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An Experimental Result on Information Exchange using USV Communication Relay System

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Abstract. In order to safely operate the Unmanned Surface Vehicle (USV) at sea, it is necessary to communicate with Vessel Traffic System (VTS) for information delivery and also manned ship for collision avoidance. For this reason, the communication relay system was designed to enable navigation information exchange in a dedicated communication network via the Maritime Control Station (MCS). However, communication experiment at sea was not conducted to demonstrate the feasibility of the USV communication relay system. In order to validate, experimental scenario was composed of the USV voice relay system according to navigation stages, and communication experiment was conducted in Mokpo sea area. A result of experiment based on the SINPO (Signal strength, Interference, Noise, Propagation, and Overall rating) code described in Document REC. ITU-R SM. 1135, overall rating was good.

1. Introduction

The USV (Unmanned Surface Vehicle) is being developed among researchers in the field of maritime technology [1-6]. In particular, USV’s ability to prevent collision with nearby obstacle is one of the most critical factors to ensure safety and effectiveness during mission. Collision avoidance of the USV follows three stages: (i) detects a target ship or obstacles and assesses the Collision risk; (ii) establishes navigation plan on the basis of the obtained collision risk and environmental factors and executes a control command to perform established navigation plan; (iii) returns to her original path when the collision risk disappears. However, before taking an action for collision avoidance, most mariners tried to communicate with approaching ships for exchanging a navigation intention message [7]. Furthermore, all of ships reported a plan of voyage to the VTS in order that they can already identify an action of own-ship from an approaching ship via the VTS. Accordingly, though the USV communication relay system [8,9] has been developed to enable navigation information exchange via an existing maritime communication channel between the USV and the VTS or manned ship, and a dedicated communication
channel between the USV and the Maritime Control Station (MCS), communication experiment to validate its performance was not conducted as presented in Figure 1. Herein, this research represents experimental results at sea, using the USV communications relay system. The plan of USV voyage and its navigation scenario were established. The results were evaluated on basis of the measured voice signals by using SINPO (Signal strength, Interference, Noise, Propagation, and Overall rating) code, as described in ITU-R SM.1135. The section 2 described the USV communications relay system, its bandwidth requirement for voice channels. Consequently, It turned out that the USV communication relay system was satisfactory from the SINPO scores in Section 3. This paper was concluded in section 4.

Figure 1. Flow of navigation information exchange via the communication channel [7].

2. Related work

2.1. Communication Relay System

Figure 2. Configuration of the USV Communication Relay System [8,9].
The communication relay system is able to be used to transmit the ship position and status information using the Automatic Identification System (AIS), the autonomous ship mission information transmission using AIS message relay received from the autonomous ship, broadcasting using TTS (Text to Speech), and VHF communication relay. Each interface is required to use the five functions [8,9]. Accordingly, it was designed by dividing VHF communication control, TTS control, and AIS control reflecting five functions. Figure 2 shows necessary communication equipment for safe navigation in the autonomous ship and the overall system configuration as to flow of information operated in the each equipment.

As presented in Figure 3, the VHF communication controller transmits the voice message received from the VTS or manned ship to the MCS via the Voice over Internet Protocol (VoIP), and the MCS respond the VTS or manned ship by sending the voice message generated by the MCS over the VoIP. The TTS controller receives the voice message composition from the MCS, requesting the TTS server by sending the message converted into the Speech Synthesis Markup Language (SSML) format. Then the TTS server synthesizes the voice as the WAV file, and transmits it to the WAV player to play it. The output is passed through the voice switch to the VHF transmitter or the broadcast amplifier. The AIS controller is responsible for transmitting AIS-ASM messages received from the USV to the MCS via VHF Data Exchange System (VDES) as shown in Figure 4. In the USV, when messages are received through the AIS transceiver interface, messages are delivered to the connected the MCS.

![VHF communication controller](image1)

Figure 3. VHF communication controller.

![VDES for AIS-ASM message exchange at USV](image2)

Figure 4. VDES for AIS-ASM message exchange at USV.

2.2. Bandwidth Requirements
In order to conduct an experiment of the USV communication relay system at sea, it is necessary to secure a frequency bandwidth required for navigation information exchange between the USV and the MCS in a dedicated communication channel. At this time, navigation information exchange can be achieved via the Control and Non-Payload Communications (CNPC) link. As presented in Table 1, available frequency bandwidth was proposed for each modulation scheme and CNPC link was required as 530 [kHz] to obtain a basic data rates between the UHF bands according to [10]. The present study has thus considered 8PSK of modulation scheme.

| Table 1. Bandwidth requirements for CNPC link [10]. |
|-----------------------------------------------|
| Modulation Scheme | 8PSK            | 16QAM           | 64QAM           |
|-------------------|-----------------|-----------------|-----------------|
| Code Rates with RS-CC | 7/8             | 7/8             | 7/8             |
| Total No. of Symbols | 5760            | 4500            | 2880            |
| Frames/sec.       | 80              | 80              | 80              |
| Symbols/sec.      | 468.8           | 360.0           | 230.4           |
| Roll-Off-Factor, α | 0.15            | 0.15            | 0.15            |
| Bandwidth [kHz]   | 529.92          | 414.00          | 264.96          |

