Proposed text with regard to BPSK-DSSS part of IEEE802.15.4d Japanese 950MHz PHY amendment

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Abstract

This document presents the proposed text to the editor to include in IEEE802.15.4d standard draft document which is expected to ask the IEEE802.15 membership to its first Letter Ballot.

Following text is the part of consolidated proposal of IEEE802.15.4d Japanese 950MHz PHY amendment, which is regarding to BPSK-DSSS modulation scheme. This part is to enhance the world wide commonality of IEEE802.15.4 technologies, especially for US 915MHz band, EU 868MHz band and similar sub-GHz band in other countries.

6. PHY specification

6.3 PPDU format

This subclause specifies the format of the PPDU packet.

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 least significant bit (LSB) first. The same transmission order should apply to data fields transferred between the PHY and MAC sublayer.

Each PPDU packet consists of the following basic components:

- A synchronization header (SHR), which allows a receiving device to synchronize and lock onto the bit stream
- A PHY header (PHR), which contains frame length information
- A variable length payload, which carries the MAC sublayer frame

The PPDU packet structure shall be formatted as illustrated in Figure 16.

		Octets			
		1		**4**	**variable**
Preamble	**SFD**	**Frame length (7 bits)**	**Reserved/PHR-Extension exists (1 bit)**	**PHR-Extension field**	**PSDU**
RHR		**PHR**			**PHY payload**

Figure 16 - Format of the PPDU

6.3.1 Preamble field

The Preamble field is used by the transceiver to obtain chip and symbol synchronization with an incoming message. The length of the preamble for the different PHYs is shown in Table 19.

Table 19 - Preamble field length

PHY	**Length**		**Duration (uS)**
868–868.6 MHz BPSK	**4 octets**	**32 symbols**	**1600**
902–928 MHz BPSK	**4 octets**	**32 symbols**	**800**
950.9–955.7 MHz BPSK	**4 octets**	**32 symbols**	**800**
868–868.6 MHz ASK	**5 octets**	**2 symbols**	**160**
902–928 MHz ASK	**3.75 octets**	**6 symbols**	**120**
868–868.6 MHz O-QPSK	**4 octets**	**8 symbols**	**320**
902–928 MHz O-QPSK	**4 octets**	**8 symbols**	**128**
2400–2483.5 MHz O-QPSK	**4 octets**	**8 symbols**	**128**

Preamble lengths for ASK are expressed in equivalent octet times as the preamble for ASK is defined using a special symbol. For all PHYs except the ASK PHY, the bits in the Preamble field shall be binary zeros. The ASK preamble format is described in 6.7.4.1.

6.3.2 SFD field

The SFD is a field indicating the end of the SHR and the start of the packet data. The length of the SFD for the different PHYs is shown in Table 20.

Table 20 - SFD field length

PHY	Length	
868–868.6 MHz BPSK	1 octet	8 symbols
902–928 MHz BPSK	1 octet	8 symbols
950.9–955.7 MHz BPSK	1 octet	8 symbols
868–868.6 MHz ASK	2.5 octets	1 symbol
902–928 MHz ASK	0.625 octets	1 symbol
868–868.6 MHz O-QPSK	1 octet	2 symbols
902–928 MHz O-QPSK	1 octet	2 symbols
2400–2483.5 MHz O-QPSK	1 octet	2 symbols

For all PHYs, exept for the ASK PHY, the SFD is an 8-bit field. For the ASK PHY, the SFD is defined using a special symbol. The lengths of the SFD for the ASK PHY are expressed in equivalent octet times. The SFD for all PHYs except the ASK PHY shall be formatted as illustrated in Figure 17. The SFD for the ASK PHY is defined in 6.7.4.2.

Bits: 0	1	2	3	4	5	6	7
1	1	1	0	0	1	0	1

Figure 17 - Format of the SFD field (except for ASK)

6.3.3 Frame Length field

The Frame Length field is 7 bits in length and specifies the total number of octets contained in the PSDU (i.e., PHY payload). It is a value between 0 and aMaxPHYPacketSize (see 6.4). Table 21 summarizes the type of payload versus the frame length value.

6.3.4 PSDU field

The PSDU field has a variable length and carries the data of the PHY packet.

6.3.5 Reserved/PHR-Extension bit

This 1 bit has been reserved for future and is recommended to be “0” when it is not used. In case of 950 MHz PHY, this bit indicates the presence of PHR Extension field which is 4 octet of fixed length. Refer to 6.3.5 with regard to the meaning of extension field.

Table 21—Frame length values

Frame length values	Payload
0–4	Reserved
5	MPDU (Acknowledgment)
6–8	Reserved
9 to *aMaxPHYPacketSize*	MPDU

6.6 868/915/950 MHz band binary phase-shift keying (BPSK) PHY specifications

6.6.1 868/915/950 MHz band data rates

The data rate of the 868/915/950 MHz band BPSK PHY shall be 20 kb/s when operating in the 868/950 MHz band, and 40 kb/s when operating in the 915 MHz band.

6.6.2 Modulation and spreading

The 868/915 MHz BPSK PHY shall employ direct sequence spread spectrum (DSSS) with BPSK used for chip modulation and differential encoding used for data symbol encoding.

6.6.2.1 Reference modulator diagram

The functional block diagram in Figure 21 is provided as a reference for specifying the 868/915 MHz band BPSK PHY modulation and spreading functions. The number in each block refers to the subclause that describes that function. Each bit in the PPDU shall be processed through the differential encoding, bit-to-chip mapping and modulation functions in octet-wise order, beginning with the Preamble field and ending with the last octet of the PSDU. Within each octet, the LSB, b0, is processed first and the MSB, b7, is processed last.

