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

Submission Title: [Enhanced OQPSK Modulation with Orthogonal DSSS Sequences]
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Re: [IEEE 802.15.4]

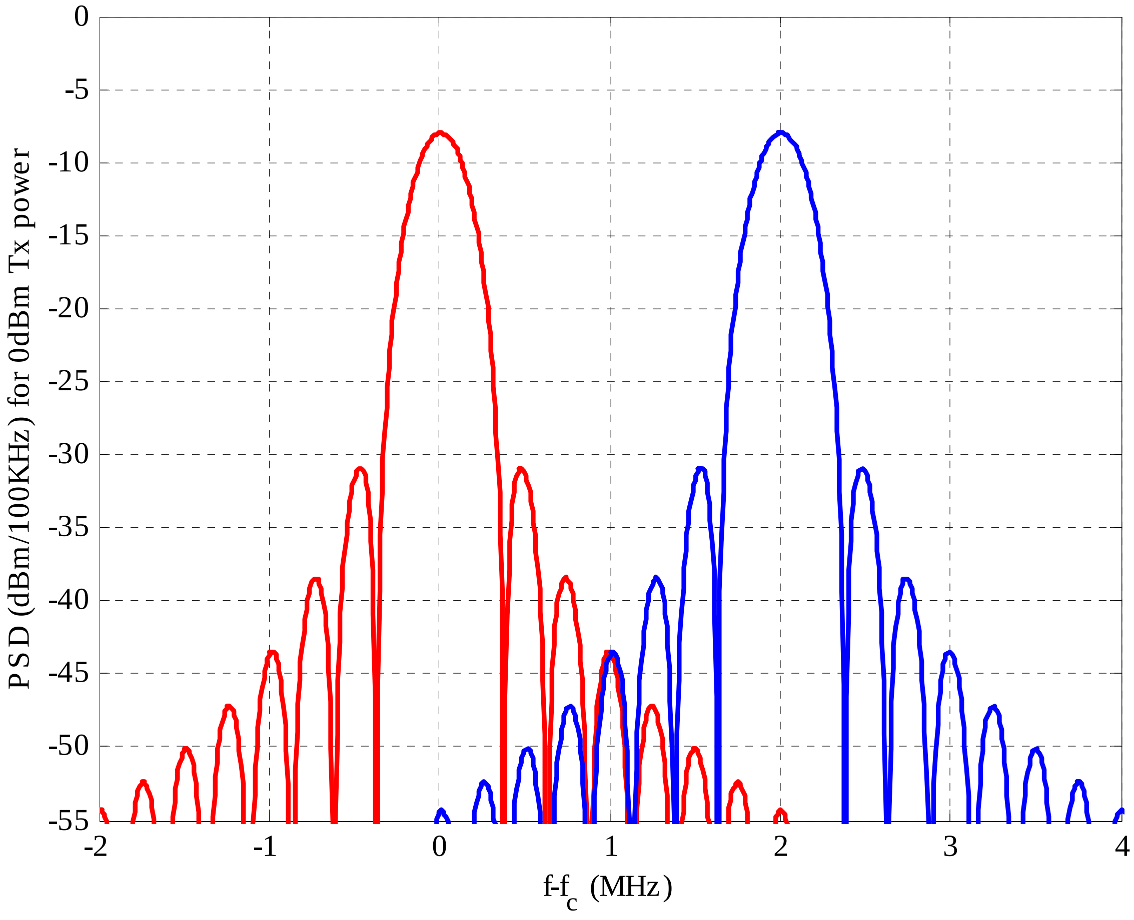
Abstract: [This contribution proposes an updated PHY for TG4b.]

Purpose: [To encourage discussion.]

Proposal

- **A new PHY for low-rate WPAN that employs the MSK modulation scheme with new DSSS sequences:**
  - Keeps the present OQPSK modulation.
  - New DSSS sequences: 16 sequences for 4-bit mapping.
  - Data rate >=125Kbps.
  - Channel separation = 2MHz.
  - The 1^{st} null-null bandwidth = 750KHz.

Spectra


0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-2
-1
0
1
2
3
4
PSD (dBm/100KHz) for 0dBm Tx power
f-f$_c$ (MHz)

Key Features of Our Proposal

- Improved DSSS sequences:
  - 16 DSSS sequences for 4-bit mapping.
  - Each sequence consists of 16 chips instead of 32, which results in ¼ chip rate (500Kcps) for 125kbps data rate.
  - Better orthogonal characteristics between the modulated symbols and improving the decoding performance.

Key Features of Our Proposal (cont.)

