WIND DEPENDENCE AND SEASONAL VARIATION OF AMBIENT NOISE IN SHALLOW WATER OF ARABIAN SEA

Vijayabaskar V.[1], Rajendran V.[2]

[1]Research Scholar, Sathyabama University, Chennai.
[2]Professor, SSN College of Engineering, Chennai.

ABSTRACT

Ambient noise data were collected from shallow water of Arabian sea using two sensitive hydrophones suspended from the measuring platform at the depth of 5 m and 12 m where the ocean depth was 17 m. Datas were collected for the period of six months between the wind speed 0.5 m/s to 7 m/s. The collected datas were categorised according to seasons. The analyses were performed between the frequencies 500 Hz to 7 KHz for premonsoon and post monsoon seasons. The relative spectral energy distribution of sea noise is presented for a number of wind speeds. Linear relationship between the sea noise spectrum levels and the wind speed were found for the entire frequency range, but the slope were frequency dependent. The analysis was performed for premonsoon and post monsoon seasons. In this paper we also presented Empirical Mode Decomposition (EMD) based noise analysis, which will be useful for denoising.

Keyword: Ambient noise, shallow water, wind dependence, Empirical Mode Decomposition (EMD), noise analysis.

I. INTRODUCTION

A. Ambient Noise in shallow water

In under water ambient noise level varies with time at a fixed location. This time variability covers a wide scale, from very fast, such as the transients of breaking waves, to very slow, such as long term changes of ship traffic or long term changes in weather and climate. So the detection of background noise is essential to enhance the signal to noise ratio of acoustic based underwater instruments. Hence measurement and characterization of ambient noise forms a significant part in any underwater activity. Shallow water is noteworthy for its variability. Waters close to shore and in busy harbours are dynamic locations where many rapid noise changes take place. Although shallow water is notably characterised by variability as a result of a highly variable background of ship and biological activity, the level at high frequencies and high wind speeds, when wind noise is prevalent, is remarkable constant from site to site at the same wind speed (Urick). Since then interest in ambient noise characterization has grown and presently is of much interest to engineers working in the fields of active and passive sonar's, underwater sensors and signal processing.

B. Wind Generated Noise

In the absence of sound from ships and marine life, underwater ambient noise levels are dependent mainly on wind speeds at frequencies between 100 Hz and 25 KHz. The process by which the wind causes the ambient noise in the sea have been speculated by many theoreticians. Different processes are dominant in different portions of the overall frequency band from 1 to 50 Khz. In shallow water, in the absence of local shipping and biological noise, wind noise dominates the noise of distant shipping over the entire frequency. If the noise level is indeed related to wind speed, in the range of kilohertz frequencies, then it is possible to use a hydrophone as an anemometer for wind speed measurements at remote underwater locations (Urick). Ocean sound in the band of 500-20,000 Hz has been called wind noise or Knudsen noise, because Knudsen discovered that it correlated very well with wind speed (Knudsen et.al 1948). Dietz, Kahn and Birch reported that in all frequency bands, they observed that at low wind speeds the average noise level was independent of wind speed but that at high wind speeds the noise level was linearly correlated with the logarithm of the wind speed. The average curves of Wenz and Knudsen are in close agreement at frequencies above 500 cps. Below this frequency the results of Piggott are much closer agreement in spectrum shape with those of Wenz [4]. In the absence of sound from ships and marine life, underwater ambient noise levels are dependent mainly on wind speeds at frequencies between 100 Hz and 25 KHz. Since the classical work of V.O. Knudsen (1948), many researchers investigated the wind dependent noise in the ocean. Gordon M. Wenz (1962) in his work on spectra and sources of ambient noise in the ocean, observed that at frequencies below 500 Hz, the dependence of the underwater ambient noise levels on wind speed and sea state decreased as the frequency decreased at 100 Hz and below there is little or no dependence. C.L. Piggot (1964) took measurements on the Scotian shelf on sea noise data and analysed the spectral energy distribution for a number of wind speeds. He observed that noise is wind dependent in the high frequency band. A seasonal variation of noise level that was independent of frequency was also observed, the noise levels at the same wind speeds being higher during winter months. Anthony J. Perrone (1970) in his work on ambient noise spectrum levels as a function of water depth reported that the correlation coefficient of noise spectrum level with wind speed is observed to be independent of water depth for low wind speeds and minimum difference in the ambient noise levels of hydrophones at different depths. James H. Wilson (1979) studied very low frequency wind generated noise produced by pressure fluctuation in the atmosphere near the ocean surface. He also studied that wind noise versus the distant storm noise at a site located away from east west pacific shipping lanes. Peter C. Wille and Detlef Gayer (1984) made measurements in the North sea and Baltic sea and studied wind dependence. They concluded that the influence of propagation loss on the wind dependent shallow water noise appears to be only marginal even at extremely different areas. Thus the study on wind dependence of shallow water ambient noise necessitates the analysis of seasonal and site specific parameters. The objective of this paper is to study the dependency of shallow water ambient noise level with wind speed and to derive a wind model based on the observed value.

