

Information technology — Radio frequency identification for item management —

Part 6: Parameters for air interface communications at 860 MHz to 960 MHz

ICS 35.040

National foreword

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This document comprises a front cover, an inside front cover, the ISO/IEC title page, pages ii to xx, pages 1 to 223 and a back cover.

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**Information technology —
Radio frequency identification for item
management —**

**Part 6:
Parameters for air interface
communications at 860 MHz to 960 MHz**

*Technologies de l'information — Identification par radiofréquence
(RFID) pour la gestion d'objets —*

*Partie 6: Paramètres pour les communications d'une interface d'air
entre 860 MHz et 960 MHz*

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

ISO/IEC 18000-6 was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

ISO/IEC 18000 consists of the following parts, under the general title *Information technology — Radio frequency identification for item management*:

- *Part 1: Reference architecture and definition of parameters to be standardized*
- *Part 2: Parameters for air interface communications below 135 kHz*
- *Part 3: Parameters for air interface communications at 13,56 MHz*
- *Part 4: Parameters for air interface communications at 2,45 GHz*
- *Part 6: Parameters for air interface communications at 860 MHz to 960 MHz*
- *Part 7: Parameters for active air interface communications at 433 MHz*

Introduction

This part of ISO/IEC 18000 describes a passive backscatter RFID system that supports the following system capabilities:

- Identification and communication with multiple tags in the field
- Selection of a subgroup of tags for identification or with which to communicate
- Reading from and writing to or rewriting data many times to individual tags
- User-controlled permanently lockable memory
- Data integrity protection
- Interrogator-to-tag communications link with error detection
- Tag-to-interrogator communications link with error detection.
- Support for both passive back-scatter tags with or without batteries.

A1 This International Standard specifies the physical and logical requirements for a passive-backscatter, interrogator-talks-first (ITF), radio frequency identification (RFID) system operating in the 860 MHz to 960 MHz frequency range. The system comprises interrogators, also known as readers, and tags, also known as labels.

An interrogator transmits information to a tag by modulating an RF signal in the 860 MHz to 960 MHz frequency range. The tag receives both information and operating energy from this RF signal. Tags are passive, meaning that they receive all of their operating energy from the interrogator's RF waveform.

An interrogator receives information from a tag by transmitting a continuous-wave (CW) RF signal to the tag; the tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the interrogator. The system is ITF, meaning that a tag modulates its antenna reflection coefficient with an information signal only after being directed to do so by an interrogator.

Interrogators and tags are not required to talk simultaneously; rather, communications are half-duplex, meaning that interrogators talk and tags listen, or vice versa. **A1**

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning radio-frequency identification technology given in the clauses identified below.

ISO and IEC take no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured the ISO and IEC that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with ISO and IEC.

Information on the declared patents may be obtained from:

Contact details	Patent number	Affected clause(s) in this part of ISO/IEC 18000
BTG plc ATTN: Mr David Armstrong 10 Fleet Place Limeburner Lane London EC4M 7SB UK Tel: +44 20 7575 0000 Fax: +44 20 7575 0010 Website: www.btgplc.com , Email: david.armstrong@btgplc.com .	US 5,537,105, US 5,966,083, US 5,995,017, US 5,557,280, US 5,699,066, US 5,519,381, US 5,726,630, EP 0494114B1, EP 0585132B1, EP 0598624B1, WO 98/52142 and WO 99/26081	6, 7

Contact details	Patent number	Affected clause(s) in this part of ISO/IEC 18000
Intercode 12, Rue des Petits Ruisseaux Z.I. des Godets 91370 Verrières le Buisson France Tel : + 33-1-6975 2170 Fax : + 33.1.60.11.00.31 Email: intercode.sarl@wanadoo.fr	US 5426423, EP 90909459.1, CA 2058 947, US 6177858B1, EP 96402556.3, CA 2191787, US 5923251, EP 96402554.8, CA 21911788, US 5808550, EP 96402555.5 and CA 2191794	7, 8
Intermec Technologies Corporation ATTN: Ronald D. Payne, Vice President, Contracts, 6001 36th Ave, West, Everett, WA 98203 USA	US 5942987, US 5521601, US 5995019, US 5030807, US 5828693, US 5850181, US 4786907, US 5550547, US 5673037, US 5777561 and US 5828318	8
Koninklijke Philips Electronics N.V ATTN: Mr. Harald Röggla Intellectual Property & Standards, Triester Strasse 64 A-1101 Vienna Austria	EP 1034503B, JP 00-560535, US 09/352317, WO 00/04485, JP 03-502778, US 2002/0186789A1 and WO 02/099741 A1	7, 8
Matrics Technology ATTN: Mr Kevin J Powell Senior Director, Product Development 8850 Stanford Blvd, Suite 3000 Columbia, MD 21045 USA +1-410-872-0300 (Voice) +1-443-782-0230 (eFax) kpowell@matrics.com	US 6002344	7, 8
SAMSys Technologies, Inc. ATTN: James Wiley, President, 2525 Meridian Parkway, Suite 60, Durham, NC 27713, USA Tel: +1-919- 281-1541, E-mail: tres.wiley@samsys.com	US 6617962	2
SUPERSENSOR (Pty) Ltd ATTN: Mr. Adelhart Kruger, D.M. Kisch Inc., P O Box 3668, Pretoria 0001, South Africa. Tel: +27-12-460-3203. E-mail: adelhartk@dmkisch.com	ZA 9810199, US 6480143 B1, EP 1001366, JP 200230978 and CN 1255689	6, 7
TAGSYS Australia Pty Ltd, ATTN: Alfio R. Grasso, TECHNICAL MANAGER 212 Pirie Street, ADELAIDE SA 5000 Australia, Tel: +61-8-8100 8324, E-mail: alfio.grasso@tagsys.net	EP 0578701B1, AU 664544, AU PCT AU/00/01493, WO 01/41043, AU PCT AU98/00017, WO 98/32092, US 5523749, AU PCT AU01/01676, WO02/054365, FR FR00/01704, and WO 01/01326	7



Contact details	Patent number	Affected clause(s) in this part of ISO/IEC 18000
Alien Technology Corporation ATTN: Dr. John Stephen Smith 18200 Butterfield Blvd Morgan Hill CA 95037 USA Tel: 1-408-782-3900 Fax: 1-408-782-3910 E-mail: ssmith@alientechology.com	6,933,848 USA, 10/141,489 USA, 11/029,445 USA, 2003/0019929 USA, 10/160,458 USA, 11/132,085 USA, 11/153,030 USA, (divisional of 6,942,155 US), Not yet assigned, (continuation of 11/153,030 USA), 2005/0114326 USA, 10/982,557 USA, Not yet assigned, (continuation of 10/982,557 USA), Not yet assigned, (continuation of 10/982,557 USA), US04/036991 PCT, WO2005048180, 2003/0137403 USA, 10/267,924 USA, WO03032240, 2820082.9 China, 1636039A China, 2801064.3 EU, 2003- 535135 Japan, 091123291 Taiwan, 60/681,656 USA, 10/915,725 USA, US04/025883 PCT, 10/140,557 US,	9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.3.4, Fig. Amd.1-22, Fig. Amd.1-26, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.3.4, Fig. Amd.1-22, Fig. Amd.1-26, 9.3.2.7, 9.3.2.10.1.1, 9.3.2.10.2.4, Table Amd.1-28, 9.3.2.7, 9.3.2.10.1.1, 9.3.2.10.2.4, Table Amd.1-28, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.2, 9.3.2.3, 9.3.2.4.7, 9.3.2.10.3.4, Table Amd.1-16, Fig. Amd.1-22, Fig. Amd.1-26, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.2, 9.3.2.3, 9.3.2.4.7, 9.3.2.10.3.4, Table Amd.1-16, Fig. Amd.1-22, Fig. Amd.1-26, 9.3.2.2, 9.3.2.3, 9.3.2.4, 9.3.2.4.1, 9.3.2.4.2, 9.3.2.4.8, 9.3.2.5, 9.3.2.8, 9.3.2.9, 9.3.2.10, 9.3.2.10.1.1, 9.3.2.10.2.1, 9.3.2.10.2.2, 9.3.2.10.2.3, 9.3.2.10.2.4, Table Amd.1-18, Table Amd.1-19, Table Amd.1-20, Fig. Amd.1-21, Fig. Amd.1-22, 9.3.2.10, Table Amd.1-18, 9.3.2.9, Fig. Amd.1-22, 9.3.2.2, 9.3.2.3, 9.3.2.4, 9.3.2.4.1, 9.3.2.4.2, 9.3.2.4.8, 9.3.2.5, 9.3.2.8, 9.3.2.9, 9.3.2.10.1.1, 9.3.2.10.2.1, 9.3.2.10.2.2, 9.3.2.10.2.3, 9.3.2.10.2.4, Table Amd.1-18, Table Amd.1-19, Table Amd.1-20, Fig. Amd.1-21, Fig. Amd.1-22, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.1.1, 9.3.2.10.2.4, 9.3.2.10.3.4, 9.3.2.10.3.5, Table Amd.1-39, Fig. Amd.1-22, Fig. Amd.1-26, Fig. Amd.1-27, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.1.1, 9.3.2.10.2.4, 9.3.2.10.3.4, 9.3.2.10.3.5, Table Amd.1-39, Fig. Amd.1-22, Fig. Amd.1-26, Fig. Amd.1-27, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.1.1, 9.3.2.10.2.4, 9.3.2.10.3.4, 9.3.2.10.3.5, Table Amd.1-39, Fig. Amd.1-22, Fig. Amd.1-26, Fig. Amd.1-27, 9.3.2.1.1.1, 9.3.2.1.2.1, 9.3.2.4.7, 9.3.2.10.1.1, 9.3.2.10.2.4, 9.3.2.10.3.4, 9.3.2.10.3.5, Table Amd.1-39, Fig. Amd.1-22, Fig. Amd.1-26, Fig. Amd.1-27, 9.3.2.10.1.1, 9.3.2.10.2.4, 9.3.1.3.2.3, 9.3.1.3.3, Table Amd.1-12, Fig. Amd.1-15, Fig. Amd.1-16, 9.3.2.2, 9.3.2.3, 9.3.2.10, 9.3.2.10.1.1, Table Amd.1-18, Table Amd.1-19, Table Amd.1-20, Fig. Amd.1-21, 9.3.2.2, 9.3.2.3, 9.3.2.10, 9.3.2.10.1.1, Table Amd.1-18, Table Amd.1-19, Table Amd.1-20, Fig. Amd.1-21, 9.3.2.1

(A1)

