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Analysis of Variation of Ambient Noise with Wind Speed and Tide Height in Shallow Water of Arabian Sea

Engineering

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ABSTRACT

This work presents a shallow water ambient noise analysis effort in the Arabian Sea. Real ambient noise recording at very shallow depths has been analyzed for two environmentally unique periods when the sound velocity profile and the wind conditions present distinct characteristics. Propagation characteristics of distant shipping noise and its impact on the ambient noise have been discussed in contrast to wind related noise for shallow water along with directionality aspects.

I. Introduction

With the end of the cold war, the threat of global conflict subsided, giving way to more local and regional conflicts. This fundamental shift from a navy designed to engage an opposing blue-water battle fleet to one focused on forward operations in the littoral waters resulted in requirement of effective underwater systems in shallow waters.. The growing threat from international terror groups & increased commercial activities related to underwater exploration for higher utilization of the undersea resources primarily in the shallow depth further reiterates the requirement of better performance of underwater systems in shallow waters.

Generalization of ambient noise characteristics is possible in deep waters as distant shipping noise typically dominates the deep water noise levels (Wenz, 1962). The shallow water ambient noise characteristics are very unique to the site due to differences in the local propagation characteristics and sea floor absorption characteristics. Ambient sea noise in deep and shallow water has been compared by Arase and Arase (1967) and, ambient noise spectrum levels as a function of water depth has been reported by Perrone (1970).

Shallow water ambient noise characteristics are dominated by the wind noise, biological noise and local shipping noise (McDonald & Hildebrand, 2008). Survey conducted by Wenz (1962) concluded that the most probable origins of noise in the frequency band 1 Hz to 20 kHz in the ocean are wind generated surface effects and ship traffic. Limited attempts at shallow water ambient noise analysis in the Indian sub-continents are reported (Vijayabaskar & Rajendran, 2010), however detailed correlation with all the surface parameters impacting the ambient noise sources and the propagation characteristics of shallow water channel is not yet reported in the open literature.

II. Ambient Noise Sources

The ambient noise spectra can be divided into three frequency bands for the purpose of understanding the source and characteristics – low (10 to 500 Hz), medium (500 Hz to 25 kHz) and high (>25 kHz) (Jensen & Kuperman, 1994).

Thermal agitation of molecules in sea water creates noise that limits acoustic detection sensitivity at high frequency (> 50 kHz). For omni-directional hydrophones and typical ocean temperatures, the background level due to thermal noise is given by:

$$NL = -15 + 20\log(f) \qquad (1)$$

where f is given in kHz with f>>1 and NL (NL in dbref1μPa) is the noise level in a 1 Hz band. It may be noted that the thermal noise increases at the rate of 20 dB decade^{-1}.

III. Measurement Area and Recording Instrumentation

The ambient noise in the coastal waters of Arabian sea was recorded off the Goa coast close to a busy port at less than 20 Nm. The shipping traffic in the port typically consists of large cargo vessels that are anchored away from the port and smaller (length 70 m, width 13.5 m and height from keel to deck 4.25 m) self propelled (twin diesel engine of 280 HP) barges carrying iron ore from the port to the cargo ships at anchorage. The recording period was such that the influence of shipping traffic would be similar, however, the surface parameters varied significantly in the two months considered for study. In the first month i.e., Jan 2010, has low sea state (< sea state 2) resulting in calm surface agitation due to lower wind speeds (< 4 m/s). The second month i.e., Mar 2010, has higher sea surface temperature resulting in rough sea conditions (> sea state 2) and higher wind speeds (> 4 m/s). The recordings were undertaken in extremely shallow waters at a depth of 30 m, with flat bottom for a major region around the recording sensors.

The recording sensors comprised of five underwater sensors at the sea bottom located at horizontal separation of 100 m apart. The data from each of the five sensors has been averaged and presented for analysis. The sensor specifications are presented in table 1. The data is acquired at 256 kHz, filtered and digitized as per the specifications presented in Table 1. Hanning window is used with a data update rate of 5 Hz for the broadband spectrum at frequency resolution of 2 Hz. A 2048 point FFT has been used for computation of the spectrum.

TABLE. 1. SENSOR SPECIFICATIONS

Specification	Description
Hydrophone Type	ITC 8264
Sensitivity	-175 dB re 1 μPa
Bandwidth	10 Hz – 100 KHz
Beam pattern	Horizontal Omni-Directional, +/-2 dB Vertical Omni-Directional, +/-2 dB for upper hemisphere
Self Noise	Less than the greater of Knudsen sea state or thermal noise
Gain	6 dB to 6 dB + 90 dB in remotely controlled steps of 6 dB
Anti-Aliase Pass band	Dc to 100 KHz
Sample rate	262144ks/sec, +/- 2 Hz

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Resolution	16 bits
Linearity	ADC only
S/N + distortion	ADC only

The data recording has been undertaken eight times in a day on specific days in the two months of Jan 2010 and Mar 2010. The data recordings has been undertaken periodically at an interval of one hour starting from 0930 hrs to 17:30 hrs (GMT + 5:30 h) for duration of 2 min. The environmental parameters have been collected at a close proximity from the recording sensor location, simultaneously for the period of data recordings.

