IEEE P802.15
Wireless Personal Area Networks

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Title	**Clause 6 - FSK PHY Draft**	
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Re:	[802.15.4 Amendment 4g]	
Abstract	[Proposed Content for Clause 6 of FSK draft.]	
Purpose	[For consideration for TG4g candidate draft.]	
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6. PHY specification

6.1 General requirements and definitions

Insert the following items to the end of the first dashed list:

— Forward error correction (FEC) for the multi-regional frequency shift keying (MRFSK) PHY (optional)

Insert the following items to the second dashed list:

— A 400 MHz PHY employing Gaussian frequency-shift keying (GFSK) modulation

— A 470 MHz PHY employing GFSK modulation

— An 863 MHz PHY employing GFSK modulation

— A 902 MHz PHY employing FSK/GFSK modulation

— A 950 MHz PHY employing GFSK modulation

— A 2400 MHz PHY employing FSK/GFSK modulation

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

In addition to the PHYs supported in IEEE Std 802.15.4-2006, and IEEE Std 802.15.4a-2007, IEEE Std 802.15.4c-2009, and IEEE Std 802.15.4d-2009, PHYs targeting SUN applications have been added. They are a GFSK PHY operating in the Chinese 470 MHz band, a GFSK PHY operating in the European 863 MHz band, an FSK/GFSK PHY operating in the 902 MHz ISM band, two GFSK PHYs operating in the Japanese 400 MHz and 950 MHz bands, and an FSK/GFSK PHY operating nearly worldwide in the 2400 MHz band. At least one of the PHYs shall be implemented when supporting SUN applications.

6.1.1 Operating frequency range

Change Table 1 (the entire table is not shown) 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
950*	950–956	—	GFSK	100	100	Binary
950*	950–956	300	BPSK	20	20	Binary
400	TBD (1 MHz within 400–430 MHz)	—	GFSK	50	50	Binary
			GFSK	50†	100	
			GFSK	100		
			GFSK	200	200	
			4-GFSK	400		4-ary

Table 1—Frequency bands and data rates

470	470–510	—	GFSK	50	50	Binary
				100 or 150 (TBD)	100 or 150 (TBD)	
				200	200	
863	863–870	—	GFSK	50	50	Binary
				100 or 150 (TBD)	100 or 150 (TBD)	
				200	200	
902	902–928	—	FSK	50	50	Binary
			FSK	150	150	
			GFSK	200	200	
950‡	950–956	—	GFSK	50	50	Binary
			GFSK	50†	100	
			GFSK	100		
			GFSK	200	200	
			4-GFSK	400		4-ary
2400	2400–2483.5	—	FSK	50	50	Binary
			FSK	150	150	
			GFSK	200	200	
TBD: Dedicated use bands	TBD	TBD	TBD	TBD	TBD	TBD

*~~For the 950 MHz PHYs, at~~ At least one of the ~~two~~ 950 MHz PHYs shall be implemented when operating in Japan.
†FEC scheme applied, as described in 6.12a.2.3.
‡As specified in P802.15.4g.

Insert the following two tables and accompanying text after the second paragraph:

For each defined frequency band, the MRFSK PHY shall support a set of mandatory data rates and associated parameters, meaning that all compliant devices shall be capable of transmitting and receiving at the specified data rate and with the specified associated parameters. The MRFSK PHY may also support optional data rates and associated parameters. Table 1a shows the modulation and channel parameters for the mandatory mode and two particular optional modes for the 470 MHz, 863 MHz, 902 MHz, and 2400 MHz bands. Table 1b shows the modulation and channel parameters for the two mandatory modes and a particular optional mode for the 400 MHz and 950 MHz bands.

In addition to the modes in Table 1a and Table 1b, the MRFSK PHY shall support a generic PHY mechanism to enable the derivation of a broader set of data rates and parameters; the specifications of the mandatory and optional modes just described are consistent with the generic PHY mechanism. Therefore, while a compliant device shall be capable of operating in the mandatory mode(s), the device may alternatively be configured to operate at a different data rate with associated parameter values, provided the alternative mode is compliant with the generic PHY mechanism. For an example of the use of the generic PHY mechanism, see Annex P.