A1	Atmel Germany GmbH ATTN: Dr. Bertram Koch Patent Division IPM Theresienstr. 2 74072 Heilbronn Germany Tel: +49(7131)67-3254 Fax: +49(7131)67-2789 Email: Bertram.Koch@hno.atmel.com	10050878.2-31 DE, 09/929703 US, 1508/01 CH, 0113094 FR, 10138217.0 DE, 10/353298 US, 02767283.1-2210 FR, 02767283.1-2210 FI, 50202435.6- 08 DE, 10335009.8 DE, 10/896670 Us, 04017298.3-1237 EP, 200410054468.5 CN, 102004019309.6 DE, 05007835.1- 2210 EP, 11/104435 US, 102004014563.6 DE, 11/087871 us, 200510059501.8 CN, 10158442.3-09 DE, 10256099.4 DE, 02026665.6.1248 EP, 10/308248 US, 10301451.9 DE, 10/753859 US, 04000202.41248 EP, 2004-4143 JP, 200410002008.8 CN, 10325399.8 DE, 0 012309 3-241 E, 10/855866 US, 2004-157635 JP, 10357665.7 DE, 10/753849 US, 04000203.2-2207 EP, 200410002047.8 CN, 2004-5689 JP, 10356259.1-35 DE, 11/002852 US, 200410098306.1 CN, 102005032590.4- 35 DE, PCT/EP2005/007 496 WO, 102004007106.3 DE, 11/058056 US, 200510008328.9 CN	6.3.1.2.2, 6.3.1.2.3, 6.3.1.2.5, 6.3.1.2.8, 6.3.1.5, 6.3.1.3.1, 6.3.1.3, 6.3.2.10.3, 6.3.2.2, 6.3.2.3
	BTG International Ltd ATTN: Mr Mathew Frankel Senior Legal Advisor 10 Fleet Place Limeburner Lane London EC4M 7SB UK Tel: +44 20 7575 0000 Fax: +44 20 7575 0010 Website: www.btgplc.com Email: info@btgplc.com	CHINA 98117396.9; EUROPE 98306849.5; JAPAN 241748.98; UNITED STATES OF AMERICA 09/138560; SOUTH AFRICA 987635 ; CHINA 98117442.6; CHINA 200410045765.3; EUROPE 98306943.6; JAPAN 10-243364; UNITED STATES OF AMERICA 09/143711; SOUTH AFRICA 987838; CHINA 98119594.6; JAPAN 272945/98; UNITED STATES OF AMERICA 09/160354; SOUTH AFRICA 988956; CHINA 99111121.4; EUROPE 99304836.2; JAPAN 171775/1999; UNITED STATES OF AMERICA 09/334151; UNITED STATES OF AMERICA 10/827814; SOUTH AFRICA 985286; SOUTH AFRICA 994046; AUSTRIA 99308924.2; BELGIUM 99308924.2; SWITZERLAND 99308924.2; CHINA 99122449.3; GERMANY 99308924.2; EUROPE 99308924.2; SPAIN 99308924.2; FRANCE 99308924.2; ITALY 99308924.2; JAPAN 318426/1999; NETHERLANDS 99308924.2; UNITED STATES OF AMERICA 435467; CHINA 00104540.7; EUROPE 00300753.1; JAPAN 2000-023891; UNITED STATES OF AMERICA 09/495456; SOUTH AFRICA 2000/0668; CHINA 00121458.6; EUROPE 00306298.1; JAPAN 2000- 222353; UNITED STATES OF AMERICA 09/624006; SOUTH AFRICA 2000/3699; EUROPE 01304980.4; JAPAN 2001-177175; UNITED STATES OF AMERICA 09/877438; SOUTH AFRICA 2001/4484; CHINA 01115964.2; EUROPE 01305116.4; JAPAN 2001-177567; UNITED STATES OF AMERICA 09/878403;	???

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	Impinj, Inc. ATTN: Todd E. Humes, CTO ATTN: Gregory T. Kavounas Sr. P.C. Impinj Patent Licensing Department 701 N. 34th Street, Suite 300 Seattle, WA 98103 USA Tel: +1(206)517-5300 Fax: +1(206)517-5262 Email: todd.humes@impinj.com / greg.kavounas@impinj.com	9.3.1.2.3; Figure Amd. 1-4; 9.3.1.2.8; Figure Amd. 1-7; Annex J; 9.3.1.3 and subsections (especially 9.3.1.3.2 and 9.3.1.3.3); 9.3.2.10.2.1; 9.3.1.2.8; Figure Amd. 1-7; 9.3.1.3.2.2; Figure Amd. 1-14; Annex J; 9.3.1.3 and subsections (especially 9.3.1.3.2 and 9.3.1.3.3); 9.3.2.10.2.1; 9.3.1.2.8; Figure Amd. 1-7; Annex D; Table D.1; 9.3.2.1; 9.3.2.10.1.1; Table Amd. 1-19; 9.3.2.10.3.2; Table Amd. 1-32; 9.3.2.10.3.3; Table Amd. 1-34; 9.3.2.10.3.7; Table Amd. 1-44; 9.3.2.10.3.8; Table Amd. 1-46; 9.3.2.10; Table Amd. 1-18; plus all uses of the header "Code" specified in Table Amd. 1-18 throughout the specification; 2.3, 4.1.5 ("cover-coding"); 9.3.2.5; 9.3.2.9; 9.3.2.10.3.3; Table Amd. 1-34; 9.3.2.10.3.4; Table Amd. 1-36; Figure Amd.1-26; 9.3.2.10.3.6; Table Amd. 1-42; Figure Amd. 1-28

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Intermec IP Corp
ATTN: Ronald D. Payne
Legal Department
6001 36th Avenue West
Everett, WA 98203
Tel: +1(425)348.2756
Fax: +1(425)348.2703
Email: ron.payne@intermec.com

5,673,037 USA; 69530547.6 DE;
0702323 EP; EP0702323 FR;
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TW; 6,172,596 USA; 6,400,274 USA;
6,404,325 USA; 4,786,907 USA;
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20040189443 USA ; 10/662950 USA;

Type C

9.1.1 Physical layer

Table 3:

Tag:7e Subcarrier Frequency
Tag:7g Subcarrier Modulation
Tag:7h Duty Cycle
Tag:8 Data Coding
Tag:9 Bit Rate

9.3.1.3 Tag-to-interrogator (T=>R) communications

9.3.1.3.2 Data encoding

9.3.1.3.2.3 Miller-modulated subcarrier

Figure Amd.1-16 — Subcarrier sequences

9.3.1.3.2.4 Miller subcarrier preamble

9.3.1.3.3 Tag supported Tari values and backscatter link rates

Table Amd.1-11 — Tag-to-interrogator link frequencies

Annex I Dense- and multiple-interrogator channelised signaling

Type A

7.3.1 Tag memory organization
7.4.7 Command codes and CRC
7.8.9 Write_single_block
7.8.10 Write_multiple_blocks
7.8.11 Lock_blocks
7.8.12 Write_AFI
7.8.13 Lock_AFI
7.8.14 Write_DSFD command
7.8.15 Lock_DSFD

Type B

8.2.4.2 Detailed Command Processing
8.2.7.6 Command codes and format
8.2.7.9.11 WRITE
8.2.7.9.12 WRITE4BYTE
8.2.7.9.13 LOCK
8.2.7.9.15 WRITE_MULTIPLE
8.2.7.9.16 WRITE4BYTE_MULTIPLE
Annex B Memory mapping for Type B

Type C

9.1.2 Tag-identification layer

Table 4 — Tag inventory and access parameters

P:5Write Size
P:7Write Transaction Time
9.3.2.1.1 Reserved Memory
9.3.2.1.2 UII Memory
9.3.2.1.3 TID memory
9.3.2.1.4 User memory
9.3.2.1.1.1 Kill password
9.3.2.1.1.2 Access password
9.3.2.1.2.2 Protocol-control (PC) bits
9.3.2.1.2.1 CRC-16
9.3.2.1.2.3 UII for EPCglobal™ applications
9.3.2.1.2.4 UII for non-EPCglobal™ applications
9.3.2.9 Accessing individual tags
Table Amd.1-17 — Access commands and tag states in which they are permitted

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9.3.2.10.3.3 Write (mandatory)
 9.3.2.10.3.4 Kill (mandatory)
 9.3.2.10.3.5 Lock (mandatory)
 9.3.2.10.3.7 BlockWrite (optional)
 9.3.2.10.3.8 BlockErase (optional)
 F.10 Command response: Write
 F.11 Command response: Kill
 F.12 Command response: Lock
 F.14 Command response: BlockWrite
 F.15 Command response: BlockErase

Type C

9.1.1 Physical layer
 Table 3 — Tag-to-interrogator (T=>R) communications:
 Tag:7e Subcarrier Frequency
 Tag:7g Subcarrier Modulation
 Tag:7h Duty Cycle
 Tag:8 Data Coding
 Tag:9 Bit Rate
 9.3.1.3 Tag-to-interrogator (T=>R) communications
 9.3.1.3.2 Data encoding
 9.3.1.3.2.3 Miller-modulated subcarrier
 Figure Amd.1-16 — Subcarrier sequences
 9.3.1.3.2.4 Miller subcarrier preamble
 9.3.1.3.3 Tag supported Tari values and backscatter link rates
 Table Amd.1-11 — Tag-to-interrogator link frequencies
 Annex I Dense- and multiple-interrogator channelised signaling

Types A, B, C

Table 2 — Interrogator-to-tag (R=>T) communications:
 Int:1d Frequency Hop Rate (frequency-hopping [FHSS] systems)
 Int:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems)
 Table 3 — Tag-to-interrogator (T=>R) communications:
 Tag:1d Frequency Hop Rate (frequency-hopping [FHSS] systems)
 Tag:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems)

Types A, B

6.4 Frequency hopping carrier rise and fall times

Type C

9.3.1.2.9 Frequency-hopping spread-spectrum waveform
 9.3.1.2.10 Frequency-hopping spread-spectrum channelisation
 Annex I Dense- and multiple-interrogator channelised signaling
 Bibliography:
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 ETSI EN 302 208-1

