

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

**Submission Title:** [ETRI HBC PHY Proposal for BAN]

**Date Submitted:** [4 May, 2009]

**Source:** [Jung-hwan Hwang, Hyung-il Park, Tae-wook Kang, Tae-young Kang, Sung-weon Kang]

Company [ETRI]

Address [138 Gajeongno, Yuseong-gu, Daejeon, 305-700, KOREA]

Voice:[+82-42-860-1176], FAX: [+82-42-860-6860], E-Mail:[jhhwang@etri.re.kr]

**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]

**Notice:** This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

**Release:** The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.

# HBC (Human Body Communication) PHY Proposal for BAN

Jung-hwan Hwang, Hyung-il Park, Tae-wook Kang, Tae-young Kang,  
Sung-weon Kang

Electronics and Telecommunications Research Institute  
(ETRI)

# Outline

- Introduction
- System Principles
  - Body Channel Characteristics
  - HBC System Overview
- Performance Analysis
  - Simulation Results
  - Link Budget
- 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
  - Extremely 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<sup>\*</sup>
  - Extremely Low Radiation
- ***Low Shadowing Effect***<sup>\*\*</sup>

\* *IEEE802.15-08-0295-00-0006*

\*\* *IEEE802.15-08-0122-00-0006*

Body Channel Characteristics

FSBT(Frequency Selective Baseband Transmission)

