Wireless Body Area Network (WBAN)

- IEEE 802.15.6 and Human Body Communication -

1. IEEE 802.15.6
2. UHF Narrow Band Radio
3. UWB (Ultrawide Band)
4. HBC (Human Body Communication)
5. Communication between Person and Robot using Human Body Communication
6. Joint Study on Human Body Communication between Korea and Japan
7. Next Generation Human Body Communication

Hideyuki Nekiba
AMPLET Communication Lab.
Medical and Healthcare
Short Range Wireless Communication (IEEE 802.15.6)

Summary of the WBAN Standard “IEEE 802.15.6”

<table>
<thead>
<tr>
<th><strong>IEEE 802.15.6</strong></th>
<th>UHF Narrow Band Radio</th>
<th>UWB</th>
<th>HRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHY</strong></td>
<td>NB-PHY</td>
<td>UWB-PHY</td>
<td>HBC-PHY</td>
</tr>
<tr>
<td><strong>Band</strong></td>
<td>402～405MHz</td>
<td>For Implant Equipment (World Wide)</td>
<td>3.1～10.6GHz</td>
</tr>
<tr>
<td></td>
<td>863～870MHz</td>
<td>Medical Telemeter (Japan)</td>
<td>(UWB)</td>
</tr>
<tr>
<td></td>
<td>862～928MHz</td>
<td>ISM Band (U.S.A.)</td>
<td>Depends on</td>
</tr>
<tr>
<td></td>
<td>850～950MHz</td>
<td>ISM Band (Japan)</td>
<td>Depends on Regulation</td>
</tr>
<tr>
<td></td>
<td>2.38～2.40GHz</td>
<td>For Medical Equipment (U.S.A.)</td>
<td>Each Country</td>
</tr>
<tr>
<td></td>
<td>2.4GHz Band</td>
<td>ISM Band (World Wide)</td>
<td>MAC</td>
</tr>
<tr>
<td><strong>MAC</strong></td>
<td>Recommend the same MAC as other similar Wireless Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>2m</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>BPSK, GFSK, GMSK, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Packet Budget</strong></td>
<td>256 byte Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data Speed</strong></td>
<td>1～10Mbps</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>Less than 10mA at 3V Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td>Star Network</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. UHF Narrow Band Radio

Super – Low – Power Consumption
UHF Narrow Band Radio ・ ・ ・ ANT, BLE

The market where the Super – Low – Power – Consumption Radio is expected

• Communication between a smart phone, or a tablet PC and a wrist watch

• Communication between a smart phone, or a tablet PC and a health care equipment

• ANT : Original proposed protocol by Dynastream Innovations
  The de facto standard of the substantial industry
  Organization → ANT+ Alliance

• BLE : bluetooth low energy
  Organization → Bluetooth SIG
ANT

- Members of ANT Alliance: Sony Ericsson Mobile Comm, Qualcomm, Samsung, Garmin, Nordic, Suunto, Timex, Citizen, Tanita, Pioneer, A and D, etc.
- Standard decision which is conscious of the smart phone vendor
- Application Platform: ANT+
- The licensing fee is free of charge concerning the development of the equipment corresponding to ANT and software compatible with ANT+.
- De facto standard in the sport related industry.
- Track record to a sport wrist watch and running shoes.

<table>
<thead>
<tr>
<th></th>
<th>ANT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nRF24AP2 (Nordic)</td>
</tr>
<tr>
<td>Frequency</td>
<td>2.4GHz ISM Band</td>
</tr>
<tr>
<td>Maximum Bit Rate</td>
<td>20kbps</td>
</tr>
<tr>
<td>Output Power</td>
<td>0dBm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>-85dBm</td>
</tr>
</tbody>
</table>

BLE

- Lower Power Consumption based on Bluetooth
- Members of BLE PUID WG: Apple, Qualcomm, Nokia, Sony Ericsson Mobile Comm, Casio, Citizen, Toshiba, Murata, etc.
- Members of BLE Medical Device WG: Atheros Comm, Broadcom, CSR, Intel, TI, Nokia, Mindtree, Murata, etc.
- Members of BLE HID: IC chip vendors, Peripheral equipment vendors, etc.
- An application profile is almost completed.
  - PUID → Time, Proximity, Find me, Alert Notification, Phone Alert Status, Soft Button, Network Availability, Emergency
  - Medical Device → Heart Rate Monitor, Physical Activity Monitor, Blood Glucose Meter, Health Thermometer, Health Device Information, Pulse oximeter, Weight Scale
  - HID → Key Board, Wireless Remote Controller, etc.
- BLE in a smart phone is expected from the past BT track record.
## BLE

