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Acquisition and Analysis of Electric Fields in Marine Environment

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Abstract. Various sources of the electric field in the marine environment are analysed, which can be divided into artificial and natural sources according to causes, DC and AC sources according to the frequency. In order to better grasp electric fields in marine environment, a data acquiring system of the electric field is introduced based on msp430. The system has characteristics of low noise, low power and high resolution etc. Then ocean tests are carried out and the electric fields are acquired in offshore port and open sea respectively successfully. It is found that the environmental electric fields of offshore port are very different from that of pelagic environment, and the amplitude and frequency of the electric fields vary greatly with the sea conditions.

1. Introduction

The electric fields in marine environment are generated for a variety of reasons. For example, tides and ocean currents cause the flow of water, which can induce electromagnetic field by cutting geomagnetic field. The electric current produced by a thunderstorm storms into the water will bring random environmental noise. Sunspot activity is one of the sources of the marine electric field. In addition, human activities, for example, electric power, transportation and other human activities are also sources of electric noise, especially coastal port industrial electric field which is an important part of the background noise. The marine environment electric fields are analysed, and the real electric field is measured by a data acquiring system.

2. Electric fields in the marine environment

According to the different forms of field sources, the underwater electric field in the marine environment can be divided into natural electric field and electric field formed by human factors[1~2]. And according to the frequency, the electric field in the marine environment can be divided into electrostatic field and alternating electric field.

2.1The sources of noise caused by electrostatic field

All countries attach great importance to anticorrosive protection of ports, wharves and offshore drilling platforms, and have formulated cathodic protection design standards about protective potential and protective current density for the offshore equipment. These currents enter seawater in the form of direct current or ultra-low frequency, forming static or quasi-static electric field interference. The design indexes of some ports and wharfs are shown in the following tables[3].

Table 1. Cathodic protection current density in some ports and wharfs

Port name	The selected current density（mA/m2）			Remarks
	In the water		Bare steel in the soil	
	Bare steel	coating		
Shanghai wharf		30		Seawater
Beilun port pier	100	20	100	Seawater
Shanghai chemical wharf		40		Seawater
Baosteel wharf	80	55	80	Seawater
Lianyungang port		25		Seawater
Sanya port wharf	107		107	Seawater

Table 2. Protective potential and protective effect in some ports and wharfs

Port name	Designed protection potential（V）	Measured protection potential（V）	protective results （%）
Shanghai port	-0.80～-1.00	-0.78～-1.00	84～90
Beilun port pier	-0.77～-1.20	-0.90～-1.20	86～97
Shanghai chemical wharf	-0.80～-1.00	-0.85～-1.00	92～95
Baosteel wharf	-0.77～-1.05	-0.85～-1.05	91～97
Lianyungang port	-0.78～-1.00	-0.94～-1.02	83～95

2.2The sources of noise caused by alternating electric fields

The seawater attenuates high-frequency electromagnetic waves more rapidly and low-frequency waves more slowly. Accompanied by low-order and high-order harmonic waves, the fundamental wave field intensity of power frequency can reach millivolt level. Power system, industrial mining enterprises and vehicles are the main sources of interference of alternating electric field. Converter devices, such as rectifier, inverter, and voltage stabilizer circuit include magnetic material equipment, rectifier components or switching devices, which are the sources of power frequency interference and harmonic interference. The power frequency interference of two different docks has been measured [4] and it can be seen that the interference waveforms in the two places have obvious differences in figure 1 and 2. In fact, there are differences not only in the same place, but also in different frequency. Fluctuations can be observed at different times in the same place, which is mainly due to the change of electricity consumption with time. Power frequency interference in harbour water is a common problem and this kind of fixed frequency interference can be dealt with in many ways, such as using band trap, filter or adaptive cancellation method.

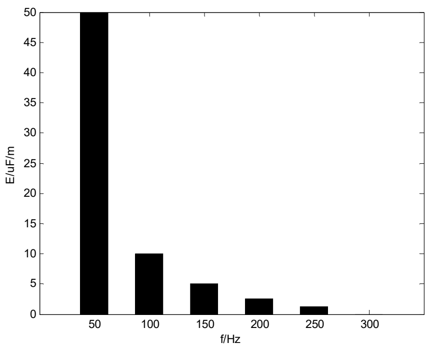

Figure 1. The power frequency in the dock.

