
Contents

Preface	ix
Chapter 1. Introduction to Chipless Radio Frequency Identification	1
1.1. Introduction	1
1.2. Chipless radio frequency identification	1
1.3. Recent developments and advancements	4
1.4. Authentication	14
1.5. Conclusion	15
Chapter 2. Literature Review	17
2.1. Introduction	17
2.2. State of the art	18
2.2.1. Basic level of security (overt or visible features)	20
2.2.2. Medium level of security (covert or hidden markers)	22
2.2.3. High level of security (forensic techniques)	23
2.2.4. Conventional RFID approaches	24
2.2.5. Classical chipless approaches	27
2.2.6. Natural randomness	28
2.3. Conclusion	30
Chapter 3. Methodology and Proof of Concept	31
3.1. Introduction	31
3.2. Randomness inherent in the realization process	32
3.3. Authentication procedure	34

3.4. Statistical analysis	37
3.5. Chipless tag discrimination using PCB tags	39
3.5.1. Chipless tag design and purposely applied dimensional variations	40
3.5.2. Chipless tag discrimination results and performance of the resemblance metrics	44
3.6. Chipless tag discrimination using inkjet-printed paper tags	47
3.6.1. Chipless tag design and purposely applied dimensional variations	47
3.6.2. Chipless tag discrimination results and performance of the resemblance metrics	48
3.7. Conclusion	51
Chapter 4. Extraction of Chipless Tag Key Parameters from Backscattered Signals	53
4.1. Introduction	53
4.2. Chipless RFID tags and measurement setup	57
4.3. Extraction of aspect-independent parameters of a second-order scatterer	61
4.3.1. Extraction with the matrix pencil method	64
4.3.2. Extraction with the spectrogram method	67
4.4. Extraction of CNRs of the multi-scatterer-based tags	73
4.5. Comparison of computational time durations between the matrix pencil method and the spectrogram method	82
4.6. Conclusion	83
Chapter 5. Chipless Authentication Using PCB Tags	85
5.1. Introduction	85
5.2. Design and the optimization of chipless tags to be employed for authentication	86
5.2.1. C-folded uni-scatterer tags (classical design)	87
5.2.2. C-folded quad-scatterer tags (optimized design)	94
5.3. Detection of minimum dimensional variation in outdoor realistic environment and authentication results	100
5.4. Detection of natural randomness and authentication results	106
5.4.1. Authentication within each realization	108
5.4.2. Authentication across different realizations	111
5.4.3. Characterization of the natural randomness	112
5.4.4. Generalization of the proposed method	117
5.4.5. Final remarks on the constraints	118
5.5. Conclusion	119

Chapter 6. Chipless Authentication Using Inkjet-Printed PET Tags	121
6.1. Introduction	121
6.2. Optimization of chipless tags to exploit natural randomness inherent in inkjet printing	122
6.3. Authentication using VNA-based chipless reader	129
6.4. Authentication using IR-UWB chipless reader	136
6.5. Conclusion	142
Conclusion	145
Appendices	149
Appendix A	151
Appendix B	153
Appendix C	155
References	157
Index	173