INTERNATIONAL STANDARD

ISO/IEC 24730-62

First edition
2013-09-01

Information technology — Real time locating systems (RTLS) —

Part 62: High rate pulse repetition frequency Ultra Wide Band (UWB) air interface

Technologie de l'information — Systèmes de localisation en temps réel (RTLS) —

Partie 62: Interface aérienne ultra large bande (UWB) à impulsions haute fréquence de répétition

Reference number
ISO/IEC 24730-62:2013(E)

Contents

Page

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.

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

ISO/IEC 24730-62 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: Direct Sequence Spread Spectrum (DSSS) 2,4 GHz air interface protocol*
- *Part 5: Chirp spread spectrum (CSS) at 2,4 GHz air interface*
- *Part 21: Direct Sequence Spread Spectrum (DSSS) 2,4 GHz air interface protocol: Transmitters operating with a single spread code and employing a DBPSK data encoding and BPSK spreading scheme*
- *Part 22: Direct Sequence Spread Spectrum (DSSS) 2,4 GHz air interface protocol: Transmitters operating with multiple spread codes and employing a QPSK data encoding and Walsh offset QPSK (WOQPSK) spreading scheme*
- *Part 61: Low rate pulse repetition frequency Ultra Wide Band (UWB) air interface*
- *Part 62: High rate pulse repetition frequency Ultra Wide Band (UWB) air interface*

Introduction

This series of standards defines one Air Interface Protocol for Real Time Locating Systems (RTLS) for use in asset management and is intended to allow for compatibility and to encourage interoperability of products for the growing RTLS market.

This document, the high rate pulse repetition frequency (HRP) UWB Air Interface Protocol, establishes a technical standard for Real Time Locating Systems that operate at an internationally available UWB frequency bands and that are intended to provide accurate location (e.g. within some tens of centimetres) with frequent updates (for example, every second).

Real Time Locating Systems are wireless systems with the ability to locate the position of an item anywhere in a defined space (local/campus, wide area/regional, global) at a point in time that is, or is close to, real time. Position is derived by measurements of the physical properties of the radio link.

Conceptually there are four classifications of RTLS:

- Locating an asset via satellite - requires line-of-sight - accuracy to 10 meters
- Locating an asset in a controlled area, e.g., warehouse, campus, airport - area of interest is instrumented - accuracy to 3 meters
- Locating an asset in a more confined area - area of interest is instrumented - accuracy to tens of centimetres
- Locating an asset over a terrestrial area using a terrestrial mounted receivers over a wide area, cell phone towers for example – accuracy 200 meters

With a further two methods of locating an object which are really RFID rather than RTLS:

- Locating an asset by virtue of the fact that the asset has passed point A at a certain time and has not passed point B
- Locating an asset by virtue of providing a homing signal whereby a person with a handheld can find an asset

Method of location is through identification and location, generally through multilateration

- Types
  - Time of Flight Ranging Systems
  - Amplitude Triangulation
  - Time Difference of Arrival (TDOA)
  - Cellular Triangulation
  - Satellite multilateration
  - Angle of Arrival

This standard defines the air interface protocol needed for the creation of an RTLS system using HRP UWB which is a physical layer UWB signalling mechanism (based on standard IEEE 802.15.4a UWB) and employing high rate pulse repetition frequencies (PRF) 16 MHz or 64 MHz, and a combination of burst position modulation (BPM) and binary phase-shift keying (BPSK.

Information technology — Real time locating systems (RTLS) —

Part 62: High rate pulse repetition frequency Ultra Wide Band (UWB) air interface

1 Scope

This part of ISO/IEC 24730 defines the air-interface for real time locating systems (RTLS) using a physical layer Ultra Wide Band (UWB) signalling mechanism (based on IEEE 802.15.4a UWB). This modulation scheme employs high rate pulse repetition frequencies (PRF) 16 MHz or 64 MHz, and a combination of burst position modulation (BPM) and binary phase-shift keying (BPSK) giving an extremely high level of performance with a fully coherent receiver.

