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

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Abstract: [Human Body Communication Physical Layer Proposal for Body Area Networks]

Purpose: [Response to “TG6 Call for Proposals” –IEEE P802.15-08-0811-02-0006]

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HBC (Human Body Communication)  
PHY Proposal for BAN

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Outline

• Introduction

• System Principles
  – Body Channel Characteristics
  – HBC System Overview

• Performance Analysis
  – Simulation Results
  – Link Budget
  – System Verification

• Conclusions
PHY Requirements for BAN?
Why HBC for BAN?

INTRODUCTION
PHY Requirements for BAN?

• Data Rate:
  – 10 Kbps to 10 Mbps
  – The lowest mandatory rate at 3 m Range

• Distance: 1 m (typically) to 3 m

• Low Power

• Low Complexity

• Regulatory Compliance
What is the Features of HBC?

• **TAP** (Touch And Play)
  – Intuitive Service, Quick Setup, Easy Use
  – Afford Privacy & Security

• **Direct Digital Baseband Signaling**
  – Easy to Implement
  – Low Power Consumption
  – Small Size
What is the Features of HBC? – *cont.*

- Support Data Rate up to 10 Mbps
  - $10^{-6}$ BER Performance *without FEC*
- Low Interference Generation*
  - Low Radiation
- *Low Shadowing Effect**
Body Channel Characteristics
FSBT (Frequency Selective Baseband Transmission)
HBC System Overview

SYSTEM PRINCIPLES
Frequency Response

- The frequency response has been modeled in the frequency range of 5 Mhz ~ 50 Mhz.

Amplitude = \[ \frac{|V_{output}|}{|V_{input}|} \]

Phase = \[ \frac{\angle V_{output}}{\angle V_{input}} \]
How to transmit Digital Signal Directly?

• **FSBT** Background
  – Direct Digital Transmission
    • **No RF**
  – Band Selection
    • **Avoid Low Frequency**
    • $P_{\text{internal Signaling}} \gg P_{\text{external radiated}}$
  – More **Processing Gain**

*FSBT: Frequency Selective Baseband Transmission*
What is FSBT?

- **Baseband Signaling**
  - Characteristics of *Walsh Code*
    - Each Walsh code has the *Fundamental Freq.*
    - Use sub-group of Walsh Code in *Selected Band*
    - Get Processing Gain by Spreading

![Diagram of FSBT](image)
HBC System Overview
Simulation Parameters
BER Performance Evaluation
Link Budget

PERFORMANCE ANALYSIS
Simulation Parameters

- Baseband Transmission Square Wave
- Data Rate: Up to 10 Mbps
- Chip Rate: Max. 64 Mcps
- Spreading Code: Walsh Code
- On-Body Channel Model
BER Performance Evaluation

- On-Body Channel Model

BER performance

Average SNR [dB]

BER

10Mbps BER

2Mbps BER
PER Performance Evaluation

- On-Body Channel Model

PER (256 octets) performance
## Link Budget

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Information Data Rate [Mbps]</td>
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<td>2</td>
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<tr>
<td>Tx Power [dBm]</td>
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<td>Path Loss [dB]</td>
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<td>54</td>
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<td>Bandwidth [dBHz]</td>
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<td>Rx Input Power (P_R) [dBm]</td>
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<td>Rx Noise Figure (N_F) [dB]</td>
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<td>Noise Power (N= kTB+ N_F) [dBm]</td>
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<td>-95</td>
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<td>SNR Required (S) [dB]</td>
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<td>Implementation Loss (I) [dB]</td>
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<td>Rx Sensitivity(R= N+S+I) [dBm]</td>
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<tr>
<td>Link Margin (M=P_R – R) [dB]</td>
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<td>21.8</td>
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</table>
Test Module
HBC Modem Chip

• Configuration
  – 130nm CMOS technology
  – AFE, Modem, and Memory

• Power Consumption
  – AFE +Digital core :
    • 8.41mA @ 1.2V
  – Digital I/O :
    • 3.0mA @ 3.3V
  – Total power consumption :
    • 20mW at 10Mbps
  – Sleep mode :
    • Less than 10uW
Prototype USB Dongle

- **Controller Board**
  - MCU: AT91SAM7X256 (Atmel)
  - Interface:
    - Modem to MCU: I²C/USART
    - Host: USB
  - Board size: 70mm x 30mm

- **HBC Modem Board**
  - HBC Modem
  - 2 pin connector: electrode
  - Board size: 48mm x 25mm
CONCLUSIONS
Conclusions

• **TAP** (Touch And Play)
  – Intuitive Service/Context Aware Service
  – Quick/Simple Pairing

• **FSBT** (Frequency Selective Baseband Transmission)
  – No RF (Direct Digital Transmission)
  – Low Interference Generation
  – Simple/Small Architecture
  – Quick Development Time
Conclusions –cont.

- Data Rate
  - Scalable from 10 Kbps to 10 Mbps
  - $10^{-6}$ BER without FEC
- Low Power Consumption
  - Active Mode: 20 mW @ 10 Mbps
  - Sleep Mode: Less than 10 uW
Q & A