The Study of Ocean Ambient Noise Reconstruction in Low and Medium Frequency Bands

Zhang Liang¹ᵃ, Wen Fengdan²ᵇ, Meng Chunxia³ᶜ and Han Jing⁴

¹²³ᵃ Science and Technology on Underwater Test and Control Laboratory Dalian, 116013, China

ᵃ53359229@qq.com, ᵇᶜ dlinstitute@163.vip

Abstract. Ocean ambient noise is the general background of the sea, the sources of which is highly variable, the generated noise signal is random, it changes with time and space. It is usually considered that ocean ambient noise is a special random process with certain power spectrum, so the broadband stationary random process can be used for fitting the continuous spectral noise. This paper carried out statistical analysis on sample data obtained by continuous observation in one day, and then the statistic characteristics of ambient noise frequency spectrum in low and medium frequency bands can be calculated. Generating filter with specific frequency response based on the probability density function of sound pressure level in each frequency randomly, and ocean ambient noise is reconstructed effectively by Gaussian white noise passing the filter above. The simulation results have important implication for low and medium frequency underwater acoustic signal analysis in lab conditions, and it is helpful to test the performance of platform in the oceanic background.

1. Introduction
Ocean ambient noise may be said to be the noise of the sea itself, the sources of which is highly variable, it is a mixture of several different types of noise: ocean dynamic noise, biological noise, shipping and industrial noise, thermal noise[1] and so on. The characteristics of ambient noise varies with different frequency bands[2], its spectrum is composed of segments of different slope having a different behavior under different condition such as wind speed or ocean depth[3].

Figure 1. Flowchart of ocean ambient noise reconstruction

Ocean ambient noise is the background of the sea [4], the properties of oceanographic equipment are different at the different marine environment [5]. Chinese scholars have conducted a significant
amount of researches on ambient noise in shallow water over the last decades [6], less research has been done in deep-sea environment owing to the lack of measured data [7], the properties of ambient noise in deep-sea still need to be studied [8]. In this paper, base on lots of ambient noise data measured in deep-water, the frequency spectrum characteristic of ocean ambient noise is analyzed statistically, and the time domain waveform of ambient noise is reconstructed, the entire flow is illustrated in Figure 1.

2. Statistical analysis of ocean ambient noise in low and medium frequency

2.1. Description of ocean ambient noise data
In the summer of 2015, ocean ambient noise data of different time period in one day was obtained during an underwater acoustic experiment in the South China sea. Hydrophone is located about in 10 meters underwater, the sensitivity of which is -172dB, it’s data sampling rate is 12kHz. In the course of that day, oceanic condition was 2 grades, the weather was clear, and the number of boat around the experimental sea area is smaller.

The effective ocean ambient noise was selected to perform time frequency analysis, Figure 2 shows the time-domain signal of ocean ambient noise, which was measured in a certain period of time.

2.2. Statistical analysis method of ambient noise
Ocean ambient noise signal is random, and the energy is discontinuous distributed. The random signal cannot be expressed by a certain time function, for this reason, ocean ambient noise’s level can only be expressed by statistical characters for a certain frequency.

- Mathematic expectation, describe the average value of a random signal. Supposing the experiments times is n, the times with measurement results of \( x_1 \) is \( m_1 \), and with results of \( x_2 \) is \( m_2 \), and so on, the times with measurement results of \( x_k \) is \( m_k \), the average is shown below.

- Variance yields, describe the variation intensity of random signal amplitude, it reflects the fluctuation of random variable’s value. Supposing X is a random variable, and variance of \( X \) exists.

- Probability density function. The probability density function of one-dimensional real random variable describes the possibility of random variable’s output quantity near a certain value point.

2.3. Statistical properties of ocean ambient noise
Selecting the ambient noise data obtained by continuous observation in one day, which length in each time period is 10 seconds, and then frequency spectrum analysis is adopted for single sample data with
frequency resolution less than 1Hz. The change rule of ambient noise spectrum in different time period of one day is shown in figure 3.

