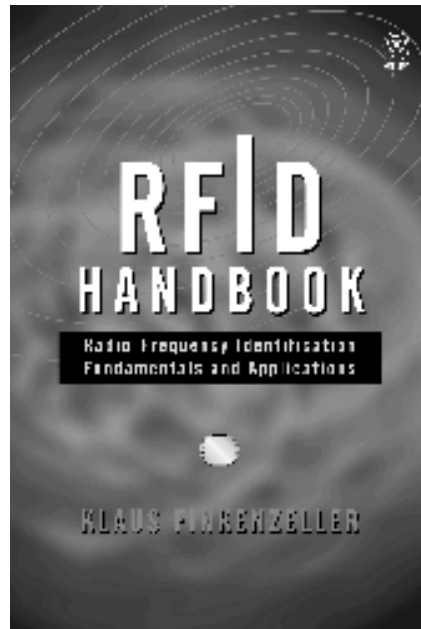


Contents and Preface of the RFID-Handbook



RFID-Handbook, Wiley & Sons LTD 1999
Radio-Frequency Identification: Fundamentals and Applications
Klaus Finkenzeller, Munich, Germany
ISBN 0-471-98851-0

Contents

chapter:	page:
preface	xiii
list of abbreviations	xv
1 Introduction	1
1.1 Automatic Identification Systems	2
1.1.1 Barcode systems	2
1.1.2 Optical character recognition	3
1.1.3 Biometric procedure	4
1.1.3.1 Voice identification	4
1.1.3.2 Finger printing procedures (dactyloscopy)	4
1.1.4 Smart cards	4
1.1.4.1 Memory cards	5
1.1.4.2 Microprocessor cards	5
1.1.5 RFID systems	6
1.2 A Comparison of Different ID Systems	6
1.3 Components of an RFID System	7
2 Differentiation Features of RFID Systems	11
2.1 Fundamental Differentiation Features	11
2.2 Transponder Construction Formats	13
2.2.1 Disks and coins	13
2.2.2 Glass housing	14
2.2.3 Plastic housing	15
2.2.4 Tool and gas bottle identification	16
2.2.5 Keys and key fobs	17
2.2.6 Clocks	19
2.2.7 ID-1 format, contactless smart cards	19
2.2.8 Other formats	21
2.3 Frequency, Range and Coupling	21
2.3.1 Close coupling	21

chapter:	page:
2.3.2 Remote coupling	22
2.3.3 Long range	22
2.3.4 System performance	23
3 Fundamental Operating Principles	25
3.1 1-Bit Transponder	26
3.1.1 Radio frequency	26
3.1.2 Microwaves	29
3.1.3 Frequency divider	31
3.1.4 Electromagnetic types	32
3.2 Full and Half Duplex Procedure	34
3.2.1 Inductive coupling	35
3.2.1.1 Power supply to passive transponders	35
3.2.1.2 Data transfer transponder ® reader	37
3.2.2 Electromagnetic backscatter coupling	41
3.2.2.1 Power supply to the transponder	41
3.2.2.2 Data transmission ® reader	41
3.2.3 Close coupling	43
3.2.3.1 Power supply to the transponder	43
3.2.3.2 Data transfer transponder ® reader	44
3.2.4 Data transfer reader ® transponder	44
3.3 Sequential Procedures	45
3.3.1 Inductive coupling	45
3.3.1.1 Power supply to the transponder	45
3.3.1.2 A comparison between FDX/HDX and SEQ systems	45
3.3.1.3 Data transmission transponder ® reader	47
3.3.2 Surface acoustic wave transponder	48
4 Physical Principles of RFID Systems	53
4.1 Magnetic Field	53
4.1.1 Magnetic field strength H	53
4.1.1.1 Path of field strength H(x) in conductor loops	55

chapter:	page:
4.1.1.2 Optimal antenna diameter	57
4.1.2 Magnetic flux and magnetic flux density	58
4.1.3 Inductance L	59
4.1.4 Mutual inductance M	60
4.1.5 Coupling coefficient k	62
4.1.6 Faraday's law	64
4.1.7 Resonance	66
4.1.8 Practical operation of the transponder	71
4.1.8.1 Power supply to the transponder	71
4.1.8.2 Voltage regulation	71
4.1.9 Interrogation field strength H_{min}	74
4.1.9.1 "Energy range" of transponder systems	76
4.1.10 Total transponder – reader system	78
4.1.10.1 Transformed transponder impedance Z_T'	80
4.1.10.2 Influencing variables of Z_T'	83
4.1.10.3 Load modulation	90
4.1.11 Measuring the coupling coefficient k	98
4.1.12 Magnetic materials	99
4.1.12.1 Properties of magnetic materials and ferrite	99
4.1.12.2 Ferrite antennas in LF transponders	101
4.1.12.3 Ferrite shielding in a metallic environment	101
4.2 Electromagnetic Waves	102
4.2.1 The creation of electromagnetic waves	102
4.2.2 Reflection of electromagnetic waves	105
4.2.3 Radar cross section of an antenna	106
4.2.4 Modulated radar cross section	109
4.2.5 Effective length	109
4.2.6 Antenna construction formats for microwave transponders	110
4.2.6.1 Slot antennas	110
4.2.6.2 Planar antennas	110

