IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	Mode Switch Text for Clause 6	
Date Submitted	January 2011	
Source	[Kuor-Hsin Chang, Bob Mason] Company [Elster Solutions]	Voice: [ ] Fax: [ ] E-mail: [kuor-hsin.chang@us.elster.com, robert.t.mason@us.elster.com]
Re:	Mode Switch Comment Resolution for LB59	
Abstract	This document provides updated mode switch text for Clause 6.	
Purpose	Provide updated mode switch text based on the proposed comment resolution for the TG4g task group to review and consider.	
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Release	The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.	

6. PHY specification

6.1 General requirements and definitions

Insert the following paragraph at the end of 6.1 as indicated:

In order to support SUN applications, the following PHYs are specified: multi-rate and multi-regional frequency shift keying (MR-FSK) (see 6.12a), multi-rate and multi-regional orthogonal frequency division multiplexing (MR-OFDM) (see 6.12b), and multi-rate and multi-regional offset quadrature phase-shift keying (MR-O-QPSK) (see 6.12c). A SUN device shall support the MR-FSK PHY.

6.1.1 Operating frequency range

Insert the following new rows at the end of Table 1, and add a footnote to the table title as indicated:

Table 1—Frequency bands and data rates[*]

PHY (MHz)	Frequency (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	**Modulation[†]**	**Bit rate (kb/s)**	**Symbol rate (ksymbols/s)**	**Symbols**
450	450–470	—	Filtered 2FSK	4.8	4.8	Binary
			Filtered 4FSK	9.6	4.8	4-ary
470	470–510	—	Filtered 2FSK	50	50	Binary
				100	100	
			Filtered 4FSK	200	100	4-ary
		—	OFDM	See 6.12b		
		100	O-QPSK	12.5 and 50 (see 6.12c)	—	—
780	779–787	—	OFDM	See 6.12b		
		1000	O-QPSK	31.25–500 (see 6.12c)	—	—
863	863–870	—	Filtered 2FSK	50	50	Binary
				100	100	
			Filtered 4FSK	200	100	4-ary
		—	OFDM	See 6.12b		
868	868–870	100	O-QPSK	12.5 and 50 (see 6.12c)	—	—
896	896–901	—	Filtered 2FSK	10	10	Binary
				20	20	
				40	40	

Table 1—Frequency bands and data rates[*] *(continued)*

PHY (MHz)	Frequency (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation[†]	Bit rate (kb/s)	Symbol rate (ksymbols/s)	Symbols
901	901–902	—	Filtered 2FSK	10	10	Binary
				20	20	
				40	40	
915	902–928	—	Filtered 2FSK	50	50	Binary
			Filtered 2FSK	150	150	
			Filtered 2FSK	200	200	
		—	OFDM	See 6.12b		
		1000	O-QPSK	31.25–500 (see 6.12c)	—	—
917	917–923.5	—	Filtered 2FSK	50	50	Binary
			Filtered 2FSK	150	150	
			Filtered 2FSK	200	200	
		—	OFDM	See 6.12b		
		1000	O-QPSK	31.25–500 (see 6.12c)	—	—
928	928–960[‡]	—	Filtered 2FSK	10	10	Binary
				20	20	
				40	40	
950	950–958	—	Filtered 2FSK	50	50	Binary
			Filtered 2FSK	100[§]	100	
			Filtered 2FSK	200	200	
			Filtered 4FSK	400		4-ary
		—	OFDM	See 6.12b		
		100	O-QPSK	12.5 and 50 (see 6.12c)	—	—
1427	1427–1518[‡]	—	Filtered 2FSK	10	10	Binary
				20	20	
				40	40	

Table 1—Frequency bands and data rates[*] *(continued)*

PHY (MHz)	Frequency (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation[†]	Bit rate (kb/s)	Symbol rate (ksymbols/s)	Symbols
2450	2400–2483.5	—	Filtered 2FSK	50	50	Binary
			Filtered 2FSK	150	150	
			Filtered 2FSK	200	200	
		—	OFDM	See 6.12b		
		2000	O-QPSK	31.25–500 (see 6.12c)	—	—

[*] Data rates shown are over-the-air data rates.
[†] See 6.12a.1 for more information on filtered FSK.
[‡] Non-contiguous.

6.1.2 Channel assignments

Insert the following new paragraph after the last paragraph of 6.1.2:

The addition of the SUN PHY specifications requires an even greater channel numbering capability. To address this issue, the definitions of channel pages seven and eight have been modified for the SUN PHYs to accommodate the larger number of channels, while maintaining consistency with the existing channel assignment schemes. See 6.1.2.7 for more information.

6.1.2.1 Channel numbering

Insert the following new paragraph before the first paragraph of 6.1.2.1:

This subclause does not apply to the SUN PHY specifications. See 6.1.2.5a for an explanation of channel numbering for the SUN PHYs.

Insert the following new subclauses (6.1.2.5a–6.1.2.5b) after 6.1.2.5:

6.1.2.5a Channel numbering for MR-FSK PHY and MR-OFDM PHY

TotalNumChan is the total number of channels for the available frequency band.

$$TotalNumChan = \mathrm{floor}\left(\frac{W - GL - GH}{ChanSpacing}\right) \quad \text{(0a)}$$

where

W is the width of the available band in MHz
GL is the guard band on the lower side of the band in MHz
GH is guard band on the higher side of the band in MHz
ChanSpacing is the channel separation in MHz

The channel separations for the MR-FSK operating modes are listed in Table 75a and Table 75b, and the channel separations for the MR-OFDM operating modes are listed in Table 75g. The Generic PHY mechanism allows other channel separations to be used in all bands (6.1.2.7.2).

ChanCenterFreq is the channel center frequency.

$$ChanCenterFreq = BandEdge + GL + \left(NumChan + \frac{1}{2}\right) \times ChanSpacing \qquad (0b)$$

where

BandEdge is the start of the frequency band in MHz, as shown in Table 1
NumChan is the channel number that starts with zero, and *NumChan* = 0, ... , *TotalNumChan* – 1

The values for the variables in Equation (0a) and Equation (0b) are shown in Table 3a for various frequency bands .

Table 3a—<work in progress. not sure yet whether we should have a table. need to get more info and see how it looks>

Frequency band (MHz)	*GL* (MHz)	*GH* (MHz)	*ChanSpacing* (MHz)
863	0.025	0	See Figure 22d
950	0.9	0.5	0.2 or 0.6
	0.7	0.7	0.4
2450	*ChanSpacing*/2	5	See Figure 22k
All other SUN bands	*ChanSpacing*/2	*ChanSpacing*/2	See 6.1.2.7.1

For the 950 MHz band (Japan), *GL* is 0.9 MHz, *GH* is 0.5 MHz for 0.2 MHz and 0.6 MHz Channel Spacing and 0.7 MHz for 0.4 MHz Channel Spacing. For the 863 MHz band, *GL* is 0.025 MHz and *GH* is zero. For the 2450 MHz band, *GH* is 5 MHz. For all other bands, both *GL* and *GH* are *ChanSpacing/*2.

6.1.2.5b Channel numbering for MR-O-QPSK PHY

Ninety-nine channels are available across the 470 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 470.2 + 0.4k$ in MHz, for $k = 0, \ldots, 98$

where k is the channel number.

Four channels are available across the 780 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 780 + 2k$ in MHz, for $k = 0, \ldots, 3$

where k is the channel number.

Three channels are available across the 868 MHz band. The center frequency of each of these channels is shown in Table 3b.

Table 3b—Center frequencies for the MR-O-QPSK PHY of the 868–870 MHz band

Channel number	Center frequency (MHz)
0	868.300
1	868.950
2	869.525

Ten channels are available across the 915 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 904 + 2k$ in MHz, for $k = 0, \ldots, 9$

where k is the channel number.

Three channels are available across the 917 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 918.1 + 2k$ in MHz, for $k = 0, 1, 2$

where k is the channel number.

Sixteen channels are available across the 950 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 950.9 + 0.4k$ in MHz, for $k = 0, \ldots, 15$

where k is the channel number.

Sixteen channels are available across the 2450 MHz band. The center frequency of each of these channels is defined as follows:

$F_c = 2405 + 5k$ in MHz, for $k = 0, \ldots, 15$

where k is the channel number.

6.1.2.6 Channel pages

Insert the following new paragraph after the second paragraph of 6.1.2.6:

When *phyCurrentPage* is equal to seven or eight, *phyCurrentSUNPageEntry* shall specify the current frequency band, modulation scheme, and PHY mode of operation. The PIB attribute *phyNumSUNPageEntriesSupported* shall contain the number of SUN channel page entries supported, and *phySUNPageEntriesSupported* shall contain a complete list of the SUN channel page entries supported.

Change Table 4 (the entire table is not shown) as indicated:

Table 4—Channel page and channel number

Channel page (decimal)	Channel page (binary) $(b_{31}, b_{30}, b_{29}, b_{28}, b_{27})$	Channel number(s) (decimal)	Channel number description
7	0 0 1 1 1	—	Specifies the standard-defined SUN PHY operating modes (see 6.1.2.7.1). The channel page is used to define the frequency band, modulation scheme, and PHY mode. The channels are defined by *phySUNChannelsSupported*.
8	0 1 0 0 0	—	Specifies the SUN PHY operating modes defined using the Generic PHY mechanism (see 6.1.2.7.2). The channel page is used to define the frequency band, modulation scheme, and PHY mode. The channels are defined by *phySUNChannelsSupported*.
~~7~~9–31	0 1 0 0 1–1 1 1 1 1	Reserved	Reserved

Insert the following new subclauses (6.1.2.7-6.1.2.7.2) after 6.1.2.6:

6.1.2.7 Channel pages for SUN PHYs

Channel page seven is used to specify the standard-defined PHY operating modes, and channel page eight is used to specify the Generic PHY operating modes. A device that implements more than one PHY operating mode described by channel page seven may have multiple channel page seven entries in the *phySUNPageEntriesSupported* table.

The structures of channel pages seven and eight are shown in Figure 22a. For more detail on channel page seven and channel page eight, see 6.1.2.7.1 and 6.1.2.7.2, respectively.

6.1.2.7.1 Channel page structure for standard-defined PHY modes

Channel page seven specifies each standard-defined SUN PHY operating mode supported by the device.

As shown in Figure 22a, channel page seven consists of the frequency band(s), modulation scheme(s), and PHY mode(s) to specify the SUN operating modes. The values used to define the frequency bands are shown in Table 4a. The values used to define the modulation scheme are shown in Table 4b. Each bit in the PHY Mode field corresponds to a standard-defined PHY mode for the particular frequency band and modulation scheme. A bit set to zero shall indicate that a particular standard-defined PHY mode is not supported by the device. A bit set to one shall indicate that a particular standard-defined PHY mode is supported by the device. A device may support more than one standard-defined PHY mode.

Figure 22b through Figure 22k enumerate the standard-defined PHY modes for the MR-FSK PHY. Figure 22p through Figure 22o enumerate the standard-defined PHY modes for the MR-OFDM PHY. Figure 22p through Figure 22o enumerate the standard-defined PHY modes for the MR-O-QPSK PHY. Note that all values of fields not defined in the figures are reserved.

<table>
<tr><th>Bits: 31–27</th><th>26–22</th><th>21–20</th><th>19–16</th><th colspan="4">15–0</th></tr>
<tr><td rowspan="3">Channel page seven</td><td rowspan="3">Frequency band</td><td>Modulation scheme = Filtered FSK</td><td>Reserved</td><td colspan="4">Bitmap, where each bit corresponds to a particular PHY mode supported by the device</td></tr>
<tr><td>Modulation scheme = O-QPSK</td><td colspan="3">Bits 19...5 Reserved</td><td>Bit 4 Spreading mode</td><td>Bit 3...0 (bitmap) Rate modes supported</td></tr>
<tr><td>Modulation scheme = OFDM</td><td colspan="2">Bits 19...13 Reserved</td><td>Bits 12...9 (integer) OFDM Option 1,2,3, or 4 (range 0...3)</td><td colspan="2">Bits 8...0 (bitmap) MCS values supported (for Option)</td></tr>
<tr><td>Channel page eight</td><td colspan="3">Reserved</td><td colspan="4">Generic-PHY-defined PHY modes (see 6.1.2.7.2)
Bitmap, where a set bit indicates a Generic PHY mode supported by the device
Each set bit position corresponds to an array in physSUNGenericPHYDescriptors</td></tr>
</table>

Figure 22a—Channel page structure for channel pages seven and eight

Table 4a—Frequency band definitions

Frequency band identifier (binary) (b_{26} b_{25} b_{24} b_{23} b_{22})	**Description (MHz)**
0 0 0 0 0	450–470 (US FCC Part 90)
0 0 0 0 1	470–510 (China)
0 0 0 1 0	779–787 (China)
0 0 0 1 1	863–870 (Europe)
0 0 1 0 0	896–901 (US FCC Part 90)
0 0 1 0 1	901–902 (US FCC Part 24)
0 0 1 1 0	902–928 (US)
0 0 1 1 1	917–923.5 (Korea)
0 1 0 0 0	928–960 (US, non-contiguous)
0 1 0 0 1	950–958 (Japan)
0 1 0 1 0	1427–1518 (US and Canada, non-contiguous)
0 1 0 1 1	2400–2483.5
0 1 1 0 0–1 1 1 1 1	Reserved

Table 4b—Modulation scheme representation

Modulation scheme identifier (binary) (b_{21} b_{20})	Description
0 0	Filtered FSK
0 1	OFDM
1 0	O-QPSK
1 1	Reserved

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 0 0 0	0 0	Reserved	Two standard-defined PHY modes (see below)
Page 7	450–470	Filtered FSK		
Bit position 0: 4.8 kbps; filtered FSK; mod index = 1; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 9.6 kbps; filtered 4FSK; mod index = 1/3; channel spacing given in Table 75a				
Bit positions 2–15 are reserved				

Figure 22b—Frequency band 450–470 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 0 0 1	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	470–510	Filtered FSK		
Bit position 0: 50 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 100 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a				
Bit position 2: 200 kbps; filtered 4FSK; mod index = 1/3; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22c—Frequency band 470–510 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 0 1 1	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	863–870	Filtered FSK		
Bit position 0: 50 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 100 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a				
Bit position 2: 200 kbps; filtered 4FSK; mod index = 1/3; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22d—Frequency band 863–870 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 1 0 0	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	896–901	Filtered FSK		
Bit position 0: 10 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 20 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 40 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22e—Frequency band 896–901 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 1 0 1	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	901–902	Filtered FSK		
Bit position 0: 10 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 20 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 40 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22f—Frequency band 901–902 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 0 1 1 0	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	902–928	Filtered FSK		
Bit position 0: 50 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 150 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 200 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22g—Frequency band 902–928 (917–923.5) MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 1 0 0 0	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	928–960	Filtered FSK		
Bit position 0: 10 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 20 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 40 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22h—Frequency band 928–960 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 1 0 0 1	0 0	Reserved	Four standard-defined PHY modes (see below)
Page 7	950–958	Filtered FSK		
Bit position 0: 50 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 100 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a				
Bit position 2: 200 kbps; filtered FSK; mod index = 1.0; channel spacing given in Table 75a				
Bit position 3: 400 kbps; filtered 4FSK; mod index = 0.33; channel spacing given in Table 75a				
Bit positions 4–15 are reserved				

Figure 22i—Frequency band 950–958 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 1 0 1 0	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	1427–1518	Filtered FSK		
Bit position 0: 10 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 20 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 40 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22j—Frequency band 1427–1518 MHz with FSK modulation

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes	
			19–16	15–0
0 0 1 1 1	0 1 0 1 1	0 0	Reserved	Three standard-defined PHY modes (see below)
Page 7	2400–2483.5	Filtered FSK		
Bit position 0: 50 kbps; FSK; mod index = 1.0; channel spacing given in Table 75a (operating mode #1)				
Bit position 1: 150 kbps; FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit position 2: 200 kbps; filtered FSK; mod index = 0.5; channel spacing given in Table 75a				
Bit positions 3–15 are reserved				

Figure 22k—Frequency band 2400–2483.5 MHz with FSK modulation

6.1.2.7.2 Channel page structure for Generic PHY modes

As shown in Figure 22a, the channel page eight structure uses the least significant 16 bits to represent the available Generic PHY operating modes. Each bit corresponds to the Generic PHY ID, and the ID is the index (0–15) in the *phySUNGenericPHYDescriptors* array (see Table 31). In channel page eight, the bit fields used to represent frequency band and modulation scheme in channel page seven are unused and the frequency band and modulation scheme are defined by the Generic PHY descriptor (see Table 31a).

