

COHERENCE PROPERTY ESTIMATION FOR VARIOUS OCEAN DEPTHS

V.G.Sivakumar¹

Department of ECE, Sathyabama University, Jeppiaar Nagar,
Chennai, Tamil Nadu 631208, India
kaviks2004@yahoo.co.in

Dr.V.Rajendran²

Department of ECE/Physics, SSN college of Engineering, Kaalavakkam,
Chennai, Tamil Nadu ZIP/Zone, India
drvrajen@yahoo.com

Abstract

Under water sound serves as a very effective communication which can be made to vary in amplitude, frequency, and periodicity. These three variables are able to produce extremely wide and complex range of signals. Ambient noise and determination of its source is the biggest challenge in underwater acoustics industry. Yet ambient noise fields' coherence is seen to be stable and hence can be utilized for determining seabed properties. Hydrophones in the form of vertical linear array at shallow depth of around 30m in the Arabian sea region are used for coherence estimation. To make better measurements of noise, it is preferred to avoid places where there is water movement relative to hydrophone array and cables. For various depths of hydrophones, the power spectrum and coherence plot of amplitude versus frequency are done and examined.

Keywords: Ambient noise; coherence; shallow water; hydrophone depths.

1. Introduction:

Ambient noise is the background sounds which are spotted in the ocean. The various sources of ambient noise are (i) geophysical - Seismic waves, rain, hail and snow, hydrostatic and hydrodynamic sources such as bubbles, waves and wind turbulence (ii) human made - Ship traffic, Coastal or off shore activity, aircraft flying over the sea (iii) Biological sources - Marine species (iv) Thermal noise - due to bombardment of molecules. These types are categorized under various bands of frequencies. Ambient noise present in the ocean is not uniform in horizontal, due to the presence of acoustic sources such as surface shipping, storm systems, ice cover, and underwater seismic events. Ambient noise in the ocean is represented as a superposition of independent, uncorrelated plane-waves propagating in all directions.

Due to the multiple bottom reflections in shallow water region, the spatial structure of the ambient noise field depends strongly on the geoacoustic properties of the seabed, which are invariant over time scales associated with most measurements. The vertical directionality and coherence are relatively stable features of the noise that are determined primarily by the seabed, rather than temporal variations in the surface source distribution. The ambient noise field is a stochastic process of many such noise sources and the respective interactions of their wave fields with the environmental boundaries. As a consequence of the multipath interaction, the time-averaged ambient noise exhibits spatial structure that is determined by the seabed properties. The geoacoustic parameters of the seabed determine the relative reflection versus refraction of sound from the water column into the seabed as a function of angle. This relationship also affects the vertical directionality and vertical coherence of the ambient noise. To predict the seabed parameters, the noise function in the ocean environment is determined earlier.

2. SPECTRAL CLASSIFICATION OF AMBIENT NOISE:

(i) Ultra-Low Band (<1Hz)

The spectrum of frequency band below 1Hz can be observed using a pressure-sensitive hydrophone; it is shown by line components. These components apart from representing acoustic pressure propagating with the velocity of sound, it also represents hydrostatic or hydrodynamic origin. Examples for this band include the tides with lunar and solar periods and their harmonics, pressure due to wave.

(ii) Infrasonic band (1 to 20 Hz)

The ship noise begins to be strong in the frequency region of 5 to 20 Hz and the spectrum levels contain a reverse slope indicating the shipping noise at the upper end of the frequency band. In shallow water where the shipping noise won't be appreciable, the spectrum will fall off and depends on wind speed for the entire band. Hence the noise in this band and in next higher one depends greatly on location, relative to the presence of ship traffic. This band contains the strong blade-rate fundamental frequency of propeller-driven vessels, one or two of its harmonics, and the band is therefore of subject to low frequency passive sonars.