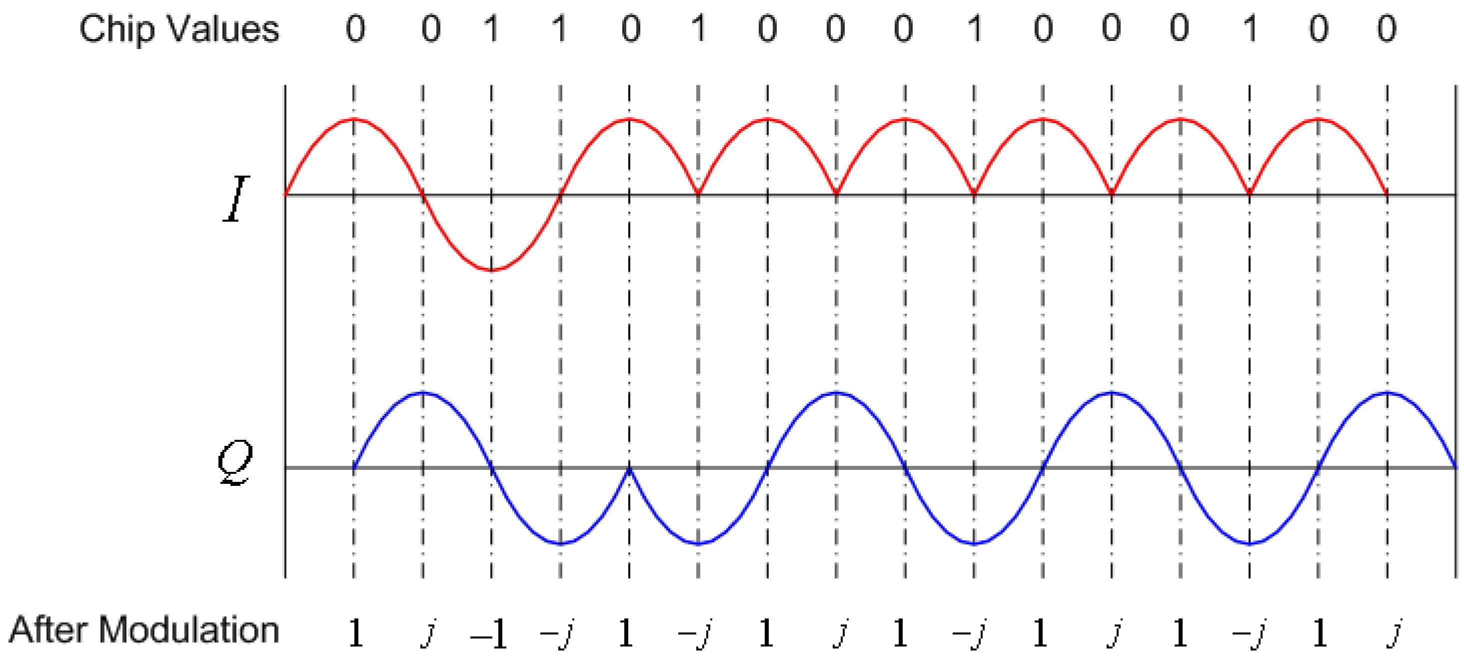
- Backward compatible:
  - The same modulation scheme

    OQPSK + Half-sine pulse shape
  - Keeps constant envelop and continuous phase.
- Lower RF requirements:
  - 2MHz channel separation, 750KHz main lobe
    - Corresponding to 5MHz channel separation and 3MHz main lobe of 15.4
  - Lower out-of-band emission.

Generating Sequence

Decimal Symbol	Binary Symbol	Chip Values
0	0 0 0 0	0 0 1 1 0 1 0 0 0 1 0 0 0 1 0 0
1	1 0 0 0	0 1 1 0 0 0 0 1 0 0 0 1 0 0 0 1
2	0 1 0 0	0 0 0 0 0 1 1 1 0 1 1 1 0 1 1 1
3	1 1 0 0	0 1 0 1 0 0 1 0 0 0 1 0 0 0 1 0
4	0 0 1 0	0 0 1 1 1 0 1 1 0 1 0 0 1 0 1 1
5	1 0 1 0	0 1 1 0 1 1 1 0 0 0 0 1 1 1 1 0
6	1 1 1 0	0 0 0 0 1 0 0 0 0 1 1 1 1 0 0 0
7	0 1 1 1	0 1 0 1 1 1 0 1 0 0 1 0 1 1 0 1
8	0 0 0 1	0 0 1 1 0 1 0 0 1 0 1 1 1 0 1 1
9	1 0 0 1	0 1 1 0 0 0 0 1 1 1 1 0 1 1 1 0
10	0 1 0 1	0 0 0 0 0 1 1 1 1 0 0 0 1 0 0 0
11	1 1 0 1	0 1 0 1 0 0 1 0 1 1 0 1 1 1 0 1
12	0 0 1 1	0 0 1 1 1 0 1 1 1 0 1 1 0 1 0 0
13	1 0 1 1	0 1 1 0 1 1 1 0 1 1 1 0 0 0 0 1
14	0 1 1 1	0 0 0 0 1 0 0 0 1 0 0 0 0 1 1 1
15	1 1 1 1	0 1 0 1 1 1 0 1 1 1 0 1 0 0 1 0