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–13	**12–9**	**8–0**
0 0 1 1 1 Page 7	Any frequency band identified in Table 1 for OFDM. See Table 4a for the coding of frequency bands in this field.	0 1 OFDM	Reserved	0 0 0 0 Option 1	Four standard-defined PHY modes (see below)
Bit position 0: MCS0; 100 kbps					
Bit position 1: MCS1; 200 kbps					
Bit position 2: MCS2; 400 kbps					
Bit position 3: MCS3; 800 kbps					
Bit positions 4–8 are reserved					

Figure 22l—OFDM bandwidth Option 1

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–13	**12–9**	**8–0**
0 0 1 1 1 Page 7	Any frequency band identified in Table 1 for OFDM. See Table 4a for the coding of frequency bands in this field.	0 1 OFDM	Reserved	0 0 0 1 Option 2	Six standard-defined PHY modes (see below)
Bit position 0: MCS0; 50 kbps					
Bit position 1: MCS1; 100 kbps					
Bit position 2: MCS2; 200 kbps					
Bit position 3: MCS3; 400 kbps					
Bit position 4: MCS4; 600 kbps					
Bit position 5: MCS5; 800 kbps					
Bit positions 6–8 are reserved					

Figure 22m—OFDM bandwidth Option 2

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–13	12–9	8–0
0 0 1 1 1	Any frequency band identified in Table 1 for OFDM. See Table 4a for the coding of frequency bands in this field.	0 1	Reserved	0 0 1 0	Six standard-defined PHY modes (see below)
Page 7		OFDM		Option 3	
Bit position 0: MCS1; 50 kbps					
Bit position 1: MCS2; 100 kbps					
Bit position 2: MCS3; 200 kbps					
Bit position 3: MCS4; 300 kbps					
Bit position 4: MCS5; 400 kbps					
Bit position 5: MCS6; 600 kbps					
Bit positions 6–8 are reserved					

Figure 22n—OFDM bandwidth Option 3

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–13	12–9	8–0
0 0 1 1 1	Any frequency band identified in Table 1 for OFDM. See Table 4a for the coding of frequency bands in this field.	0 1	Reserved	0 0 1 1	Five standard-defined PHY modes (see below)
Page 7		OFDM		Option 4	
Bit position 0: MCS2; 50 kbps					
Bit position 1: MCS3; 100 kbps					
Bit position 2: MCS4; 150 kbps					
Bit position 3 MCS5; 200 kbps					
Bit position 4: MCS6; 300 kbps					
Bit positions 5–8 are reserved					

Figure 22o—OFDM bandwidth Option 4

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 0 0 1	1 0	Reserved	0	Two standard-defined PHY modes (see below)
Page 7	470–510	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 100 kchip/s; (4,1) spreading; rate 1/2 FEC; data rate = 12.5 kbps					
Bit position 1: chip rate = 100 kchip/s; no spreading; rate 1/2 FEC; data rate = 50 kbps					
Bit positions 2–3 are reserved					

Figure 22p—Frequency band 470–510 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of DSSS.

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 0 1 0	1 0	Reserved	0	Four standard-defined PHY modes (see below)
Page 7	779–787	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 1000 kchip/s; (16,1) spreading; rate 1/2 FEC; data rate = 31.25 kbps					
Bit position 1: chip rate = 1000 kchip/s; (16,4) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 1000 kchip/s; (8,4) spreading; rate 1/2 FEC; data rate = 250 kbps					
Bit position 3: chip rate = 1000 kchip/s; no spreading; rate 1/2 FEC; data rate = 500 kbps					

Figure 22q—Frequency band 779–787 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of direct sequence spread spectrum (DSSS).

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 0 1 0	1 0	Reserved	1	Four standard-defined PHY modes (see below)
Page 7	779–787	O-QPSK		Spreading mode MDSSS*	
Bit position 0: chip rate = 1000 kchip/s; (64,8) spreading; rate 1/2 FEC; data rate = 62.5 kbps					
Bit position 1: chip rate = 1000 kchip/s; (32,8) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 1000 kchip/s; (32,8) spreading; data rate = 250 kbps					
Bit position 3: chip rate = 1000 kchip/s; (16,8) spreading; data rate = 500 kbps					

Figure 22r—Frequency band 779–787 MHz with O-QPSK modulation and MDSSS spreading mode

*See 6.12c.1.5 for more information on the use of multiplexed direct sequence spread spectrum (MDSSS).

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 0 1 1	1 0	Reserved	0	Two standard-defined PHY modes (see below)
Page 7	868–870	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 100 kchip/s; (4,1) spreading; rate 1/2 FEC; data rate = 12.5 kbps					
Bit position 1: chip rate = 100 kchip/s; no spreading; rate 1/2 FEC; data rate = 50 kbps					
Bit positions 2–3 are reserved					

Figure 22s—Frequency band 868–870 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of DSSS.

Channel page bits: 31–27	Frequency band 26–22	Modulatio n scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 1 1 0	1 0	Reserved	0	Four standard-defined PHY modes (see below)
Page 7	902–928	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 1000 kchip/s; (16,1) spreading; rate 1/2 FEC; data rate = 31.25 kbps					
Bit position 1: chip rate = 1000 kchip/s; (16,4) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 1000 kchip/s; (8,4) spreading; rate 1/2 FEC; data rate = 250 kbps					
Bit position 3: chip rate = 1000 kchip/s; no spreading; rate 1/2 FEC; data rate = 500 kbps					

Figure 22t—Frequency band 902–928 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of DSSS.

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 1 1 0	1 0	Reserved	1	Four standard-defined PHY modes (see below)
Page 7	902–928	O-QPSK		Spreading mode MDSSS*	
Bit position 0: chip rate = 1000 kchip/s; (64,8) spreading; rate 1/2 FEC; data rate = 62.5 kbps					
Bit position 1: chip rate = 1000 kchip/s; (32,8) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 1000 kchip/s; (32,8) spreading; data rate = 250 kbps					
Bit position 3: chip rate = 1000 kchip/s; (16,8) spreading; data rate = 500 kbps					

Figure 22u—Frequency band 902–928 MHz with O-QPSK modulation and MDSSS spreading mode

*See 6.12c.1.5 for more information on the use of multiplexed direct sequence spread spectrum (MDSSS).

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 0 1 1 1	1 0	Reserved	1	Four standard-defined PHY modes (see below)
Page 7	917–923.5	O-QPSK		Spreading mode MDSSS*	
Bit position 0: chip rate = 1000 kchip/s; (64,8) spreading; rate 1/2 FEC; data rate = 62.5 kbps					
Bit position 1: chip rate = 1000 kchip/s; (32,8) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 1000 kchip/s; (32,8) spreading; data rate = 250 kbps					
Bit position 3: chip rate = 1000 kchip/s; (16,8) spreading; data rate = 500 kbps					

Figure 22v—Frequency band 917–923.5 MHz with O-QPSK modulation and MDSSS spreading mode

*See 6.12c.1.5 for more information on the use of multiplexed direct sequence spread spectrum (MDSSS).

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 1 0 0 1	1 0	Reserved	0	Two standard-defined PHY modes (see below)
Page 7	950–958	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 100 kchip/s; (4,1) spreading; rate 1/2 FEC; data rate = 12.5 kbps					
Bit position 1: chip rate = 100 kchip/s; no spreading; rate 1/2 FEC; data rate = 50 kbps					
Bit positions 2–3 are reserved					

Figure 22w—Frequency band 950–958 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of DSSS.

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 1 0 1 1	1 0	Reserved	0	Four standard-defined PHY modes (see below)
Page 7	2400–2483.5	O-QPSK		Spreading mode DSSS*	
Bit position 0: chip rate = 2000 kchip/s; (32,1) spreading; rate 1/2 FEC; data rate = 31.25 kbps					
Bit position 1: chip rate = 2000 kchip/s; (32,4) spreading; rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 2000 kchip/s; (16,4) spreading; rate 1/2 FEC; data rate = 250 kbps					
Bit position 3: chip rate = 2000 kchip/s; (8,4) spreading; rate 1/2 FEC; data rate = 500 kbps					

Figure 22x—Frequency band 2400–2483.5 MHz with O-QPSK modulation and DSSS spreading mode

*See 6.12c.1.4 for more information on the use of DSSS.

Channel page bits: 31–27	Frequency band 26–22	Modulation scheme 21–20	Standard-defined PHY modes		
			19–5	4	3–0
0 0 1 1 1	0 1 0 1 1	1 0	Reserved	1	Four standard-defined PHY modes (see below)
Page 7	2400–2483.5	O-QPSK		Spreading mode MDSSS*	
Bit position 0: chip rate = 2000 kchip/s; (128,8) spreading; rate 1/2 FEC; data rate = 62.5 kbps					
Bit position 1: chip rate = 2000 kchip/s; (64,8) spreading, rate 1/2 FEC; data rate = 125 kbps					
Bit position 2: chip rate = 2000 kchip/s; (64,8) spreading; data rate = 250 kbps					
Bit position 3: chip rate = 2000 kchip/s; (32,8) spreading; data rate = 500 kbps					

Figure 22y—Frequency band 2400–2483.5 MHz with O-QPSK modulation and MDSSS spreading mode

*See 6.12c.1.5 for more information on the use of MDSSS.

The structure of the Generic PHY descriptor is shown in Figure 22z. A Generic PHY descriptor consists of fields to define a specific frequency band (Channel Descriptor), a particular modulation scheme, and parametric descriptors specific to the modulation scheme. The *phySUNGenericPHYDescriptors* array consists of up to 16 Generic PHY descriptors. For an example of the use of the Generic PHY mechanism, refer to Annex M.

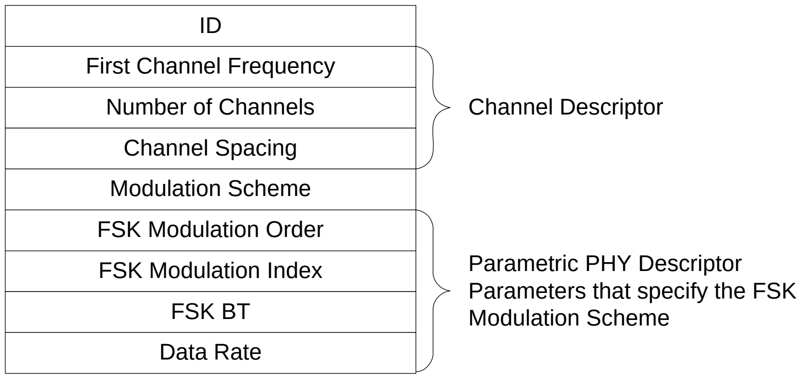

Figure 22z—Generic PHY descriptor

The Generic PHY Channel Descriptor consists of the following fields:

— First Channel Frequency is the center frequency, in hertz, of the lowest channel.

— Number of Channels is the number of contiguous channels starting at the first channel frequency.

— Channel Spacing is the spacing between adjacent channels in hertz.

The Modulation Scheme specifies the modulation method for Generic PHY. FSK is the only specified modulation scheme for Generic PHY. The Parametric PHY Descriptor fields associated with FSK are listed as follows:

— ModulationScheme indicates if it is FSK or Gaussian frequency shift keying (GFSK).

— FSK BT is used only if the ModulationScheme value is set to GFSK.

— Symbol Rate is the number of symbols per second transmitted over the air. The data rate can be derived from modulation order and symbol rate. The bit to symbol mapping follows SUN PHY convention.

6.1.3 Minimum long interframe spacing (LIFS) and short interframe spacing (SIFS) periods

Insert the following new rows at the end of Table 5:

Table 5—Minimum LIFS and SIFS period

PHY	*macMinLIFSPeriod*	*macMinSIFSPeriod*	Units
MR-FSK	40	12	Symbols
MR-OFDM	40	12	Symbols
MR-O-QPSK	40	12	Symbols

6.1.7 Receiver sensitivity definitions

Change the first paragraph of 6.1.7 as indicated:

The receiver sensitivity definitions used ~~throughout this standard~~ for every PHY except the MR-OFDM PHY are defined in Table 6. The receiver sensitivity definition for the MR-OFDM PHY is defined in 6.12b.3.2.

Change Table 6 (the entire table is not shown) as indicated:

Table 6—Receiver sensitivity definitions

Term	Definition of term	Conditions
Receiver sensitivity	Threshold input signal power that yields a specified PER.	– PSDU length = 250 octets for MR-FSK PHY with data rates 50 kbps and greater, 25 octets for MR-FSK PHY with data rates less than 50 kbps, 20 octets for all other PHYs. – PER < 1%. – Power measured at antenna terminals. – Interference not present. – For the MR-FSK PHY, forward error correction (FEC) disabled.

