

# Geoacoustic inversion of ambient noise and applications to sonar processing

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## I. INTRODUCTION

Knowledge of seabed properties such as compressional sound speed and attenuation are important for sonar performance prediction (e.g., transmission loss) to estimate the effectiveness of various sonar systems. Environmentally adaptive sonar signal processing (e.g., matched field processing) holds the promise of improving sonar performance by exploiting known features of the environment [1]. One of the obstacles to matched field processing (MFP) has been the required seabed properties needed as input. In this paper, results will be described that use measured ambient noise data to characterize the seabed. This characterization can be used for predicting transmission loss as well as for detecting and localizing using MFP.

## II. METHOD

Although there are many methods for characterizing the properties of the seabed there are several advantages to using ambient noise: 1) Only receivers are required (i.e., no sound projectors) which simplifies the measurement strategy. 2) Ambient noise conveniently contains energy over a broad band of frequencies so measurements can be tailored to the application. 3) A completely passive system can generally be placed anywhere without concerns (to the environment for example). 4) There is potential for rapid, *in-situ* seabed characterization (as opposed to reliance on archived data) which can be used as input to adaptive sonars such as MFP. Two ambient noise techniques that have recently been developed are used here to characterize the seabed and both use a vertical array of hydrophones. The first method uses the intensity of vertically beamformed noise to determine the magnitude of the bottom reflection loss [2]. The second uses the coherent noise field in the vertical direction to estimate the seabed layering [3]. Both are important for determining a complete geoacoustic description of the seabed that can be used for either TL prediction or for MFP. A brief description of these methods is given here and details can be found in the cited references.

To measure the magnitude of the reflection loss, vertical beam steering is used to determine the intensity of the noise field at angles between vertical (straight up or down) and horizontal. The loss in intensity between beams arriving directly from the sea-surface differs from beams arriving from the seabed by the amount of loss introduced by the seabed. Therefore, by taking the difference between up steered beams and down steered beams (on a log-scale) the reflection loss intensity can be estimated.

To illustrate, data were taken from the MAPEX2000 experiment which took place near Sicily, Italy. The array was in a fixed position and had 64 hydrophones (3 nested apertures of 32 hydrophones with 0.5, 1 and 2 m spacing). The usable frequency band was up to about 1600 Hz. In the left top panel of Fig. 1, the vertically steered noise intensity is shown with the up angles showing higher intensity than those from the seabed. In the right top panel the inferred reflection loss magnitude is shown (dB scale).

In addition to bottom losses that occur due to geoacoustic properties, the seabed layering can also cause complicated frequency dependent losses. This is due to constructive and destructive interference that occurs as waves reflect off various layers in the sub-bottom. This interference can be seen as the band in the reflection loss in Fig. 1. Failure to account for this could result in large errors when modeling the pressure field. The seabed layering can be estimated from the coherent noise by correlating the noise field between sensors in the vertical array. This can be thought of as correlating the beam arriving from the surface (straight up) with the beam arriving from the seabed (straight down). The beam coming from the seabed will contain an exact replica of the surface beam delayed by the two way travel time to the seabed. Further, this beam will contain various echoes from seabed reflections that occur at various layers. In the lower panel of Fig. 1 are the coherent bottom echoes from the

MAPEX2000 array (same data as for the reflection loss estimate in the upper right panel). The notable features are the strong return from the seabed at 130 m and also the two layers at about 20 m below which give rise to the observed interference pattern seen in the reflection loss.

The bottom reflection loss along with the layering information can be used to determine a geoacoustic model for the seabed. Here, the layering information is measured directly and is fixed. The geoacoustic properties for each layer (compressional sound speed, attenuation and density) are adjusted until a reasonable match is found with the measured data. This inversion process involves no forward propagation modeling, only a reflection loss calculation with some adjustments to correct for beamforming effects.

