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

Submission Title: Higher Order APSK Constellations Implementation - Required Edits
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Re: Enhancements to the Physical Layer of IEEE 802.15.3d for Increased Data Rate and Coexistence/0125-01

Abstract: The necessary edits and discussion points are highlighted in order to implement higher order APSKs to the SC PHY mode of IEEE 802.15.3d.

Purpose: For discussion and consideration to edit IEEE 802.15.3d Standard

IEEE P802.15.3ma Proposal Follow-up:
Higher Order APSK Constellations
Implementation – Required Edits

In-Line Edits

4.5b.1 THz PHY characteristics

Currently in Standard

The THz-SC PHY is designed for extremely high PHY-SAP payload data rates up to 100 Gb/s, depending on the combination of modulation, bandwidth, and coding used. The THz-SC PHY supports a wide range of modulations: $\pi/2$ BPSK, $\pi/2$ QPSK, $\pi/2$ 8-PSK, $\pi/2$ 8-APSK, 16-QAM, and 64-QAM. The FEC consists of two low-density parity-check (LDPC) codes with rates of 14/15 and 11/15.

The THz-OOK PHY is designed for cost effective DEVs that require low complexity and simple design. The THz-OOK PHY supports a single modulation scheme, OOK, and three FEC schemes. The Reed Solomon (RS) code is mandatory and allows simple decoding without soft decision information. The LDPC codes with rates of 14/15 and 11/15 are optional and allow the use of soft-decision information.

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Proposed Edit

The THz-SC PHY supports a wide range of modulations: $\pi/2$ BPSK, $\pi/2$ QPSK, $\pi/2$ 8-PSK, $\pi/2$ 8-APSK, 16-APSK, 32-APSK, 16-QAM, and 64-QAM…

In-Line Edits

6.4.11d THz PRC Capability IE

Currently in Standard

Table 6-17h—SC Supported Modulations field format

Bit	Description
0	π/2 8-PSK
1	π/2 8-APSK
2	16-QAM
3	64-QAM

Proposed Edit

Have to include 16-APSK and 32-APSK

Decision for Discussion:

- **We could add two additional bits**
  - **There are the same 2 reserved bits later in the field (b28 & b29). (Is this what they were reserved for?)**
- **Make it mandatory to support the 8-PSK modulation (only solves half the problem)**
- **Other ideas…?**

In-Line Edits

6.4.11f THz Pairnet Operation parameter IE

Currently in Standard

Figure 6-87o—PRC Capability field format

Bits: b16	b17	b18	b19	b20	b21	b22	b23
Preferred Payload Size		Preferred Total Aggregation Size			Supported Unit of Subframe Padding		Pilot Symbol Capable

Bits: b24	b25	b26	b27	b28	b29	b30	b31
SC Supported Modulations				Reserved	Reserved	OOK Supported FEC	

Proposed Edit

Have to include 16-APSK and 32-APSK

Decision for Discussion (same as before):
- **We could add two additional bits**
  - **There are the same 2 reserved bits later in the field (b28 & b29). (Is this what they were reserved for?)**
- **Make it mandatory to support the 8-PSK modulation (only solves half the problem)**
- **Other ideas…?**

In-Line Edits

6.4.11e THz PRDEV Capability IE

Currently in Standard

Figure 6-87r—Operation Parameters field format

Bits: b0	b1	b2	b3	b4	b5	b6	b7
PHY Mode		Supported SIFS					Multi-protocol Support

Bits: b8	b9	b10	b11	b12	b13	b14	b15
Reserved							

Bits: b16	b17	b18	b19	b20	b21	b22	b23
Preferred Payload Size		Preferred Total Aggregation Size			Reserved		Reserved

Bits: b24	b25	b26	b27	b28	b29	b30	b31
SC Supported Modulations				Reserved	Reserved	OOK Supported FEC	

Bits: b32	b33	b34	b35	b36	b37	b38	b39
				andwidths			

Proposed Edit

Have to include 16-APSK and 32-APSK

Similar issues here as well…
- **Can we use b8-15, b21-b22, or b28-29 now?**

In-Line Edits

6.4.11f THz Pairnet Operation Parameter IE

Currently in Standard

The SC Supported Modulations field is defined in 6.4.11d. Each bit in this field shall be set to one if both of the bits in the SC Supported MCS fields in the PRC Capability IE and the PRDEV Capability IE are set to one and shall be set to zero otherwise.