(iii) Low sonic band (20 to 200 Hz)

This frequency band is characterized by the noise of distant shipping in areas and man made activities other than shipping. Away from areas of shipping the band depends on wind speed as in case of lower and higher frequencies. Below 20 Hz bands and above 200 Hz the noise is dependent on wind speed. In the band 20 to 200 Hz, the non-wind dependent noise, with peaks at 20 and 60 Hz, is attributed to a combination of biological sources, shore activities (60 Hz) and distant ocean ship traffic.

(iv) High sonic band (200 to 50 KHz)

The absence of shipping will be responsible for the dominance of the wind down to such a low frequency. The ship traffic near shore radiates into sound channel by propagation. If the noise level is indeed related to wind speed, as is certain to be the case at kilohertz frequencies, it allows to use a hydrophone as an anemometer for measurement of wind speed at remote underwater locations. This band includes noise due to wind and heavy rain.

(v) Ultrasonic Band (> 50 kHz)

At frequencies from 50 to 200 kHz, depending on wind speed, thermal noise begins to dominate this band. Thermal noise is the noise of molecular bombardment. The noise levels to increase with decreasing latitude.

Thus the noises prevailing under ocean are classified based on the frequency spectrum between various ranges. This classification enhances the study and research of under water acoustics.

3. NOISE AT SHALLOW WATERS

Noise process at shallow waters is highly variable due to

- High variability of ship traffic
- Wave guide nature of shallow water environment
- Reflection of noise from the bottom and surface
- Biological activities
- Sound speed in shallow waters vary substantially
- Hence noise field characterization is complex in shallow waters

But this has to be carried out because of its greater applications in Naval operations

4. CROSS CORRELATION FUNCTION

The cross-correlation function is related to the cross spectral density by a Fourier inversion integral. Since the cross-spectral density of a spatially homogeneous noise field is the coherence function multiplied by the power spectrum, $S_0(\omega)$, the cross-correlation function may be written in the form

$$\psi_{12}(\tau) = \frac{1}{2\pi} \int S_0(\omega) \Gamma_{12}(\omega) e^{i\omega\tau} d\omega \quad (1)$$

The cross-correlation is easily performed in the frequency domain, computed via the point wise multiplication of the two Fourier transforms, utilizing the convolution theorem,

$$S_{xy}(\omega) = FT\{x * y\} = FT\{x\} FT\{y\}^* \quad (2)$$

Where S_{xy} is the cross-spectrum, the asterisk denotes the convolution and the superscript asterisk denotes the complex conjugate. If X and Y are the same process, the cross-spectrum reduces to the power spectrum.

$$S_{xx}(\omega) = FT\{x * x\} = FT\{x\} \cdot FT\{y\}^* = |FT\{x\}|^2 \quad (3)$$

Coherence is a normalized cross spectrum, normalized by the magnitude of the two processes. This will prove to be particularly useful in noise analysis over a wide range of frequencies. The coherence can be calculated by,

$$\Gamma(\omega) \approx \frac{(FT\{x\} \cdot FT\{y\}^*)}{\sqrt{(FT\{x\} \cdot FT\{x\}^*)(FT\{y\} \cdot FT\{y\}^*)}} \quad (4)$$

The normalization by the amplitude of the two processes bounds the magnitude of coherence between +/- 1. The coherence between two completely related signals, or the same signal, will be one, while two completely unrelated variables will average out to zero.

5. COHERENCE

Coherence is defined as a measure of the phase and amplitude relationships between sets of acoustic waves. Coherence is the property by which two or more waves, fields are in phase with every other one. The coherence of waves is quantified by cross-correlation function [1]. The pressure sensors placed at various points will give same outputs if and only if the noise is perfectly coherent and vice-versa.

For the case of a single frequency uni-directional plane wave incident at an angle θ to the normal between two hydrophones spaced a distance d apart, the correlation coefficient is easily found to be $p_t = \cos \omega t$ where $\omega = 2\pi$ times the frequency and $t = \frac{d}{c} \sin \theta$, the travel time of a plane wave between the two hydrophones.

