Internal wave effects on the ambient noise field

Daniel Rouseff and Dajun Tang

I. Overview

The vertical directivity pattern of mid-frequency ambient noise in shallow water is anisotropic. The directivity pattern is asymmetric about the horizontal, a fact that can be exploited to estimate seabed reflectivity, and under appropriate oceanographic conditions it might also show a pronounced notch in the horizontal, a fact that can be exploited for source localization. The ambient noise field is typically highly variable in time, however, hampering its usefulness for either purpose.

In the present work, a recently developed model for the mid-frequency ambient noise field is reviewed [1]. The premise of the model is that internal waves are responsible both for some of the observed variability in the noise field and for partially filling the noise notch. The model integrates three components: a modern shallow-water internal wave model, a noise model, and an acoustic propagation model that uses transport theory. The model output is the vertical directivity pattern of the ambient noise. Model predictions are compared to results from the 2001 East China Sea Experiment using data collected on a vertical array in the 1 to 5 kHz band. Making the realistic assumption that the background internal waves are of moderate strength, the predicted depth of the ambient noise notch is in good agreement with the observations.

II. 2001 Asian Seas International Acoustics Experiment

As part of the 2001 Asian Seas International Acoustics Experiment (ASIAEX), data were collected in the East China Sea between May 28 and June 9. Both acoustic and environmental data were collected [2]. Of current interest are ambient noise data collected on a 31 element vertical array deployed from the R/V *Melville*. The deepest array element was 7.5 m above the seabed with 21.43 cm spacing between the elements. All the array elements were below the nominal thermocline. Noise data were sampled at 12 kHz, bandpass filtered between 0.5 and 5 kHz, and stored in 0.5 s long sections. Nearby research vessels, numerous fishing boats, distant shipping, and the wind all contributed to the noise field. Other sections of data collected on the array were previously used to study the reverberation beam pattern [3].

Fig. 1 is a typical result showing the ambient noise beam pattern at 3 kHz as a function of steering angle. The figure is the result of averaging over 140 consecutive time windows, each 0.5 s in duration. The high noise level at –90 deg is from the R/V *Melville* directly above the array. The local maxima at approximately –10 and +10 deg are labeled B_{up} and B_{down}, respectively. The noise notch B_{notch} in the horizontal, 0 deg, is approximately 6 dB down relative to the adjacent maxima.

III. Model

A detailed discussion of the model is beyond the scope of this short communication; the interested reader should see [1] for the mathematics. Briefly, the model seeks to calculate the width, in degrees, and depth, in relative decibels, of the noise notch observed in ambient noise beam pattern. The acoustic model uses transport theory and allows coupling between the acoustic modes [4]. Coupling between the acoustic modes is caused by internal waves modeled by a shallow water version of the classic Garrett–Munk model [5].

Fig. 2 shows the predicted depth of the ambient noise notch at 3 kHz as a function of the strength of the internal waves. The internal wave strength is parameterized in terms of the usual Garrett–Munk parameter bE_{GM}. The prediction in Fig. 2 should be compared to the observation in Fig. 1. If internal waves are ignored (bE_{GM}=0) the predicted noise notch is several decibels deeper than what was observed in the experiment. If strong but realistic internal waves are assumed (bE_{GM}>0.5 m), the predicted noise notch is too shallow. Moderate strength internal waves, however, produce a noise notch similar to the experimental observation.

In the oral presentation, possible future directions for this research will be discussed. These include generalizations of the

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D. Rouseff and D. Tang are with the Applied Physics Laboratory, College of Ocean and Fishery Sciences, University of Washington, 1013 NE 40th St., Seattle, WA 98105 (phone: 206-543-1300; fax: 206-685-3078; e-mail: rouseff@apl.washington.edu, tang@apl.washington.edu).

model and applications to other data sets.