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		ETSI EN 302 208-2 US Code of Federal Regulations (CFR) Title 47, Chapter I, Part 15 Types A, B, C Table 2 — Interrogator-to-tag (R=>T) communications: Int:1d Frequency Hop Rate (frequency-hopping [FHSS] systems) Int:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems) Table 3 — Tag-to-interrogator (T=>R) communications: Tag:1d Frequency Hop Rate (frequency-hopping [FHSS] systems) Tag:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems) Types A, B 6.4 Frequency hopping carrier rise and fall times Type C 9.3.1.2.9 Frequency-hopping spread-spectrum waveform 9.3.1.2.10 Frequency-hopping spread-spectrum channelisation Annex I Dense- and multiple-interrogator channelised signaling Bibliography: ETSI EN 300 220 ETSI EN 302 208-1 ETSI EN 302 208-2 US Code of Federal Regulations (CFR) Title 47, Chapter I, Part 15 Type A, B 6.5.5 Message Format 6.5.6 Return preamble Type C 9.3.1.3.3 Tag supported Tari values and backscatter link rates Type C 9.1.1 Physical layer Table 3: Tag:7e Subcarrier Frequency Tag:7g Subcarrier Modulation Tag:7h Duty Cycle Tag:8 Data Coding Tag:9 Bit Rate 9.3.1.3 Tag-to-interrogator (T=>R) communications 9.3.1.3.2 Data encoding 9.3.1.3.2.3 Miller-modulated subcarrier Figure Amd.1-16 — Subcarrier sequences 9.3.1.3.2.4 Miller subcarrier preamble 9.3.1.3.3 Tag supported Tari values and backscatter link rates Table Amd.1-11 — Tag-to-interrogator link frequencies Annex I Dense- and multiple-
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		interrogator channelised signaling CLAIMS 11-et seq Types A, B, C Table 2: Int:1d Frequency Hop Rate (frequency-hopping [FHSS] systems) Int:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems) Table 3: Tag:1d Frequency Hop Rate (frequency-hopping [FHSS] systems) Tag:1e Frequency Hop Sequence (frequency-hopping [FHSS] systems) Types A, B 6.4 Frequency hopping carrier rise and fall times Type C 9.3.1.2.9 Frequency-hopping spread- spectrum waveform 9.3.1.2.10 Frequency-hopping spread-spectrum channelisation Annex I Dense- and multiple- interrogator channelised signaling Bibliography: ETSI EN 300 220 ETSI EN 302 208-1 ETSI EN 302 208-2 US Code of Federal Regulations (CFR) Title 47, Chapter I, Part 15 Type A 7.8.9 Write single block 7.8.10 Write multiple blocks 7.8.11 Lock single block 7.8.12 Write AFI 7.8.13 Lock AFI 7.8.14 Write DSFID command 7.8.15 Lock DSFID Type B 8.2.1.3.3 WRITE_OK 8.2.7.9.11 WRITE 8.2.7.9.12 WRITE4BYTE 8.2.7.9.13 LOCK 8.2.7.9.14 QUERY_LOCK 8.2.7.9.15 WRITE_MULTIPLE 8.2.7.9.16 WRITE4BYTE_MULTIPLE Type C 9.3.2.10.3.3 Write (mandatory) 9.3.2.10.3.4 Kill (mandatory) 9.3.2.10.3.5 Lock (mandatory) 9.3.2.10.3.7 BlockWrite (optional) 9.3.2.10.3.8 BlockErase (optional) Annex E State-transition tables Type A Tag state storage Type B 8.2.1.3.2 Data exchange status bit (DE_SB)
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		Type C persistent memory or persistent flag 9.3.2.2 Sessions and inventoried flags 9.3.2.3 Selected flag 9.3.2.7 Selecting tag populations 9.3.2.8 Inventorying tag populations 9.3.2.10.1.1 Select (mandatory) 9.3.2.10.2.1 Query (mandatory) 9.3.2.10.2.2 QueryAdjust (mandatory) 9.3.2.10.2.3 QueryRep (mandatory) Annex E State-transition tables Annex F Command-Response Tables
Magellan Technology Pty Limited ATTN: Ms E. J. Angus Company Secretary 65 Johnston St ANNANDALE NSW 2038 Australia Tel: +61 2 9562 9800 Fax: +61 2 9518 7620 E-mail : jeana@magtech.com.au	US10/204159 USA , AU3711301 Australia , WO0165712 International PCT, EP1266458 Europe , 2003526148 Japan	6, 7, 8, 9
OMRON Corporation ATTN: Atsushi Hisano Business Development Group Planning Division Business Management Department Gate City Ohsaki West Tower 14F, 1-11-1, Ohsaki, Shinagawa-ku, Tokyo, 141-0032 Japan Tel: +81(3)5435-2004 Fax: +81(3)5435-2025 Email: atsushi_hisano@omron.co.jp	2949728/ Japan	6.3.1.3.3
Koninklijke Philips Electronics N.V. ATTN: Harald Röggla Triester Strasse 64 1101 Vienna Austria Tel: 43(1)60101 1469 Fax: +43(1)60101 1101 Email: harald.roeggla@philips.com	AT 401 127/ AT;EP 0 669 591 / BE, CH, De, DK, ES, FR, GB, IT, LI, NL, SE;EP 1 038 257 /AT, DE, ES, FR, GB, IT;IN /PCT/00/00034 / IN;US10/382262;JP00-561579 / JP;	2.5.1
Symbol Technologies, Inc. ATTN: Aaron Bernstein, VP of IP, Legal Department One Symbol Plaza, MS A6 Holtsville, NY 11742 USA Tel: 1-800-927-9626 Fax 1-631-738-4110 E-mail aaron.bernstein@symbol.com	6,784,813 (USA); 10/926,269 (USA); 10/932,279 (USA); 761843 (AU); 2,310,623 (CA); 98812462.9 (CN); 1031120 (DE); 1031120 (EP); 1320062 (EP); 1031120 (FR); 1031120 (GB); 1032468 (HK); 136,220 (IL); 1031120 (IT); 2000-521687 (JP); 10/688,535 (USA); 2003282941 (AU); TBA (CN); TBA (EP); TBA (JP); TBA (KR); 10/725,010 (USA); 10/073,000 (USA); 10/072,885 (USA); 10/693,687 (USA); 2003286702 (AU); TBA (CA); TBA (CN); 03777912.1 (EP); TBA (JP); 10- 2005-7007116 (KR); TBA (SG); 10/927,775 (USA); US04/027999(WO); 2,503,407 (CA); TBA (EP); TBA (JP); 0480001172.5 (CN); 1020057007371 (KR); 2004269728 (AU)	Type C



TAGSYS, S.A. ATTN: Alastair McArthur, CTO 180 Chemin de Saint Lambert 13821 La Penne sur Huveaune France Tel: +33(0)4 91 27 57 01 Fax: +33(0)4 91 27 57 00 E-mail: alastair.mcarthur@tagsys.net	US 6,641,036; EP 1232471; WO 02054365; WO 0141043; EP 0953181; US 6,538,564	???
Texas Instruments Incorporated ATTN: Mrs. Scharlene Franks Contract Manager, RFID Business Group 6550 Chase Oaks Boulevard, MS 8470 Plano, Texas 75023 USA Tel: +1(214) 567-8830 Fax: +1(214) 567-2409 Email: s-franks@ti.com	NONE	Not applicable
Zebra Technologies Corporation ATTN: Eric McAlpine IP Counsel Legal Dept. 333 Corporate Woods Parkway Vernon Hills, IL 60061 USA Phone: 1.847.793.5640 Fax: 1.847.955.4514 E-mail: emcalpine@zebra.com	92/10006 AUSTRALIA; BW/A/97/00142 BOTSWANA; 2058692 CANADA; 02017523.8 EPC; 95112753.9 EPC (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, NL, PT, SE); 92300041.8 EPC (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, NL, PT, SE); 91/346821 JAPAN; 9609578-1 SINGAPORE; 92/0039 SOUTH AFRICA; 08/976949 USA; 07/816893 USA; 08/976948 USA; 326618 ARGENTINA; 93/50781 AUSTRALIA; BW/A/97/00141 BOTSWANA; PI9304761-4 BRAZIL; 2103288 CANADA; 93121410 CHINA; 01117486.9 EPC; 97104997.8 EPC (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, NL, PT, SE); 97104998.6 EPC (AT, BE, CH, DK, DE, ES, FR, GB, GR, IE, IT, NL, PT, SE); 93309232.2 EPC (AT, BE, CH, ES, FR, GB, GR, IE, IT, NL, PT, SE); 0598624UKREG GUERNSEY; 98109976.2 HONG KONG; 93/01312 INDIA; 107636 ISRAEL; 47219/03 JAPAN; 93/289591 JAPAN; 0598624UKREG JERSEY; 93/02408 MALAYSIA; 9307214 MEXICO; 250219 NEW ZEALAND; 314270 NEW ZEALAND; 314269 NEW ZEALAND; 19934177 NORWAY; 19993092 NORWAY; 19993091 NORWAY; 93051222 RUSSIAN FEDERATION; 9609092-3 SINGAPORE; 93/8624 SOUTH AFRICA; 93/024833 SOUTH KOREA; 82109793 TAIWAN; 93003717 UKRAINE; 08/154329 USA; 08/580913 USA; 95/16530 AUSTRALIA; 93/44940 AUSTRALIA; BW/A/97/00144 BOTSWANA; 2104829 CANADA; 93118806 CHINA; 93306790.2 EPC (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MN, NL, PT, SE); 93/00956 INDIA; 108621 ISRAEL; 93/211454 JAPAN; 93049090 RUSSIAN FEDERATION; 9608519-6	???



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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

Information technology — Radio frequency identification for item management —

Part 6: Parameters for air interface communications at 860 MHz to 960 MHz

1 Scope

This part of ISO/IEC 18000 defines the air interface for radio frequency identification (RFID) devices operating in the 860 MHz to 960 MHz Industrial, Scientific, and Medical (ISM) band used in item management applications. Its purpose is to provide a common technical specification for RFID devices that may be used by ISO committees developing RFID application standards. This part of ISO/IEC 18000 is intended to allow for compatibility and to encourage inter-operability of products for the growing RFID market in the international marketplace. This part of ISO/IEC 18000 defines the forward and return link parameters for technical attributes including, but not limited to, operating frequency, operating channel accuracy, occupied channel bandwidth, maximum EIRP, spurious emissions, modulation, duty cycle, data coding, bit rate, bit rate accuracy, bit transmission order, and where appropriate operating channels, frequency hop rate, hop sequence, spreading sequence, and chip rate. It further defines the communications protocol used in the air interface.

A1 This part of ISO/IEC 18000 contains one mode with three types. All three types are ITF. Type A uses Pulse-Interval Encoding (PIE) in the forward link and an adaptive ALOHA collision-arbitration algorithm. Type B uses Manchester in the forward link and an adaptive binary-tree collision-arbitration algorithm. Type C uses Pulse-Interval Encoding (PIE) in the forward link and a random slotted collision-arbitration algorithm. The detailed technical differences between the three types are shown in the associated parameter tables.

This part of ISO/IEC 18000 specifies

- physical interactions (the signalling layer of the communication link) between interrogators and tags,
- interrogator and tag operating procedures and commands, and
- the collision arbitration scheme used to identify a specific tag in a multiple-tag environment. **A1**

2 Conformance

A1 2.1 Claiming conformance

To claim conformance with this part of ISO/IEC 18000, an interrogator or tag shall comply with all relevant clauses of this part of ISO/IEC 18000, except those marked as “optional”. The interrogator or tag shall also operate within local radio regulations, which may further restrict operation.

Relevant conformance test methods will be provided in a future Technical Report (ISO/IEC TR 18047-6).

Conformance may also require a licence from the owner of any intellectual property utilized by said device. **A1**

A1) 2.2 Interrogator conformance and obligations

To conform to this part of ISO/IEC 18000, an interrogator shall

- support at least one type of A, B or C – it may optionally support two or all three;
- implement the mandatory commands defined in this part of ISO/IEC 18000;
- modulate/transmit and receive/demodulate a sufficient set of the electrical signals defined in the signalling layer of this part of ISO/IEC 18000 to communicate with conformant tags; and
- operate within applicable local regulations.

To conform to this part of ISO/IEC 18000, an interrogator may

- implement any subset of the optional commands defined in this part of ISO/IEC 18000, and
- implement any proprietary and/or custom commands in conformance with this part of ISO/IEC 18000.

To conform to this part of ISO/IEC 18000, the interrogator shall not

- implement any command that conflicts with this part of ISO/IEC 18000, or
- require using an optional, proprietary, or custom command to meet the requirements of this part of ISO/IEC 18000.

2.3 Tag conformance and obligations

To conform to this part of ISO/IEC 18000, a tag shall

- support at least one type of A, B or C – it may optionally support two or all three;
- operate over the frequency range from 860 MHz to 960 MHz, inclusive;
- implement the mandatory commands defined in this part of ISO/IEC 18000;
- modulate a backscatter signal only after receiving the requisite command from an interrogator; and
- conform to local radio regulations.

To conform to this part of ISO/IEC 18000, a tag may

- implement any subset of the optional commands defined in this part of ISO/IEC 18000; and
- implement any proprietary and/or custom commands as defined in clauses 7, 8 and 9 of this part of ISO/IEC 18000.

To conform to this part of ISO/IEC 18000, a tag shall not

- implement any command that conflicts with this part of ISO/IEC 18000;
- require using an optional, proprietary, or custom command to meet the requirements of this part of ISO/IEC 18000; or
- modulate a backscatter signal unless commanded to do so by an interrogator using the signalling layer defined in ISO/IEC 18000. **A3**

3 Normative references

A1 The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Text deleted **A1**

ISO/IEC 7816-6, *Identification cards — Integrated circuit cards — Interindustry data elements for interchange*

A1 ISO/IEC 15961, *Information technology — Radio frequency identification (RFID) for item management — Data protocol: application interface*

ISO/IEC 15962, *Information technology — Radio frequency identification (RFID) for item management — Data protocol: data encoding rules and logical memory functions*

ISO/IEC 15963, *Information technology — Radio frequency identification for item management — Unique identification for RF tags*

ISO/IEC 18000-1, *Information technology — Radio frequency identification for item management — Part 1: Reference architecture and definition of parameters to be standardized*

ISO/IEC 19762 (all parts), *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

EPCglobal™ Tag Data Standards version 1.3 and above, EPCglobal™ **A1**

4 Terms, definitions, symbols and abbreviated terms

4.1 Terms and definitions

A1 For the purposes of this document, the terms and definitions given in ISO/IEC 19762 (all parts) and the following apply. **A1**

4.1.1

collision arbitration loop

algorithm used to prepare for and handle a dialogue between an interrogator and a tag. This is also known as collision arbitration.

