A Robust High Resolution Processor to Localize and Track Acoustic Sources

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LONG-TERM GOALS

Localizing a source using matching-field processing requires enough array elements to have an adequate array gain and a very good knowledge of the oceanic environment. It often is complicated by the presence of loud, fast-moving interferers, and the source itself being non-stationary. Our goal is to develop a robust matched-field processing technique well suited for practical applications in challenging environments.

OBJECTIVES

Matched-field processing (MFP) is extremely sensitive to environmental mismatch. Indeed the localization process is based on the comparison between the acoustic data received on a submerged array and the synthetic ones issued from a source at a hypothetical position, an environmental model of the waveguide and a propagation code. Therefore an important area of research, and one of our main objectives, is to increase the robustness of adaptive matched-field processing methods to mismatch while keeping their high resolution characteristics. We would like to find a way to improve the signal detectability by increasing the gain at the output of the array. Since the sensitivity to mismatch is enhanced in the process, the accent is put on finding a robust processor as well. Finally the problem of "snapshot deficiency", in which targets and interferers move across resolution cells before enough data vectors can be recorded at the array and combined to construct a full rank cross-spectral density matrix, will be investigated as well.

APPROACH

Adaptive matched-field processing is commonly used instead of conventional methods to get a high resolution localization of a source, and a large number of array elements is desirable to better detect the source signal imbedded in noise. But both adaptivity and large arrays lead to an increased sensitivity of the algorithm to environmental mismatch. Moreover, large arrays also mean larger cross-spectral density matrices, which typically require more data samples recorded from each source position to be able to invert the matrix and localize the source successfully. The white noise constraint algorithm is a good candidate to overcome both those issues. It has been localizing sources in many challenging environments and snapshot-deficient scenarios without seeking more accurate environmental information. But while the choice of the processor involves additional signal processing only, the requirement for a large number of array elements can be problematic. Larger arrays are more costly and less practical than shorter ones, and there is no way to increase the number of transducers used *a posteriori*. One way to get around this problem is to use additional frequencies coherently, i.e.

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14. ABSTRACT
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implement a coherent broadband processor, instead of using additional array elements. These extra-frequencies essentially increase the size of the cross-spectral density matrix, exactly as if more array elements were involved in the processing. Therefore, we propose to investigate the performance of a coherent broadband white noise constraint processor in a shallow water environment.

WORK COMPLETED

The Hudson Canyon experiment was chosen to test our algorithm. It took place in shallow water (73 m) out of the New Jersey coast. An acoustic source was towed at 36 m deep over an essentially flat bottom, and the acoustic field was sampled by a 24 element vertical array.

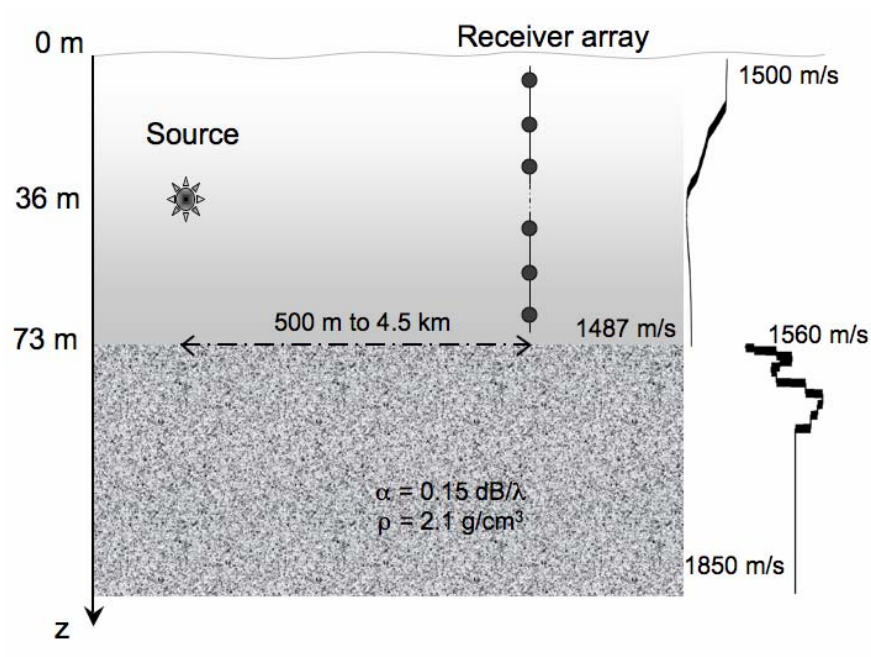

Figure 1. The Hudson Canyon environment model used to create the replica vectors

Data from two source tracks (ten different ranges per track) are provided. In the first one, the source sent multitones at 50, 175, 375, and 425 Hz and moved up to 4.5 km away from the receivers. The source traveled back toward the receiver array in the second track, emitting tones at 75, 275, 525, and 600 Hz. Ten observations are available for each source range, and the average SNR at each element was approximately 10 dB.

