Measurements and Predictions of High Frequency Ambient Noise

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Abstract. A great deal has been published on ambient noise. Most of this has covered (a) omni directional levels, and (b) the vertical and horizontal directivity of shipping noise at low frequencies. There is some published material on the vertical directivity of wind generated noise at lower frequencies, but very little at higher frequencies. In order to study wind generated ambient noise at higher frequencies, work has recently started using a small planar array from QinetiQ Bincleaves. As well as measurements, a model called CANARY has been written to predict ambient noise vertical directivity and array responses to this noise. This paper contains some comparisons between CANARY predictions and (a) previous measured vertical directivity data at 4.5 kHz, (b) measured omni-directional data, and (c) initial analysis of the planar array measurements. The paper shows the nature of the ambient noise vertical structure at higher frequencies and that the CANARY predictions are in good agreement with the measurements.

INTRODUCTION

Ambient noise has been a big field of research from the 1960's. Initially, the emphasis was on its omni-directional properties, and then this shifted to the vertical and horizontal directivity of shipping noise at low frequencies. Since the mid 1980's near surface bubble layers have been an area of interest. An area that seems to have received little attention is the vertical directivity of wind generated noise, particularly at higher frequencies. Wind generated ambient noise in the ocean forms a noise field with a distinct vertical directivity. At low frequencies there are high noise levels at upward steer angles towards the sea surface, lower levels at angles towards the seabed, while there is a noise notch, a region of very low noise, in the horizontal. Recently there has been interest in studying the vertical directivity of ambient noise and determining the nature of the noise notch at higher frequencies of up to 50 kHz.

In order to study wind-generated ambient noise at frequencies of up to 50 kHz, work has recently started using a small planar array from QinetiQ Bincleaves. This array is being used to make measurements in a range of environments.

As well as measurements, predictions have been made using the CANARY (Coherence and Ambient Noise for ARraYs) model [1,2] Version 8.1. This model was written to predict the vertical directivity of ambient noise due to wind, rain and shipping, and to predict the array responses to ambient noise for arbitrary 3D arrays with directional hydophones. It is a range independent ray tracing model and was designed primarily for the 1 to 6 kHz frequency band. CANARY array response predictions have been found to be in good agreement with measured data in the 1 to 6 kHz band.

This paper contains previous measurements and predictions at 4.5 kHz, compares CANARY predictions with measured omni-directional data, and gives the initial analysis of the planar array measurements and corresponding CANARY predictions.

CANARY MODEL

This section gives brief details about the assumptions in CANARY model and how they relate to higher frequencies.

Wind generated surface noise is modelled by an infinite sheet of point sources at the sea surface, radiating sound with a dipole directionality. The wind source formula is an empirical fit to the derived source levels by Kuperman/Ferla [3]. Above 3.2 kHz the formula provides a 3.6 dB per Octave slope.

The sound absorption coefficient is calculated using the Thorp equation [4] that is only a function of frequency. A good fit can be obtained between this equation and Francois-Garrison equation [5] for particular combinations of frequency, salinity, PH and temperature. For other combinations there can be significant differences between the two equations.

Surface loss can be treated as either; (a) a look up table of loss versus grazing angle, or (b) using a formula that is limited to low grazing angles, low frequencies and moderate sea states. The formula can produce unrealistic surface loss values if any of these bounds are exceeded.

Bottom loss can be treated as either; (a) single layered solid with a look up table of loss versus grazing angle, or (b) as two layers, a sediment and a substrate. The two layered technique [6] uses the reflection coefficients at the water/sediment and sediment/substrate to derive an analytical expression for the overall three layer reflection coefficient. The technique in [6] is stated to be valid at high frequencies.

MEASURED AND PREDICTED AMBIENT NOISE

This section gives measurements and predictions of the vertical directivity of ambient noise. It should be noted that the vertical directivity cannot be seen directly, but only through the smoothing effect of an array beampattern.

In order to make the predictions, it is necessary to have good environmental data. Unfortunately, none of the measurements presented have a complete set of environmental data, hence some aspects have been assessed.

The first results to be shown come from previous work to assess CANARY. This work involved measuring and predicting the vertical array response of a line array in several environments and for a range of frequencies. The array was of the order of 1m high and was canted down at a 20^{o} angle. The measurement shown in Figure 1 is at 4.5 kHz, in a deep water environment and for an array depth of about 100m. This measurement was typical of measurements obtained during the work. Two beamformer shading functions are applied, uniform and Dolph-Chebychev. The corresponding CANARY predictions are shown in Figure 2.

