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Low Frequency Broad Band Acoustic Propagation in Andaman Sea

Nimmi R. Nair*, R. Suganthbalaji, Elizabeth Shani N.X., and P.V. Nair

DRDO-Naval Physical and Oceanographic Laboratory, Kochi - 682 021, India

*E-mail: nimmirnair@npol.drdo.in

ABSTRACT

During November 2017, an active source seismic survey was performed in Andaman Sea to study the acoustic propagation characteristics. High power low frequency acoustic signals generated by 20-air gun array onboard Research Vessel Samudra Ratnakar were recorded from *INS Sagardhwani* at four different depths within 8 km ranges in shallow and deep waters. The received level was estimated using root mean square and power spectral values. Amplitude levels were analysed with respect to arrival time variation with frequency and is presented.

Keywords: Low frequency underwater propagation; Cut off frequency; Indian Ocean

1. INTRODUCTION

Low frequency band less than 250 Hz is the band of Anti-submarine Warfare (ASW) interest for platform detection. The constraint in conducting broadband low frequency experiment is the size of transducer. An alternate is air gun as a low frequency broadband source[1]. The air gun shot sound data acquired during one of the gas hydrate surveys conducted onboard Research Vessel Samudra Ratnakar (RV-SR) of Geological Survey of India is utilised for this present study. Similar studies have been conducted in other oceans, but this experiment is the first of its kind in northern Indian Ocean.

2. LOCATION AND EXPERIMENTAL CONFIGURATION

This experiment was carried out near Andaman Sea, covering both deep and shallow water configuration. During this mission air gun signals were recorded onboard *INS Sagardhwani* (INSS) during 11-12 Nov 2017.

3. DATA AND METHODOLOGY

During this experiment, twenty air guns towed at a depth of 7 m and 70 m behind RV-SR. This configuration is expected to generate a source level of 235dBrms re 1 µPa. Air gun shots were fired with a repetition period of 9s .

Air gun signals were recorded from INSS by lowering 4 hydrophones at different depths. Depth sensors were attached to hydrophone for observing accurate depths. CTD profiles were taken at periodic intervals for analysing sound speed variation with depth. A total of about 700 airgun shots were recorded at 51.2 k sample rate using National instruments C-Rio Recorder. Further analysis on recorded data was carried out using Matlab and Labview. This transmission loss experiment is planned in order to quantify the range dependent signal characteristics in low frequency band.

Day1 experiment was in shallow waters where RV-SR was moving from 260 m depth location to 310 m depth location whereas INSS occupied position at a location where depth is around ~300 m. On day2, ORV-SR survey track was from 1500 m to 1700 m deep and INSS occupied a location at a depth of 2000 m. This experiment configuration is considered as deep water as compared to day1. Range variation during these experiments is of the order of 5 km to 9 km for day1 and 6.8 km to 8 km for day2.

4. ACOUSTIC SIGNAL PROCESSING METHODOLOGY

The recorded signals were analysed and necessary corrections were made as per gain and sensitivity.

4.1 Root Mean Square Level

The standard measure of signal estimation of any broadband signal is root-mean-square pressure (RMS)[1-2] which is[2,3]

$$Root\ Mean\ square = 20\log_{10}\left(\left(\frac{1}{n}\sum_{i=1}^{n}(s_i-\overline{s})^2\right)^{\frac{1}{2}}\right)[dB\ \ re\ \ 1\mu Pa] \quad (1)$$

where s represents the pressure time series of the signal used to analyse gross energy variation.

4.2 Cut-off Frequency

The sound source, air gun was towed below the ocean surface, which is well within the mixed layer. This surface duct acts as waveguide for long range propagation with a lower cut off frequency (f_c). Theoretically, only the frequencies above this cut off frequency will be trapped in the duct.

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In this paper empirical relation[4] used to estimate f_c is

$$f_c = \left(\frac{2700}{H(\Delta C)^{\frac{1}{3}}} \right)^{\frac{3}{2}} \quad (2)$$

where $\Delta C = C_H - C_0$

C_H = Sound speed at sonic layer depth

H = Depth in feet

C_0 = Sound speed at surface

5. RESULTS AND DISCUSSION

Received acoustic signals are processed to understand the low frequency propagation characteristics. Both time domain and frequency domain analysis has been carried out on this channel data.

