

Contents

Summary	i
Acknowledgements	ii
List of Figures	vii
List of Tables	xii
Abbreviations	xiii
Notations	xvii
1 Introduction	1
1.1 Motivation and Research Focus	1
1.2 Outline	3
2 Fundamentals of Interference Channels	7
2.1 Interference Channel	7
2.1.1 System Model	8
2.1.2 Two-User Interference Channel Capacity	9
2.2 Known Results of Interference Channel Capacity	11
2.2.1 Interference-Free Channel	11
2.2.2 Strong Interference Channel	12
2.2.2.1 Very Strong Interference Channel	14
2.2.2.2 Moderately Strong Interference Channel	16
2.2.3 Mixed Interference Channel	17
2.2.4 Noisy Interference Channel	19
2.3 Achievable Rate Region of an Interference Channel	23
2.3.1 Inner Bounds	24
2.3.1.1 Treating Interference as Noise	24
2.3.1.2 Orthogonalization	25
2.3.1.3 Joint Decoding	26
2.3.1.4 Han-Kobayashi Scheme	26
2.3.2 Outer Bounds	29
2.3.2.1 No Interference Outer Bound	30
2.3.2.2 Genie-aided Outer Bound	30
2.4 Simple Han-Kobayashi Scheme	31
2.4.1 Overview	31
2.4.2 Characterization of Interference Mitigation Techniques	38
2.4.3 Achievable Rate Regions	40
2.4.3.1 Weak Interference Channel	41

2.4.3.2	Mixed Interference Channel	46
2.4.3.3	Conclusions	47
2.5	Conclusions	47
3	Han-Kobayashi Scheme for Cellular Wireless Networks	49
3.1	Downlink Multi-cell OFDMA Networks	49
3.1.1	Introduction	50
3.1.2	Interference-limited Scenarios	51
3.1.2.1	Interference from Macro-cells	52
3.1.2.2	Interference between Macro- and Small-cells	53
3.1.2.3	Conclusions	53
3.2	Coordinated Multipoint Transmission Strategies	55
3.2.1	Joint Processing	55
3.2.2	Coordinated Scheduling/Coordinated Beamforming	56
3.3	Comparison of Interference Avoidance and Interference Exploitation	59
3.3.1	A Case Example of a Heterogeneous Network	59
3.3.2	Interference Avoidance	61
3.3.2.1	Sum-rate Maximization without Peak Subcarrier Power Constraint	61
3.3.2.2	Sum-rate Maximization s.t. Peak Subcarrier Power Constraint	63
3.3.2.3	Conclusions	63
3.3.3	Interference Exploitation	64
3.4	Application Scenarios of a Han-Kobayashi Scheme	65
3.4.1	Macro-Macro Interference Scenario	65
3.4.2	Macro-Pico Interference Scenario	68
3.5	On the Expanded Region of a Pico-cell	72
3.5.1	System Model	73
3.5.2	Interference Scenario 1	74
3.5.3	Interference Scenario 2	75
3.5.4	Key Design Aspects	75
3.6	Conclusions	76
4	Successive Decoding for Han-Kobayashi based Interference Exploitation	77
4.1	Capacity-Approaching Coding and Modulation	77
4.1.1	Coded Modulation	78
4.1.2	Trellis Coded Modulation	78
4.1.3	Multi-level Coding	79
4.1.4	Bit-Interleaved Coded Modulation	79
4.1.5	Superposition Coded Modulation (SCM)	80
4.2	Detection-Decoding for Two-User MAC	82
4.2.1	Joint Detection-Decoding	82
4.2.2	Iterative Detection-Decoding	83
4.2.3	Rate Splitting with Single-User Detection-Decoding	85
4.3	Detection-Decoding for Interference Channel	86
4.3.1	Joint Detection-Decoding	86
4.3.2	Iterative Detection-Decoding	87
4.3.3	Rate Splitting Scheme for a Two-User MAC	90
4.4	Multi-Layer Rate Splitting for Joint Decoding	91

4.4.1	System Structure	92
4.4.2	Power Allocation for $L = 2$	94
4.4.3	Power Allocation for $L = 3$	97
4.4.4	Power Allocation for any L	99
4.4.5	Extension to Weak Interference Channels	101
4.5	Conclusions	105
5	System Design of Multi-Layer Rate Splitting	107
5.1	Analysis and Design of SCM	107
5.1.1	System Model	107
5.1.2	Iterative Detection and Decoding Receiver	109
5.1.3	Detection Schemes	110
5.1.3.1	MSD and Log-APP Detection	110
5.1.3.2	Parallel Independent Decoding (PDL)	112
5.1.3.3	Linear Detection (LD)	113
5.1.3.4	MSD with MMSE Detection	117
5.1.3.5	Simulation Results and Discussion	119
5.1.4	Design of superposition coded modulation (SCM) Systems	119
5.1.4.1	Signal Constellation Generation	121
5.1.4.2	Capacity Comparison and Discussion	121
5.2	MLRS System based on SCM-OFDM	123
5.2.1	Application Scenario	123
5.2.2	Transmitter Structure based on SCM-OFDM	125
5.2.3	Receiver Structure for Interference Exploitation	127
5.2.3.1	Receiver Structure in a Weak Interference Channel	128
5.2.3.2	Receiver Structure in a Strong Interference Channel	130
5.2.3.3	Performance Evaluation Setup	131
5.3	Interference-Aware Detection Techniques	131
5.3.1	Tree Search Based Joint Detection	133
5.3.2	Interference Randomization	134
5.3.3	Interference Avoidance	136
5.3.4	Simulation Results and Discussion	136
5.4	Conclusions	139
6	MLRS System for Practical Applications	141
6.1	Application of the Simple Han-Kobayashi Scheme	141
6.1.1	Transmitter Structure	141
6.1.2	Two-Step Decoding Receiver	142
6.1.3	Simulation Results and Discussion	143
6.2	Optimal Power Allocation for an MLRS System	145
6.2.1	The Power Allocation Optimization Problem	145
6.2.2	Optimal Power Splitting for $L = 2$	146
6.2.3	Optimal Power Splitting for $L = 3$	149
6.2.4	Simulation Results and Discussion	152
6.3	Distributed Power Allocation for an MLRS System	154
6.3.1	Brief Review of Game Theory	154
6.3.2	Problem Formulation as a Game	157
6.3.2.1	Maximization of Sum Rate of all players	157
6.3.2.2	Maximization of Sum Rate of all Layers	158
6.3.2.3	Maximization of Sum Logarithmic SINR of all Layers	160

6.3.2.4	Maximization of Sum Mutual Information of all Layers with Specified Constellation	161
6.3.2.5	Summary	163
6.3.3	Distributed Algorithm for Game G_2	163
6.3.4	Distributed Algorithm for Game G_3	166
6.3.5	Distributed Algorithm for Game G_4	173
6.3.6	Simulation Results and Discussion	184
6.4	Conclusions	186
7	Conclusions	189
A	Review of Mathematical Foundations	195
A.1	Worst Case Noise Lemma	195
A.2	Log-Likelihood Ratios	195
B	Rate Allocation for Two-User MAC	197
B.1	System Model	197
B.2	Definition of EXIT Charts and Area Theorem	198
C	System Simulation Assumptions	203
	Bibliography	205