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Information technology — Real-time locating systems (RTLS) —

Part 5: Chirp spread spectrum (CSS) at 2,4 GHz air interface

Technologies de l'information — Systèmes de localisation en temps réel (RTLS) —
Partie 5: Spectre étalé de compression d'impulsions (CSS) à une interface d'air de 2,4 GHz

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Contents

Page

Foreword

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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.

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ISO/IEC 24730-5 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

ISO/IEC 24730 consists of the following parts, under the general title *Information technology — Real-time locating systems (RTLS)*:

— *Part 1: Application program interface (API)*

— *Part 2: 2,4 GHz air interface protocol*

— *Part 5: Chirp spread spectrum at 2,4 GHz air interface*

Introduction

CSS is a technique for spreading the bandwidth of a digital signal by using chirp pulses. Chirp pulses are pulses with a monotonically increasing or decreasing instantaneous frequency. Chirp pulses were originally used for radar applications. Recently, systems and standards have been developed which use chirp pulses also for communication applications. This part of ISO/IEC 24730 includes ranging and bidirectional communication between tags and infrastructure. Bidirectional communication enables the infrastructure to control the behaviour of tags in a timely manner.

Information technology — Real-time locating systems (RTLS) —

Part 5:
Chirp spread spectrum (CSS) at 2,4 GHz air interface

1 Scope

ISO/IEC 24730 defines air interface protocols and an application programming interface (API) for real-time locating systems (RTLS). This part of ISO/IEC 24730 defines an air interface protocol which utilizes chirp spread spectrum (CSS) at frequencies from 2,4 GHz to 2,483 GHz. This protocol supports bidirectional communication and two-way ranging between the readers and tags of an RTLS. The mandatory default mode ensures interoperability between tags and infrastructure from various manufacturers, while the availability of several options offers flexibility to the developer of the infrastructure to adapt the behaviour of the overall system to the specific needs of his application.

2 Normative references

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.

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

ISO/IEC 19762-1, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 1: General terms relating to AIDC*

ISO/IEC 19762-3, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 3: Radio frequency identification (RFID)*

ISO/IEC 19762-4, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 4: General terms relating to radio communications*

ISO/IEC 19762-5, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 5: Locating systems*

ISO/IEC 24730-1, *Information technology — Real-time locating systems (RTLS) — Part 1: Application program interface (API)*

Guidelines on Limiting Exposure to Non-Ionizing Radiation, International Commission on Non-Ionizing Radiation Protection (ICNIRP), Munich, 1999

IEC 62369-1 ed1.0, *Evaluation of human exposure to electromagnetic fields from short range devices (SRDs) in various applications over the frequency range 0 GHz to 300 GHz — Part 1: Fields produced by devices used for electronic article surveillance, radio frequency identification and similar systems*

IEEE Std C95.1-2005, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762-1, ISO/IEC 19762-3, ISO/IEC 19762-4, ISO/IEC 19762-5 and the following apply.

3.1
chirp spread spectrum
technique for spreading the bandwidth of a digital signal using linear frequency sweep signals

3.2
Class I
system that operates at a radiated power of up to 10 mW EIRP

3.3
Class II
system that operates at a radiated power higher than 10 mW up to the maximum defined by local regulations

3.4
ranging
process of determining the distance between two RTLS transceivers through the exchange of a specific set of messages

3.5
ranging peer
RTLS transceiver with which to perform ranging

3.6
RF channel
combination of a centre frequency value and bandwidth value

3.7
RTLS tag
RTLS transceiver that accepts commands from RTLS readers and sends blinks and/or reports to the RTLS readers

3.8
RTLS transmitter
part of an RTLS transceiver which is capable of sending messages

3.9
demultiplexer
equipment for reversing the process of multiplexing

3.10
medium
wireless channel

3.11
trilateration
method of determining the relative positions of objects using the known locations of three reference points and the measured distance between the object to be located and each reference point

3.12
interleaving
rearrangement or transposition of data to enhance the effectiveness of error control schemes

3.13
interleaver
unit that performs interleaving (3.12)

3.14
baseband
frequency band occupied by the aggregate of the signals used to modulate a carrier before they combine with the carrier in the modulation process

3.15
orthogonal
inner product being close to zero

3.16
peer X
x'th peer in a description of a situation with multiple peers

4 Symbols and abbreviated terms

ACK	acknowledge
ARQ	Automatic Repeat Query
BTS	Backoff Time Slot
CIFS	Carrier sense Inter Frame Space
CTS	Clear To Send
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access / Collision Avoidance
CSS	Chirp Spread Spectrum
dBr	decibel relative
DEMUX	demultiplexer
DQPSK	Differential Quadrature Phase Shift Keying
DQPSK-CSS	Differential Quadrature Phase Shift Keying over Chirp Spread Spectrum
Dst	Destination address
EIRP	Equivalent Isotropical Radiated Power
LFSR	Linear Feedback Shift Register
LSB	Least Significant Bit
MMSE	Minimum Mean Square Error
MAC	Medium Access Control
NAV	Network Allocation Vector
PHR	PHY header
PHY	physical layer
PPDU	PHY Protocol Data Unit

