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Robust Adaptive Beamforming Using Noise Reduction Preprocessing-Based Fully Automatic Diagonal Loading and Steering Vector Estimation

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ABSTRACT Diagonal loading provides a powerful and effective way to improve the robustness of the standard Capon beamformer. Several parameter-free robust adaptive beamformers (RAB) are considered in this paper. We reveal that the performances of them have somewhat degradation when the number of snapshots or that of sensors is large. To solve this problem, we emphatically study the well-known generalized linear combination-based method, the performance of which may degrade severely when the number of sensors increases, and propose a novel parameter-free technique, which is a combination of noise reduction preprocessing technique and truncated minimum mean square error criterion. As most of the parameter-free RAB techniques are very sensitive to the desired signal steering vector mismatch, this paper further proposes to construct a series connection between these RAB techniques and a steering vector estimation (SVE) method, where the SVE is implemented by a convex optimization technique. Simulation results show that the proposed method can achieve a promising performance in comparison with the competing methods.

INDEX TERMS Diagonal loading, robust adaptive beamforming, parameter-free, steering vector estimation.

I. INTRODUCTION

The standard Capon beamformer (SCB) is an optimal spatial filter with remarkable resolution and interference suppression capability [1]. However, it is very sensitive to the imprecise knowledge of the true covariance matrix and the mismatch of the steering vector of signal-of-interest (SOI). In the last half century, many robust adaptive beamformers (RAB) have already been proposed to improve the robustness of SCB. They can be roughly classified into four categories: diagonal loading method [2]–[5], uncertainty set-based method [6]–[11], eigenspace-based method [12]–[14], and interference-plus-noise covariance matrix reconstruction-based method [15]–[18].

Diagonal loading is one of the most widely used RAB method, where a scaled identity matrix is injected into the sample covariance matrix according to some rules [2]. Most of the conventional diagonal loading methods are user parameter dependent. For example, the norm constrained Capon beamforming is a frequently used conventional

diagonal loading method, whose the diagonal loading level is determined by the user parameter upper bound of the square of the weight vector norm [2]. In recent decades, the uncertainty set-based robust adaptive beamformers have been proposed, such as the worst-case performance optimization beamformer [7], the linear programming beamformer [8], and the distributional robust chance-constrained beamformer [9]. They are proved equivalent to the diagonal loading method [6], and their corresponding diagonal loading level can be calculated by the user defined size of the uncertainty set of the array steering vector. Therefore, the conventional diagonal loading method and the uncertainty set-based diagonal loading method have the common problem that their diagonal loading level is uneasy to be determined beforehand.

Several parameter-free RAB techniques have been presented in the literature, including the Hoerl-Kennard-Baldwin (HKB) method [19], the general linear combination-based (GLC) method [20], the spatial matched filter-based (SMF) method [21], and the quadratically

Robust Adaptive Beamforming

Ingvar Claesson, Sven Nordholm



Robust Adaptive Beamforming:

Robust Adaptive Beamforming Jian Li, Petre Stoica, 2005-10-10 The latest research and developments in robust adaptive beamforming. Recent work has made great strides toward devising robust adaptive beamformers that vastly improve signal strength against background noise and directional interference. This dynamic technology has diverse applications including radar, sonar, acoustics, astronomy, seismology, communications, and medical imaging. There are also exciting emerging applications such as smart antennas for wireless communications, handheld ultrasound imaging systems, and directional hearing aids. Robust Adaptive Beamforming compiles the theories and work of leading researchers investigating various approaches in one comprehensive volume. Unlike previous efforts, these pioneering studies are based on theories that use an uncertainty set of the array steering vector. The researchers define their theories, explain their methodologies, and present their conclusions. Methods presented include: Coupling the standard Capon beamformers with a spherical or ellipsoidal uncertainty set of the array steering vector; Diagonal loading for finite sample size beamforming; Mean squared error beamforming for signal estimation; Constant modulus beamforming; Robust wideband beamforming using a steered adaptive beamformer to adapt the weight vector within a generalized sidelobe canceller formulation. Robust Adaptive Beamforming provides a truly up-to-date resource and reference for engineers, researchers, and graduate students in this promising, rapidly expanding field. *Robust Adaptive Beamforming Using Spatial Filter Design* Ingvar Claesson, Sven Nordholm, 1990

