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.]
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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 $\geq 125$Kbps.
  – Channel separation $= 2$MHz.
  – The 1st null-null bandwidth $= 750$KHz.
Spectra

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 $\frac{1}{4}$ 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

<table>
<thead>
<tr>
<th>Decimal Symbol</th>
<th>Binary Symbol</th>
<th>Chip Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0000</td>
<td>00110100010001000100</td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
<td>01100001000100010001</td>
</tr>
<tr>
<td>2</td>
<td>0100</td>
<td>000001110111011111</td>
</tr>
<tr>
<td>3</td>
<td>1100</td>
<td>01010010001000010010</td>
</tr>
<tr>
<td>4</td>
<td>0010</td>
<td>0011101101001011011</td>
</tr>
<tr>
<td>5</td>
<td>1010</td>
<td>01101110000111110110</td>
</tr>
<tr>
<td>6</td>
<td>1110</td>
<td>000010000111100000</td>
</tr>
<tr>
<td>7</td>
<td>0111</td>
<td>01011101001011101101</td>
</tr>
<tr>
<td>8</td>
<td>0001</td>
<td>00110100101111011111</td>
</tr>
<tr>
<td>9</td>
<td>1001</td>
<td>01100001111011101111</td>
</tr>
<tr>
<td>10</td>
<td>0101</td>
<td>000001111100010000</td>
</tr>
<tr>
<td>11</td>
<td>1101</td>
<td>01010010110111011011</td>
</tr>
<tr>
<td>12</td>
<td>0011</td>
<td>00111011101110110000</td>
</tr>
<tr>
<td>13</td>
<td>1011</td>
<td>01101110111000010</td>
</tr>
<tr>
<td>14</td>
<td>0111</td>
<td>0000100010000111</td>
</tr>
<tr>
<td>15</td>
<td>1111</td>
<td>0101110111010010010</td>
</tr>
</tbody>
</table>
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:

\[ s_0 = \begin{bmatrix} 1 & j & -1 & -j & 1 & j & 1 & -j & 1 & 1 & -j & 1 & j \end{bmatrix}^T \]

Similarly, we can get all 16 symbols \( s_0, s_1, \ldots, s_{15} \), where

\[
\begin{align*}
    s_m^H s_n &= \begin{cases} 
        16 & m = n \\
        0 & m \neq n 
    \end{cases} 
    \quad (m, n = 0, \ldots, 15)
\end{align*}
\]

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. $E_b/N_0$ 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.