Table 1a—Modulation and channel parameters for 470, 863, 902, and 2400 MHz bands

Frequency band (MHz)	Parameter	Mandatory data rate	Optional data rate #1	Optional data rate #2
470–510 (China)	Data rate (kb/s)	50	100 or 150 (TBD)	200
	Modulation	GFSK	GFSK	GFSK
	Modulation index	1.0	0.5	0.5
	Channel spacing (kHz)*	200	400	400
863–870 (Europe)	Data rate (kb/s)	50	100 or 150 (TBD)	200
	Modulation	GFSK	GFSK	GFSK
	Modulation index	1.0	0.5	0.5
	Channel spacing (kHz)	200	400	400
902–928 (ISM) 2400–2483.5 (Worldwide)	Data rate (kb/s)	50	150	200
	Modulation	FSK	FSK	GFSK
	Modulation index	1.0	0.5	0.5
	Channel spacing (kHz)	200	400	400
TBD: Dedicated use bands	TBD	TBD	TBD	TBD

*Channel spacing shows bundling of 200 kHz regulatory channels.

Table 1b—Modulation and channel parameters for 400 and 950 MHz bands

Frequency band (MHz)	Parameter	Mandatory data rate #1	Mandatory data rate #2	Optional data rate
400–430 (Japan) 950.1–955.7 (Japan)	Data rate (kb/s)	50	100	200/400
	Modulation	GFSK	GFSK	GFSK/4-GFSK
	Modulation index	1.0	1.0	1.0/0.33
	Channel spacing (kHz)* †	200/400	400	600

*Channel separation of 200 kHz is used.
†Channel spacing shows bundling of 200 kHz regulatory channels.

The generic PHY mechanism defines the set of parameters necessary to describe a PHY mode. The set of PHY mode parameters is defined by the descriptors in *phyCapabilitiesTable* (see Table 31).

The capabilities table specifies the mode or modes supported by a specific device, and this table is defined in terms of the just-described PIB attributes. The capabilities table shall include the mandatory mode(s) and may include the optional modes defined in Table 1a and Table 1b or other modes derived using the generic PHY mechanism. Capabilities messages may be exchanged between two compliant devices, and the content

of such messages would consist of the information carried by the PHY mode parameters. Defintion of the capabilities message is TBD. The operating mode table specifies the current PHY mode of operation.

6.1.2 Channel assignments

TBD - The combination of channel numbering and channel paging needs to be revisited.

The introduction of the " 400/470/863/902/950/2400 MHz FSK/GSFK/4-GFSK PHY specifications" results in the total number of channel assignments exceeding the channel numbering capability of 32 channel pages that was defined in the 2006 edition of this standard. However, to support the growing number of channels, channel assignments shall be defined through a combination of channel numbers and channels pages.

The 2006 edition of this standard, states that the upper 5 most significant bits (MSBs) of the 32-bit channel bitmaps in *phyChannelsSupported* shall be used as an integer value to specify 32 possible channel pages. The lower 27 bits of the channel bit map shall be used as a bit mask to specify channel numbers within a channel page.

The present ammendment shall define a method of using the 32 bits of the 32-bit channel bitmaps in *phyChannelSupported* while being compatible with the 2006 edition of this standard.