Simplified Robust Adaptive Detection and Beamforming for Wireless Communications Ayman ElNashar, 2018-06-11 This book presents an alternative and simplified approach for the robust adaptive detection and beamforming in wireless communications. It adopts several systems models including DS-SS, CDMA, OFDM, MIMO with antenna array, and general antenna arrays beamforming model. It presents and analyzes recently developed detection and beamforming algorithms with an emphasis on robustness. In addition, simplified and efficient robust adaptive detection and beamforming techniques are presented and compared with existing techniques. Practical examples based on the above systems models are provided to exemplify the developed detectors and beamforming algorithms. Moreover, the developed techniques are implemented using MATLAB, and the relevant MATLAB scripts are provided to help the readers to develop and analyze the presented algorithms. *Simplified Robust Adaptive Detection and Beamforming for Wireless Communications* starts by introducing readers to adaptive signal processing and robust adaptive detection. It then goes on to cover Wireless Systems Models. The robust adaptive detectors and beamformers are implemented using the well-known algorithms including LMS, RLS, IQRD, RLS, RSD, BSCMA, CG, and SD. The robust detection and beamforming are derived based on the existing detectors/beamformers including MOE, PLIC, LCCMA, LCMV, MVDR, BSCMA, and MBER. The adopted cost functions include MSE, BER, CM, MV, and SINR, SNR. Efficient Robust Adaptive Beamforming Algorithms for Sensor Arrays Hang Ruan, 2016

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beamforming Recent work has made great strides toward devising robust adaptive beamformers that vastly improve signal strength against background noise and directional interference This dynamic technology has diverse applications including radar sonar acoustics astronomy seismology communications and medical imaging There are also exciting emerging applications such as smart antennas for wireless communications handheld ultrasound imaging systems and directional hearing aids Robust Adaptive Beamforming compiles the theories and work of leading researchers investigating various approaches in one comprehensive volume Unlike previous efforts these pioneering studies are based on theories that use an uncertainty set of the array steering vector The researchers define their theories explain their methodologies and present their conclusions Methods presented include Coupling the standard Capon beamformers with a spherical or ellipsoidal uncertainty set of the array steering vector Diagonal loading for finite sample size beamforming Mean squared error beamforming for signal estimation Constant modulus beamforming Robust wideband beamforming using a steered adaptive beamformer to adapt the weight vector within a generalized sidelobe canceller formulation Robust Adaptive Beamforming provides a truly up to date resource and reference for engineers researchers and graduate students in this promising rapidly expanding field

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Robust Adaptive Beamforming with Coherent Interferences Lei Yu, 2011

Robust Adaptive Beamforming, 1996 The minimum variance distortionless response MVDR beamforming method revolves around the computation of a set of sensor weights via a sample covariance matrix formed from field observations made at the sensors Reducing or constraining the sensor weight amplitudes is an effective way of ameliorating problems with the method and can be optimally implemented in many cases by an extremely

simple modification of the sample covariance matrix prior to computing the weights This consists of writing the weights in vector form where the constraint is on the value of the inner product vectors known as a quadratic function This report features a reasonably extensive set of simulation results which attempt to examine the practical impact of the quadratically constrained MVDR approach Infinite and finite time behaviour are discussed for various scenarios known to cause performance degradation for the standard MVDR adaptive beamformer The transient behaviour of the method in highly dynamic fields is also briefly examined Performance gains using the new method are demonstrated in terms of output signal to noise ratio

Academic Press Library in Signal Processing Mats Viberg, Abdelhak Zoubir, 2013-08-31 This third volume edited and authored by world leading experts gives a review of the principles methods and techniques of important and emerging research topics and technologies in array and statistical signal processing With this reference source you will Quickly grasp a new area of research Understand the underlying principles of a topic and its application Ascertain how a topic relates to other areas and learn of the research issues yet to be resolved Quick tutorial reviews of important and emerging topics of research in array and statistical signal processing Presents core principles and shows their application Reference content on core principles technologies algorithms and applications Comprehensive references to journal articles and other literature on which to build further more specific and detailed knowledge Edited by leading people in the field who through their reputation have been able to commission experts to write on a particular topic