chapter:	page:
4.2.6.3. Overview – antenna parameters	110
5 Frequency Ranges and Radio Licensing Regulations	111
5.1 Frequency Ranges Used	111
5.1.1 Frequency range 9 – 135 kHz	111
5.1.2 Frequency range 6.78 MHz	114
5.1.3 Frequency range 13.56 MHz	114
5.1.4 Frequency range 27.125 MHz	114
5.1.5 Frequency range 40.680 MHz	115
5.1.6 Frequency range 433.920 MHz	115
5.1.7 Frequency range 869.0 MHz	115
5.1.8 Frequency range 915.0 MHz	116
5.1.9 Frequency range 2.45 GHz	116
5.1.10 Frequency range 5.8 GHz	116
5.1.11 Frequency range 24.125 GHz	116
5.1.12 Selection of a suitable frequency for inductively coupled RFID systems	116
5.2 International Licensing Regulations	119
5.2.1 CEPT/ERC 70-03	119
5.2.2 EN 300330: 9 kHz – 25 MHz	119
5.2.2.1 Carrier power – limit values for class 1 transmitters	120
5.2.2.2 Carrier power – limit values for class 2 transmitters	120
5.2.2.3 Modulation bandwidth	122
5.2.2.4 Spurious emissions	122
5.2.3 EN 300220-1, EN 300220-2	122
5.2.4 EN 300440	123
5.3 National Licencing Regulations – U.S.A	124
6 Coding and Modulation	125
6.1 Coding in the Baseband	126
6.2 Digital Modulation Procedures	128
6.2.1 Amplitude shift keying (ASK)	129
6.2.2 2 FSK	132

chapter:	page:
6.2.3 2 PSK	133
6.2.4 Modulation procedures with subcarrier	134
7 Data Integrity	137
7.1 The Checksum Procedure	137
7.1.1 Parity checking	137
7.1.2 LRC procedure	138
7.1.3 CRC procedure	139
7.2 Anticollision	141
7.2.1 How collision arises	141
7.2.2 Anticollision procedures	142
7.2.2.1 Spatial domain anticollision procedures	142
7.2.2.2 Frequency domain anticollision procedures	143
7.2.2.3 Time domain anticollision procedures	143
7.2.3 Application example – binary search algorithm	144
8 Data Security	151
8.1 Mutual Symmetrical Authentication	151
8.2 Authentication Using Derived Keys	153
8.3 Encrypted Data Transfer	154
8.3.1 Stream cipher	155
9 Standardisation	159
9.1 Animal Identification	159
9.1.1 ISO 11784 – Code structure	159
9.1.2 ISO 11785 – Technical concept	160
9.1.2.1 Requirements	160
9.1.2.2 Full/half duplex system	162
9.1.2.3 Sequential system	162
9.2 Contactless Smart Cards	163
9.2.1 ISO 10536 – Close coupling smart cards	163
9.2.1.1 Part 1 – Physical characteristics	163
9.2.1.2 Part 2 – Dimensions and locations of coupling areas	164

chapter:	page:
9.2.1.3 Part 3 – Electronic signals and reset procedures	164
9.2.1.4 Part 4 - Answer to reset and transmission protocols	165
9.2.2. ISO 14443 – Proximity coupling smart cards	165
9.2.3 ISO 15693 – Vicinity coupling smart cards	166
9.3 ISO 69873 – Data Carriers for Tools and Clamping Devices	167
9.4 ISO 10374 – Container Identification	167
9.5 VDI 4470 – Anti-theft Systems for Goods	168
9.5.1 Part 1 – Detection gates – inspection guidelines for customers	168
9.5.1.1 Ascertaining the false alarm rate	169
9.5.1.2 Ascertaining the detection rate	169
9.5.1.3 Forms in VDI 4470	169
9.5.2 Part 2 – Deactivation devices, inspection guidelines for customers	170
10 The Architecture of Electronic Data Carriers	171
10.1 Transponder with Memory Function	172
10.1.1 HF interface	172
10.1.2 Address and security logic	173
10.1.2.1 State machine	174
10.1.3 Memory architecture	175
10.1.3.1 Read-only transponder	175
10.1.3.2 Writeable transponder	177
10.1.3.3 Transponder with cryptological function	177
10.1.3.4 Segmented memory	179
10.1.3.5 MIFARE® application directory	181
10.2 Microprocessors	185
10.2.1 Dual interface card	187
10.2.1.1 MIFARE® plus dual interface card	189
10.3 Memory Technology	190
10.3.1 RAM	190
10.3.2 EEPROM	191
10.3.3 FRAM	192

