Wearable Devices
Agenda

• Wearable devices
• Regulatory Testing
• Radiated Performance Testing
Wearable devices
Wearable Devices
Possible Usage

• Low power application

• Extension of your portable devices

• A connectivity device itself
Possible RF technology involved

• Low Energy wireless interface to the host
  – Most low-power wireless networks find homes in consumer, medical, health, sports, and fitness applications. These mobile applications require small size and coin-cell power that can function for years without attention
  – ANT+
  – Bluetooth Low Energy
  – etc…

• Wireless interface on the wearable devices
  – GPS
  – WiFi
  – Cellular
  – RFID
  – etc…
Possible applications

- Consumer
  - Proximity detection for use in identification, authentication, and wireless locks
  - HID (human interface devices) peripherals
  - RFID-like cases
  - Automatic meter reading
  - Toys
  - Automotive applications
  - Home area networks
Possible applications

- Medical and health care
  - Heart-rate monitor
  - Temperature monitor
  - Other medical instrumentation
  - Body area networks (BANs)
Possible applications

• Sports, fitness, and wellness
  – Sports watches and monitors
  – Heart-rate belts
  – Bike computers
  – Speed and distance monitoring
  – Fitness equipment
  – Other performance monitoring
Quick Introduction of Bluetooth LE

- Bluetooth Smart (4.0 LE) uses a different set of technical and radio techniques to ensure very low power consumption.

- The data protocol was changed to create low-duty-cycle transmissions or a very short transmission burst between long periods.

- In addition to extremely low-power sleep modes, the low duty cycle allows a Bluetooth Smart product to operate for many years on a coin cell.

- Standard Bluetooth offers gross data rates of 1, 2, or 3 Mbits/s, while BLE’s maximum rate is 1 Mbit/s with a net throughput of 260 kbits/s.
Quick Introduction of ANT+

- ANT represents another ultra-low-power, short-range wireless technology designed for sensor networks and applications in 2.4-GHz ISM band.

- ANT+ is a relatively recent addition to ANT. This software function provides interoperability in a managed network. It facilitates the collection, automatic transfer, and tracking of sensor data for monitoring all involved nodes and devices.

<table>
<thead>
<tr>
<th>Technology</th>
<th>ANT</th>
<th>Bluetooth Low Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4 to 2.483 GHz</td>
<td>2.4 to 2.483 GHz</td>
</tr>
<tr>
<td>Topologies supported</td>
<td>P2P, star, tree, mesh</td>
<td>P2P, star</td>
</tr>
<tr>
<td>Modulation</td>
<td>GFSK</td>
<td>GFSK</td>
</tr>
</tbody>
</table>
Quick Introduction of ULP FSK

- An ultra low power (ULP) frequency shift keying (FSK) receiver can be applied for wearable or implantable physiology sensors and environment monitor sensors.
- Owing to variable data rate of the FSK demodulator, power consumption and transmission data rate of the FSK demodulator can be trade-off for optimization under different operating conditions.

<table>
<thead>
<tr>
<th>Frequency Bands/frequencies</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 kHz to 90 kHz</td>
<td>Inductive devices, Generic use</td>
</tr>
<tr>
<td>90 kHz to 119 kHz</td>
<td>Inductive devices, Generic use</td>
</tr>
<tr>
<td>119 kHz to 140 kHz</td>
<td>Inductive devices, Generic use</td>
</tr>
<tr>
<td>140 kHz to 148.5 kHz</td>
<td>Inductive devices, Generic use</td>
</tr>
<tr>
<td>148.5 kHz to 5 MHz</td>
<td>Inductive devices, Generic use</td>
</tr>
</tbody>
</table>

- SRD Device
- EN 300440
Regulatory Testing
Regulatory Testing

• Normally the following 4 aspects may be required

  – Electromagnetic Compatibility
  – Radio Frequency Spectrum usage
  – RF Exposure
  – Safety
Electromagnetic Compatibility

- **EMI (Interference)**
  - Radiated Emission
    (EN 55022 / FCC 15B)

- **EMS (Susceptibility)**
  - ESD
    (IEC 61000-4-2)
  - Radio Frequency Immunity
    (IEC 61000-4-3)
Radio Spectrum

• Test with the device transmitting/receiving, monitor the RF signal level to the regulatory requirement
  – Similar to what we test non-wearable devices (ex: handset, tablet, etc)

