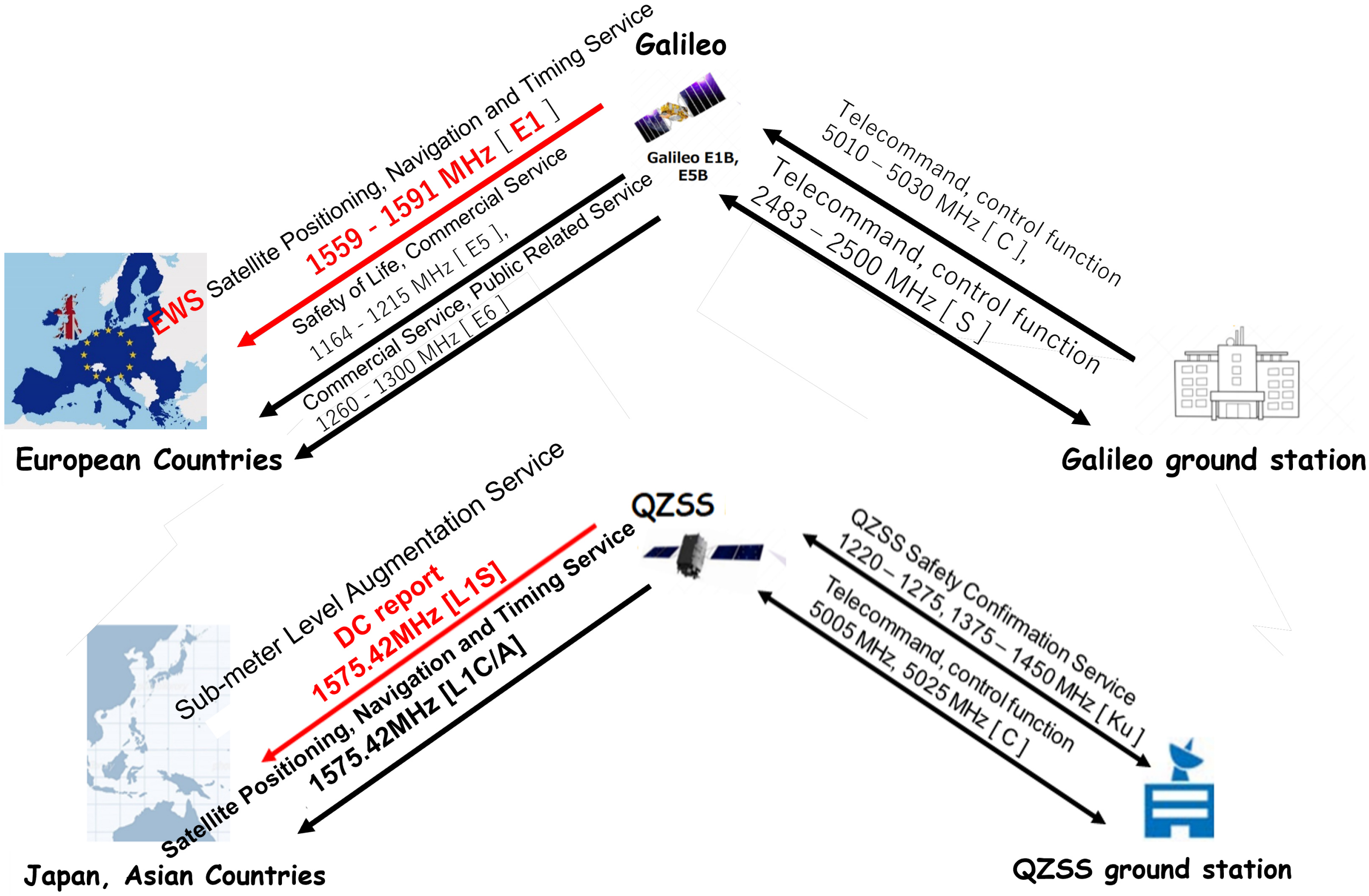

Figure 1: Radio transmitting band of Galileo and QZSS

without any obvious noise or obstructions, there were instances where the DCReport signal was not outputted, as illustrated in Figure 3. Based on these observations,[3] reported the occurrence of missing DCReport signal outputs.

On the other hand, Takahashi reported the findings of a study[4] regarding efficient power consumption methods for reliably receiving the DCReport signal. This study assumes that the DCReport signal can be received in a similar manner to the reception of positioning signals. In reality, as mentioned earlier, there are instances where signal loss occurs despite having sufficient power. Takahashi's findings demonstrate their effectiveness only when the DCReport signal can be received on par with the positioning signals.

