Contents

Introduction ix

Chapter 1. Automatic Identification Technology 1

1.1. Barcodes 2
1.1.1. Labels 2
1.1.2. Different types of readers 4
1.2. RFID 8
1.2.1. General introduction 8
1.2.2. History 9
1.2.3. Classification of RFID tags 10
1.2.4. The passive RFID market 12
1.2.5. Passive UHF RFID tag function: backscatter method 13
1.2.6. Limitations of RFID 15
1.3. Chipless RFID 16
1.3.1. General operating principle 17
1.3.2. Basic example of a chipless tag and performance factors 19
1.3.3. Positioning chipless RFID tags in relation to other automatic identification technologies 22
1.3.4. Conclusion and situating the study 23

Chapter 2. State of the Art of Chipless RFID Coding Methods 25

2.1. Introduction 25
2.1.1. Lines of research and positioning the study 25
2.1.2. Classification of chipless RFID tags 26
2.2. Tags coded in the temporal domain 29
2.2.1. SAW tags 29
2.2.2. Transmission line tags 31
2.2.3. Variable terminal impedance tags 32

2.3. Tags coded in the frequency domain 34
2.3.1. Planar filter tags 35
2.3.2. Tags using a loaded wideband antenna 38
2.3.3. RF encoding particle approach 40
2.4. Hybrid tags 44
2.5. Conclusion 49

Chapter 3. Theory of Chipless RFID Tags 51

3.1. Response of a chipless RFID tag 51
3.1.1. Radar Cross Section (RCS) 52
3.1.2. Polarimetric scattering matrix 55
3.1.3. The electromagnetic signature of a chipless RFID tag 56
3.2. Reading system 57
3.2.1. Radar range equation 57
3.2.2. Calibration 59
3.3. Re-radiation mechanisms for chipless tags 61
3.3.1. Structural mode and antenna mode 61
3.3.2. Analogy with antennas 63
3.3.3. Application for the Design of REPs 65
3.4. Characterization of resonant systems 70
3.4.1. Series RLC circuit 70
3.4.2. Quality factor 72
3.4.3. Damping factor 73
3.4.4. Bandwidth 74
3.4.5. Electromagnetic resonators 76
3.5. Separation of the tag and its environment 78
3.5.1. Depolarizing tag interrogated with cross-polarization 78
3.5.2. Temporal separation 81
3.6. Conclusion 84

Chapter 4. Magnitude Coding 87

4.1. Introduction 87
4.1.1. Hybrid coding 88
4.1.2. Magnitude coding method 91
4.1.3. Difficulties related to magnitude coding 92
4.2. Tags without ground planes 93
4.2.1. Tag design 93
4.2.2. Measurement results 104
4.2.3. Compensation technique 114
4.2.4. Partial conclusion for tags without ground planes 117
4.3. Tags with ground planes 118
4.3.1. Tag design 119

4.3.2. Measurement results 134
4.3.3. Coding capacity 141
4.3.4. Partial conclusion – tags with ground planes 144
4.4. General conclusion 145

Chapter 5. RCS Synthesis 147

5.1. Introduction 147
5.1.1. Coding on the appearance of the response 147
5.1.2. Problem analysis 151
5.1.3. Principle of the resolution method 155
5.2. Sampling method 158
5.2.1. Preliminary version of the design algorithm 159
5.2.2. Improved version of the design algorithm 173
5.3. Decomposition on broadband structures 182
5.3.1. Basis of resonators 182
5.3.2. Decomposition on the basis 185
5.3.3. Accounting for couplings and corrections 188
5.4. Conclusion 190
5.5. Appendices 191
5.5.1. Appendix A: Effect of the read range on the signature of a tag 191
5.5.2. Appendix B: Frequency deviation related to a parasitic reactive element 192

Conclusion 195

Bibliography 199

Index 209