Master's Thesis

Coil Array Inductive Power Transfer System for Autonomous Underwater Vehicle

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Abstract

For a long time, providing a stable, safe, and efficient power supply for underwater electromechanical equipment has always been a concern in deep-sea exploration. Compared with the complicated docking mechanism, potential safety hazards, and expensive price of traditional wet-mate connectors, wireless power transmission (WPT) technology can transmit energy without any electrical contact between the power supply and the electrical equipment, which provides an effective solution to the aforementioned drawbacks of wired charging. There are many uncontrollable factors in the seawater working environment. Therefore, this topic takes the equivalent circuit and magnetic field distribution as the theoretical basis to study the energy transmission characteristics of underwater WPT and proposes corresponding improvements and solutions to the current problems and deficiencies. Especially for the unstable output voltage of the receiver and excessive magnetic flux density at the internal of AUV.

Keywords:

Autonomous underwater vehicle, inductive power transfer, underwater wireless power transfer, undersea

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1 Introduction

1.1 Background and research purpose

In the foreseeable future, the electrification of ocean systems, renewable ocean power sources and ocean energy networks will be necessary, which will help accelerate the growth and deployment of ocean renewable energy and ways to explore and understand the ocean [1]. To achieve electrification in the ocean, it is necessary to deploy corresponding sensor networks underwater and process the data received by underwater sensors in a timely manner. At the same time, underwater sensors are also an important tool for studying the marine environment. They can easily and flexibly explore underwater terrain and ecological environment, which provides convenience for the deployment of underwater sensor networks. A good underwater AUV needs to have good equipment waterproofness, long-distance underwater controllability and durability. For the water resistance of the equipment, we can use high-performance waterproof and pressure-resistant materials. The remote controllability needs to solve the problems of long-distance underwater communication. The durability of electrical equipment requires low energy consumption AUV and high-energy batteries or continuous equipment. Energy supply. Sufficient energy supply can keep underwater sensors and AUV equipment in an efficient and stable working state for a long time. Reducing human interference when electrical equipment is working underwater can also improve work efficiency and reduce deployment costs. Therefore, the energy supply for underwater electrical equipment has become a novel research direction. Such methods can solve the energy supply problem of underwater equipment economically and ensure the system to perform long-term and stable work [3]. In traditional marine engineering, power is supplied to underwater equipment through wet plug-in interfaces [4]. For the traditional wet plug interface technology, its high cost, complex docking method, poor safety performance, and easy to be corroded by seawater, make its disadvantages in marine engineering increasingly obvious. Wireless Power Transfer (WPT) simplifies the connection between underwater equipment and power supply, reduces the continuous operating cost of underwater equipment, saves a lot of resources, and gradually gains the favor of scholars.

The ocean itself and its surroundings contain a lot of energy, such as tidal energy, wave energy, ocean current energy, sea temperature difference energy, and sea salt difference energy. Ocean energy is rich, widely distributed, clean and pollution-free, but low energy density and strong regionality. These advantages make it attractive as a grid-connected energy, and may also make it an isolated and remote ocean energy source, thereby providing a valuable source of ocean space. Continuous development provides power solutions that are attractive. The rapid development of distributed ocean energy applications (such as underwater sensor networks, ocean sensors and monitoring technologies, ocean automatic network buoys, and deep sea and tsunami buoys) is beneficial. In particular, it can power an autonomous underwater vehicle (AUV) whose service life is limited by its battery power.

1.2 Wireless power transfer technologies

Broadly speaking, energy transmission without direct "electrical contact" between the primary and secondary is wireless energy transmission. Wireless energy technology can be divided into two main categories, Near-field (nonradiative region) power transfer and Far-field (radiative region) power transfer. Near-field means the area within about 1 wavelength (λ) of the antenna. The range of near-field devices is conventionally divided into two categories:

- Short range – up to about one antenna diameter: $D_{range} \leq D_{ant}$.
- Mid-range – up to 10 times the antenna diameter: Drange $\leq$ 10 Dant.

Long-distance wireless energy transmission includes microwave, light, and sound wireless energy transmission. Short-distance wireless energy transmission includes short-distance magnetic field transmission using inductive coupling or elec-