6.1.2.1 Channel numbering

6.1.2.2 Channel numbering for CSS PHY

6.1.2.3 Channel numbering for 779–787 MHz band

6.1.2.4 Channel numbering for 950 MHz PHYs

6.1.2.5 Channel numbering for UWB PHY

Insert the following new subclause (6.1.2.5a) after 6.1.2.5:

6.1.2.5a Channel numbering for MRFSK PHY

The channel center frequency *ChanCenterFreq* shall be derived using Equation (1), where *BandEdge* is the start of the frequency band in MHz, *ChanNum* is the channel number, and *ChanSep* is the channel separation in MHz. In Japan, the channel separation for the modes defined in Table 1b is 200 kHz. In all other bands, the channel separation is 200 kHz for the mandatory mode and 400 kHz for the optional modes (see Table 1a). The generic PHY mechanism allows other channel separations to be used in all bands.

$$ChanCenterFreq = BandEdge + ((ChanSep)/2) + (ChanNum - 1) \times ChanSep \quad (1)$$

Exceptions may apply to the upper part of the European 868 MHz band, where channel carrier assignment may be individually tailored to suit regulatory requirements.

6.1.2.6 Channel pages

TBD

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

TBD

6.1.4 RF power measurement

6.1.5 Transmit power

TBD

6.1.6 Out-of-band spurious emission

6.1.7 Receiver sensitivity definitions

Insert text into 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 = 20 octets. – PSDU length for MRFSK = 1500 octets.* – PER < 1%. – Power measured at antenna terminals. – Interference not present.

*For the mandatory PHY mode (e.g., no FEC).

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 (before the closing parenthesis):

PHRCoding,
PayloadCoding,
FCSOption,
ModeSwitching,
TBD

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

Table 8—PD-DATA.request parameters

Name	Type	Valid range	Description
PHRCoding	Boolean	TRUE or FALSE	A value of FALSE indicates that PHR coding is off, and a value of TRUE indicates that PHR coding is on.
PayloadCod-ing	TBD	TBD	TBD
FCSOption	Boolean	TRUE or FALSE	A value of FALSE indicates that the FCS contains a 32-bit CRC. A value of TRUE indicates a 16-bit CRC.
ModeSwitch-ing	Boolean	TRUE or FALSE	TRUE = mode switching will occur with next PPDU; FALSE = Mode switching will not occur with next PPDU (current mode will be used for the following PPDU)
TBD			

6.2.1.1.2 Appropriate usage

6.2.1.1.3 Effect on receipt

TBD

6.2.1.2 PD-DATA.confirm

6.2.1.2.1 Semantics of the service primitive

TBD

6.2.1.2.2 When generated

6.2.1.2.3 Appropriate usage

6.2.1.3 PD-DATA.indication

6.2.1.3.1 Semantics of the service primitive

Insert the following new parameters at the end of the list in 6.2.1.3.1 (before the closing parenthesis):

PayloadCoding,
FCSOption,
TBD

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

Table 10—PD-DATA.indication parameters

Name	Type	Valid range	Description
TBD			
PayloadCoding	TBD	TBD	TBD
FCSOption	Boolean	TRUE or FALSE	TBD

6.2.1.3.2 When generated

6.2.1.3.3 Appropriate usage

6.2.2 PHY management service

6.2.3 PHY enumerations description

6.3 PPDU format

Change the third paragraph of subclause 6.3 as indicated:

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, containing the preamble and the SFD
- A PHY header (PHR), which contains frame control, frame length information and, for UWB PHYs, rate, ranging, and preamble information
- ~~A variable length payload, which carries the MAC sublayer frame~~

Insert the following new paragraph after the third paragraph of subclause 6.3:

A PPDU packet may optionally include 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, Figure 26a, or Figure 26b.

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

The MRFSK PHY has two possible PPDU formats. Figure 26a shows the mandatory PPDU format, and Figure 26b shows the optional PPDU format that is used to enable PHY mode switching (e.g., a change in data rate, modulation type, and/or other modulation parameters).

Insert the following new figures after Figure 26:

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		Octets		
		2		variable
Preamble	SFD	Frame Control (5 bits)	Frame Length (11 bits)	PSDU
SHR		PHR		PHY payload

Figure 26a—Format of the MRFSK PPDU

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		Octets	
		2	
Preamble	SFD	Frame Control (TBD bits)	
SHR		PHR	

Figure 26b—Mode switching PPDU format

6.3.1 Preamble field

Insert the following text into the last paragraph of 6.3.1:

The bits in the preamble field for the MRFSK PHY shall be multiple strings of "01010101."

