



Contents

Certificate	iv
Declaration	v
Acknowledgments	vi
Abstract	vii
List of Tables	xii
List of Figures	xiii
List of Acronyms	xv
1 Introduction	1
1.1 Evolution of Wireless Access Technologies	3
1.2 Significance of research	3
1.3 Thesis Organization	5
2 Background and Related work: MIMO Wireless Communication	7
2.1 Introduction	7
2.1.1 MIMO Wireless System model	7
2.2 MIMO Channel Capacity Analysis	8
2.2.1 Shannon capacity of wireless channels	9
2.2.2 Ergodic Capacity	13
2.2.3 Outage Capacity	16
2.3 MIMO Performance Gains	18
2.3.1 Spatial Multiplexing Gain	18
2.3.2 Spatial Diversity Gain	18
2.3.3 Array Gain	19
2.3.4 Interference Canceling Gain	20
2.4 Tradeoffs in MIMO Wireless System	20
2.4.1 Diversity-Multiplexing Tradeoff	21
2.5 MIMO Transmission Techniques	23
2.6 GUI for Capacity and Performance Analysis	24
2.7 Concluding Remarks	26
3 Conceptual Design of MIMO Wireless Systems	27
3.1 Introduction	27
3.2 System Design Methodology	27
3.2.1 Hardware Concept of MIMO Wireless System	28
3.2.2 MIMO Wireless Testbeds and Prototypes	31
3.3 Model-Based Design for Rapid Prototyping	31
3.3.1 Mathworks Model-based Design	32
3.3.2 MATLAB Design Tools for FPGA	33
3.3.3 MATLAB Design Tools for DSP	35

3.4	Case Study: Wireless control of FTE Robot	36
3.4.1	Overview of FTE Robot	37
3.4.2	Wireless Module	39
3.4.3	Implementation	40
3.5	Concluding Remarks	42
4	Long Term Evolution-Advanced: Downlink Physical Layer	43
4.1	Introduction	43
4.2	E-UTRAN Architecture and Protocol Stack	45
4.3	LTE Downlink Physical Layer	48
4.3.1	LTE Frame and Subframe Structure	48
4.3.2	Downlink Slot Structure	49
4.3.3	Downlink Physical Channel Processing	51
4.4	MIMO Downlink Transmission modes	53
4.4.1	Transmit Diversity	53
4.4.2	Spatial Multiplexing	53
4.5	LTE-A Downlink Link Level Simulator	55
4.5.1	LTE Transmitter	56
4.5.2	Channel Model	57
4.5.3	LTE Receiver	57
4.5.4	Simulation Results	58
4.6	Results Summary	63
4.7	Concluding Remarks	66
5	Soft-Computing Techniques and Development Tools	67
5.1	Overview of Soft-Computing Techniques	67
5.2	Fuzzy Logic System	69
5.2.1	MATLAB Simulation-Fuzzy Logic Toolbox	71
5.3	Artificial Neural Networks	73
5.3.1	McCulloch and Pitts Model of Neuron	73
5.3.2	ANN Network Architectures	75
5.3.3	Designing Neural Network	76
5.3.4	MATLAB Simulation: Neural Network Toolbox	77
5.4	Genetic Algorithms	80
5.4.1	Introduction	80
5.4.2	MATLAB Simulation: Global Optimization Toolbox	81
5.5	Applications of Soft Computing Techniques in Wireless Communication	83
5.6	Concluding Remarks	84
6	Artificial Neural Network Based MIMO Channel Estimation	85
6.1	Introduction	85
6.2	LTE-A MIMO channel estimation	85
6.3	ANN based MIMO Channel Estimation	87
6.3.1	ANN Simulation Parameters and results	90
6.4	ANN trained by Genetic Algorithm for MIMO Channel Estimation	93
6.4.1	ANN-GA Simulation Parameters and Result	95
6.5	Concluding Remarks	96

7 Fuzzy Logic Decision model for MIMO mode switching	97
7.1 Introduction	97
7.2 MIMO Channel Condition Number	97
7.2.1 Statistics of Demmel Condition Number	98
7.3 Investigation of Switching Point between TxD and OLSM for 2x2 MIMO	104
7.4 FL Decision model for MIMO mode switching	105
7.4.1 Fuzzification	106
7.4.2 Fuzzy Rule Base	107
7.4.3 Defuzzification	108
7.4.4 FL Decision Algorithm	108
7.5 Simulation Parameters and Results	109
7.6 Conclusion	115
8 Hardware Implementation of Throughput Optimization Algorithms	116
8.1 Embedded Architecture Implementation	116
8.1.1 XUP Atlys Spartan-6 Development Kit	117
8.1.2 TMS320C6713 DSP Starter Kit	118
8.1.3 Implementation of FL Decision model for MIMO mode switching	119
8.1.3.1 Implementation on Atlys Spartan 6 Development kit	120
8.1.3.2 Implementation on TMS320C6713 DSP Starter Kit	121
8.1.3.3 Implementation Results	123
8.1.4 Implementation of ANN based MIMO Channel Estimation	127
8.1.4.1 Implementation on TMS320C6713 DSP Starter Kit	128
8.1.4.2 Implementation Results	128
8.2 Concluding Remarks	132
9 Conclusion and Further developments	133
9.1 Research Contributions	133
9.1.1 Channel Capacity Analysis and Conceptual Design of MIMO Wireless System	133
9.1.2 Performance Analysis of LTE-A Downlink Physical Layer	134
9.1.3 Throughput Optimization of LTE-A Downlink Physical Layer	135
9.1.3.1 ANN based Channel Estimation Technique	135
9.1.3.2 FL Decision model for MIMO mode switching	135
9.1.3.3 GUI developed for performance analysis of MIMO Wireless System	136
9.2 Further Developments	137
10 Bibliography	138
Appendix A: User manual for GUI of Embedded Architecture Using Soft-Computing Techniques for Parametric Optimization of MIMO Wireless System	162
Appendix B: Development Tools and Software programs	168
Appendix C: Photo Gallery	171
Appendix D: Research Publications	174
Appendix E: Training Programs attended based on Research Work	176