Proposed Edit

Depends on decisions from slides 4 - 6

In-Line Edits

13.2.2.1 Modulation

Currently in Standard

The constellation diagram of $\pi/2$ 8-APSK is shown in Figure 13-3. The $\pi/2$ 8-APSK shall encode 3 bits per symbol, with input bit d_1 being the earliest in the stream. The $\pi/2$-rotation is performed in the same manner as in 11.2.2.5.1.

The normalization factors for $\pi/2$ QPSK, $\pi/2$ 8-PSK, $\pi/2$ 8-APSK, 16-QAM, and 64-QAM are 1, 1, $\sqrt{2}/\sqrt{11}$, $1/(\sqrt{10})$, and $1/\sqrt{42}$, respectively. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization can be used as long as the DEV conforms to the modulation accuracy requirements described in 13.2.4.1.

All modulation schemes are used for payload, and $\pi/2$ BPSK is also used for preamble and header sequences. The modulations of $\pi/2$ BPSK and $\pi/2$ QPSK are mandatory for THz-SC PHY; other modulations are optional.

Proposed Edit

The constellation diagrams of $\pi/2$ 8-APSK, 16-APSK, and 32-APSK are shown in Figure 13-3, Figure 13-4, and 13-5 respectively.

The normalization factors for $\pi/2$ QPSK, $\pi/2$ 8-PSK, $\pi/2$ 8-APSK, 16-APSK, 32-APSK, 16-QAM 64-QAM are 1, 1, $\sqrt{2}/\sqrt{11}$, _____ , _____ , $1/\sqrt{10}$, and $1/\sqrt{42}$ respectively.

Questions for the Group:
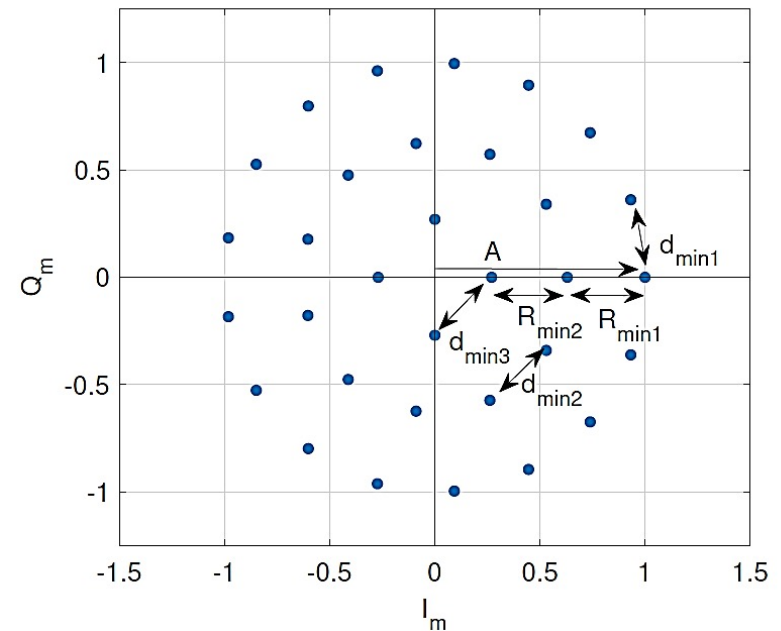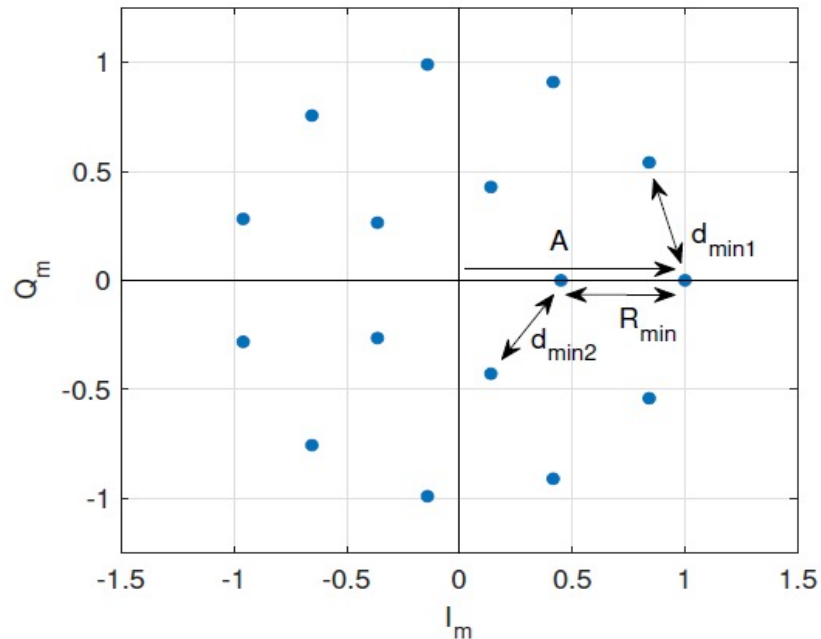**Why do you specify 3 bits per symbol? What do you mean by the input bit d1? Also are the parenthesis around sqrt(10) intentional?**

