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Adaptive signal processing (ASP) and iterative signal processing (ISP) are important techniques in improving the performance of receivers in communication systems. Using examples from practical transceiver designs, this book describes the fundamental theory and practical aspects of both methods, providing a link between the two where possible. The book is divided into three parts: the first two parts deal with ASP and ISP, respectively, each in the context of receiver design over intersymbol interference (ISI) channels. In the third part, the applications of ASP and ISP to receiver design in other interference-limited channels, including CDMA and MIMO, are considered; the author attempts to illustrate in this section how the two techniques can be used to solve problems in channels that have inherent uncertainty. With illustrations and worked examples, this text will be suitable for graduate students and researchers in electrical engineering, as well as for practitioners in the telecommunications industry. Further resources for this title are available online at www.cambridge.org/9780521864862.

Professor Jinho Choi received his Ph.D. in electrical engineering from the Korea Advanced Institute of Science and Technology (KAIST) in 1994. He currently holds a Chair position in the Institute of Advanced Telecommunications (IAT), the University of Wales Swansea, UK. He is a senior member of the IEEE and an associate editor of *IEEE Transactions on Vehicular Technology* and an editor of the *Journal of Communications and Networks*. In 1999, he was awarded the Best Paper Award for Signal Processing from EURASIP.

Preface

Various signal processing techniques are actively used in communication systems to improve the performance. In particular, adaptive signal processing has a strong impact on communications. For example, various adaptive algorithms are applied to the channel equalization and interference rejection. Adaptive equalizers and interference cancellers can effectively mitigate interference and adapt to time-varying channel environments.

Even though iterative signal processing is not as advanced as adaptive signal processing, it plays a significant role in improving the performance of receivers, which may be limited by interfering signals. In addition, the estimation error of certain channel parameters, for example the channel impulse response, can degrade the performance. An improvement in interference cancelation or a better estimate of channel parameters may be available due to iterative signal processing. After each iteration, more information about interfering signals or channel parameters is available. Then, the interference cancelation is more precise and the channel parameters can be estimated more accurately. This results in an improvement in performance for each iteration.

It would be beneficial if we could study adaptive and iterative signal processing with respect to communications. There are a number of excellent books on adaptive signal processing and communication systems, though it is difficult to find a single book that covers both topics in detail. Furthermore, as iterative signal processing is less advanced, I have been unable to find a book that balances the subjects of signal processing and its applications in communication. My desire to locate such a book increased when I took a postgraduate course entitled "Adaptive Signal Processing in Telecommunications." This provided me with the motivation to write this book, in which I attempt to introduce adaptive and iterative signal processing along with their applications in communications.

This book can be divided into three parts. In Part I, we introduce intersymbol interference (ISI) channels and adaptive signal processing techniques for ISI channels. The ISI channel is a typical interference-limited channel, and its performance is limited by the ISI. There are a number of methods used to mitigate the ISI to improve the performance. The reader will learn how adaptive signal processing techniques can be used successfully to mitigate the ISI.

In Part II, two different key methods for iterative signal processing are introduced. One is based on the expectation-maximization (EM) algorithm and the other is based on the turbo-principle. The EM algorithm was introduced to solve the maximum likelihood (ML) estimation problem. The EM algorithm is an iterative algorithm that can find ML estimates numerically. Since the EM algorithm is numerically stable and improves the likelihood through iterations, it has been extensively studied in statistics. In statistical signal processing areas, the EM algorithm is regarded as a standard approach for parameter estimation problems. As the channel estimation problem is a parameter estimation problem, it is natural to apply the EM algorithm.

The turbo-principle was quite a suprising idea when it appeared for turbo decoding. The performance of a simple channel code can approach a limit with the turbo decoding algorithm of reasonably low complexity. Once the turbo-principle was understood, it was widely adopted to solve difference problems including the channel equalization problem. Based on the turbo-principle, turbo equalizers were employed suppress the ISI effectively through iterations.

In Part III, we introduce different interference-limited channels. Code division multiple access (CDMA) systems suffer from multiuser interference (MUI). Therefore, the performance of CDMA is limited by MUI and can be improved by sucessfully mitigating it. Multiple input multiple output (MIMO) channels are also interference-limited since multiple transmit antennas transmit signals simultaneously and the transmitted signals from the other antennas become interfering signals. For both CDMA and MIMO channels, adaptive and iterative signal processing techniques are used to mitigate interfering signals effectively and estimate channels more precisely.

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Symbols

$\mathbf{b}$	symbol vector
b_l	(binary) data symbol transmitted at time l
$\{b_m\}$	symbol sequence
$f(\cdot)$	generic expression for a pdf
$\mathbf{h}$	CIR
$\mathbf{h}_l$	CIR at time l
$\Im(x)$	imaginary part of a complex number x
$\Re(x)$	real part of a complex number x
$\mathbf{R}_\mathbf{y}$	covariance matrix of $\mathbf{y}$
$\lceil x \rceil$	smallest integer that is greater than or equal to x
$\lfloor x \rfloor$	largest integer that is smaller than or equal to x
$\mathbf{y}$	received signal vector
y_l	received signal at time l
$\{y_m\}$	received signal sequence

Abbreviations

AWGN	additive white Gaussian noise
BCJR algorithm	Bahl–Cocke–Jelinek–Raviv algorithm
BER	bit error rate
CAI	co-antenna interference
cdf	cumulative density function
CDMA	code division multiple access
CIR	channel impulse response
CLT	central limit theorem
CP	cyclic prefix
CRB	Cramer–Rao bound
CSI	channel state information
DFE	decision feedback equalization (or equalizer)
EGC	equal gain combining
EM	expectation-maximization
EXIT	extrinsic information transfer
FBF	feedback filter
FFF	feedforward filter
FIR	finite impulse response
IDD	iterative detector and decoder
iid	independent identically distributed
ISI	intersymbol interference
KF	Kalman filter
LE	linear equalization (or equalizer)
LLR	log likelihood ratio
LMS	least mean square
LRT	likelihood ratio test
LS	least squares
MAI	multiple access interference
MAP	maximum *a posteriori* probability
MIMO	multiple input multiple output
ML	maximum likelihood
MLSD	maximum likelihood sequence detection
MMSE	minimum mean square error
MRC	maximal ratio combining

MSE	mean square error
MUI	multiple user interference
OFDM	orthogonal frequency division multiplexing
PAPR	peak-to-average-power ratio
pdf	probability density function
PSP	per-survivor processing
RLS	recursive least square
SC	soft (interference) cancelation
SD	selection diversity
SINR	signal-to-interference-plus-noise ratio
SNR	signal-to-noise ratio
VA	Viterbi algorithm
ZF	zero-forcing

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