Toyohashi University of Technology Press Release

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Wireless power transfer in fresh water using capacitive coupling

- Using underwater inspection robots to detect the early-stage deterioration of structures −

A research team led by Associate Professor Masaya Tamura of the Department of Electrical and Electronic Information Engineering at Toyohashi University of Technology successfully achieved wireless power transfer in fresh water using capacitive coupling. In the field of wireless power transfer, it had been considered difficult to realize wireless power transfer in fresh water using capacitive coupling because fresh water behaves as a dielectric material with extremely high dielectric loss. In this research, the team elucidated the high-frequency properties of fresh water through experiments. The team also discovered the frequency band that enables power transfer with high efficiency using an electric field and an electrode structure that can realize this high efficiency.

Wireless power transfer has attracted attention within a wide range of fields, ranging from mobile terminals to automobiles. Previously, research was mainly done in dry-land environments, though expectations are high for studies in underwater environments as the next target of research. For example, with regard to structural health monitoring systems for pipes, cooling towers or dam walls, there is an urgent need to develop underwater inspection robots that can move freely and perform inspection, even in the event of a disaster. Because these robots are battery-powered, with conventional technology it is necessary to pull them out of the water, charge them, and have them dive back into the water repeatedly. The development of technology to transfer power and information wirelessly in water (Figure 1) is crucial in order to remedy the low efficiency of work using conventional technology.

As a solution, the research team led by Associate Professor Masaya Tamura developed a capacitive coupler that can supply power wirelessly in fresh water with high efficiency.

The efficiency of wireless power transfer depends on the *kQ* product, which is the product of the coupling coefficient *k* of the coupler and the *Q*-factor of the coupler loss including the influence of the surrounding environment. The higher the *kQ* product, the better the transfer efficiency. Since the influence of water surrounding the coupler is dominant over the coupler itself in an underwater environment, the study focused on the high-frequency properties of fresh water. The team made its own cell for measurements and clarified the relationship between frequency and the *Q*-factor of fresh water. Based on these results, the team used electromagnetic field analysis to find the frequency of power transfer and the structure of the coupler where the value of the *kQ* product in fresh water is at a maximum. The team achieved a power transfer efficiency of at least 90% at a transfer distance of 2cm and at least 80% at 5cm. The team also succeeded in activating a sensor module via wireless power transfer to conduct infrared data communication. Power transfer efficiency was maintained at 90% or higher over a distance of 2cm, even when transferring 400W of power. Considering that the robot will park on top of the power supply station, this technology is suitable for practical use.

The result of this study will allow for robots that inspect the pipes and cooling towers of power plants or dam walls to communicate information and charge their batteries within the areas of inspection. The research team believes the technology will contribute to drastic improvements in user safety as well as in the operational efficiency of the robots. The coupler newly developed by the team is simple and lightweight, and therefore the impact on the total weight of the underwater inspection robot is kept to a minimum. Use of this lightweight coupler can also eliminate the need for an extensive redesign of the buoyancy system. The team seek to soon achieve the communication of information with electric field coupling in fresh water, as well as highly efficient wireless power transfer in seawater. Their ultimate goal is to realize the wireless transfer of power and information transfer in both fresh water and sea water.

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Further information
Toyohashi University of Technology
1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi Prefecture, 441-8580, JAPAN
Inquiries: Committee for Public Relations
E-mail: press@office.tut.ac.jp

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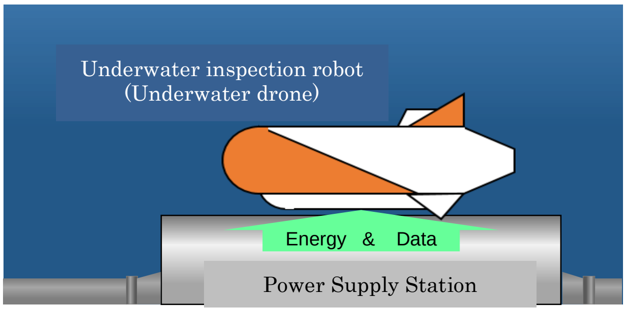

Figure 1: Conceptual image of wireless power transfer in fresh water

Caption: The underwater inspection robot parks on top of the power supply station, charges its battery and communicates information such as its collected data.

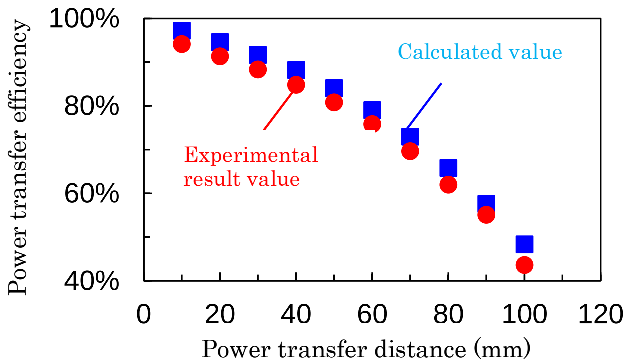

Figure 2: Relationship between power transfer distance and power transfer efficiency in fresh water

Caption: The calculated values and the experimental result values were in close agreement. The research team achieved a transfer efficiency of at least 90% at a distance of 2cm and at least 80% at 5cm.

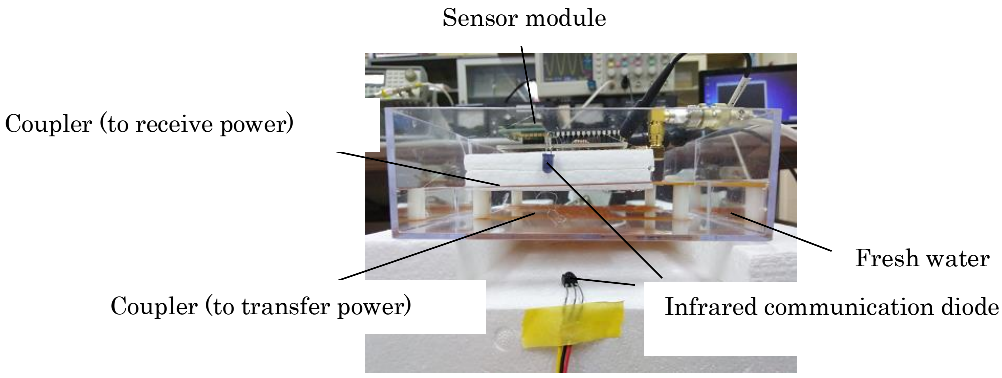

Figure 3: Wireless power and data transfer under fresh water

Caption: The sensor module was activated by wireless power transfer in fresh water to conduct infrared data communication in this experiment.