

## Bio-magnetic systems for fish behavior studies developed from Helmholtz coils

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**Abstract.** As the development of economic construction, China has paid more and more attention to electrical energy, especially in the requirement and development of clean energy. Wind power, as a supplying channel of clean energy, has been developing rapidly in China's coastal waters recently. However, with the increase of construction scale and density of offshore wind turbine, its negative impact on organisms emerges gradually. Especially the effects of the electromagnetic radiation effects on marine life have attracted more and more attention. Studies have shown that research on biological effects of electricity and magnetism has long been discovered and used, but little research has been done in the field of marine research, due largely to the lack of experimental equipment. Bio-magnetic response research system on the basis of the Helmholtz coils was introduced in this paper. It includes excitation equipment and power supply and was made through scientific design and assembling. This instrument can create a magnetic field with different features for different needs of electromagnetic experiment and provide a suitable magnetic field research platform for general scientific research institutions.

### Introduction

With the development of economic construction, electrical energy was paid more and more attention in China, especially in the requirement and development of clean energy. Wind power, as a supplying channel of clean energy, has been developing rapidly in China's coastal waters recently. However, with the increase of construction scale and density of offshore wind turbine, its negative impact on organisms emerges gradually. Especially the electromagnetic radiation effects on marine habitat, breeding, growth, maturation and spawning have caused more and more attention. Many studies have also shown that biological effects of electric and magnetic have been discovered and used. However, few studies about biological effects of electric and magnetic in the field of marine research were reported<sup>[1]</sup>.

Magnetic effects of the wind farm on marine life have attracted people's attention, but the extent of influence and impact was unknown, and the progress of studies on it was slow. On the one hand, the complexity of the maritime magnetic field experiment was an obstacle to marine electromagnetic research. On the other hand, the earth's magnetic field emission device was not perfect in the laboratory, so the study of magnetic field effect on the sea animals be cam every difficult. Though biological research of the simple biological phenomena and the muscle contractions caused by electrical stimulation had a long history, the system of marine electromagnetics research was still difficult. Excitation devices at lab test are useful to study the magnetic field of solenoid magnetic field effect, surge arrester surge current circuit and formation of

pulsed magnetic fields. In addition, in order to study the magnetic field, people also invented the rotated magnetic field experimental apparatus and steady magnetic field experimental apparatus. Steady magnetic field generation device, with poor operating flexibility, was made of permanent-magnet materials<sup>[2]</sup>. There have no historical precedent for using Helmholtz coils in many tests.

Helmholtz coils were a pair of coaxial and parallel circular coils which had the same turns and RADIUS, the distance  $d$  between the two coils was exactly equal to the circle radius  $r$ . This coil centered on a common axis generates a wide range of uniform magnetic field in the vicinity, it has great practical value in production and scientific research. The coil has advantages of great open space, easy-to-use, linear relationships between magnetic field and supply current, using magnetic field uniform space has a wide area and suitable for the manufacture of one or, two or three-dimensional space magnetic field and so on. At present, the commonly used electromagnetic field in many experiments to is Extremely Low Frequency Electromagnetic Field(referred to as ELF), it has the definition of owing the electromagnetic frequencies between 0~100Hz (wave), including static magnetic fields and electrostatic fields, and low frequency (frequency) electromagnetic field<sup>[3,4]</sup>. The Extremely Low Frequency Electromagnetic Field is part of non-ionizing radiation. ELF in the environment field is used primarily by high-voltage transmission lines and home appliances (television sets, microwave ovens, electric blankets, hair dryers, etc)<sup>[5]</sup>. Helmholtz coil produces a magnetic field of a constant uniform magnetic field.

### **The functions of bio-magnetic response system**

In order to combine Helmholtz coil with biological experiments, the system is designed to establish a set of convenient magnetic field generator, and a scientific magnetic field experimental environment. Due to the lack of appropriate experimental equipment, it is difficult to transfer the operations of marine electromagnetic experiments to Labs. The design of bio-magnetic response system can meet the needs of laboratory experiments and improve maneuverability, reducing costs, increasing experimental convenience.

Main technical points lies in the larger size of Helmholtz coil and DC regulated power supply and the selection of metal filling materials and appearance of the packaging materials of Helmholtz coil. In addition ,it also includes bio-electromagnetic excitation device of the system-the Helmholtz coils and DC power supply.