In addition to defining the air interface protocol (AIP) in terms of the physical layer modulation, this part of ISO/IEC 24730 also defines the AIP in terms of the messages sent over the air. This AIP supports simple one-way communication of a basic blink that may be used for a one-way Time Difference of Arrival (TDOA) based RTLS, where mobile tags periodically transmit the blink message which is received by an infrastructure consisting of a number of fixed reader nodes.

This AIP also optionally supports bidirectional communication and two-way ranging between the readers and tags of an RTLS. The support of two-way ranging depends on additionally including a UWB receiver in the tag and UWB transmitters in the reader infrastructure.

The mandatory default operational 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/IEEE 8802-15-4, *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements Part 15-4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)*

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

ISO/IEC 19762, *Information technology AIDC techniques — Harmonized vocabulary — (all parts)*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 8802-15-4, ISO/IEC 19762 (all parts), and the following apply.

3.1.1
burst
group of ultra wide band (UWB) pulses occurring at consecutive chip periods

3.1.2
complex channel
combination of a channel [radio frequency (RF) center frequency] and a ternary code sequence

3.1.3
frame
format of aggregated bits that are transmitted together in time

3.1.4
hybrid modulation
modulation used in the ultra wide band (UWB) physical layer (PHY) that combines both binary phase-shift keying (BPSK) and burst position modulation (BPM) so that both coherent and non-coherent receivers can be used to demodulate the signal

3.1.5
idle period
duration of time where no transceiver activity is scheduled to take place

3.1.6
local clock
symbol clock internal to a device

3.1.7
mean pulse repetition frequency (PRF)
total number of pulses within a symbol divided by the symbol duration

3.1.8
payload data
contents of a data message that is being transmitted

3.1.9
peak pulse repetition frequency (PRF)
maximum rate at which an ultra wide band (UWB) physical layer (PHY) emits pulses

3.1.10
ranging frame (RFRAME)
ultra wide band (UWB) frame having the ranging bit set in the physical layer (PHY) header (PHR)

3.1.11
ranging marker (RMARKER)
first ultra wide band (UWB) pulse of the first bit of the physical layer (PHY) header (PHR) of a ranging frame (RFRAME)

3.1.12
symbol
period of time and a portion of the transmitted signal that is logically considered to be a unit signaling event conveying some defined number of data bits or repeated portion of the synchronization signal

3.2 Abbreviated terms

AGC	automatic gain control
API	application program interface
BPM	burst position modulation
BPSK	binary phase-shift keying
CRC	cyclic redundancy check
DPS	dynamic preamble selection
DSN	data sequence number
FCS	frame check sequence
FEC	forward error correction
HRP	high rate PRF
LFSR	linear feedback shift register
LRP	low rate PRF
LSB	least significant bit
MAC	medium access control
MSB	most significant bit
PHR	PHY header
PHY	physical layer
PPDU	PHY protocol data unit
PRBS	pseudo-random binary sequence
PRF	pulse repetition frequency
PSD	power spectral density
PSDU	PHY service data unit
RF	radio frequency
RFID	Radio Frequency Identification
RFRAME	ranging frame
RMARKER	ranging marker
RTLS	Real Time Locating System
RX	receive or receiver
SFD	start-of-frame delimiter
SHR	synchronization header
SNR	signal-to-noise ratio
SYNC	synchronization
TDOA	time difference of arrival
TOF	time of flight

TX transmit or transmitter

UWB ultra wide band

4 Overview

4.1 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.