If this equation is integrated over θ and normalized, the result is, for isotropic noise at a single frequency, $p = \frac{\sin kd}{kd}$, where $k = \frac{2\pi}{\lambda}$. This function falls to zero, and noise becomes uncorrelated, at multiples of a half wavelength.

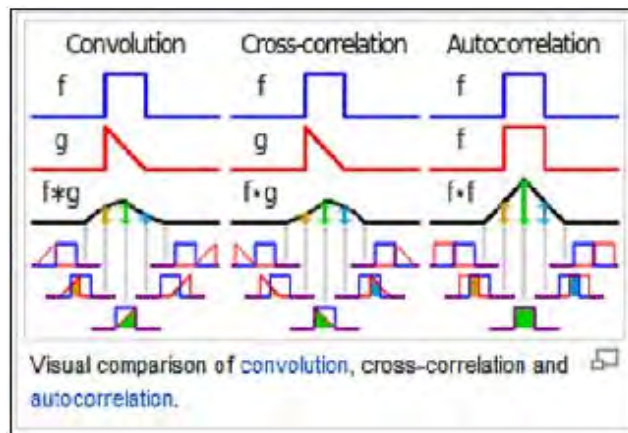


Fig1. Comparison of convolution, cross-correlation and autocorrelation [2]

6. RESULT AND DISCUSSION

Ambient noise originating at surface of sea decrease with depth due to attenuation but shipping noise is not severely affected since its frequency is low. High-frequency surface noise is rapidly attenuated and does not penetrate to great depths, and at moderate depths becomes so low in level that it is overcome by the noise of molecular bombardment and often by the electronic noise of a pre-amplifier [3].

Below the channel (i.e., below the critical depth, defined as the depth at which the velocity is the same as at the surface), the noise level should decrease rapidly with depth as the trapped modes of wave theory attenuate with increasing distance a deep hydrophone near the sea bed to be more quiet than one near the surface or at mid-depth. There is more noise in the surface duct (called the mixed layer by oceanographers), then at depths below the duct.

At frequencies where ship noise is dominant, there is a gradual quieting with depth amounting to a few decibels, down to the critical depth (if there is one in the profile), below which the quieting becomes more rapid.

The quietest depth is at or near the ocean floor[4].

Sea surface noise at higher frequencies tends to have no variation[5] with depth because this noise is of local origin, except for a greater amount of noise in the surface duct, if one is present. Surface noise is negligible at high kilohertz frequencies at moderate depths.

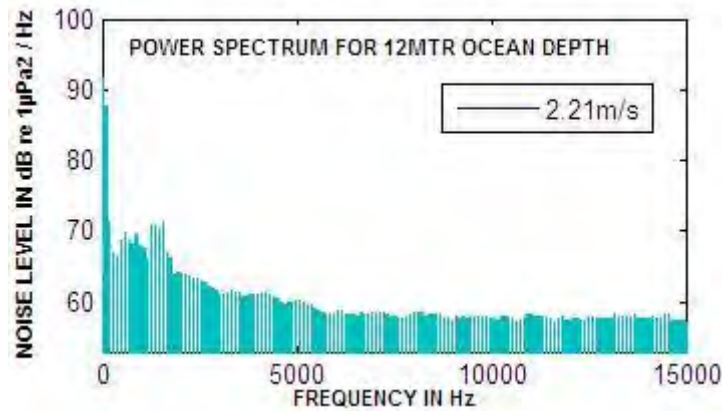


Fig2.Power spectrum for 12mt ocean depth

Because frequency and wavelength are inversely proportional characteristics of sound waves, low-frequency signals produce long sound wavelengths. These long-wavelength signals encounter fewer suspended particles as they pass through the medium and thus are not as subject to scattering, absorption, or reflection. As a result, low-frequency signals are able to travel farther without significant loss of signal strength. From the fig 2 & 3 the noise spectrum levels are increases with depth for low frequencies. At higher frequencies of signal like from 4000Hz to 5500Hz(fig2) and from 4000Hz to 5000Hz(fig3) decreases. After the range of frequencies the noise levels are almost stable.