### **Excitation equipment**

Helmholtz coil is produced by 12mm thick high quality acrylic sheet, the hardness and strength of acrylic sheet also meet the qualification. The device, containing the coil base, can be placed on a flat surface. The main specifications of the device are as follow, the inner diameter of 850mm  $\pm$  5mm; the outer diameter of 975mm  $\pm$  5mm; total height of 1087mm  $\pm$  5mm, the width of 52mm, the effective RADIUS (the radius of the BIOT-savart equation) 450mm; 1.5mm for each coil wire turns of insulated wire around 400, 200 turns of a tapped two total coil resistance of about 24 euro, the magnetic flux density at 3.5mT, voltage 120V. Excitation system produces a complete ring-shaped magnetic field. The middle level of the coil is the uniform magnetic field and the surrounding area of the coil is the non-uniform magnetic field.

Bio-magnetic response of instrument – Helmholtz coil layout as shown in Figure 1:

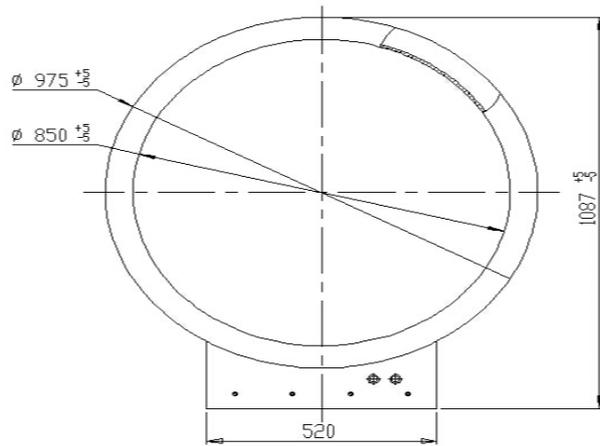


Figure 1 bio-magnetic response of instrument – Helmholtz coil layout

Bio-magnetic response of instrument-the three dimensional Helmholtz coils structure diagram shown in Figure 2:

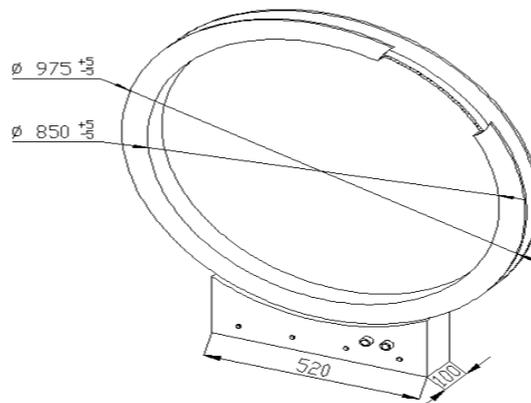


Figure 2-bio-magnetic response of instrument-three dimensional Helmholtz coils

### Power supply device

Power supply is a kind of high-precision DC power supply which has continually adjustable output voltage and automatic conversion of voltage regulators and steady flow. Thus, we can control the intensity of magnetic field by adjusting the flexibility of input current. The DC power supply, voltage 0-60V , adjustable, current 0-5A , adjustable, LED digital display, can be used in series and connected to 220V voltage, rated input power 720W.

Design of DC power supply diagram in Figure 3:

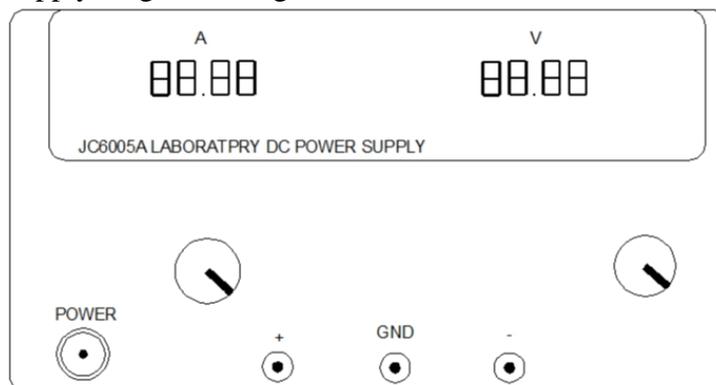


Figure 3 DC power supply designs

## Experiment of system

In actual experiments, turn RADIUS and the same two coaxial coils are placed in parallel, in series, current direction.  $D$  is equal to the space between two coil radius  $r$  (450mm). Before AC DC power supply, first excitation device connected to the DC power supply. Connect the positive pole of DC power supply with the positive excitation device, coil outlet and coil 2 and 1 negative positive connection coil 2 negative and negative DC power supply connected. We cannot supply DC power until the circuit connection has been completed.