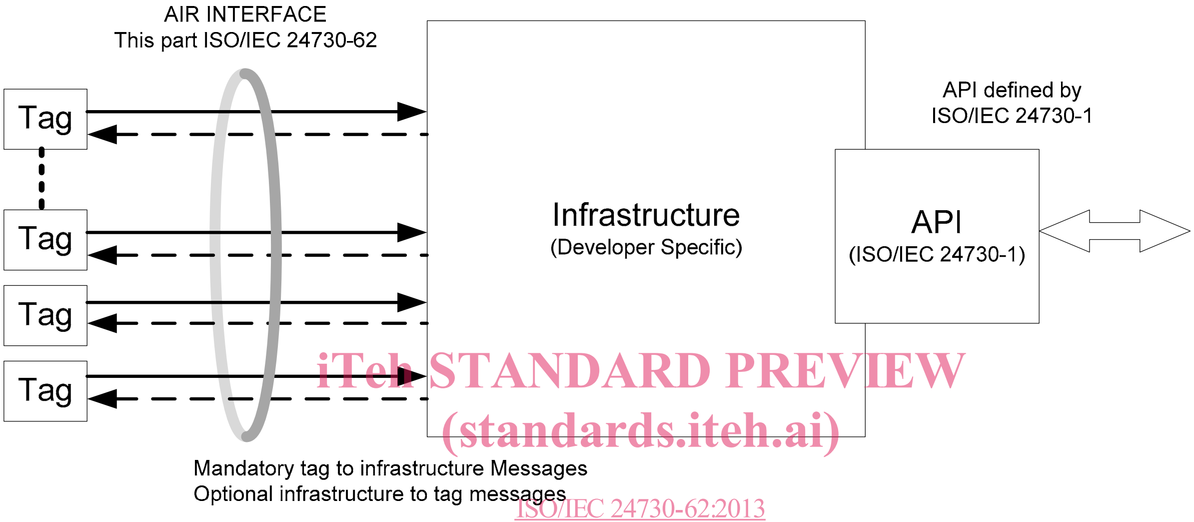

Figure 1 — RTLS components

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].

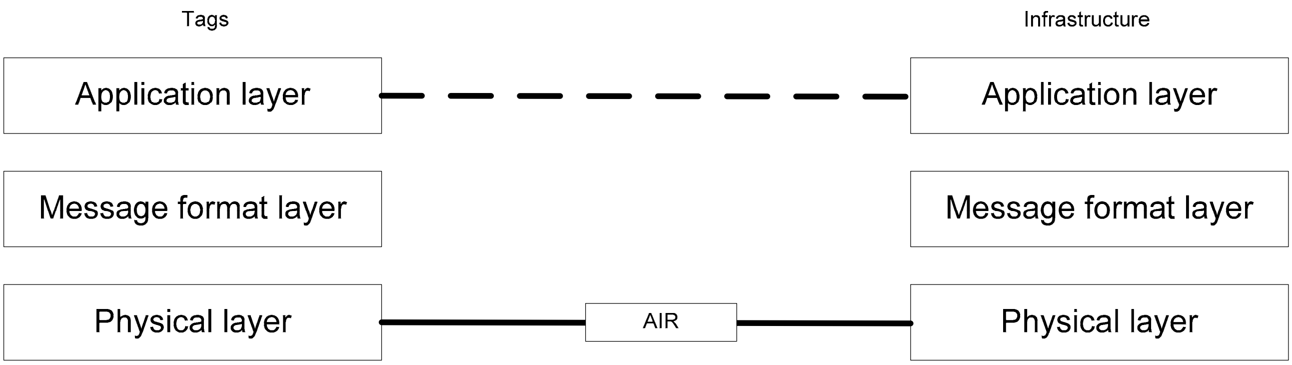

Figure 2 — air interface layers

4.2 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 reader nodes 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 need to receive the blink message from a tag, measuring its time of arrival, in order to locate the tag.

4.3 System

After power on, a tag uses a default profile in which it blinks periodically. With each blink the tag signals its physical address and optional information about whether and when it can receive commands from the infrastructure.

The infrastructure may use the arrival times of the blink at a number of time synchronised readers to compute the tag location using TDOA mechanisms.

The infrastructure may decide (for two-way capable tags) to command the tag to perform two-way ranging to a number of similarly capable reader nodes in the vicinity. By sending commands to the tag while the tag is listening, the infrastructure may select the reader nodes with which the tag performs two-way ranging. 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.

When a two-way tag loses connection to the infrastructure, i.e. doesn't receive any commands for a certain time, it reverts to its default blink activity.

4.4 Document structure

The remainder of this part of ISO/IEC 24730 firstly defines and specifies the Physical Layer (PHY) layer modulation and then defines the basic message format before separately detailing the messages of the default one-way communications mode of operation and the messages of the optional two-way communications mode of operation.