Insert the following new subclause (6.1a) after 6.1.7:

6.1a Common signaling mode (CSM)

To facilitate the multi-PHY management (MPM) scheme described in 7.5.8a, a common PHY mode, CSM, is specified. A SUN device acting as a coordinator and with a duty cycle greater than 1% shall support CSM. The specification of CSM is given in Table 6a. The modulation and channel specification of CSM are given in 6.12a.

Table 6a—PHY Specification of the CSM for MPM scheme

Band (MHz)	Modulation	Modulation index	Channel spacing (kHz)	Data rate (kb/s)
2400-2483.5 902–928 863–870 470–510 950–958	Filtered FSK	1	200	50

The value of the SFD field (see 6.3a.1.2) for CSM shall be that associated with a value of zero for the PIB attribute *phyMRFSKSFD* (see Table 31).

6.2 PHY service specifications

6.2.1 PHY data service

6.2.1.1 PD-DATA.request

6.2.1.1.1 Semantics of the service primitive

Insert the following new parameters at the end of the list in 6.2.1.1.1 as indicated:

```
PD-DATA.request          (
                          psduLength,
                          psdu,
                          UWBPRF,
                          Ranging,
                          UWBPreambleSymbolRepetitions,
                          DataRate,
                          TxChannel,
                          PPDUCoding,
                          FCSLength,
                          ModeSwitch,
                          NewModeSUNPage,
                          ModeSwitchParameterEntry,
                          MROQPSKRateMode,
                          MROQPSKSpreadingMode
```

Insert the following new rows at the end of Table 8:

6.2.1.1.3 Effect on receipt

Change the first paragraph of 6.2.1.1.3 as indicated:

The receipt of the PD-DATA.request primitive by the PHY entity will cause the transmission of the supplied PSDU to be attempted on the channel specified by the TxChannel parameter. Provided the transmitter is enabled (TX_ON state) and the transmit channel specified by the TxChannel parameter is supported, if ModeSwitch is FALSE the PHY will first construct a PPDU, that contains~~ing~~ the supplied PSDU, and then attempt to transmit the PPDU. ~~When the PHY entity has completed the transmission, it will issue the PD-DATA.confirm primitive with a status of SUCCESS.~~ If ModeSwitch is TRUE, the receipt of the PD-DATA.request primitive by the PHY entity will cause the transmission of two PPDUs. The first PPDU will be the mode switch PPDU and the second PPDU will be the PPDU that contains the PSDU. The second PPDU will be transmitted in the new PHY mode.

Delete the second and third paragraph of 6.2.1.1.3:

~~If the PD-DATA.request primitive is received while the receiver is enabled (RX_ON state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of RX_ON. If the PD-DATA.request primitive is received while the transceiver is disabled (TRX_OFF state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of TRX_OFF.~~

Table 8—PD-DATA.request parameters

Name	Type	Valid range	Description
TxChannel	Integer	0–65535	The channel on which to send the PPDU.
PPDUCoding	Boolean	TRUE or FALSE	A value of FALSE indicates that the (PHR+PSDU) is uncoded, and a value of TRUE indicates that the (PHR+PSDU) is coded as a single block of data.
FCSLength	Enumeration	SHORT_FCS, LONG_FCS	The length of the FCS contained in the PSDU to be transmitted. A value of SHORT_FCS indicates a 2-octet FCS, and a value of LONG_FCS indicates a 4-octet FCS.
ModeSwitch	Boolean	TRUE or FALSE	A value of TRUE instructs the PHY entity to send a mode switch PPDU first then a new mode PPDU that contains the PSDU using the associated mode switch parameters. The mode switch PPDU is transmitted using the PHY mode specified by *phyCurrentSUNPageEntry*. The PPDU containing the PSDU is transmitted using the PHY mode specified by NewModeSUNPageEntry. A value of FALSE instructs the PHY to send the PSDU in a single PPDU using the PHY mode specified by *phyCurrentSUNPageEntry* on *phyCurrentChannel*. This parameter is only valid for SUN PHYs.
NewMode-SUNPageEntry	Bitmap	0x00000000–0xffffffff	The modulation scheme and particular PHY mode for the new mode as defined by the channel page structure. The type and valid range are the same as defined for phyCurrentSUNPageEntry. This parameter is only valid if ModeSwitch = TRUE.
ModeSwitch-ParameterEntry	Integer	0x00–0x03	The mode switch parameter entry specifies the index in the *phyModeSwitchParameterEntries* array for the ModeSwitchDescriptor to be used for this PHY mode switch. This parameter is only valid if ModeSwitch = TRUE.
MROQPSK-RATEMode	Integer	0x00–0x03	Parameter of PSDU data rate for MR-O-QPSK PHY (see 6.12c.1.4 and 6.12c.1.5).
MROQPSK-Spreading-Mode	Integer	0x00–0x01	Parameter of PSDU spreading mode for MR-O-QPSK PHY (see 6.12c.1.4 and 6.12c.1.5). This parameter can take one of the following values: 0x00=DSSS 0x01=MDSSS

~~If the PD-DATA.request primitive is received while the transmitter is already busy transmitting (BUSY_TX state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of BUSY_TX.~~

6.2.1.2 PD-DATA.confirm

6.2.1.2.1 Semantics of the service primitive

Change Table 9 (the entire table is not shown) as indicated:

Table 9—PD-DATA.confirm parameters

Name	Type	Valid range	Description
status	Enumeration	SUCCESS, RX_ON, TRX_OFF, BUSY_TX, ~~or~~UNSUPPORTED_PRF, UNSUPPORTED_RANGING, UNSUPPORTED_TX_CHANNEL, UNSUPPORTED_PPDU_FEC, UNSUPPORTED_MODE_SWITCH, or UNSUPPORTED_MR_OQPSK_SPREADING_MODE	The result of the request to transmit a packet. ~~A value of UNSUPPORTED_PRF indicates that the PHY is not capable of transmitting at the requested PRF. A value of UNSUPPORTED_RANGING is returned if the PHY does not implement a ranging counter.~~

6.2.1.2.2 When generated

Change the paragraph as indicated:

The PD-DATA.confirm primitive is generated by the PHY entity and issued to its MAC sublayer entity in response to a PD-DATA.request primitive. The PD-DATA.confirm primitive will return a status of either SUCCESS, indicating that the request to transmit was successful, or an error code of RX_ON, TRX_OFF, ~~or~~ BUSY_TX, UNSUPPORTED_TX_CHANNEL, UNSUPPORTED_PPDU_FEC, UNSUPPORTED_MODE_SWITCH, or UNSUPPORTED_MR_OQPSK_SPREADING_MODE. ~~The reasons for these status values are fully described in 6.2.1.1.3~~.

6.2.1.2.3 Appropriate usage

Insert the following seven new paragraphs after the first paragraph of 6.2.1.2.3:

If the PD-DATA.request primitive is received while the receiver is enabled (RX_ON state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of RX_ON. If the PD-DATA.request primitive is received while the transceiver is disabled (TRX_OFF state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of TRX_OFF.

If the PD-DATA.request primitive is received while the transmitter is already busy transmitting (BUSY_TX state), the PHY entity will discard the PSDU and issue the PD-DATA.confirm primitive with a status of BUSY_TX.

A value of UNSUPPORTED_PRF indicates that the PHY is not capable of transmitting at the requested PRF. A value of UNSUPPORTED_RANGING is returned if the PHY does not implement a ranging counter.

If the TxChannel parameter of the PD-DATA.request primitive specifies a channel that is not supported by the current PHY configuration, the PHY entity will issue the PD-DATA.confirm primitive with a status of UNSUPPORTED_TX_CHANNEL.

If the PPDUCoding parameter of the PD-DATA.request primitive specifies that FEC coding is to be applied to the (PHR+PSDU) but the feature is either disabled or not supported, the PHY entity will issue the PD-DATA.confirm primitive with a status of UNSUPPORTED_PPDU_FEC.

If the ModeSwitch parameter of the PD-DATA.request primitive is TRUE but the feature is not supported, the PHY entity will issue the PD-DATA.confirm primitive with a status of UNSUPPORTED_MODE_SWITCH.

If the MROQPSKSpreadingMode parameter of the PD-DATA.request primitive is not supported, the PHY entity will issue the PD-DATA.confirm primitive with a status of UNSUPPORTED_MR_OQPSK_SPREADING_MODE.

6.2.1.3 PD-DATA.indication

6.2.1.3.1 Semantics of the service primitive

Insert the following new parameter at the end of the list in 6.2.1.3.1 as indicated:

```
PD-DATA.indication          (
                            psduLength,
                            psdu,
                            psduLinkQuality,
                            UWBPRF,
                            UWBPreambleSymbolRepetitions,
                            DataRate,
                            RangingReceived,
                            RangingCounterStart,
                            RangingCounterStop,
                            RangingTrackingInterval,
                            RangingOffset,
                            RangingFOM,
                            FCSLength,
                            MROQPSKRateMode,
                            MROQPSKSpreadingMode
                            )
```

Insert the following new row at the end of Table 10:

6.2.3 PHY enumerations description

Insert the following new rows at the end of Table 25:

6.3 PPDU format

Delete the third paragraph in 6.3 as indicated:

Table 10—PD-DATA.indication parameters

Name	Type	Valid range	Description
FCSLength	Enumeration	SHORT_FCS, LONG_FCS	The length of the FCS contained in the PSDU to be transmitted. A value of SHORT_FCS indicates a 2-octet FCS, and a value of LONG_FCS indicates a 4-octet FCS.
MROQPSK-RATEMode	Integer	0x00–0x03	Parameter of PSDU data rate for MR-O-QPSK PHY (see 6.12c.1.4 and 6.12c.1.5).
MROQPSK-Spreading-Mode	Integer	0x00–0x01	Parameter of PSDU spreading mode for MR-O-QPSK PHY (see 6.12c.1.4 and 6.12c.1.5). This parameter can take one of the following values: 0x00=DSSS 0x01=MDSSS

Table 25—PHY enumerations description

Enumeration	Value	Description
UNSUPPORTED_MODE_SWITCH	0x22	A mode switch was requested before the transmission of the PPDU, but it is not a supported feature.
UNSUPPORTED_PPDU_FEC	0x23	FEC coding was requested to be applied to the PPDU (i.e., PHR+PSDU), but the feature is either disabled or not supported.
UNSUPPORTED_TX_CHANNEL	0x24	The requested transmit channel is not supported by the current PHY configuration.
UNSUPPORTED_MR_OQPSK_SPREADING_MODE	0x25	For the MR-O-QPSK PHY, a spreading mode out of {DSSS,MDSSS} was requested, but it is not a supported feature.

~~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 and, for UWB PHYs, rate, ranging, and preamble information~~
— ~~A variable length payload, which carries the MAC sublayer frame~~

Change the fourth paragraph of 6.3 as indicated:

The PPDU packet structure shall be formatted as illustrated in Figure 24, Figure 25, or Figure 26 for all PHYs except the SUN PHYs. The PPDU format for SUN PHYs is given in 6.3a.

Insert the following new paragraph after the fourth paragraph of 6.3:

All reserved fields shall be set to zero upon transmission and shall be ignored upon reception.

6.3.1 Preamble field

Change the last paragraph of 6.3.1 as indicated:

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, CSS, UWB, ~~and~~ 950 MHz GFSK, MR-FSK, and MR-OFDM PHYs, the bits in the Preamble field shall be binary zeros. The ASK preamble format is described in 6.9.4.1. The bits in the preamble field for the 950 MHz GFSK PHY shall be "01010101010101010101010101010101."

6.3.2 SFD field

Change the second paragraph of 6.3.2 as indicated:

For all PHYs that transmit an SFD, except for the ASK, CSS, ~~and~~ UWB, MR-FSK and MR-O-QPSK PHYs, 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, MR-FSK, and MR-O-QPSK PHYs, shall be formatted as illustrated in Figure 27. The SFD for the ASK PHY is defined in 6.9.4.2.

Replace Figure 27 with the following new figure:

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

Figure 27—Format of the SFD field (except for ASK, UWB, ~~and~~ CSS, MR-FSK, and MR-O-QPSK PHYs)

6.3.3 Frame Length field

Change the first paragraph of 6.3.3 as indicated:

The Frame Length field is 7 bits in length for all PHYs except the SUN PHYs, and it specifies the total number of octets contained in the PSDU (i.e., PHY payload). ~~It~~ The Frame Length field is a value between 0 and *aMaxPHYPacketSize* (see 6.4). Table 29 summarizes the type of payload versus the frame length value.

Change Table 29 as indicated:

Table 29—Frame length values

Frame length values	Payload
0–4	Reserved
5, 7	MPDU (Acknowledgment)
6, 8 ~~–8~~	Reserved
9 to *aMaxPHYPacketSize*	MPDU

Insert the following new subclauses after 6.3 (6.3a–6.3a.3.4):

6.3a PPDU format for SUN PHYs

The following subclauses describe the PPDU formats for the MR-FSK, MR-O-QPSK, and MR-OFDM PHYs.

The SHR, PHY header (PHR), and PHY payload components are treated as bit strings of length *n*, numbered b_0 on the left and b_{n-1} on the right. When transmitted, they are processed b_0 first to b_{n-1} last, without regard to their content or structure.

All reserved fields shall be set to zero upon transmission and shall be ignored upon reception.

6.3a.1 PPDU format for MR-FSK

The MR-FSK PPDU shall support the format shown in Figure 27a and may support the format shown in Figure 27b if mode switching is enabled.

		Octets	
		2	**variable**
Preamble	SFD	(see 6.3a.1.3)	PSDU
SHR		PHR	PHY payload

Figure 27a—Format of the MR-FSK PPDU (without mode switching)

		Octets
		2
Preamble	SFD	(see 6.3a.1.4)
SHR		PHR

Figure 27b—Format of the MR-FSK mode switch PPDU

6.3a.1.1 Preamble field

The Preamble field shall contain *phyFSKPreambleRepetitions* multiples of the 8-bit sequence "01010101."

