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| Title | IEEE 802.15.4z LRP PHY |
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| Source | David Barras (3db Access), Boris Danev (3db Access) |
| Re: | Updated Text for LRP PHY (802.15.4z\_D006e) |
| Abstract | This contribution proposes updated text for the baseline draft 802.15.4z\_D006e |
| Purpose | Provision of the text to facilitate its incorporation into the draft text of the IEEE 802.15.4z standard currently under development in TG4z. |
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Draft Standard for Low-Rate Wireless Networks Amendment of LRP UWB PHY

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NOTE—The editing instructions contained in this **amendment** define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

1. PHY PIB attributes
   1. PHY constants

[ir-0138: remove *aReturnTime* in the table 11-1 “PHY constants”, new PHY PIB attribute defined instead]

* 1. PHY PIB attributes

[ir-0139: Insert the following new PHY PIB attributes for signaling schemes (data rates) into Table 11-2 “PHY PIB Attributes”]

[ir-0137: Insert preamble length attribute attributes into Table 11-2 “PHY PIB Attributes”]

[ir-0138: Insert *phyUwbFixedReplyTime* to replace removed *aReturnTime* PIB constant]

|  |  |  |  |
| --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** |
| *phyLrpUwbSignaling* | Integer | 0 to 15 | For LRP, when this attribute is non-zero, it overrides the DataRate parameter of the MCPS-Data.request and configures the PHY to send and receive with the signaling scheme defined in Table 19-1 “Signaling modes and data rates for LRP UWB PHY”. |
| *phyLrpUwbPreambleLength* | Integer | 16 to 256 | Number of pulse periods in the preamble pattern as described in 19.3.1. A LRP device shall support default value of 128. |
| *phyFixedReplyTime* | Enumeration | 4U, 8U, 16U, 32U | Define fixed reply times for RDEV using SS-TWR ranging with values of 4, 8, 16 and 32 microseconds. A LRP device shall support default value of 16 microseconds. |
| *phyFixedReplyTimeSupported* | Boolean | true, false | Define whether an RDEV can support a fixed reply time. |
| *phyLrpUwbLeipEnabled* | Boolean | true, false | For LRP-SRDEV, this attributes overrides the LEIP related parameters of the MCPS-DATA.request. |
| *phyLrpUwbLeipLength* | Integer | 16 to 256 | For LRP-SRDEV, this attributes overrides the LEIP related parameters of the MCPS-DATA.request. |
| *~~phyLrpUwbSfdLength~~* | ~~Integer~~ | ~~32, 64 or 128~~ | ~~For LRP-SRDEV, indicates which SFD length is used 19.3.2.1~~ |
| *phyLrpUwbSfdSelector* | Integer | 0 to 7 | For LRP-SRDEV, indicates which SFD is used 19.3.2.2 |

1. LRP UWB PHY specification
   1. Overview

[ir-0139: replace Table 19-1 with the new table below to address editor’s footnote in P802.15.4z\_D00.6e ]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Mode** | **Modulation** | **PRF [MHz]** | **Pulses per  symbol** | **Peak data rate**  **[Mb/s]** | ***phyLrpUwbSignaling* PHY PIB attribute** | **DataRate as used in**  **MCPS-Data primitive (phyLrpUwbSignaling=0)** |
|
| **Long-range Mode** | PPM | 2 | 32 | 0.03125 | 1 | 1 |
| **Extended Mode** | OOK | 1 | 4 | 0.25 | 2 | 2 |
| **Base Mode** | OOK | 1 | 1 | 1 | 3 | 3 |
| **Dual-Frequency**  **Modes** | BFSK | 1 | 1 | 1 | 4 | N/A |
| 2 | 1 | 2 | 5 |
| 4 | 1 | 4 | 6 |
| **Extended**  **Dual-Frequency**  **Modes** | BFSK | 1 | 4 | 0.25 | 7 (default) |
| 2 | 4 | 0.5 | 8 |
| 4 | 4 | 1 | 9 |
| **Dual-Frequency**  **Modes with EPC** | BFSK-8PPM | 1 | 1/3 | 3 | 10 |
| BFSK-16PPM | 1 | 1/4 | 4 | 11 |
| BFSK-32PPM | 1 | 1/5 | 5 | 12 |
| BFSK-8PPM | 2 | 1/3 | 6 | 13 |
| BFSK-16PPM | 2 | 1/4 | 8 | 14 |
| BFSK-32PPM | 2 | 1/5 | 10 | 15 |

* 1. LRP UWB PHY symbol structure
     1. Dual-frequency LRP UWB PHY symbol structure
        1. Frequency deviation for dual-frequency modes

[from TBD in P802.15.4z\_D00.6e: insert the following text]

The modulation for the LRP-SRDEV PHY shall be binary frequency shift keying (BFSK) with amplitude modulation to generate the UWB pulse envelope. The frequency deviation shall be fdev=153.6 MHz.

