Submission Title: [Meiji University UWB PHY Proposal for Body Area Network]
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Re: [This document is a response of Meiji University to the Call For Proposal from the IEEE P802.15 Task Group 6 on BAN.]
Abstract: [This document describes preliminary PHY proposal with UWB-IR]
Purpose: [This document is intended as a preliminary proposal for consideration in IEEE 802.15.6.]
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Meiji University UWB PHY Proposal: Flexible UWB-IR PHY Proposal for Body Area Network

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Meiji University
Kawasaki Japan
Presentation summary:
UWB-IR with flexibilities

- Preliminary proposal for PHY only
- UWB-IR PPM-SS (TBD)
- Scalable data rate
- Non-coherent detection
- Tx power can be reduced. Tx power may be less than -41.3dBm/MHz at short range, e.g. on-body to on-body
- Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible, for coexistence or avoiding interferences
On-body to on-body link may be kept with less transmitting power than on-body to external

<table>
<thead>
<tr>
<th>Link</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - B</td>
<td>Through the hand</td>
</tr>
<tr>
<td>C - D</td>
<td>Through the wrist</td>
</tr>
<tr>
<td>E - F</td>
<td>Torso, front to back</td>
</tr>
<tr>
<td>G - H</td>
<td>Through the thigh</td>
</tr>
<tr>
<td>I - J</td>
<td>Through the ankle</td>
</tr>
<tr>
<td>K - L</td>
<td>Left ear to right ear</td>
</tr>
<tr>
<td>M – N</td>
<td>Glucose sensor to Glucose pump</td>
</tr>
</tbody>
</table>

Why should we transmit maximal Tx power of -41.3dBm/MHz in shorter and lower data rate operation?

Can we reduce Tx power to coexist with other systems?  YES!
Radio Regulation for Reduced Tx Power UWB

- In some regions, Tx power of lower than -41.3dBm/MHz UWB relaxes radio regulation in certain frequency band usages
- Examples: (P802.15-08-0034r10)
  3.1-6GHz for -70dBm/MHz or
  8.5-10.6GHz for -65dBm/MHz in EU,
  3.4-4.8GHz for -70dBm/MHz in Japan,
  can operate without DAA function

DAA: Detection and Avoidance
UWB Spectrum Mask

Japanese spectrum mask  P802.15-08-0034r10
Proposal PHY

UWB-IR PPM-SS (TBD)

- Non-coherent detection
- Center freq.: UWB band (3.1GHz to 10.6GHz)
- Tx Bandwidth: ~500MHz, ~1GHz, (~2GHz and wider)
- Scalable data rate: 10kbps to 10Mbps
- Multiple piconets with SS codes
- Tx power may be reduced for short range. Tx power may be less than -41.3dBm/MHz at short range, e.g. on-body to on-body ~ -70dBm/MHz
- Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible, for coexistence or avoiding interferences
BPPM-UWB in principle

unit pulses are shifted based on data “0” and “1”
Example Modulation: PPM-SS-UWB

Pulse train
\[ [1001011] \]
corresponds data “0”

Pulse train
\[ [0110100] \]
corresponds data “1”

Ikebe et.al, IWUWBT2005
UWB-IR: Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible in principle

• When PPM with energy detection of pulse is employed,

• As long as correlation output of Rx produce a certain level for PPM detection, transfer function of Rx front-end or template waveform at correlator does not have to match the transmitted one.
Advantage of IR-PPM with Energy Detection

\[ X(f) = S(f) U(f) \]: Tx Signal

\[ R_f(f) \] does not have to match transmitted signal \( H(f)X(f) \)

- \( S(f) \): Tx UWB-IR PPM Pulse
- \( U(f) \): Tx BPF, and Antenna
- \( H(f) \): Channel including Rx Antenna
- \( R_f(f) \): Rx BPF, Template, etc.
We allow Tx-Rx mismatched filter. This eases UWB-IR design

- If we allow mismatch loss, receiver front end transfer function $R_f(f)$ does not have to match transmitted signal $H(f)X(f)$. $R_f(f)$ can be designed based on interference resistant manner [Ikegami, IWUWBS2003, Ohno, IEEE MTT2006].
- $H(f)$: transfer function of channel including Rx antenna
- $X(f)=S(f)U(f)$
- $X(f)$: transmitted signal
- $S(f)$: transmitting UWB pulse
- $U(f)$: transfer function of Tx filter and antenna
## Link Budget Analyses 1 (3m distance, Rx NF 6dB)

