Towards Passive Ocean Acoustic Tomography Using Shipping Noise

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Abstract

This work addresses the usage of ship radiated noise to estimate the ocean acoustic water propagation channel response between two vertical line arrays. We derive an expression for the frequency response channel estimate using a normal mode development based on cross-correlation methods, in a similar way as Roux et al. [1]. Its applicability and limitations in simulated and real conditions is discussed. Simulations are conducted using the normal mode model KRAKEN, based on the experimental setup and environmental parameters gathered during the RADAR'07 sea trial, off the west coast of Portugal, in July of 2007. In this sea trial two drifting vertical line arrays with 16 and 8 hydrophones were deployed in a range independent bathymetric area, at 300 m and 1.3 km distance from the Research Vessel NRP D. Carlos I, whose track then moved away from the arrays, radiating noise in the frequency band bellow 750 Hz. Automatic Information System (AIS) recordings for this period reveal a major tanker maneuvering in the same area, who's influence is analyzed, as well as Setubal's Canyon influence propagation channel. The wave fronts structure, obtained from actual acoustic data of the above referred sea trial, reveals agreement with the simulations obtained with the proposed approach. These results suggest the feasibility of the method for future application in a passive ocean acoustics tomography framework to the estimation of sound speed perturbations in the water column.

Motivation

Is:

- **The main source of anthropogenic noise in the ocean**
- **Characterized by low frequency discrete tones and diffuse broadband signals**
- **Travels over long distances**
- **Water column structure information carrier**

Shipping noise

Enables:

- **Development of passive methods, therefore environmental friendly methods**
- **Long time characterization of the ocean**
- **Low cost systems implementation**

Setúbal's canyon influence

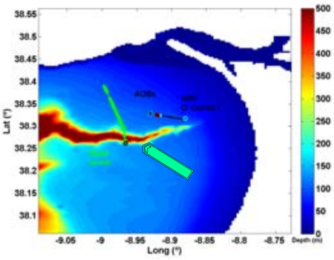


Fig. 1 (a): Estimated trajectories of ships passing in the area from 10h50m to 11h50m of July, 13th.

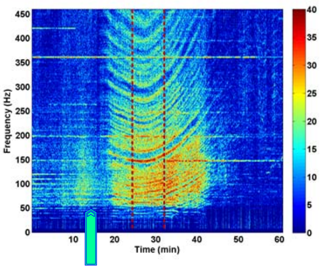


Fig. 1 (b): Recorded radiated noise from 10h50m to 11h50m of July, 13th.

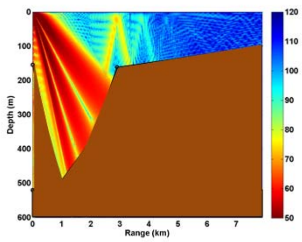
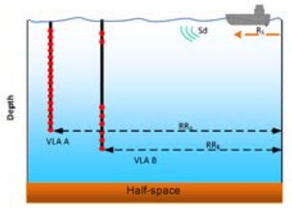


Fig. 1 (c): 2D Modeled propagating channel between the tanker and a receiver in one of the VLA's.

The bathymetric effect of the Setúbal canyon has a strong influence in the propagation acoustic channel, i. e. the sound is strongly attenuated when traversing this region.

Frequency Response Estimation and Data Processing



Baseline environmental model based on RADAR07 sea trial

In a monochromatic regime and using the far-field normal mode approximation, the received signal at location in VLA A can be written as:

$$\mathbf{Y_A} = \alpha \mathbf{U_A} \mathbf{K_{sa}} \mathbf{x_s} + \mathbf{w_a}$$

where $\mathbf{U_A}$ is the modes function matrix sampled at VLA A depths, $\mathbf{K_{sa}}$ is a diagonal matrix carrying information on the horizontal wave numbers and range, $\mathbf{x_s}$ represents the mode functions at source depth, α is a random factor regarding the source strength and $\mathbf{w_a}$ is additive noise.

The cross correlation matrix obtained from both received signals at vertical arrays A and B is

$$\mathbf{C} = \mathbb{E}[\mathbf{Y_A} Y_B^H]$$

Leading to a Shaded Frequency Response between a pair of sensors in each VLA, after the time averaging process [2].

$$\tilde{H}(A,B) \propto \sum_n \frac{U_n^2}{k_n} U_n(A) U_n(B) e^{-jk_n r_{AB}} e^{2\alpha_n r_{med}}$$

Stacking the cross correlations for the period of alignement between the VLAs and the major tanker.

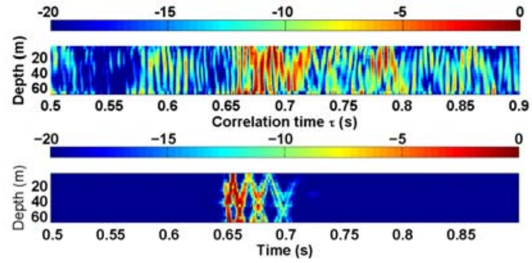
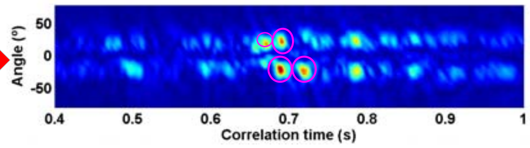


Fig. 2 : (a) Wave front obtained from 7 min stacking when the 2 VLAs are aligned with the tanker. The corresponding time interval is highlighted between vertical red lines in Fig. 1 (b).

(b): Simulation obtained with the Shaded Frequency Response

Spatial filtering (beamforming) by delay and coherent sum of the signals to obtain coherent information traversing both VLAs from propagating paths direction and respective arrival times.

Fig. 2 (c): Estimating direction of arrival from common ray paths and selection of the high intensity angle amplitudes / arrival times



Conclusions / Work in progress

- **The developed expression allows to obtain the acoustic field between 2 VLAs**
- **Wave front structure was obtained from shipping noise**
- **Simulated wave front has the same trend**
- **Using beamforming to obtain coherent wave fronts and select the angle time delay arrival structure**

Ocean Acoustic Tomography

- **Track sound speed/ temperature perturbations**

Acknowledgments

Thanks are due to Fundação Para a Ciência e Tecnologia.

References

[1] P. Roux, W. A. Kuperman, and the NPAL Group, "Extracting coherent wave fronts from acoustic ambient noise in the ocean," J. Acoust. Soc. Am., vol. 116, no. 4, pp. 1995 – 2003, 2004.

[2] A. B. Santos, P. Felisberto, S. M. Jesus, "Acoustic Channel Frequency Response Estimation Using Sources of Opportunity". In 2016 IEEE/OES COA, Harbin, 2016.

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FCT Fundação para a Ciência e a Tecnologia