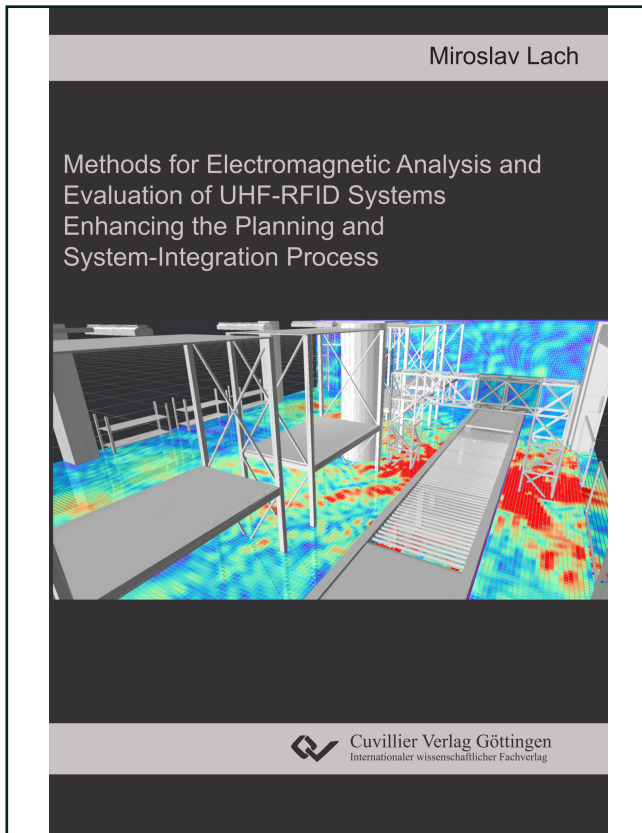




Miroslav Lach (Autor)

Methods for Electromagnetic Analysis and Evaluation of UHF-RFID Systems

Enhancing the Planning and System-Integration Process



<https://cuvillier.de/de/shop/publications/8988>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Table of Contents

1	Introduction	1
1.1	Importance of RFID in the Modern Factory and Supply Chain	2
1.2	State of the Art and Current Challenges	3
1.3	Goals and Contents of this Work	6
2	Signal Coverage Prediction and Planning of UHF-RFID Systems	9
2.1	Fundamentals of UHF-RFID Systems	9
2.2	Methods for Signal Coverage and System Performance Prediction	12
2.2.1	Analytical and Empirical Prediction Methods	13
2.2.2	Deterministic Prediction Methods	16
2.2.3	Conclusion with Outlook on Data-Driven Prediction Methods	20
2.3	Planning of the Operational Environment – Phases and Informational Content	21
3	Computational Electromagnetics	23
3.1	Electromagnetic Fundamentals	23
3.2	Model Preparation and Discretization Techniques for Numerical Analysis	25
3.3	Methods and Solvers for Electromagnetic Analysis	26
3.3.1	Finite Integration Technique	28
3.3.2	Method of Moments and Boundary Element Method	30
4	Implementation of Large-Scale Simulations for UHF-RFID Scenarios	33
4.1	Selection and Setup of Simulation Methods for Large-Scale Analysis	33
4.2	Pre-Processing and Complexity Reduction of Simulation Model	39
4.2.1	Geometrical Model and Discretization	39
4.2.2	Excitation and Equivalent Sources	44
4.3	Validation of Simulation Results	47
4.4	Key Findings at a Glance	48
5	Methods for Evaluation of UHF-RFID System Performance	49
5.1	Macro-Level Analysis – Large-Scale Interference	49
5.1.1	Stage I Evaluation – Fundamental Functionality Rating	50
5.1.2	Stage II Evaluation – Tag Readability Rating	52
5.1.3	Degree of Impact – Significance of Impact Rating	55
5.1.4	Investigated Operational Environments	56
5.1.5	Evaluation of RFID Use-Cases in a Logistical Facility	57

5.2	Micro-Level Analysis – Tag to Object Interference	68
5.2.1	Analysis Based on Conventional Simulation	70
5.2.2	Analysis Utilizing Deep Learning Technology	75
5.3	Key Findings at a Glance	85
5.3.1	On the Macro-Level	86
5.3.2	On the Micro-Level	87
6	Result Validation Utilizing Comprehensive Measurement Data Acquisition	89
6.1	Autonomous Signal Coverage Mapping System for UHF-RFID	89
6.1.1	Drone-Based Positioning Platform	90
6.1.2	Measurement and Probing System	93
6.2	Validation of Prediction and Simulation Results	94
6.2.1	Demonstration Environment and Investigated RFID Use-Cases	94
6.2.2	Validation Measurements	95
6.2.3	Evaluation of Predicted Results	102
6.3	Key Findings at a Glance	105
7	Recommended Course of Action – Method Selection Considering Planning Processes	107
7.1	General Overview	107
7.2	Deterministic Method Selection	109
8	Conclusion and Outlook	113
A	Appendix	117
A.1	Fading Margins for Small-Scale Fading Environments	117
A.2	Dielectric Material Properties	118
A.3	Investigated Operational Environments	119
A.4	Evaluation of UHF-RFID Use-Cases (Macro-Level)	120
A.5	Evaluation of UHF-RFID Use-Cases (Micro-Level)	122
A.6	Measurement Campaigns in the Operational Environment	123
	Symbols	125
	Acronyms	131
	List of Figures	135
	List of Tables	143
	Bibliography	145
	Own Publications	157