IV. Results and Analysis

The shallow water region where the data has been recorded limits, the propagation of high frequency, thus the analysis has been restricted to the lower frequency band. The analysis has been undertaken for varying Tide heights and wind speeds. The two parameters considered for analysis are equally strong in influencing the ambient noise characteristics. Both these parameters have been observed to be varying simultaneously during the period of recording.

In Fig. 1, the ambient noise variation with wind speed has been presented. The ambient noise level variation is observed to be random with increase in wind speed. The random fluctuations in the ambient noise levels are attributable to the shallow water condition in the recording area. The severe multi-path phenomenon, coupled with the time-varying channel characteristics due to tide, temperature, etc results in arbitrary fluctuations of the medium properties causing random ambient noise variations. It may be understood that the wind speed variations cause change in the ambient noise source, whereas the simultaneous fluctuations in the tide, temperature, etc results in alterations in the medium properties. It may be understood that the ambient noise recorded encompasses, both the source and medium variations.

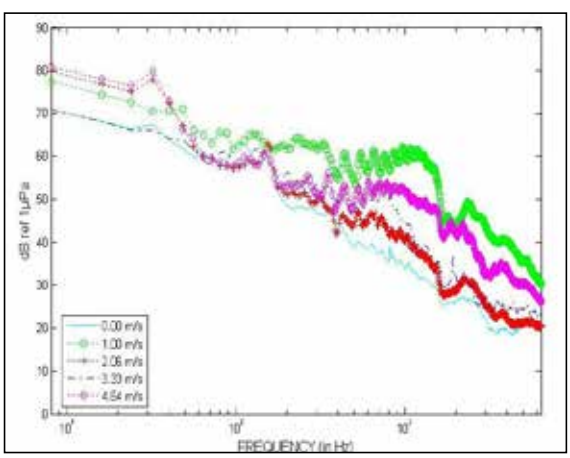

Fig. 1 Ambient Noise Plot for varying Wind Speeds

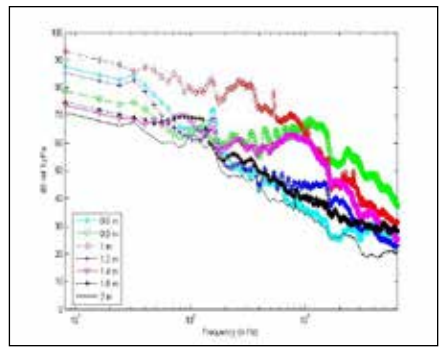

Fig. 2 Ambient Noise Plot for varying Tide heights

In Fig. 2, the ambient noise variation with tide height has been presented. Here again we observe the change in ambient noise levels with increasing tide heights is random. The random fluctuations in the ambient noise level with tide height variation are also attributable to the shallow water characteristics and simultaneous variation of source and medium parameters. The source components of the ambient noise are also known to be varying during the period of recording, in addition to the medium characteristics, thus to attempt an one to one correspondence of the ambient noise levels to the source or medium parameters may not be appropriate.

The tropical waters of the recording region further add to the random fluctuations. The diurnal variation of the environmental parameters of the tropical waters has a very profound impact on the ambient noise characteristics. Since the recordings have been done over the entire day and over different days with varying climatic conditions the randomness in the ambient noise levels is unavoidable. The precise attribution of the ambient noise level to specific tide height variation will require very detailed experimental planning over a long duration. The shallow water characteristics further add to the complexity, thus advanced signal processing algorithms will have to be designed to decouple the medium characteristics from the source for more precise analysis effort.

V. CONCLUSION

The ambient noise variation with wind speed and Tide heights has been analyzed and it has been observed that the ambient noise levels randomly fluctuate with increase in wind speed and Tide heights. This is attributable to the simultaneous fluctuation in the medium and the source parameters. The tropical waters in the recording region contribute to a large and frequent variation in the medium characteristics influencing the ambient noise level during the recording duration. The shallow water in the recording region, further adds to the random fluctuations in the propagation characteristic due to multi-path and time varying channel fluctuations. The shallow water fluctuations result in distortion in the amplitude, phase and the spectral characteristics of the received signal.

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