Underwater Drone-Mounted Antennas Using Offshore Wind Turbines As A Transmission Line

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***Abstract*— In this report, a drone-mounted antenna that uses cylindrical concrete, which serves as the foundational structure for offshore floating wind turbines, as a low-loss transmission line is proposed. The antenna features a cavity filled with concrete, and it is designed to avoid losses due to seawater by bringing the underwater drone into contact with the transmission line. The maximum received power between the transmitting and receiving antennas is evaluated through numerical analysis, clarifying the relationship between antenna shape and propagation efficiency.**

***Keywords*— Offshore Wind Turbines, Seawater Antenna, AUV**

I. Introduction

In recent years, the installation of floating offshore wind farms has been increasing as part of efforts to expand renewable energy in Japan. Offshore wind turbines require maintenance and inspections, which are extremely difficult to perform on their underwater foundations. The use of underwater drones (AUVs, Autonomous Underwater Vehicles) is considered a promising method for inspections, and wireless communication with the drones is expected. In this study, we propose an antenna structure and propagation system to be attached to a drone.

As shown in Figure 1, the cylindrical base structure of an offshore wind turbine is made of concrete and immersed in seawater. Considering that seawater is a high conductivity medium, the base structure in Figure 1 can be regarded as a coaxial transmission line, and the TEM mode can propagate inside the concrete [1]. However, because seawater is a high-loss medium, there is a problem that electromagnetic waves are greatly attenuated before they reach the concrete cylinder from the antenna. Therefore, we propose an antenna and system in which the antenna is in contact with the concrete cylinder. In this structure, the antenna is covered with concrete to reduce the loss due to reflection of electromagnetic waves incident on the concrete. In this study, we clarify that low-loss transmission is

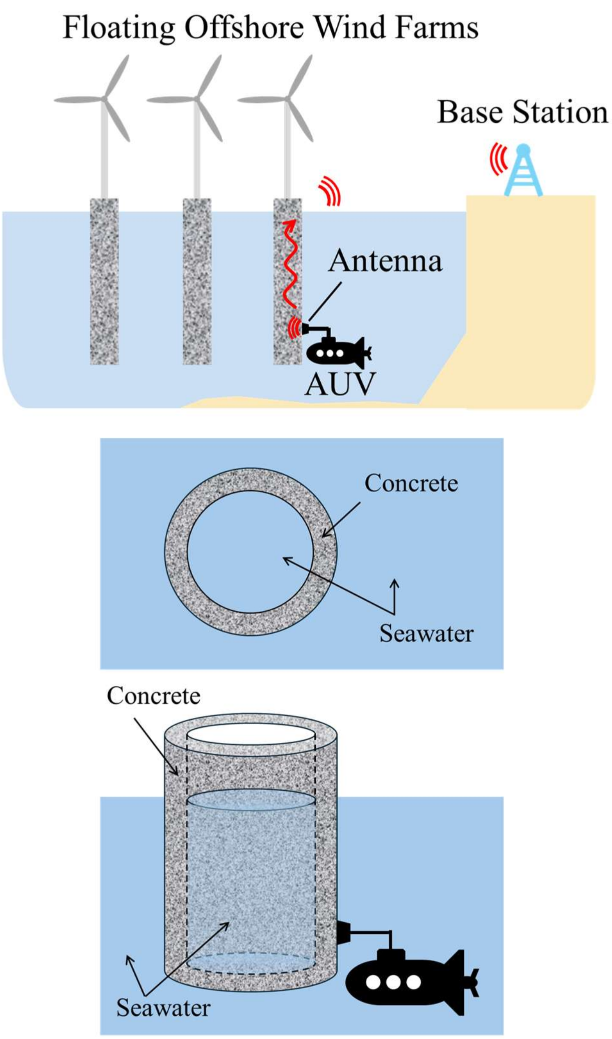

Figure 1. Offshore wind turbine and base structure.