• FCC, CE
  – Transmitting level @ fundamental frequency
  – Out-of-band Emission level
  – Spurious Domain for 2\textsuperscript{nd} harmonic or image

• Other national standards..
RF Spurious Emission
ISM 13.56MHz Emission

-60 dBμA/m for 13.56 MHz
+42 dBμA/m for 6.78 MHz and 13.56 MHz
+9 dBμA/m
-1 dBμA/m at 6.78 MHz
-3.5 dBμA/m at 13.56 MHz
-10 dBμA/m
-16 dBμA/m
ISM 2.4GHz Emission

- **A:** -10 dBm/MHz e.i.r.p.
- **B:** -20 dBm/MHz e.i.r.p.
- **C:** Spurious Domain limits

BW = Occupied Channel Bandwidth in MHz or 1 MHz whichever is greater.
**Short Range Device Emissions**

for fundamental frequency below 30MHz

<table>
<thead>
<tr>
<th>State</th>
<th>Frequency $9 \text{ kHz} \leq f &lt; 10 \text{ MHz}$</th>
<th>Frequency $10 \text{ MHz} \leq f &lt; 30 \text{ MHz}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>27 dBµA/m at 9 kHz descending 3 dB/oct</td>
<td>-3.5 dBµA/m</td>
</tr>
<tr>
<td>Standby</td>
<td>5.5 dBµA/m at 9 kHz descending 3 dB/oct</td>
<td>-25 dBµA/m</td>
</tr>
</tbody>
</table>

| State    | 47 MHz to 74 MHz  
87.5 MHz to 118 MHz  
174 MHz to 230 MHz  
470 MHz to 862 MHz | Other Frequencies between 30 MHz to 1 000 MHz |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>4 nW</td>
<td>250 nW</td>
</tr>
<tr>
<td>Standby</td>
<td>2 nW</td>
<td>2 nW</td>
</tr>
</tbody>
</table>
Europe Adaptivity Test Requirement

- Only for Adaptive systems and RF Output Power > 10dBm

<table>
<thead>
<tr>
<th>ETSI</th>
<th>EN 300 328 V1.8.1</th>
<th>Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2.4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering the essential requirements of article 3.2 of the R&amp;TTE Directive</th>
<th>23/10/2012</th>
<th>EN 300 328 V1.7.1</th>
<th>31/12/2014</th>
<th>Note 2.1</th>
<th>Article 3(2)</th>
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<tr>
<td>ETSI</td>
<td>EN 301 893 V1.7.1</td>
<td>Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&amp;TTE Directive</td>
<td>23/10/2012</td>
<td>EN 301 893 V1.6.1</td>
<td>31/12/2014</td>
<td>Note 2.1</td>
<td>Article 3(2)</td>
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Ready for Test

• Q1 : How to enable as high as possible duty cycle for testing?
• Q2 : Battery capacity to sustain the testing?

• Solution
  – Test tool to achieve continuous transmitting / receiving function.
  – External power supply to provide sufficient duration for testing.
  – Some reasonable/acceptable explanation for using low duty cycle
  – The reason for duty cycle limitation shall be documented.
RF exposure

• It’s an assessment of how RF transmission expose and impact the human
  – Familiarly know as Specific Absorption Rate (SAR) level

• Different nations have different requirement
  – FCC:
    • Body, trunk: 1g-SAR with limit 1.6 W/kg
    • Limbs: 10g-SAR with limit 4 W/kg
  – CE:
    • Body, trunk: 10g-SAR with limit 2 W/kg
    • Limbs: 10g-SAR with limit 4 W/kg
RF exposure (cont’d)

• Devices are used against the human body
• The antenna is designed/tuned for the body effect

• Test as it is on the body, testing in free space may not be representative

• Battery capacity to sustain the testing?
  – Test at lower power level or low duty factor, then scaling it up
RF exposure (cont’d)

- Position EUT “radiating structure” under the phantom, at the separation which represents the normal usage
  - Phantom shell thickness is 2mm

- The tissue-equivalent medium “loads” the EUT properly
RF exposure
– EUT positioning
RF exposure
– EUT positioning
Radiated Performance
Radiated Performance

• Antenna radiated performance of the device, when it is worn on the human
  – The Over-The-Air (OTA) performance may attract some interests

• Testing in free-space may not be sufficient…..

• Battery capacity to sustain the testing?
Reverberation Chamber
Radiated Performance

• Some phantoms examples below (there may be others from other vendors)

• Phantom for Ankle?
誠摯感謝、敬請指導