Insert Figures

13.2.2.1 Modulation

Insert Figures 12-4 and 13-5

Questions for the Group:
- **Would we like to standardize the 3-ring or the 2-ring 32-APSK or both? (I think 3-ring to help with phase noise, but we can also see how the simulations perform)**

In-Line Edits

13.2.2.1 Modulation

Table 13-4—MCS dependent parameters for the THz-SC PHY

Currently in Standard

MCS identifier	Modulation	FEC rate	Bandwidth 2.16 GHz Data rate (Gb/s)		Bandwidth 4.32 GHz Data rate (Gb/s)		Bandwidth 8.64 GHz Data rate (Gb/s)		Bandwidth 12.96 GHz Data rate (Gb/s)		Bandwidth 17.28 GHz Data rate (Gb/s)		Bandwidth 25.92 GHz Data rate (Gb/s)		Bandwidth 51.84 GHz Data rate (Gb/s)		Bandwidth 69.12 GHz Data rate (Gb/s)	
			with out PW	with PW	with out PW	with PW	with out PW	with PW	with out PW	with PW	with out PW	with PW	with out PW	with PW	with out PW	with PW	with out PW	with PW
0	BPSK	11/15	1.29	1.13	2.58	2.26	5.16	4.52	7.74	6.78	10.33	9.04	15.49	13.55	30.98	27.11	41.30	36.14
1	BPSK	14/15	1.64	1.44	3.29	2.87	6.57	5.75	9.86	8.62	13.14	11.50	19.71	17.25	39.42	34.50	52.56	45.99
2	QPSK	11/15	2.58	2.26	5.16	4.52	10.33	9.03	15.49	13.55	20.65	18.07	30.98	27.10	61.95	54.21	82.60	72.28
3	QPSK	14/15	3.29	2.87	6.57	5.75	13.14	11.50	19.71	17.25	26.28	23.00	39.42	34.50	78.85	68.99	105.13	91.99
4	8-PSK	11/15	3.87	3.39	7.74	6.78	15.49	13.55	23.23	20.33	30.98	27.11	46.47	40.66	92.93	81.32	123.91	108.42
5	8-PSK	14/15	4.93	4.31	9.86	8.62	19.71	17.25	29.57	25.87	39.42	34.50	59.13	51.74	118.27	103.49	157.69	137.98
6	8-APSK	11/15	3.87	3.39	7.74	6.78	15.49	13.55	23.23	20.33	30.98	27.11	46.47	40.66	92.93	81.32	123.91	108.42
7	8-APSK	14/15	4.93	4.31	9.86	8.62	19.71	17.25	29.57	25.87	39.42	34.50	59.13	51.74	118.27	103.49	157.69	137.98