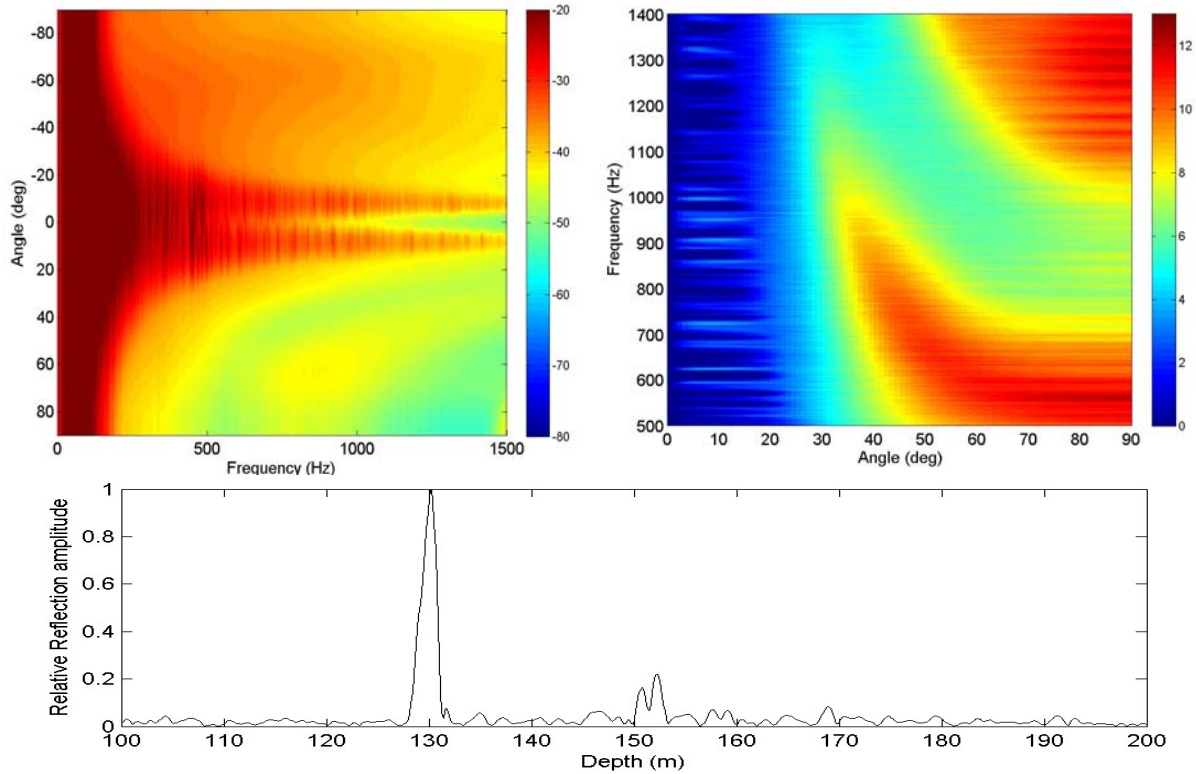


Fig. 1 Top left: the vertically beamformed noise intensity is shown. The negative angles at the top of the plot are from the surface and the positive angles from the seabed direction. Top right: the inferred magnitude of the reflection loss is shown. Bottom panel: the reflections of the coherent noise field from the seabed. Note the large peak that occurs at the water-sediment interface as well as the two layers approximately 20 m below.

### III. CONCLUSION

Using a fixed receiver array, the ambient noise field was measured and estimates for the sediment properties were made. The beamformed noise intensity pattern was used to estimate the magnitude of the reflection loss curve while the coherent noise field is used to determine the layering. In this case, a strong interference pattern in the reflection loss is caused by layers that are evident from the coherent noise processing. The coherent noise field was also used to correct for the position of the array relative to the seabed. This seabed characterization was then used for predicting transmission loss and for matched field processing. Particularly for matched field processing this methodology might be useful to overcome the usual lack of seabed information needed to generate the matched field replicas.

### REFERENCES

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