Fig4 shows the real coherence of hydrophone pairs with various ocean depths. From the figure we can clearly observe that for 12mt ocean depth 14mt depth and 15mt depth there is drop in the coherence level and after that the coherence level is increases for increasing the ocean depth this may be due to the seabed. The fig5 shows the imaginary coherence of the hydrophone pair for various hydrophone depths. Here the coherence level will oscillates for entire level of frequency.

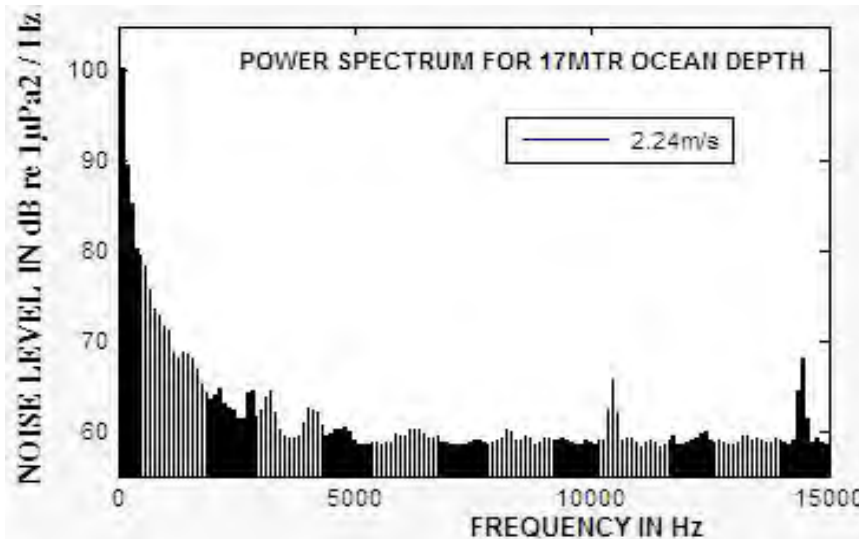


Fig3.Power spectrum for 17mt ocean depth

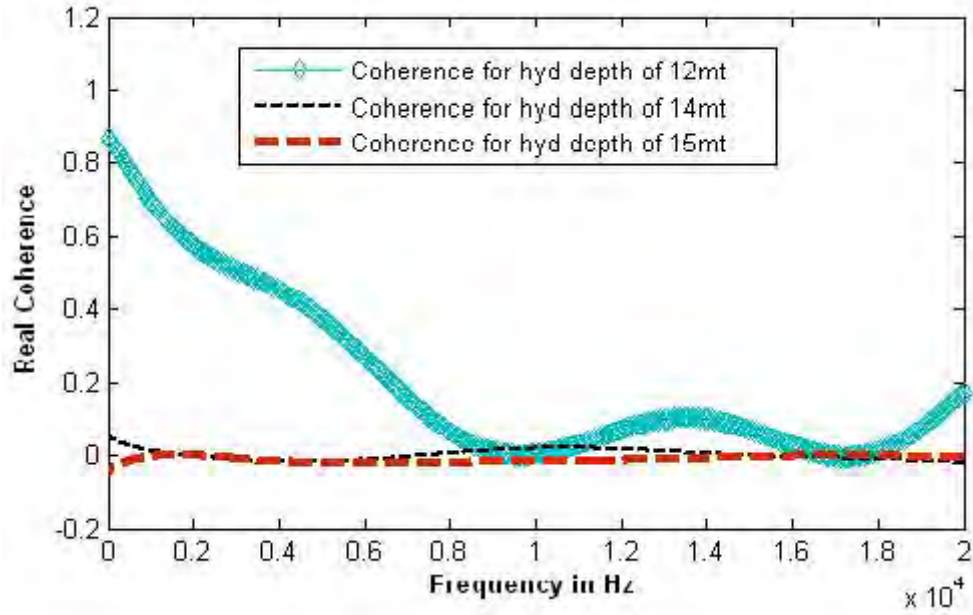


Fig4.Real coherence for various hydrophone depth.