PSDU	PHY Service Data Unit
QPSK	Quadrature Phase Shift Keying
RTS	Request To Send
RTLS	Real Time Locating System
SFD	Start of Frame Delimiter
SHR	synchronization header
SIFS	Short Inter Frame Space
Src	source address
TWR	Two Way Ranging
SDS-TWR	Symmetric Double Sided Two Way Ranging
e	Euler constant
j	imaginary unit
$\tilde{s}^{M_0}(t)$	continuous time baseband representation of 2-ary orthogonal CSS signal
$\tilde{r}^{M_0}(t)$	implemented version of $\tilde{s}^{M_0}(t)$
$\tilde{s}_m^{M_1}(t)$	continuous time baseband representation of DQPSK-CSS signal
$\tilde{r}_m^{M_1}(t)$	implemented version of $\tilde{s}_m^{M_1}(t)$
m	configuration constant determining the type (one our of four possibilities) of sub-chirp sequence used
M_0	superscript indicating that 2-ary orthogonal CSS is described
M_1	superscript indicating that DQPSK-CSS is described
k	index variable
n	index variable
b_n	n'th symbol to be transmitted
$c_b(t)$	continuous time baseband representation of chirp pulse b for 2-ary orthogonal CSS
μ_0	configuration constant determining the chirp rate for 2-ary orthogonal CSS
μ_1	constant determining the chirp rate for DQPSK-CSS
T_{base}	timebase

T_{SBIFS}	time in between two sub blinks
T_{Blink}	average blink repetition time
T_{Rand}	random time
T_{Rxon}	duration of time interval for during which the receiver of a tag is activated
$T_{Contact}$	maximum expected duration between a tag receiving any packets from infrastructure if such is present
$T_{TimeoutApplication}$	duration of time interval during which a tag application shall respond to certain requests
$T_{WaitAfterRange}$	duration of time for which a tag shall go to Wait state after leaving Range state
T_0	configuration constant determining the duration of a chirp pulse for 2-ary orthogonal CSS
T_1	duration of sub-chirp sequence
T_{sub}	duration of sub-chirp
$T_{n,k,m}$	time position of k'th sub-chirp of n'th sub-chirp sequence of type m
$W_T(t)$	raised cosine window of duration T
α	roll of factor of the raised cosine window
A	amplitude variable which is minimized in minimum mean square error computation
τ_d	time delay variable that is minimized in minimum mean square error computation
φ	phase variable that is minimized in minimum mean square error computation
$d_{n,k}$	information sample of k'th sub-chirp in n'th sub-chirp sequence
$C_{k,m}^{sub}(t)$	continuous time baseband representation of k' sub-chirp of sub-chirp sequence type m
τ_m	timing constant that determines the time-gap between subsequent sub-chirp sequences for the sub-chirp sequence type m
$f_{k,m}$	offset centre frequency of k'th sub-chirp in sub-chirp sequence type m
$\zeta_{k,m}$	chirp direction of k'th sub-chirp in sub-chirp sequence type m
$S_m^{sub}(t)$	continuous time baseband representation of sub-chirp sequence of type m

5 Overview

5.1 Components

The major components of a real-time locating system (RTLS) and the relationship of those components are shown in Figure 1. As shown in this Figure the tags communicate with an infrastructure. The infrastructure provides an application program interface (API) through which an application can control the RTLS and retrieve information about location and state of tags.

