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

Submission Title: Higher Order APSK Constellations Implementation - Required Edits
Date Submitted: 04 May 2022
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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: π/2 BPSK, π/2 QPSK, π/2 8-PSK, π/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: π/2 BPSK, π/2 QPSK, π/2 8-PSK, π/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

2	16-APSK
3	32-APSK
4	16-QAM
5	64-QAM

Question: Is it important that the standard is backwards-compatible? It may make more sense to have the APSKs in bits 2 & 3 where the QAMs used to go.

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	

These reserved bits should be included in the SC Supported Modulations

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
Supported Bandwidths							

These reserved bits should be included in the SC Supported Modulations

In-Line Edits

13.2.2.1 Modulation

Currently in Standard

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

The normalization factors for π/2 QPSK, π/2 8-PSK, π/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 π/2 BPSK is also used for preamble and header sequences. The modulations of π/2 BPSK and π/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.

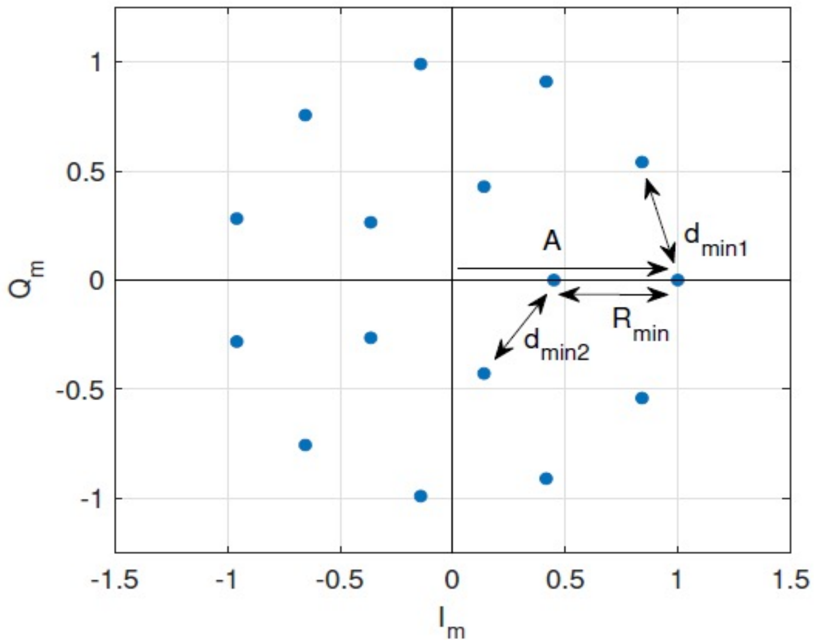
The normalization factors for $\pi/2$ QPSK, $\pi/2$ 8-PSK, $\pi/2$ 8-APSK, 16-APSK, 32-APSK, 16-QAM 64-QAM are 1, 1, $\sqrt{2}/\sqrt{11}$, ____ , _____ , $1/\sqrt{10}$, and $1/\sqrt{42}$ respectively.

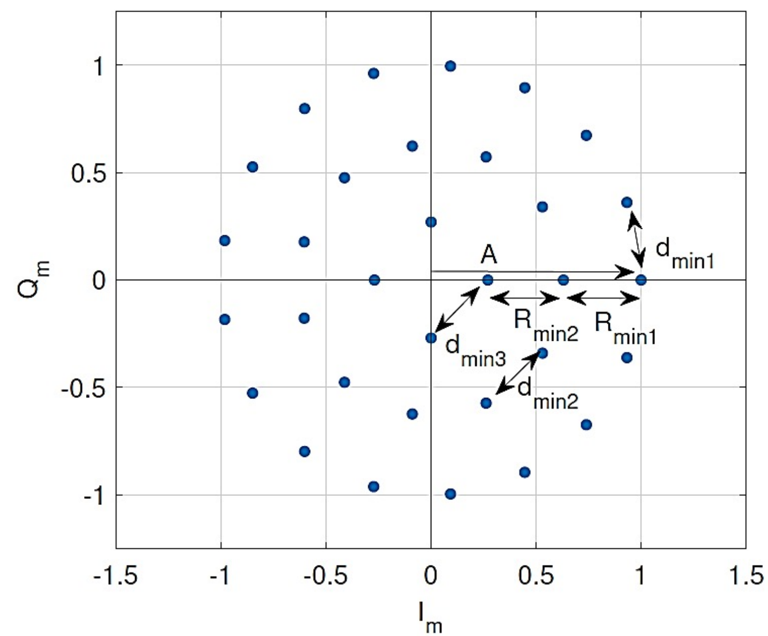
Questions for the Group:
Why do you specify 3 bits per symbol? What do you mean by the input bit d1? Also are the parenthesis around sqrt(10) intentional?

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? (3-ring may help with phase noise, but we can see how simulations perform)

In-Line Edits

13.2.2.1 Modulation

Currently in Standard

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

MCS identifier	Modulation	FEC rate	Bandwidth 2.16 GHz Data rate (Gb/s) without PW	Bandwidth 2.16 GHz Data rate (Gb/s) with PW	Bandwidth 4.32 GHz Data rate (Gb/s) without PW	Bandwidth 4.32 GHz Data rate (Gb/s) with PW	Bandwidth 8.64 GHz Data rate (Gb/s) without PW	Bandwidth 8.64 GHz Data rate (Gb/s) with PW	Bandwidth 12.96 GHz Data rate (Gb/s) without PW	Bandwidth 12.96 GHz Data rate (Gb/s) with PW	Bandwidth 17.28 GHz Data rate (Gb/s) without PW	Bandwidth 17.28 GHz Data rate (Gb/s) with PW	Bandwidth 25.92 GHz Data rate (Gb/s) without PW	Bandwidth 25.92 GHz Data rate (Gb/s) with PW	Bandwidth 51.84 GHz Data rate (Gb/s) without PW	Bandwidth 51.84 GHz Data rate (Gb/s) with PW	Bandwidth 69.12 GHz Data rate (Gb/s) without PW	Bandwidth 69.12 GHz Data rate (Gb/s) 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 Networks
Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Phys

These numbers may change in accordance with the next slide

Discussion Points:

Still unsure of how to calculate these values…

- We are unsure how long the headers are
- There seems to be quite a bit of variation in how long the payload can be for the frames

Is there a script that was used to create this chart? Or is there someone we could reach out to help us understand how they got these numbers?

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.

Proposed Edit

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

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
8,9,10	256	224
11	320	280
12,13	384	336

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

Discussion Points:
The MCS identifier numbers will change depending on what order we decide to list the modulation schemes and what/how many FEC rates we will support for the new APSKs.

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

Discussion Points:

Still unsure of how to calculate these values for the higher order APSKs…

Is the process to…

- Calculate the standard BER v. SNR
- Calculate the BER v. SNR curve considering the given FEC rate
- Find the SNR corresponding to BER $=10^{-12}$
- Calculate Max EVM based on this SNR

If not, how do you calculate these EVM values?

If so, how do you calculate the coding gain?

These are LDPC codes, correct? Do we know what the minimum distance is? Or is there a different way to find the coding gain?

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

Discussion Points:
Same as previous slide…