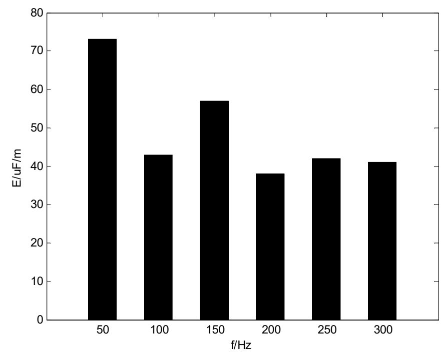

Figure 2. The power frequency in other dock.

3. Acquisition of real marine environmental electric field

In order to study the electric field in the marine environment, a set of electric field environment acquisition system is designed. Using the system, the marine environment fields are measured in different area and sea conditions.

3.1 measuring system

Based on msp430 microcontroller Unit, the entire system consisting of electric sensor, signal conditioning circuit, Analogy to Digital Converter (ADC) and MCU is developed. System theory chart is shown in figure 3.

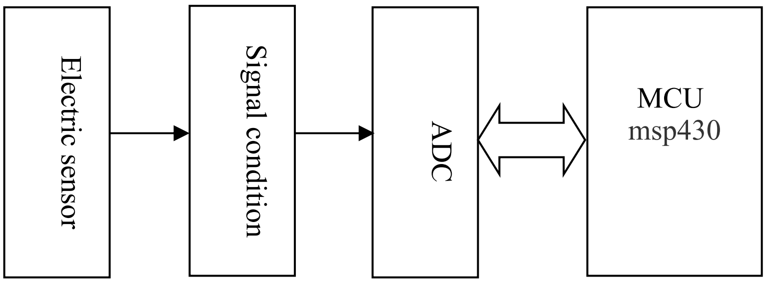

Figure 3. The measuring system of the marine environment fields.

The msp430 has one active mode and five software selectable low-power modes of operation. An interrupt event can wake up the device from any of the five low-power modes, service the request and restore back to the low-power mode on return from the interrupt program. Power consumption is less than 1mA in active mode and less than 1μA in standby mode. As has been test practically, the consumption of the entire system is 0.9mA at standby mode and 7.1mA at active mode. With two groups of battery packs, it can run reliably for 40 days [5].

Materials which are inert in seawater in general are characterized as polarisable and have potentials which vary widely depending on the surface condition of the electrode and the current drawn from it. They are not suitable for low noise sensors. Carbon fibres based technologies are subject to capacitance effects at low frequencies and as such are not well suited to low noise measurements at frequencies close to DC[6]. The chlorides in seawater are non-polarisable and as such have relatively constant potentials when small changes in current occur. Many of the chloride type electrodes are poisonous and not suitable in range applications. Ag/AgCl however is robust and has excellent long term stability. It has been used for cathodic protection monitoring for over 40 years and for almost 20 years in military applications. The electric sensor is designed and produced by China University of Geosciences. The voltage measured by a two-electrode sensor depends on the electrode spacing.

3.2Preparation before measurement

The depth at which the underwater measuring body is located is provided by the depth sensor, and the azimuth, roll and pitch are provided by the electronic compass.

As long as the bottom of the survey area is flat, it can basically ensure the horizontal placement of the measure system. However, the specific direction of the square upward is difficult to guarantee. The method of coordinate change is used to determine the direction.

With sea level as the plane and sea level as the origin, the z-axis is perpendicular to sea level and the Y-axis points to the north pole of the magnetic field line, a rectangular coordinate $O-xyz$ system is established.

