

Unbiased Blind Adaptive Channel Identification and Equalization

David Gesbert and Pierre Duhamel, *Fellow, IEEE*

Abstract—The blind adaptive equalization and identification of communication channels is a problem of important current theoretical and practical concerns. Recently proposed solutions for this problem exploit the diversity induced by sensor arrays or time oversampling, leading to the so-called second-order algebraic/statistical techniques. The prediction error method is one of them, perhaps the most appealing in practice, due to its inherent robustness to ill-defined channel lengths as well as for its simple adaptive implementation. Unfortunately, the performance of prediction error methods is known to be severely limited in noisy environments, which calls for the development of noise (bias) removal techniques. We present a low-cost algorithm that solves this problem and allows the adaptive estimation of unbiased linear predictors in additive noise with arbitrary autocorrelation. This algorithm does not require the knowledge of the noise variance and relies on a new constrained prediction cost function. The technique can be applied in other noisy prediction problems. Global convergence is established analytically. The performance of the denoising technique is evaluated over GSM test channels.

Index Terms—Blind equalization, blind estimation, convergence, denoising, linear prediction.

I. INTRODUCTION

BLIND channel equalization exploiting the channel diversity induced by sensor arrays and/or time oversampling has attracted a lot of research efforts over the last few years. Methods can be found in the literature, based on the optimization of various second-order criteria, which offer fast converging alternatives to the previously reported higher order statistics (HOS)-based techniques [1], [2]. For the most part, algebraic and second-order statistical techniques have been proposed that exploit the structural properties (Hankel, Toeplitz, *et al.*) of the single-input multiple-output (SIMO) channel or data matrices. The information on channel parameters or transmitted data is typically recovered through subspace decompositions of the received data matrix (deterministic methods, e.g., [3], [8], [9], [10]) or that of the received data correlation matrix (stochastic methods, e.g., [4], [6]).

Although very appealing from the conceptual and signal processing points of view, the use of the aforementioned techniques in real-world telecom applications faces serious

challenges. First, subspace-based techniques are usually computationally involved and difficult to implement in contexts with strict delay/complexity constraints. To a large extent, adaptive signal processing solutions are better suited to high dynamic conditions commonly encountered in telecom (especially wireless) applications. Note, however, that instances of adaptive second-order equalization methods can be found, including [11] and [16].

Another drawback of subspace-based methods lies in the fact that they rely on the existence of numerically well-defined dimensions of the signal or noise subspaces or other related subspaces. Since these dimensions are obviously closely related to the channel length, subspace-based techniques are extremely sensitive to channel order modeling errors [7].

The prediction error methods (PEM's) offer an alternative to the class of techniques above. PEM's, which were first introduced in [5] and later refined in [7], exploit the i.i.d. property of the transmitted symbols and apply a minimum prediction error filter on the received data. When the PE filter is chosen long enough, the filter output becomes white and corresponds to a signal free of intersymbol-interference (ISI), which in turn can be used to estimate the channel.

The PEM offers great practical advantages over most other proposed techniques. First, channel estimation using the PE method remains consistent in the presence of channel length mismatch.¹ In fact, we can actually improve the reconstruction performance offered by PEM by capturing the energy of the more distant and less significant channel taps (which corresponds to a practical case of channel length overestimation) just by increasing the prediction horizon. This property guarantees the robustness of the technique with respect to the difficult channel length estimation problem. This is unlike subspace-based approaches in which the incorporation of smaller taps in the channel model introduces ambiguities and degrades the identification/equalization performance. Another significant advantage of the PE method is that it lends itself easily to a low-cost adaptive implementation.

Unfortunately the PEM not only has attractive properties, but it is also known to be sensitive to channel additive noise. Additive noise induces residual ISI in the output of the prediction error filter, which in turn causes inconsistency in the channel estimate. For this reason, a denoising procedure must be applied to remove the predictor's bias [7].