4.1.2

byte

8 bits of data designated b1 to b8, from the most significant bit (MSB, b8) to the least significant bit (LSB, b1).

A1 4.1.3

command set

set of commands used to explore and modify a tag population

4.1.4

continuous wave

typically sinusoid at a given frequency, but more generally any interrogator waveform suitable for powering a passive tag without amplitude and/or phase modulation of sufficient magnitude to be interpreted by a tag as transmitted data **A1**

A1 4.1.5

cover-coding

method by which an interrogator obscures information that it is transmitting to a tag; to cover-code data or a password an interrogator first requests a random number from the tag, then performs a bit-wise EXOR of the data or password with the received random number, and, finally, transmits the cover-coded (also called ciphertext) string to the tag; the tag uncovers the data or password by performing a bit-wise EXOR of the received cover-coded string with the original random number

4.1.6

dense-interrogator environment

operating environment (4.1.13) within which most or all of the available channels are occupied by active interrogators

EXAMPLE 25 active interrogators operating in 25 available channels.

4.1.7

dense-interrogator mode

set of interrogator-to-tag and tag-to-interrogator signalling parameters used in dense-interrogator environments

4.1.8

EPCglobal™ Application

application whose usage denotes an acceptance of EPCglobal™ standards and policies

NOTE Compare non-EPCglobal™ Application (4.1.12).

4.1.9

inventoried flag

flag that indicates whether a tag may respond to an interrogator; tags maintain a separate **inventoried** flag for each of four sessions, where each flag has symmetric *A* and *B* values within any given session, and in which interrogators typically inventory tags from *A* to *B* followed by a re-inventory of tags from *B* back to *A* (or vice versa)

4.1.10

inventory round

period initiated by a *Query* command and terminated by either a subsequent *Query* command (which also starts a new inventory round) or a *Select* command

4.1.11

multiple-interrogator environment

operating environment (4.1.13) within which a modest number of the available channels are occupied by active interrogators

EXAMPLE 5 active interrogators operating in 25 available channels.

4.1.12

non-EPCglobal™ Application

application whose usage does not denote an acceptance of EPCglobal™ standards and policies

NOTE Compare EPCglobal™ Application (4.1.8). **A1**

A1 4.1.13**operating environment**

region within which an interrogator's RF transmissions are attenuated by less than 90 dB

NOTE 1 In free space, the operating environment is a sphere whose radius is approximately 1000 m, with the interrogator located at the centre.

NOTE 2 In a building or other enclosure, the size and shape of the operating environment depends on factors such as the material properties and shape of the building, and may be less than 1000 m in certain directions and greater than 1000 m in other directions

4.1.14**operating procedure
tag-identification layer**

set of functions and commands used by an interrogator to identify and modify tags

4.1.15**permalock or permalocked**

memory location whose lock status is unchangeable (i.e. the memory location is permanently locked or permanently unlocked)

4.1.16**persistent memory or persistent flag**

memory or flag value whose state is maintained during a brief loss of tag power

4.1.17**physical layer**

data coding and modulation waveforms used in interrogator-to-tag and tag-to-interrogator signalling

4.1.18**random-slotted collision arbitration**

collision-arbitration algorithm where tags load a random (or pseudo-random) number into a slot counter, decrement this slot counter based on interrogator commands, and reply to the interrogator when their slot counter reaches zero

4.1.19**session**

inventory process comprising an interrogator and an associated tag population; an interrogator chooses one of four sessions and inventories tags within that session; the interrogator and associated tag population operate in one and only one session for the duration of an inventory round (4.1.10); for each session, tags maintain a corresponding **inventoried** flag; sessions allow tags to keep track of their inventoried status separately for each of four possible time-interleaved inventory processes, using an independent **inventoried** flag for each process

4.1.20**single-interrogator environment**

operating environment (4.1.13) within which there is a single active interrogator at any given time

4.1.21**singulation**

identifying an individual tag in a multiple-tag environment

4.1.22**slot**

point in an inventory round at which a tag may respond, which corresponds to the value output by a tag's slot counter

NOTE Tags reply when their slot (i.e. the value in their slot counter) is zero. **A1**

4.2 Symbols

$\boxed{A_1}$ BLF	Backscatter-link frequency ($BLF = 1/T_{pri} = DR/TR_{cal}$) $\boxed{A_1}$
Cht	Carrier high-level tolerance
Clf	Carrier low-level tolerance
D	Modulation depth of data coding pulse
$\boxed{A_1}$ DR	Divide ratio $\boxed{A_1}$
f_c	Frequency of operating field (carrier frequency)
$\boxed{A_1}$ FDM	Frequency-division multiplexing
FT	Frequency tolerance $\boxed{A_1}$
M	Modulation Index
Ma	Modulation upper tolerance type B
Mb	Modulation lower tolerance type B
$\boxed{A_1}$ M _h	RF signal envelope ripple (overshoot)
M _{hh}	FHSS signal envelope ripple (overshoot)
M _{hl}	FHSS signal envelope ripple (undershoot)
M _{hs}	FHSS signal level during a hop
M _l	RF signal envelope ripple (undershoot)
M _s	RF signal level when OFF
Q	Slot-count parameter. Q is an integer in the range (0,15)
R=>T	Interrogator-to-tag (reader-to-tag)
RTcal	Interrogator-to-tag (reader-to-tag) calibration symbol $\boxed{A_1}$
Taq	Quiet time - type A
Tapf	Pulse fall time - type A
Tapr	Pulse rise time - type A
Tapw	Pulse width - type A
$\boxed{A_1}$ Tari	Reference time interval for a data-0 in interrogator-to-tag signalling $\boxed{A_1}$
Tbmf	Manchester fall time – type B
Tbmr	Manchester rise time – type B
Tcf	Carrier fall time
Tcr	Carrier rise time
Tcs	Carrier steady state time
Tf	Fall time
Tfhf	Carrier FHSS fall time
Tfhr	Carrier FHSS rise time
Tfhs	Carrier FHSS steady time
Tr	Rise Time
Trlb	Return link bit time

$\langle A_1 \rangle T \Rightarrow R$	Tag-to-interrogator (tag-to-reader)
T_1	Time from interrogator transmission to tag response
T_2	Time from tag response to interrogator transmission
T_3	Time an interrogator waits, after T_1 , before it issues another command
T_4	Minimum time between interrogator commands
T_f or $T_{f,10-90\%}$	RF signal envelope fall time
T_{hf}	FHSS signal envelope fall time
T_{hr}	FHSS signal envelope rise time
T_{hs}	Time for an FHSS signal to settle to within a specified percentage of its final value
T_{pri}	Backscatter-link pulse-repetition interval ($T_{pri} = 1/BLF = TRcal/DR$)
T_r or $T_{r,10-90\%}$	RF signal envelope rise time
TRcal	Tag-to-interrogator (tag-to-reader) calibration symbol
T_s	Time for an RF signal to settle to within a specified percentage of its final value
UII	Unique Item Identifier
x_{fp}	floating-point value
$xxxx_2$	binary notation
$xxxx_h$	hexadecimal notation $\langle A_1 \rangle$

4.3 Abbreviated terms

AFI	Application family identifier
$\langle A_1 \rangle$ Ciphertext	Information that is cover-coded $\langle A_1 \rangle$
CRC	Cyclic redundancy check
CRC-5	Five bit CRC used in type a Interrogator to tag commands, used in Type A
CRC-16	Sixteen bit CRC used in both Type A and Type B commands and responses
$\langle A_1 \rangle$ CW	Continuous wave
dBch	Decibels referenced to the integrated power in the reference channel
DSB	Double sideband
DSB-ASK	Double-sideband amplitude-shift keying $\langle A_1 \rangle$
DSFID	Data storage format identifier
DSSS	Direct Sequence Spread Spectrum
EOF	End of frame
$\langle A_1 \rangle$ EPC™	Electronic product code
FCC	Federal Communications Commission $\langle A_1 \rangle$
FHSS	Frequency Hopping Spread Spectrum
LSB	Least significant bit
$\langle A_1 \rangle$ Handle	16-bit tag-authentication number
ITF	Interrogator-talks-first (Note: the common usage is RTF (Reader-talks-first) but the more precise term is ITF, which is used throughout the document.) $\langle A_1 \rangle$

BS ISO/IEC 18000-6:2004

MSB	Most significant bit
NRZ	Non Return to Zero
 NSI	Numbering system identifier 
PIE	Pulse interval encoding, used in Type A
 Pivot	Decision threshold differentiating an R=>T data-0 symbol from a data-1 symbol
Plaintext	Information that is not cover-coded
ppm	parts per million
PR-ASK	Phase-reversal amplitude shift keying
RFU	Reserved for future use
RN16	16-bit random or pseudo-random number
RNG	Random or pseudo-random number generator 
RFU	Reserved for future use
SOF	Start of frame
 SSB	Single sideband
SSB-ASK	Single-sideband amplitude-shift keying 
SUID	Sub unique identifier
TEL	Tag excitation level
 TID	Tag-identification or tag identifier, depending on context 
UID	Unique identifier
 Word	16 bits

4.4 Notation

This part of ISO/IEC 18000 uses the following notational conventions for type C:

- States and flags are denoted in bold. Example: **ready**.
- Commands are denoted in italics. Variables are also denoted in italics. Where there might be confusion between commands and variables, this specification will make an explicit statement. Example: *Query*.
- Command parameters are underlined. Example: Pointer.
- For logical negation, labels are preceded by '~'. Example: If **flag** is true, then **~flag** is false.
- The symbol, R=>T, refers to commands or signalling from an interrogator to a tag (reader-to-tag).
- The symbol, T=>R, refers to commands or signalling from a tag to an interrogator (tag-to-reader). 

5 Overview

5.1 General

This part of ISO/IEC 18000 specifies three communication types: Type A, Type B and Type C.

Figure 1, Figure 2, and Figure 3 show the architecture of each of the three interrogator types. Figure Amd.1-1, Figure Amd.1-2, and Figure Amd.1-3 show the architecture of each of the three tag types.

Table 1 provides an overview of the three communication types showing the protocol blocks from interrogator input (demodulator) to interrogator output (modulator) independent of the communication flow. 