5.1 Geo Acoustic Environment and Sound Propagating Waveguide

Estimated sound speed profile using CTD measured temperature and salinity (onboard *INS Sagardhwani*) is plotted in Figs. 1(a) and 1(b) for day1 and day2, respectively. The bathymetry of trial location from ETOPO is included in Fig. 1(c). Variation of range between source and receiver with time is as given in Fig. 1(d).

5.2 Root Mean Square Analysis

Estimated RMS values with range for shallow and deep waters for different depths of the hydrophone are as shown in Fig. 2. At first sight there is not much variation with range for both shallow and deep waters. However, it can be seen that for a depth increase of 10 m, a decrease of about 8 dB - 10 dB in RMS is noticed. And only 5 dB - 7 dB difference is seen for the same hydrophone for this range variation. A similar decreasing trend of RMS level with range is noticed in all hydrophones. A comparable RMS level for 2nd and 4th depth is also seen in Fig. 2.

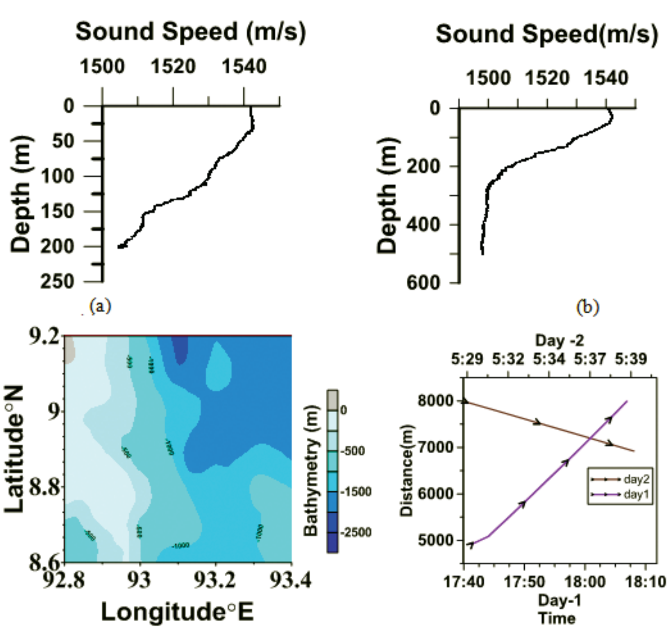

Figure 1. Sound Speed for (a) Day1 (b) Day2 (c) Bathymetry from etopo and cruise track (d) Time *vs* Range.

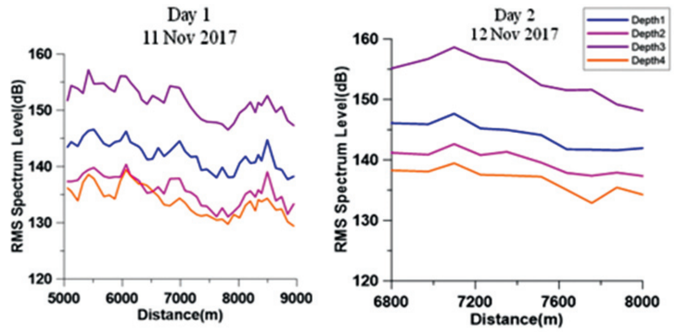

Figure 2. Range vs received rms.

5.3 Surface Duct Cut-off Frequency

Cut off frequency for the surface duct is estimated using equation 2 from measured CTD profile and is as presented in Table 1. For both days, estimated cut off frequencies are higher than 200 Hz.