6.3a.1.2 SFD

The SFD shall be a 2-octet sequence selected from the list of values shown in Table 29a. Devices which do not support FEC shall support the SFD associated with uncoded (PHR+PSDU) and a value of zero for the PIB attribute *phyMRFSKSFD;* these devices may also support the SFD associated with uncoded (PHR+PSDU) and a value of one for the PIB attribute *phyMRFSKSFD*. Devices which support FEC shall support both of the SFDs associated with a value of zero for the PIB attribute *phyMRFSKSFD;* these devices may additionally support both of the SFDs associated with a value of one for the PIB attribute *phyMRFSKSFD*.

The SFD is transmitted starting from the leftmost bit (i.e., starting with b_0).

Table 29a—MR-FSK PHY SFD values

	SFD value for coded (PHR+PSDU) (bits 0–15)	SFD value for uncoded (PHR+PSDU) (bits 0–15)
***phyMRFSKSFD* = 0**	0 1 1 0 1 1 1 1 0 1 0 0 1 1 1 0	1 0 0 1 0 0 0 0 0 1 0 0 1 1 1 0
***phyMRFSKSFD* = 1**	0 1 1 0 0 0 1 1 0 0 1 0 1 1 0 1	0 1 1 1 1 0 1 0 0 0 0 0 1 1 1 0

6.3a.1.3 PHR (without mode switching)

The format of the PHR is shown in Figure 27c. All multi-bit fields are unsigned integers and shall be processed MSB first.

Bit string index	0	1	2	3	4	5–15
Bit mapping	MS	R_1	R_0	FCS	DW	$L_{10}...L_0$
Field name	Mode Switch	Reserved		FCS Length	Data Whitening	Frame Length

Figure 27c—Format of the PHR (without mode switching) for MR-FSK

The Mode Switch field (MS) shall be set to zero, indicating that the entire packet shall be transmitted at a single data rate and using a single modulation scheme.

The FCS Length field (FCS) indicates the length of the FCS field described in 7.2.1.9 that is included in the MPDU. The FCS Length field shall be set to zero upon transmission when a 32-bit FCS is indicated in the PD-DATA.request primitive; the FCS Length field shall be set to one on transmission when a 16-bit FCS is indicated in the PD-DATA.request primitive. Upon reception, the PD-DATA.indication primitive parameter for FCS length shall be set according to the value of this field.

The Data Whitening field (DW) indicates if data whitening of the PSDU is used upon transmission. A value of one indicates the PSDU is whitened; a value of zero indicates the PSDU is not whitened. Data whitening shall not be applied to the SHR or PHR.

The Frame Length field (L_{10}–L_0) 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). The most significant bit (leftmost) shall be transmitted first. Table 29 summarizes the type of payload versus the frame length value.

6.3a.1.4 PHR for mode switch packet

The format of the PHR is shown in Figure 27d. All multi-bit fields are unsigned integers and shall be processed MSB first.

The Mode Switch field (MS) shall be set to one, indicating that a mode switch shall occur. The mode of the next PPDU transmitted (i.e., the new mode PPDU) shall be as described by the remaining fields contained in the PHR in Figure 27d. If the new mode is MR-FSK, the new mode PPDU is the same as Figure 27a except that the preamble and SFD are optional. If the new mode is MR-O-QPSK, the new mode PPDU is the same as Figure 26f. For MR-OFDM, the new mode PPDU has the same format as Figure 26i.

Bit string index	0	1	2	3	4–10	11-14	15
Bit mapping	MS	M_1	M_0	FEC	See Figure 27e	B_3–B_0	PC
Field name	Mode Switch	Mode Switch Parameter Entry		New Mode FEC	New Mode	Checksum	Parity Check

Figure 27d—Format of the PHR for MR-FSK mode switching

The Mode Switch Parameter Entry field (M_1–M_0) is the index of the entry in the *phyModeSwitchParameterEntries* array (see Table 31) that defines the mode switch parameters (see Table 31b) to be used.

The New Mode FEC field (FEC) specifies whether the packet following the mode switch PPDU is transmitted using FEC. A value of zero indicates that the new mode packet is transmitted without FEC, and a value of one indicates that it is transmitted with FEC. If the new mode packet has an SFD (and, therefore, packet coding information) (see 6.12a.1.3), that SFD shall override this value of the New Mode FEC field.

The New Mode field is formatted as shown in Figure 27e. The format of the new mode PPDU is determined by the New Mode field. The Page bit (PAGE) shall be set to zero to indicate channel page seven or set to one to indicate channel page eight. The Modulation Scheme bits (MOD_1–MOD_0) indicate the modulation scheme (see Table 4b) when *phyCurrentChannel* equals seven; when *phyCurrentChannel* equals eight, the Modulation Scheme bits shall be set to zero upon transmission and ignored upon reception. The Mode bits (MD_3–MD_0) specify the new mode of operation. When the PAGE field is zero (channel page seven), the interpretation of the MODE field (MD_3-MD_0) is based on the modulation scheme:

— If the modulation scheme is filtered FSK, the integer value of MD_3-MD_0 corresponds to the bit position in the PHY mode bitmap, and selects the particular PHY mode.

— If the modulation scheme is not filtered FSK, the bits (MD_3-MD_0) are set to zero by the transmitter and ignored by the receiver. The corresponding data rates are specified in the PHR of the new mode PPDU

When the PAGE field is one (channel page eight), the MODE field selects one element (0-15) in the *phySUNGenericPHYDescriptors*, and the new PHY mode is defined by the Generic PHY mechanism..

Bit string index	4	5	6	7–10
Bit mapping	PAGE	MOD_1	MOD_0	MD_3–MD_0
Subfield name	Page	Modulation Scheme		Mode

Figure 27e—Format of the New Mode field

The Checksum field (B_3-B_0) is the checksum for the BCH(15,11) code. The generator polynomial for the BCH (Bose Chaudhuri Hocquenghem) code is as follows:

$$G(x) = 1 + x + x^4 .$$

The Parity Check (PC) field provides error detection for the mode switch PPDU. The value of PC is calculated from the following equation:

$$PC = MS \oplus M_0 \oplus M_1 \oplus FEC \oplus PAGE \oplus MOD_0 \oplus MOD_1 \oplus MD_0 \oplus MD_1 \oplus MD_2 \oplus MD_3$$

where $\oplus$ is modulo-2 addition (addition over GF(2)). The combination of the BCH(15,11) code and one parity bit allows for the achievement of single error correction and double error detection over the 11 bits of information in the mode switch PPDU.

The receiving device validates the BCH(15,11) codeword and then the Parity Check field. If either validation fails, the receiver terminates the receive procedure; otherwise the receiver continues processing received symbols to decode the subsequent PPDU.

6.3a.1.5 PSDU field

The PSDU field carries the data of the PPDU for PHY packets not employing mode switching.

6.3a.2 PPDU format for MR-O-QPSK

The MR-O-QPSK PPDU shall be formatted as illustrated in Figure 26f.

		Octets	
		3	**variable**
Preamble	SFD	(see 6.3a.2.3)	PSDU
SHR		PHR	PHY payload

Figure 26f—Format of the MR-O-QPSK PHY PPDU

6.3a.2.1 Preamble field

The Preamble field shall contain a sequence of seven, zero octets for the 780 MHz, 915 MHz, 917 MHz, and 2450 MHz frequency bands. It shall contain a sequence of four, zero octets for the 470 MHz, 868 MHz, and 950 MHz frequency bands.

6.3a.2.2 SFD

The SFD shall be the sequence described in Table 29b.

Table 29b—Format of the SFD field for the MR-O-QPSK PHY

SFD value (bits 0–15)
1 1 1 0 1 0 1 1 0 1 1 0 0 0 1 0

6.3a.2.3 PHR

The format of the PHR is shown in Figure 26g. All multi-bit fields are unsigned integers and shall be processed MSB first.

Bit string index	0	1	2	3	4	5–15	16–23
Bit mapping	SM	RM_1	RM_0	R_1	R_0	L_{10}–L_0	H_7–H_0
Field name	Spreading Mode	Rate Mode		Reserved		Frame Length	HCS

Figure 26g—Format of the PHR for MR-O-QPSK

For the 915 MHz and 2450 MHz frequency bands, the Spreading Mode (SM) field shall be set to one if multiplexed direct sequence spread spectrum (MDSSS) is used for spreading the PSDU (variable SpreadingMode is “MDSSS”; see 6.12c.1.5). Otherwise, the SM field shall be set to zero (direct sequence spread spectrum [DSSS] is used for spreading the PSDU; variable SpreadingMode is “DSSS”; see 6.12c.1.4). For the 470 MHz, 868 MHz, and 950 MHz frequency bands, the SM field shall be set to zero (MDSSS is not supported).

The MR-O-QPSK PHY supports up to four different PSDU rate modes within each frequency band, and the rate mode is given by the Rate Mode field (RM_1–RM_0). Table 29c shows the mapping of the bit values to the variable RateMode (see 6.12c.1.4 and 6.12c.1.5).

Table 29c—Rate mode mapping of the MR-O-QPSK PHY

(RM_1,RM_0)	RateMode
(0,0)	0
(0,1)	1
(1,0)	2
(1,1)	3

The Reserved field (R_1–R_0) can be used for future usage and its bit entries shall be set to zero if not used.

The Frame Length field (L_{10}–L_0) 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 29 summarizes the type of payload versus the frame length value.

The Header Check Sequence (HCS) field is 8 bits in length and contains an 8-bit ITU-T CRC. The HCS is calculated over the first 16 PHR bits $(b_0, b_1, \ldots, b_{15})$, where b_0 is the PHR bit at bit string index 0 and b_{15} is the PHR bit at bit string index 15 (see Figure 26g). The HCS field is defined as

$$(H_7, H_6, \ldots, H_1, H_0) = (r_7, r_6, \ldots, r_1, r_0) \quad \text{(0b)}$$

for certain coefficients $r_0, r_1, \ldots, r_6, r_7$. The computation of the those coefficients is shown by the following algorithm.

The HCS shall be calculated using the following standard generator polynomial of degree 8:

$$G_8(x) = x^8 + x^2 + x + 1 .$$

The HCS shall be calculated as follows:

— Let $M(x) = b_0 x^{k-1} + b_1 x^{k-2} + \ldots + b_{k-2} x + b_{k-1}$ be the polynomial representing the sequence of bits for which the checksum is to be computed.

— Multiply $M(x)$ by x^8, giving the polynomial $x^8 \times M(x)$.

— Divide modulo 2 by the generator polynomial, $G_8(x)$, to obtain the remainder polynomial, $R(x) = r_0 x^7 + r_1 x^6 + \ldots + r_6 x + r_7$.

The HCS field is given by the coefficients of the remainder polynomial as shown in Equation (0b). An example HCS is shown Figure 27h.

Bit string index	**0**	**1**	**2**	**3**	**4**	**5–15**	**16–23**
Bit mapping	SM	RM_1	RM_0	R_1	R_0	L_{10}–L_0	H_7–H_0
Example value	0	0	1	0	0	0 0 0 0 0 1 0 1 0 1 0	0 0 0 1 1 1 1 0

Figure 27h—Example HCS for MR-O-QPSK

6.3a.2.4 PSDU field

The PSDU field carries the payload data of the PHY packet.

6.3a.3 PPDU format for MR-OFDM

The MR-OFDM PPDU shall be formatted as illustrated in Figure 26i. Definitions are provided in the frequency domain for the Short Training field (STF) and Long Training field (LTF). In each case, a normative set of operations is specified to transform the frequency domain fields to the time domain and to insert prescribed repetitions or cyclic prefixes of these time domain sequences.

The DATA field is composed of the PSDU, tail bits, and pad bits. The PPDU Tail Bit field (TAIL) is described in 6.12b.2.9. The method for adding pad bits (PAD) is described in 6.12b.2.10.

<table>
<tr><td></td><td></td><td colspan="2">Number of OFDM Symbols</td><td></td><td></td></tr>
<tr><td></td><td></td><td>variable</td><td>variable</td><td>6 bits</td><td>variable</td></tr>
<tr><td>STF</td><td>LTF</td><td>(see 6.3a.3.3)</td><td>PSDU</td><td>TAIL</td><td>PAD</td></tr>
<tr><td colspan="2">SHR</td><td>PHR</td><td>PHY payload</td><td></td><td></td></tr>
</table>

Figure 26i—Format of the MR-OFDM PPDU

6.3a.3.1 Short Training field (STF)

The following subclauses describe the STF.

6.3a.3.1.1 Frequency domain STF

The STF for the four scalable bandwidth OFDM options are defined by the following four tables. Table 29d shows the frequency domain representation of the STF for Option 1. The scaling factor used in the table is sqrt(104/12).

Table 29d— Frequency domain representation of Option 1 STF_freq(0)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–64	0	–32	–2.9439	0	0	32	2.9439
–63	0	–31	0	1	0	33	0
–62	0	–30	0	2	0	34	0
–61	0	–29	0	3	0	35	0
–60	0	–28	0	4	0	36	0
–59	0	–27	0	5	0	37	0
–58	0	–26	0	6	0	38	0
–57	0	–25	0	7	0	39	0
–56	0	–24	2.9439	8	2.9439	40	–2.9439
–55	0	–23	0	9	0	41	0
–54	0	–22	0	10	0	42	0
–53	0	–21	0	11	0	43	0
–52	0	–20	0	12	0	44	0
–51	0	–19	0	13	0	45	0
–50	0	–18	0	14	0	46	0
–49	0	–17	0	15	0	47	0
–48	–2.9439	–16	2.9439	16	–2.9439	48	2.9439
–47	0	–15	0	17	0	49	0
–46	0	–14	0	18	0	50	0
–45	0	–13	0	19	0	51	0
–44	0	–12	0	20	0	52	0
–43	0	–11	0	21	0	53	0

Table 29d— Frequency domain representation of Option 1 STF_freq(0) *(continued)*

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–42	0	–10	0	22	0	54	0
–41	0	–9	0	23	0	55	0
–40	–2.9439	–8	2.9439	24	2.9439	56	0
–39	0	–7	0	25	0	57	0
–38	0	–6	0	26	0	58	0
–37	0	–5	0	27	0	59	0
–36	0	–4	0	28	0	60	0
–35	0	–3	0	29	0	61	0
–34	0	–2	0	30	0	62	0
–33	0	–1	0	31	0	63	0

Table 29e shows the frequency domain representation of the STF for Option 2. The scaling factor used in the table is sqrt(52/12).

