

Date of publication xxxx-00-0000, date of current version xxxx-00-0000.

Digital Object Identifier 10.1109/ACCESS.2017.10000

# Robust Adaptive Beamforming with Subspace Projection and Covariance Matrix Reconstruction

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**ABSTRACT** In this paper, we present a Subspace Projection and Covariance Matrix Reconstruction (SPCMR) algorithm for adaptive beamforming to improve the robustness against large SV mismatch. The SPCMR algorithm consists of two parts: projection subspaces estimation and interference-plus-noise covariance matrix (INCM) reconstruction. Specifically, we estimate two projection subspaces containing the signal component and obtain the signal SV from their intersection. The first projection subspace is estimated from the constructed signal covariance matrix via the distortionless responses principle. The second one is gotten according to the subspace proximity between the nominal signal SV and the eigenvectors of the sample covariance matrix. Subsequently, the interference SVs are estimated by using the Capon spatial estimator, and each interference power is obtained via the oblique projectors. After that, an accurate INCM is reconstructed, and the SPCMR beamformer is proposed. Simulation results show that the SPCMR algorithm is robust to several model mismatches and outperforms other adaptive algorithms.

**INDEX TERMS** Robust adaptive beamforming, subspace projection, steering vector estimation, covariance matrix reconstruction, power estimation

## I. INTRODUCTION

ADAPTIVE beamforming is a fundamental signal processing technique and has been widely used in radar, sonar, and wireless communications to improve signal receiving quality [1]. As one of the well-known adaptive beamformer design principle, minimum variance distortionless response (MVDR) is introduced to suppress the interference and noise with the distortionless signal. However, adaptive beamformers are sensitive to slight model mismatch caused by random direction error, sensor location error, local scattering and so forth. Therefore, numerous robust adaptive beamforming (RAB) methods have been proposed to address the above issues [2]–[33]. According to the research contents and emphases, these methods can be roughly classified into two categories: signal steering vector (SV) processing-based techniques and covariance matrix processing-based techniques.

The signal SV processing-based techniques can be divided into three types: eigenspace technique [2]–[5], optimization-based technique [6]–[16], and subspace estimation-based technique [17]–[19]. The main idea of eigenspace approaches is to project the nominal SV onto the estimated signal-plus-

interference subspace to mitigate the adverse effect caused by noise subspace disturbance. However, the performance of eigenspace beamformer [2] will degrade drastically under the circumstance of low signal-to-noise ratio (SNR), since some noise eigenvalues may be larger than the signal eigenvalues and subspace swap occurs in this scenario [34]. The optimization-based technique can be roughly divided into three types: uncertainty set-based technique [6]–[9], quadratic programming-based technique [11]–[14] and subspace fitting-based technique [15], [16]. The mechanism of the uncertainty set-based technique is to limit the object parameter in a spherical or an ellipsoidal uncertainty set, and the parameter is estimated after solving an optimization problem. The quadratic programming-based technique obtains the mismatch vector by solving a quadratic programming problem. However, when the mismatch is large, or the actual parameter does not locate in the presumed set, these methods are no longer valid. For the subspace fitting technique, the signal SV is obtained by using the orthogonality of the noise subspace and the signal direction matrix. However, their computational complexity is high. To effectively reduce the problem-solving complexity, the subspace estimation-based approaches [17]–

# 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 approaches for the robust adaptive detection and beamforming in wireless communications It adopts several systems models including DS 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

em style mso-bidi-font-style normal 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

Robust Adaptive Beamforming Jian Li, Petre Stoica, 2006 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.

**Efficient Robust Adaptive Beamforming Algorithms for Sensor Arrays** Hang Ruan, 2016

[Simplified Robust Adaptive Detection and Beamforming for Wireless Communications](#) Ayman ElNashar, 2018-08-20

This book presents an alternative and simplified approaches 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.

[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

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**Robust Adaptive Beamforming Using Rao-Blackwellized Particle Filters** Rohith Chandrasekar, 2010 **Computationally Efficient Algorithms for Robust Adaptive Beamforming and Multiuser Detection** Amr Elkeyi, 2006 *Microphone Arrays* Michael Brandstein, Darren

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

Combination of Robust Adaptive Beamforming with Acoustic Echo Cancellation for Acoustic Human-machine Interfaces Wolfgang Herbordt,2004

Adaptive Signal Processing in Wireless Communications Mohamed Ibnkahla,2017-12-19 Adaptive techniques play a key role in modern wireless communication systems The concept of adaptation is emphasized in the Adaptation in Wireless Communications Series through a unified framework across all layers of the wireless protocol stack ranging from the physical layer to the application layer and from cellular systems to next generation wireless networks This specific volume Adaptive Signal Processing in Wireless Communications is devoted to adaptation in the physical layer It gives an in depth survey of adaptive signal processing techniques used in current and future generations of wireless communication systems Featuring the work of leading international experts it covers adaptive channel modeling identification and equalization adaptive modulation and coding adaptive multiple input multiple output MIMO systems and cooperative diversity It also addresses other important aspects of adaptation in wireless communications such as hardware implementation reconfigurable processing and cognitive radio A second volume in the series Adaptation and Cross layer Design in Wireless Networks cat no 46039 is devoted to adaptation in the data link network and application layers

**Communications, Signal Processing, and Systems** Qilian Liang,Xin Liu,Zhenyu Na,Wei Wang,Jiasong Mu,Baoju Zhang,2019-05-04 This book brings together papers from the 2018 International Conference on Communications Signal Processing and Systems which was held in Dalian China on July 14-16 2018 Presenting the latest developments and discussing the interactions and links between these multidisciplinary fields the book spans topics ranging from communications signal processing and systems It is aimed at undergraduate and graduate electrical engineering computer science and mathematics students researchers and engineers from academia and industry as well as government employees

*Low-cost Smart Antennas* Qi Luo,Steven Shichang Gao,Wei Liu,Chao Gu,2019-01-18 An authoritative guide to the latest

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*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 Networks is the first book of its kind and will appeal

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