The coordinate system of the three-axis electric field sensor is $O'-x'y'z'$. If roll angle, pitch angle and azimuth angle are respectively set as α, β and ϕ, then the transformation relationship in the two coordinate systems is as follows:

$$G(\varphi,\alpha,\beta)\cdot \boldsymbol{V}_{earth}=\boldsymbol{V}_{sensor} \quad (1)$$

$$\begin{aligned}\boldsymbol{G}(\varphi,\alpha,\beta)&=\boldsymbol{G}_x(\beta)\boldsymbol{G}_y(\alpha)\boldsymbol{G}_z(\varphi)\\&=\begin{pmatrix}1&0&0\\0&\cos\beta&\sin\beta\\0&-\sin\beta&\cos\beta\end{pmatrix}\cdot\begin{pmatrix}\cos\alpha&0&\sin\alpha\\0&1&0\\-\sin\alpha&0&\cos\alpha\end{pmatrix}\cdot\begin{pmatrix}\cos\varphi&\sin\varphi&0\\-\sin\varphi&\cos\varphi&0\\0&0&1\end{pmatrix}\\&=\begin{pmatrix}\cos\varphi\cos\alpha&\sin\varphi\cos\alpha&\sin\alpha\\-\cos\varphi\sin\alpha\sin\beta-\sin\varphi\cos\beta&\cos\varphi\cos\beta-\sin\varphi\sin\alpha\sin\beta&\cos\alpha\sin\beta\\-\cos\varphi\sin\alpha\cos\beta+\sin\varphi\sin\beta&-\cos\varphi\sin\beta-\sin\varphi\sin\alpha\cos\beta&\cos\alpha\cos\beta\end{pmatrix}\end{aligned} \quad (2)$$

The electric fields obtained by the sensor can be converted according to the following formula:

$$\boldsymbol{V}_{earth}=\boldsymbol{G}^{-1}(\alpha,\beta,\gamma)\cdot\boldsymbol{V}_{sensor} \quad (3)$$

Position coordinates conversion of three-axis electric sensors is shown in figure 4.

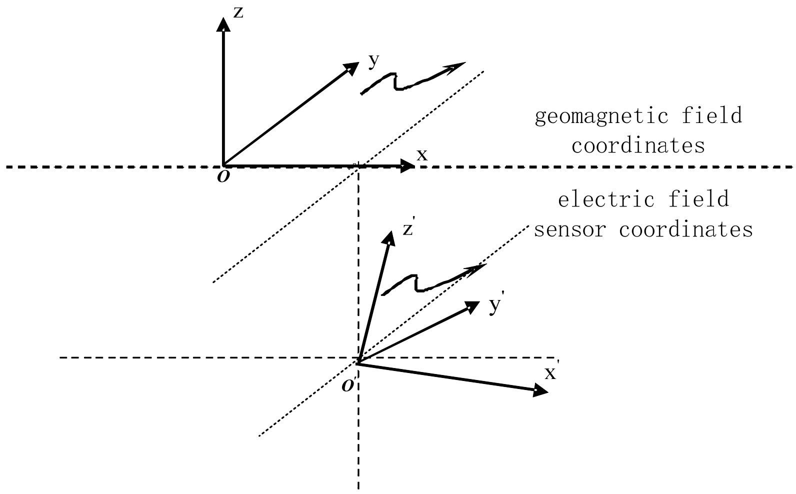

Figure 4. Position coordinates conversion of three-axis electric sensors.

3.3Measuring results

3.3.1Marine environmental electric field in near and far sea（1~5Hz）

The measuring results for the near sea can be seen in the figure 5, 6 and 7. There is the strong impact of interference in the environmental electric field signal. The intensity of the environmental electric field varies greatly in different time, and the time interval of the strong impact is between 5 ~ 25 seconds and the duration of each shock is about 2.5 seconds. The cause of the interference has not yet been identified. Figure 8, 9 and 10 show that the results of the far sea survey. As the measuring area is far from the coast and there are relatively few industrial zones near the coast, the environmental interference is not as complex as the offshore area. It can be seen from the results that the environmental electric fields in different sea areas vary greatly.

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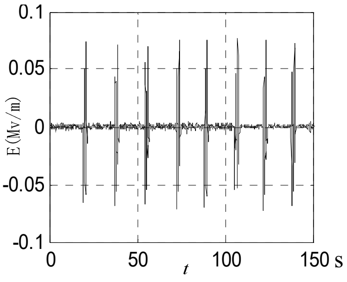

Figure 5. The electric field intensity in x direction in offshore port.