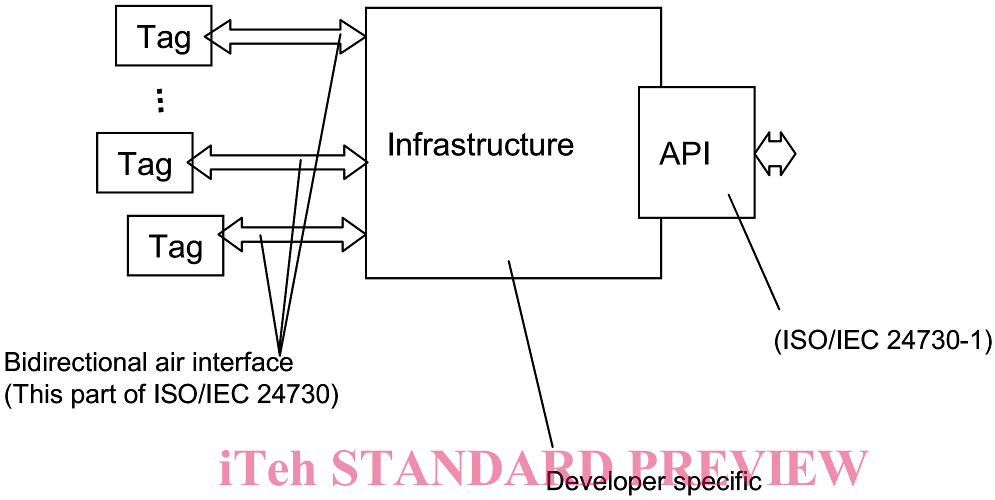

Figure 1 – RTLS components

As indicated in Figure 1 tags communicate with infrastructure over an air interface. Generally the air interface includes the definition of waveforms, formats of packets as well as commands and reports to be exchanged between tags and infrastructure. This can be depicted in a layered approach as shown in Figure 2. Similar interpretations can be found in other standards e.g. in ISO/IEC 18000-1[1].

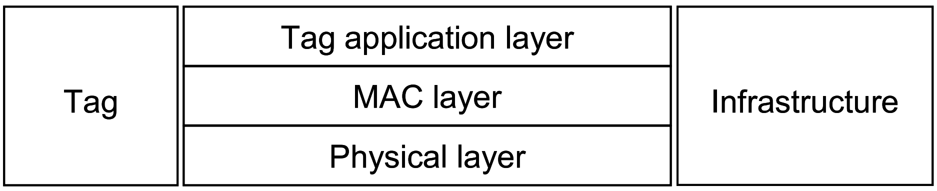

Figure 2 – Air interface layers

5.2 Purpose

This part of ISO/IEC 24730 defines an air interface protocol that optimizes small scale RTLS with an installation that enables simple, and also handheld, RTLS readers. Although the infrastructure itself is not defined in this part of ISO/IEC 24730, it is anticipated that the air interface protocol has a strong impact on the realization of the infrastructure and the related installation effort.

The key condition for simple installation is the possibility of 'autonomous' infrastructure nodes. In this part of ISO/IEC 24730, "autonomous" means there is not a requirement for these nodes to be synchronized with other infrastructure nodes. After being placed at a fixed location, an autonomous node simply responds to requests from RTLS tags.

This condition is achieved by specifying bidirectional communication and two-way ranging. As a consequence, the tag must also support bidirectional communication. Although this requirement increases the complexity of

the tag in one area, it also decreases the complexity in other areas, as additional interfaces for programming and conditioning the tag are not required. Thus bidirectional communication with the tag is seen as beneficial for many applications. Finally in order to utilize existing state of the art communication technology this part of ISO/IEC 24730 includes parts that correspond with IEEE 802.15.4a[5], which is a PHY amendment of IEEE 802.15.4[4], a successful standard for low power, low data rate wireless communication.

5.3 Not covered by the standard

The design of the infrastructure is left completely to the developer, e.g. the density of RTLS reader nodes, how the RTLS readers are controlled and communicate with each other, how the infrastructure is set up, etc. may be different in various scenarios and for systems from different vendors. For typical RTLS applications, at least three RTLS readers will communicate with each tag, measuring time of flight in order to locate the tag. For more details on this interaction, see Clause 9, Tag application layer specification.

5.4 System

After power on, a tag uses a default profile in which it blinks periodically. With each blink the tag signals its physical address, its capabilities and information about when it will be ready to receive commands from the infrastructure.

The infrastructure decides whether it needs to send commands to the tag while the tag is listening. By sending commands to the tag, the infrastructure controls which RTLS readers are part of the infrastructure the tag performs ranging with. Furthermore the infrastructure can adapt the behaviour of the tags to the actual conditions such as the number of tags in range, number of infrastructure nodes available, etc. For example, the infrastructure is able to instruct the tag to change to another mode (bandwidth, centre frequency, data rate) according to the actual environment or to perform ranging with a specific set of RTLS readers.

When the tag assumes that it has lost connection to the infrastructure e.g. because it doesn't receive any commands for a certain time, it reverts to the default profile. A more detailed description of complete system behaviour can be found in Annex D.

5.5 Document structure

The remainder of this part of ISO/IEC 24730 follows the "layered structure" mentioned above. This means that after the Requirements clause the three layers that form an air interface protocol (the Physical Layer [PHY], Media Access Control [MAC] and the Tag application layer) are addressed and specified separately. Additional information for the user of this part of ISO/IEC 24730 is provided in the informative annexes.

6 Requirements

6.1 Frequency range

This part of ISO/IEC 24730 addresses real-time locating systems (RTLS) operating in the 2,400 to 2,4835 GHz frequencies.

6.2 2,4 GHz spread spectrum air interface specifications

The minimum requirements shall include:

- RTLS transceivers shall autonomously generate a chirp spread spectrum frequency beacon indicating when the receiver will be activated.
- RTLS transceivers shall be able to perform two-way ranging when the receiver is activated.
- RTLS transmitters shall be fully compliant with local regulatory requirements.