2.3. SINPO Code
SINPO [11], an acronym for Signal, Interference, Noise, Propagation, and Overall, is a Signal Reporting Code used to describe the quality of radiotelegraph transmissions. SINPO code is most frequently used in reception reports written by shortwave listeners. Each letter of the code stands for a specific factor of the signal, and each item is graded on a 1 to 5 scale (where 1 stands for nearly undetectable/severe/unsusable and 5 for excellent/nil/extremely strong). Each category is rated from 1 to 5 with 1 being 'unusable' or 'severe' and 5 being 'perfect' or 'nil' as presented in Table 2.

| Table 2. ITU-R SINPO code [11]. |
|---------------------------------|
| Rating scale | S | I | N | P | O |
|----------------|---|---|---|---|---|
| Degrading effect of | Signal strength | Interference (man-made) | Noise (natural) | Propagation disturbance | Overall rating |
| 5              | Excellent | Nil | Nil | Nil | Excellent |
| 4              | Good | Slight | Slight | Slight | Good |
| 3              | Fair | Moderate | Moderate | Moderate | Fair |
| 2              | Poor | Severe | Severe | Severe | Poor |
| 1              | Barely audible | Extreme | Extreme | Extreme | Unusable |

3. Experimental Result

3.1. Experimental Scenario
In order to demonstrate the USV communication relay system, experimental scenario was composed as follows: (i) reports ship name, call sign, departure point, way point, destination point, mission, and mission area to the VTS via the MCS before sailing; (ii) exchanges navigation information with manned ship in encounter situation for safe navigation of the USV via the MCS.; and (iii) reports ship name, call sign, present position, mission termination, and destination to the VTS via the MCS. Figure 5 shows navigation passage of the USV for experimental scenario.
As described in Table 3, experimental scenario was composed according to the navigation phased. S2, S7, and S9 defined that the USV must report a navigation plan to the VTS. S3 denoted sailing situation, and S4, S5, and S6 were encountering situation with manned ship (MS).

**Table 3.** Experimental scenario of the USV.

| Navigation Scenario | Equipment | MCS | USV | VTS | MS |
|---------------------|-----------|-----|-----|-----|----|
| **S2**             | VHF Telephone |     |     |     |    |
| **PLAN A :** USV1 M1WX 440123400, 34.27N 126.03E, WP1 34.29N 126.08E, WP2 34.33N 126.10E, 34.36N 126.13E, SAR, Area Notice 34.36N 126.13E, 34.38N 126.13E, 34.38N 126.15E | VHF Telephone | s | r | d | m |
| USV1, DE VTS, Roger. Stand by Ch14. Clear and out | VHF Telephone | d | s | m | |
| **S3**             | UHF Telephone |     |     |     |    |
| CQ CQ DE USV1 PSN 34.28N 126.06E, Alter Co. 030DEG. SPD. 15KTS. | UHF Telephone | s | r | |
| CQ CQ DE USV1 PSN 34.29N 126.08E, Alter Co. 030DEG. SPD. 15KTS. | VHF Telephone | s | d | d | |
| **S4**             | UHF Telephone |     |     |     |    |
| SAEYUDAL, DE USV1, How do you read me over? | UHF Telephone | s | r | |
| USV1, DE SAEYUDAL, Go Ahead, PLS. | VHF Telephone | s | d | |
|                       | UHF Telephone | r | s | |
|                       | VHF Telephone | d | s | |
SAEYUDAL, DE USV1, I want to pass SAEYUDAL to PS. I alter Co. 50DEG to STBD. PLS KEEP Your Present Co.

USV1, DE SAEYUDAL, Roger. SB(Stand by) Ch.14, Clear and Out.

S7 Mokpo VTS, DE USV1, ARR. at 34.36N 126.13E for SAR operations.

S8 CQ CQ DE USV1 start SAR operations, Area 34.36N 126.13E, 34.36N 126.15E, 34.38N 126.13E, 34.38N 126.15E by LT 17:00. Keep clear of USV1.

* s (sending), d (destination), r (relaying), m (monitoring)

3.2. Result
As shown in Figure 6 and Table 4, the USV sailed according to the experimental scenario, and the quality of the VHF communication controller’s transmissions was measured via the SINPO code. Signal strength, Interference, Noise, Propagation disturbance were more than 4 point in S2, S4, and S5. Whereas, S6, S7, S8 were 3 point in aspects of Noise and Propagation disturbance. Overall rating of each navigation phrase was 4.75, 4.50, 4.25, 3.75, 3.75, and 3.75, respectively. In other words, rating scale was between Excellent and Fair, and average overall rating was 4.125 (i.e., good).
Table 4. Result of measurement by using the VHF communication controller.

| Navigation Phrase | S | I | N | P | O |
|-------------------|---|---|---|---|---|
|                   | Degrating effect of | | | | |
|                   | Signal strength | Interference (man-made) | Noise (natural) | Propagation disturbance | Overall rating |
| S2                | 5 | 5 | 4 | 5 | 4.75 |
| S4                | 4 | 5 | 4 | 5 | 4.50 |
| S5                | 4 | 5 | 4 | 4 | 4.25 |
| S6                | 4 | 5 | 3 | 3 | 3.75 |
| S7                | 4 | 5 | 3 | 3 | 3.75 |
| S8                | 4 | 5 | 3 | 3 | 3.75 |

4. Conclusion
To evaluate the performance the USV communications relay system, the experiments were conducted at sea. As the results, we demonstrated the feasibility of the USV communication relay system at sea under the situations of navigating with the existing manned ships existing. The voyage plan and navigation scenario were made. Following the scenario, we presented (i) the performance of the USV voice relay system; and (ii) turned out to be satisfactory for reception rate of voice signals. The experimental results were represented by using SINPO code.

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