In the existing batch implementations of PEM, we solve the noise problem by removing the pre-estimated noise contribution from the signal's second-order statistics. Then, approximately

¹When the assumed channel length is greater than the theoretical channel length.

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D. Gesbert is with Gigabit Wireless, Inc., Mountain View, CA 94043 USA, on leave from the Information Systems Laboratory, Stanford University, Stanford CA 94305 USA (e-mail: gesbert@nocsli.stanford.edu).

P. Duhamel is with Telecom Paris/STG, Paris, France, (e-mail: duhamel@sig.ensst.fr).

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Blind Channel Equalization And Identification

Lajos Hanzo



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Blind Channel Identification and Equalization Using Cyclostationary And/or Higher Order Statistics Ye Li, 1994

Blind Equalization and System Identification Chong-Yung Chi, Chih-Chun Feng, Chii-Horng Chen, Ching-Yung Chen, 2006-05-20 The absence of training signals from many kinds of transmission necessitates the widespread use of blind equalization and system identification There have been many algorithms developed for these purposes working with one or two dimensional signals and with single input single output or multiple input multiple output real or complex systems It is now time for a unified treatment of this subject pointing out the common characteristics of these algorithms as well as learning from their different perspectives Blind Equalization and System Identification provides such a unified treatment presenting theory performance analysis simulation implementation and applications This is a textbook for graduate courses in discrete time random processes statistical signal processing and blind equalization and system identification It contains material which will also interest researchers and engineers working in digital communications source separation speech processing and other similar applications

Blind Channel Identification and Equalization Using Subspace Algorithm Muzahid Shah Abdul Rahman, 2007

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Signal Processing for Wireless Communication Systems H. Vincent Poor, Lang Tong, 2002-03-31 Signal Processing for Wireless Communication Systems brings together in one place important contributions and up to date research results in this fast moving area The Contributors to this work were selected from

leading researchers and practitioners in this field The book s 18 chapters are divided into three areas systems Networks and Implementation Issues Channel Estimation and Equalization and Multiuser Detection The Work originally published as Volume 30 Numbers 1 3 of the Journal of VLSI Signal Processing Systems for Signal Image and Video Technology will be valuable to anyone working or researching in the field of wireless communication systems It serves as an excellent reference providing insight into some of the most challenging issues being examined today

Adaptive Filtering Paulo S. R. Diniz, 2019-11-28 In the fifth edition of this textbook author Paulo S R Diniz presents updated text on the basic concepts of adaptive signal processing and adaptive filtering He first introduces the main classes of adaptive filtering algorithms in a unified framework using clear notations that facilitate actual implementation Algorithms are described in tables which are detailed enough to allow the reader to verify the covered concepts Examples address up to date problems drawn from actual applications Several chapters are expanded and a new chapter Kalman Filtering is included The book provides a concise background on adaptive filtering including the family of LMS affine projection RLS set membership algorithms and Kalman filters as well as nonlinear sub band blind IIR adaptive filtering and more Problems are included at the end of chapters A MATLAB package is provided so the reader can solve new problems and test algorithms The book also offers easy access to working algorithms for practicing engineers

Advances in Neural Networks - ISSN 2007 Derong Liu, Zeng-Guang Hou, 2007-05-24 Annotation The three volume set LNCS 4491 4492 4493 constitutes the refereed proceedings of the 4th International Symposium on Neural Networks ISSN 2007 held in Nanjing China in June 2007 The 262 revised long papers and 192 revised short papers presented were carefully reviewed and selected from a total of 1 975 submissions The papers are organized in topical sections on neural fuzzy control neural networks for control applications adaptive dynamic programming and reinforcement learning neural networks for nonlinear systems modeling robotics stability analysis of neural networks learning and approximation data mining and feature extraction chaos and synchronization neural fuzzy systems training and learning algorithms for neural networks neural network structures neural networks for pattern recognition SOMs ICA PCA biomedical applications feedforward neural networks recurrent neural networks neural networks for optimization support vector machines fault diagnosis detection communications and signal processing image video processing and applications of neural networks