High-Resolution and Robust Signal Processing Yingbo Hua, Alex Gershman, Qi Cheng, 2017-12-19 High Resolution and Robust Signal Processing describes key methodological and theoretical advances achieved in this domain over the last twenty years placing emphasis on modern developments and recent research pursuits Applications grounded this sophisticated resource links theoretical background with high resolution methods used in wireless communications brain signal analysis and space time radar signal processing Chapter extras include theorem proofs derivations and computational shortcuts as well as open problems numerical measurement and performance examples and simulation results Sixteen illustrious field leaders invest High Resolution and Robust Signal Processing with in depth reviews of parametric high resolution estimation and detection techniques robust array processing solutions for adaptive beam forming and high resolution direction finding Parafac techniques for high resolution array processing and specific areas of application high resolution nonparametric methods and implementation tactics for spectral analysis multidimensional high resolution data models and discussion of R D unitary ESPRIT with colored noise multidimensional high resolution parameter estimation techniques applicable to channel sounding estimation procedures for high resolution space time radar signal processing using 2 D or 1 D 1 D models and models and methods for EEG MEG space time dipole source estimation and sensory array design

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Ward,2013-04-17 The study and implementation of microphone arrays originated over 20 years ago Thanks to the research and experimental developments pursued to the present day the field has matured to the point that array based technology now has immediate applicability to a number of current systems and a vast potential for the improvement of existing products and the creation of future devices In putting this book together our goal was to provide for the first time a single complete reference on microphone arrays We invited the top researchers in the field to contribute articles addressing their specific topics of study The reception we received from our colleagues was quite enthusiastic and very encouraging There was the general consensus that a work of this kind was well overdue The results provided in this collection cover the current state of the art in microphone array research development and technological application This text is organized into four sections which roughly follow the major areas of microphone array research today Parts I and II are primarily theoretical in nature and emphasize the use of microphone arrays for speech enhancement and source localization respectively Part III presents a number of specific applications of array based technology Part IV addresses some open questions and explores the future of the field

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Low-cost Smart Antennas Qi Luo,Steven Shichang Gao,Wei Liu,Chao Gu,2019-01-18 An

authoritative guide to the latest developments for the design of low cost smart antennas Traditional smart antenna systems are costly consume great amounts of power and are bulky size Low cost Smart Antennas offers a guide to designing smart antenna systems that are low cost low power and compact in size and can be applied to satellite communications radar and mobile communications The authors noted experts on the topic provide introductions to the fundamental concepts of antennas array antennas and smart antennas The book fills a gap in the literature by presenting the design techniques of low cost radio frequency RF smart antennas as well as approaches for implementing the hardware of the antenna and the beamforming network BFN A comprehensive and accessible book Low cost Smart Antennas not only presents an up to date review of the topic but includes illustrative case studies that contain in depth explorations of the theory and technology of smart antennas While other resources highlight the software signal processing algorithms this book is unique by focusing on the antenna hardware This important book Offers an introduction to the most recent developments of the design of low cost smart antennas and their applications Presents a unique book that puts the focus on antenna hardware Includes a variety of case studies that clearly demonstrate the implementation of current design techniques Introduces both fundamental theories as well as more advanced topics Written for students and researchers and antenna engineers Low cost Smart Antennas explores the most recent advances in the field with an emphasis on antenna hardware

Handbook on Array Processing and Sensor Networks Simon Haykin, K. J. Ray Liu, 2010-02-12 A handbook on recent advancements and the state of the art in array processing and sensor Networks Handbook on Array Processing and Sensor Networks provides readers with a collection of tutorial articles contributed by world renowned experts on recent advancements and the state of the art in array processing and sensor networks Focusing on fundamental principles as well as applications the handbook provides exhaustive coverage of wavelets spatial spectrum estimation MIMO radio propagation robustness issues in sensor array processing wireless communications and sensing in multi path environments using multi antenna transceivers implicit training and array processing for digital communications systems unitary design of radar waveform diversity sets acoustic array processing for speech enhancement acoustic beamforming for hearing aid applications undetermined blind source separation using acoustic arrays array processing in astronomy digital 3D 4D ultrasound imaging technology self localization of sensor networks multi target tracking and classification in collaborative sensor networks via sequential Monte Carlo energy efficient decentralized estimation sensor data fusion with application to multi target tracking distributed algorithms in sensor networks cooperative communications distributed source coding network coding for sensor networks information theoretic studies of wireless networks distributed adaptive learning mechanisms routing for statistical inference in sensor networks spectrum estimation in cognitive radios nonparametric techniques for pedestrian tracking in wireless local area networks signal processing and networking via the theory of global games biochemical transport modeling estimation and detection in realistic environments and security and privacy for sensor networks Handbook on Array Processing and Sensor

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