Measurement and analysis of motor-noise in underwater glider

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Abstract. Self-noise is a very disadvantageous factor for underwater glider to observe ocean ambient noise, in which the noise caused by motor is very significant. In order to grasp the characteristics of the motor-noise and its influence on the measurement of ocean ambient noise, a long-term sea trial was conducted in the South China Sea in May 2020, and the self-noise data of underwater glider under different working conditions are obtained. By analyzing the noise level and spectrum level of the motor noise, we obtained the self-noise spectrum characteristics and know that the influence of control motor noise on the noise measurement of head and tail hydrophone is mainly below 5 kHz band, and the influence of full-frequency noise level brought by motor is within 10dB and 5dB respectively. The results lay an important foundation for further analysis of ocean ambient noise measured by underwater glider.

1. Introduction
Autonomous Underwater Gliders (AUG), a new type of unmanned Underwater vehicle powered by its own buoyancy, play an important role in the emerging global ocean observing system [1]. Its unique driving mode, with the advantages of low noise, low power consumption, high concealment, can achieve large-scale, long-term, continuous cross-section data acquisition, compared with the traditional methods of ocean ambient noise observation has obvious advantages. Therefore, the underwater glider with acoustic equipment has become the research hotspot of ocean ambient noise observation.

In order to use underwater glider as an observation platform of ocean ambient noise, the basic characteristics of self-noise of underwater glider should be studied firstly. The self-noise of the glider platform not only affects the accuracy of the observed data, but also affects its concealment performance. At present, the research on underwater glider only highlights the low noise characteristics of its unique driving mode, but there are few researches on the self-noise characteristics of the glider. In 2015, the Ocean University of China used an underwater glider to observe turbulence, and experiments have shown that the self-noise of the glider body has little effect on the measurement of turbulence energy, the vibration of the glider platform is mainly caused by the movement of the fuel pump and the battery pack and the Large Oscillation during control adjustment [2].The control adjustment is made by the motor to adjust the weight (battery) by moving back and forth along the axis in order to complete the glide control when diving or floating, and the transition control from diving to floating [3]. Therefore, the motor plays an important role in the glider system, so this paper...
will focus on the study of the motor-noise characteristics of underwater glider and its influence on the measurement of ocean ambient noise. The research platform of this paper is Petrel-L glider, which is a self-developed and mature underwater glider system in China. It has the advantages of low power consumption, deep diving depth, strong flexibility and low noise. Based on this platform, a two-channel acoustic data acquisition system was carried out in May 2020 in a sea area of the South China Sea to obtain the self-noise data of the glider platform. Through the time-frequency analysis of motor noise data, we obtained the basic characteristics of motor-noise of underwater glider. It is meaningful to further study the motor noise of gliders for the development of ocean ambient noise measurement based on gliders.

2. Petrel-L glider and acoustic acquisition system

2.1. Petrel-L glider
Petrel-L glider is a long-range underwater glider developed by the Tianjin University. It relies on its own net buoyancy to dive and float. It is a multi-type underwater glider developed independently in our country, a glider system that operates continuously for long periods of time. The main performance indexes of Petrel-L system are as follows: (1) the maximum working depth is 1000m; (2) the maximum glide speed is 0.7 m/s; (3) the maximum designed range is 3000Km; (4) it has BeiDou Navigation Satellite System (BDS) and Global Positioning System (GPS) positioning capability and is equipped with wireless and satellite communication terminals. (5) it has CTD sensor, and can extend the capability of altimeter, hydrophone, magnetic probe and so on.

2.2. Acoustic acquisition system
In order to collect noise data, an acoustic acquisition system is installed on the Petrel-L glider platform. The acoustic acquisition system used in this experiment includes two parts: head (figure 1, CH1) and tail (figure 1, CH2) hydrophone and data acquisition system. The deep-water hydrophones are responsible for collecting signals and converting them into electrical signals. The electrical signals are filtered, amplified and stored by the data acquisition system. The Acoustic acquisition system is very sensitive to the self-noise of the glider, so the installation position of the hydrophone on the glider is also an important factor to determine the success of the data acquisition[4].

In general, the noise of underwater vehicles mainly comes from hydrodynamic noise, mechanical noise, and propeller noise. Among them, hydrodynamic noise refers to the random sound produced by the relative movement between the water medium and the surface of the navigation body or the boundary surface of the water flow in the bounded waters; friction, impact force or non-equilibrium force between the parts make the mechanical parts and the shell produce vibration and radiation noise; propeller noise is the noise caused by the rotating propeller. Because the underwater glider works up and down by its own net buoyancy, there is no need to consider the noise of propeller. Moreover, the speed of the glider is low, and the cavitation noise caused by the direct impact of water flow is weak, so hydrodynamic noise is negligible. That is, in the actual navigation, the measured mechanical noise has the greatest impact on the self-noise of the glider, this paper mainly analyzes the mechanical noise produced by the motor.

Figure 1. Installation sketch map of acoustic system.
3. Motor-noise measurement
Motor-noise can be obtained by means of direct sampling in water tank or sea trial and computer simulation modeling. It is difficult to accurately simulate the motor noise due to the interlacing of motor noise and various sound sources, the complicated and changeable transmission route and the unstable sound field[5]. In order to obtain accurate motor noise data, we conducted a direct motor noise measurement experiment in the South China Sea in May 2020, and collected 114 profiles in 20 days, the sea trial is shown as figure 2. The sea condition is good when surveying profile data, there is no man-made noise nearby, and the vertical depth of each profile is more than 900m, which avoids the chance of measuring results.