<table>
<thead>
<tr>
<th></th>
<th>Free Sp</th>
<th>CM3</th>
<th>Low PSD</th>
<th>Missmatch</th>
<th>Upper B</th>
<th>Lower B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center [MHz]</td>
<td>6350</td>
<td>6350</td>
<td>6350</td>
<td>6350</td>
<td>8125</td>
<td>4000</td>
</tr>
<tr>
<td>TX BPF BW [MHz]</td>
<td>7500</td>
<td>7500</td>
<td>7500</td>
<td>7500</td>
<td>1250</td>
<td>1700</td>
</tr>
<tr>
<td>RX BPF BW [MHz]</td>
<td>7500</td>
<td>7500</td>
<td>7500</td>
<td>6000</td>
<td>1250</td>
<td>1700</td>
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<tr>
<td>TX PSD[dBm/MHz]</td>
<td>-41.3</td>
<td>-41.3</td>
<td>-70</td>
<td>-70</td>
<td>-70</td>
<td>-70</td>
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<tr>
<td>EIRP[dBm]</td>
<td>-2.5</td>
<td>-2.5</td>
<td>-31.2</td>
<td>-31.2</td>
<td>-39.0</td>
<td>-37.7</td>
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<tr>
<td>Free space path loss[dB]</td>
<td>58.0</td>
<td>58.0</td>
<td>58.0</td>
<td>58.0</td>
<td>60.2</td>
<td>54.0</td>
</tr>
<tr>
<td>CM3 Excess Path loss[dB]</td>
<td>0.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Total path loss [dB]</td>
<td>58.0</td>
<td>74.0</td>
<td>74.0</td>
<td>74.0</td>
<td>76.2</td>
<td>72.0</td>
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<tr>
<td>N0[dBm/Hz]</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
</tr>
<tr>
<td>C[dBm]</td>
<td>-60.6</td>
<td>-76.6</td>
<td>-105.3</td>
<td>-106.3</td>
<td>-115.2</td>
<td>-91.7</td>
</tr>
<tr>
<td>C/No[dBHz]</td>
<td>108.5</td>
<td>92.5</td>
<td>63.8</td>
<td>62.8</td>
<td>53.9</td>
<td>77.4</td>
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<tr>
<td>Bit Rate [Mbps]</td>
<td>10</td>
<td>100</td>
<td>0.15</td>
<td>0.15</td>
<td>0.016</td>
<td>0.064</td>
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<tr>
<td>Eb/No[dB]</td>
<td>38.5</td>
<td>12.5</td>
<td>12.0</td>
<td>11.1</td>
<td>11.8</td>
<td>11.3</td>
</tr>
<tr>
<td>Req. Eb/No[dB]</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>margin [dB]</td>
<td>27.5</td>
<td>1.5</td>
<td>1.0</td>
<td>0.1</td>
<td>0.8</td>
<td>0.3</td>
</tr>
</tbody>
</table>

100Mbps OK  150kbps OK  150kbps OK  16kbps OK  64kbps OK
## Link Budget Analyses 2 (1m distance, Rx NF6dB)

<table>
<thead>
<tr>
<th></th>
<th>Free Sp</th>
<th>CM3</th>
<th>Low PSD</th>
<th>10kbps</th>
<th>Mismatch</th>
<th>8GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Freq [MHz]</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>8000</td>
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<tr>
<td>TX BPF BW [MHz]</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>RX BPF BW [MHz]</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>TX PSD[dBm/MHz]</td>
<td>-41.3</td>
<td>-41.3</td>
<td>-70</td>
<td>-70</td>
<td>-70</td>
<td>-70</td>
</tr>
<tr>
<td>EIRP[dBm]</td>
<td>-14.3</td>
<td>-14.3</td>
<td>-43.0</td>
<td>-43.0</td>
<td>-43.0</td>
<td>-43.0</td>
</tr>
<tr>
<td>Free space path loss[dB]</td>
<td>44.5</td>
<td>44.5</td>
<td>44.5</td>
<td>44.5</td>
<td>44.5</td>
<td>50.5</td>
</tr>
<tr>
<td>CM3 Excess Path loss[dB]</td>
<td>0.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Total path loss [dB]</td>
<td>44.5</td>
<td>60.5</td>
<td>60.5</td>
<td>60.5</td>
<td>60.5</td>
<td>66.5</td>
</tr>
<tr>
<td>N0[dBm/Hz]</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
<td>-169.1</td>
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<tr>
<td>C[dBm]</td>
<td>-58.8</td>
<td>-74.8</td>
<td>-103.5</td>
<td>-103.5</td>
<td>-110.5</td>
<td>-109.5</td>
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<tr>
<td>C/No[dBHz]</td>
<td>110.3</td>
<td>94.3</td>
<td>65.6</td>
<td>65.6</td>
<td>58.6</td>
<td>59.6</td>
</tr>
<tr>
<td>Bit Rate [Mbps]</td>
<td>10</td>
<td>10</td>
<td>0.15</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Eb/No[dB]</td>
<td>40.3</td>
<td>24.3</td>
<td>13.8</td>
<td>25.6</td>
<td>18.6</td>
<td>19.6</td>
</tr>
<tr>
<td>Req. Eb/No[dB]</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>margin [dB]</td>
<td>29.3</td>
<td>13.3</td>
<td>2.8</td>
<td>14.6</td>
<td>7.6</td>
<td>8.6</td>
</tr>
</tbody>
</table>

**Submission**

150kbps
- 10Mbps OK
- 14.6dB
- 7.6dB
- 6.6dB

10Mbps OK
- OK

Tetsushi Ikegami, Meiji University
Simpler is better!

- Non-coherent UWB-IR
- Flexible Tx power
- Flexible Rx bandwidth
UWB PHY, Rx is subject to interference, robust receiver design will be key (may be out of scope TG6 spec.)

- Interference detection and rejection type receiver design
- Interference rejection by BPF or notch filter [Ikegami, IEEE IWUWBS2003]
- Interference rejection by receiver template waveform processing [Ohno, IEEE MTT 2006]
- UWB-IR type IEEE802.15.4a signal can be detected by simpler energy detector [Hasegawa, IEEE ICUWB2008]
- Use of chirp template to detect interferences [Ohno, IEEE ICUWB2008]
Conclusion: UWB-IR with flexibilities

- UWB-IR PPM-SS
- Scalable data rate
- Non-coherent detection
- Tx power can be reduced. Tx power may be less than -41.3dBm/MHz.
- Bandwidth, center frequency and pulse shape of Tx or Rx template are flexible, for coexistence or avoiding interferences.
References


Thank you for your attention.