![Figure 3](image3.jpg)

**Figure 3.** The statistic result of sound pressure level in different time period

As can be seen from the figure, the distribution of ambient noise in different frequency remains consistent roughly in different time period, the maximal value of spectra level in 100Hz may be caused by ship traffic. The result shows that ambient noise level changes over time in one day, the variation reach up to 10dB approximately in low frequency band, which may be caused by the changes of surface wave and current all the time.

Some statistical feature can be obtained by performing statistical analysis on sound pressure level of all the data samples, such as average, variance, probability density function and so on. Figure 4 shows the average and variance of sound pressure level at different frequency point.

![Figure 4](image4.jpg)

**Figure 4.** Sample mean and variance

As is shown in figure 4, the variation tendency of ocean ambient noise measured in South China sea is roughly same with Wens-noise-level in summer: the noise level is high in low-frequency band, and is low in mid-frequency band, the maximal value is about 100Hz. The analysis results in this paper show that ocean ambient noise level fluctuate obviously in frequency less than 100Hz and more than 2kHz, the variation of which in frequency from100Hz to 2kHz is small.

Acoustic pressure spectrum of each data sample at each frequency point is calculated, and the probability density function is obtained, as an example, figure 5 shows the probability distribution of ocean ambient noise at frequency of 200Hz.

As can be seen from the analysis results in figure 5, the probability distribution at 200Hz is similar to Gaussian distribution, which is related to the randomness of ocean ambient noise.
Basing on these analyses, the probability density distribution can be calculated, as is shown in Figure 6.

Figure 6 shows the probability distribution of ambient noise pressure level at different frequency point, and the changing curve of 95% confidence intervals can also be found in the above picture. As is shown, the sample is dispersive in frequency less than 100Hz and more than 1 kHz; this situation is more obvious in low frequency band.

3. Algorithmic generation of Gaussian white noise random sequence
There are many methods of generating Gaussian white noise random sequence, Box-Muller method is a typical in signal processing at present, the long period Gaussian white noise random sequence obtained by this method is authentic enough.

4. Generating filter with specific frequency response based on measured data
By using the statistical analysis algorithm, the random variable in each frequency can be generated randomly, which satisfies the probability density function, the random variable can be treated as the amplitude-frequency value of the filter with specific frequency response. Figure 7 shows the filter with specific frequency response generated randomly. It is worth reminding that ocean ambient noise spectrum in the acoustic field is dynamic, each of the reconstructed frequency spectrum satisfy statistical regularities.
5. Signal reconstruction of ocean noise background in time domain

In order to get the signal of ocean noise background in time domain, filter with specific frequency response in part 3 is adopted to filter the white noise in part 2. The generated time-domain signal meets the requirement of ocean noise background, which amplitude satisfies the statistical regularity, and the phase angles are randomly distributed.

6. Conclusions

In this paper, basing on statistical analysis, lots of measured data were used to study the reconstruction method of middle-frequency and low-frequency ambient noise in deep water. Filter with specific frequency response is adopted to filter the Gaussian white noise, and the time-domain waveform of ocean ambient noise was obtained by simulation, the waveform meets the requirement of spectrum statistical characteristic.

Ocean ambient noise has a variety of different sources, in the deep water, sound speed profile together with the sea and its boundary, forming a remarkably complex medium for the sound propagation; all of them have great influence on acoustic energy emitted from the sources. The sound vertical velocity varies with the seasons, and the surface roughness is different under different sea conditions. From the above mentioned, therefore, the method proposed in this article can be used to analyze the ocean ambient noise in different seasons and different sea conditions, so that the statistical property has a universal meaning. Further researches are still needed.

Acknowledgments

This study was funded by the Defense Advanced Research project (No. 414160603) and foundation research project (No. JCKY2016207A037). The authors would like to thank colleagues for technical assistance with acoustic data collection, and the organizers are thanked very much by the author for providing the international academic exchange opportunity.

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