2-8 Under Seawater Radio Communications

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Currently, wireless communications under seawater has been one of attractive research fields of radio frequency (RF) communications. NICT and JAMSTEC have started a joint research on this research field, and have developed a under-seawater channel sounder for conducting measurement on radio propagation characteristics available in the depth of 500 meters. This report shows an overview of the channel sounder and a couple of measurement results.

1 Introduction

Concerning the usage of undersea radio waves, the needs such as the radar for resource exploration under the seabed and the several Mbps undersea wireless communications come to light in association with the progress of recent exploratory techniques targeted to the deep sea and ocean floor[1][2]. Figure 1 shows the radio usage example in waters to which JAMSTEC points. There are high expectations for electromagnetic wave utilization for exploratory radar for seabed minerals and seabed exploration robot control with an aim of resource exploration under the seabed.

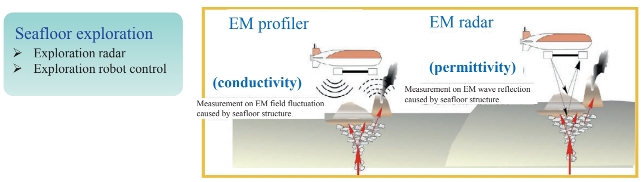

Fig. 1 Example of undersea electromagnetic wave utilization [1][2]

To design and develop the undersea radio wave usage system based on the said usage examples, it is essential to reveal the characteristics of the radio propagation in the waters. To measure the radio propagation characteristics, it is possible to utilize an analytical method in which the channel sounder is built on land and its measuring results are taken, but the building of a new measuring system is required because many restrictions occur undersea due to effects such as hydraulic pressure. For this reason, this paper describes the development of the underseawater

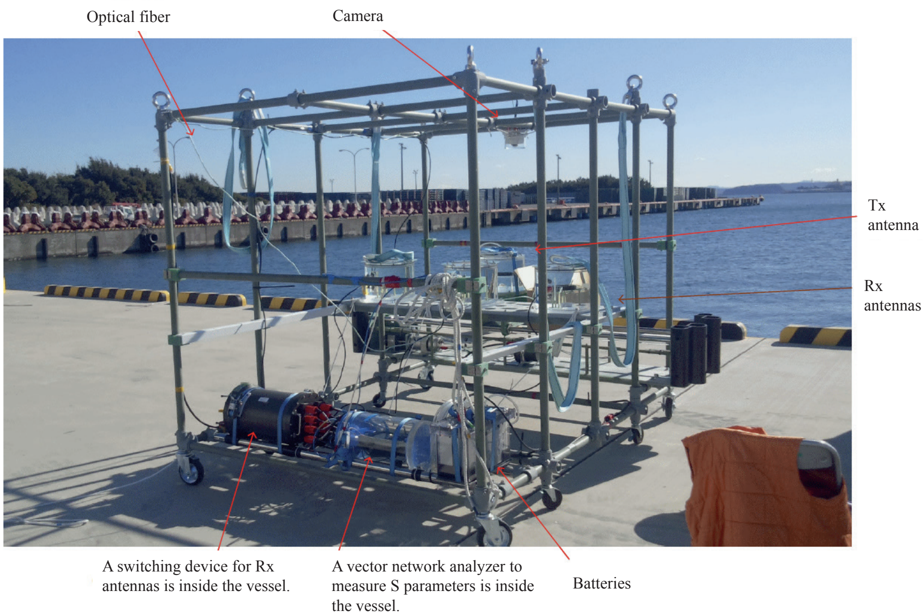

Fig. 2 Appearance of underseawater channel sounder

channel sounder which is a measuring system for the radio propagation characteristics of the subject undersea environment.

2 Development of underseawater channel sounder

2.1 Configuration[3]

Figure 2 shows the appearance of the underseawater channel sounder. The size is 2.7 m (depth) × 2.5 m (width) × 2.2 m (height), and the weight is around 500 kg. It is designed to be able to resist the hydraulic pressure at a depth of 500 m from the surface. The channel sounder is mainly composed of the undersea antennas for measurement that send and receive, a switch to switch a connected antenna (Antenna switching device), and a vector network analyzer to measure the radio propagation characteristics between antennas.

Concerning the undersea antennas, one is placed for sending and three for receiving on the stands, -arrayed at a 60 cm distance between each antenna. The distance between antennas for sending and receiving can be changed to up to about 2 m. This makes it possible to measure the propagation loss and phase rotation amount, which are necessary for the design of an undersea wireless transmission method, between antennas for sending and receiving. In addition, as the sending antenna is placed on the single dimensional positioner (Y stage) and it is possible to emit radio waves by changing the position for a sending source, the undersea direction estimate experiment for a wave source can be conducted using three receiving antennas. This experiment result is important to establish the signal processing technology on the radar under the seabed and so on. The underseawater channel sounder is equipped with a CTD meter to measure the electric characteristics of the sea, a triaxial inclination sensor to measure the tilt of the channel sounder, an underwater camera to monitor the measuring system, and a battery to drive them, as well as a radio wave propagation measuring system. These devices all connect to the shipboard controller through the optical cable in order to be controlled and transmit data remotely.