IEEE Std 802.15.3d-2017 IEEE Standard for High Data Rate Wireless Multi-Media Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Phy

Questions for the Group:
How exactly are you calculating these data rates? Do you take the headers into account?
Where can I find Section 11a.2.3.22?

13.2.3. THz-SC PHY frame format

The PHY preamble is described in 13.2.3.1. The MAC header is defined in 6.2. The PHY header is defined in 13.2.3.2.1, and the header check sequence (HCS) is defined in 11a.2.3.2.2. The header FEC is defined in 11a.2.3.2.3. The PHY Payload field consisting of the MAC frame body, the pilot preamble (PPRE), and stuff bits is described in 13.2.3.3. The PPRE is described in 13.2.3.4.2. The stuff bits are described in 11a.2.2.7.

In-Line Edits

13.2.2.6 Frame Related Parameters

Currently in Standard

modulation schemes are 1, 2, 3, 3, 4, and 6 for BPSK, QPSK, 8-PSK, 8-APSK, 16-QAM and 64-QAM, respectively.

Table 13-7—MCS dependent coded bits per block for the THz-SC PHY

MCS identifier	N_{CBPB} (PW length = 0)	N_{CBPB} (PW length = 8)
0,1	64	56
2,3	128	112
4,5,6,7	192	168
8,9	256	224
10,11	384	336

Table 13-8—MCS field definition for the THz-SC PHY

MCS field value	MCS identifier
0b0000	0
0b0001	1
0b0010	2
0b0011	3
0b0100	4
0b0101	5

Questions for the Group:
Is there a reason we have two 3s and skip 5?

Proposed Edit

modulation schemes are 1, 2, 3, 4, 5, 6, 7, and 8 for BPSK, QPSK, 8-PSK, 8-APSK, 16-APSK, 32-APSK, 16-QAM, 64-QAM, respectively.

In-Line Edits

13.2.4.1 EVM Requirement

Currently in Standard

Table 13-10—Max EVM

MCS identifier	Modulation	FEC rate	Max. EVM (dB)
0	BPSK	11/15	−3
1	BPSK	14/15	−6
2	QPSK	11/15	−6
3	QPSK	14/15	−9
4	8-PSK	11/15	−11
5	8-PSK	14/15	−14
6	8-APSK	11/15	−11
7	8-APSK	14/15	−14
8	16-QAM	11/15	−13

Questions for the Group:
How do you calculate the maximum EVM?

Proposed Edit

Add the higher order APSKs

In-Line Edits

13.2.5.2 Receiver sensitivity

Currently in Standard

Table 13-11—Reference sensitivity levels for MCS for the THz-SC PHY

MCS identifier	Modulation	FEC rate	Receiver Sensitivity (dBm) depending on the bandwidth							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	BPSK	11/15	−67	−64	−61	−59	−58	−56	−53	−52
1	BPSK	14/15	−63	−60	−57	−55	−54	−52	−49	−48
2	QPSK	11/15	−64	−61	−58	−56	−55	−53	−50	−49
3	QPSK	14/15	−60	−57	−54	−52	−51	−49	−46	−45
4	8-PSK	11/15	−59	−56	−53	−51	−50	−48	−45	−44
5	8-PSK	14/15	−57	−54	−51	−49	−48	−46	−43	−42

Questions for the Group:
How do you calculate the receiver sensitivity?

Proposed Edit

Add the higher order APSKs