* 1. LRP UWB SHR
     1. LRP UWB SHR preamble
        1. LRP UWB base mode SHR preamble

[ir-0137: Change the text of clause 19.3.1.1 to include preamble length of 256 as follows]

The LRP UWB base mode SHR preamble consists of a continuous stream of pulses at the base mode PRF 10 of 1 MHz, with a length between 16 and 256.

* + 1. LRP UWB SHR SFD

[ir-0137: Define SFDs of 32, 64 and 128 pulses to enable reliable detection of SFD in 19.3.2 LRP UWB SHR SFD, added PHY PIB attribute for SFD selection in 11.3]

* + - 1. LRP UWB SHR SFD for non-SRDEV
      2. LRP UWB SHR SFD for SRDEV

The SFD for the LRP-SRDEV UWB PHY can be of length 32, 64 or 128 pulse periods selected from the values shown in Table AAA.

**Table AAA – LRP UWB SHR SFD for SRDEV**

|  |  |  |
| --- | --- | --- |
| **SFD**  **length** | **PIB Attribute**  *phyLrpUwbSfdSelector* | **SFD [b0 … b31/b63/b127]** |
| 32 | 0 | 1000 1001 1000 0000 1001 1100 1000 0111 |
| 1 | 0000 0010 1100 0010 1100 1000 0101 0111 |
| 64 | 2 | 1000 1100 0000 0011 0101 0101 1101 0100  0000 1010 1001 1101 1010 0000 1000 0001 |
| 3 | 1010 1011 1000 0000 1001 1100 1000 0111  0100 1000 1011 0000 0101 1010 0110 0010 |
| 4 | 0011 0001 0111 0010 0010 1011 0110 1100  1100 0100 0101 1100 0100 0100 0010 1000 |
| 5 | 1000 0110 1001 1001 0100 0100 1011 1011  1101 1101 1000 0100 0000 1001 0010 0000 |
| 128 | 6 | 0001 0001 1011 0111 1011 0010 1100 0010  0111 1000 1100 0010 0010 0011 0001 0101  0000 0011 0111 1000 0001 1011 0000 0101  0100 0110 0000 0111 1110 1101 0110 0000  **(default SFD for LRP-SRDEV)** |
| 7 | 0001 0001 1011 0111 1011 0010 1100 0010  0111 1000 1100 0010 0010 0011 0001 0101  0000 0011 0111 1000 0001 1011 0000 0101  0100 0110 0000 0111 1110 1101 0110 0000 |

* 1. LRP UWB PHR

[ir-347: change title of 19.4.7 into “Optional Frame Payload only mode”]

* + 1. Optional Frame Payload only mode

[ir-347: replace text by the following]

In certain use cases where only the Frame Payload as defined in 7.2.9 contains relevant information, for example where secure ranging is the last step of communication between devices that have already discovered each other, the PHR and the MAC overhead can be omitted and only the Frame Payload portion of the message is sent after SHR, saving time and power and potentially improving the link budget in energy limited systems. The PPDU format is then as shown in Figure 85.

[ir-374: insert RMARKER in figure 85 and rename PHY payload into “frame payload”, Visio source file: “Figure 85 LRP-SRDEV PPDU format with Frame Payload.vsd”]



**Figure 85 - LRP-SRDEV PPDU format with Frame Payload only**

* 1. LRP UWB PSDU
     1. PSDU in EPC mode

[ir-0140: Modified figure 86 for the “compatibility issue with previously defined structure”: see Visio file “Figure 86 Dual-Frequency EPC mode symbol structure.vsd”]

[ir-0140: Replace text section of lines 13 to 17 of page 102 in P802.15.4.z\_D00.6e with the following text]

The earliest of the M pulse positions of the PPM modulation is located in the center of the chip and symbol period Tdsym as shown in Figure 86. The time interval dPPM is selected according to the modulation as specified in Table 28. The guard time Tguard is the total time before and after the active portion of the symbol TPPM. With the two PRF of 1 and 2 MHz and the time intervals of 7.8125 ns (1/64th of the PRF) and 15.625 ns (1/32nd of the PRF), the PSDU provides data rates from 3 to 10 Mb/s with various guard intervals to accommodate different channel conditions.