Table 1. Surface duct cut off frequency

Experiment	Duct thickness (m)	Cut off frequency (Hz)
Day1	42.2	210
Day2	30.8	550

5.4 Frequency Components with Range

Spectral analysis of the received acoustic signals are carried out to understand the sound propagation of different frequency components in the sound source and presented in Fig. 3 for selected ranges. Here top panel plots correspond to the day1 recordings while the bottom panel corresponds to that of the day2. As per air gun array survey configuration, higher source levels are expected in the frequency range 50-150Hz and it can be seen in day2 of Fig. 3. The spectrum has almost constant slope for day1 compared to day2. The hydrophones were placed within the duct and hence the propagation follows ducted channel criteria. Thus only the frequencies higher than cut off can travel long distance in this upper waters. As the cut off frequency of day1 was less compared to day2 more energy could be trapped in the duct during day1. To find the long distance propagating frequency for this waveguide, a plot of range vs frequency was made and is as presented in Fig. 4. Here left panel plot corresponds to day1 recordings while the right panel corresponds to that of day2. In the case of day1 where the depth is shallow, 50 Hz - 80 Hz band signals are received at longer ranges and in day2 such continuous reception is not observed.

In this particular configuration of airgun, higher source level was maintained only in 50-150 Hz bandwidth. Other higher frequency components near 1kHz (Fig. 3) are received, with a variation maximum of 20dB.

5.5 Time Frequency Analysis

Spectrogram for selected shots is as presented in Fig. 5. Here top panel represents received acoustic signal of a particular

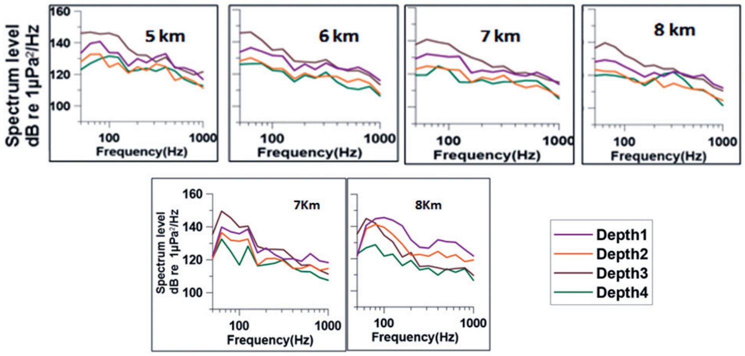

Figure 3. Spectral analysis results at typical depth, top panel for day1 and bottom panel for day2.

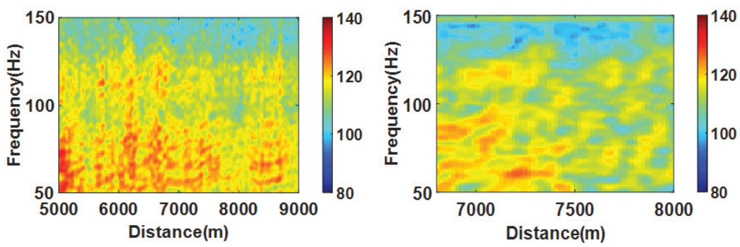

Figure 4. Range *vs* frequency plot of signal received level.

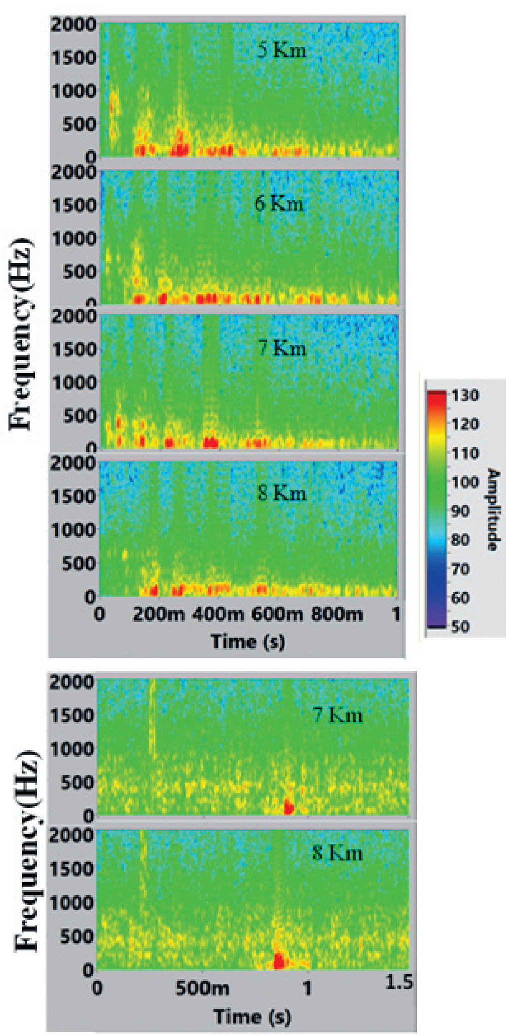

Figure 5. Spectrogram of airgun shots left panel for day-1 and right panel for day-2.