Blind Equalization and Identification of Time-varying Communication Channels Weilin Luo, 2003

Quadrature Amplitude Modulation Lajos Hanzo, 2004-11-30 Motivated by the rapid evolution of the consecutive generations of wireless communication systems this volume continues to provide an overview of the majority of single and multi carrier QAM techniques Now fully revised and updated with more than 300 pages of new material this new edition presents the wide range of recent developments in the field and places particular emphasis on the family of coded modulation aided OFDM and CDMA schemes In addition it also includes a fully revised chapter on adaptive modulation and a new chapter characterizing the design trade offs of adaptive modulation and space time coding Divided

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Wireless Communications Giorgio A. Vitetta, Desmond P. Taylor, Giulio Colavolpe, Fabrizio Pancaldi, Philippa A. Martin, 2013-03-29 This book introduces the theoretical elements at the basis of various classes of algorithms commonly employed in the physical layer and in part in MAC layer of wireless communications systems It focuses on single user systems so ignoring multiple access techniques Moreover emphasis is put on single input single output SISO systems although some relevant topics about multiple input multiple output MIMO systems are also illustrated Comprehensive wireless specific guide to algorithmic techniques Provides a detailed analysis of channel equalization and channel coding for wireless applications Unique conceptual approach focusing in single user systems Covers algebraic decoding modulation techniques channel coding and channel equalisation

Wireless Communication Systems Ke-Lin Du, M. N. S. Swamy, 2010-04-15 This practically oriented all inclusive guide covers all the major enabling techniques for current and next generation cellular communications and wireless networking systems Technologies covered include CDMA OFDM UWB turbo and LDPC coding smart antennas wireless ad hoc and sensor networks MIMO and cognitive radios providing readers with everything they need to master wireless systems design in a single volume Uniquely a detailed introduction to the properties design and selection of RF subsystems and antennas is provided giving readers a clear overview of the whole wireless system It is also the first textbook to include a complete introduction to speech coders and video coders used in wireless systems Richly illustrated with over 400 figures and with a unique emphasis on practical and state of the art techniques in system design rather than on the mathematical foundations this book is ideal for graduate students and researchers in wireless communications as well as for wireless and telecom engineers

Blind Identification and Equalization of Nonminimum Phase Channel Using Second-order Cyclostationary Statistics Kai He, 1995 *1997 IEEE Workshop on Signal Processing Advances in Wireless Communications* IEEE Signal Processing Society, 1997 *2002 6th International Conference on Signal Processing* Baozong Yuan, Xiaofang Tang, 2002 **A Novel Approach for Adaptive Signal Processing** Ya-Chin Chen, Institute for Computer Applications in Science and Engineering, 1998 Abstract Adaptive linear predictors have been used extensively in practice in a

wide variety of forms In the main their theoretical development is based upon the assumption of stationarity of the signals involved particularly with respect to the second order statistics On this basis the well known normal equations can be formulated If high order statistical stationarity is assumed then the equivalent normal equations involve high order signal moments In either case the cross moments second or higher are needed This renders the adaptive prediction procedure non blind A novel procedure for blind adaptive prediction has been proposed and considerable implementation has been made in our contributions in the past year The approach is based upon a suitable interpretation of blind equalization methods that satisfy the constant modulus property and offers significant deviations from the standard prediction methods These blind adaptive algorithms are derived by formulating Lagrange equivalents from mechanisms of constrained optimization In this report other new update algorithms are derived from the fundamental concepts of advanced system identification to carry out the proposed blind adaptive prediction The results of the work can be extended to a number of control related problems such as disturbance identification The basic principles are outlined in this report and differences from other existing methods are discussed The applications implemented are speech processing such as coding and synthesis Simulations are included to verify the novel modelling method

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