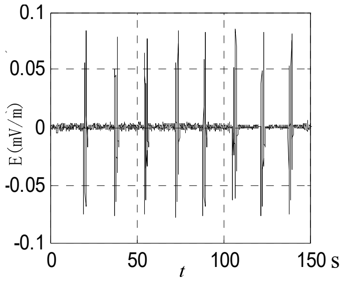

Figure 6. The electric field intensity in y direction in offshore port.

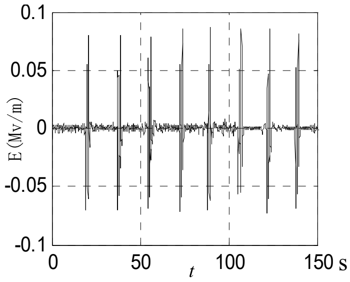

Figure 7. The electric field intensity in z direction in offshore port.

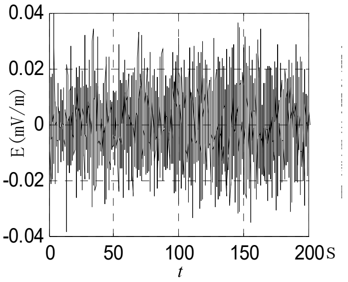

Figure 8. The electric field intensity in x direction in open sea.

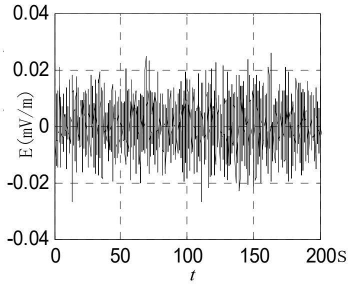

Figure 9. The electric field intensity in y direction in open sea.

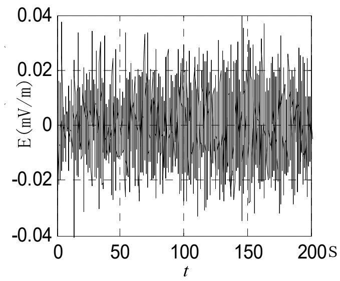

Figure 10. The electric field intensity in z direction in open sea.

3.3.2The marine environment electric field in different sea conditions（DC～0.5Hz）

To study the movement of the waves on the environment the influence of electric field, the environmental electric field is measured under different sea conditions. Figure 11 is an environmental electric field in the primary sea condition. And most of electric field energy focuses on 0 ~ 0.1 Hz. Compared with figure 12 , the amplitude of electric fields become larger and the electric field energy in low frequency more concentrated with the increase of sea condition.

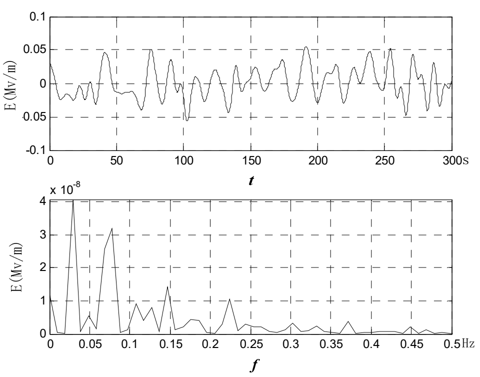

Fig 11. Power spectrum of marine environment electric field in one-level ocean waves.

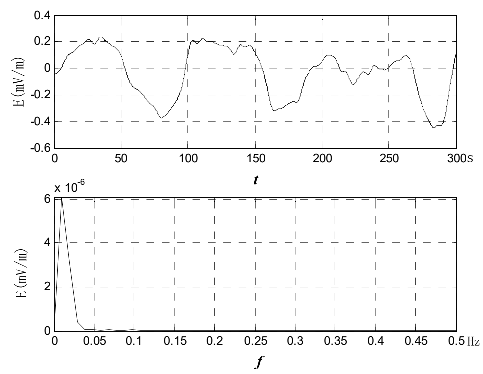

Fig 12. Power spectrum of marine environment electric field in three-level ocean waves.

4. Conclusion

As environmental noise, the marine environment electric fields interfere with the operation of underwater precision instruments, marine biological activities, target detection and so on. In order to better understand the nature of the marine environment electric field, the actual measurement of the electric field is carried out in different areas and sea conditions. It has been proved that there is a fundamental difference for electric field in near and far sea area, and the energy of electric field concentrates to low frequency with the increase of sea conditions.

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