**Figure 86—Dual-Frequency EPC mode symbol structure**

[ir-0142 and ir-0144: addition of the missing parameters Tdsym in Table 28 in P802.15.4.z\_D00.6e and modification of erroneous values]

**Table 28 – Modulation parameters in EPC modes**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Modulation** | **PRF**  **(MHz)** | **Pulses per bit** | **Data rate**  **(Mb/s)** | **dPPM**  **(ns)** | **Tdsym**  **(μs)** | **TPPM**  **(ns)** | **Tguard**  **(ns)** |
| PBFSK-8PPM | 1.0 | 1/3 | 3 | 15.625 | 1 | 109.3750 | 890.6250 |
| PBFSK-16PPM | 1.0 | 1/4 | 4 | 15.625 | 1 | 234.3750 | 765.6250 |
| PBFSK-32PPM | 1.0 | 1/5 | 5 | 7.8125 | 1 | 242.1875 | 757.8125 |
| PBFSK-8PPM | 2.0 | 1/3 | 6 | 15.625 | 0.5 | 109.3750 | 445.3125 |
| PBFSK-16PPM | 2.0 | 1/4 | 8 | 15.625 | 0.5 | 234.3750 | 382.8125 |
| PBFSK-32PPM | 2.0 | 1/5 | 10 | 7.8125 | 0.5 | 242.1875 | 257.8125 |

[ir-0142: better explanation of EPC with modified repetition periods, replace lines 4 to 8 of page 103 in P802.15.4.z\_D00.6e by the following text]

When using EPC in conjunction with the modified pulse repetition period described in 19.2.5, the appropriate *Tdsym* is taken from Table 27 and used to calculate guard times.

The example below computes the resulting PPM active time TPPM and guard time Tguard when using the modified pulse repetition period kPRP = 7 in EPC resulting in a chip and symbol period of Tdsym | kPRP=7 = 945.3125 ns (derived from mode with nominal Tdsym of 1 μs) and targeting a peak data rate of approximately 5 Mb/s by using PBFSK 32-PPM modulation (M=32):

TPPM = (M - 1) ∙ dPPM = 31 ∙ 7.8125 ns = 242.1875 ns;

Tguard = Tdsym | kPRP=7 - TPPM = 945.3125 ns - 242.1875 ns = 703.125 ns.

* 1. LRP UWB transmitter specification
     1. Pulse shape

[ir-0143: figure 87 is not of a good quality, replace by figure below, located in file “SRDEV-LRP band allocation (source file for figures and tables).xlsx” in sheet entitled “Figure 87”.]



**Figure 87—Example of PSD mask spectral compliance for dual-frequency mode for band 6 using Gaussian pulse envelope (LRP-SRDEV)**

* + 1. Pulse timing

[ir-0145: insert the following after the first paragraph]

For a LRP-SRDEV, the transmission time of any individual pulse shall not drift more than 2 ns from its nominal transmission time during 128 pulse periods transmitted at the lowest PRF of 1 MHz over the specified operating temperature range of the device.

* 1. LRP UWB Return Time Requirements

[ir-0139: According to new PHY PIB attribute defining the fixed return time, sections below are replaced by keeping the former “turnaround” time (time for the device to switch from rx to tx and vice-versa, which will be bounded by the fixed return time) instead of “return” time]

* + 1. Receive-to-transmit turnaround time

An LRP-(S)RDEV capable of fixed reply time Round-Trip Time-of-Flight measurement as defined by PHY PIB attribute *phyFixedReplyTimeSupported* shall implement a receive-to-transmit turnaround time faster than the smallest supported *phyFixedReplyTime*.

* + 1. Transmit-to-receive turnaround time

An LRP-(S)RDEV capable of fixed reply time for Round-Trip Time-of-Flight measurement shall implement a transmit-to-receive turnaround time sufficiently fast to receive the response from a device supporting the receive-to-transmit return time specified by the smallest supported *phyFixedReplyTime*.