Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Comment Resolution LB-95

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Abstract: Comment Resolution

Purpose: Comment Resolution for comments collected from LB-95

Summary:

All resolutions in this document are discussed and approved by the BRC in the San Antonio meeting (November 2014) and subsequent BRC conference calls.

Addressed Comment IDs in this document:

1014 – slide 3
1017 – slide 4
1047 – slide 5 – 6
1151 – slide 7 – 12
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1172 – slide 21 – 22
1174 – slide 23 – 25
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1176 – slide 27
1177 – slide 28
1178 – slide 29 – 30
1188 – slide 31 – 33
1194 – slide 29 – 30
1197 – slide 34
1238 – slide 35

Comment ID: 1014

Comment: The draft does not meet the 5C requirement of uniqueness. There are already 6 FSK PHYs defined in 802.15.4, with data rates ranging from 2.4 kb/s to 400 kb/s operating in all of the bands already identified for the proposed ULP PHY. There is nothing in the current definition of the ULP FSK PHY that enables it to be lower power than the existing FSK PHYs.

Proposed change: Delete Clause 31 and references to the ULP FSK PHY.

Resolution: Rejected. The PAR states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. The highest FSK data rate currently defined in 802.15.4 is 400kb/s which is only specified for Japan. The highest rate in other bands is only 200kb/s. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves saves.

Comment ID: 1017

Comment: Nothing in the draft standard supports the assertion that the ULP-TASK or ULP-GFSK PHY supports the PAR goal that the PHY power consumption is < 15 mW. As defined - power consumption is a silicon or application implementation and thus out of scope. There already exists a low energy 802.15.4 MAC and PHY amendment (802.15.4k). In addition since silicon vendors have already produced or demonstrated silicon that meets the power consumption figure quoted in the PAR as justification for the standard with EXISTING 15.4 PHY modes, this proposed standard is superfluous

Proposed change: Justify standard

Resolution: Rejected. As correctly stated in this comment, the proposed PHYs meet the peak power requirement as stated in the PAR. Besides the peak power requirement the PAR also states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. The highest FSK data rate currently defined in 802.15.4 is 400kb/s which is only specified for Japan. The highest rate in other bands is only 200kb/s. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves energy.

Comment ID: 1047 – slide 1 of 2

Comment: "The Rate Switch field shall be set to one if rate switch mode, as described in 31.3, is supported and shall be set to zero otherwise." Subclause 31.3 reads, in its entirety -- and I am not making this up -- "An ULP GFSK device shall support the Rate Switch field set to zero. Support for the Rate Switch field set to one is optional." Where is the description of the rate switch mode I was promised?

Proposed change: Please provide a description of the rate switch mode. What does it do? When? To what?

Comment ID: 1047 – slide 2 of 2

Resolution: Accept in principle. Replace line 25 & 26 on page 32 and line 9 and 10 on page 33 with: "The Rate Switch field indicates if Rate Switch is enabled or disabled. The Rate Switch field shall be set to one when enabled and shall be set to zero otherwise."

Correct reference on page 32 line 27 to 31.3 instead of 31.2.

Replace text in sub clause 31.3 by "Enabling Rate Switch is optional. When Rate Switch is enabled the SHR and the PHR shall be transmitted in any 2-GFSK MCS with modulation index 0.72 and the PSDU shall be transmitted using the same symbol rate as is used during SHR and PHR employing 4-GFSK with modulation index 0.24. When Rate Switch is disabled then a single MCS is used during the transmission of the PPDU. The Rate Switch may be enabled from a higher layer using the *macRateSwitchEnabled* MAC PIB attribute. For example, when the Energy Detect level is crossing a threshold." Add **two** MAC PIB attribute:

Attribute	Type	Range	Description	Default
macRateSwitchEnabled	Boolean	TRUE, FALSE	An indication of whether the device is using a Rate Switch in its transmission as described in 31.3. If TRUE, the device is using Rate Switching. If FALSE, it is not.	FALSE
macShortPHREnabled	Boolean	TRUE, FALSE	An indication of whether the device is using a Short PHR in its transmission as described in 31.1.4. If TRUE, the device is using a Short PHR. If FALSE, it is using a Long PHR.	FALSE

Comment ID: 1151 & 1171, slide 1 of 6

Comment ID: 1151

Comment: Without loss of generality the following for the 863-876 and 915-921 bands:

1st Channel Center Freq.: 863.25, 915.35

Number of Channels: 63, 27 Channel Spacing: 200,000, 200,000

Modulation Scheme: GFSK, GFSK FSK Mod. Order: 2, 2

FSK Mod. Index: 0.7, 0.7 FSK BT: 0.5, 0.5 Symbol Rate: 100,000, 100,000

provide nearly the same number of channels while providing/allowing for an an improvement in nearly all receiver performance parameters.