RESULTS

The advantage of using the white noise constraint (WNC) adaptive algorithm versus the minimum variance (MV) one was first investigated. The MV is found to be quite sensitive to mismatch, and averaging single-frequency outputs reinforces the maximum constructively in only 10 % of the cases. Processing those same frequencies coherently shows a great improvement, now localizing the source in 90% of the cases, though with a peak-to-sidelobe ratio of only 2 dB or less. The WNC, in contrast,

localizes the source consistently with lower sidelobes, even when processing the multitones incoherently, as seen on Fig. 2. Figure 3 displays the ambiguity surface corresponding to the same portion of data obtained by combining the WNC processor with the coherent broadband method.

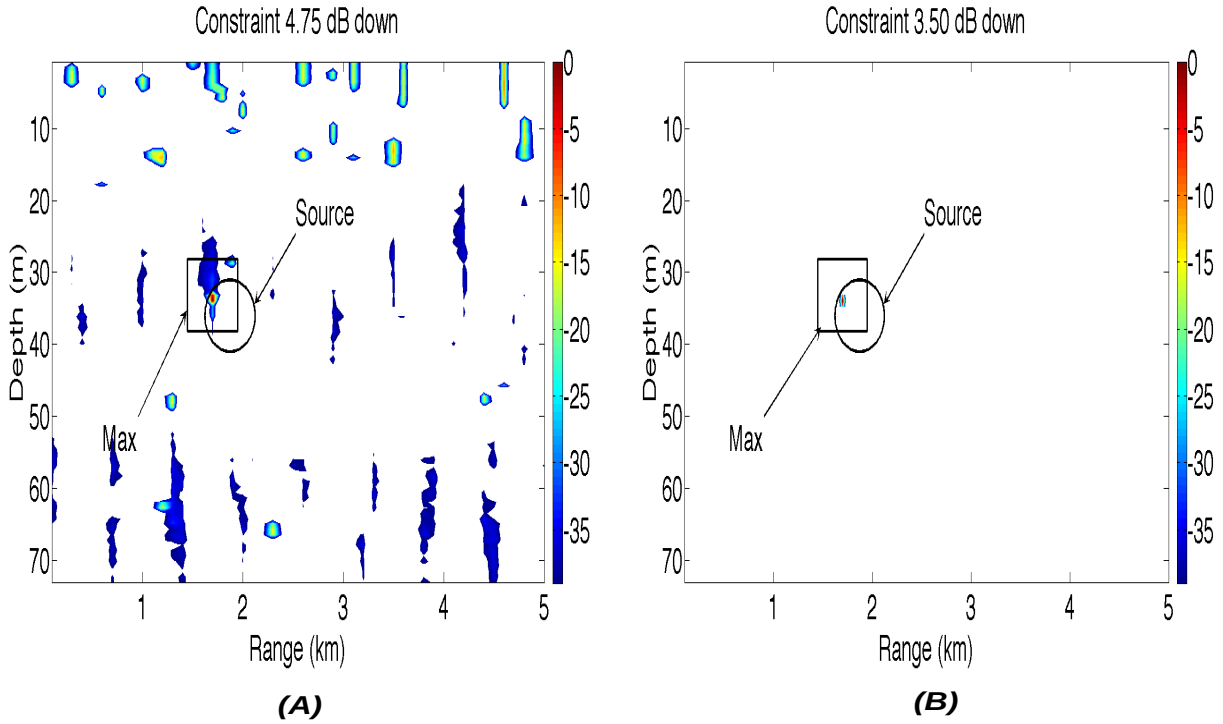

Figure 2. White noise constraint MFP ambiguity surfaces obtained by (A) an incoherent decibel average of four frequencies and (B) a coherent processing of the same four frequencies. The source is correctly localized in both cases, but the sidelobe level is much lower in the coherent case.

As apparent on the figure, the coherent broadband WNC algorithm is non-only robust to mismatch between the experimental and modeled fields since the source is successfully localized, but also discriminating, as suggested by the very low sidelobe levels (at -146 dB down).

This non-physically low peak-to-background level was proven to be due to the presence of a bias in dynamic range associated with snapshot deficient scenarios. Since we had only ten observations available instead of the approximately 200 ones necessary to construct an invertible cross-spectral density matrix, we were in a particularly problematic snapshot deficient scenario. The white noise constraint algorithm was shown to take advantage of that power bias and turn it into an increased dynamic range, convenient for localization purposes.

The robustness of the algorithm as the environmental mismatch is increased and the position of the source changes was also investigated. We processed each of the twenty frames present in the outgoing and incoming legs, and introduced a slight sound speed mismatch. The localization performance in range and depth of the coherent and incoherent MVDR and WNCM matched-field processors was then compared.