chapter:	page:
10.3.4 Performance comparison FRAM – EEPROM	194
10.4 Measuring Physical Variables	194
10.4.1 Transponder with sensor functions	194
10.4.2 Measurements using microwave transponders	195
11 Readers	199
11.1 Data Flow in an Application	199
11.2 Components of a Reader	200
11.2.1 HF-interface	202
11.2.1.1 Inductively coupled system, FDX/HDX	202
11.2.1.2 Microwave systems – half duplex	203
11.2.1.3 Sequential systems – SEQ	204
11.2.2 Control unit	205
11.3 Low Cost Configuration – Reader IC U2270B	207
11.4 Connection of Antennas	209
11.4.1 Antennas for inductive systems	209
11.4.1.1 Connection using current matching	209
11.4.1.2 Supply via coaxial cable	211
11.4.1.3 The Influence of the Q Factor	215
11.4.2 Antennas for microwave systems	216
11.5 Reader Designs	217
12 The Manufacture of Transponders and Contactless Smart Cards	219
12.1 Module Manufacture	219
12.2 Semi-Finished Transponder	221
12.3 Completion	222
12.4 Contactless Smart Cards	222
13 Example Applications	227
13.1 Contactless Smart cards	227
13.2 Public Transport	229
13.2.1 The starting point	229

chapter:	page:
13.2.2 Requirements	230
13.2.2.1 Transaction time	230
13.2.2.2 Resistance to degradation, lifetime, convenience	231
13.2.3 Benefits of RFID systems	231
13.2.4 Fare systems using electronic payment	232
13.2.5 Market potential	234
13.2.6. Example projects	234
13.2.6.1 Korea – Seoul	234
13.2.6.2 Germany – Lüneburg, Oldenburg	236
13.3 Ticketing	237
13.3.1 Lufthansa Miles & More card	237
13.3.2 Ski tickets	239
13.4 Access Control	241
13.5 Transport Systems	242
13.5.1 Eurobalise S21	242
13.5.2 International container transport	244
13.6 Animal Identification	245
13.6.1 Stock keeping	245
13.6.2. Carrier pigeon races	251
13.7 Electronic Immobilisation	253
13.7.1 The functionality of an immobilisation system	253
13.7.2 Brief success story	256
13.7.3 Predictions	257
13.8 Container Identification	257
13.8.1 Gas bottles and chemical containers	257
13.8.2 Waste disposal	259
13.9 Sporting Events	261
13.10 Industrial Automation	263
13.10.1 Tool identification	263
13.10.2 Industrial Production	266

chapter:	page:
13.10.2.1 Benefits from the use of RFID systems	269
13.10.2.2 The selection of a suitable RFID system	270
13.10.2.3 Example projects	271
14 Market Overview	275
14.1 Selection Criteria	275
14.1.1 Operating frequency	275
14.1.2 Range	276
14.1.3 Security requirements	277
14.1.4 Memory size	278
14.2 System Overview	278
14.3 Contact Addresses, Technical Periodicals	287
14.3.1 Industrial associations	287
14.3.2 Technical journals and events	290
14.3.3 RFID on the Internet	292
15 Appendices	293
15.1 Relevant Standards and Regulations	293
15.1.1 Sources of supply for standards and regulations	294
15.2 References	294
16 Index	299

Preface

This book is aimed at an extremely wide range of readers. First and foremost it is intended for students and engineers who find themselves confronted with RFID technology for the first time. A few basic chapters are provided for this audience describing the functionality of RFID technology and the physical and IT-related principles underlying this field. The book is also intended for practitioners who, as users, wish to or need to obtain as comprehensive and detailed an overview of the various technologies, the legal framework or the possible applications of RFID as possible.

Although a wide range of individual articles are now available on this subject, the task of gathering all this scattered information together when it is needed is a tiresome and time-consuming one – as researching this book has proved. This book therefore aims to fill a gap in the range of literature on the subject of RFID.

This book uses numerous pictures and diagrams to attempt to give a graphic representation of RFID technology in the truest sense of the word. Particular emphasis is placed on practical considerations. For this reason the chapter entitled "Example Applications" is particularly comprehensive.

Technological developments in the field of RFID technology are proceeding at such a pace that although a book like this can explain the general scientific principles it is not dynamic enough to be able to explore the latest trends regarding the most recent products on the market. I am therefore grateful for any suggestions and advice – particularly from the field of industry. The basic concepts and underlying physical principles remain, however, and provide a good background for understanding the latest developments.

At this point I would also like to express my thanks to those companies who were kind enough to contribute to the success of this project by providing numerous technical data sheets, lecture manuscripts and photographs.

Munich, January 1998
Klaus Finkenzeller