

Contents

Kurzfassung	xi
Abstract	xiii
1 Introduction	1
1.1 Technological Classification	2
1.2 Motivation and Necessity	4
2 Selected Aspects of Wireless Industrial Communication	7
2.1 Industrial Applications and Requirements	7
2.1.1 Application Categories	8
2.1.2 Communication Requirements	9
2.2 Multi-Cell Network System Design	13
2.2.1 Cell-Master Distribution	16
2.2.2 Communication Cell Synchronization	17
2.2.3 Communication Device Resources and Capabilities	20
2.2.4 Backbone and Network Integration	21
2.2.5 Network Arbiter	22
2.2.6 Packet Structure	23
2.3 Industrial Reference Application Scenarios	25
2.3.1 Closed Loop Control	25
2.3.2 Printing Machine	27
2.3.3 Production Hall	29
2.4 Regulatory Aspects	29
2.5 Industrial Channel Model	31
2.5.1 Pathloss	33
2.5.2 Frequency Selectivity	34

2.5.3	Receiver SNR	35
3	System Inherent Interference Modelling	37
3.1	Continuous Phase FSK Modulation	37
3.2	GFSK Modulation	38
3.2.1	Impulse Shaping	39
3.2.2	Power Density Spectrum	40
3.3	Low Expenditure Receivers	42
3.3.1	Optimum Receivers	43
3.3.2	Discriminator Receiver	47
3.3.3	Differential Receiver	48
3.4	Advanced Receivers	49
3.4.1	Multi-symbol Observation	49
3.4.2	Viterbi Based Detection	50
3.5	Bit Error Performances in AWGN	51
3.5.1	Coherent Optimum Receiver	51
3.5.2	Noncoherent Optimum Receiver	53
3.5.3	LDI Receiver	54
3.5.4	Differential Receiver	55
3.5.5	Evaluation and Comparison	56
3.6	Interference Modelling	58
3.6.1	SINR Based Models	59
3.6.2	SSI Model	60
3.7	Model Evaluation and Comparison	61
3.7.1	Co-channel Interference	63
3.7.2	Adjacent Channel Interference	66
3.7.3	Channel Spacing	68
4	Frequency Allocation Concepts	71
4.1	Frequency Assignment in Cellular Systems	72
4.1.1	FAP Graph Representation	73
4.1.2	Problem Classification	77

4.2	Minimum Interference Frequency Assignment for Individual Links	81
4.2.1	Interference Penalties	81
4.2.2	Blocking Penalties	83
4.2.3	Minimization of the Cumulative Penalty	83
4.2.4	Minimization of the Maximum Penalty	84
4.3	Integer Programming Formulation	85
4.4	Heuristic Allocation Algorithms	88
4.4.1	Interference Aware Heuristic	88
4.4.2	Channel Priority Aware Heuristic	90
4.4.3	Blocking Aware Heuristic	91
4.4.4	Allocation with Sparse Link States	92
4.5	Simulation Results	93
4.5.1	Minimal Scenario	94
4.5.2	Full Scale Scenario	100
4.5.3	Applicability for Industrial Communication	102
5	System Adaptivity and Enhancements	103
5.1	Dynamic Allocation Optimization	103
5.1.1	Fixed Sequence Allocation	104
5.1.2	Local Pool Optimization	105
5.1.3	Shared Pool Optimization	108
5.1.4	Optimized Global Channel Assignment	111
5.2	Channel Coherence Time Impact	113
5.3	Adaptive Transmit Power Control	114
5.3.1	Centralized Co-Channel Power Control	115
5.3.2	Adjacent Channel Power Control Enhancement	117
6	System-Level Evaluation	121
6.1	Simulation Parameters and System Specific Constraints	121
6.2	Closed Loop Control	123
6.2.1	Increased Channel Bandwidth	123
6.2.2	Feasibility Analysis	126

6.3	Printing Machine	126
6.3.1	Feasibility Analysis	130
6.4	Production Hall	130
6.4.1	Shared Pool I-DSatur Initialization	133
6.4.2	Feasibility Analysis	133
7	Conclusion	135
7.1	Summary	135
7.2	Discussion	136
7.3	Outlook	138
	Appendix A BFSK Receiver Correlation Coefficients	139
A.1	Coherent Optimum Receiver	139
A.2	Noncoherent Optimum Receiver	140
	Appendix B BFSK Receiver Bit Error Probabilities in AWGN	143
B.1	Coherent Optimum Receiver	143
B.2	Noncoherent Optimum Receiver	146
B.3	Coherent MSK Receiver	148
	Terms and Definitions	151
	Jitter	151
	Packet Error Ratio	151
	Packet Loss Ratio	152
	Residual Error Rate	152
	Response Time	152
	Service Availability	152
	Transmission Time	152
	Update Time	153
	List of Acronyms	155
	Lists of Constants, Functions, Operators and Symbols	161
	Constants	161
	Functions and Operators	161

Symbols	163
Lists of Figures and Tables	169
Figures	169
Tables	173
Lists of Algorithms and Problems	175
Algorithms	175
Problems	175
Bibliography	177
Author's Publications	195
Author's Supervised Theses	199