The vertical angle of 0^o is the horizontal direction and -90^o is directed straight down at the sea bed. The fall off in array response towards the endfire directions of the array is due to hydrophone directionality and the changing DI. This has the effect of making the array's view of the noise notch look less pronounced.

It can be noted that the array does not see the notch at 0^o. This is due to the width of the beampattern's main lobe and the array geometry. It is also predicted that depending on the environment, the location of the notch can occur at angles slightly below 0^o.

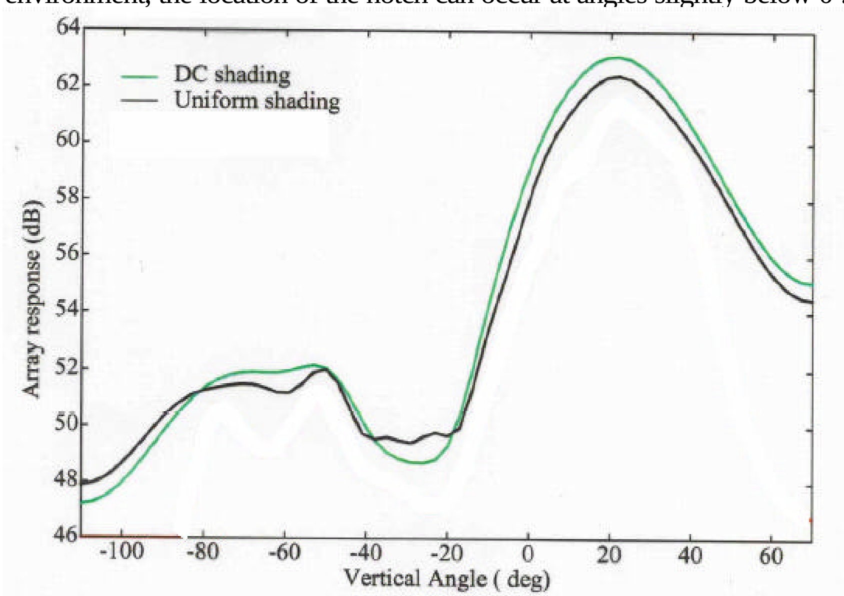

FIGURE 1. Measured vertical array response in deep water at 4.5 kHz.

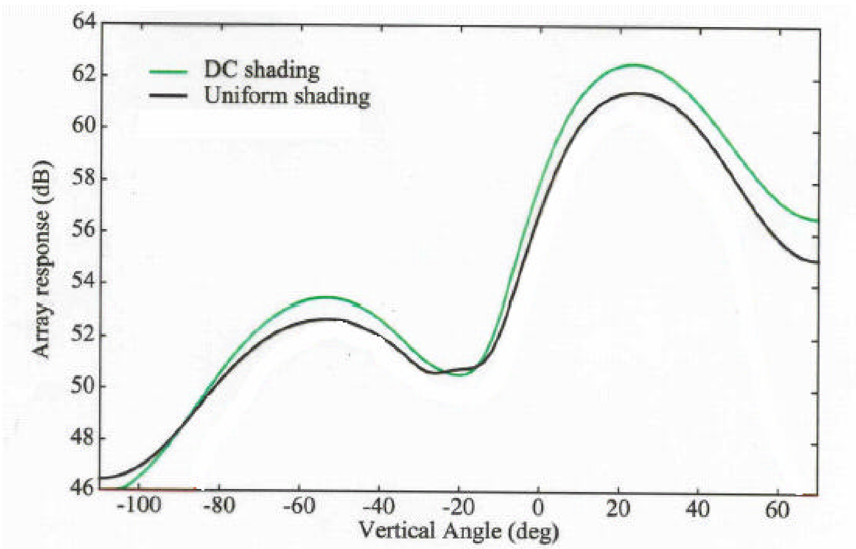

FIGURE 2. Predicted vertical array response in deep water at 4.5 kHz.

A wide range of measured omni directional data has been published. Some general upper and lower bounds of this data is shown in Figures 3 and 4. Some CANARY wind source only predictions for an omni directional hydrophone are also given for a possible high ambient noise environment (shallow water with a sandy sea bed) and a possible low ambient noise environment (deep water with a mud sea bed).

