

---

# Contents

---

<b>Preface</b> . . . . .	ix
<b>Chapter 1. Introduction to RFID Technologies</b> . . . . .	1
1.1. Introduction. . . . .	1
1.2. The history of RFID. . . . .	1
1.3. RFID technologies. . . . .	4
1.3.1. General operating principle . . . . .	4
1.3.2. LF and HF technologies . . . . .	7
1.3.3. UHF and SHF technologies . . . . .	9
1.3.4. Ultra-wide-band technology . . . . .	20
1.4. Conclusion . . . . .	26
<b>Chapter 2. The Latest Developments on Chipless RFID Technologies</b> . . . . .	27
2.1. Introduction. . . . .	27
2.2. The latest developments on chipless RFID technologies . . . . .	27
2.2.1. Temporal tags . . . . .	30
2.2.2. Frequency tags . . . . .	37
2.2.3. Tags in 2D imaging. . . . .	52
2.2.4. TFTC tags . . . . .	53
2.3. Comparison of current chipless RFID technologies . . . . .	54
2.4. Market study on printable and chipless RFID technologies . . . . .	56
2.4.1. Current applications . . . . .	59
2.4.2. Future applications . . . . .	60

---

2.5. Issues covered in this book. . . . .	61
2.6. Conclusion . . . . .	62
<b>Chapter 3. Information Coding Techniques in Chipless RFID . . . . .</b>	<b>63</b>
3.1. Introduction. . . . .	63
3.2. Waveform and informational content of a signal. . . . .	63
3.3. Basic principle of coding. . . . .	65
3.3.1. Presence or absence . . . . .	65
3.3.2. Pulse position coding. . . . .	66
3.3.3. Coding on symbol width. . . . .	67
3.3.4. Coding on signal waveform. . . . .	67
3.4. Temporal coding. . . . .	69
3.4.1. Presence/absence or OOK. . . . .	71
3.4.2. Pulse-position or PPM. . . . .	72
3.4.3. Anti-collision principle . . . . .	74
3.5. Frequency coding . . . . .	76
3.5.1. Amplitude rate . . . . .	76
3.5.2. Phase . . . . .	80
3.5.3. Anti-collision principle . . . . .	84
3.6. Coding efficiency improvement. . . . .	84
3.6.1. Constellation diagram and graphic representations . . . . .	84
3.6.2. Use of several states . . . . .	86
3.6.3. Hybrid coding . . . . .	87
3.7. Comparison of amplitude and phase coding. . . . .	89
3.8. Coding performance criteria . . . . .	91
3.9. Conclusion . . . . .	92
<b>Chapter 4. Design of Chipless RFID Tags . . . . .</b>	<b>93</b>
4.1. Introduction. . . . .	93
4.2. Classification of chipless technologies. . . . .	94
4.2.1. “Temporal” and “frequency” chipless tags. . . . .	94
4.2.2. Circuit approach or use of resonant scatterers . . . . .	95
4.3. Problem modeling: example of a basic resonator. . . . .	97
4.3.1. Backscattering mechanisms. . . . .	98
4.3.2. Electromagnetic response modeling . . . . .	104
4.3.3. Radiation pattern . . . . .	109
4.3.4. Polarization . . . . .	110

---

4.4. Parametric study of basic resonators and performance criteria . . . . .	112
4.4.1. Determination of performance criteria . . . . .	113
4.4.2. Comparison of resonators . . . . .	114
4.5. Combination of several resonators and optimization method . . . . .	117
4.5.1. Conclusion . . . . .	121
4.6. Design of tags without a ground plane . . . . .	122
4.6.1. Presentation of design no. 1: double “C” tag . . . . .	122
4.6.2. Presentation of design no. 2: “C” tag with 20 elements . . . . .	128
4.6.3. Presentation of design no. 3: simple “C” tags at hybrid coding. . . . .	132
4.6.4. Environmental considerations, self-compensation method on the resonance frequencies extraction for tags without a ground plane . . . . .	141
4.7. Design of tags with a ground plane . . . . .	148
4.7.1. Presentation of design no. 4: polarization independent tag . . . . .	149
4.7.2. Presentation of design no. 5: polarization-coded tag . . . . .	156
4.7.3. Presentation of design no. 6: depolarizing tag . . . . .	163
4.8. Conclusion . . . . .	169
<b>Chapter 5. Implementation and Measurements of Chipless RFID Tags . . . . .</b>	<b>171</b>
5.1. Introduction. . . . .	171
5.2. Manufacturing process of chipless RFID tags . . . . .	171
5.2.1. Manufacturing in the conventional electronics industry. . . . .	172
5.2.2. Printed electronics . . . . .	175
5.2.3. Performance achieved/comparison between the different manufacturing processes . . . . .	180
5.3. Measurement methods of chipless RFID tags. . . . .	186
5.3.1. Study of a frequency radar measuring bench. . . . .	187
5.3.2. Cavity measurements . . . . .	195
5.3.3. Study of a temporal radar measuring bench . . . . .	200

5.3.4. Design of a reader of chipless tags . . . . .	210
5.3.5. Signal formatting and decoding . . . . .	217
5.3.6. Measurements in a real environment . . . . .	218
5.4. Conclusion . . . . .	226
<b>Conclusion</b> . . . . .	229
<b>Bibliography</b> . . . . .	233
<b>Index</b> . . . . .	245