

Contents

Abstract	iii
Resumen	v
Resum	ix
Acknowledgements	xi
List of symbols	xxiii
Abbreviations and Acronyms	xxv
1 Introduction	1
1.1 Introduction	3
1.2 Motivation and Scope	8
1.3 Key Contributions	11
1.4 Organization of the Thesis	13
2 Preliminaries and State of the Art	17
2.1 Multiple-Input Multiple-Output Systems	19
2.1.1 The BLAST System	19
2.1.2 Capacity of the MIMO Channel	23
2.1.3 Maximum-Likelihood Detection	24
2.2 Linear and Successive Interference Cancellation Detectors	26
2.2.1 Matched Filter Detector	26
2.2.2 Zero-Forcing and Minimum Mean Square Error Detectors	26
2.2.3 Successive Interference Cancellation Detectors	27
2.2.4 Reordered Detection	28
2.2.5 Performance Comparison	29
2.3 Tree-Search-Based Detection/Sphere Decoding	31
2.3.1 Sphere Decoding Fundamentals	31
2.3.2 Fincke-Pohst and Schnorr-Euchner Enumerations	37
2.3.3 K-Best Sphere Decoder	39

2.3.4	Automatic Sphere Decoder	41
2.3.5	Fixed-Complexity Sphere Decoder	42
2.4	MIMO-Bit-Interleaved Coded-Modulation Systems	45
2.4.1	System Model and Log-Likelihood-Ratios	45
2.4.2	Tree-Search-Based Soft Demodulation	47
2.5	Multiuser MIMO-OFDM Communication Systems	48
2.5.1	System Model	48
2.5.2	Vector Perturbation Precoding	50
2.5.3	Zero-Forcing Precoding	51
2.5.4	Tomlinson-Harashima Precoding	51
2.5.5	Lattice-Reduction-Aided Precoding	52
2.6	Conclusion	53
3	MIMO Preprocessing Techniques	55
3.1	Introduction	57
3.2	VBLAST ZF-DFE Ordering	59
3.2.1	Algorithm Description	59
3.2.2	Complexity Analysis	60
3.2.3	Low-Complexity Implementation	61
3.2.4	Performance Evaluation	64
3.3	Lattice-Reduction Algorithms	64
3.3.1	LLL and Seysen's Algorithms	66
3.3.2	Complexity Analysis	69
3.3.3	Performance Evaluation	71
3.4	Complexity and Performance Comparison	72
3.5	Conclusion	76
4	Efficient Hard-Output Detection	79
4.1	Introduction	82
4.2	Variable-Breadth K-Best Detector	83
4.3	Channel Matrix Condition Number Estimator	86
4.3.1	The Power Method to Estimate σ_{max}	87
4.3.2	Estimator of σ_{min}^{-1}	88
4.3.3	Joint Estimator of $\kappa(\mathbf{H})$	88
4.4	Threshold Selection	89
4.5	LRA K-Best Detector Based on Condition Number	92
4.6	Results	95
4.6.1	VB K-Best Detector	95
4.6.2	LRA K-Best Based on Condition Number	100

4.7	Conclusion	103
5	Efficient Lattice-Reduction-Aided Algorithms	105
5.1	Introduction	107
5.2	LRA-SIC K-Best detection	109
5.3	LRA K-Best Detector	112
5.3.1	Boundary Calculation of the Transformed Lattice Points	114
5.3.2	Extended LLL Algorithm	115
5.3.3	Performance Evaluation	117
5.3.4	Computational Cost Analysis	118
5.4	Complexity Reduction Using Boundaries	120
5.4.1	LRA K-Best with Candidate Limitation	120
5.4.2	Dynamic-K and Dynamic-N LRA K-Best Detectors	122
5.5	Relationship among the proposed hard-output schemes	127
5.6	Multiuser Precoding using the Extended LLL Method . . .	129
5.6.1	Lattice-Reduction-Aided Precoding	130
5.6.2	Enhanced Lattice-Reduction-Aided Precoding	130
5.6.3	Lattice-Reduction-Aided Tomlinson-Harashima Pre- coding	131
5.6.4	Performance Comparison	132
5.6.5	Computational Cost Analysis and Comparison . . .	134
5.7	Conclusion	139
6	Efficient Soft-Output Detection	141
6.1	Introduction	143
6.2	System model	145
6.3	Soft-output Fixed-complexity Detection	148
6.4	Proposed SFSD with quantized outputs	150
6.4.1	Quantization-based Pruning	151
6.4.2	Clipping-based Pruning	151
6.5	Results	152
6.6	Conclusion	156
7	GPU Implementation of MIMO Detectors	159
7.1	Introduction	162
7.2	GPU and CUDA	163
7.2.1	CUDA Programming Model	163
7.2.2	GPU Architecture	167

7.3	Algorithms Selected for GPU Implementation	168
7.3.1	FSD versus K-Best	168
7.3.2	Proposed Soft-Output Detection Scheme	169
7.4	Implementation of MIMO Detection Algorithms in CUDA .	172
7.4.1	Hard-Output FSD	173
7.4.2	Soft-Output FSD	175
7.4.3	Fully-Parallel SFSD	178
7.5	Results	180
7.5.1	Configuration Parameters and Performance Measures	180
7.5.2	Hard-Output FSD	182
7.5.3	Soft-Output FSD	185
7.5.4	Fully-Parallel SFSD	190
7.6	Conclusion	195
8	Conclusions	197
8.1	Summary	199
8.2	Further Work	201
8.3	List of Publications	203
	Bibliography	208