**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | Text input into D1 for Pulsed Modulation PHY | |
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| Abstract | [Proposal for pulsed modulation PHY in D1 of 802.15.13] | |
| Purpose | [Inform TG13 about most recent work.] | |
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1. **Pulsed Modulation PHY**

**1.1 PPDU format**

t.b.d.

**1.2 Transmission**

**1.2.1 Preamble**

**1.2.1.1 Synchronization sequence**

The synchronization preamble contains a sequence that is repeated N times. This

t.b.d.

**1.2.1.2 Channel estimation sequence**

t.b.d.

**1.2.2 Header**

t.b.d.

**1.2.2.1 General**



Figure 1 – Transmitter structure in Pulsed Modulation PHY

**1.2.2.2 Generation of HCS bits**

t.b.d.

**1.2.2.3 Header encoding and modulation**

The transmitter structure in Fig. 1 is used for the header. The header uses RS(36,24) code as defined below with 8B10B line code and OOK modulation defined in Appendix X.

**1.2.2.3.1 RS(36,24) code**

t.b.d.

**1.2.3 PHY payload**

**1.2.3.1 General**

The transmitter structure in Fig. 1 is used for the data. The payload uses RS(255,248) code with code rate 248/255 with 8B10B line code and OOK modulation defined in Appendix X.

**1.2.3.2 Scrambler**

t.b.d.

**1.2.3.3 Encoding**

Systematic RS codes are used for the PM PHY FEC with GF(256), generated by the polynomial *x*4*+x+*1. The codes rates may varied in fixed steps as follows (t.b.d.).

The generators for the RS(n, k) codes for PM PHY are described in Appendix X. The Reed-Solomon code may be shortened for the last block if it does not meet the block size requirements. No zero padding is required for the RS code. A shortened RS code is used for frame sizes not matching code word boundaries via the following operation to minimize padding overhead.

Using a RS(n,k) encoder, one can get an shortened RS(n-s, k-s) code as follows:

a) Pad the *k-s* input data symbols with *s* zero symbols.

b) Encode using RS(n, k) encoder.

c) Delete the padded zeros (do not transmit them).

d) At the decoder, add the zeros, then decode.

**1.2.3.4 Interleaver**

t.b.d.

**1.2.3.5 Line Encoder**

The line encoder uses 8B10 or Binary PPM. Note that, for maintaining a constant average light output, both the systematic output of the FEC ( bits) and the redundant part (*k*-*n* bits) should pass through the line encoder.

**1.2.3.5.1 8B10B**

The PM PHY mode shall use 8B10B encoding as specified in Appendix X following ANSI/INCITS 373. See also http://application-notes.digchip.com/056/56-39724.pdf

**1.2.3.5.2 Manchester encoding**

In case of binary PPM, Manchester encoding is used for DC balancing. The Manchester code expands each bit into an encoded 2-bit symbol as shown in Table 1. The output of the Manchester encoder in fed into a pulse-shaping filter in which the pulse width can be changed according to the dimming level.

Table 1 Manchester encoding

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**1.2.3.6 Pulse Amplitude Mapping**

The PAM mapper is using 2 or 4 levels. For 2 levels, each input bit is mapped in one symbol. The symbols are mapped to levels as {0, 1} to {0, 1}. With 4 levels, two consecutive bits are combined in a symbol. The symbols are mapped to levels as {00, 01, 10, 11} to {0, . , 1}.

**1.2.4 Visibility pattern**

*Descriptive part of Pulsed Modulation PHY*

b) Pulsed Modulation PHY: This PHY is intended for applications requiring moderate data rate from 1 Mbit/s up to few 100 Mbit/s. The main target here is to achieve higher data rates by increasing the optical clock rate. Also it includes techniques to adapt the data rate to varying channel conditions while using a constant optical clock rate. Therefore, it uses PAM modulation with variable line coding and code rates as defined in Table 107.

*Normative part*

**10 Pulsed Modulation PHY**

**10.1 Transmitter Structure**

**10.2 Forward Error Correction Encoder**

**10.3 Line Encoder**

**10.3.1 8B10B**

**10.3.1. Manchester encoding**

**10.4.1 PAM Mapper**

The PAM mapper is using 4-PAM only. It puts two consecutive bits into a symbol and maps them as {00, 01, 10, 11} to {0, . , 1}.

**10.4.3 HCM Mapper**

Hadamard Coded Modulation (HCM) is a bit to symbol mapper that is applied on the signal after OOK or PAM, and removes the need for line coding. In this block, as shown in Figure 180, a block of (where is a power of two) data symbols are inserted into a fast Walsh-Hadamard transform (FWHT). As described in [Ref A], the HCM signal is generated from the data sequence as , where is the binary Hadamard matrix of order [Ref B], and is the complement of . The components of are assumed to be -ary pulse amplitude modulated (PAM), where o for .

As shown in [Ref A], the DC part of HCM signals can be reduced without losing any information, making HCM more average power efficient. Let the first component of () be set to zero and only codewords of the Hadamard matrix be modulated, as proposed in [Ref A]. In this scheme, the average transmitted power is reduced by sending () instead of , An example of DC reduction is shown in Figure 181. The reduced DC level is per HCM symbol and its value can be different for each symbol. This makes the transmitted signals orthogonal to DC bias at a overhead cost on data-rate. The overhead for different ’s are listed in Table 145.

