Multi-antenna Transceiver Techniques for 3G and Beyond

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Preface

The target of this book is to present the core ideas behind a very up-to-date research area involving modulation design for multi-input multi-output (MIMO) wireless channels. Our discussion is aimed at presenting the key principles of different mathematical and engineering approaches that have recently emerged in a number of current and upcoming standards. We restrain ourselves from delving into the physical aspects related to the design of practical antenna elements for mobile or fixed wireless communication units. Rather, we choose to explore and develop multi-antenna transceiver techniques from the signal processing perspective. Such an approach is commonly used when proposing and developing new coding or modulation concepts for wireless systems.

Many of the concepts described herein are aimed at improving data rates, signal quality, capacity or system flexibility. To reach this goal, we adopt matrix-valued modulation alphabets, defined over two orthogonal dimensions, usually referred to as *space* and *time*. The space-dimension is realized by using multiple transmit and receive antennas, and involve multi-antenna transceiver structures. Such multi-antenna techniques are generally considered as the most promising avenue for significantly increasing the bandwidth efficiency of wireless data transmission systems. In MIMO systems, multiple antennas are deployed both at the transmitter and the receiver. In ideal situations, this allows signalling over several parallel channels between the transmitter and receiver. These channels can be separated using signal processing means, provided that the channels are sufficiently different. In MISO (multiple-input single-output) systems, the receiver has only one antenna, and the multiple transmit antennas are used for transmit diversity.

This book presents the key aspects of multiple antenna transceiver techniques for evolving 3G systems and beyond. MIMO and MISO (transmit diversity) techniques are explained in a common setting. A special emphasis is put on combining theoretical understanding with engineering applicability.

In particular, the book covers linear processing transmit diversity methods with and without side information at the transmitter, including a description of the current transmit diversity concepts in the WCDMA and cdma2000 standards, as well as promising MIMO concepts, crucial for future high data-rate systems. Furthermore, examples of high throughput, low complexity matrix modulation schemes will be provided, when signalling without side information (open loop concepts). The theory of linear matrix modulations will be developed, and optimal non-orthogonal high throughput schemes will be constructed, both for MIMO and MISO systems.

Performance may be further improved by feedback from receiver to transmitter. The corresponding closed-loop modes in the current 3GPP specifications will be discussed, along with their extensions for more than two transmit antennas. In addition, feedback signalling for MIMO channels will be addressed, as well as optimal quantization methods of the feedback messages. Finally, hybrid schemes are constructed, where the amount of overhead due to feedback is reduced by combining open-loop transmission with closed-loop signalling.

We would like to express our gratitude to a number of colleagues who have helped in preparing this work. We thank Drs Jyri Hämäläinen, Rinat Kashaev and Jussi Vesma and Mr Mikko Kokkonen for fruitful collaboration related to the subject matter of this book. Numerous discussions with colleagues at Nokia Research Center are also acknowledged. Drs Nikolai Nedefov and Kari Kalliojärvi provided a number of constructive comments that enabled us to improve the readability of the text. Financial support from Nokia Foundation is also gratefully acknowledged. A large part of the results documented here have been developed at Nokia Research Center in recent years with support from Dr Jorma Lilleberg at Nokia Mobile Phones. Finally, we appreciate the seemingly unlimited patience of our respective home troops.

Acronyms

AMC	Adaptive Modulation and Coding
AOA	Angle Of Arrival
ARQ	Automatic Repeat reQuest
AS	Azimuth Spread
ASTMA	Adaptive Space–Time Modulation Arrangement
BEP	Bit-Error Probability
BER	Bit-Error Rate
BICM	Bit Interleaved Coded Modulation
BLAST	Bell Laboratories Layered Space-Time architecture
BPSK	Binary PSK
BS	Base Station
CDMA	Code Division Multiple Access
CDTD	Code Division Transmit Diversity
CL	Closed-Loop
CPICH	Common PIlot CHannel
CQI	Channel Quality Indicator
CSI	Channel State Information
DOT	Direction Of Transmission
DSTTD	Double STTD
D-BLAST	Diagonal BLAST