5 Physical (PHY) layer specification

5.1 General

The High Rate PRF (HRP) UWB physical layer herein called the UWB PHY, employs a mean PRF that is nominally 16 MHz or optionally nominally 64 MHz. The UWB PHY waveform is based upon an impulse radio signaling scheme using band-limited data pulses. The UWB PHY supports two independent bands of operation:

— The low band, which consists of four channels and occupies the spectrum from 3.1 GHz to 4.8 GHz

— The high band, which consists of eleven channels and occupies the spectrum from 6.0 GHz to 10.6 GHz

Within each channel, there is support for at least two complex channels that have unique length 31 SHR preamble codes. The combination of a channel and a preamble code is termed a *complex channel*.

A combination of burst position modulation (BPM) and binary phase-shift keying (BPSK) is used to support both coherent and non-coherent receivers using a common signaling scheme. The combined BPM-BPSK is used to modulate the symbols, with each symbol being composed of an active burst of UWB pulses. The various data rates are supported through the use of variable-length bursts.

Figure 3 shows the sequence of processing steps used to create and modulate a packet. The sequence of steps indicated here for the transmitter is used as a basis for explaining the creation of the UWB waveform. Note that the receiver portion of Figure 3 is informative and meant only as a guide to the essential steps that any compliant UWB receiver needs to implement in order to successfully decode the transmitted signal.

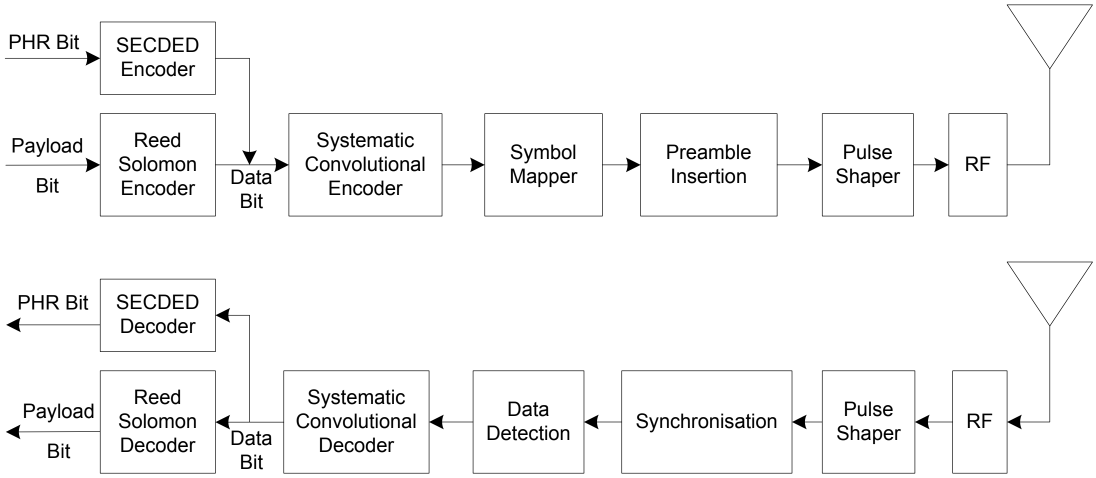

Figure 3 — signal flow

5.2 Default operating mode for a HRP UWB tag

The default operating parameters for the tag shall be as follows:

- Default band used by the tag shall be channel 5. This has centre frequency of 6489.6 MHz. This band is widely acceptable and suitable for use in many regions around the world.
  - Where national regulations prohibit transmission within this default band, another UWB channel may be used as an alternative along with an associated preamble code, as per Table 6.
- The nominal PRF employed by the tag shall be 16 MHz.
- The default preamble code employed by the tag for the transmitting the blink message shall be preamble code 3.
- The default preamble length shall be 256 symbols. Where this preamble length is not supported by the tag a preamble length of 1024 symbols may be used as an alternative.
- The default data rate shall be 850 kb/s.
- The default blink period shall be 3 seconds.
  - A random dither should be applied to this value so that tags with closely aligned crystal frequency do not stay in lock-step with long periods where their transmissions collide.

5.3 PPDU format

Figure 4 shows the format for the UWB frame, which is composed of three major components: the SHR preamble, the PHR, and the PSDU. For convenience, the PPDU packet structure is presented so that the leftmost field as written in this standard shall be transmitted or received first. All multiple octet fields shall be transmitted or received least significant octet first, and each octet shall be transmitted or received LSB first. The same transmission order should apply to data fields.