Proposed change: Consider these changes for the 863-876, 915-921 and apply similarly for all other bands.

Resolution: AiP

Comment ID: 1151 & 1171 – slide 2 of 6

Lowering the mod-index from 1 to 0.7 as suggested in Comment ID 1151 increases the Euclidean distance → lowers Eb/No in receiver → increases link budget. See figure below:

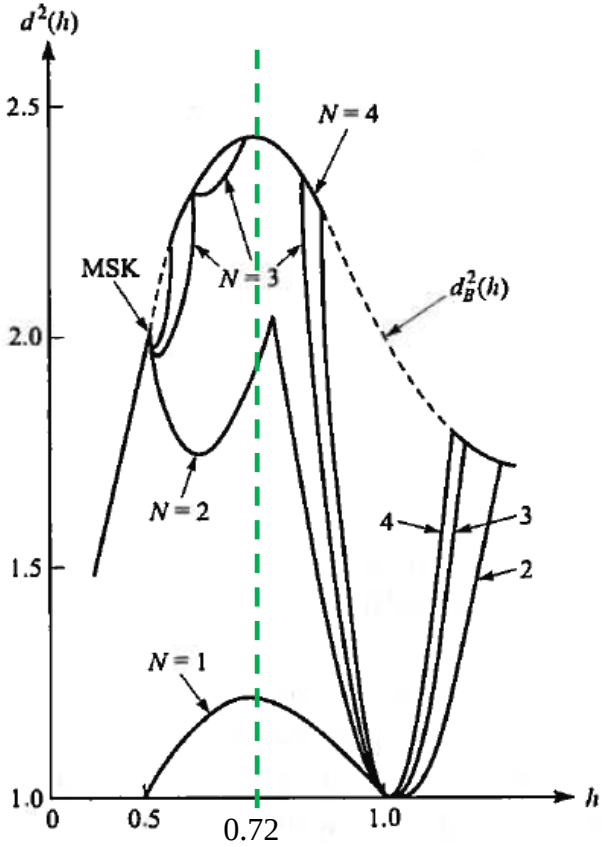


FIGURE 5.3–6
Squared minimum Euclidean distance as a function of the modulation index for binary CPFSK. The upper bound is d_B^2. [*From Aulin and Sundberg (1981), © 1981 IEEE.*]

Graph from: John G. Proakis, Digital Communications, Fourth edition, page 290

Comment ID: 1151 & 1171, slide 3 of 6

Comment ID: 1171

Comment: A MCS should be added to Table 21 to support FCC digital modulation according to FCC part 15 clause 247. This provides an option to increase the RF transmit power without frequency hopping.

Proposed change: Add MCS with identifier 9: Data Rate = 500kbps, Channel spacing = 1MHz, modulation index = 0.75. This results in a flat spectrum suitable to meet the FCC requirements for wideband digital modulation. Also add identifier 9 in Table 23 in the 915 and 2450 MHz rows.

Resolution: AiP.

Comment ID: 1151 & 1171, slide 4 of 6

Comment ID: 1171 – slide 2 of 3

Excerpts from FCC Part 15-247:

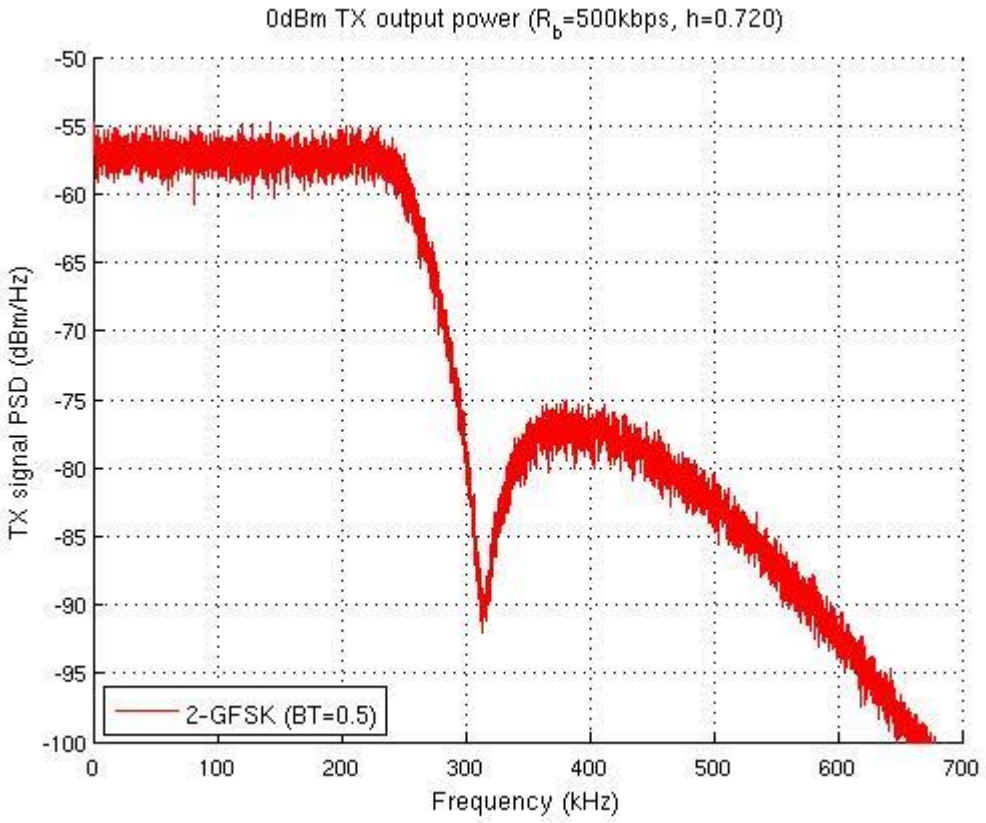
(2) Systems using digital modulation techniques may operate in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

(e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

Comment ID: 1151 & 1171 – slide 5 of 6

Modulation parameters:

- Data Rate = 500kbps, BT= 0.5, Channel spacing = 1MHz, mod-index = 0.72.
- Spectrum optimally flat at mod-index = 0.72:



Comment ID: 1151 & 1171 – slide 6 of 6

Resolution: (1151, 1171 and 1003): replace 400/800kbps with 500/1000kbps and reduce mod-index of MCS 0, 1, 2, 3, 4, 0a, 1a, 2a, 3a and 4a by 28%

- Edit table 21 (changes in green) :

ULP GFSK MCS Identifier	Data Rate [kbps]	Channel Spacing [kHz]	Modulation index
0	4.8	12.5	**0.72**
1	9.6	25	**0.72**
2	50	200	**0.72**
3	150	400	**0.72**
4	**500**	1000	**0.72**
5	250	500	0.5
6	500	1000	0.5
7	1000	2000	0.5

- Edit table 22 (changes in green):

ULP GFSK Operating Mode Identifier	Data Rate [kbps]	Channel Spacing [kHz]	Modulation index
0a	9.6	12.5	**0.24**
1a	19.2	25	**0.24**
2a	100	200	**0.24**
3a	300	400	**0.24**
4a	**1000**	1000	**0.24**

- Add sentence below table 22: "MCS 4 may be used for wideband digital modulation according to FCC part 15.247 which allows for transmit power in excess of -1.23 dBm without requiring frequency hopping"
- Note: MCS numbers are changed according to the resolution of comment ID 1003.

Comment ID: 1154

Comment: What is different about the FSK mode defiend in this amendment, that provides for substantially lower power over that of plethora of FSK modes already defined in 802.15.4?

Proposed change: While the PAR stated 15mA as the upper limit, given that implmentations have already been doing that for a number of years and newer ones are in the 6-8mA, once would expect the draft seek to be in the <1.5mA range to make it compeling. The PHY's defined here do not seem to support these expected levels. Rework these PHYs to achieve/promote more aggressive power levels.

Resolution: Rejected. The PAR does not state 15mA as the upper limit. The PAR states: "The desired peak power consumption for the PHY should be typically less than 15 mW." Also this is only a part of the scope. It also states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves energy.

