Utilizing Floating Wind Turbine Foundations for Underwater-to-Air Radio Wave Propagation

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***Abstract*—Utilizing the existing foundation of a floating wind power turbine in the ocean as the channel for radio wave communication from underwater to air is studied. It is demonstrated that the foundation can be a low-loss transmission line for radio propagation in the sea. Additionally, on the opposite side of the excitation source, fields decrease more slowly in the radial direction.**

***Index Terms*—Underwater communication, seawater–air communication, Radio wave propagation, Field distribution.**

I. Introduction

Wireless communications in marine environments are facing complex challenges. Radio wave communication simultaneously possesses the characteristics of high speed and stability. However, it typically operates at extremely low frequencies, necessitating a transmitting antenna of substantial physical size [1].

An experiment demonstrated that the designed antenna could propagate radio waves in MHz range within 85 meters distance [2]. In addition, surface wave propagation using the interface between seawater and air has been proposed [3]. Further work implemented a three-layer interface (seabed- seawater-air), achieving 7 meters radio signal propagation at 50 MHz [4].

In this work, the foundation of a wind power turbine, accompanied by a hollow cylindrical structure, was demonstrated to have the ability to serve as an interface for radio wave propagation in the ocean. Simulation results showed that power was transmitted by the part of the foundation submerged in seawater and radiated by the part in the air. It is demonstrated that the foundation can be a low-loss transmission line for radio propagation in the sea, making underwater drones possible for image communication.

II. Fields Distribution of Radiating Process

A. Establishment of Model and the Source

The structure of a Spar-Buoy offshore wind turbine foundation made of concrete was investigated, as shown in Fig.1. A miniature model with a total length of 7 meters was used, with most of the model submerged in the sea and a small portion in the air. All dimension information is displayed in the figure. For ease of analysis, the bottom structure and top tower were considered as loads, which causes the reflection of waves. The cross-section is shown in Fig.1 (b), with air filling inside and seawater surrounding the foundation model.

A small electric length dipole antenna ($2l < 0.01\lambda_0$) was placed close to the outer surface of the foundation model for excitation, simulating the actual underwater drone situation.

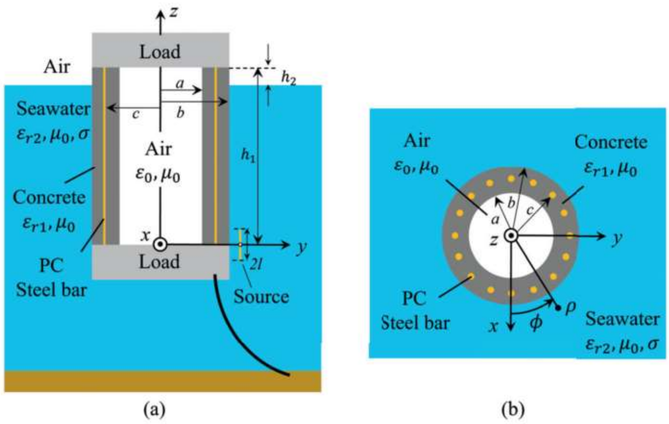

Fig. 1. Structure of Spar-Buoy offshore wind turbine foundation, $h_1 = 7$ m, $h_2 = 1$ m, $a = 0.34$ m, $b = 0.39$ m, $c = 0.365$ m, $2l = 0.1$ m, $\epsilon_{r1} = 6$, $\epsilon_{r2} = 72$, $\sigma = 4.8$ (S/m). (a) Front View. (b) Cross View.

B. Simulation Results of Field Distributions

Under ideal conditions, seawater is non-dispersive, and the sea surface is free from wind and waves. The position of the foundation model in the cylindrical coordinate system is shown in Fig.1 (b). The bare dipole antenna, with a length of 0.1 m, operates at 30 MHz and has a power of 1 W. It is located at (0.391 m, 90°, 0 m).

The simulation results of field strength along the z-direction inside the concrete foundation are shown in Fig.2 and Fig.3. After the concrete passes through the sea level ($z = 6$ m), the amplitude value of the E component drops sharply, while the H component remains almost unchanged.