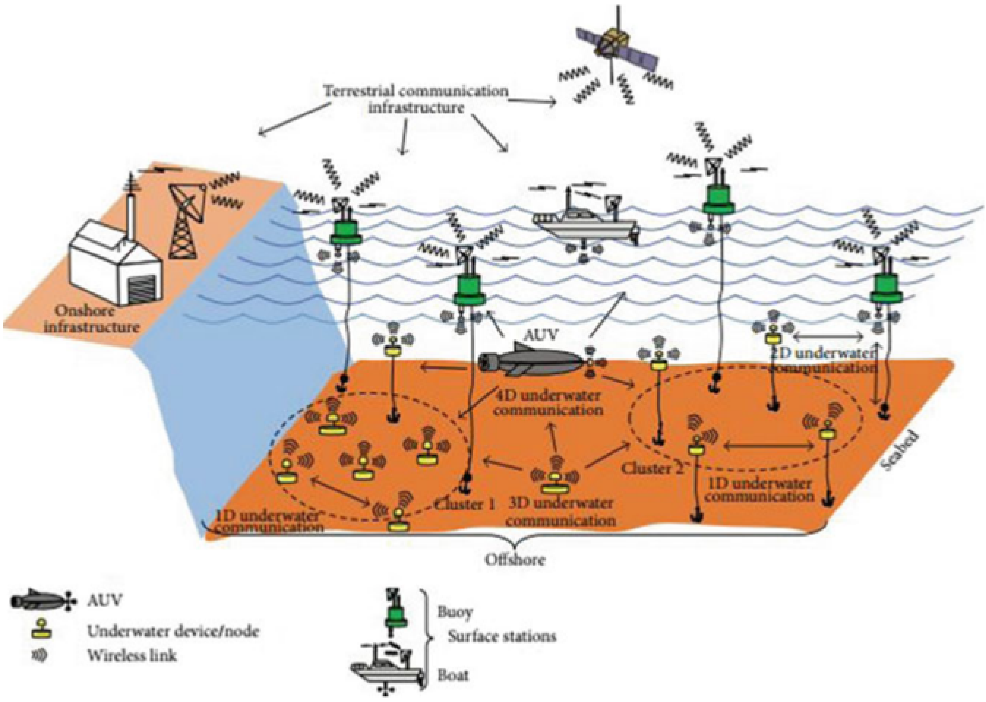


Figure 1.1: Underwater sensor networks architecture [2].

tric field using capacitive coupling transmission. The respective characteristics are shown in the table 1.1.

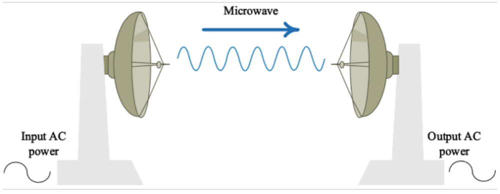
1.3 Underwater wireless power transfer

1.4 The main research content of this thesis

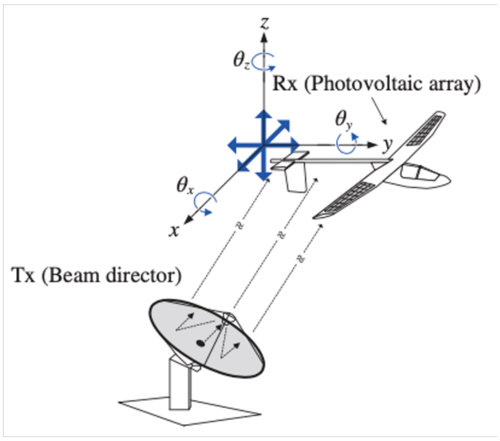
1.5 Roadmap

Table 1.1: The different wireless power technologies.

Technology	**Range**	**Frequency**	**Antenna devices**	**Applications**
Microwaves	hm - km	GHz	Parabolic dishes, phased arrays, rectennas	Satellite, drone aircraft
Optical	dam - km	≥THz	Lasers, photocells, lenses	Drone aircraft, space elevator
Capacitive	cm - m	kHz – MHz	Metal plate electrodes	Smartcards, biomedical implant
Inductive	mm - m	Hz – GHz	Tuned wire coils, lumped element resonators	Electric toothbrush, smartphone, electric vehicle

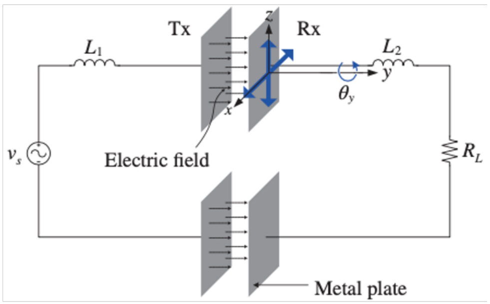


(a) Microwave power transfer [1].

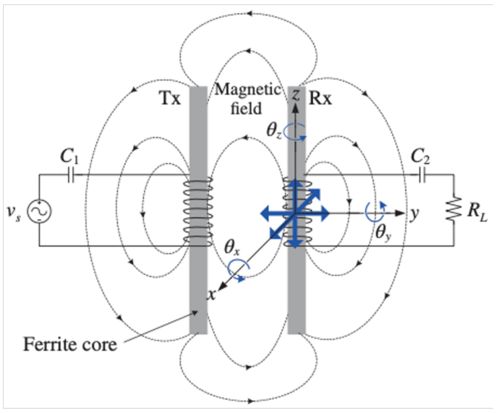


(b) Laser power transfer [3].

Figure 1.2: Far-field wireless power transfer.



(a) Capacitive power transfer [3].



(b) Inductive power transfer [3].

Figure 1.3: Near-field wireless power transfer.

2 Basic principles of WPT

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2.1 Compensation network technology

2.2 Underwater WPT system model

3 Coil array WPT

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3.1 Simulation evaluation

3.2 Coil array WPT in the air

3.3 Coil array WPT under seawater

4 Conclusion

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