![Figure 2. Glider layout](image)

![Figure 3. Working diagram of glider](image)

4. Motor-noise analysis
The motor-noise level of the glider may be different in different sea area, different depth and different working conditions during the measurement at sea. In order to analyze the self-noise of glider accurately, three typical profiles of motor noise are selected in this paper. The horizontal distance of each profile is 36km, 147km and 202km, and the vertical depth is about 980m. The experimental area is shown in figure 4 and figure 5.

During the first 100 meters of a glider’s descent, strong shallow currents can affect the glider’s course, and the motors need to be constantly turned on to correct course. The noise of shallow ocean environment is influenced by sea wind and ship, so it is necessary to choose the noise data when the motor is located in deep ocean[6]. Therefore, we choose the time point of motor noise in shallow sea (40m, 100m) and deep sea (800m), ignore the difference of ocean ambient noise in several tens of meters depth, and study the characteristics of motor noise of glider.

Motor-noise has unique time-frequency characteristics, especially in the time domain there will be a significant increase in amplitude, which provides a convenient identification and study of motor-noise. Section 1 at 40 meters CH1 and CH2 recorded motor noise waveform changes as shown in figure 6 and figure 7, from the amplitude can see a significant amplitude fluctuations. The time-domain data are processed by spectral analysis, and the 1/3 octave spectrum as shown in figures 8 and 9.

Comparing the 1/3 octave spectrum of CH1 and CH2, it is found that the maximum effect of motor-noise on CH1 is 2.7 dB below 5 kHz band, and the average contribution of all frequency band is 0.4 dB. The influence of motor-noise on CH2 is also below 5 kHz band, which is 1.4 dB with almost no contribution in the whole frequency band. From the above analysis, it can be concluded that motor noise has a greater effect on CH1 than CH2, which may be related to the proximity of motor to CH1.
Figure 4. Experimental area.

Figure 5. Larger image of experimental area.
By dealing with the motor-noise data under three profiles and non-motor noise data at the same depth, the influence degree of motor-noise can be obtained by processing 1/3 octave spectrum. The results are shown in Table 1 and Table 2:

**Table 1. Profile 1 motor-noise influence degree table**

| Depth(m) | Channel | Frequency band(dB) | Status     |
|----------|---------|--------------------|------------|
|          |         | 20Hz-1kHz | 1kHz-5kHz | 5kHz-10kHz | 10kHz-25kHz | 20Hz-25kHz |
| 40       | CH1     | -0.003    | 2.7       | 0.6        | 0.8         | 0.4        | submergence |
|          | CH2     | -0.4      | 1.4       | 0.6        | 0.1         | -0.3       |             |
| 800      | CH1     | 2.7       | 8.6       | 1.9        | 1.1         | 4.0        | surfacing   |
|          | CH2     | 1.4       | 0.4       | -0.4       | -0.5        | 1.2        |             |

**Table 2. Profile 1 motor-noise influence degree table**

| Depth(m) | Channel | Frequency band(dB) | Status |
|----------|---------|--------------------|--------|
|          |         | 20Hz-1kHz | 1kHz-5kHz | 5kHz-10kHz | 10kHz-25kHz | 20Hz-25kHz |
| 40       | CH1     | -0.003    | 2.7       | 0.6        | 0.8         | 0.4        | submergence |
|          | CH2     | -0.4      | 1.4       | 0.6        | 0.1         | -0.3       |             |
| 800      | CH1     | 2.7       | 8.6       | 1.9        | 1.1         | 4.0        | surfacing   |
|          | CH2     | 1.4       | 0.4       | -0.4       | -0.5        | 1.2        |             |
Based on the above data analysis, the effect of underwater glider motor on ocean ambient noise measurement is as follows:

1) The motor-noise has little influence on the depth and working state of the glider, which shows that the motor noise has a stable influence on the observation of ocean environment noise based on the underwater glider.

2) The influence of motor-noise on the hydrophone's measurement is the largest in the frequency band of 5 kHz, the average is over 10 dB, and the influence is obviously smaller in the frequency band of over 5 kHz.

3) Motor-noise has the greatest influence on the noise measurement of the tail hydrophone in the frequency band of 5 kHz, the average influence is less than 5 dB, and above 5 kHz motor has almost no influence;

4) The influence of motor-noise on the tail hydrophone is much less than that of the head hydrophone.

### 5. Conclusion

In this paper, we studied the noise of Petrel-L glider motor in detail through the motor-noise data collected from an sea trial in the South China Sea in May 2020. It is found that motor-noise has little influence on the depth and working state of the glider, motor-noise has more influence on the head hydrophone than on the tail hydrophone, and the maximum frequency range of motor noise is less than 5 kHz, the average intensity is less than 10dB (CH1) and 5dB (CH2), and the influence of motor noise on the head hydrophone is obviously reduced, while the tail hydrophone is hardly affected in the frequency band above 5 kHz. In conclusion, it is suggested that the hydrophone should be installed in the tail of the glider in the following ocean ambient noise measurement. The research of this paper has certain guiding significance for the research of ocean ambient noise measurement based on underwater glider.

### 6. References

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