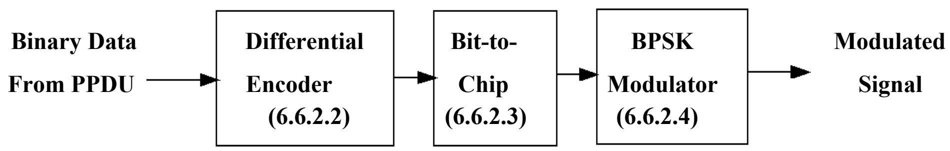

Figure 21 - Modulation and spreading functions

6.6.2.2 Differential encoding

Differential encoding is the modulo-2 addition (exclusive or) of a raw data bit with the previous encoded bit. This is performed by the transmitter and can be described by Equation (1):

$$E_n = R_n \oplus E_{n-1} \quad (1)$$

where
Rn is the raw data bit being encoded
En is the corresponding differentially encoded bit
En?1 is the previous differentially encoded bit

For each packet transmitted, R1 is the first raw data bit to be encoded and E0 is assumed to be zero.

Conversely, the decoding process, as performed at the receiver, can be described by Equation (2):

$$R_n = E_n \oplus E_{n-1} \qquad (2)$$

For each packet received, E1 is the first bit to be decoded, and E0 is assumed to be zero.

6.6.2.3 Bit-to-chip mapping

Each input bit shall be mapped into a 15-chip PN sequence as specified in Table 27.

Table 27 - Symbol-to-chip mapping

Input bits	**Chip values** (c_0 c_1 … c_{14})
0	1 1 1 1 0 1 0 1 1 0 0 1 0 0 0
1	0 0 0 0 1 0 1 0 0 1 1 0 1 1 1

6.6.2.4 BPSK modulation

The chip sequences are modulated onto the carrier using BPSK with raised cosine pulse shaping (roll-off factor = 1) where a chip value of one corresponds to a positive pulse and a chip value of zero corresponds to a negative pulse. The chip rate is 300 kchip/s for the 868 MHz band and 600 kchip/s in the 915 MHz band.

6.6.2.4.1 Pulse shape

The raised cosine pulse shape (roll-off factor = 1) used to represent each baseband chip is described by Equation (3):

$$P(t) = \begin{cases} \dfrac{\sin \pi t/T_c}{\pi t} \dfrac{\cos \pi t/T_c}{1-4 t^2/T_c^2} & , t \neq 0 \\ 1 & , t = 0 \end{cases} \qquad (3)$$

6.6.2.4.2 Chip transmission order

During each symbol period, the least significant chip, c0, is transmitted first, and the most significant chip, c15, is transmitted last.

6.6.3 868/915 MHz band radio specification

6.6.3.1 Operating frequency range

The 868/915/950 MHz BPSK PHY operates in the 868.0?868.6 MHz frequency band and in the 902?928 MHz frequency band and 950.9-955.7MHz frequency band.

6.6.3.2 915/950 MHz band transmit PSD mask

The transmitted spectral products shall be less than the limits specified in Table 28. For both relative and absolute limits, average spectral power shall be measured using a 100 kHz resolution bandwidth. For the relative limit, the reference level shall be the highest average spectral power measured within ± 600 kHz of the carrier frequency in case of 915 MHz band and within ± 300 kHz of the carrier frequency in case of 950 MHz band.

Table 28 - 915 MHz band transmit PSD limits

Frequency Band	Frequency	Relative limit	Absolute limit
915MHz band	$\|f - f_c\| > 1.2$ MHz	–20 dB	–20 dBm
950MHz band (1mW channels)	$\|f - f_c\| = 0.3$ MHz	–20 dB	—
	$\|f - f_c\| > 0.5$ MHz	—	–39 dBm
	0.5MHz > $\|f - f_c\|$ > 0.3MHz	—	–26 dBm/200kHz
950MHz band (10mW channels)	$\|f - f_c\| = 0.3$ MHz	–20 dB	—
	$\|f - f_c\| > 0.5$ MHz	—	–39 dBm
	0.5MHz > $\|f - f_c\|$ > 0.3MHz	—	–18 dBm/200kHz

6.6.3.3 Symbol rate

The symbol rate of an 868/915 MHz BPSK PHY conforming to this standard shall be 20 ksymbol/s when operating in the 868 MHz band and 40 ksymbol/s when operating in the 915 MHz band with an accuracy of ± 40 ppm.

6.6.3.4 Receiver sensitivity

Under the conditions specified in 6.1.7, a compliant device shall be capable of achieving a sensitivity of -92 dBm or better.

6.6.3.5 Receiver jamming resistance

This subclause applies only to the 902 - 928 MHz band as there is only one channel available in the 868.0 - 868.6 MHz band.

The minimum jamming resistance levels are given in Table 29. The adjacent channel is one on either side of the desired channel that is closest in frequency to the desired channel, and the alternate channel is one more removed from the adjacent channel. For example, when channel 5 is the desired channel, channel 4 and channel 6 are the adjacent channels, and channel 3 and channel 7 are the alternate channels.

Table 29 - Minimum receiver jamming resistance requirements for 915 MHz PHY

Adjacent channel rejection	Alternate channel rejection
0 dB	30 dB

The adjacent channel rejection shall be measured as follows: the desired signal shall be a compliant 915 MHz IEEE 802.15.4 BPSK PHY signal, as defined by 6.6.2, of pseudo-random data. The desired signal is input to the receiver at a level 3 dB above the maximum allowed receiver sensitivity given in 6.6.3.4. In either the adjacent or the alternate channel, a compliant IEEE 802.15.4 signal, as defined by 6.6.2, is input at the relative level specified in Table 29. The test shall be performed for only one interfering signal at a time. The receiver shall meet the error rate criteria defined in 6.1.7 under these conditions.