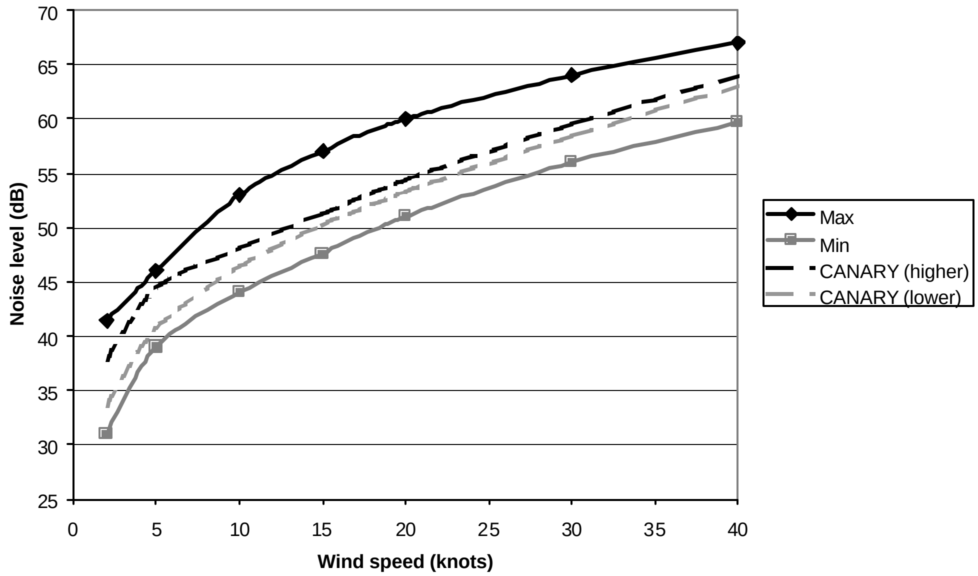

FIGURE 3. General bounds of measured omni directional noise and CANARY predictions 5 kHz.

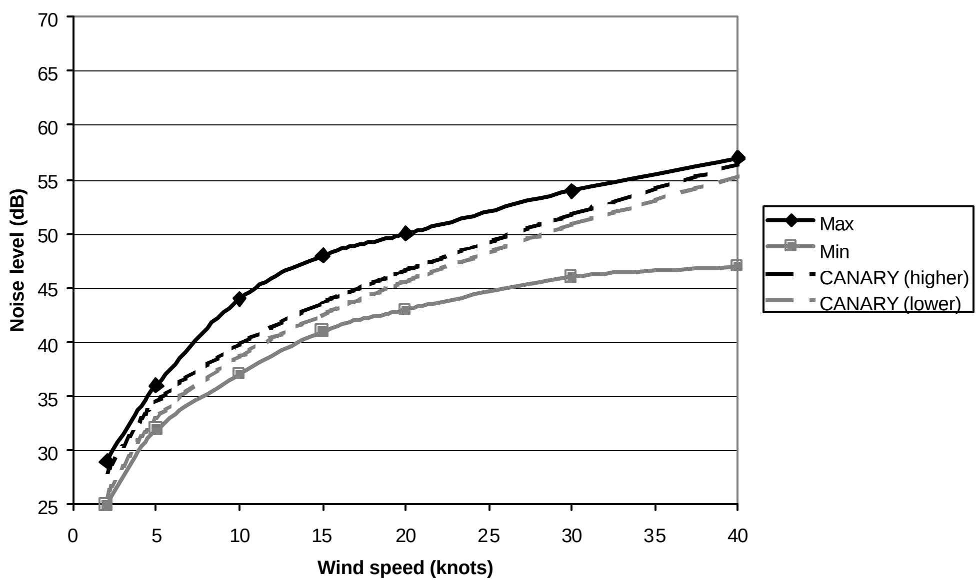

FIGURE 4. General bounds of measured omni directional noise and CANARY predictions 20 kHz.

The predictions show that the environment seems to make little impact on the ambient noise level, while the measurements show that the environment can make a significant difference. This needs further investigation. One explanation is that there could be ship noise in some of the measured data.