Table 29e— Frequency domain representation of Option 2 STF_freq(1)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–32	0	–16	–2.0817	0	0	16	2.0817
–31	0	–15	0	1	0	17	0
–30	0	–14	0	2	0	18	0
–29	0	–13	0	3	0	19	0
–28	0	–12	2.0817	4	2.0817	20	–2.0817
–27	0	–11	0	5	0	21	0
–26	0	–10	0	6	0	22	0
–25	0	–9	0	7	0	23	0
–24	–2.0817	–8	2.0817	8	–2.0817	24	2.0817
–23	0	–7	0	9	0	25	0
–22	0	–6	0	10	0	26	0
–21	0	–5	0	11	0	27	0
–20	–2.0817	–4	2.0817	12	2.0817	28	0
–19	0	–3	0	13	0	29	0
–18	0	–2	0	14	0	30	0
–17	0	–1	0	15	0	31	0

Table 29f shows the frequency domain representation of the STF for Option 3. The scaling factor used in the table is sqrt(26/6).

Table 29f— Frequency domain representation of Option 3 STF_freq(2)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–16	0	–8	2.0817	0	0	8	2.0817
–15	0	–7	0	1	0	9	0
–14	0	–6	0	2	0	10	0
–13	0	–5	0	3	0	11	0
–12	2.0817	–4	2.0817	4	–2.0817	12	–2.0817
–11	0	–3	0	5	0	13	0
–10	0	–2	0	6	0	14	0
–9	0	–1	0	7	0	15	0

Table 29g shows the frequency domain representation of the STF for Option 4. The scaling factor used in the table is sqrt(14/6).

Table 29g— Frequency domain representation of Option 4 STF_freq(3)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–8	0	–4	1.5275	0	0	4	1.5275
–7	0	–3	0	1	0	5	0
–6	1.5275	–2	1.5275	2	–1.5275	6	–1.5275
–5	0	–1	0	3	0	7	0

6.3a.3.1.2 Time domain STF generation

The time domain STF for Option-n (n=1,2,3,4) is obtained as follows:

STF_time(Option-n) = IFFT(STF_freq(Option-n))

The cyclic prefix is then prepended to the OFDM symbol.

6.3a.3.1.3 Time domain STF repetition

There are four STF OFDM symbols, and the last 1/2 of the fourth OFDM symbol is negated in the time domain. For Options 2, 3, and 4, the cyclic prefix is 1/4 of the OFDM symbol. Therefore, there are 18 repetitions of the 1/4 STF symbol followed by the last 1/2 of the fourth OFDM symbol, which is negated in the time domain.

For Option 1, the cyclic prefix is also 1/4 symbol, and the STF repetition is eight times per STF symbol. Therefore, there are 36 repetitions of 1/8 STF symbol in the four STF symbols followed by the last 1/2 of the fourth OFDM symbol, which is negated in the time domain.

Figure 27j shows the STF structure for all four options.

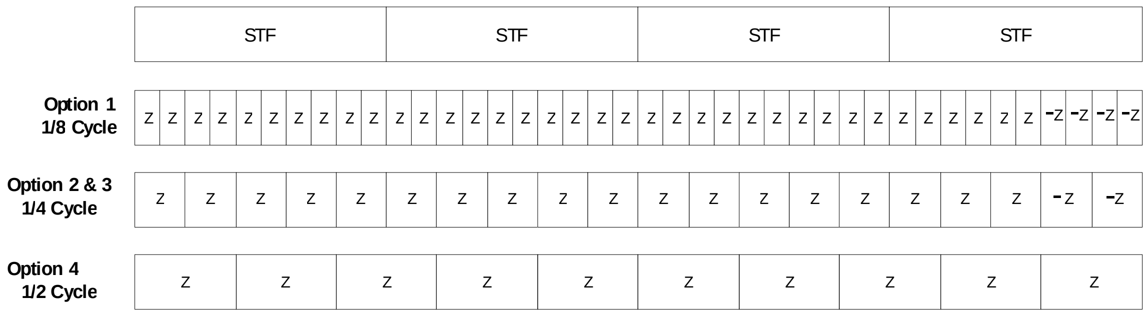

Figure 27j—Structure of STF for MR-OFDM for Options 1, 2, 3, and 4

6.3a.3.1.4 STF normalization

The STF uses a lesser number of tones than the data portion. Hence, normalization of the frequency domain STF is required to ensure that the STF power is the same as the rest of the data frame. In order to have the same power as the data, the normalization value is as follows:

$$\mathrm{sqrt}(N_{active}/ (2*N_{stf}))$$

where

N_{active} is the number of used subcarriers in rest of the OFDM frame for the particular FFT option

N_{stf} is the number of subcarriers used in the STF.

Power boosting shall be applied to the STF symbols in order to aid preamble detection. The power boosting factors for each of the four options shall be 1.94 dB.

6.3a.3.2 Long Training field (LTF)

The following subclauses describe the LTF.

6.3a.3.2.1 Frequency domain LTF

The LTF for the four scalable bandwidth OFDM options are defined by the following four tables. Table 29h shows the frequency domain representation of the LTF for Option 1.

Table 29i shows the frequency domain representation of the LTF for Option 2.

Table 29j shows the frequency domain representation of the LTF for Option 3.

Table 29k shows the frequency domain representation of the LTF for Option 4.

Table 29h— Frequency domain representation of Option 1 LTF_freq(0)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–64	0	–32	–1	0	0	32	–1
–63	0	–31	–1	1	1	33	–1
–62	0	–30	–1	2	–1	34	–1
–61	0	–29	1	3	1	35	1
–60	0	–28	1	4	–1	36	1
–59	0	–27	–1	5	1	37	1
–58	0	–26	–1	6	1	38	1
–57	0	–25	–1	7	–1	39	1
–56	0	–24	–1	8	–1	40	1
–55	0	–23	–1	9	1	41	–1
–54	0	–22	1	10	–1	42	–1
–53	0	–21	1	11	1	43	–1
–52	–1	–20	–1	12	1	44	–1
–51	1	–19	1	13	1	45	–1
–50	1	–18	–1	14	1	46	–1
–49	–1	–17	–1	15	–1	47	1
–48	–1	–16	1	16	1	48	–1
–47	–1	–15	–1	17	1	49	1
–46	–1	–14	1	18	1	50	1
–45	1	–13	1	19	1	51	–1
–44	1	–12	1	20	1	52	1
–43	–1	–11	1	21	–1	53	0
–42	–1	–10	–1	22	1	54	0
–41	1	–9	–1	23	–1	55	0
–40	1	–8	1	24	1	56	0
–39	1	–7	1	25	–1	57	0
–38	–1	–6	–1	26	1	58	0
–37	–1	–5	1	27	–1	59	0
–36	1	–4	1	28	1	60	0
–35	1	–3	–1	29	1	61	0
–34	–1	–2	1	30	–1	62	0
–33	–1	–1	1	31	1	63	0

Table 29i— Frequency domain representation of Option 2 LTF_freq(1)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–32	0	–16	1	0	0	16	1
–31	0	–15	–1	1	1	17	–1
–30	0	–14	1	2	–1	18	–1
–29	0	–13	1	3	1	19	–1
–28	0	–12	–1	4	1	20	–1
–27	0	–11	–1	5	–1	21	–1
–26	–1	–10	–1	6	1	22	1
–25	–1	–9	1	7	–1	23	–1
–24	–1	–8	1	8	–1	24	–1
–23	–1	–7	–1	9	1	25	–1
–22	1	–6	1	10	–1	26	1
–21	1	–5	1	11	1	27	0
–20	1	–4	1	12	1	28	0
–19	–1	–3	–1	13	–1	29	0
–18	1	–2	–1	14	–1	30	0
–17	–1	–1	–1	15	1	31	0

Table 29j— Frequency domain representation of Option 3 LTF_freq(2)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–16	0	–8	1	0	0	8	–1
–15	0	–7	1	1	–1	9	1
–14	0	–6	1	2	–1	10	1
–13	1	–5	1	3	1	11	–1
–12	–1	–4	1	4	–1	12	–1
–11	1	–3	1	5	1	13	1
–10	–1	–2	1	6	1	14	0
–9	1	–1	–1	7	–1	15	0

6.3a.3.2.2 Time domain LTF generation

The time domain LTF for Option-n (n=1,2,3,4) is obtained as follows:

LTF_time(Option-n) = IFFT(LTF_freq(Option-n)).

Table 29k— Frequency domain representation of Option 4 LTF_freq(3)

Tone#	Value	Tone#	Value	Tone#	Value	Tone#	Value
–8	0	–4	1	0	0	4	1
–7	1	–3	–1	1	–1	5	–1
–6	–1	–2	1	2	1	6	–1
–5	1	–1	1	3	1	7	–1

Then a 1/2 symbol cyclic prefix is inserted followed by two copies of the useful part of the LTF OFDM symbol.

6.3a.3.2.3 LTF normalization

Power boosting is not used by the LTF.

6.3a.3.3 PHR

The PHR consists of the Frame Length field and frame control bits. The list of data rates for each OFDM bandwidth option can be found in 6.12b.1. The PHR structure shall be formatted as illustrated in Figure 27k. All multi-bit fields are unsigned integers and shall be processed MSB first.

Bit string index	**0–4**	**5**	**6–16**	**17–18**	**19–20**	**21**	**22–29**	**30–35**
	RA_4–RA_0	R	L_{10}–L_0	R_1–R_0	S_1–S_0	R	H_7–H_0	T_5–T_0
Field name	Rate	Reserved	Frame Length	Reserved	Scrambler	Reserved	HCS	Tail

Figure 27k—PHY header fields for MR-OFDM

The PHR occupies three OFDM symbols for Option 1 and six OFDM symbols for Options 2, 3, and 4. It shall be transmitted using the lowest supported modulation and coding scheme (MCS) level for the option being used. The PHR is sent to the convolutional encoder starting from left-most bit in Figure 27k to the right-most bit.

The Rate field (RA_4–RA_0) specifies the data rate of the payload frame and is equal to the number of the MCS (e.g., the Rate field is 0 0 0 0 0 for MCS0).

The Frame Length field (L_{10}–L_0) 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 29 summarizes the type of payload versus the frame length value.

The Scrambler field (S_1–S_0) specifies the scrambling seed (see 6.12b.2.11).

The Header Check Sequence (HCS) field (H_7–H_0) is an 8-bit CRC taken over the PHY header (PHR) fields.

The HCS shall be computed using the first 22 bits of the PHR. The HCS shall be calculated using the polynomial $G_8(x) = x^8 + x^2 + x + 1$.

The HCS is the one's complement of the modulo 2 sum of the two remainders in a) and b):

a) The remainder resulting from $[x^8(x^{21}+x^{20}+x^{19}+x^{18}+x^{17}+x^{16}+x^{15}+x^{14})]$ divided (modulo 2) by $G_8(x)$.

b) The remainder resulting from the calculation field contents, treated as a polynomial, multiplied by x^8 and then divided (modulo 2) by $G_8(x)$.

At the transmitter, the initial remainder of the division shall be preset to all ones and then modified via division of the calculation field by the generator polynomial $G_8(x)$. The one’s complement of this remainder is the HCS field. An example of HCS generation is given in N.3.1.

The Tail bit field (T_5–T_0), which consists of all zeros, is for Viterbi decoder flushing (see 6.12b.2.9).

6.3a.3.4 PSDU field

The PSDU field carries the data of the PHY packet.

6.4 PHY constants and PIB attributes

6.4.1 PHY constants

Change Table 30 (the entire table is not shown) as indicated:

6.4.2 PHY PIB attributes

The first paragraph of 6.4.2 is reproduced here to assist the reader in understanding the notation used in Table 31. No changes are made to this paragraph.

The PHY PIB comprises the attributes required to manage the PHY of a device. The attributes contained in the PHY PIB are presented in Table 31. Attributes marked with a dagger (†) are read-only attributes (i.e., attribute can only be set by the PHY), which can be read by the next higher layer using the PLME-GET.request primitive. Attributes marked with an asterisk (*) have specific bits that are read-only attributes (i.e., attribute can only be set by the PHY), which can be read by the next higher layer using the PLME-GET.request primitive and other bits that can be read or written by the next higher layer using the PLME-GET.request or PLME-SET.request primitives, respectively. All other attributes can be read or written by the next higher layer using the PLME-GET.request or PLME-SET.request primitives, respectively.

Change Table 31 (the entire table is not shown) as indicated. The entries for phyChannelsSupported and phyCurrentPage are reproduced here to assist the reader in understanding this draft standard. No changes are made to these entries:

Insert the following new tables (Table 31a, Table 31b) after Table 31:

Insert after 6.12.15.3 the following new subclauses (6.12a through 6.12c.3.4):

Table 30—PHY constants

Constant	Description	Value
aMaxPHYPacketSize	The maximum PSDU size (in octets) the PHY shall be able to receive.	2047 for SUN PHYs 127 for all other PHYs
aTurnaroundTime	RX-to-TX or TX-to-RX maximum turnaround time ~~(in symbol periods)~~ (see 6.13.1 and 6.13.2)	1 ms for the SUN PHYs. The duration of 12 symbol periods for all other PHYs.
aCCATime	The time required to perform CCA detection	For the SUN PHYs other than MR-O-QPSK,8 symbol periods at the lowest mandatory symbol rate for that channel page. For the MR-O-QPSK PHY, this value is defined in Table 75ao. For all other PHYs, the duration of 8 symbol periods.
aMRFSKSFDLength	The length of the SFD, in octets, for the MR-FSK PHY.	2
aMRFSKPHRLength	The length of the PHR, in octets, for the MR-FSK PHY.	2
aMROQPSKSFDLength	The length of the SFD, in octets, for the MR-O-QPSK PHY.	2
aMROQPSKPHRLength	The length of the PHR, in octets, for the MR-O-QPSK PHY.	3

Table 31—PHY PIB attributes

Attribute	Identifier	Type	Valid ~~R~~range	Description
phyCurrentChannel	0x00	Integer	0–~~26~~65535	The ~~RF~~logical channel to use for all following transmissions and receptions (see 6.1.2).
phyChannelsSupported†	0x01	Array	An R x 32 bit array, where R ranges from 1 to 32	The array is composed of R rows, each of which is a bit string with the following properties: The 5 MSBs (b_{27}, …, b_{31}) indicate the channel page, and the 27 LSBs (b_0, b_1, …, b_{26}) indicate the status (1=available, 0=unavailable) for each of the up to 27 valid channels (b_k shall indicate the status of channel *k* as in 6.1.2) supported by that channel page. The device only needs to add the rows (channel pages) for the PHY(s) it supports.