Based on the reports from the aforementioned related works, we conducted this experiment to observe whether the occurrence of DCReport signal loss could be attributed to the differences in the receiver chip products. Our aim was to identify the cause of signal loss in the DCReport signal.

Figure 2: Rinkai Road Omori No.1 and Rinkai Road Shimohama Line

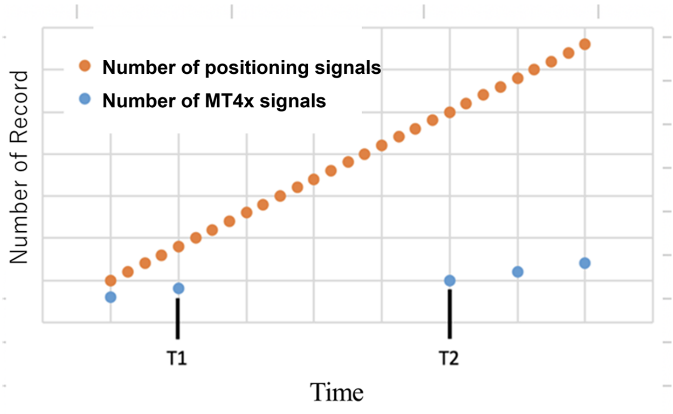

Figure 3: Missing MT4X

3 EXPERIMENTAL SPECIFICATIONS

We observed whether there were any differences in the reception conditions of the DCReport signal when adopting Spresense and MAX-M10S as the respective receiver chips. The other components, such as antennas, were kept identical for both receiver chip products, and two sets of receivers were placed in parallel at a designated experimental location.

Procedure

1. Equipment: Two sets of receivers, namely Spresense and MAX-M10S, were utilized for the experiment.

2. Signal Band: The experiment focused on the reception of the ”disaster crisis report” (DCReport) signal transmitted in the L1S band of the QZSS.

3. Connection: The same external components, such as antennas, were used for both Spresense and MAX-M10S.

4. Procedure: The experiment involved observing and comparing the reception tendencies between Spresense and MAX-M10S when receiving the DCReport signal using the QZSS's L1S band.

5. Observation: The occurrence of signal loss or any notable differences in reception tendencies between the two receiver models was documented.

6. Data Collection: Relevant data, including signal strength, signal integrity, and any observed differences, were recorded for analysis.

7. Experiment Duration: The experiment was conducted over a specified time period to gather sufficient data for analysis and comparison.

8. Replication: The experiment was repeated to ensure the consistency and reliability of the results.

9. Data Analysis: The collected data was analyzed to determine if any significant differences in reception tendencies occurred between the Spresense and MAX-M10S receivers when receiving the DCReport signal in the QZSS's L1S band.

Tables are “float elements” which should be inserted after their first text reference and have specific styles for identification. Do not use images to present tables, or they will be inaccessible to readers using assistive technologies.

Experimental Target Receiver Chips

The common features shared by both Spresense and MAX-M10S as receiver components for the DCReport signal are as follows:

1. Sufficiently compact size to serve as a receiver component for the DCReport signal.

2. Capable of receiving signals from multiple positioning satellite systems such as GPS, GLONASS, and Galileo.

3. Capable of receiving the DCReport signal broadcasted by QZSS.

Both products are introduced on the website of the Cabinet Office's Quasi-Zenith Satellite System project[5,6].

Receiver Antennas

Both chips were connected to JC Antennas manufactured by ZHEJIANG JC Antenna Co., Ltd. This product integrates a patch antenna (dielectric antenna) and a low-noise amplifier (LNA) within the case. It is reported to have good signal reception not only for GPS but also for various GNSS signals, including QZSS[7].

Additionally, we considered using the same chip antenna as the one on the Spresense main board for the MAX-M10S. However, based on preliminary experiments, concerns arose regarding the quality of the chip antenna on the Spresense main board. Therefore, as mentioned earlier, we opted to use a different antenna connection method.

Receiver Experiment Location

The reception experiments were conducted at a balcony railing facing south on the 4th floor of an apartment in Hino City, Tokyo, Japan, as depicted in Figure 4. Six antennas were deployed, with four of them connected to the indoor Spresense and MAX-M10S devices using 3-meter coaxial cables, with two devices for each. The remaining two devices were not used in this experiment. All four devices used in the experiment were connected to the same PC, and the output from each receiver was recorded and observed. The cross-sectional diagram of the reception experiment location is shown in Figure 5.