TBD preamble length.

6.3.2 SFD field

The MRFSK SFD field consists of 3 bytes. The value is TBD.

Insert the following new row at the end of Table 27 as indicated:

Table 27—SFD field length

PHY	Length	
MRFSK	3 octets	—

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, MRFSK and CA-CDM PHYs)

Insert the following new paragraphs and new tables (Table 28a, Table 28b) at the end of 6.3.2:

The SFD used by the MRFSK PHY shall be a TBD-bit sequence selected from the list of values in Table 28a.

Table 28a—MRFSK PHY SFD values

Format of the SFD field	Indicates
TBD	Mandatory uncoded PHR
TBD	Optional coded PHR

Insert the following new subclauses after 6.3.2:

6.3.2a Frame Control field

The Frame Control field is 5 bits in length and is shown in Figure 27a. This field controls the data rate and modulation scheme for the remaining portion of the packet, the length of the FCS, and whether FEC is used (note: maybe the FEC method also).

Bits			
1 or 2	**1**	**1**	**1 or 2**
Reserved	Mode Switching	FCS Option	FEC Option

Figure 27a—Format of the Frame Control field for MRFSK

6.3.2a.1 Mode Switching subfield

A Mode Switching subfield set to zero indicates that the entire packet shall be transmitted at a single data rate and using a single modulation scheme. A value of one indicates that a mode switch shall occur according to the information contained in TBD (fig 26b; appropriate subclause cross-reference).

6.3.2a.2 FCS Option subfield

If the FCS Option subfield is set to zero, the FCS field (7.2.1.9) contains a 32-bit CRC. If the field is set to one, the FCS subfield contains a 16-bit CRC.

6.3.2a.3 FEC Option subfield

Support for uncoded header and uncoded payload is mandatory; support for coded header/payload is optional.

Details of this subfield are TBD.

6.3.3 Frame Length field

Insert the following three new paragraphs after the first paragraph of 6.3.3:

For the MRFSK PHY, the Frame Length field is 11-bits in length. It is a value between 0 and *aMaxSUNPHYPacketSize* octets (see 6.4).

Insert the following new row at the end of Table 29:

Table 29—Frame length values

Frame length values	Payload
9 to *aMaxSUNPHYPacketSize*	MPDU (SUN PHY)

Insert the following new subclauses <decide where to add them after the structure is known>:

6.3.3a <placeholder for mode switching fields to be shown in Table 26b>

TBD

6.3.4 PSDU field

Insert the following text at the end of 6.3.4:

If the Mode Switching subfield (Figure 27a) of the Frame Control field (Figure 26a) is set to one, the PSDU field shall not be included in the packet.

6.4 PHY constants and PIB attributes

6.4.1 PHY constants

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

Table 30—PHY constants

Constant	Description	Value
aMaxSUNPHYPacketSize	The maximum PSDU size (in octets) a SUN PHY shall be able to receive.	2047

6.4.2 PHY PIB attributes

Change Table 31 (the entire table is not shown) as indicated:

Insert the following new table (Table 31a) after Table 31:

6.5 2450 MHz PHY specifications

6.6 2450 MHz PHY chirp spread spectrum (CSS) PHY

6.7 868/915/950 MHz band binary phase-shift keying (BPSK) PHY specifications

6.8 780 MHz band (optional) O-QPSK PHY specifications

6.9 868/915 MHz band (optional) amplitude shift keying (ASK) PHY specifications

6.10 868/915 MHz band (optional) O-QPSK PHY specifications

6.11 950 MHz band Gaussian frequency-shift keying (GFSK) PHY specifications

6.12 UWB PHY specification

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

Table 31—PHY PIB attributes

Attribute	Identifier	Type	Range	Description
TBD				
phyScrambleSeed		Integer	0-0xffff	Seed for the data whitening algorithm.
phyScramblePSDU		Boolean	TRUE or FALSE	When FALSE, the PSDU shall not be scrambled. When TRUE, the PSDU shall be scrambled.
phyScramblePHR		Boolean	TRUE or FALSE	When FALSE, the PHR shall not be scrambled. When TRUE, the PHR shall be scrambled.
phyCurrentChannel	0x00	Integer	1–*phyMaxNumChannels*	The RF channel to use for all following transmissions and receptions (see 6.1.2).
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.
phyMaxNumChannels		Integer	Frequency band dependent	The number of channels supported by the frequency band currently in use for a transmission/reception.
phyMode			Implementation dependent	The PHY operating mode currently in use.
phyNumSets		Integer	1–TBD	The number of PHY Sets (i.e., PHY modes) supported by an MRFSK device.
phyCapabilitiesTable		List of CapabilitiesDescriptor entries (see Table 31a)	—	A table of CapabilitiesDescriptor entries, each containing the PHYSets supported by the device.

6.12a MRFSK PHY specification

6.12a.1 Data transfer

TBD

6.12a.2 Modulation and coding

The modulation choices provided by the MRFSK PHY are FSK and GFSK, and the modulation may be 2-level or 4-level. The generic PHY mechanism also allows other modulation schemes to be supported.

6.12a.2.1 Reference modulator diagram

TBD

Table 31a—Elements of CapabilitiesTable*

Attribute	Identifier	Type	Range	Description
phyType		Enumeration	FSK, GFSK, OFDM, DSSS	TBD
phyFSKModOrder		Enumeration	2-level FSK, 4-level FSK	TBD
phyFSKModIndex		Float	0.25–2.50	1-byte value with fixed divisor of 100, yielding values of 0.00 - 2.55. Resolution of 0.05.
phyFSKBT		Float	0.5, 1.0	TBD
phyDataRate		Integer	0x00000000–0xffffffff	1 bps resolution
phyChannelSpacing		Integer	0x00000000–0xffffffffff	1 Hz resolution
phyFirstChannelFreq		Integer	all bands	Specifies the center frequency, in Hz, of the first channel in the list. The resolution is 10 Hz.
phyNumChannels		Integer	1–65000	resolution is 1

*Note the format, range and resolution of the parameters in this table are still under consideration.

6.12a.2.2 Bit-to-symbol mapping

Each FSK symbol represents one data bit for 2-FSK and 2-GFSK, and two data bits for 4-FSK and 4-GFSK. For 2-FSK, the offset is toggled by the transmit data bit so that a positive offset is generated for a '1' and a negative offset is generated for a '0.'

6.12a.2.3 Forward error correction (FEC)

Support for forward error correction is optional. The details of the FEC algorithm are TBD.

6.12a.3 Data whitening

Data whitening is allowed, controlled by a number of PIB variables. The seeding of the data whitening algorithm is controlled by a PIB variable *phyScrambleSeed,* that allows the seed to be set and changed dynamically as needed. The scrambling of the PSDU is optional and controlled by a PIB variable *phyScramblePSDU* that allows PSDU scrambling to be turned on or off. The scrambling of the PHR is optional and controlled by a PIB variable *phyScramblePHR* that allows the scrambling of the PHR to be turned on or off.

6.12a.4 Frequency hopping modes (optional)

TBD

6.12a.5 Packet timestamping

TBD

6.12a.6 Radio specification

TBD

6.12b OFDM PHY specification

6.12c SUN DSSS specification

6.13 General radio specifications

TBD

6.13.1 TX-to-RX turnaround time

TBD

6.13.2 RX-to-TX turnaround time

TBD

6.13.3 Error-vector magnitude (EVM) definition

TBD

6.13.4 Transmit center frequency tolerance

TBD

6.13.5 Transmit power

TBD

6.13.6 Receiver maximum input level of desired signal

6.13.7 Receiver ED

6.13.8 Link quality indicator (LQI)

6.13.9 Clear channel assessment (CCA)

6.13.9a Channel to channel slew times (per band) (max)

6.13.9b Transmit and power amplifier rise and fall times (max)