

Matched Field Inversion in Underwater Acoustics

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Matched field inversion is a full wave inversion method based on matched field processing and efficient global search techniques. Matched field processing (MFP) is a model-based signal processing method that was originally introduced in underwater acoustics as an inversion technique for localization of a sound source in the ocean [1]. In its simplest form, MFP determines the source location by comparing measured acoustic fields with replica fields that are calculated for a known waveguide environment and a specified experimental geometry. The best match is obtained for the correct source position, if the environment is accurately modelled. Errors in the model of the environment are manifested as mismatch in the MF comparison process. In practice, a search procedure is carried out over a regular grid of possible source ranges, depths and bearings. However, MFP is a powerful full-wave inversion method, and it has more recently been applied to the general inverse problem of estimating the properties of the ocean waveguide itself. Matched field inversion has been applied to estimate quantities such as the sound speed profile in the water, under-ice roughness, and geoacoustic properties of the ocean bottom. The emphasis of this paper is on the last application, inversion for geoacoustic properties of the bottom.

Matched field inversion for geoacoustic properties is formulated as a global optimization problem, rather than a pure inverse problem. This approach is amenable to the addition of any prior knowledge of the environment. The components the MF inversion algorithm are very simple, consisting of: (1) a specific form for the geoacoustic model itself; (2) a numerical model for calculating the acoustic fields for a specific experimental geometry; (3) a cost function for assessing the measured and modelled fields; and (4) an efficient global search method. The form for the geoacoustic model is usually a layered earth model, with parameter value bounds that are based on any prior knowledge of the specific environment. The model parameters include the layer depths, and the density and sound speeds and attenuations (compressional and shear) for each layer. The replica acoustic fields can be calculated using normal mode methods for range independent problems, or parabolic equation techniques for range independent environments; in

some cases, adiabatic normal mode methods may also apply for weak range dependence. The cost function for the global search process is based on a linear Bartlett matched field processor; this function is robust to mismatch and is more effective for use in a random search. Successful application of the method depends on the use of an efficient global search algorithm to search the multidimensional parameter space of candidate geoacoustic models. In practical problems, the number of model parameters can be large (8-10), so that regular grid searches are precluded. Two efficient global search algorithms are currently in use: simulated annealing [2] and genetic algorithms [3]. Both these methods have the ability to escape from local minima, so that the search process is not trapped by a false 'solution'. Although the inversion is sensitive to mismatch in the parameters that define the experimental geometry, these uncertainties can be tolerated in the inversion by including parameters such as range and array depth in the search process.

In this paper the MF inversion method is applied to data that were obtained using a vertical line array of hydrophones. The experiment was carried out in shallow water on the continental shelf off the west coast of Vancouver Island. Estimates were obtained for the parameters of a 2-layer elastic geoacoustic model, including the depth of the upper layer and the compressional and shear speeds of both layers. The estimated values were in good agreement with ground truth data that were obtained by conventional seismic methods.

References

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