The current work involves measuring ambient noise using a small planar array in deep and shallow water for a range of frequencies. A measurement of ambient noise level vs vertical and horizontal angle at 20 kHz, an array depth of 90m, in deep water for a 20dB level scale is shown in Figure 5. The CANARY prediction is shown in Figure 6. High levels can be seen towards the sea surface and low level towards the sea bed. There is a reasonably good agreement between the measurement and predictions.

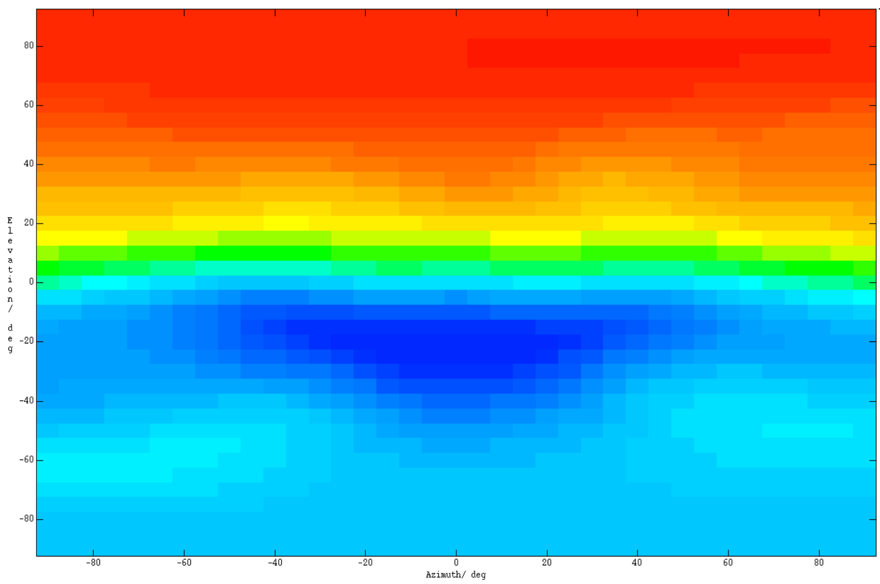

FIGURE 5. Measured ambient noise vs horizontal and vertical angle at 20kHz.

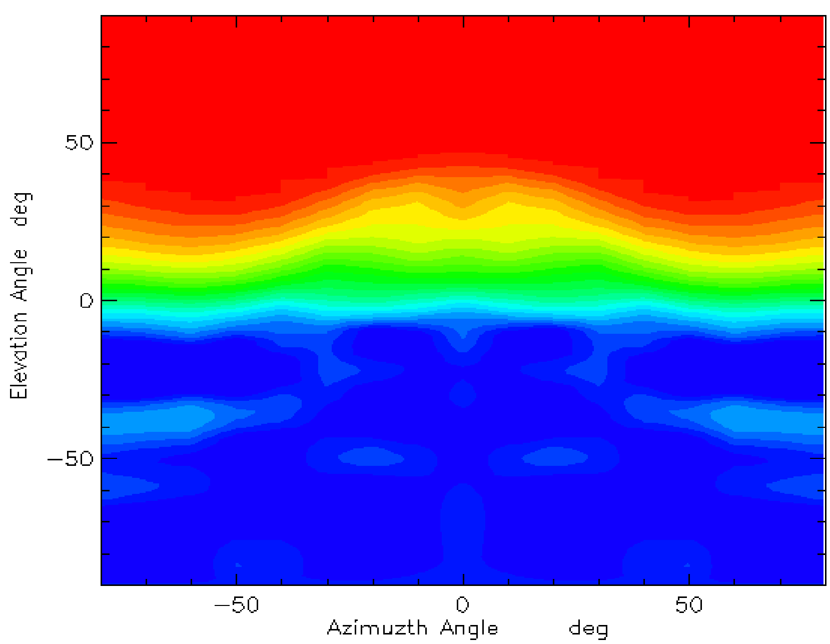

FIGURE 6. Predicted ambient noise vs horizontal and vertical angle at 20kHz.

CONCLUSIONS

This paper has investigated measurements and predictions of high frequency ambient noise. It has been shown that the ambient noise field has a distinct vertical structure at higher frequencies and that there is generally good agreement between the CANARY predictions and the measured data.

Further work needs to be done to explain the differences the environment brings to the variability of predictions and measurements.

ACKNOWLEDGMENTS

I would like to thank QinetiQ Bincleaves, Weymouth, UK for providing some of the measured data for this paper.

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