Figure 1 — Type A interrogator architecture

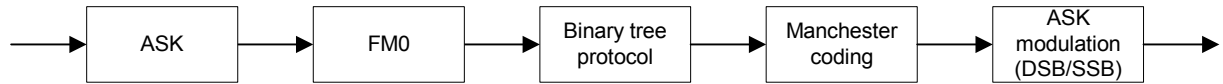


Figure 2 — Type B interrogator architecture

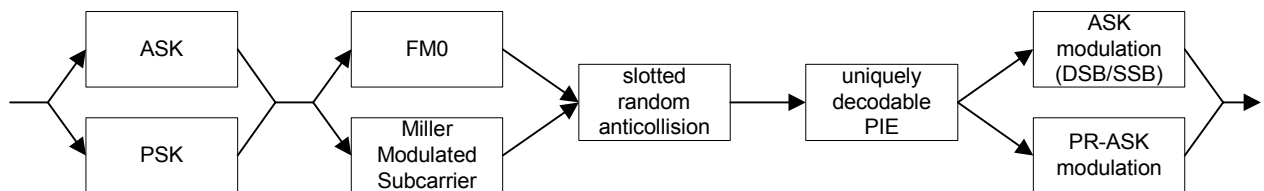


Figure 3 — Type C interrogator architecture

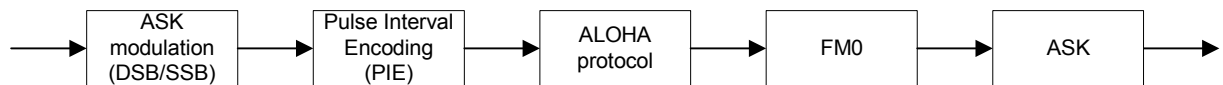


Figure Amd.1-1 — Type A tag architecture

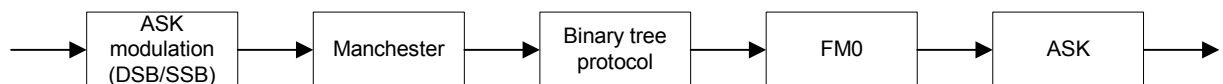


Figure Amd.1-2 — Type B tag architecture

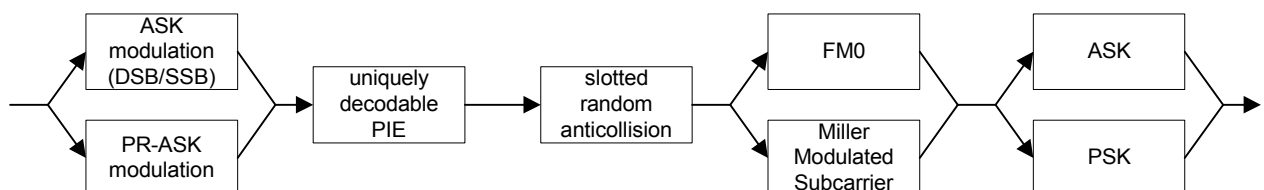
Figure Amd.1-3 — Type C tag architecture A1



Table 1 — Overview of Types A, B and C

Parameter	Type A	Type B	Type C
Forward link encoding	PIE	Manchester	Uniquely decodeable PIE
Modulation depth	27% to 100%	30.5% or 100%	80% to 100%
Data rate	33 kbit/s (assuming equiprobable data)	10 or 40 kbit/s (according to local regulations)	26.7 kbit/s to 128 kbit/s (assuming equiprobable data)
Return link encoding	FM0	FM0	FM0, Miller subcarrier
Collision arbitration	ALOHA / FST	Binary Tree	random slotted collision-arbitration
Tag unique identifier	64 bits (40 bit SUID)	64 bits	Variable: minimum 16 bits, maximum 496 bits
Memory addressing	Blocks up to 256 bits	Byte blocks, 1,2,3 or 4 byte writes	Bit, word (16-bit), or vendor-defined block boundaries (depending on command)
Error detection, forward link	5 bit CRC for all commands (with an additional 16-bit CRC appended for all long commands)	16-bit CRC	16-bit CRC, except a 5-bit CRC for the <i>Query</i> command
Error detection, return link	16-bit CRC	16-bit CRC	16-bit CRC, except no error check for RN16
Collision arbitration linearity	2048	Up to 2^{256}	Linear up to 2^{15} tags in the interrogator's RF field; above that number, $N \log(N)$ for tags with unique UIIs



5.2 Parameter tables

Table 2, Table 3, Table 4 and Table 5 contain the parameters for both types A and B in accordance with ISO/IEC 18000-1. Detailed description of the operating modes and parameters are specified in the subsequent clauses.



Table 2 — Interrogator-to-tag link parameters

Ref.	Parameter Name	Description	Ref Type C
Int:1	Operating Frequency Range	Types A and B: 860 – 960 MHz The interrogator operating frequency range shall be determined by the radio regulations in force in a particular regulatory jurisdiction and by the type approval requirements of the particular jurisdiction. Before an interrogator may be used, it shall meet the local radio regulations of the country in which it is to be used. It is envisaged that there will be more than one version of interrogator having different frequency and power characteristics in order to comply with local regulations. NOTE Performance will vary according to bandwidth and power output permitted by local regulations. Type C: 860 MHz – 960 MHz, as required by local regulations	See clause 9.3.1.1
Int:1a	Default Operating Frequency	Types A and B: In accordance with the local radio regulations. See Int: 1 Type C: Determined by local radio regulations and by the radio-frequency environment at the time of the communication	See clause 9.3.1.1
Int:1b	Operating Channels (spread-spectrum systems)	Types A and B: In accordance with the local radio regulations. See Int: 1 Type C: In accordance with local regulations; if the channelisation is unregulated, then as specified	See clause 9.3.1.2.10, Annex I
Int:1c	Operating Frequency Accuracy	Types A and B: In accordance with the local radio regulations See Int: 1 Type C: As specified	See clause 9.3.1.2.1
Int:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Types A and B: Not applicable for single fixed frequency or channelized Adaptive Frequency Agile systems. Where FHSS is permitted, the hop rate shall be in accordance with the local radio regulations. Type C: In accordance with local regulations	See clause 9.3.1.2.9



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Table 2 (continued)

Ref.	Parameter Name	Description	Ref Type C
Int:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Types A and B: In accordance with the local radio regulations. Where not specified by such regulations a pseudo-random hopping sequence shall be used that ensures an even distribution of transmissions over the available channels. Type C: In accordance with local regulations	See clause 9.3.1.2.9
Int:2	Occupied Channel Bandwidth	In accordance with local regulations	
Int:2a	Minimum Receiver Bandwidth	In accordance with local regulations	
Int:3	Interrogator Transmit Maximum EIRP	In accordance with local regulations	
Int:4	Interrogator Transmit Spurious Emissions	Types A and B: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by local regulations	See clause 9.3.1.2.11
Int:4a	Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems)	Types A and B: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by local regulations	See clause 9.3.1.2.11
Int:4b	Interrogator Transmit Spurious Emissions, Out-of-Band	Types A and B: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by local regulations	See clause 9.3.1.2.11
Int:5	Interrogator Transmitter Spectrum Mask	Types A and B: As per Int: 2 and Int: 4a. Type C: As specified; tighter emission limits may be imposed by local regulations	Figure Amd.1-9, Figure Amd.1-10
Int:6	Timing	Types A and B: See below Int: 6x. Type C: As specified	See clause 9.3.1.6, Figure Amd.1-19, Table Amd.1-15
Int:6a	Transmit-to-Receive Turn-Around Time	Types A and B: The interrogator transmit/receive settling time shall not exceed 85 μ s. Type C: MAX(RTcal, 10T _{pri}) nominal	See clause 9.3.1.6, Figure Amd.1-19, Table Amd.1-15
Int:6b	Receive-to-Transmit Turn-Around Time	Types A and B: As determined by the communication protocol – refer Tag: 6a. Type C: 3T _{pri} minimum; 20T _{pri} maximum when tag is in reply & acknowledged states; no limit otherwise	See clause 9.3.1.6, Figure Amd.1-19, Table Amd.1-15
Int:6c	Dwell Time or interrogator Transmit Power-On Ramp	1500 μ s, maximum settling time	See clause 9.3.1.2.6, Figure Amd.1-6, Table Amd.1-8
Int:6d	Decay Time or interrogator Transmit Power-Down Ramp	Types A and B: Maximum 1 ms. Type C: 500 μ s, maximum	Figure Amd.1-6, Table Amd.1-9
Int:7	Modulation	Types A and B: Amplitude Modulation. Type C: DSB-ASK, SSB-ASK, or PR-ASK	See clause 9.3.1.2.2

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Table 2 (continued)

Ref.	Parameter Name	Description	Ref Type C
Int:7a	Spreading Sequence (direct-sequence [DSSS] systems)	Not applicable.	
Int:7b	Chip Rate (spread-spectrum systems)	Not applicable.	
Int:7c	Chip Rate Accuracy (spread-spectrum systems)	Not applicable.	
Int:7d	Modulation Depth	Type A: Nominal 30 % to 100 %. See Table 11 and clause 7.1.1. Type B: Nominal 18% or 100% . Type C: 90% nominal	See clause 9.3.1.2.5, Figure Amd.1-5, Table Amd.1-7
Int:7e	Duty Cycle	Types A and B: In accordance with local regulations. Type C: 48% – 82.3% (time the waveform is high)	See clause 9.3.1.2.3, Figure Amd.1-4, Table Amd.1-7
Int:7f	FM Deviation	Not applicable.	
Int:8	Data Coding	Type A: Pulse Interval Encoding Type B: Manchester bi-phase Type C: PIE	See clause 9.3.1.2.3, Figure Amd.1-4
Int:9	Bit Rate	Type A: 33 kbit/s as constrained by the local radio regulations Type B: 10 kbit/s or 40 kbit/s as constrained by the local radio regulations. Type C: 26.7 kbit/s to 128 kbit/s (assuming equiprobable data)	See clause 9.3.1.2.4
Int:9a	Bit Rate Accuracy	Types A and B: 100 ppm Type C: +/- 1%, minimum	See clause 9.3.1.2.4
Int:10	Interrogator Transmit Modulation Accuracy	Types A and B: Not applicable. Type C: As specified	See clause 9.3.1.2.4
Int:11	Preamble	Type A: has no preamble Type B: See clause 8.1.4.3 Type C: Required	See clause 9.3.1.2.8
Int:11a	Preamble Length	Type A: not applicable. Type B: 9 bits. See clause 8.1.4.3. Type C: As specified	See clause 9.3.1.2.8
Int:11b	Preamble Waveform(s)	Type A: not applicable . Type B: See clause 8.1.4.3. Type C: As specified	See Figure Amd.1-7
Int:11c	Bit Sync Sequence	Type A: not applicable. Type B: see clause 8.1.4.3 Type C: None	
Int:11d	Frame Sync Sequence	Types A and B: Not applicable. Type C: Required	See clause 9.3.1.2.8, Figure Amd.1-7
Int:12	Scrambling (spread-spectrum systems)	Not Applicable.	
Int:13	Bit Transmission Order	MSB is transmitted first	See clause 9.3.1.4

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Table 2 (continued)

Ref.	Parameter Name	Description	Ref Type C
Int:14	Wake-up process	Types A and B: Presence of an appropriate RF signal at the tag followed by a wake-up command as required by the tag type. See relevant clauses. Type C: As specified	See clause 9.3.1.3.4
Int:15	Polarization	Types A and B: Interrogator dependent. Not defined in this part of ISO/IEC 18000. Type C: Not specified	

Table 3 — Tag-to-interrogator link parameters

Ref.	Parameter Name	Description	Ref Type C
Tag:1	Operating Frequency Range	860 MHz – 960 MHz, inclusive	See clause 9.3.1.1
Tag:1a	Default Operating Frequency	Types A and B: The tag shall respond to an interrogator signal within the frequency range specified in Tag: 1. Type C: Tags respond to interrogator signals that satisfy Int:1a	See clause 9.3.1.1
Tag:1b	Operating Channels (spread-spectrum systems)	Types A and B: The tag shall respond to an interrogator signal within the frequency range specified in Tag: 1. Type C: Tags respond to interrogator signals that satisfy Int:1b	See clause 9.3.1.2.10
Tag:1c	Operating Frequency Accuracy	Types A and B: The tag shall respond to an interrogator signal within the frequency range specified in Tag: 1. Type C: As specified	See clause 9.3.1.3.3 Table Amd.1-11
Tag:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Types A and B: Not applicable Type C: Tags respond to interrogator signals that satisfy Int:1d	See clause 9.3.1.2.9
Tag:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Types A and B: Not applicable Type C: Tags respond to interrogator signals that satisfy Int:1e	See clause 9.3.1.2.9
Tag:2	Occupied Channel Bandwidth	In accordance with local regulations	
Tag:3	Transmit Maximum EIRP	In accordance with local regulations	
Tag:4	Transmit Spurious Emissions	In accordance with local regulations	
Tag:4a	Transmit Spurious Emissions, In-Band (spread spectrum systems)	In accordance with local regulations	
Tag:4b	Transmit Spurious Emissions, Out-of-Band	In accordance with local regulations	
Tag:5	Transmit Spectrum Mask	In accordance with local regulations	





Table 3 (continued)