The SHR preamble is first, followed by the PHR, and finally the PSDU. The SHR preamble is always sent at the base rate for the preamble code. The PHR is sent at a nominal rate of 850 kb/s for all data rates above 850 kb/s and at a nominal of 110 kb/s for the nominal data rate of 110 kb/s. The PSDU is sent at the desired information data rate as defined in Table 3 — Rate-dependent and timing dependent parameters.

5.3.1 PPDU encoding process

The encoding process is composed of many steps as illustrated in Figure 4. The details of these steps are fully described in later sub-clauses, as noted in the following list, which is intended to facilitate an understanding of those details:

a) Perform Reed-Solomon encoding on PSDU as described in 5.4.3.1.

b) Produce the PHR as described in 5.3.6.1.

c) Add SECDED check bits to PHR as described in 5.3.6.2 and prepend to the PSDU.

d) Perform further convolutional coding as described in 5.4.3.2. Note that in some instances at the 27 Mb/s data rate, the convolutional encoding of the data field is effectively bypassed and two data bits are encoded per BPM-BPSK symbol.

e) Modulate and spread PSDU according to the method described in 5.4.1 and 5.4.2. The PHR is modulated using BPM-BPSK at 850 kb/s or at 110 kb/s (for the 110 kb/s data rate) and the data field is modulated at the rate specified in the PHR.

f) Produce the SHR preamble field from the SYNC field (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition) and the SFD field (used to indicate the start of frame). The SYNC and SFD fields are described in 5.3.5.1 and 5.3.5.2, respectively.