../../UVA%20-%20HCM%20(JSAC)/Main/HCM-TCOM/HCM-Transmitter.pdf

Figure 180. HCM encoder structure

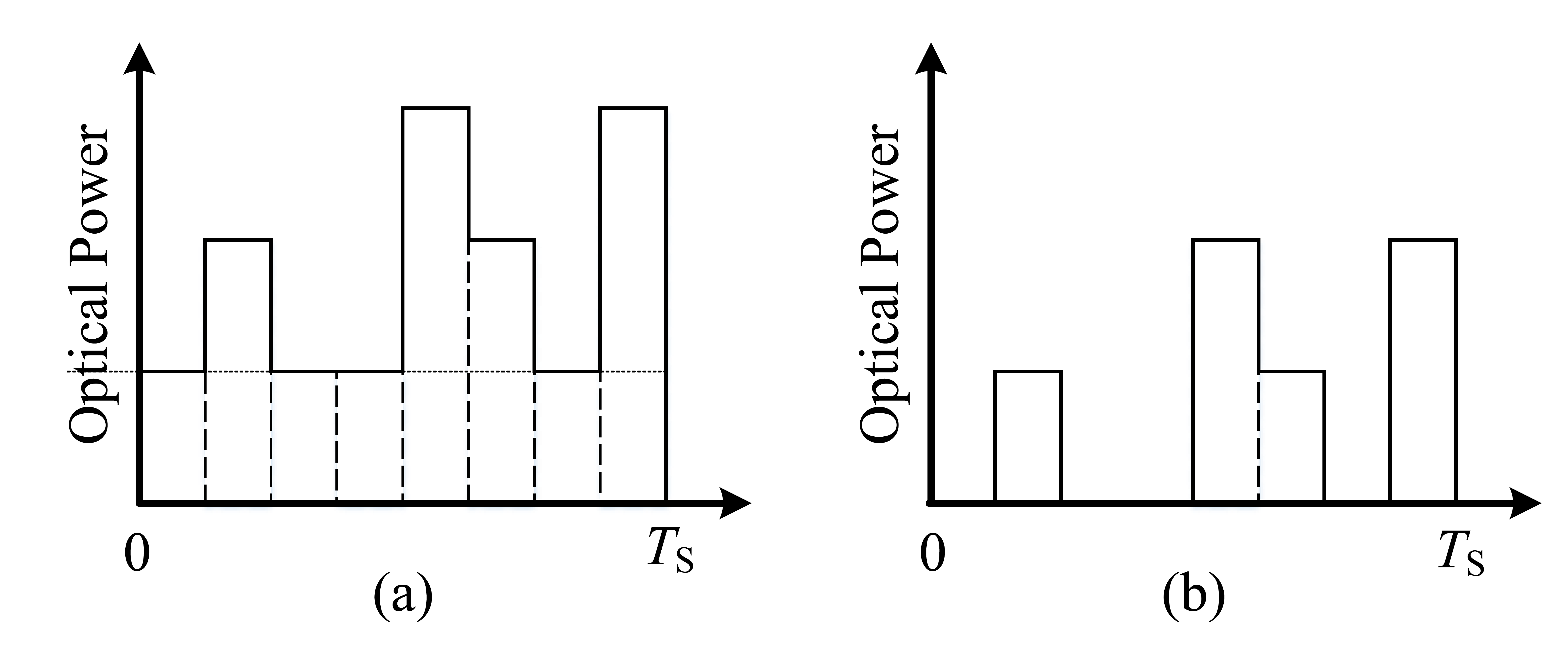


Figure 181. (a) An HCM signal, and (b) its corresponding DC reduced signal.

|  |  |
| --- | --- |
| Size of Hadamard Matrix ( | Data-rate overhead |
| 4 | 25% |
| 8 | 12.5% |
| 16 | 6.25% |
| 32 | 3.125% |

Table 145. Over-head of HCM for different ’s

At the receiver side, the decoder is realized by an inverse FWHT (IFWHT) as shown in Figure 182.

../../UVA%20-%20HCM%20(JSAC)/Main/HCM-TCOM/HCM-Receiver.pdf

Figure 182. HCM decoder structure

**Parameter settings**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Modulation | Level | FEC RS(n,k) | Line code | HCM | Optical Clock Rates/MHz | Data Rate/Mbps |
| PAM | 2 | (255, 248)  (36,24) | 8B10B | (1,1) | 200/2N with N=0…7 | t.b.d. |
| Manchester  encoding |
| 2 | 1B1B | (7,8) |
| 4 | (15,16) |

[Ref A] Noshad, Mohammad, and Maïté Brandt-Pearce. "Hadamard-coded modulation for visible light communications." *IEEE Transactions on Communications* 64.3 (2016): 1167-1175.

[Ref B] K. J. Horadam, Hadamard Matrices and Their Applications. Princeton University Press, 2006.