<table>
<thead>
<tr>
<th></th>
<th>Bluetooth (EDR Mode)</th>
<th>BLE (Bluetooth Low Energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4GHz ISM Band</td>
<td>2.4GHz ISM Band</td>
</tr>
<tr>
<td>System</td>
<td>Frequency Hopping Spread Spectrum (FH-SS)</td>
<td>GFSK, π/4-DQPSK, 8DPSK</td>
</tr>
<tr>
<td>Modulation</td>
<td>GFSK</td>
<td>GFSK</td>
</tr>
<tr>
<td>Number of FHSS Channels</td>
<td>79</td>
<td>40</td>
</tr>
<tr>
<td>FHSS Channel Separation</td>
<td>1MHz</td>
<td>2MHz</td>
</tr>
<tr>
<td>Output Power</td>
<td>+20dBm (Class=1)</td>
<td>+8dBm (CSR1000/CSR)</td>
</tr>
<tr>
<td></td>
<td>+4dBm (Class=2)</td>
<td>+4dBm (CC2540/ TI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0dBm (nRF8001/Nordic)</td>
</tr>
<tr>
<td>Communication Range</td>
<td>-92dBm (CSR1000)</td>
<td>-93dBm (CC2540)</td>
</tr>
<tr>
<td></td>
<td>-87dBm (nRF8001)</td>
<td>-92dBm (CSR1000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-93dBm (CC2540)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-87dBm (nRF8001)</td>
</tr>
<tr>
<td>AOK Packet Length</td>
<td>128μS</td>
<td>80μS</td>
</tr>
<tr>
<td>Maximum Packet Length</td>
<td>2875μS</td>
<td>32μS</td>
</tr>
<tr>
<td>Maximum Bit Rate</td>
<td>3Mbps</td>
<td>3Mbps (CSR1000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1Mbps (CC2540)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variable (nRF8001)</td>
</tr>
<tr>
<td>Pico Net Topology</td>
<td>Corresponding</td>
<td>Un-corresponding</td>
</tr>
<tr>
<td>Voice Communication</td>
<td>Corresponding</td>
<td>Un-corresponding</td>
</tr>
</tbody>
</table>

### 3. UWB (Ultrawide Band)
ASK Impulse UWB

PSK Impulse UWB
Relation between Impulse and Spectrum

4. HBC (Human Body Communication)
Electric Field Communication System
by Dr. Thomas G. Zimmerman

4-1. Ultra Basic Electromagnetism
What is Magnetic Field?

What is Electric Field?

Magnetic Force

As well known, a Magnet gives the power to pull certain things. Magnetic Field depicts the Force exerted on between one north pole and one south pole.
Experiment using Static Electricity

The Static Electricity makes your hair stand straight out from your head.

Concept of HBC

TXD = 0

TXD = 1
### Operation Principle of HBC

**TXD = 0**

- Electric field becomes "Stronger"
- NO Transmitter

**TXD = 1**

- Electric field becomes "Weak"
- Remote Transmitter

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**4-2. Body as a Transmitter**

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Body as a Transmitter

The cyclic movement of the Heart

HBC System with ECG (electrocardiogram)
HBC Applications for Medical

If a patient uses wearable vital sensors connected to a data logging equipment, a patient cannot change sides of the bed, and cannot go to a toilet.

This is the reason why the HBC as short range wireless communication to be required at the hospital.

The HBC Project at the University of Tokyo Hospital

While the doctor at the hospital talks with the elderly people living alone by Cellular Phone, this system can check the battery voltage of auxiliary medical equipment, the electrocardiogram, and the pulse on the display of the PC at the hospital.

Using HBC Communication between Vital Sensors and Cellular Phone
4-3. Suitable Frequency for “Electric Field Communication System”

Radiation from the Body

Suitable Frequency for “Electric Field Communication System” is HF.
Normalized Propagation Characteristics by Experiment between a Wearable Transmitter and a Wearable Receiver

Normalized Propagation Characteristics by Experiment between a Desk-mounted Transmitter and a Desk-mounted Receiver
4-4. How to design an Electrode

Condition of Leakage Current = 0

\[ \Rightarrow C_1 : C_3 = C_2 : C_4 \]
4–5. Our Dream using HBC Technology

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5. Communication between Person and Robot using Human Body Communication

The Personal Care Robot for aged Person

Vestibular: Contribute to balance Human body, which constitutes the labyrinth of the inner ear.
The Issue of Wire Harness Breakage at Joints of a Robot

After many times bending Arms of the Robot ..., Wire Harness Breakage at the Joint should happen to occur. It is a Problem!!

The Solution of Wire Harness Breakage using Human Body Communication Technology

Feb. 21, 2017
6. Joint Study on Human Body Communication Between Korea and Japan

Joint Seminar on Human Body Communication MoU between ETRI, Korea and AMPLET, Japan

Chair of Korea: Dr. Byong Nam Lee (ETRI)
Chair of Japan: Dr. Hideyuki Nebiya (AMPLET, The University of Tokyo)
Education Agreement on Human Body Communication
MoU between CNU, Korea and AMPLET, Japan

Korea : Prof. Jong Myung Woo (CNU)
Japan : Dr. Hideyuki Nebiya (AMPLET Communication Laboratory)

7. Next Generation Human Body Communication
On-body Communication / In-body Communication

HBC Transmitter (On-body) — TX Electrode (+) RX Electrode (-)
HBC Receiver (On-body) — TX Electrode (-) RX Electrode (+)

Cold Electrode (On-body) — Reference Plane (Ground) (On-body)

In-body Communication (Capsule Endoscopy)

HBC Transmitter (Capsule Endoscopy) — TX Electrode (+)
HBC Receiver (Display) — TX Electrode (-) RX Electrode (+)
RX Electrode (-)
Noise Suppression using Differential Electrodes

Thank you for your attention.