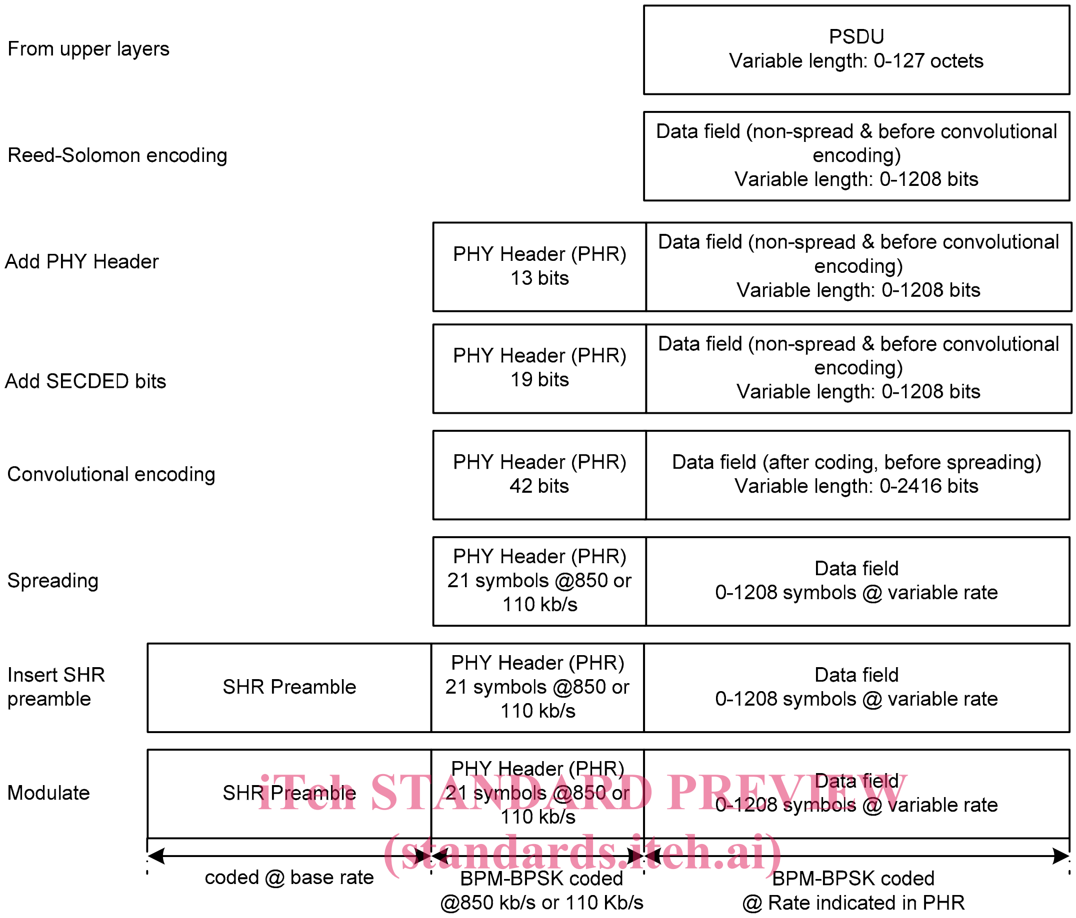

Figure 4 — PPDU encoding process

Table 1 and Table 2 show how the 19 header bits (H_0-H_{18}), N data bits (D_0-D_{N-1}), and two tail bits (T_0-T_1) are mapped onto the symbols. In these tables, the polarity bit column operation is an XOR. The tables also show when the transition from the header bit rate to the data bit rate takes place. Note that the delay line of the convolutional code is initialized to zero. For this reason, the position bit of Symbol 0 shall always be zero. This means that Symbol 0 is always transmitted in the first half of the first header symbol.

Table 1 — Mapping of header bits, data bits and tail bits onto symbols with Viterbi rate 0.5

Symbol #	Input data	Position bit	Polarity bit	
0	H_0	0	H_0	21 symbols of header at 850 kb/s
1	H_1	H_0	H_1	
2	H_2	H_1	$H_0 \oplus H_2$	
3	H_3	H_2	$H_1 \oplus H_3$	
…	…	…	…	
16	H_{16}	H_{15}	$H_{14} \oplus H_{16}$	
17	H_{17}	H_{16}	$H_{15} \oplus H_{17}$	
18	H_{18}	H_{17}	$H_{16} \oplus H_{17}$	
19	D_0	H_{18}	$H_{17} \oplus D_0$	
20	D_1	D_0	$H_{18} \oplus D_1$	
21	D_2	D_1	$D_0 \oplus D_2$	N symbols of data at data rate, e.g., 6.8 Mb/s
…	…	…	…	
N+17	D_{N-2}	D_{N-3}	$D_{N-4} \oplus D_{N-2}$	
N+18	D_{N-1}	D_{N-2}	$D_{N-3} \oplus D_{N-1}$	
N+19	T_0	D_{N-1}	$D_{N-2} \oplus T_0$	
N+20	T_1	T_0	$D_{N-1} \oplus T_1$	

5.3.2 Symbol structure

In the BPM-BPSK modulation scheme, a symbol is capable of carrying two bits of information: one bit is used to determine the position of a burst of pulses while an additional bit is used to modulate the phase (polarity) of this same burst.

The structure and timing of a symbol is illustrated in Figure 5. Each symbol shall consist of an integer number of possible chip positions, N_c, each with duration T_c. The overall symbol duration denoted by T_{dsym} is given by $T_{dsym} = N_c T_c$. Furthermore, each symbol is divided into two BPM intervals each with duration $T_{BPM} = T_{dsym} /2$, which enables binary position modulation.

A burst is formed by grouping N_{cpb} consecutive chips and has duration $T_{burst} = N_{cpb} T_c$. The location of the burst in either the first half or second half of the symbol indicates one bit of information. Additionally, the phase of the burst (either –1 or +1) is used to indicate a second bit of information.

In each symbol interval, a single burst event shall be transmitted. The fact that burst duration is typically much shorter than the BPM duration, i.e., $T_{burst} << T_{BPM}$, provides for some multi-user access interference rejection in the form of time hopping. The total number of burst durations per symbol, N_{burst}, is given by $N_{burst} = T_{dsym} / T_{burst}$. In order to limit the amount of inter-symbol interference caused by multipath, only the first half of each T_{BPM} period shall contain a burst. Therefore, only the first $N_{hop} = N_{burst}/4$ possible burst positions are candidate hopping burst positions within each BPM interval. Each burst position can be varied on a symbol-to-symbol basis according to a time hopping code as described in 5.4.