shot on day-1 and bottom panel represents that of day-2. Total variation in arrival time is confined in the range of 0.15 s to 0.6 s considering the reception on both days. High pass filtering nature of the channel can be seen from the first arrival. For day1, first arrivals can be seen for frequencies above 300 Hz and for day2 it is above 1000 Hz. It was observed that the f_c estimated from Spectrogram was higher than the f_c computed earlier using empirical relations. Low frequency components of the previous shots are received continuously.

5.6 Signal Arrival structure

To compare the arrival pattern of different shots for day2, received signals were synced based on first arrival and stacked in time/distance format in Fig. 6. In the current experimental configuration, it was observed that first three arrivals not vary with distance then subsequent delayed arrivals that arrival time vary with distance are received.

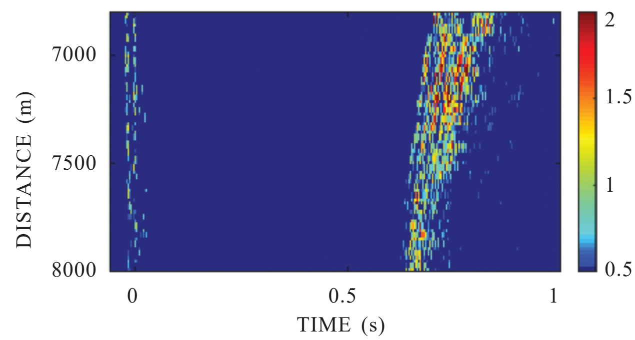

Figure 6. Acoustic intensity as arrival time-distance plot for day2.

6. CONCLUSIONS

Preliminary results of low frequency acoustic propagation characterisation off Andaman are presented. Direct arrival of higher frequency components higher than 300 Hz for day-1 and 1000 Hz for day-2 is noticed from spectrogram analysis. Continuous arrival of low frequency components in shallow waters and late arrivals (bottom reflected) are observed in deep waters. From spectral analysis minimum propagation loss of 80 dB - 100 dB observed for frequency of 50 Hz - 150 Hz in 5 km - 9 km range. Characterisation of these losses, as a function of frequency would provide resolution at which propagation models need to incorporate bathymetry for the desired accuracy.

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CONTRIBUTORS

Dr Nimmi R. Nair obtained her Masters and PhD from Cochin University of Science and Technology, Kochi. She has acquired AMIE in Electronics and communication. Presently she is working as Scientist 'F' with Ocean Acoustic Division of DRDO-Naval Physical and Oceanographic Laboratory, Kochi.
In the current study, she was instrumental for planning and execution this joint experiment guided for signal processing.

Mr R. Suganthbalaji obtained his Masters in Instrumentation engineering from Madras Institute of Technology, Chennai, Tamilnadu. Presently working as Senior research fellow in DRDO-Naval Physical and Oceanographic Laboratory, Kochi. His research areas include: Underwater Instrumentation, communication and acoustic modelling.
In the current study, he has carried out the data collection and analysis.

Ms Elizabeth Shani N.X. obtained her MTech (Ocean Technology) from Cochin University Science and Technology (CUSAT), Kochi and currently pursuing PhD in CUSAT. Presently working as Senior Research Fellow in DRDO-Naval Physical and Oceanographic Laboratory, Kochi. Her research areas include analysis of ambient noise and the governing oceanographic parameters for its variability, marine traffic ambient noise model.
In the current study, she has carried out the data analysis. In the current study, she has carried out the data analysis.

Mr P.V. Nair is working as Scientist 'G' in DRDO-Naval Physical and Oceanographic Laboratory, Kochi. He experience in underwater acoustic experiments and specialised in marine instrumentation.
In the current study he has guided in the analysis of data and execution of experiment.