Figure 4: Antennas

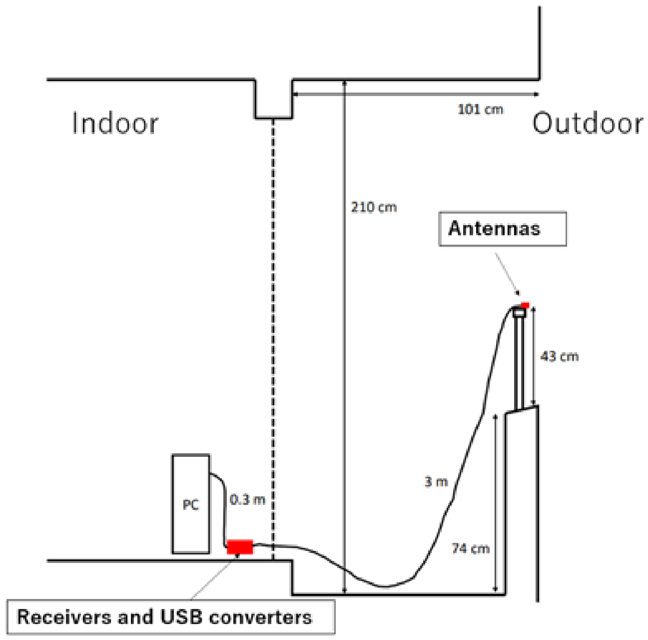

Figure 5: Test environment

Experimental Duration and Frequency

The experiments were conducted for a duration of 23 hours and 56 minutes, continuously receiving and outputting the DCReport signal alongside the positioning signals. We performed seven experiments; Table 1 shows each experiment starting.

Table 1: Experiment starts date and time

	Experiment starts date and time
1st observation	March 31st, 2023, at 00:00
2nd observation	April 1st, 2023, at 00:00
3rd observation	April 2nd, 2023, at 00:00
4th observation	April 3rd, 2023, at 00:00
5th observation	April 4th, 2023, at 00:00
6th observation	April 5th, 2023, at 00:00
7th observation	April 6th, 2023, at 00:00

Expected Experimental Results

The utilized reception chips in the experiment output positioning signals every second. The DCReport signal is broadcasted every 4 seconds. When a disaster information is issued, it is broadcasted as MT43, and in the absence of corresponding information, it is broadcasted as MT63. Therefore, both reception chips are expected to output the DCReport signal every 4 seconds after receiving it. Since the experimental duration for all seven experiments is 23 hours and 56 minutes, if the positioning and DCReport signals are output every 4 seconds without the presence of noise or obstacles, both signals should be outputted 21,540 times per experiment.

4 EXPERIMENTAL RESULTS

The MAX-M10S exhibited no missing output in the positioning signal (after reception), but it experienced missing output in the DCReport signal. On the other hand, the Spresense not only had missing output in the DCReport signal but also in the positioning signal (after reception). We organized the experimental results into four tables. Table 2 shows the number of outputs for both the positioning signal and the DCReport signal when using Spresense-01. Similarly, Table 3 displays the output counts for the positioning signal and the DCReport signal when using Spresense-02. Table 4 presents the output counts for the positioning signal and the DCReport signal when using MAX-M10S-01, while Table 5 presents the output counts for the positioning signal and the DCReport signal when using MAX-M10S-02. All tables represent the results observed at 4-second intervals. Please note that the branch numbers following ”Spresense” and ”MAX-M10S” are used for individual identification of the devices, as explained in Section 3.

According to the referenced tables, the following results were obtained. When using Spresense (regardless of the chip used), both the positioning signal and the DCReport signal fall short of the expected output count of 21,540. Additionally, the number of DCReport signal outputs, which should be equivalent to the number of positioning signal outputs (since observations were made every 4 seconds), is consistently lower than the positioning signal outputs. On the other hand, when using MAX-M10S (regardless of the chip used), the positioning signal is outputted every 4 seconds. However, the output count of the DCReport signal varies and may not occur every 4 seconds. Nevertheless, the tendency for missing data is lower compared to Spresense.

5 DISCUSSION AND FUTURE PLANS

Based on the experimental results presented in the previous section, it has been observed that the number of outputs following the reception of the DCReport signal may vary between the Spresense and MAX-M10S receiver chips, indicating potential differences in signal reception accuracy. Furthermore, it became apparent that achieving the same level of reception accuracy for the DCReport signal as that of the positioning signal is challenging, regardless of the chosen receiver product.