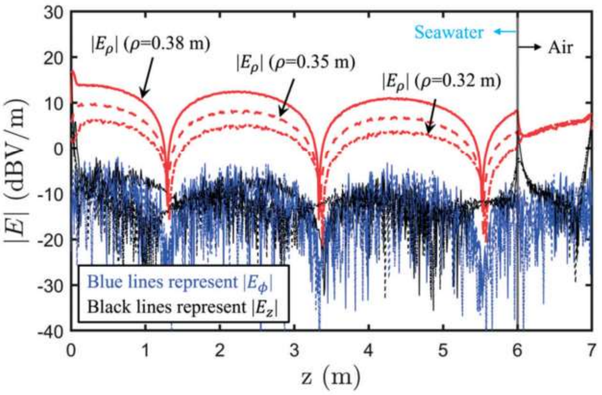

Fig. 2. Variation of E fields distribution with z inside the concrete foundation from seawater to air, $\phi = 90°$, $\rho = 0.38$ m, 0.35 m, 0.32 m.

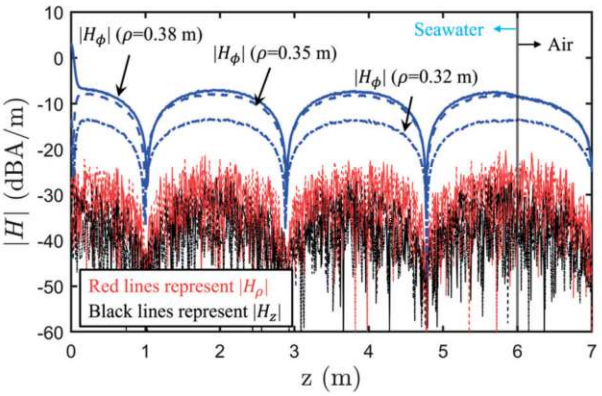

Fig. 3. Variation of H fields distribution with z inside the concrete foundation from seawater to air, $\phi = 90°$, $\rho = 0.38$ m, 0.35 m, 0.32 m.

The field distributions along the ρ direction above and below sea level were analyzed, as shown in Fig.4 and 5. Above the sea surface, the E_ρ and H_ϕ components are the largest. On the side of model close to the source antenna ($\rho > 0.39$ m), there is a rapid roll-off of the field components, especially at H_ϕ. On the other side of the model opposite the source ($\rho < -0.39$ m), the decrease of the field component is smoother.

III. CONCLUTION

In this work, it was studied to use the existing foundations of floating wind power turbines in the ocean as a transmission line for radio wave propagation. Based on the results of field distribution, it can be found that the part of the foundation above the sea surface radiates energy outward through an electric field of radial direction. Additionally, compared to the field on the same side of the excitation source, fields on the opposite side decrease more slowly with distance.

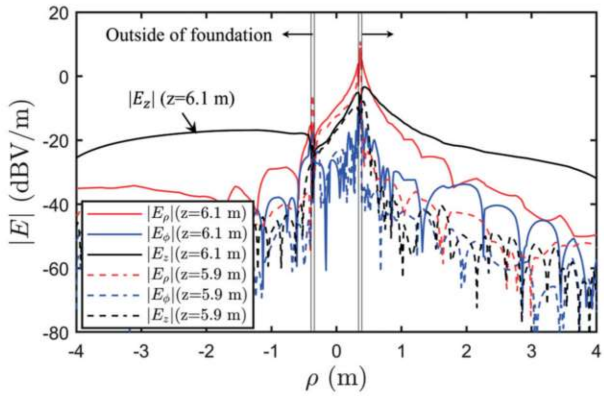

Fig. 4. Variation of E fields distribution with ρ upper and below the seawater surface, $\phi = 90°$.

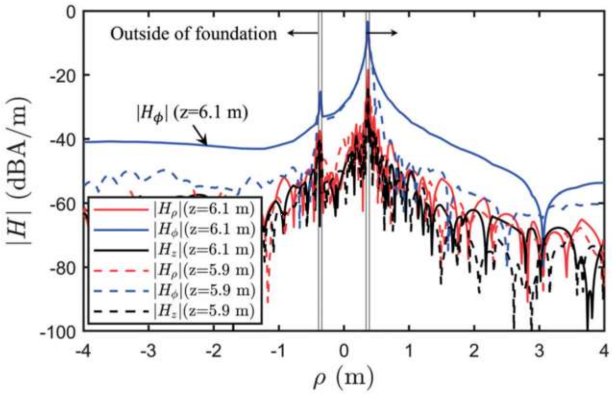

Fig. 5. Variation of H fields distribution with ρ upper and below the seawater surface, $\phi = 90°$.

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