Table 31—PHY PIB attributes *(continued)*

Attribute	Identifier	Type	Valid ~~R~~range	Description
phyCurrentPage	0x04	Integer	0–31	This is the current PHY channel page. This is used in conjunction with *phyCurrentChannel* to uniquely identify the channel currently being used.
phyCurrentSUNPageEntry	0x22	Bitmap	0x00000000–0xffffffff	Defines the current frequency band, modulation scheme, and particular PHY mode when *phyCurrentPage* = 7 or 8. It is a 32-bit field per the channel page seven or channel page eight definitions. If it is a channel page seven entry, the set bits specify a standard-defined PHY mode that consists of the frequency band, modulation scheme, and PHY operating mode. If it is a channel page eight entry, the set bit indicates the index or ID in the *phySUNGenericPHYDescriptors* array used to define the current PHY mode.
phyFSKFECScheme	0x23	Integer	0x00–0x01	A value of 0x00 indicates that a non-recursive and non-systematic code (NRNSC) is employed. A value of 0x01 indicates that a recursive and systematic code (RSC) is employed. See 6.12a.1.4 for more information on FEC. This attribute is only valid for the MR-FSK PHY.
phyFSKFECInterleaving	0x24	Integer	0x00–0x01	A value of 0x00 indicates that interleaving is disabled. A value of 0x01 indicates that interleaving is enabled. This attribute is only valid for the MR-FSK PHY.
phySUNGenericPHYDescriptors	0x25	Array	An array sized by *phySUNNumGenericPHYDescriptors*. The size of each element is per the GenericPHYDescriptor entry (see Table 31a).	A table of GenericPHYDescriptor entries, where each entry is used to define a channel page eight PHY mode.

Table 31—PHY PIB attributes *(continued)*

Attribute	Identifier	Type	Valid ~~R~~range	Description
phyMaxFrameDuration†	0x05	Integer	55, 212, 266, 1064 except UWB, ~~and~~ CSS, SUN PHYs	The maximum number of symbols in a frame, except for UWB, ~~and~~ CSS, and SUN PHYs: = *phySHRDuration* + ceiling([*aMaxPHYPacketSize* + 1] × *phySymbolsPerOctet*) For UWB PHYs, see 6.4.2.1. For CSS PHYs, one of two values depending on data rate. See 6.4.2.2. For MR-FSK PHY (uncoded frames): = *phySHRDuration* + (*aMRFSKPHRLength* + *aMaxPHY-PacketSize*) × *phySymbolsPerOctet*. For MR-OFDM PHY: = *phySHRDuration* + *phyPHRDuration* + ceiling[(*aMaxPHYPacketSize* + 1) × *phySymbolsPerOctet*]. For MR-O-QPSK PHY, see 6.12c.1.14.
phyMaxSUNChannelSupported†	0x26	Integer	0–65535	The maximum channel number supported by the device. It, therefore, defines the number of bits in *phySUNChannelsSupported*. This attribute is only valid if *phyCurrentPage* equals 7 or 8.
phyModeSwitchParameterEntries	0x27	Array	RxS array of ModeSwitchDescriptor entries. R ranges from 1 to 4. S contains the elements of ModeSwitchDescriptor entry in Table 31b.	An array of up to four rows, where each row consists of a set of ModeSwitchDescriptor entries. This attribute is only valid for the MR-FSK PHY.
phyMRFSKSFD	0x28	Integer	0–1	Determines which group of SFDs is used (see Table 29a). This attribute is only valid for the MR-FSK PHY.
phySUNNumGenericPHYDescriptors	0x29	Integer	0–16	The number of GenericPHYDescriptor entries supported by the device (see Table 31a).
phyNumSUNPageEntriesSupported	0x2A	Integer	0–63	The number of SUN channel page entries supported.

Table 31—PHY PIB attributes *(continued)*

Attribute	Identifier	Type	Valid ~~R~~range	Description
phySHRDuration†	0x06	Integer	3, 7, 10, 40 except UWB, ~~and~~ CSS, and SUN PHYs. For UWB PHYs see 6.4.2.1 For CSS PHY, 12, 24.	The duration of the synchronization header (SHR) in symbols for the current PHY. For CSS PHY, a value of 12 corresponds to 1 Mb/s and 24 corresponds to 250 kb/s. For MR-FSK PHY:= *phySymbolsPerOctet* × (*phyFSKPreambleRepetitions* + *aMRFSKSFDLength*). For MR-O-QPSK PHY, see 6.12c.1.14. For MR-OFDM PHY, the value is 6.
phySUNChannelsSupported‡	0x2B	Bitmap	*phyMaxSUNChannelSupported*+1 bits	The channel bitmap identifying which channels may be used when *phyCurrentPage* = 7 or 8. Bit zero in the first octet corresponds to channel 0, and bit seven in the first octet corresponds to channel 7. Bit zero in the second octet corresponds to channel 8, and bit seven in the second octet corresponds to channel 15, etc. A bit is set (=1) to indicate the channel is available, and a bit is cleared (=0) to indicate the channel is unavailable.
phySUNPageEntriesSupported	0x2C	Array	An R x 32-bit array, where R ranges from 0 to *phyNumSUNPageEntriesSupported*	Each row is a 32-bit element defining a supported SUN channel page seven or eight entry. The 32 bits are per the channel page seven and channel page eight “channel page” definitions (see 6.1.2.7).
phySymbolsPerOctet	0x07	Float	0.4, 1.3, 1.6, 2, 4, 5.3, 8	The number of symbols per octet for the current PHY. For UWB PHYs, see 6.4.2.1. For CSS PHYs, 4/3 corresponds to 1 Mb/s and 32/6 corresponds to 250 kb/s. This attribute is not used by the MR-O-QPSK PHY. For MR-OFDM PHY, see 6.12b.2.3.
phyFSKPreambleRepetitions	0x2D	Integer	4–1000	The number of times the 1-octet preamble pattern (see 6.3a.1.1) is repeated. This attribute is only valid for the MR-FSK PHY.

Table 31—PHY PIB attributes *(continued)*

Attribute	Identifier	Type	Valid ~~R~~range	Description
phyFSKScramblePSDU	0x2E	Boolean	TRUE or FALSE	A value of FALSE indicates that data whitening of the PSDU is disabled. A value of TRUE indicates that data whitening of the PSDU is enabled. This attribute is only valid for the MR-FSK PHY.
phyOFDMInterleaving	0x2F	Integer	0–1	A value of zero indicates an interleaving depth of one symbol. A value of one indicates an interleaving depth of the number of symbols equal to the frequency domain spreading factor. This attribute is only valid for the MR-OFDM PHY.
phyPHRDuration	0x30	Integer	3 or 6	A value of three for OFDM Option 1. A value of six for OFDM Options 2, 3, and 4. This attribute is only valid for the MR-OFDM PHY.

6.12a MR-FSK PHY specification

6.12a.1 Modulation and coding

The modulation for the MR-FSK PHY is either 2 or 4 level filtered FSK that meets the transmit spectral mask, as defined in 6.12a.4.1. GFSK with a BT value of 0.5 should be used in the 950 MHz band.

Table 75a shows the modulation and channel parameters for the operating modes for the 450 MHz, 470 MHz, 863 MHz, 896 MHz, 901 MHz, 915 MHz, 928 MHz, 1427 MHz, and 2450 MHz bands. For the 470 MHz band, a device shall support operating mode #1 and operating mode #2. For all other bands, a device shall support operating mode #1 and may additionally support operating modes #2 and #3.

Table 75b shows the modulation and channel parameters for the operating modes for the 950 MHz Japanese band. For this band, a device shall support both operating modes #1 and #2 and may additionally support operating modes #3 and #4.

In addition to the standard-defined PHY modes, the MR-FSK PHY may support a Generic PHY mechanism, which enables the use of a broader set of data rates and PHY parameters to describe a PHY mode. The set of PHY operating mode parameters is defined by the Generic PHY Descriptor (see 6.1.2.7.2 and Table 31a). A SUN device may operate in a PHY mode either defined in this specification or via the Generic PHY mechanism. An example of the Generic PHY mechanism is given in Annex M.

6.12a.1.1 Reference modulator diagram

The functional block diagram in Figure 65l is provided as a reference for specifying the MR-FSK PHY data flow processing functions. The subclause number in each block refers to the subclause that describes that function. Each bit shall be processed using the bit order rules defined in 6.3a.

Table 31a—Elements of GenericPHYDescriptor

Name	Type	Valid range	Description
GenericPHYID	Integer	0–15	An identifier of the Generic PHY mode. This ID corresponds to a bit position (0–15) in the channel page eight channel page definition (see 6.1.2.7.2).
FirstChannelFrequency	Integer	All bands	Specifies the center frequency, in hertz, of the first channel in the list.
NumChannels	Integer	0–65535	The number of channels defined for the particular PHY mode. The actual channels supported by the device are defined by *phySUNChannelsSupported.*
ChannelSpacing	Integer	1–4,000,000	The distance between adjacent channel center frequencies in hertz.
DataRate	Integer	1–1,000,000	The data rate in bps.
ModulationScheme	Integer	0x00–0x03	The modulation scheme of the Generic PHY entry. This parameter can take one of the following values: 0x00 = FSK 0x01 = GFSK 0x02–0x03 = reserved The remaining Generic PHY parameters are determined based on the modulation scheme.
FSKModulationOrder	Integer	0x00–0x03	The modulation order if the value of the ModulationScheme parameter is 0x00 or 0x01. This parameter can take one of the following values: 0x00 = 2-level 0x01 = 4-level 0x02–0x03 = reserved This parameter is not valid for other values of the ModulationScheme parameter.
FSKModulationIndex	Float	0.25–2.50 (step size of 0.05)	The modulation index if the value of the ModulationScheme parameter is 0x00 or 0x01. This parameter is not valid for other values of the ModulationScheme parameter.
FSKBT	Float	0.3–1.0	The BT value if the value of the ModulationScheme parameter is 0x01. This parameter is not valid for other values of the ModulationScheme parameter.

When FEC is enabled, PHR and PSDU shall be processed for coding as a single block of data (see 6.12a.1.3). When data whitening is enabled, the scrambling shall be only applied over the PSDU (see 6.12a.2).

Table 31b—Elements of ModeSwitchDescriptor

Name	Type	Valid range	Description
settlingDelay	Integer	0–255	The settling delay, in µs, between the end of the final symbol of the mode switch packet and the start of the first symbol of the following PPDU transmitted using the new PHY mode.
secondaryFSKPreambleLength	Integer	0–16	If the new mode is MR-FSK, the number of preamble repetitions, in octets, for the secondary preamble. This parameter does not apply if the new mode is MR-OFDM or MF-O-QPSK
secondaryFSKSFD	Boolean	TRUE or FALSE	If the new mode is MR-FSK, a value of TRUE indicates a secondary SFD is transmitted. A value of FALSE indicates that a secondary SFD is not transmitted. This parameter does not apply if the new mode is MR-OFDM or MF-O-QPSK

Table 75a—MR-FSK modulation and channel parameters*

Frequency band (MHz)	Parameter	Operating mode #1	Operating mode #2	Operating mode #3
450–470† (FCC Part 22/90)	Data rate (kb/s)	4.8	9.6	—
	Modulation	Filtered 2FSK	Filtered 4FSK	—
	Modulation index	1.0	1/3	—
	Channel spacing (kHz)	12.5	12.5	—
470–510 (China)	Data rate (kb/s)	50	100	200
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 4FSK
	Modulation index	1.0	1.0	1/3
	Channel spacing (kHz)	200	400	400
863–870 (Europe)	Data rate (kb/s)	50	100	200
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 4FSK
	Modulation index	1.0	1.0	1/3
	Channel spacing (kHz)	200	400‡	400‡

Table 75a—MR-FSK modulation and channel parameters* *(continued)*

Frequency band (MHz)	Parameter	Operating mode #1	Operating mode #2	Operating mode #3
902–928 (ISM)	Data rate (kb/s)	50	150	200
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 2FSK
	Modulation index	1.0	0.5	0.5
	Channel spacing (kHz)	200	400	400
2400–2483.5 (Worldwide)	Data rate (kb/s)	50	150	200
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 2FSK
	Modulation index	1.0	0.5	0.5
	Channel spacing (kHz)	200	400	400
896–901 (FCC Part 90) 901–902 (FCC Part 24) 928–960§ (FCC Part 22/24/90/101) 1427–1518§ (US FCC Part 90)/ (Canada SRSP 301.4)	Data rate (kb/s)	10	20	40
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 2FSK
	Modulation index	0.5	0.5	0.5
	Channel spacing (kHz)	25	25	25

*Data rates shown are over-the-air data rates.
†Operating mode #1 is allowed per FCC 90.203(j)(8). Operating mode #2 will be used when necessary to meet FCC 90.203(j)(3).
‡Channel spacing shows bundling of 200 kHz channels.
§Non-contiguous.

Table 75b—MR-FSK modulation and channel parameters for Japanese band*

Frequency band (MHz)	Parameter	Operating mode #1	Operating mode #2	Operating mode #3	Operating mode #4
950–958 (Japan)	Data rate (kb/s)	50	100	200	400
	Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 2FSK	Filtered 4FSK
	Modulation index	1.0	1.0	1.0	0.33
	Channel spacing (kHz)†	200, 400	400	600	600

*Data rates shown are over-the-air data rates.
†Channel separation of 200 kHz is used. Channel spacing shows bundling of 200 kHz channels.

All fields in the PPDU use the same symbol rate and modulation order, unless otherwise specified elsewhere in this standard.