Comment ID: 1162 & 1163, slide 1 of 2

Comment ID: 1162

Comment: SFD for uncoded is the same SFD as in MR-FSK for coded. Also SFD for coded is the same as in MR-FSK for uncoded.

Proposed change: Reverse uncoded/coded SFDs in table 20.

Comment ID: 1163

Comment: There may be a coexistence issue when the same SFDs are used between a MR-FSK PAN and a ULP-GFSK PAN. Especially when FEC is enabled since the MR-FSK and ULP-GFSK have different convolutional codes.

Proposed change: Add set of SFDs to fix coexistence issue in case that interop with MR-FSK is not desired. Suggested additional SFD option: Uncoded: 1001 1010 1111 0000. Coded: 0011 0101 1100 0110.

Comment ID: 1162 & 1163, slide 2 of 2

Resolution: Accept in Principle. Replace table in sub clause 31.1.2.

	SFD for coded (b_0-b_{15})	SFD for un-coded (b_0-b_{15})
phyULPGFSKSFD = 0	0110 1111 0100 1110	1001 0000 0100 1110
phyULPGFSKSFD = 1	0011 0101 1100 0110	1001 1010 1111 0000

Add sentence after the first paragraph in sub clause 31.1.2: "If interoperation with MR-FSK PHY is desired a value of zero for the PIB attribute *phyULPGFSKSFD* may be used. If interoperation with MR-FSK PHY is not desired a value of one for the PIB attribute *phyULPGFSKSFD* may be used.

Attribute: *phyULPGFSKSFD*

Type: Integer

Valid range: 0.1

Description: "Determines which group of SFDs is used, as described in Table xx. This attribute is only valid for the ULP-GFSK PHY."

Comment ID: 1164

Comment: Value definition of reserved Bit 0 in the PHR is missing.

Proposed change: Add text in sub clause 31.1.3: “Bit 0 in the Long PHR shall be set to "0". When a SFD is used that is shared with MR-FSK, bit 0 in the PHR won't trigger a Mode Switch in a MR-FSK device.”

Resolution : Accepted. Add text in sub clause 31.1.3, below Figure 19: "Bit 0 in the Long PHR shall be set to zero when transmitted. When a ULP device is transmitting an SFD that is the same as used in a MR-FSK network, Bit 0 in the PHR won't trigger a Mode Switch in a MR-FSK receiver."

Comment ID: 1165

Comment: The value of the reserved bit at bit location 4 needs definition.

Proposed change: The reserved bit at bit location 4 shall be set to "0".

Resolution : Accepted in principle: Add text before last paragraph (page 33, above line 4) in sub-clause 31.1.3: “The reserved bit at Bit 4 shall be set to one.”

Comment ID: 1166

Comment: Bit 0 in the PHR should always be set to "0" when a SFD is used that is shared with MR-FSK so that it won't trigger a Mode Switch in a MR-FSK device.

Proposed change: Add text in sub clause 31.1.4: “Bit 0 in the Short PHR shall be set to "0".”

Resolution : Accepted in Principle: Add text in sub clause 31.1.4 (page 33, above line 9): “Bit 0 in the Short PHR shall be set to zero”

Comment ID: 1167

Comment: HL mode may result in false interpretation of the frame control field at the receiver side. E.g. the receiver will need the source address of header-less frame to decide if Rate-Switch should be enabled. So every time a HL-SFD is received the receiving device will need to evaluate the frame control field for a valid address assuming Rate Switch enabled AND Rate Switch disabled. This leads to an ambiguity which may lead to frame corruption. E.g. when frames are received with and without Rate Switch, from many end nodes, the receiver may find two valid addresses: one with Rate Switching assumed and one with assumed without Rate Switching.

Proposed change: Remove headerless and the entire sub clause 31.1.5.

Resolution : Accepted: Remove sub clause 31.1.5 and all references to headerless (HL)

Comment ID: 1168

Comment: When HL SFD is received the use of FEC is not specified.

Proposed change: Remove headerless and the entire sub clause 31.1.5.

Resolution: Accepted: Remove sub clause 31.1.5 and all references to headerless (HL)

Comment ID: 1169 and 1172 – slide 1 of 2

Comment ID: 1169

Comment: This wording is unclear: "The PSDU may be transmitted using either 2-GFSK or 4-GFSK modulation, i.e. one of the operating modes in Table 21 or Table 22 with the same symbol rate used during transmission of the SHR and PHR."