Ref.	Parameter Name	Description	Ref Type C
Tag:6a	Transmit-to-Receive Turn-Around Time	Type A: The tag shall open its receive command window within 2 bit periods of the end of its response. Type B: 400 μs Type C: $3T_{pri}$ minimum, $20T_{pri}$ maximum in reply & acknowledged states; no limit otherwise	See clause 9.3.1.6, Figure Amd.1-19, Table Amd.1-15
Tag:6b	Receive-to-Transmit Turn-Around Time	Type A: Range from 150 to 1150 μs (see clause 7.5.3 and Table 28) Type B: Range 85 to 460 μs (see clause 8.1.5.2) Type C: $\text{MAX}(\text{RTcal}, 10T_{pri})$ nominal	See clause 9.3.1.6, Figure Amd.1-19, Table Amd.1-15
Tag:6c	Dwell Time or Transmit Power-On Ramp	Types A and B: Not applicable. Type C: Receive commands 1.5 ms after power-up	See clause 9.3.1.3.4
Tag:6d	Decay Time or Transmit Power-Down Ramp	Not applicable.	
Tag:7	Modulation	Types A and B: Bi-state amplitude modulated backscatter. Type C: ASK and/or PSK modulation (selected by tag)	See clause 9.3.1.3.1
Tag:7a	Spreading Sequence (direct sequence [DSSS] systems)	Not applicable.	
Tag:7b	Chip Rate (spread spectrum systems)	Not applicable.	
Tag:7c	Chip Rate Accuracy (spread spectrum systems)	Not applicable.	
Tag:7d	On-Off Ratio	Types A and B: The tag Delta RCS (Varying Radar Cross Sectional area) affects system performance. A typical value is greater than 0.005m^2. Type C: Not specified	
Tag:7e	Subcarrier Frequency	Types A and B: Not applicable. Type C: 40 kHz to 640 kHz	See clause 9.3.1.3.3, Table Amd.1-11
Tag:7f	Subcarrier Frequency Accuracy	Types A and B: Not applicable. Type C: As specified	Table Amd.1-11
Tag:7g	Subcarrier Modulation	Types A and B: Not applicable. Type C: Miller, at the data rate	See clause 9.3.1.3.2.3, Figure Amd.1-16
Tag:7h	Duty Cycle	Types A and B: The tag shall transmit its response when commanded to do so by the interrogator. Type C: FM0: 50%, nominal Subcarrier: 50%, nominal	See clause 9.3.1.3.2.1, 9.3.1.3.2.3
Tag:7i	FM Deviation	Not applicable.	
Tag:8	Data Coding	Types A and B: Bi-phase space (FM0) Type C: Baseband FM0 or Miller-modulated subcarrier (selected by the interrogator)	See clause 9.3.1.3.2



Table 3 (continued)

Ref.	Parameter Name	Description	Ref Type C
Tag:9	Bit Rate	Types A and B: Typical 40 kbit/s or 160 kbit/s (subject to tag clock tolerance see Table 9), The return bit rate selection for 160 kbit/s for Type B is defined in clause 8.1.4.4.5. Type C: FM0: 40 kbps to 640 kbps Subcarrier modulated: 5 kbps to 320 kbps	See clause 9.3.1.3.3 Table Amd.1-11
Tag:9a	Bit Rate Accuracy	Types A and B: +/- 15% (refer to Table 9) Type C: Same as Subcarrier Frequency Accuracy; see Tag:7f	See clause 9.3.1.3.3, Table Amd.1-11, Table Amd.1-12
Tag:10	Tag Transmit Modulation Accuracy (frequency-hopping [FHSS] systems)	Not applicable.	
Tag:11	Preamble	Types A and B: The preamble is defined in clause 6.5.6 Type C: Required	See clause 9.3.1.3.2.2, See clause 9.3.1.3.2.4
Tag:11a	Preamble Length	Types A and B: 16 bits made up of a quiet period, followed by sync, followed by a code violation followed by an orthogonal code. Type C: As specified	See Table Amd.1-11, See Figure Amd.1-18
Tag:11b	Preamble Waveform	Types A and B: Bi-phase encoded data '1'. Type C: As specified	See Table Amd.1-11, See Figure Amd.1-18
Tag:11c	Bit-Sync Sequence	Types A and B: Included in the preamble. Type C: None	
Tag:11d	Frame-Sync Sequence	Types A and B: Included in the preamble. Type C: None	
Tag:12	Scrambling (spread-spectrum systems)	Not applicable.	
Tag:13	Bit Transmission Order	MSB is transmitted first	See clause 9.3.1.4
Tag:14	Reserved	Deliberately left blank.	
Tag:15	Polarization	Types A and B: Product design feature. Not defined in this part of ISO/IEC 18000. Type C: Tag dependent; not specified by this document	
Tag:16	Minimum Tag Receiver Bandwidth	Types A and B: 860 – 960 MHz Type C: Tag dependent; not specified by this document.	





Table 4 — Protocol parameters

Ref.	Parameter Name	Description	Ref Type C
P:1	Who talks first	Interrogator	See clause 9.3
P:2	Tag addressing capability	Type A see clause 7.3.1 Type B see clause 8.2.2 Type C : As specified	See clause 9.3.2.1
P:3	Tag UII	Types A and B : Contained in tag memory and accessible by means of a command. Type C : Contained in Tag memory	See clause 9.3.2.1
P:3a	UII Length	Type A : 64 bits. An SUID of 40 bits is used during census or collision arbitration transactions. Type B : 64 bits Type C : As specified	9.3.2.1.2.2
P:3b	UII Format	See clause 7.2.1 for type A . See clause B.2 for type B . Type C : NSI < 100 _h : As specified in EPCglobal™ Tag Data Standards (Version 1.3 and above), NSI ≥ 100 _h : As specified in ISO/IEC 15961	9.3.2.1.2.2 9.3.2.1.2.3 9.3.2.1.2.4
P:4	Read size	Type A : Addressable in blocks of up to 256 bits, but always an integer multiple of bytes. Type B : Addressable in byte blocks. Type C : Multiples of 16 bits	See clause 9.3.2.10.3.2 Table Amd.1-32
P:5	Write Size	Type A : Addressable in blocks of up to 256 bits, but always an integer multiple of bytes. Type B : Addressable in byte blocks. Writing in blocks of 1, 2, 3 or 4 bytes. See details in relevant clauses. Type C : Multiples of 16 bits	See clause 9.3.2.10.3.3, Table Amd.1-34, See clause 9.3.2.10.3.7, Table Amd.1-44
P:6	Read Transaction Time	Types A and B : A single tag can typically be identified and have its first 128 bits of user memory read in less than 10 ms. This time may vary depending on the data rate used as constrained by the local radio regulations. Type C : Varied with R=>T and T=>R link rate and number of bits being read	See clause 9.3.2.10.3.2
P:7	Write Transaction Time	Types A and B : Once a tag has been identified and selected, a 32-bit data block can typically be written in less than 20 ms. This time may vary depending on the data rate used as constrained by the local radio regulations. Type C : 20 ms (maximum) after end of <i>Write</i> command	See clause 9.3.2.10.3.3, See clause 9.3.2.10.3.7, Figure Amd.1-25





Table 4 (continued)

Ref.	Parameter Name	Description	Ref Type C
P:8	Error detection	Type A: Interrogator to tag: 16-bit commands: CRC-5. Commands of more than 16 bits have an additional CRC-16, bit protection. Tag to interrogator: CRC-16 Type B: Interrogator to tag: CRC-16 Tag to interrogator: CRC-16 Type C: Interrogator-to-tag: <i>Select</i> command: CRC-16 <i>Query</i> command: CRC-5 Other Inventory commands: Command length Access commands: CRC-16 Tag-to-interrogator: PC, UII: CRC-16 RN16: None or CRC-16 (varies with command) <i>handle</i>: CRC-16 All other: CRC-16	See clause 9.3.2.10 and its subsections
P:9	Error correction	Types A and B: No forward error correction code used. Errors are handled by signalling an error to the interrogator that then repeats its last transmission. Type C: None	
P:10	Memory size	Types A and B: No minimum user memory size is specified, but if user memory is provided it shall be an integer multiples of 4 bytes. Type C: Tag dependent, extensible (size is neither limited nor specified by this document)	
P:11	Command structure and extensibility	Type A: Several command codes are reserved for future use. In addition, a Protocol extension flag allows for further extensions. Type B: Several command codes are reserved for future use. Type C: As specified	Table Amd.1-18



Table 5 — Anti-collision parameters

Ref.	Parameter Name	Description	Ref Type C
A:1	Type (Probabilistic or Deterministic)	Probabilistic	See clause 9.3.2.6
A:2	Linearity	Type A: Essentially linear using adaptive slot allocation up to 256 slots for 250 tags in an interrogator zone. Type B: Essentially linear up to 2^{256} tags depending on size of data content. Type C: Linear up to 2^{15} tags in the interrogator's RF field; above that number, $N \log N$ for tags with unique UIIs	See clause 9.3.2.8
A:3	Tag inventory capacity	Types A and B: The algorithm permits the reading of not less than 250 tags in the reading zone of the interrogator. Type C: Unlimited for tags with unique UIIs	See clause 9.3.2.8

6 Common elements of the physical layer for types A and B

6.1 General

Types A and B have several common elements for the physical layers. They are specified in the following sub-clauses.

6.2 Interrogator power-up waveform

The interrogator power-up waveform shall comply with the mask specified in Figure 4 and Table 6.

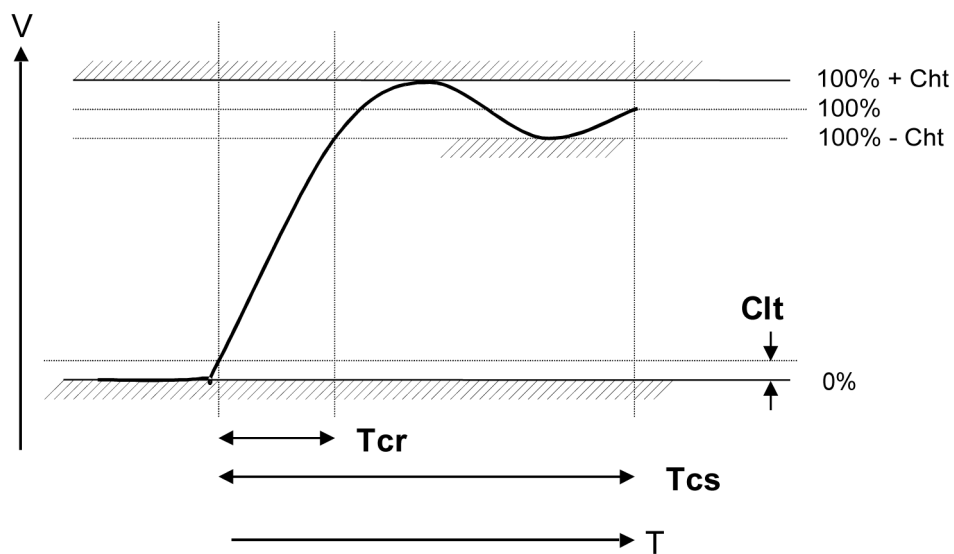


Figure 4 — Interrogator power-up waveform

Table 6 — Interrogator power-up waveform parameter values

Parameter	Min	Max
Tcs		1500µs
Tcr	1 µs	500 µs
Cht		10%
Clt		1%

6.3 Interrogator power-down

Once the carrier level has dropped below the ripple limit Cht, power down shall be monotonic and of duration Tcf, as specified in Figure 5 and Table 7.