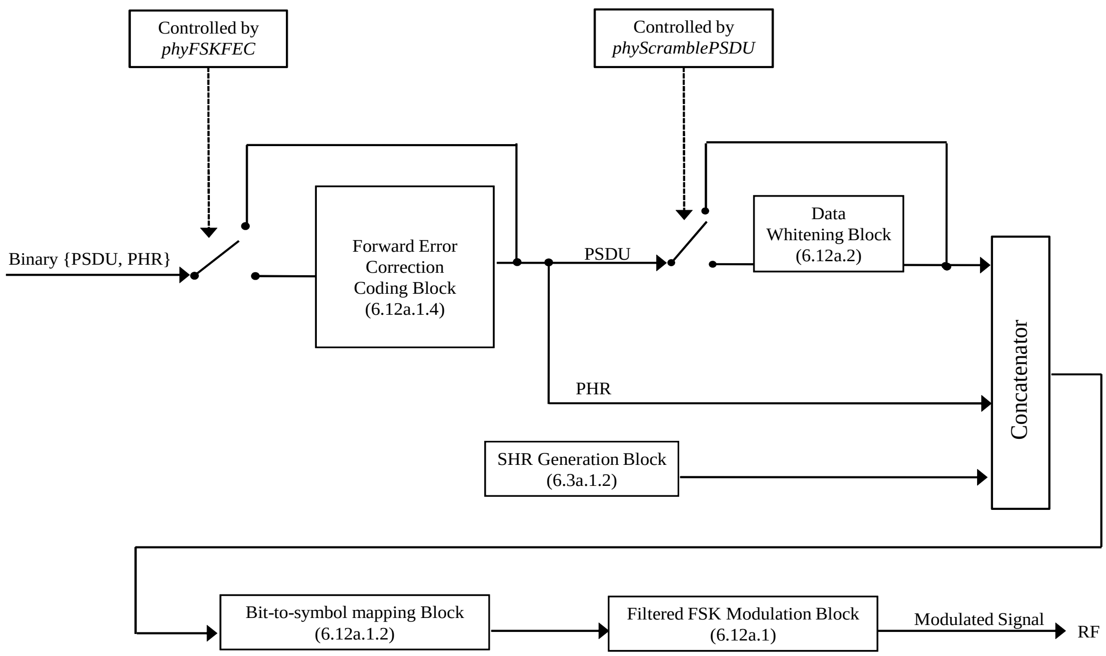

Figure 65l—MR-FSK FEC, data whitening, and modulator functions

6.12a.1.2 Bit-to-symbol mapping

The nominal frequency deviation, Δf, shall be the (symbol rate) × (modulation index) / 2. The symbol encoding for both filtered 2-level and 4-level FSK modulation is shown in Table 75c.

Table 75c—MR-FSK symbol encoding

2-level	
Symbol (binary)	Frequency deviation (Δf)
0	–1
1	+1
4-level	
Symbol (binary)	Frequency deviation (Δf)
01	–3
00	–1
10	+1
11	+3

For filtered 4FSK modulation, two bits shall be mapped to four frequency deviation levels for the PHR and PSDU. For the SHR, bit 0 and bit 1 shall be mapped to the lowest (-3*Δf) and the highest (+3*Δf) frequency deviations respectively. The symbol rate shall be the same for the entire PPDU. PPDU encoding for filtered 4FSK is shown in Figure 65m.

SHR*	PHR†	PSDU†

Figure 65m—PPDU encoding for filtered 4FSK

*Two outermost frequency deviation levels
†Four frequency deviation levels

6.12a.1.3 Modulation quality

Modulation quality shall be measured by observing the frequency deviation tolerance and the zero crossing tolerance of the eye diagram caused by a PN9 sequence of length 512 bits.

6.12a.1.3.1 Frequency deviation tolerance

Modulation frequency tolerance is measured as a percentage of the maximum frequency deviation, f_{dev}, dictated by the modulation index. In the case of filtered 2FSK the measured frequency deviation, f, at $T_s/2$ shall be constrained to the range 70% f_{dev} < |f| < 130% f_{dev} as shown in Figure 65n. In the case of filtered 4FSK the measured frequency deviation, f, at $T_s/2$ shall be constrained to the range 12% f_{dev} < |f| < 50% f_{dev} for the inner levels, and 75% f_{dev} < |f| < 125% f_{dev} for the outer levels as shown in Figure 65o.

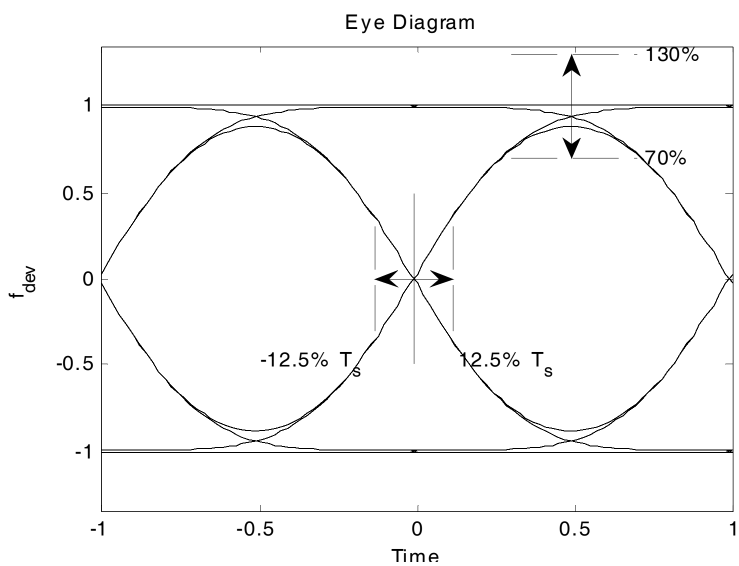

Figure 65n—Eye diagram for filtered 2FSK

6.12a.1.3.2 Zero crossing tolerance

In the case of filtered 2FSK the excursions for the zero crossings for all trajectories of the eye diagram shall be constrained to within +-12.5% of the symbol time T_s as shown in Figure 65n. In the case of filtered 4FSK the excursions for the zero crossings for all trajectories of the eye diagram shall be constrained to within +-30% of the symbol time T_s as shown in Figure 65o.

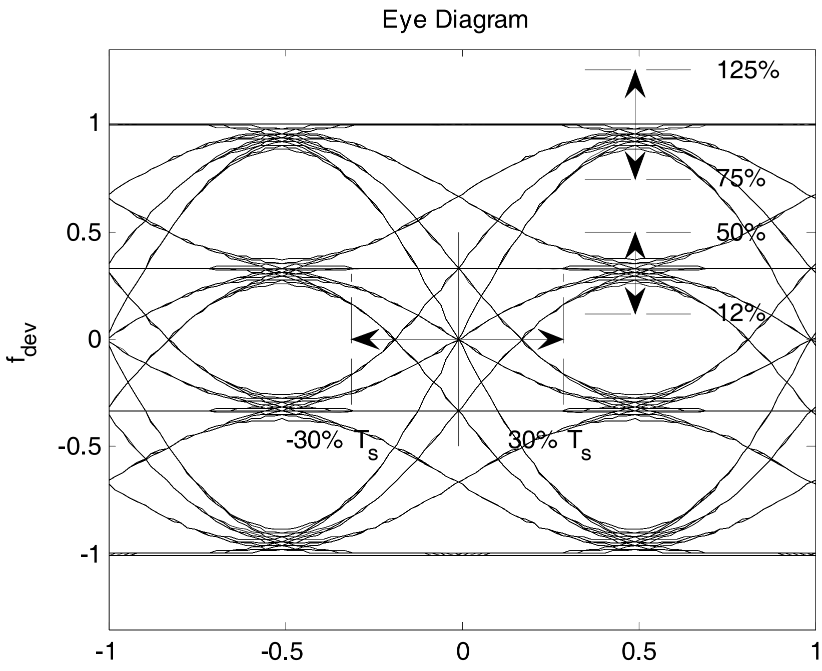

Figure 65o—Eye Diagram for filtered 4FSK

6.12a.1.4 Forward error correction (FEC)

Forward error correction (FEC) is optional. If the SFD indicates that FEC is used (see Table 29a), then the FEC is applied to the PHR and PSDU as a single block of data.

Two types of FEC may be applied: a recursive and systematic code (RSC) or a non-recursive and non-systematic code (NRNSC). The use of RSC or NRNSC coding shall be controlled by the PIB attribute *phyFSKFECScheme* (see Table 31).

Interleaving of code-bits can be employed in conjunction with either RSC or NRNSC coding, in order to improve robustness against burst errors and to break correlation of consecutive bits (see 6.12a.1.5). The use of interleaver is controlled by the PIB attribute *phyFSKFECInterleaving*. No interleaving shall be employed if FEC is not used.

When the SFD value indicates a coded packet, FEC shall be employed on the PHR and PSDU bits, applying either a ½ rate systematic or non-systematic convolution coding with constraint length K = 4 and using the generator polynomials shown in Equation (21a) and Equation (21b).

$$G_0(x) = 1 + x + x^2 + x^3 \tag{21a}$$

$$G_1(x) = 1 + x^2 + x^3 \tag{21b}$$

The RSC encoder is shown in Figure 65p, and the NRNSC encoder is shown in Figure 65q.

For an input sequence of bits with length N, $B = \{b_i, i \in [0, 1, 2, \ldots, N-1]\}$, the i^{th} input bit shall be represented as b_i. The output sequence S also comprises N code symbols.

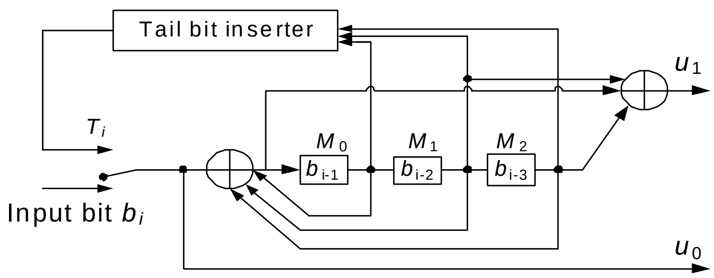

Figure 65p—The recursive and systematic code (RSC) encoder

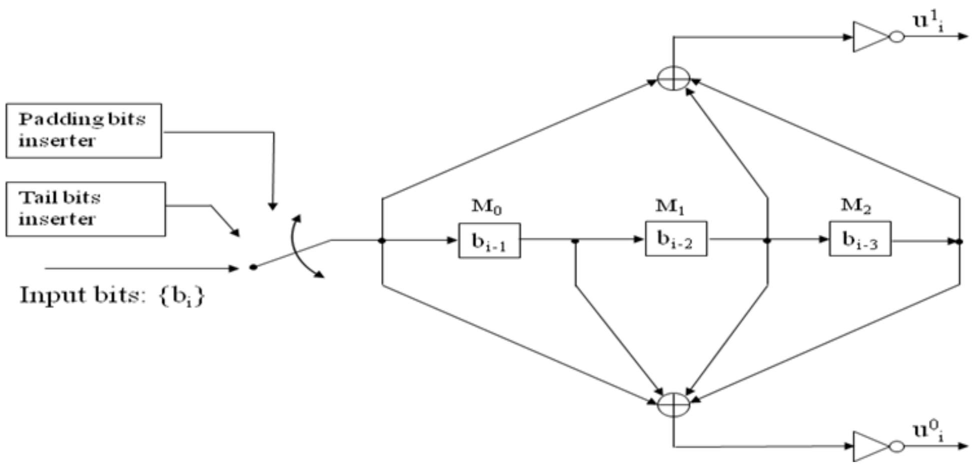

Figure 65q—Non-recursive and non-systematic code (NRNSC) encoder

$$S = \{s(0), s(1), s(2), \ldots, s(N-1)\} = \{u_0^{\ 1}, u_0^{\ 0}, \ldots, u_i^{\ 1}, u_i^{\ 0}, u_{i+1}^{\ \ 1}, u_{i+1}^{\ \ 0}, \ldots, u_{N-1}^{\ \ 1}, u_{N-1}^{\ \ 0}\}$$

Each code symbol is denoted by $s(i) = \{u_i^{\ 1}, u_i^{\ 0}\}, \forall i = 0, \ldots, N-1$, where *s(i)* is the i^{th} output code symbol due to the i^{th} input bit and $u_i^{\ 1}$ and $u_i^{\ 0}$ indicate the first and second output bits of the convolutional encoder, respectively. The code symbol *s*(*i*) shall precede the code symbol *s*(*i*+1) and the code bit $u_i^{\ 1}$ shall precede the code bit $u_i^{\ 0}$.

For the RSC encoder, the first and the second output bits of the encoder shall be generated according to Equation (21c):

$$u_i^{\ 1} = b_i \oplus (b_{i-1} \oplus b_{i-2} \oplus b_{i-3}) \oplus b_{i-2} \oplus b_{i-3}, \ u_i^{\ 0} = b_i \qquad (21c)$$

where $\oplus$ stands for modulo-2 addition.

For the NRNSC encoder, the first and the second output bits of the encoder shall be generated according to Equation (21d)

$$u_i^{\ 1} = \overline{b_i \oplus b_{i-2} \oplus b_{i-3}}, \ u_i^{\ 0} = \overline{b_i \oplus b_{i-1} \oplus b_{i-2} \oplus b_{i-3}} \qquad (21d)$$

where the “overline” indicates the complement of the modulo-2 addition.

The total size of bits to be encoded, N, is obtained by summing up the size of the PHR, L_{PHR}, the length of the PSDU, L_{PSDU} (FCS included), the number of tail bits, L_{TAIL}, and the number of padding bits, L_{PAD}. N shall be computed according to Equation (21e):

$$N = L_{PHR} + L_{PSDU} + L_{TAIL} + L_{PAD} . \quad (21e)$$

Note that L_{PSDU} is zero in the case of a mode switching frame.

Immediately after encoding the PHR and PSDU, a termination sequence with length L_{TAIL} = 3 bits (the tail bits) shall be inserted into the encoder, as shown in Figure 65r. The “so-called tail bits” are required to return the encoder to the zero state.

PHR	PSDU	Tail bits (T0 T1 T2)

Figure 65r—Data block extension with tail bits prior to coding

The value of the tail bits are dependent on the coding scheme and shall be set as shown in Table 75d.

Table 75d—Tail bit pattern for the RSC and NRNSC encoders

Memory state (M0–M1)	Tail bits	
	RSC (T0 T1 T2)	NRNSC (T0 T1 T2)
000	000	000
100	100	000
010	110	000
110	010	000
001	111	000
101	011	000
011	001	000
111	101	000

When interleaving is used in conjunction with convolutional coding, a padding sequence of L_{PAD} bits shall be further inserted into the encoder immediately after the tails bits. The padding bits are required to completely fill up the last interleaver buffer (see 6.12a.1.5). L_{PAD} shall be computed as follows:

$$L_{PAD} = 5, when\frac{L_{PHR} + L_{PSDU}}{8} \text{ is odd. } L_{PAD} = 13, when\frac{L_{PHR} + L_{PSDU}}{8} \text{ is even.}$$

It is strongly recommended to use padding bit patterns that do not contain a long series of '1's or '0's. Figure 65s and Figure 65t illustrate examples of such patterns.

PHR	PSDU	Tail bits (T0 T1 T2)	5-bit padding pattern 01011

Figure 65s—An example of extension with padding bits prior to encoding, when $(L_{PHR} + L_{PSDU})/8$ is odd

PHR	PSDU	Tail bits (T0 T1 T2)	13-bit padding pattern 01011 00001011

Figure 65t—An example of extension with padding bits prior to encoding, when $(L_{PHR} + L_{PSDU})/8$ is even

6.12a.1.5 Code-symbol interleaving

The interleaver is optional. The interleaver is defined by a permutation of code symbols, where each permuted element contains exactly one code symbol, i.e., a pair of two bits (see 6.12a.1.3). The process of interleaving is illustrated in Figure 65u.