II. CONVENTIONAL NOISE ANALYSIS METHOD

A. Data collection

The ambient noise data were measured periodically, over different times in a month for a period of one year.The datas were segregated in to four seasons as premonsoon, postmonsoon, summer and winter. Noise measurements were made using two calibrated omni directional hydrophones mounted in a vertical array at different ocean depths. The hydrophones were suspended from the measurement platform using the rope and mounting arrangement that links to the rope. The hydrophones have a receiving sensitivity of – 170 dB over a frequency range between 0.1 Hz and 120 kHz. The data were acquired at a rate of 500 KHz and 200 KHz, filtered and digitized with portable data acquisition system with 12-bit resolution. During the period of data collection all machinery on the boat/ship were switched off and the recording system was powered by battery. The wind speed was simultaneously measured during each sampling. The measurement consists of 78 sets of data during premonsoon, 150 sets of data during postmonsoon, 69 sets of data during summer and 85 data sets during winter season. The wind speeds of collected data ranging from 0.5 m/s to 7 m/s. Measurements showing the evidence of noise from non-wind dependent sources such as rain, dolphin and ship were not included in the analysis.

B. Algorithm

Theoretically the relationship between the noise levels is assumed to be linear to the logarithm of the wind speed and this can be expressed as

$$NL = B + 20\, n \log (U) \quad (1)$$

where NL and U stand for noise level and wind speed, respectively. The constants 'B' and 'n' were determined by fitting the experimental data to the model at different frequencies. The slope (1/20) of the regression line gives 'n' and the ordinate intercept of the line gives 'B' for each empirical fit. The spectral analysis was carried out in matlab using Welch method of averaging periodogram [9]. First the noise level in dB was plotted against frequency for different wind speed. Then the noise level in dB was plotted against wind speed for different frequency according to the seasons. The frequency range of interest for the current study was from 500 Hz to 7 kHz where the best correlation between the wind speed and the noise level has been observed.

III. EMD BASED NOISE ANALYSIS

Empirical Mode Decomposition (EMD) is suitable method for analysing non stationary signals. Since it is adaptive in nature, it

Performs well with non stationary signal than wavelet.please refer [11] to know more about EMD.It decomposes the signal $x(t)$, into set of Instrinsic Mode Functions (IMFs) c_j, i.e.,

$$x(t) = \sum_{j=1}^{n} c_j + \gamma_n \qquad (1)$$

Where r_n is the residue of data $x(t)$, after n number of IMFs is extracted. IMFs are simple oscillatory functions with varying amplitude and frequency. EMD was applied to the noise signal, which decomposes it into set of IMFs. Then the power spectrum was calculated for each IMFs using pwelch method. By studying the spectrum of IMFs, it is possible to develop an algorithm for removing ambient noise from sonar signal.

