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

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   Robust Adaptive Beamforming Jian Li,Petre Stoica,2005-10-10 The latest research and developments in robust adaptivebeamforming Recent work has made great strides toward devising robust adaptivebeamformers that vastly improve signal strength against backgroundnoise and directional interference This dynamic technology hasdiverse applications including radar sonar acoustics astronomy seismology communications and medical imaging There are alsoexciting emerging applications such as smart antennas for wirelesscommunications handheld ultrasound imaging systems anddirectional hearing aids Robust Adaptive Beamforming compiles the theories and work ofleading researchers investigating various approaches in onecomprehensive volume Unlike previous efforts these pioneeringstudies are based on theories that use an uncertainty set of thearray steering vector The researchers define their theories explain their methodologies and present their conclusions Methodspresented include Coupling the standard Capon beamformers with a spherical orellipsoidal 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 beamformerto adapt the weight vector within a generalized sidelobe cancellerformulation Robust Adaptive Beamforming provides a truly up to date resourceand reference for engineers researchers and graduate students inthis promising rapidly expanding field   *Robust Adaptive Beamforming Using Spatial Filter Design* Ingvar Claesson,Sven Nordholm,1990

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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   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 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 exiting 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   *Efficient Robust Adaptive Beamforming Algorithms for Sensor Arrays* Hang Ruan,2016   *Robust Adaptive Beamforming with Coherent Interferences* Lei Yu,2011   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   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 form 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

   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   **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 **Robust Adaptive Beamforming Using Rao-Blackwellized Particle Filters** Rohith Chandrasekar,2010 *Computationally Efficient Algorithms for Robust Adaptive Beamforming and Multiuser Detection* Amr Elkeyi,2006 **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 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 Networks is the first book of its kind and will appeal to researchers professors and graduate students in array processing sensor networks advanced signal processing and networking   **Academic Press Library in Signal Processing, Volume 7** ,2017-12-01 Academic Press Library in Signal Processing Volume 7 Array Radar and Communications Engineering is aimed at university researchers post graduate students and R D engineers in the industry providing a tutorial based comprehensive review of key topics and technologies of research in Array and Radar Processing Communications Engineering and Machine Learning Users will find the book to be an invaluable starting point to their research and initiatives With this reference readers will quickly grasp an unfamiliar area of research understand the underlying principles of a topic learn how a topic relates to other areas and learn of research issues yet to be resolved Presents a quick tutorial of reviews of important and emerging topics of research Explores core principles technologies algorithms and applications Edited and contributed by international leading figures in the field Includes comprehensive references to journal articles and other literature upon which to build further more detailed knowledge   **Intelligent Computing & Optimization** Pandian Vasant,Gerhard-Wilhelm Weber,José Antonio Marmolejo-Saucedo,Elias Munapo,J. Joshua Thomas,2022-10-20 This book of Springer Nature is another proof of Springer s outstanding and greatness on the lively interface of Smart Computational Optimization Green ICT Smart Intelligence and

Machine Learning It is a Master Piece of what our community of academics and experts can provide when an Interconnected Approach of Joint Mutual and Meta Learning is supported by Modern Operational Research and Experience of the World Leader Springer Nature The 5th edition of International Conference on Intelligent Computing and Optimization took place at October 27 28 2022 via Zoom Objective was to celebrate Creativity with Compassion and Wisdom with researchers scholars experts and investigators in Intelligent Computing and Optimization across the planet to share knowledge experience innovation a marvelous opportunity for discourse and mutuality by novel research invention and creativity This proceedings book of ICO 2022 is published by Springer Nature Quality Label of wonderful   *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 re searchers in the field to contribute articles addressing their specific topic s of study The reception we received from our colleagues was quite enthusi astic 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 the oretical in nature and emphasize the use of microphone arrays for speech enhancement and source localization respectively Part III presents a num ber of specific applications of array based technology Part IV addresses some open questions and explores the future of the field   Advances in Neural Networks - ISNN 2004 Fuliang Yin,2004-08-11 The two volume set LNCS 3173 3174 constitutes the refereed proceedings of the International Symposium on Neural Networks ISNN 2004 held in Dalian China in August 2004 The 329 papers presented were carefully reviewed and selected from more than 800 submissions The papers span the entire scope of neural computing and its applications they are organized in 11 major topical parts on theoretical analysis learning and optimization support vector machines blind source separation independent component analysis and principal component analysis clustering and classification robotics and control telecommunications signal image and time series analysis biomedical applications detection diagnosis and computer security and other applications

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