Proposed change: Suggested text: "The MCS shall be such that the symbol rate and the outer deviation are the same across the PPDU. When the Rate Switch bit is set to "1" the PSDU shall be transmitted in 4-GFSK (i.e. one of the operating modes in Table 22) . When the Rate Switch bit is set to "0" the PSDU shall be transmitted in 2-GFSK.

Comment ID: 1172

Comment: Symbol rate is not defined.

Proposed change: In 2-GFSK mode the symbol rate is equal to the bit rate. In 4-GFSK mode the symbol rate is equal to the bit rate divided by 2.

Comment ID: 1169 and 1172 – slide 2 of 2

Resolution: Accepted in principle: Replace wording with: “The MCS shall be such that the symbol rate and the outer levels are the same across the entire PPDU. When the Rate Switch bit is set to "1" the PSDU shall be transmitted in 4-GFSK. When the Rate Switch bit is set to "0" the PSDU shall be transmitted in 2-GFSK. In 2-GFSK modulation the outer level is equal to the modulation index multiplied by the symbol rate divided by 2. In 4-GFSK modulation the outer level is equal to the modulation index multiplied by the symbol rate multiplied by 1.5. In 2-GFSK mode the symbol rate is equal to the data rate. In 4-GFSK mode the symbol rate is equal to the data rate divided by 2.”