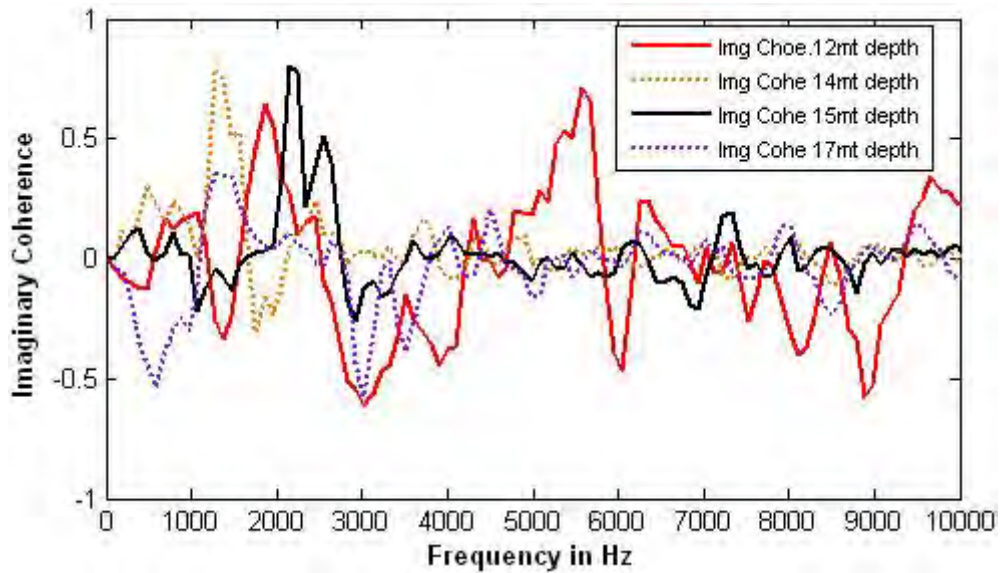


Fig4.Imaginary coherence for various hydrophone depth.

7. CONCLUSION

Underwater ambient noise is a very complex and critical one to predict for different sea state. The data collected by two elements of the vertical line array for a period of one week. The spectral shape of the noise at the high frequencies is found to be stable. Analyses of the data over the frequencies from 0 to 15000 Hz show that at low frequencies the noise level increases with increasing depth. Increasing of noise level with depth is moderate at the shallow water region. The Variation of noise is may be due to the background noises like mammal noise, wind noise and other noises. As per the theoretical aspects the noise level should be decreases with increasing depth. In this research consideration the data availability is only from 12mt to17mts, so it is very difficult to predict the noise level exactly. In the second stage of research the coherence level is properly various with increasing depth, with the increasing of depth the coherence level decreases. In this research for three different ocean depth the coherence level is analysed At low level frequency the coherence level is oscillates and at higher level frequencies the noise levels are in stable condition. Several aspects will be focused in future works. We will focus on two things mainly: 1) the computation and the analysis of the coherence function and power spectrum with very high sea depth for this particular Arabian sea region, and 2) how the coherence level various with salinity, temperature and the influence of seafloor roughness .

References:

- [1] Spatial coherence and cross correlation of three-dimensional ambient noise fields in the ocean Shane C. Walker and Michael J. Buckingham Marine Physical Laboratory, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0238
- [2] Referred from <http://en.wikipedia.org/wiki/Cross-correlation>
- [3] [3]-[5] R. J. URICK, Adjunct Professor, The Catholic University of America Washington, D.C. 20046 published by undersea warfare technology office naval sea systems, command department of the navy Washington, D.C
- [4] Figured referred from Ambient noise data buoy for time series measurements and Characterization of noise field S.Ramji, G.Latha, V.Rajendran and K.Premkumar National Institute of Ocean Technology, NIOT Campus, Pallikaranai, Chennai - 601 302, India
- [5] Equations (2)-(4) A Study of the Spectral and Directional Properties of Ambient Noise in Puget Sound David R. Dall'Osto