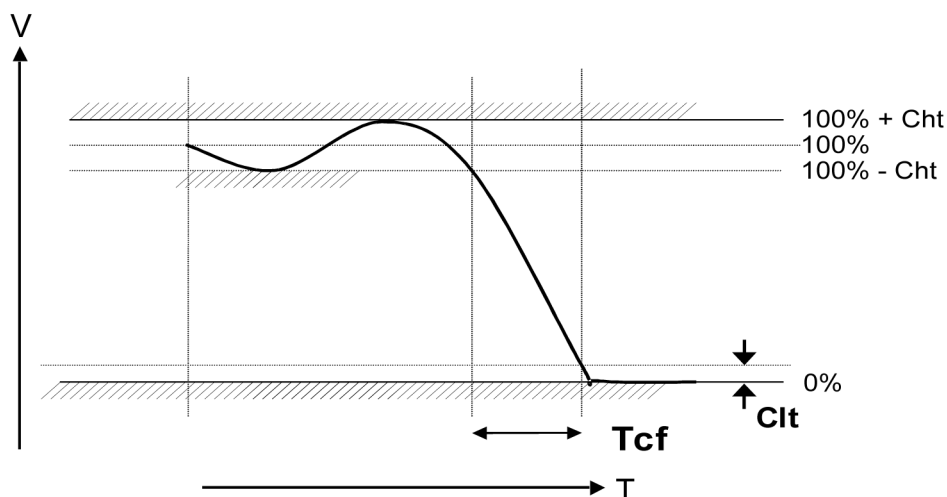


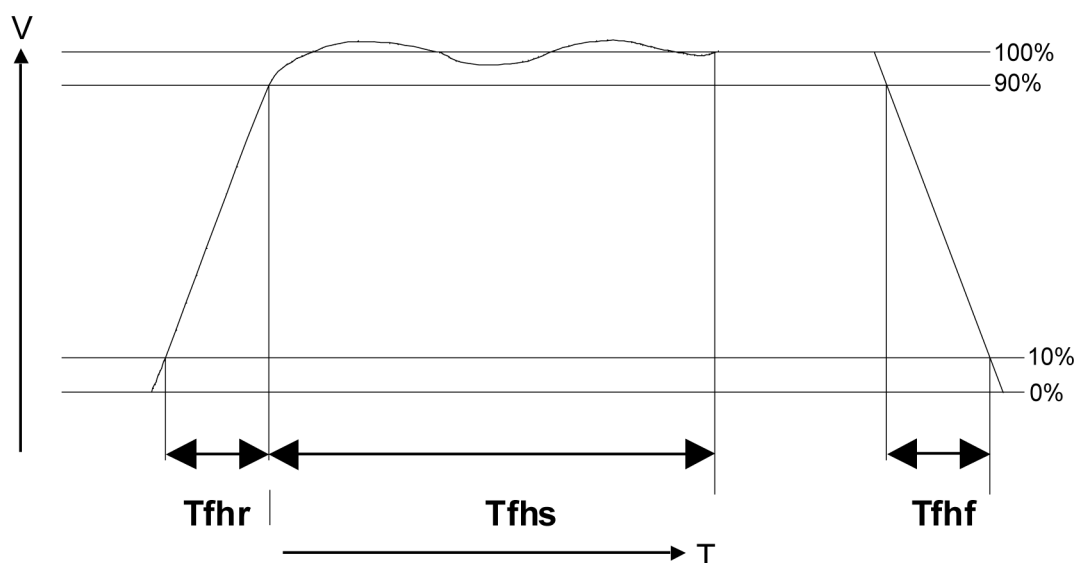
Figure 5 — Interrogator power-down waveform

Table 7 — Interrogator power-down timings

Parameter	Min	Max
Tcf	1 μ s	500 μ s
Cht		$\pm 5\%$ of steady state (100 %) level
Clc		1 %

6.4 Frequency hopping carrier rise and fall times

When the interrogator operates in the frequency operating hopping spread spectrum mode (FHSS), the carrier rise and fall times shall conform to the characteristics specified in Figure 6 and Table 8. The interrogator shall complete a frequency hop in a time not exceeding 30 μ s (to ensure that the tag is not reset by the frequency hop). The frequency hop is measured from the beginning of Tfhr to the end of Tfhr.



NOTE Ripple is $\pm 5\%$ of 100 % of steady state level

Figure 6 — FHSS carrier rise and fall characteristics

Table 8 — FHSS carrier rise and fall parameters

Parameter	Min	Max
Tfhr		30 μ s
Tfhs	400 μ s	
Tfhf		30 μ s

6.5 FM0 return link

6.5.1 FM0 return link general

The tag transmits information to the interrogator by modulating the incident energy and reflecting it back to the interrogator (backscatter).

6.5.2 Modulation

The tag switches its reflectivity between two states. The “space” state is the normal condition in which the tag is powered by the interrogator and able to receive and decode the forward link. The “mark” state” is the alternative condition created by changing the antenna configuration or termination.

6.5.3 Data rate

A1 The return link datarate shall be 40 or 160 kbit/s, which may be selected at the time of tag configuration. The interrogator shall be able to read and decode the tag reply at either datarate without the need to have prior knowledge of the tag configuration in order to handle mixed populations. **A1**

6.5.4 Data coding

Data is coded using the FM0 technique, also known as Bi-Phase Space.

One symbol period Trlb, as specified in Table 9, is allocated to each bit to be sent. In FM0 encoding, data transitions occur at all bit boundaries. In addition, data transitions occur at the mid-bit of logic 0 being sent.

A1

Table 9 — Return link parameters

Data rate	Trlb	Tolerance	Note
40kbit/s	25 μ s	+/-15%	Chip set to 40kbit/s Return Link Data Rate
160kbit/s	6.25 μ s	+/-15%	Chip set to 160kbit/s Return Link Data Rate

A1

Coding of data is MSB first. Figure 7 illustrates the coding for the 8 bits of 'B1'.

FM0 Data Coding
MSB first encoding of Byte 10110001 = 'B1'

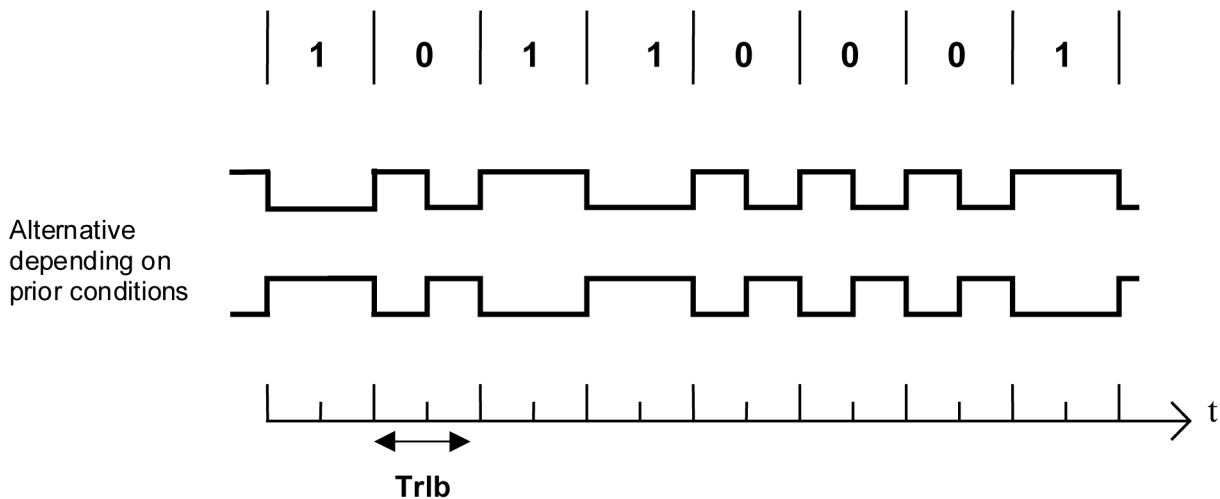


Figure 7 — Tag to interrogator data coding

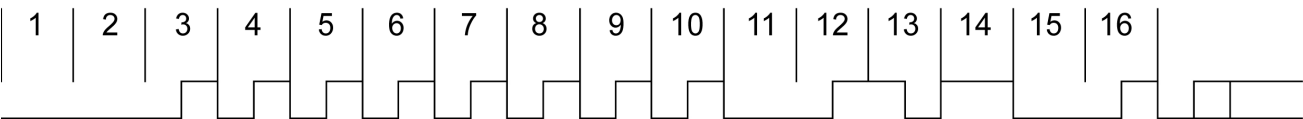
6.5.5 Message format

A return Link Message consists of n data bits preceded by the Preamble. The data bits are sent MSB first.

The Preamble enables the interrogator to lock to the tag data clock and begin decoding of the message. It consists of 16 bits as shown in Figure 8. There are multiple code violations (sequences not conforming to FM0 rules) that act as a frame marker for the transition from Preamble to Data.

6.5.6 Return preamble

The return preamble is a sequence of backscatter modulation specified in Figure 8.



NOTE The high state represents high reflectivity and the low state represents low reflectivity.

Figure 8 — Preamble waveform

Changing the Tag's modulator switch from the high impedance state to the low impedance state causes a change in the incident energy to be back-scattered, see Figure 9.

The tag shall execute backscatter, a half-low and half-high sent by the tag defined as follows:

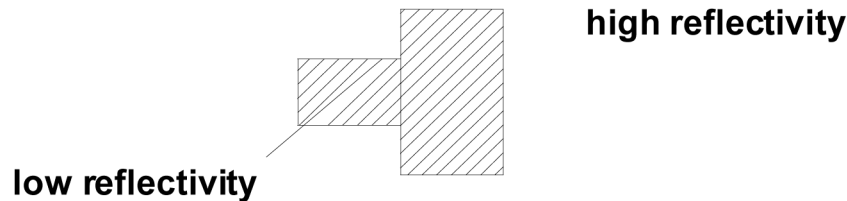


Figure 9 — Return link bit coding

6.5.7 Cyclic redundancy check (CRC)

6.5.7.1 CRC General

Types A and B use the same CRC-16 for the forward and the return links. In addition, Type A uses CRC-5 for short commands when it satisfies the required level of protection against errors.

On receiving a command from the interrogator, the tag shall verify that the checksum or the CRC value is valid. If it is invalid, it shall discard the frame, shall not respond and shall not take any other action.

6.5.7.2 Interrogator to tag 5 bit CRC-5

The 5 bit CRC shall be calculated on all the command bits after the SOF up to but not including the first CRC bit.

The polynomial used to calculate the CRC is $x^5 + x^3 + 1$.

A possible implementation is using a 5-bit shift register as defined in Clause A.1. The 5 bit CRC register is named Q4 to Q0, with Q4 being the MSB and Q0 being the LSB. The 5-bit register must be preloaded with '01001' (MSB to LSB) or in hexadecimal notation 0x09 (HEX), as shown in Table A.1

The 11 bits of data must be clocked through the CRC register, using the MSB first. The 5 CRC bits are then sent, MSB first. After the LSB of the CRC-5 bit is clocked through, the 5-bit CRC register should contain all zero's.

NOTE A schematic of a possible implementation is provided in Annex A.

6.5.7.3 Interrogator to tag 16 bit CRC-16

6.5.7.3.1 Interrogator to tag CRC-16 general

The 16 bit CRC shall be calculated on all the command bits after the SOF up to but not including the first CRC bit.

The polynomial used to calculate the CRC is $x^{16} + x^{12} + x^5 + 1$. The 16-bit register shall be preloaded with 'FFFF'. The resulting CRC value shall be inverted, attached to the end of the packet and transmitted.

The most significant byte shall be transmitted first. The most significant bit of each byte shall be transmitted first.

NOTE A schematic of a possible implementation is provided in Annex A.

The CRC may be implemented in one of two ways:

6.5.7.3.2 Inversion of incoming CRC bits by the tag

At the tag, the incoming CRC bits are inverted and then clocked into the register. After the LSB CRC bit is clocked into the register the 16 bit CRC register should contain all zero's.