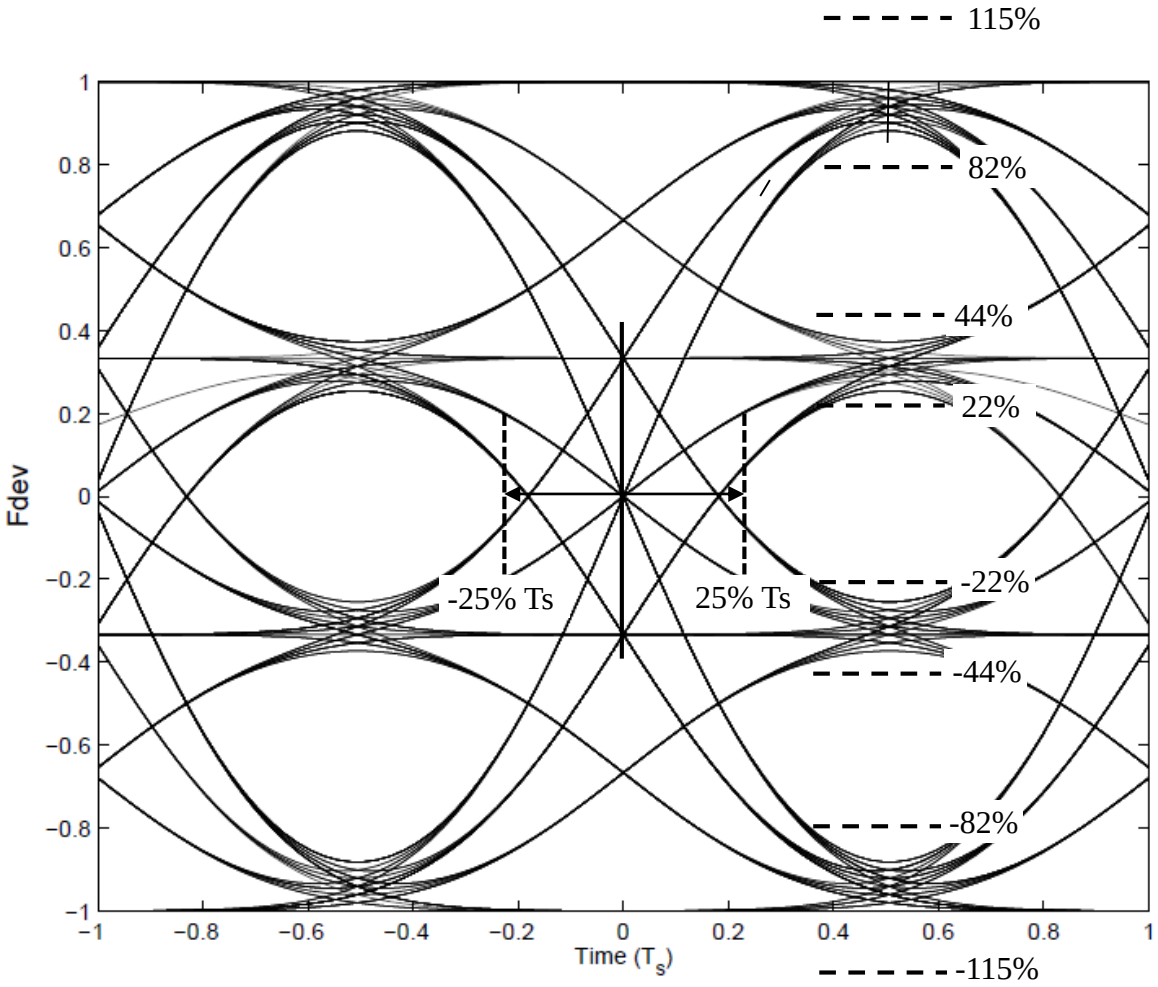
Comment ID: 1174 – slide 1 of 3

Comment: The frequency deviation tolerances are too course. Will degrade the receive sensitivity.

Proposed change: Reduce the deviation tolerance.

Comment ID: 1174 – slide 2 of 3

Resolution : Accepted in principle. Add new figure below to sub clause 31.2.5. with title: “Eye diagram of 4GFSK modulation”



Comment ID: 1174 – slide 3 of 3

Replace sentence "The frequency deviation tolerance shall be as given in 18.1.2.3.1" by "The frequency deviation tolerance for 2-GFSK shall be as given in 18.1.2.3.1. The frequency deviation tolerance for 4-GFSK shall be as given in Figure xx"

Comment ID: 1175

Comment: The symbol timing accuracy should not be less than clock frequency tolerance in the transmitter as specified in sub clause 31.4.1. because it may lead to high implementation costs without any benefit.

Proposed change: Change max symbol timing accuracy to 30ppm.

Resolution: Accepted in principle: replace “The symbol timing accuracy shall be better than ± 20 ppm” by “The symbol timing accuracy shall be the same or better than the radio frequency tolerance as specified in sub clause 31.4.1”

Comment ID: 1176

Comment: FEC does not make much sense when Rate Switch is enabled because the 4GFSK mode will reduce the receive sensitivity while FEC is intended to increase the link budget.

Proposed change: The Rate Switch bit in the PHR shall be set to "0" when FEC is enabled.

Resolution: Accepted in principle. Add text to sub-clause 31.3 (grey font shows resolution text of comment ID-1047 "Rate Switch is optional. When Rate Switch is enabled the SHR and the PHR shall be transmitted in any 2-GFSK MCS with modulation index 1 and the PSDU shall be transmitted using the same symbol rate as is used during SHR and PHR employing 4-GFSK with modulation index 0.333. When Rate Switch is disabled then a single MCS is used during the transmission of the PPDU. The Rate Switch may be enabled from a higher layer, e.g. when the Energy Detect level is crossing a threshold. The Rate Switch shall be disabled when FEC is used."

Comment ID: 1177

Comment: FEC in combination with Short Header will reduce the traceback length to 5 bits which inhibits full coding gain.

Proposed change: The Short Header bit in the PHR shall be set to "0" when FEC is enabled.

Resolution: Accepted in principle. Add text on page 33, line 12, after "The Short PHR field shall be set to one to indicate the use of the short PHR." → "The Short Header shall not be used when FEC is used."

Comment ID: 1178 & 1194 – slide 1 of 2

Comment ID: 1178

Comment: Turnaround time should be a function of the symbol rate because the propagation delay in the Gaussian filter (TX) and the channel filter (RX) are proportional to the symbol rate.

Proposed change: Minimum channel switch time shall be 5xTs + 120us

Comment ID: 1194

Comment: Channel switch time consumes energy, reducing this time saves energy

Proposed change: change 500 µs to 200µs

Comment ID: 1178 & 1194 – slide 2 of 2

Resolution: Accepted in principle: Turnaround time should be a function of the symbol rate because the propagation delay in the Gaussian filter (TX) and the channel filter (RX) are proportional to the symbol rate. A fixed time component is required to allow circuits, like frequency synthesizer, to transition from RX to TX and vice versa.

Add a new sentence right under the title: "The TX-to-RX turnaround time is described in Table 178."