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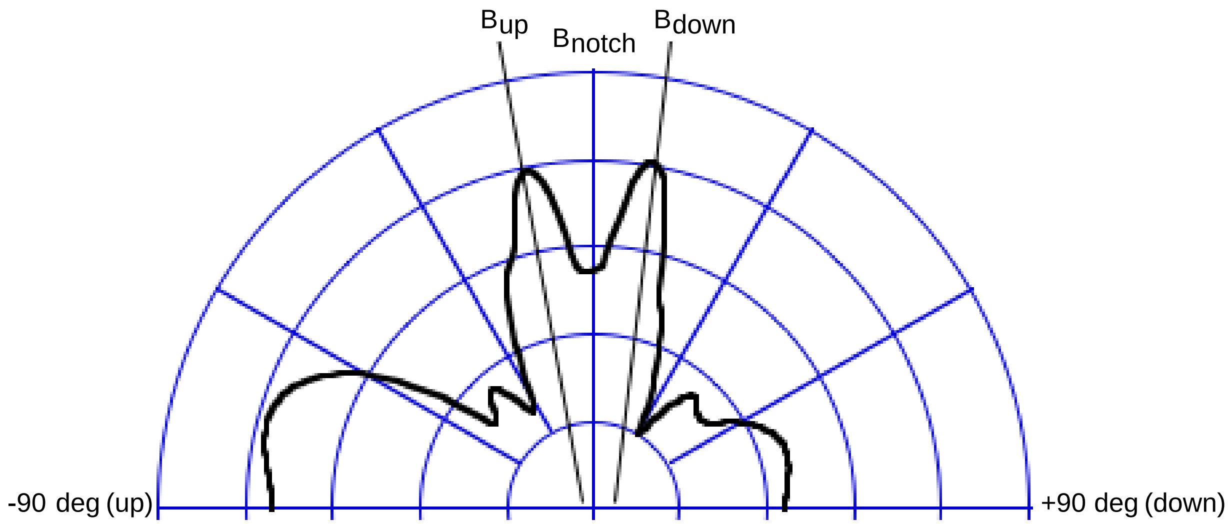

Fig. 1. Typical result showing beampattern of ambient noise observed at 3 kHz in ASIAEX experiment. Results plotted in decibels with arbitrary reference and with 5 dB steps between concentric circles. Noise notch at 0 deg is approximately 6 dB deep relative to the peaks B_{up} and B_{down} and is clearly visible.

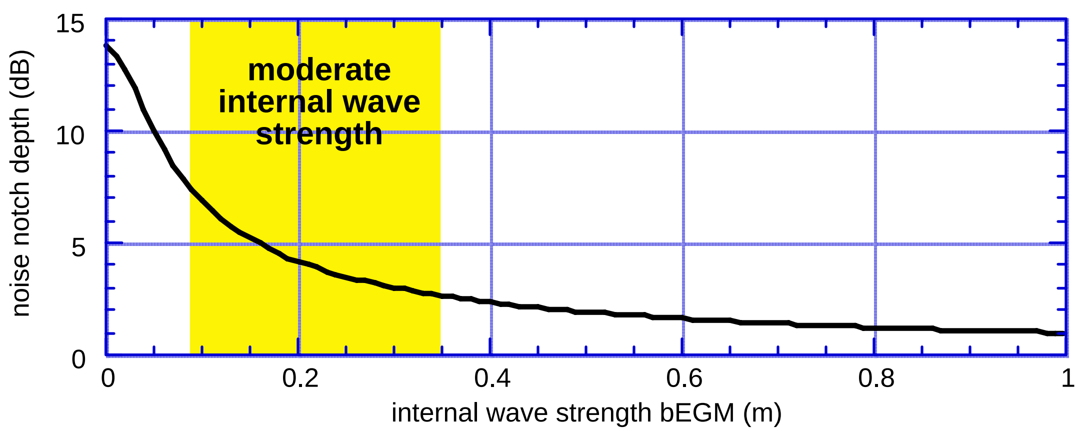

Fig. 2. Effect of internal wave strength on depth of noise notch. Output of model at 3 kHz showing depth of noise notch in decibels plotted versus internal wave strength specified in terms of standard Garrett–Munk internal wave parameter bE_{GM}. Assuming internal waves of moderate strength produces a noise notch depth similar to what was observed in the experiment; see Fig. 1.