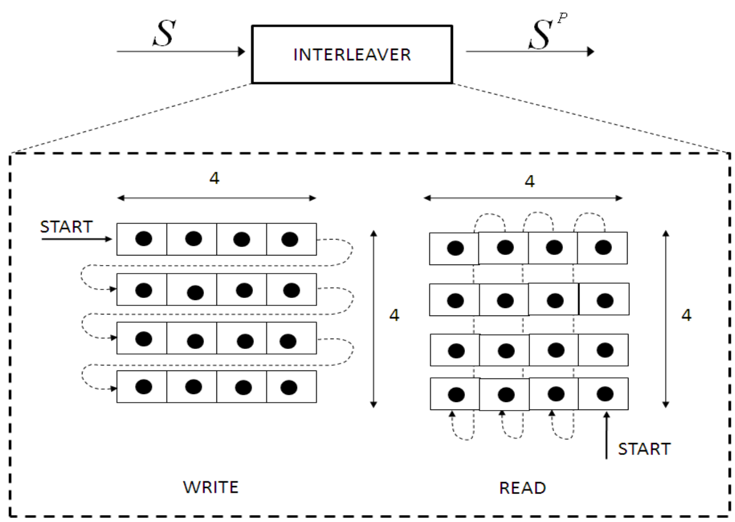

Figure 65u—The interleaving block

The sequence S = {s(0), s(1), …, s(N-1)} exiting the encoder shall be passed to the interleaver in the following way. The first sample of code symbols shall be passed to the interleaver first in time, and the last sample of code symbols shall be passed to the interleaver last in time. Additionally, the complete sequence of code symbols S = {s(0), s(1), …, s(N-1)} is passed to the interleaver as N_{BLOCK} consecutive subsequences, where each subsequence has a size equal to $N_{INTERLEAV}/2$ code-symbols. All subsequences shall be structured according to Equation (21f) and Equation (21g).

$$s = \{S^{(0)}, S^{(1)}, \ldots, S^{(N_{BLOCK}-1)}\} \quad (21f)$$

$$S^{(ii)} = \left\{s(j), j = ii \times \frac{N_{INTERLEAV}}{2}, ii \times \frac{N_{INTERLEAV}}{2} + 1, \ldots, (ii+1) \times \frac{N_{INTERLEAV}}{2} - 1\right\}, ii = [0, N_{BLOCK} - 1] \quad (21g)$$

N_{BLOCK} and $N_{INTERLEAV}$ values shall be computed according to Equation (21h) and Equation (21i).

$$N_{INTERLEAV} = 32 \tag{21h}$$

$$N_{BLOCK} = \frac{(N/r)}{N_{INTERLEAV}} = \frac{2 \times N}{32} = \frac{N}{16}, \tag{21i}$$

N is a non-zero integer multiple of 8, with $N \geq 16$ (see Equation (21e)).

For each sequence

$$S^{(ii)} = \{s(j), j = ii \times N_{INTERLEAV}/2, ii \times N_{INTERLEAV}/2 + 1, \ldots, (ii+1) \times N_{INTERLEAV}/2 - 1\}$$

passed to the interleaver, the index of code-symbols before the interleaver process shall be denoted by j, where the sample $j = ii \times N_{INTERLEAV}/2$ shall be passed to the interleaving block first in time and the sample $j = (ii+1) \times N_{INTERLEAV}/2 - 1$ shall be passed to the interleaving block last in time. The index k shall be the index after the interleaving process. The subsequence exiting the interleaving block shall be computed according to Equation (21j).

$$S^{(ii)} = \left\{ s(k), k = \left[(ii+1) \times \frac{N_{INTERLEAV}}{2} - 1 \right] - 4 \times mod(j, 4) - \left\lfloor \frac{j}{4} \right\rfloor \right\}, \forall ii = [0, N_{BLOCK} - 1] \tag{21j}$$

The function $\lfloor x \rfloor = floor(x)$ returns the largest integer value not greater than x.

The deinterleaver, which achieves the inverse operation, uses the same rules as the interleaver. For an input interleaved subsequence

$$S^{(ii)} = \{s(k), k = ii \times N_{INTERLEAV}/2, ii \times N_{INTERLEAV}/2 + 1, \ldots, (ii+1) \times N_{INTERLEAV}/2 - 1\}$$

passed to the deinterleaver, the subsequence exiting the deinterleaving block shall be generated according to Equation (21k). The index k shall denote the index of code-symbols before deinterleaving, and index j shall denote the index of code-symbols after deinterleaving.

$$S^{(ii)} = \left\{ s(j), j = \left[(ii+1) \times \frac{N_{INTERLEAV}}{2} - 1 \right] - 4 \times mod(k, 4) - \left\lfloor \frac{k}{4} \right\rfloor \right\}, \forall ii = [0, N_{BLOCK} - 1] \tag{21k}$$

6.12a.2 Data whitening

Support for data whitening is optional.

When data whitening is enabled at the transmitter, the Data Whitening field of the PHR shall be set to one (see 6.3a.1.3), and the scrambled data shall be the exclusive or (XOR) of the PSDU with the PN9 sequence, as described by Equation (21l).

$$E_{\mathrm{n}} = R_{\mathrm{n}} \oplus \mathrm{PN9}_{\mathrm{n}} \tag{21l}$$

where

E_{n} is the whitened bit
R_{n} is the data bit being whitened

$PN9_n$ is the PN9 sequence bit

For each packet transmitted with data whitening enabled, R_0 is the first bit of the PSDU and the index *n* increments for subsequent bits of the PSDU.

For packets received with the Data Whitening field of the PHR set to one, the receiver decodes the scrambled data, as described by Equation (21m).

$$R_n = RE_n \oplus PN9_n \quad (21m)$$

where

RE_n is the PSDU bit at the output of the filtered FSK demodulator
R_n is the PSDU bit after de-whitening

The PN generator is defined by the schematic in Figure 65v.

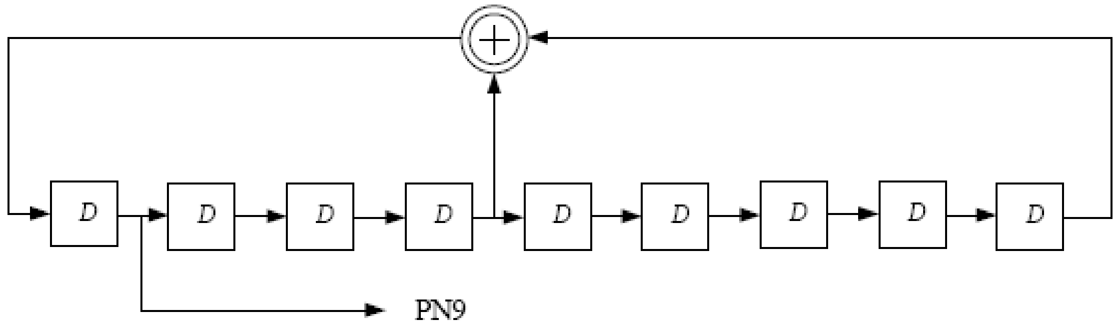

Figure 65v—Schematic of the PN9 sequence generator

The seed in the PN9 shall be all ones: "111111111." The PN9 shall be reinitialized to the seed after each packet (either transmit or receive).

The PN9 generator is clocked starting from the seed. For example, the first 30 bits out of the PN9, once it is enabled, would be as follows:

$PN9_n$= 0_0, 0_1, 0_2, 0_3, 1_4, 1_5, 1_6, 1_7, 0_8, 1_9, 1_{10}, 1_{11}, 0_{12}, 0_{13}, 0_{14}, 0_{15}, 1_{16}, 0_{17}, 1_{18}, 1_{19}, 0_{20}, 0_{21}, 1_{22}, 1_{23}, 0_{24}, 1_{25}, 1_{26}, 0_{27}, 1_{28}, 1_{29}.

6.12a.3 Mode switch mechanism

The mode switch mechanism is optional.

The mode switch mechanism is enabled by setting the Mode Switch subfield to one. The MR-FSK mode switch PPDU is transmitted on *phyCurrentChannel*, and the PPDU containing the PSDU is transmitted on the channel that corresponds to the same center frequency used for the MR-FSK mode switch PPDU. When a valid MR-FSK mode switch PPDU (see Figure 27b) is received, a device that supports mode switching shall change its mode of operation to the new mode defined in the MR-FSK mode switch PPDU, in order to receive the following frame.

When changing from the current operating mode to the new mode, a settling delay may exist. The settling delay shall ensure that the receiver maintains correct timing and is ready to receive the new mode PPDU. Also, the data rate for switching from FSK to FSK is within the data rate range of SUN PHY. The settling delay is part of a ModeSwitchDescriptor (see Table 31b). The value specified in the Mode Switch Parameter Entry field of the PHR (see Figure 27d) is the index of the PIB attribute array *phyModeSwitchParameterEntries*, which contains the elements of the ModeSwitchDescriptor. How the Mode Switch Parameter Entry field maps to ModeSwitchDescriptor is exemplified in Table 75e. For the mode switch operation of FSK->FSK, the symbol rate is changed. For the mode switch operation of FSK->4FSK, the modulation order and/or the symbol rate is changed. The Mode Switch Parameter Entry table is defined by the next higher layer.

Table 75e—An example of mapping between *phyModeSwitchParameterEntries*[ ] and ModeSwitchDescriptor

***phyModeSwitchParameterEntries*[ ]**	**Mode Switch Operation**	**ModeSwitchDescriptor**		
		Settling Delay	**SecondaryFSK Preamble Length**	**Secondary FSKSFD**
0	FSK->FSK	20	0	FALSE
1	FSK->4FSK	40	0	FALSE
2	FSK->OFDM	160	n/a	n/a
3	FSK->O-QPSK	80	n/a	n/a

Reception of the new mode PPDU starts settlingDelay microseconds after the end of the mode switch PPDU. The reception and rejection of the following frame follows the same mechanism described in 7.5.6.2. When the new mode PPDU has been received, the receiver shall return to the mode specified by *phyCurrentSUNPageEntry* within the SIFS or LIFS period, depending on the received frame length (see 7.5.1.3). If the transmission of an ACK is requested by the transmitter, the ACK is transmitted using the PHY mode specified by *phyCurrentSUNPageEntry*.

The sequence of the MR-FSK mode switch PPDU, the optional settling delay, and the PPDU transmitted in the new PHY mode is shown in Figure 65w.

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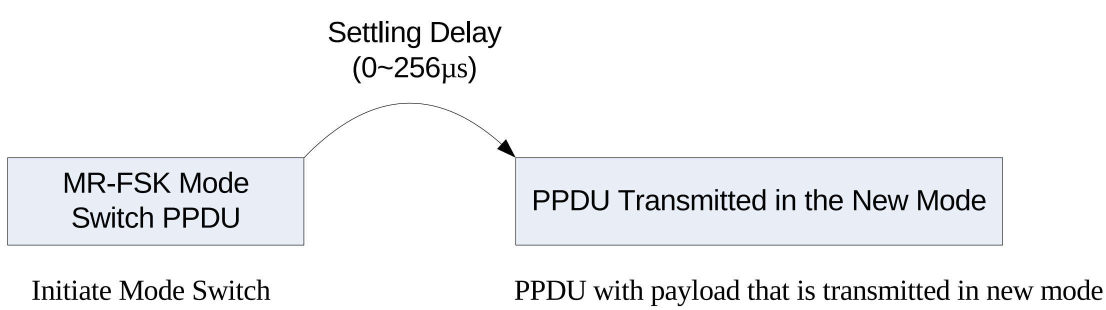

Figure 65w—Transmitting sequence between MR-FSK mode switch PPDU and the new mode PPDU

Devices employing the mode switch mechanism shall meet the MAC timing requirements of 7.5.1.1.1 and 7.5.1.1.2, using the symbol duration of the default PHY mode.

The frequency band is not changed by the PHY mode switch mechanism. The center frequency of the channel is also not changed by a PHY mode switch and channel center frequencies for the various modulation schemes are aligned as shown in Table 75f.

Table 75f—Channel alignment for 915 MHz band

FSK (200 kHz)	FSK (400 kHz)	O-QPSK	OFDM
902.2			
902.4	902.4		902.4
902.6			
902.8	902.8		902.8
903.0			
903.2	903.2		903.2
903.4			
903.6	903.6		903.6
903.8			
904.0	904.0	904.0	904.0
904.2			
904.4	904.4		904.4
904.6			
904.8	904.8		904.8
905.0			
905.2	905.2		905.2
905.4			
905.6	905.6		905.6
905.8			
906.0	906.0	906.0	906.0
906.2			
906.4	906.4		906.4
906.6			
906.8	906.8		906.8
907.0			
907.2	907.2		907.2
907.4			
907.6	907.6		907.6
907.8			
908.0	908.0	908.0	908.0

Table 75f—Channel alignment for 915 MHz band *(continued)*

FSK (200 kHz)	FSK (400 kHz)	O-QPSK	OFDM
908.2			
908.4	908.4		908.4
908.6			
908.8	908.8		908.8
909.0			
909.2	909.2		909.2
909.4			
909.6	909.6		909.6
909.8			
910.0	910.0	910.0	910.0
⋮	⋮	⋮	⋮
etc.	etc.	etc.	etc.

6.12a.4 Radio specification

The single-sided clock frequency tolerance *T*, in ppm, shall be set as follows:

$$T \leq min\left(\frac{T_0 \times R \times h \times F_0}{R_0 \times h_0 \times F}, 50ppm\right),$$

where

R is the symbol rate in ksps
h is the modulation index
F is the carrier frequency in MHz
R_0 is 50 ksps
h_0 is 1
F_0 is 915 MHz
T_0 is 30 ppm for modes in all bands, except at 2450 MHz for which the value of T_0 is 40 ppm

In addition, a SUN device shall also satisfy regulatory requirements applicable to frequency tolerance.

Channel switch time is a transmitter parameter defined as the time taken for a transmitter on channel A to exit that channel, enter channel B, and be ready to transmit on that channel; both channels are co-resident in a single band defined in Table 1. The channel switching time shall be ≤ 500 µs.

The adjacent channels are those on either side of the desired channel that is closest in frequency to the desired channel. The adjacent channel rejection shall be greater than or equal to 10 dB.

The alternate channel is more than one removed from the desired channel in the operational bandwidth. The alternate channel rejection shall be greater than or equal to 30 dB.