Replace text in sub-clause 31.4.5 by an instruction for the 15.4 editor “Add description in Table 178 (P802.15.4-REVc-DF2) in value column at the “aTurnaroundTime” row: “For the ULP-GFSK PHY, the value is 5xTs + 120 us expressed in modulation symbol periods, rounded up to the next integer number of symbol periods using the ceiling function.””

Comment ID: 1188 – slide 1 of 3

Comment (part-1): The IEEE 802.15.4q PAR paragraph 5.5 states "5.5 Need for the Project: Emerging applications in sensor networks demand increasingly small form factor, low power consumption and low cost solutions. From a power consumption perspective, this amendment addresses solutions making it possible to achieve a battery life of several years when connected to coin cell batteries and/or making it possible to use harvested energy sources while meeting the targeted data rates and continuing to support the small form factor, low cost attributes of 802.15.4.' Thus how does the 802.15.4q PAR substancially differ from the IEEE 802.15.4f PAR where paragraph 5.5 states "...Active RFID tags require the ability to provide bi-directional communications as well as ranging, and congestion control for high density reads using ultra-low power. There are no international standards that meet this capability and moreover, EPCglobal has specifically identified 802.15.4 as one clear possible air interface protocol for active RFID tags that may meet active RFID tag requirements.

Comment ID: 1188 – slide 2 of 3

Comment (part-2): There is considerable demand for a globally available standard that includes, but is not limited to, the identified requirements:

- Ultra-low energy consumption (low duty cycle), Low PHY transmitter power,...Accurate location determination capability..." Examples, the GuardRFID IEEE 802.15.4f 433 MHz MSK PHY provides a 3-year zero maintenence lifetime http://guardrfid.com/guardrfid-and-omni-id-demonstrate-interoperability-between-their-products-based-on-the-ieee-802-15-4f-2012-standard/ while the Zebra 802.15.4f Low Rate PRF UWB PHY provides a long tag battery life - Up to 7 years of battery life https://www.zebra.com/content/dam/zebra/product-information/en-us/brochures-datasheets/location-solutions/dartuwb-tech-datasheet-en-us.pdf .
- **Proposed change:** Make the appropriate changes to the 802.15.4q PAR to substancially differenctiate it from the IEEE 802.15.4f PAR to resolve this issue or proceed no further with the 802.15.4q draft standard.

Comment ID: 1188 –slide 3 of 3

Resolution: Rejected: The highest data rate supported by the MSK PHY is 250kbps. A ULP-GFSK frame can be transmitted in a quarter of the time compared to the MSK PHY using the highest available rate. The LRP UWB PHY is not suitable for Ultra Low Power since the zero symbols (the off part of the OOK) do not contribute to the Eb/No at the receiver side. During transmission of zero symbols most transmitter and receiver functions still consume power which make OOK inferior w.r.t. energy efficiency compared to FSK. Furthermore, when considering sub-GHz, the MSK PHY and the LRP UWB PHY are only specified for usage in the 433 MHz band.

Comment ID: 1197

Comment: There are many FSK PHYs specified in 802.15.4, this PHY does not distinguish itself from the others as far as power/energy consumption

Proposed change: delete 31

Resolution: Rejected. The PAR states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. The highest FSK data rate currently defined in 802.15.4 is 400kb/s which is only specified for Japan. The highest rate in other bands is only 200kb/s. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves energy.

Comment ID: 1238

Comment: The draft does not meet the 5C requirement of distinct identity. There are already 6 FSK PHYs defined in 802.15.4, with data rates ranging from 2.4 kb/s to 400 kb/s operating in all of the bands already identified for the proposed ULP PHY. There is nothing in the current definition of the ULP FSK PHY that enables it to be lower power than the existing FSK PHYs.

Proposed change: Delete Clause 31 and references to the ULP FSK PHY.

Resolution: Rejected. The PAR states: "This amendment defines an ultra low power (ULP) physical layer .... supporting typical data rates up to 1 Mbps." The ULP-GFSK PHY is supporting rates up to 1Mbps, no other FSK PHY in 15.4 supports this. The highest FSK data rate currently defined in 802.15.4 is 400kb/s which is only specified for Japan. The highest rate in other bands is only 200kb/s. Using the higher data rates as specified in the ULP-GFSK PHY drastically reduces the on-time which conserves energy.