
Contents

Preface	ix
Acknowledgements	xi
Chapter 1. Introduction to RFID and Chipless RFID	1
1.1. RFID: state of the art	2
1.1.1. Introduction to RFID	2
1.1.2. Chipless RFID	5
1.2. Extending RFID capabilities: from ID to sensing	10
1.2.1. Existing technologies for WSNs	12
1.2.2. RFID-enabled wireless sensors	13
1.3. Ultra-wideband technology for RFID applications	14
1.3.1. Introduction to ultra-wideband technology	14
1.3.2. UWB-based RFID	16
1.4. Organization of this book	18
Chapter 2. Chipless Time-coded UWB RFID: Reader, Signal Processing and Tag Design	19
2.1. Introduction	19
2.2. Theory	20
2.3. Reader design	27
2.3.1. Frequency-step approach	27
2.3.2. Impulse-based approach	28
2.3.3. Comparison and conclusions	31

2.4. Signal processing techniques	32
2.4.1. Time-windowing and background subtraction	33
2.4.2. Continuous wavelet transform	34
2.5. Design of chipless time-coded UWB RFID tags	39
2.5.1. Design of UWB antennas	39
2.5.2. Integrating delay lines with UWB antennas	44
2.5.3. Circularly polarized UWB RFID tags	49
2.6. Characterization of chipless time-coded UWB RFID tags	52
2.6.1. Time-domain response: distance and resolution	53
2.6.2. Angular behavior	58
2.6.3. Influence of materials	59
2.6.4. Polarization	67
2.6.5. Flexible substrates: bending	68
2.7. Conclusions	73
 Chapter 3. Wireless Sensors Using Chipless Time-coded UWB RFID	75
3.1. Introduction	75
3.2. Amplitude-based chipless time-coded sensors	76
3.2.1. Principle of operation	76
3.2.2. Temperature sensor based on chipless time-coded UWB tags	79
3.2.3. Temperature threshold detectors based on chipless time-coded UWB tags	89
3.2.4. Self-calibration and reliability	99
3.3. Delay-based time-coded chipless sensors	105
3.3.1. Principle of operation	106
3.3.2. Permittivity sensor based on chipless time-coded UWB tags	109
3.4. Conclusions	122
 Chapter 4. Semi-passive Time-coded UWB RFID: Analog and Digital Approaches	123
4.1. Introduction	123
4.2. Wake-up system	125
4.2.1. Overview	125
4.2.2. Schottky diode-based detector	126
4.2.3. Reader: modulation schemes	130
4.2.4. Interferences and coexistence with other systems	131
4.3. Microcontroller-based semi-passive UWB RFID system	132

4.3.1. Introduction	132
4.3.2. Microcontroller: tag core logic	134
4.3.3. UWB backscatterer design and evaluation.	136
4.3.4. Differential coding and detection techniques	140
4.3.5. Communication protocol	142
4.3.6. System scalability, applications and sensor integration	143
4.3.7. Results	145
4.4. Analog semi-passive UWB RFID system	149
4.4.1. Introduction	149
4.4.2. Switch-based UWB backscatterer.	151
4.4.3. PIN diode-based UWB backscatterer.	155
4.4.4. Detector circuit design	157
4.5. Discussion, comparison between systems and conclusions	160
Chapter 5. Wireless Sensors Using Semi-passive UWB RFID	163
5.1. Introduction	163
5.2. Solar-powered temperature sensor based on analog semi-passive UWB RFID	164
5.2.1. Introduction	164
5.2.2. Sensor design and calibration	165
5.2.3. Solar-cell integration: power requirements	167
5.2.4. Results and error study	170
5.3. Nitrogen dioxide gas sensor based on analog semi-passive UWB RFID	176
5.3.1. Introduction	176
5.3.2. CNT-based nitrogen dioxide sensor	177
5.3.3. Wireless sensor design and calibration	181
5.3.4. Results	182
5.4. Sensor integration in microcontroller-based semi-passive UWB RFID	186
5.4.1. Multi-sensor tag	187
5.4.2. Nitrogen dioxide gas sensor	189
5.5. Comparison between chipless and semi- passive approaches: conclusions	192
Chapter 6. Active Time-coded UWB RFID	197
6.1. Introduction	197
6.2. Active UWB RFID system based on cross-polarization amplifier	198

6.2.1. Introduction	198
6.2.2. Cross-polarization amplifier design	199
6.2.3. UWB and UHF link budget	204
6.2.4. Results	208
6.3. Active UWB RFID system based on reflection amplifier	212
6.3.1. Introduction	212
6.3.2. Reflection amplifier design	214
6.3.3. UWB link budget	215
6.3.4. Results	216
6.4. Discussion and comparison between systems	218
 Chapter 7. Indoor Localization with Smart Floor Based on Time-coded UWB RFID and Ground Penetrating Radar	221
7.1. Introduction	221
7.2. Smart floor design alternatives	222
7.3. Results	224
7.3.1. Smart floor based on passive reflectors	224
7.3.2. Smart floor based on chipless time-coded UWB RFID tags	228
7.3.3. Smart floor based on semi-passive time-coded UWB RFID tags	230
7.4. Conclusions	231
 Bibliography	233
 Index	253