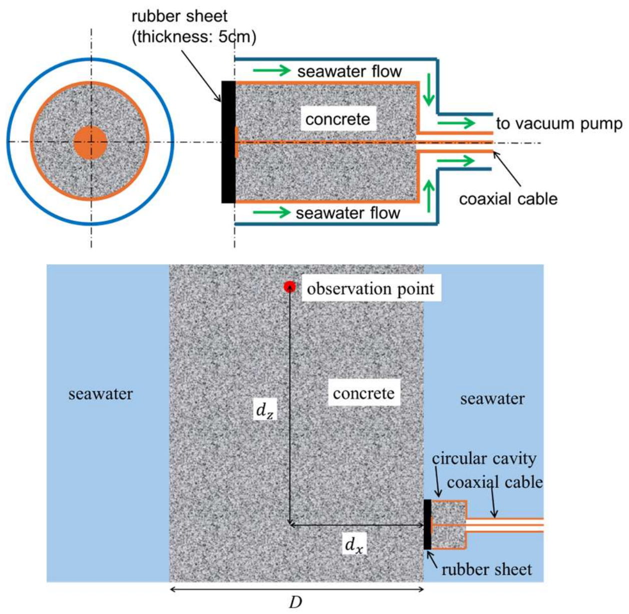

Figure 2. Proposed monopole antenna with concrete-filled cavity.

possible using the proposed antenna and the base structure of an offshore wind turbine.

II. DRONE-MOUNTED ANTENNA

Transmitting and receiving antennas are usually exposed to seawater and they will be affected by significant loss of seawater [2]. For reference, the attenuation constant of seawater with a relative dielectric constant ε_r of 80 and a conductivity σ of 4 S/m is 327 dB/m at the frequency of 100 MHz. In case when a cylindrical concrete is used as a transmission line, the antenna structure which realize efficient coupling with the transmission line is expected.

The proposed monopole antenna with a concrete-filled cavity is shown in Figure 2. Since the monopole antenna is covered with concrete material, the reflection at the boundary can be suppressed by contacting the cavity structure with the cylindrical concrete transmission line. In addition, it has the characteristic of affect-free structure by seawater losses when it is perfectly contact with concrete transmission line.

III. FDTD ANALYSIS

The cross section of the cylindrical concrete transmission line was approximated by parallel plate waveguide (PPW), and a planar concrete PPW sandwiched between seawater was considered. The receiving antenna was installed in the concrete and the received power was evaluated when the length of PPW d_z was 4 m. The normalized received power when both the transmitting and receiving antennas satisfy the conjugate matching condition, i.e., the transmission factor τ [1], was evaluated.

The analysis results of the transmission factor τ are shown in Figure 3. At a frequency of 100 MHz, the transmission factor of -26.4 dB was observed in the case of the proposed antenna. Although the proposed antenna is not affected by seawater loss, the propagation loss of cylindrical waves inside PPW with 1/2 power of distance. On the other hand, the transmission factor τ of -76.9 dB was observed in the case of dipole antenna separated 5 cm from concrete PPW. Even a distance of 5 cm causes significant attenuation due to seawater loss.

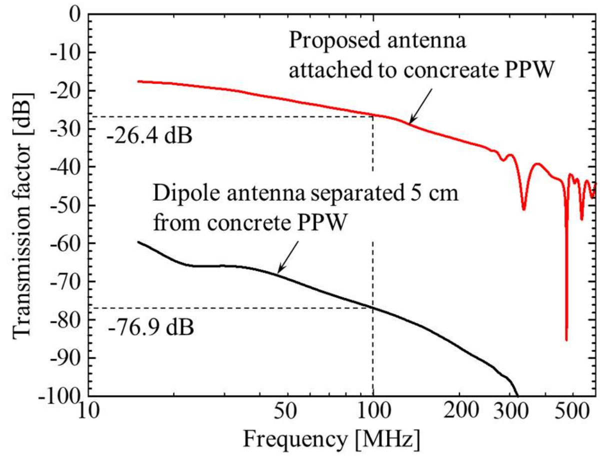

Figure 3. Transmission factors. (Red: proposed antenna attached to concreate PPW, Black: Dipole antenna separated 5 cm from concrete PPW)

These results show that the proposed antenna mounted on a drone will be significantly attenuated by seawater if it is slightly separated from the concrete transmission line, and it is found that the contact between concrete PPW and proposed antenna is necessary to use it with low loss communications.

IV. CONCLUSION

A drone-mounted seawater antenna using the foundation structure of an offshore wind turbine as the transmission line were proposed. It is demonstrated that the high efficient power transfer is possible by using the proposed antenna configuration.

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