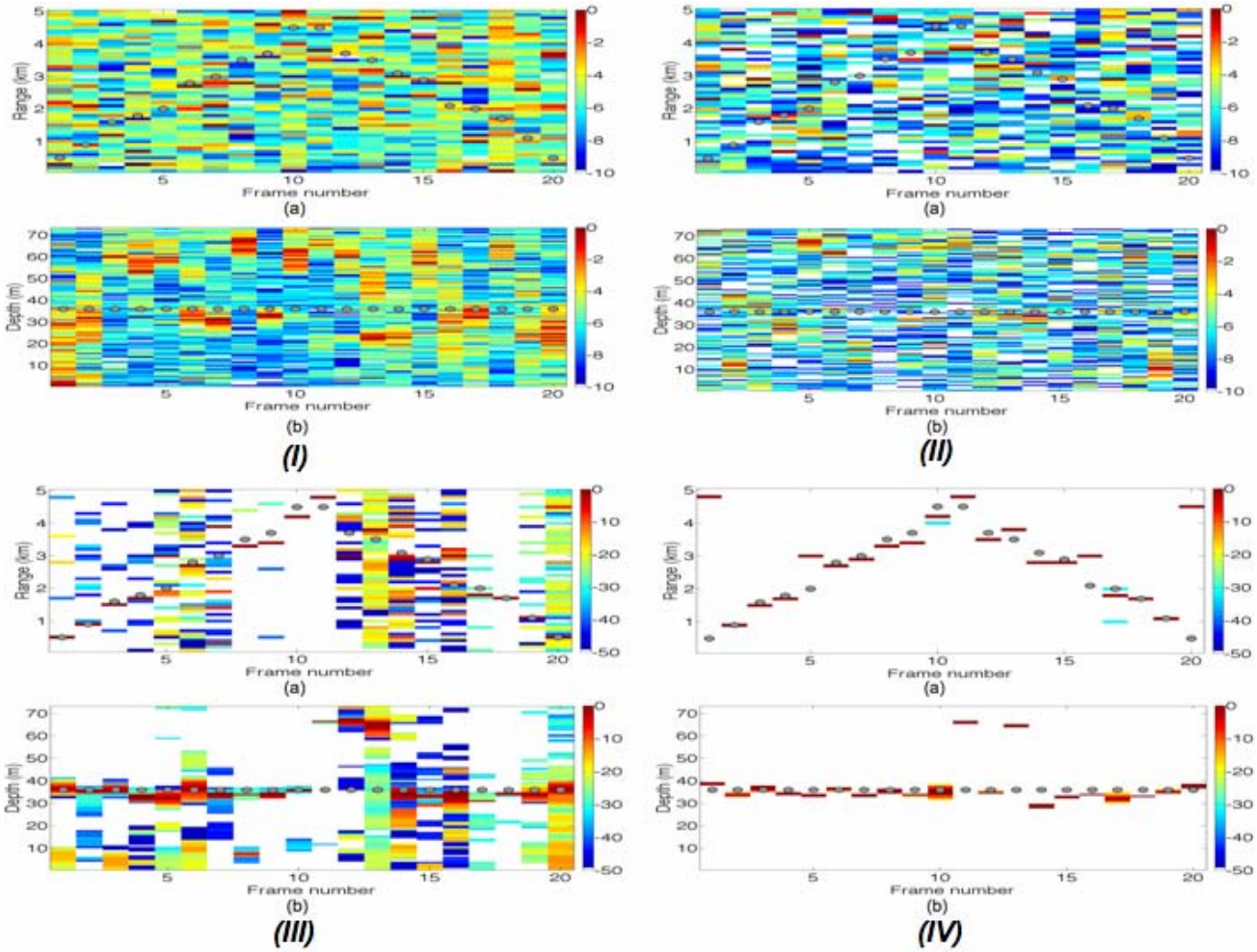

Figure 3. Source track obtained using the (I) incoherent and (II) coherent MV algorithm, (III) incoherent and (IV) coherent WNC algorithm. The top plots (a) represent range tracks at the source depth of 36 m and the bottom ones (b) depth tracks along the estimated range tracks. The black circles indicate the true source positions.

Fig. 3 (Ia) displays the range slices obtained with the incoherent minimum variance processor for each source position, and Fig. 3 (Ib) shows the depth track intersecting those estimated ranges. The black circles indicate the known source ranges and depths. Fig. 3 (IIa) and (IIb) are the corresponding figures obtained by processing the frequencies coherently. In this case, the mismatch is sufficient to lose track of the source at most positions for both incoherent and coherent processors. The sidelobe level is, however, lower in the coherent case. Fig. 3 (IIIa), (IIIb), (IVa) and (IVb), show the same type of plots using the incoherent and coherent white noise constraint algorithms. This time the source is tracked in range and depth in both cases, with a significantly lower sidelobe level obtained when using the coherent processor. The white noise constraint is therefore more robust to environmental mismatch than the minimum variance algorithm and produces low sidelobes when combined with a coherent method.

IMPACT/APPLICATIONS

Improving the robustness and detectability of sound sources in the ocean without sacrificing resolution has implications for monitoring of marine life and human vessels. Robustness is particularly important in continental shelf regions where the sound interaction with the surroundings is complicated, and can't be described accurately.

RELATED PROJECTS

PlusNET

PUBLICATIONS

Claire Debever and W. A. Kuperman, "Robust matched-field processing using a coherent broadband white noise constraint processor", J. Acoust. Soc. Am. **122** (4), October 2007 [in press].

HONRS/AWARDS/PRIZES

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