IV. RESULTS AND DISCUSSION

The ambient noise data collected over the frequency range of 500 Hz to 12 KHz was divided in to low frequency band (500 Hz to 7 KHz) and high frequency band (7 KHz to 12 KHz). Analysis has been carried out for four different season over these two different frequency bands. Variation in Noise spectrum level over two different frequency bands at different wind speeds during four seasons is shown in Fig. 1 and Fig. 8. The figures clearly shows that there is better correlation between the NSL and wind speed in the low frequency band compared to the high frequency band for all the four seasons. It is seen that the noise level increases with wind speeds in the low frequency band for all the seasons. The amplitudes are higher than that of Knudsen curves because shallow water ambient noise are more pronounced by surface winds where as the Knudsen curves were derived for deep water.

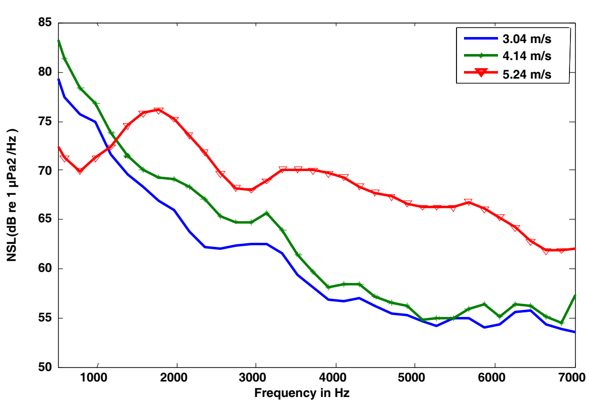

Fig. 1. Noise spectrum at different wind speeds during premonsoon

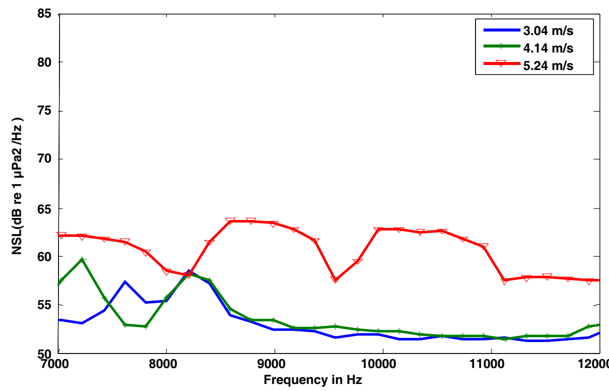

Fig. 2. Noise spectrum at different wind speeds during premonsoon

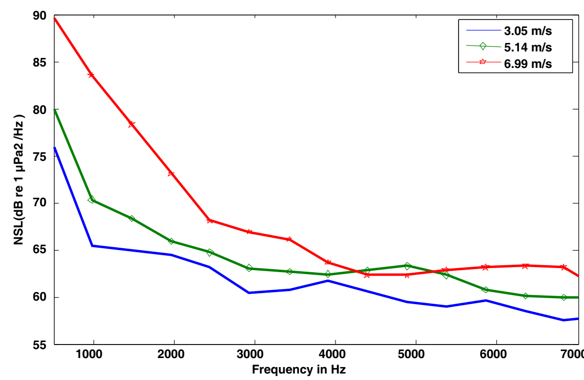

Fig. 3. Noise spectrum at different wind speeds during postmonsoon

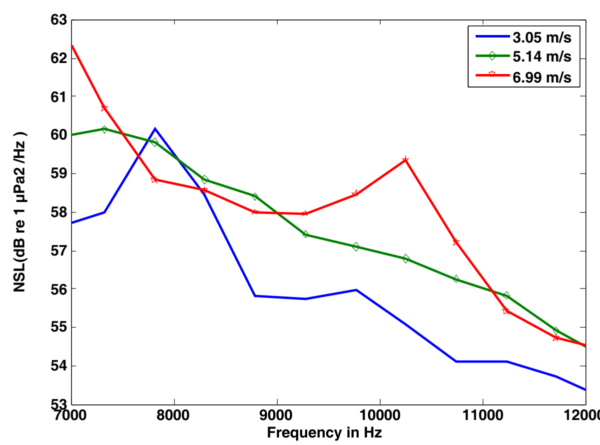

Fig. 4. Noise spectrum at different wind speeds during postmonsoon

The regression plot at 4 KHz frequency during postmonsoon and premonson is presented in Fig. 9 and Fig. 10. The slope of the regression line is more during premonsoon compared to postmonsoon. The regression line for various frequencies during premonsoon and postmonsoon seasons are shown in Fig. 11 and Fig. 12. The figure clearly shows that in both seasons the slope decreases as the frequency increases. But in premonsoon the slope is positive for all frequencies and slope is negative during postmonsoon. This is due to the depths variation. From the graph it is clear that the correlation is good upto 7 KHz during premonsoon and postmonsoon, during summer it is up to 5.8 KHz and it is up to 5.2 KHz during winter.