After powering up, we can see two groups on the power supply screen, namely the output current and output voltage. Output current and voltage are continuously adjustable and voltage stabilization and steady flow can converse automatically through the adjustment knob at the bottom. The device also has a direction of flow variability.

Based on the BIOT-savart law, electromagnetic intensity of the excitation device ranges from 0 to 4mT. Regulate the working current to 2-4A, the output state will be stable, the excitation device under the working current will also be stable, as a result of this, the magnetic field of the corresponding will be stable.

Power connection diagram in Figure 4:

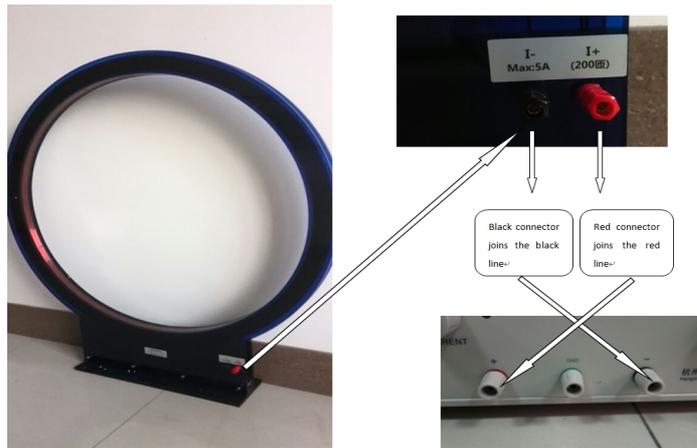


Figure 4 power connection diagram

After completing the installation of Helmholtz coil, the inventor measured the strength of the magnetic field by using the Gauss meter being fixed in the two intermediate regions perpendicular of the coil section central axis in the Shanghai Ocean University physics laboratory. At the same time, qualitative simulation was carried out by MATALAB, simulation results as following in Figure 5:

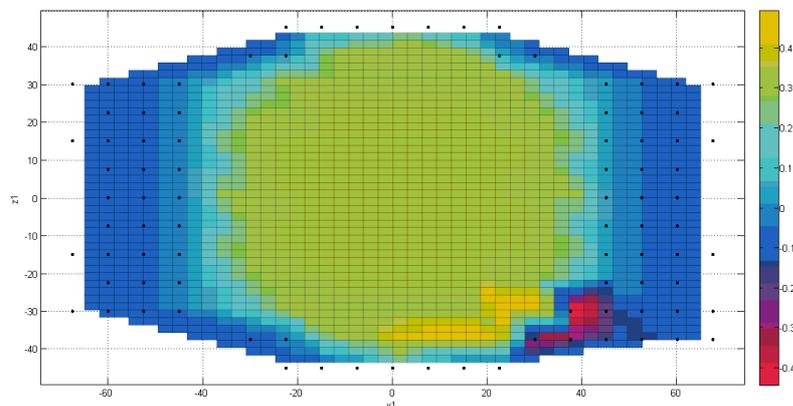


Figure 5 intermediate regions perpendicular to the central axis of Helmholtz coil magnetic field strength of the section qualitative simulation

According to Helmholtz coils magnetic field strength of intermediate regions perpendicular to the central axis profile qualitative simulation, we can see that magnetic field was uniform in the middle area, and significantly, the strength in the middle area is higher than that in the surrounding magnetic field.

## Summary

Since its birth, the influence of electromagnetic field on biological has been existed, as the development of economy and technology, the electromagnetic field's impact on biological is being wider and wider. There was no appropriate experimental apparatus that can be applied in the magnetic field , in order to meet the demand of experiment, the Bio-magnetic response of instrument was designed by combining the current knowledge of physical biology, designed and assembled the biological magnetic response of instrument. The instrument was used to study the magnetic response of marine life in the laboratory, and it can greatly reduce the high cost of the experiment on the sea. The device was well designed for its humanization, and it could create a constant electromagnetic field environment with stability and distribution characteristics. The intensity can be controlled and reproducible, thereby it has improved operability of the actual experiment and larger batch experiments are allowed being operated at the same time. The inside structure of the device was made of metal, so there was no magnetic interference in the work process, the design make the device more conformed to the scientific standards. The device utilizes characteristics of the Helmholtz coil excitation, it also lays the theoretical and technological foundation for a series of magnetic field experimental, and it will have a wide range of applications in the future, and it can help to promote the development of electromagnetic biology experiments.

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