Particularly when referring to the recorded signal outputs using Spresense-02, which exhibited higher occurrences of missing data, it appears that these missing data points coincide with the timing of switching the tracked satellites within the four satellites that make up the QZSS system. However, it is understood that this explanation does not account for all instances of missing data. For example, Figure 6 illustrates that missing data occurs around the transition from 58 to 56 in the third column of numbers, representing the tracked satellites. In contrast, Figure 7 shows instances of missing data despite no change in the tracked satellite, which remains at 57.

The previous study by Takahashi et al. utilized the ZED-F9P receiver chip, which outperforms the receiver chips used in this experiment[8]. Therefore, in the future, we plan to conduct further experiments using the same product to identify the causes of the missing data observed in the DCReport signal.

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Table 2: Result of Spresense-01

	Expected number of outputs per 4 sec.	Number of positioning signal outputs	Number of DCReport outputs	Percentage to expected number of outputs per 4 sec.
1st observation	21540	21526	21435	99.58%
2nd observation	21540	21518	21479	99.82%
3rd observation	21540	21511	21375	99.37%
4th observation	21540	21508	21265	98.87%
5th observation	21540	21515	21450	99.70%
6th observation	21540	21512	21276	98.90%
7th observation	21540	21516	21348	99.22%

Table 3: Result of Spresense-02

	Expected number of outputs per 4 sec.	Number of positioning signal outputs	Number of DCReport outputs	Percentage to expected number of outputs per 4 sec.
1st observation	21540	21525	21163	98.36%
2nd observation	21540	21520	21278	98.88%
3rd observation	21540	21534	21236	98.62%
4th observation	21540	21538	21281	98.81%
5th observation	21540	21534	21400	99.38%
6th observation	21540	21539	21428	99.49%
7th observation	21540	21536	21300	98.90%

Table 4: Result of MAX-M10S-01

	Expected number of outputs per 4 sec.	Number of positioning signal outputs	Number of DCReport outputs	Percentage to expected number of outputs per 4 sec.
1st observation	21540	21540	21539	100.00%
2nd observation	21540	21540	21539	100.00%
3rd observation	21540	21540	21540	100.00%
4th observation	21540	21540	21540	100.00%
5th observation	21540	21540	21540	100.00%
6th observation	21540	21540	21539	100.00%
7th observation	21540	21540	21067	97.80%

Table 5: Result of MAX-M10S-02

	Expected number of outputs per 4 sec.	Number of positioning signal outputs	Number of DCReport outputs	Percentage to expected number of outputs per 4 sec.
1st observation	21540	21540	20521	95.27%
2nd observation	21540	21540	20440	94.89%
3rd observation	21540	21540	20466	95.01%
4th observation	21540	21540	21008	97.53%
5th observation	21540	21540	21429	99.49%
6th observation	21540	21540	21022	97.60%
7th observation	21540	21540	18913	87.80%

83656	1672795456	58	66	203
83660	1672795460			
83664	1672795464			
83668	1672795468	58	66	203
83672	1672795472			
83676	1672795476			
83680	1672795480			
83684	1672795484			
83688	1672795488	58	66	203
83692	1672795492			
83696	1672795496	58	66	203
83700	1672795500			
83704	1672795504			
83708	1672795508			
83712	1672795512			
83716	1672795516			
83720	1672795520			
83724	1672795524			
83728	1672795528			
83732	1672795532			
83736	1672795536			
83740	1672795540			
83744	1672795544			
83748	1672795548			
83752	1672795552			
83756	1672795556	56	56	164
83760	1672795560	56	56	164

Figure 6: Missing communication when switching satellite

1	1684	1.67E+09	57	81	205
1	1688	1.67E+09	57	81	205
1	1692	1.67E+09	57	81	205
1	1696	1.67E+09	57	81	205
1	1700	1.67E+09			
1	1704	1.67E+09			
1	1708	1.67E+09	57	81	205
1	1712	1.67E+09			
1	1716	1.67E+09			
1	1720	1.67E+09			
1	1724	1.67E+09			
1	1728	1.67E+09			
1	1732	1.67E+09	57	82	205
1	1736	1.67E+09			
1	1740	1.67E+09	57	82	205
1	1744	1.67E+09	57	82	205
1	1748	1.67E+09			
1	1752	1.67E+09			
1	1756	1.67E+09	57	82	205
1	1760	1.67E+09	57	82	205
1	1764	1.67E+09			
1	1768	1.67E+09	57	82	205
1	1772	1.67E+09	57	82	205
1	1776	1.67E+09			

Figure 7: Missing communication when not switching satellite

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