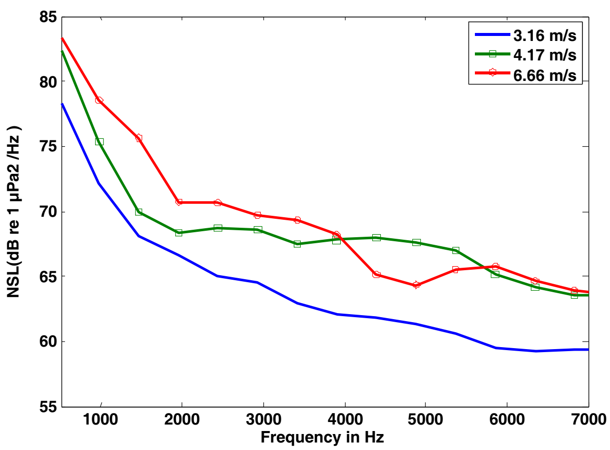

Fig. 5. Noise spectrum at different wind speeds during summer

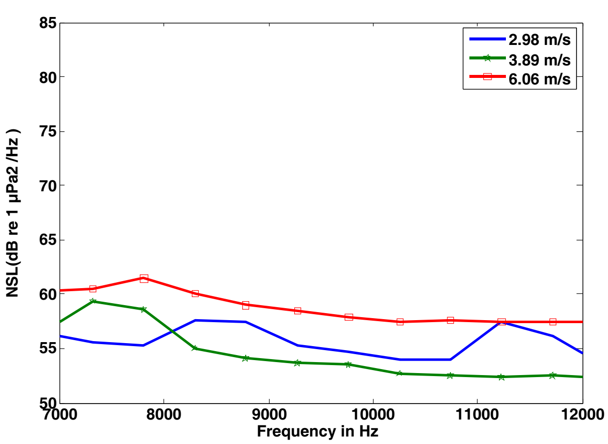

Fig. 6. Noise spectrum at different wind speeds during summer

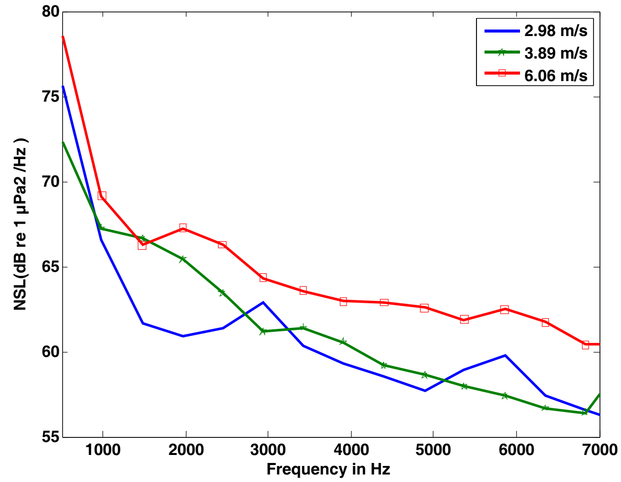

Fig. 7. Noise spectrum at different wind speeds during winter

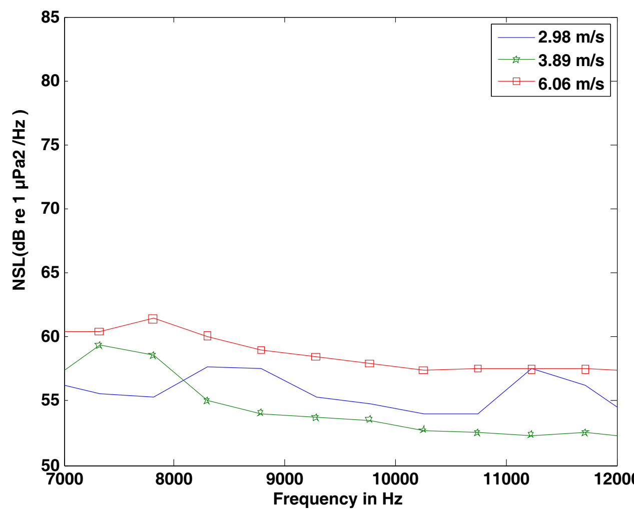

Fig. 8. Noise spectrum at different wind speeds during winter

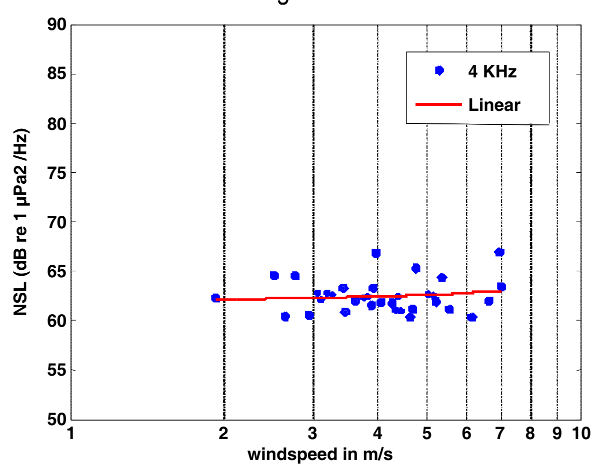

Fig. 9. Noise spectrum level Vs wind speed at 4 Khz during postmonsoon