Modulation



The case for symbol 0

Orthogonal Characteristic

With OQPSK modulation, half-sine pulse shaping and a sampling rate of 500KHz, after spreading and modulation, the symbol "0" can be written as:

$$\mathbf{s}_0 = \begin{bmatrix} 1 & j & -1 & -j & 1 & -j & 1 & j & 1 & -j & 1 & j & 1 & -j & 1 & j \end{bmatrix}^T$$

Similarly, we can get all 16 symbols $\mathbf{s}_0$, $\mathbf{s}_1$, … $\mathbf{s}_{15}$, where

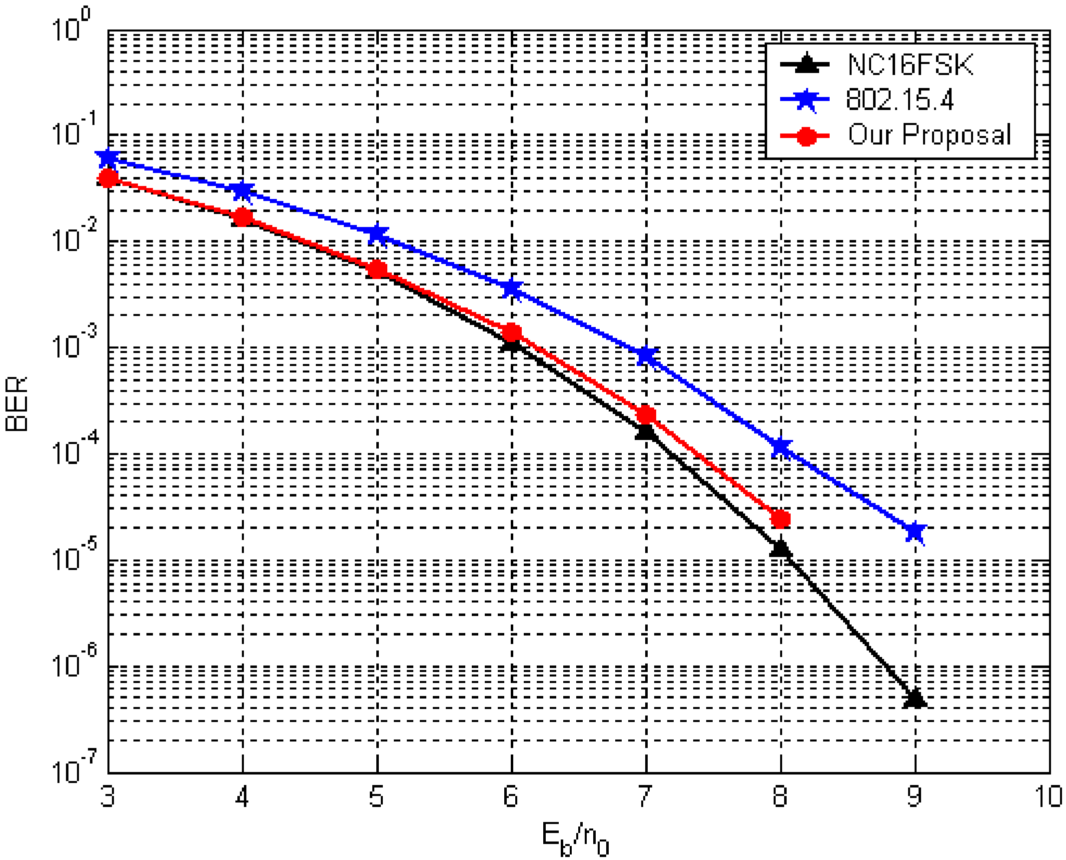
$$\mathbf{s}_m^H \mathbf{s}_n = \begin{cases} 16 & m = n \\ 0 & m \neq n \end{cases} \qquad (m, n = 0, \cdots, 15)$$

Sampled at the chip rate, the transmitted symbols keep their mutually orthogonal.

Remarks

- Simulation shows the decoder having a 0.5 to 1dB improvement in BER vs. E_b/N_o performance over 802.15.4.
- Effective bandwidth of 750KHz for 125kbps
- Lower calculation complexity
- Lower requirements on RF filter
- Possible to implement a full-rate (250 kbps) system using 1M chip rate without adding any complexity and still conform to the spectrum specifications with a 2MHz channel bandwidth.

Performance



NC-16FSK is the results of the non-coherent demodulation of 16-FSK which uses envelope detection.