Figure 3 shows the appearance of the undersea antenna used by the underseawater channel sounder. The undersea antenna is composed of a cylindrical container (size: 320 mm dia., 253 mm high) which is filled with fresh water and in which a magnetic loop antenna (black element in Fig. 3) is arranged. The fresh water layer is provided with an aim to improve the electrical matching and to have a role to absorb the effect of the hydraulic pressure exerted on the element. The resonance frequency band of this antenna (underwater) is 10 MHz. This is selected as the frequency band making it possible to measure the radiated electromagnetic field even taking into account the distance between the sending antenna and receiving antenna of the underseawater channel sounder. The passband width for these antennas is around 45 kHz, if the frequency bandwidth is VSWR 2.0 or less.

2.2 Example of measured result [4]-[7]

The measurement in waters was made in the large-scale water tank facilities (40 m long, 4 m wide and 2 m deep), which JAMESTEC possesses, with the aim of the functional verification of the developed undersea radio wave propagation measuring system. Figure 4 shows the description at the time of the functional verification. As this verification is the measurement underwater, the measurement was made after removing the sending and receiving antennas from the frame of the underseawater channel

Fig. 3 Appearance of undersea antenna developed

Fig. 4 Function verification of underseawater channel sounder using large-scale water tank facilities

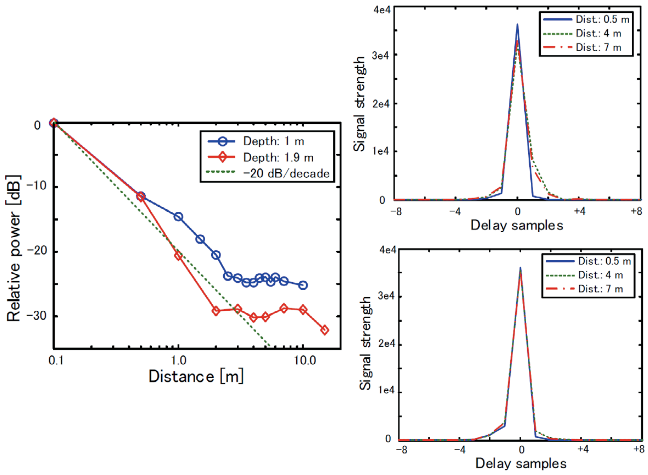

Fig. 5 Delay characteristic of received signal power and signal strength by distances (Left: 1 m depth; right: 1.9 m depth)

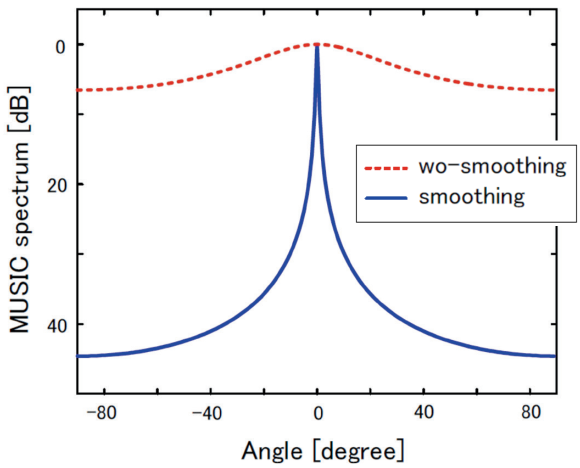

Fig. 6 Test result of direction of arrival estimation (at the arrival from zero degrees direction)

sounder to elongate the distance between the sending antenna and the receiving antenna to more than 2 m.

Figure 5 shows a part of the measuring result. It is the measuring result of comparing the relative power level, which defines the received signal power as 0 dB at a 0.1 m distance, to the distance between the sending antenna and the receiving antenna. The measurements are the cases where the depths of the measuring antenna are 1 m (blue solid line) and 1.9 m (red solid line).

From the measuring result, we confirmed that the measured power level decayed in accordance with theoretical values (green dashed line) of the power attenuation in fresh water up to a 2 m distance. The figure tells that a floor is made at a distance of 2 m or more. To consider the causes, we evaluated the delay characteristic of the signal strength from measured signal waveforms for each depth. As the result, we found that for the synchronization point — the timing for which the correlation value between the sending waveform and the receiving wave form peaks — the delay of one sampling was created if the distance is 3 m or more at a depth of 1 m. For a depth of 1.9 m, the said synchronizing delay is not created for the distance between transceivers. It is believed that the floor creation at a depth of 1 m is due to the slow-wave activity from the water surface direction because of the effect of the slow wave activity.

In addition, we implemented the test for the direction of arrival (DoA) estimation underwater at the same time. Consequently, Fig. 6 shows the direction of arrival estimation by the MUSIC algorithm. As 10 MHz is used as a frequency, the wavelength for 0.6 m distance between receiving antennas is around 3.3 m (underwater), and for normal signal processing (creation of a covariance matrix from measured values), a sharp MUSIC spectrum is not created due to high correlation between antennas (red dashed line). In contrast, we confirmed that applying the space smoothing method — the processing that assigns the single dimension to the smoothing processing — provided the sharp spectrum (blue solid line) as shown in the figure.

3 Future prospects

As the underseawater channel sounder developed this time can measure up to a depth of 500 m, we will measure the radio propagation characteristics in various environments (water depth, depth, ocean area, etc.) and clarify the undersea radio propagation characteristics.

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