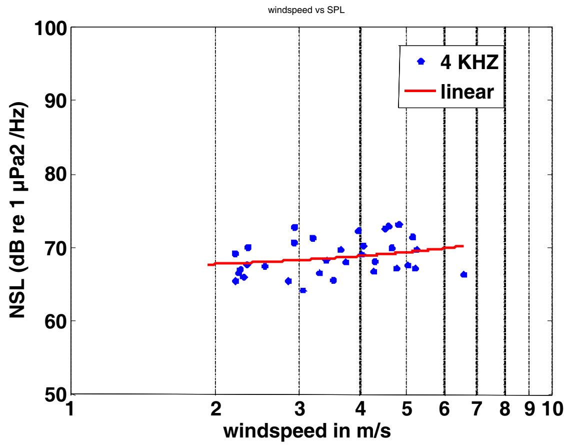

Fig. 10. Noise spectrum level Vs wind speed at 4 Khz during premonsoon

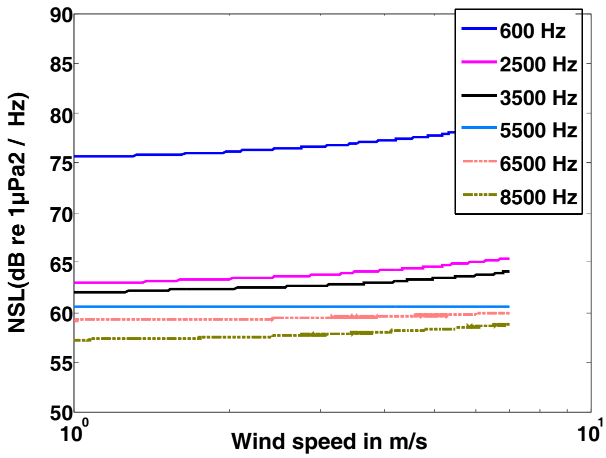

Fig. 11. Noise level at different frequencies during premonsoon

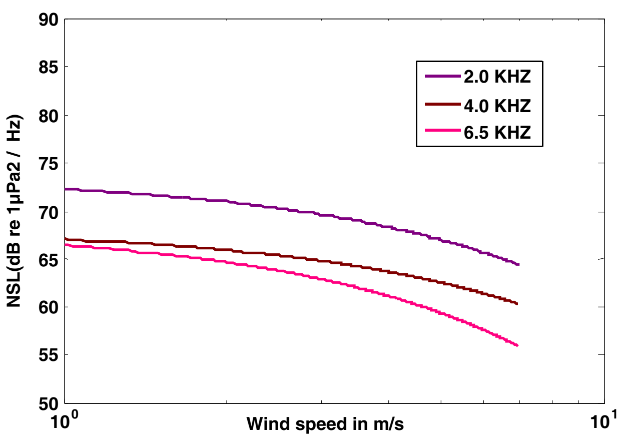

Fig. 12. Noise level at different frequencies during postmonsoon

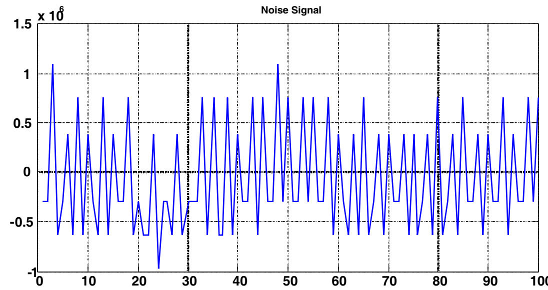

Fig. 13 Noise signal at 5.06 m/s wind speed

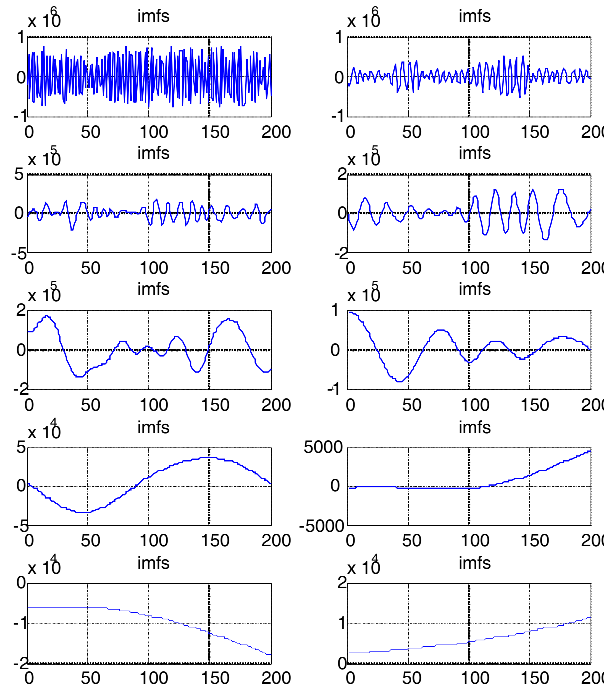

Fig. 14. IMFs of noise signal

For EMD based noise analysis approach, we have considered a noise signal, which was collected at the wind speed of 5.06 m/s as shown in Fig. 13. EMD was applied to this signal, which produced a set of IMFs as shown in Fig. 14. Then power spectrum was applied to each IMF using pwelch method, which is shown in Fig. 15. From the spectrum, we can find the power of noise signal in each IMF. Since we know the power of sonar signal, this analysis can be useful for denoising.

