1. Abstract

This work presents a computational framework for the analysis and design of large scale algorithms utilized in the estimation of acoustic double dispersive randomly time-variant, underwater communication channels. Channel estimation results are, in turn, used in the proposed framework for the development of efficient high performance algorithms, based on fast Fourier transforms, for the search, detection, estimation, and tracking (SDET) of underwater moving objects.

2. Introduction

This work formulates a computational framework for the development of efficient algorithms to effect computational signal processing operations to address the problem of surveillance and acoustic monitoring of underwater moving objects. From the point of view of computational complexity theory, the combined problem of search, detection, estimation, and tracking of underwater moving objects is considered an NP-Hard problem.

3. Delay-Doppler MIMO Estimation

A Matching Pursuit algorithm implementation is used to estimate MIMO channel parameters. The delay-Doppler spread function is used as characterizing channel function. This function plays the role of surrogate of the input-delay spread function. Variants of matching pursuit algorithms were implemented: basic, orthogonal, and order-recursive least-square. Their complexities are shown in the Table 1.

<table>
<thead>
<tr>
<th>MP Variant</th>
<th>Alg. Type</th>
<th>Computational Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic MP</td>
<td>Greedy</td>
<td>O(MNDL²)</td>
</tr>
<tr>
<td>Orthogonal MP</td>
<td>Greedy</td>
<td>O(MNDL² + MNDLL²)</td>
</tr>
<tr>
<td>Order Recursive LS-MP</td>
<td>Greedy</td>
<td>O(MNDL² + MNDLL²)</td>
</tr>
<tr>
<td>Direct Computation</td>
<td>Pseudo Inverse</td>
<td>O((K MNDL)²)</td>
</tr>
</tbody>
</table>

4. MIMO Channel

The MIMO case has M transmitter transducers, and N receiver transducers. Equation 1 shows the input-output relation for a MIMO channel system.

\[ \mathbf{w} = \bigcup_{\alpha} \bigotimes_{\theta} \mathbf{c}(\alpha, \theta) V \bigcup_{\theta} \bigotimes_{\alpha} \mathbf{h}(\alpha, \theta) = \mathbf{Vh} \]

**Equation 1: MIMO Channel I/O Relation**

While in the channel sounding mode, some series of predefined pulses are transmitted. These pulses are compared with the received signals for characterizing the MIMO channel.

5. Kuck’s Paradigm

David Kuck presented an abstract manner to represent parallel computational structures. This methodology of representation may be related to the Parallel Random Machine Model (PRAM) used to describe an abstract parallel machine. Figure 4 illustrates the Kuck’s diagram representation of the parallel MIMO estimation problem.

6. Results

Our experimental results show that the order recursive least-square matching pursuit algorithm performs best for MIMO channel estimation. Figures 1 and 2 relate to the estimation of two underwater objects moving at constant speed but using two different transmitted pulses. The use of chirp pulses as predefined pulses improved the resolution of the objects detection on MIMO channel environments.

**References**