6.5.7.3.3 Non-inversion of incoming CRC bits by the tag

If the received CRC bits are not inverted before clocking into the register, then after the LSB CRC bit is clocked into the register the 16 bit CRC register will have the value 0x1D0F (HEX)

6.5.7.4 Tag to interrogator 16 bit CRC-16**6.5.7.4.1 Tag to interrogator to tag CRC-16 general**

The 16 bit CRC shall be calculated on all data bits up to, but not including, the first CRC bit.

The polynomial used to calculate the CRC is $x^{16} + x^{12} + x^5 + 1$. The 16-bit register shall be preloaded with 0xFFFF (HEX). The resulting CRC value shall be inverted, attached to the end of the packet and transmitted.

The most significant byte shall be transmitted first, see Table 10. The most significant bit of each byte shall be transmitted first.

On receiving of a response from the tag, it is recommended that the interrogator verifies that the CRC value is valid. If it is invalid, appropriate remedial action is the responsibility of the interrogator designer.

NOTE A schematic of a possible implementation is provided in Annex A.

Table 10 — CRC-16 bits and bytes transmission rules

MSByte	LSByte
MSB LSB	MSB LSB
CRC-16 (8 bits)	CRC-16 (8 bits)
↑ first transmitted bit of the inverted CRC	

The CRC may be implemented in one of two ways.

6.5.7.4.2 Inversion of incoming CRC bits by the interrogator

At the reader receiver, the incoming CRC bits are inverted and then clocked into the register. After the LSB CRC bit is clocked into the register the 16 bit CRC register should contain all zero's.

6.5.7.4.3 Non-inversion of incoming CRC bits by the interrogator

If the received CRC bits are not inverted before clocking, the CRC register will have the value 0x1D0F (HEX).

7 Type A

7.1 Physical layer and data coding

7.1.1 PIE (Pulse interval encoding) forward link

7.1.1.1 Carrier modulation pulses

The data transmission from the interrogator to the tag is achieved by modulating the carrier amplitude (ASK). The data coding is performed by generating pulses at variable time intervals. The duration of the interval between two successive pulses carries the data coding information.

The tag shall measure the inter-pulse time on the high to low transitions (falling) edges of the pulse as shown in Figure 10.

The carrier modulation pulses are negative-going raised cosine shaped, their characteristics are specified in Figure 11 and Table 11.

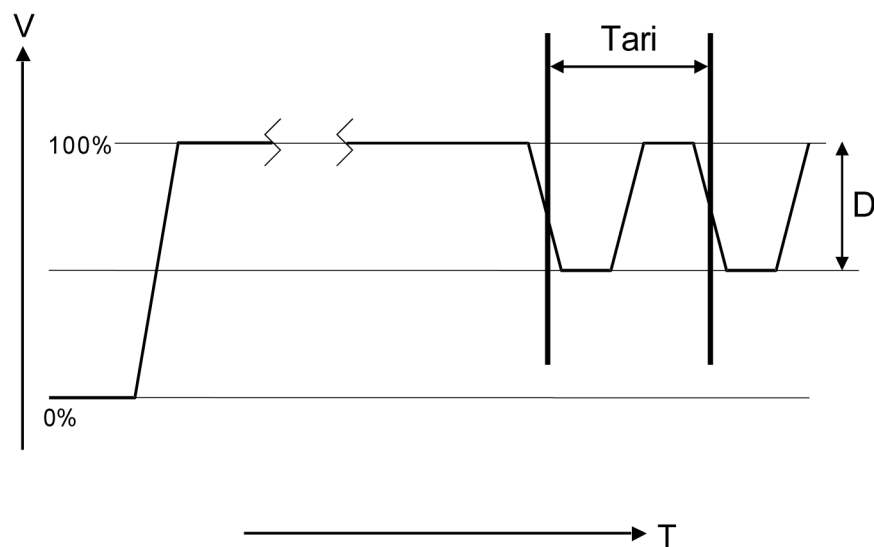
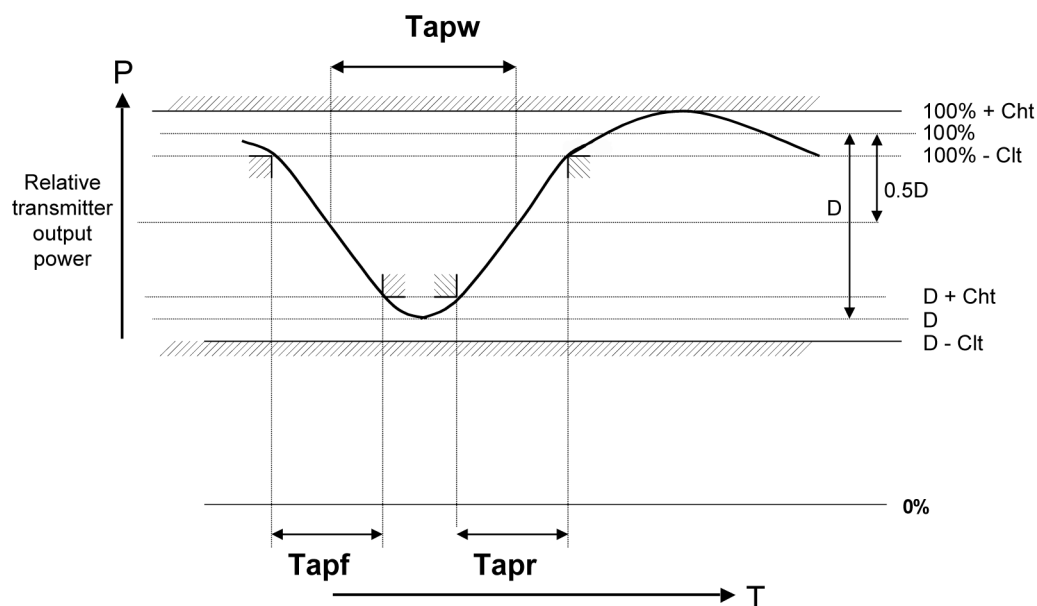


Figure 10 — Inter-pulse mechanism



NOTE The vertical lines occur at the half power (3dB) point on the modulation carrier dip.

Figure 11 — Modulation shaping

Table 11 — Modulation parameters

Parameter	Min	Nominal	Max
Tapw		10µs	
D	27% See NOTE 1		See NOTE 2
Tapf		4µs	
Tapr		4µs	
Cht			0.1 D
Clc			0.1 D
NOTE 1 The minimum modulation depth value is the absolute limit over the interrogator's operating temperature range.			
NOTE 2 The maximum modulation depth is may be in the range of 0.73 to 0 times the steady state value and will depend on the radio regulatory environment.			

The interrogator shall maintain a constant modulation depth during the transmission of a command, within the Cht and Clc tolerances.

7.1.1.2 Data coding and framing

The time Tari specifies the reference interval between the falling edges of two successive pulses representing the symbol '0' as transmitted by the interrogator; its value is specified in Table 12

Table 12 — Reference interval timing

Tari	Stability
10 to 20 μ s	± 100 ppm

Four symbols are defined as shown as shown in Table 13 and Figure 12. The symbols are referenced to the interval Tari and have a duration of 1 Tari, 2 Tari, and 4 Tari being integer multiples of Tari and shall have a tolerance with respect to Tari as defined in Table 13. The Start of Frame, SOF symbol is a combinational symbol made up by concatenating a '0' symbol with a symbol having a duration of 3 Tari, for an overall length of 4 Tari.

Table 13 — PIE symbols, coding

Symbol	Duration	Tolerance with respect to 1 Tari
0	1 Tari	
1	2 Tari	± 100 ppm
SOF	1 Tari followed by 3 Tari	± 100 ppm
EOF	4 Tari	± 100 ppm

Symbol	Number of Tari
'0'	1
'1'	2
SOF	4
EOF	4

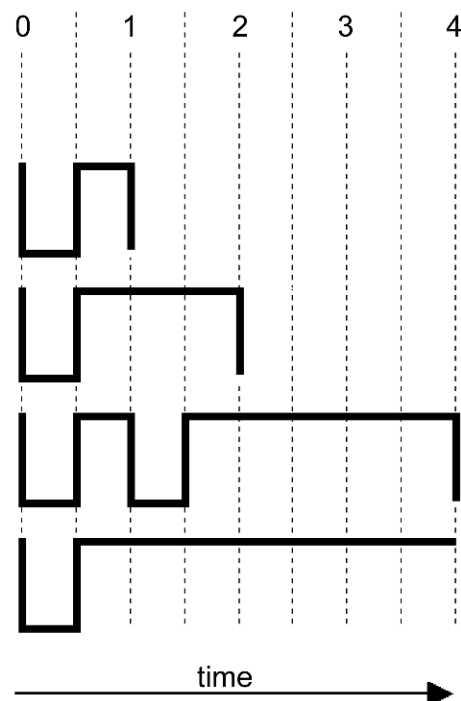


Figure 12 — PIE symbols

7.1.1.3 Decoding of PIE symbols by the tag

The tag shall be able to decode a PIE encoded transmission having symbols of duration as specified in Table 14:

Table 14 — Pie symbols, decoding

Symbol	Mean duration	Limits
0	1 Tari	$1/2 \text{ Tari} < '0' \leq 3/2 \text{ Tari}$
1	2 Tari	$3/2 \text{ Tari} < '1' \leq 5/2 \text{ Tari}$
SOF	1 Tari followed by 3 Tari	Calibration sequence
EOF	4 Tari	$\geq 4 \text{ Tari}$

The reference for the decoder is derived from the SOF and is $= 3/2 \text{ Tari}$

The tag shall interpret an interval between received symbols of $>4 \text{ Tari}$ as an EOF and shall discard the preceding data.

If the tag does not receive data for a period greater than EOF, the tag shall wait for a SOF.

7.1.1.4 Frame format

The bits transmitted by the interrogator to the tag are embedded in a frame as specified in Figure 13.

Before sending the frame, the interrogator shall ensure that it has established an unmodulated carrier for a duration of at least T_{aq} (Quiet time) of $300\mu\text{s}$.

The frame consists of a Start Of Frame (SOF), immediately followed by the data bits and terminated by an End Of Frame (EOF). After having sent the EOF the interrogator shall maintain a steady carrier for the time specified by the protocol so that the tags are powered for transmitting their response.

If the tag does not receive data for a period greater than EOF, then the command decoder shall revert to the ready state and await another SOF.

The tag shall interpret an interval between received symbols of $>4 \text{ Tari}$ as an error and shall discard the preceding data.

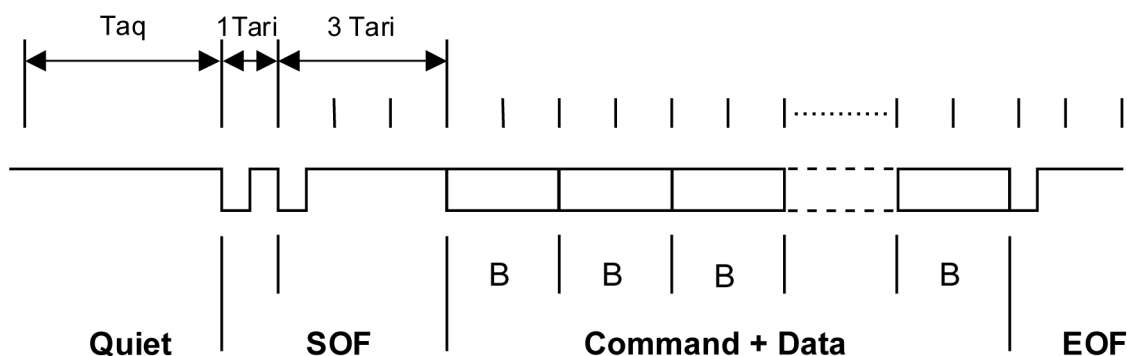


Figure 13 — Forward link frame format