IV. CONCLUSION AND SCOPE

In this work the wind dependency of shallow water ambient noise in Arabian sea for four different seasons are reported. The analysis shows that noise level increases as wind speed increases. There was

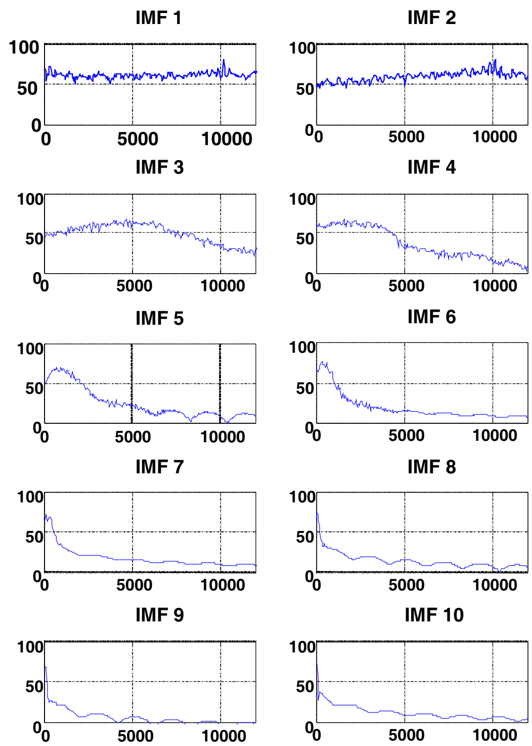

Fig. 15. Spectrum of noise IMFs

good correlation between wind speed and noise level in the frequency range between 500 Hz to 7000 Hz.

The result shows that noise level and noise variations are more in postmonsoon and summer seasons compared to premonsoon and winter seasons. Using the results of conventional noise analysis method, we can obtain a wind model, which can predict the noise level for the given wind speed. This study also helpful to improve the performance of underwater acoustic instruments. The EMD based noise analysis can be useful to develop a suitable noise removal algorithm.

ACKNOWLEDGMENT

The data collection for the above analysis is done in collaboration with National Institute of Ocean Technology, Chennai. The authors wish to acknowledge the valuable support given by NIOT, Chennai.

REFERENCES

[1] Urick R.J. Ambient noise in the sea. Peninsula Publishing; 1984.

[2] Cato D.H. Ambient sea noise in waters near Australia. J Acoust Soc Am 1976; 60 (2): 320-8.

[3] Ramji S., latha G., Rajendran V. and Ramakrishnan S. Wind dependence of ambient noise in shallow water of bay of Bengal Applied acoustics (2007).

[4] Knudsen V.O., Alford R.S., Emling J.W. Underwater ambient noise. J Mar Res 1948; 7: 410-29.

[5] Piggott C.L. Ambient sea noise at low frequencies in shallow water of the Scotian shelf. J Acoust Soc Am 1964; 36 (11): 2152-63.

[6] Wenz G.M. Acoustic ambient noise in the ocean: spectra and sources. J Acoust Soc Am 1962; 34 (12): 1936-56.

[7] Perrone A.J. Ambient noise spectrum as a function of water depth. J Acoust Soc Am 1970; 48 (1): 362-70.

[8] Walkinshaw H.M. Measurements of Ambient noise spectra in South Norwegian Sea. IEEE J Ocean Eng 2005; 30 (2): 262-6.

[9] Hazen M.G., Desharnais F. The Eastern Canada shallow water ambient noise experiment. Proc. IEEE Oceans 1997; 1: 471-6.

[10] Chapman N.R., Cornish J.W. Wind dependence of deep ocean ambient noise at low frequencies. J Acoust Soc Am 1993; 93 (2): 782-9.

[11] Norden E Huang AND Samuel S P Shen "Hilbert-Huang Transform and Its Applications", (Interdisciplinary mathematical sciences ; v. 5) ,World Scientific Publishing Co. Pte. Ltd.