ROBUST ADAPTIVE PROCESSING IN LITTORAL REGIONS WITH ENVIRONMENTAL UNCERTAINTY

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One of the main challenges in shallow water passive sonar is the complex propagation physics for both target and interferer signatures. Matched Field Processing (MFP) addresses this challenge by incorporating a propagation model into the steering vector calculation, but it is extremely sensitive to inaccuracies in the knowledge of the underwater environment. Robust algorithms have been developed to address the losses due to environmental mismatch and to target motion. To address the losses associated with target motion, a motion compensation algorithm based on the invariance principle has been developed. A second algorithm exploits the presence of a strong source to obtain a steering vector which can then be transformed to form beams at other ranges and depths.

1 Introduction

Detection and localization of quiet targets in littoral regions presents a challenging problem both because of the complicated acoustic propagation that occurs and the prevalence of loud surface ship interference. Matched Field Processing (MFP) can help address the first concern by using a propagation model to determine the steering vectors, thus providing optimal array gain and localization accuracy. Adaptive MFP (AMFP) can provide the ability to null surface interference, particularly when an array has vertical aperture that allows discrimination of surface and submerged sources. Under ideal situations, AMFP can provide super-resolution and add 10–20 dB interference suppression.

However, performance gains from AMFP have yet to be realized in practice, for several reasons. Perhaps the most important limitation is that precise information on the underwater channel is generally not available. The mismatch between the computed and actual array steering vectors can result in loss of array gain and - for adaptive processing - significant target self-nulling. A second factor influencing the performance of AMFP is the motion of the targets and interferers which introduces additional signal loss, smearing of source peaks, and consumption of adaptive degrees of freedom.

In this paper, we begin by examining the detection and localization performance for stationary sources as a function of the beamformer. We then quantify the effects of target and interferer motion. Finally, we present two methods that address two of these loss mechanisms. The first method uses the invariance principle to compensate for target motion and decrease signal gain degradation. The second method uses the observed response from a loud source and applies a depth shifting operation to construct a steering vector at the depth of interest.

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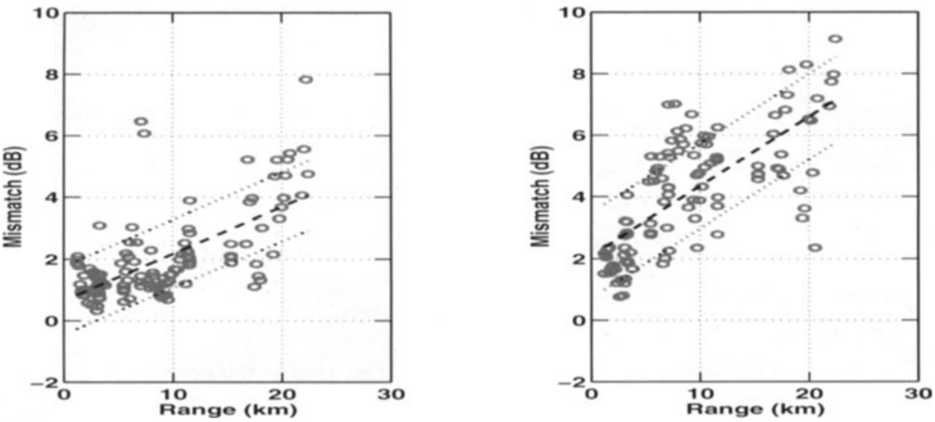

Figure 1. Mismatch from SBCX data as a function of source range for towed source tones at 94 Hz (lefthand plot) and 235 Hz (righthand plot).

2 System performance

MFP suffers signal gain degradation due to imperfect knowledge of the underwater channel. Range-focused single-path beamformers (RFBF) suffer loss due to approximation of a multipath envionment as a single path one. The losses of both of these are a function of the array topology, the position of the target, and the underwater environment. For sonar systems, it is useful to understand the expected losses to determine the appropriate beamformer for the best detection performance (i.e., minimal losses) in a given target region.

Monte Carlo simulations that incorporate the expected error in the shallow water environment were used to determine MFP mismatch loss. These simulations indicate that the loss grows as a function of target range. If one models the error as a perturbation of the modal wavenumbers, it can be easily understood that the total error will accumulate as the range to the source grows. This has been verified with experimental data from the Santa Barbara Channel Experiment, which is shown in Fig. 1, where the measured mismatch to a towed source are plotted for the tone at 94 Hz (left) and 235 Hz (right).

RFBF simulations show that the losses do not grow as a function of target range, implying that there is a range at which the losses from MFP exceed those of RFBF. RFBF losses are also greatest at endfire, where exposure to the unaccounted-for modal structure produces the greatest error. This is particularly true for arrays with vertical aperture, where one sees splitting of target energy into different beams (i.e., "mode splitting").

The implications of the above are that standard MFP might provide acceptable detection performance at close ranges and in endfire regions, but in other regions mismatch losses can be excessive and application of a RFBF may provide superior detection performance .

When localization performance is considered, MFP provides vastly increased localization accuracy. In the littoral region, where interferers are typically on the surface and targets of interest are submerged, the ability to determine depth (in particular) allows one to easily classify sources. This same discrimination capability allows adaptive processors to cancel interference while retaining target. Drawbacks of such fine resolution are the