Chapter II
Robust Adaptive Beamforming

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INTRODUCTION

In this chapter, we first review the background, basic principle and structure of adaptive beamformers. Since there are many robust adaptive beamforming methods proposed in literature, for easy understanding, we organize them into two categories from the mathematical point of view: one is based on quadratic optimization with linear and nonlinear constraints; the another one is max-min optimization with linear and nonlinear constraints. With the max-min optimization technique, the state-of-the-art robust adaptive beamformers are derived. Theoretical analysis and numerical results are presented to show their superior performance.

BACKGROUND

The array signal processing has been studied for some decades as an attractive method for signal detection and estimation in harsh environment. An array of sensors can be flexibly configured to exploit spatial and temporal characteristics of signal and noise and has many advantages over single sensor. It has many applications in radar, radio astronomy, sonar, wireless communication, seismology, speech acquisition, medical diagnosis and treatment (Tsoulos, 2001) (Krim & Viberg, 1996) (Van Veen & Buckley, 1988), etc.

There are two kinds of array beamformers: fixed beamformer and adaptive beamformer. The weight of fixed beamformer is pre-designed and it does not change in applications. The adaptive beamformer automatically adjusts its weight according to some criteria. It significantly outperforms the fixed beamformer in noise and interference suppression. A typical representative is the linearly constrained minimum variance (LCMV) beamformer (Compton, 1988) (Hudson, 1981) (Johnson & Dudgeon, 1993) (Monzingo & Miller, 1980) (Naidu, 2001). A famous representative of the LCMV is...
The robust beamforming methods discussed above solve part of robust beamforming problems. More research works still need to be carried out, especially in real applications. In (Er & Ng, 1994), a new approach was proposed for robust beamforming in the presence of steering direction error. It iteratively searches for the optimal direction by maximizing the mean output power of the Capon beamformer using first-order Taylor series approximation in terms of steering direction error. This method does not suffer from performance loss in interference/noise suppression. However, its performance degrades when there exist multiple errors, such as the steering direction error, the array geometry error and the array sensor phase error, because the array steering vector in (Er & Ng, 1994) is assumed to be a vector function of steering direction only. When multiple imperfections exist, the assumed model of the ASV is violated. In (Yu & Er, 2006a) (Yu, 2006), a new model of the ASV is adopted. All of these array imperfections are modeled as general phase errors (GPEs).
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