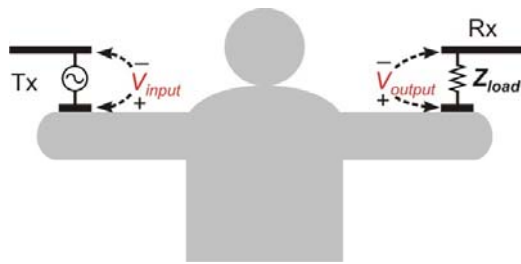
HBC System Overview

# SYSTEM PRINCIPLES



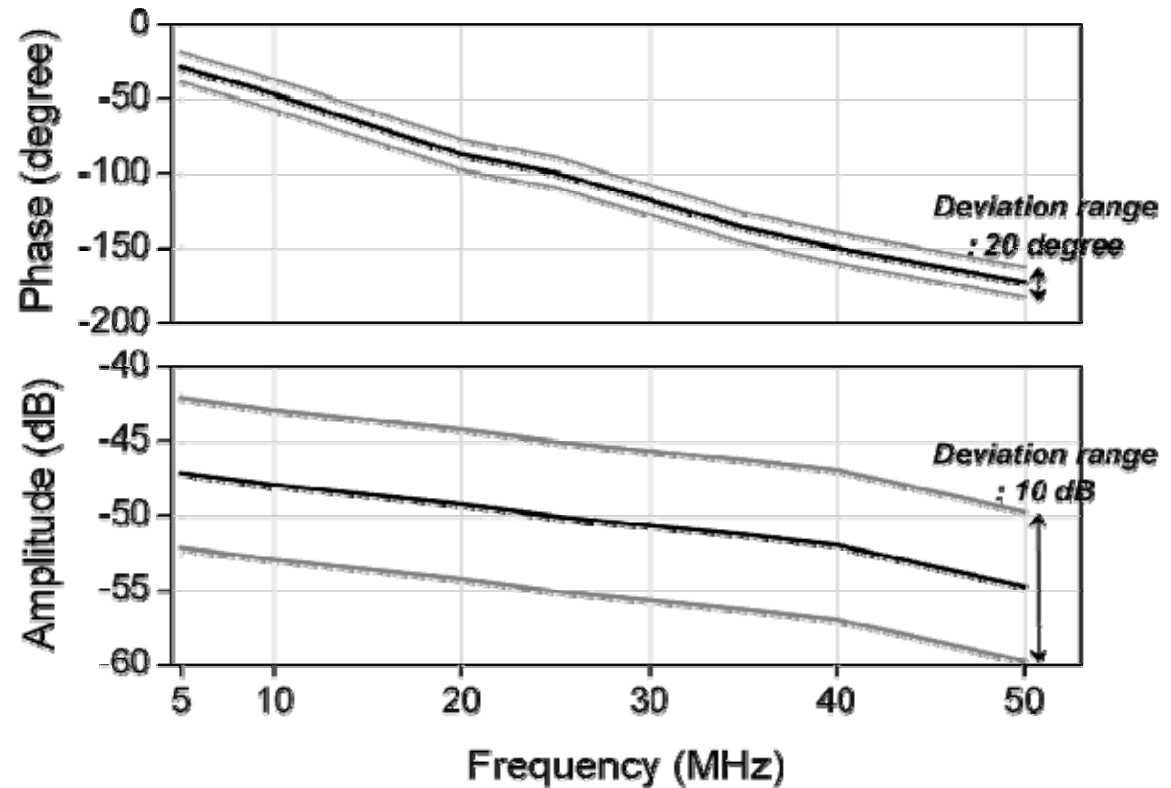
# Frequency Response

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



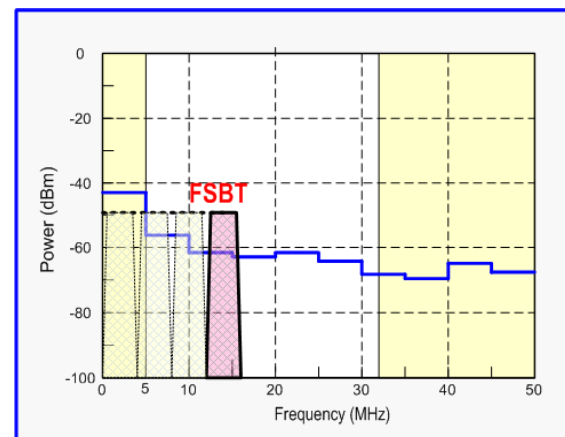
$$\text{Amplitude} = \frac{|V_{\text{output}}|}{|V_{\text{input}}|}$$

$$\text{Phase} = \frac{\angle V_{\text{output}}}{\angle V_{\text{input}}}$$



# How to transmit Digital Signal Directly?

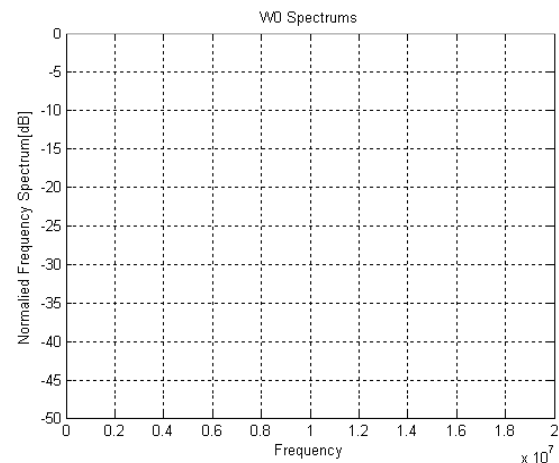
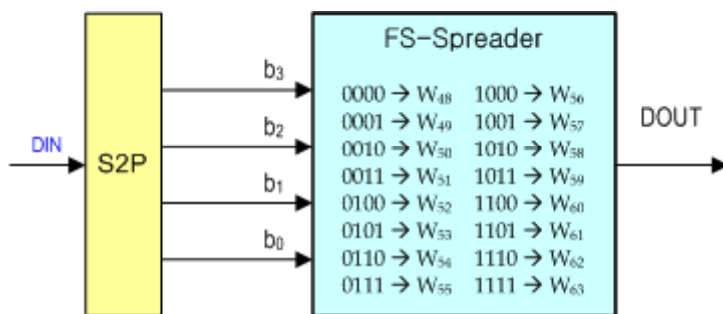
- **FSBT** Background
  - Direct Digital Transmission
    - **No RF**
  - Band Selection
    - **Avoid Low Frequency**
    - $P_{\text{internal Signaling}} \gg P_{\text{external radiated}}$
  - More **Processing Gain**



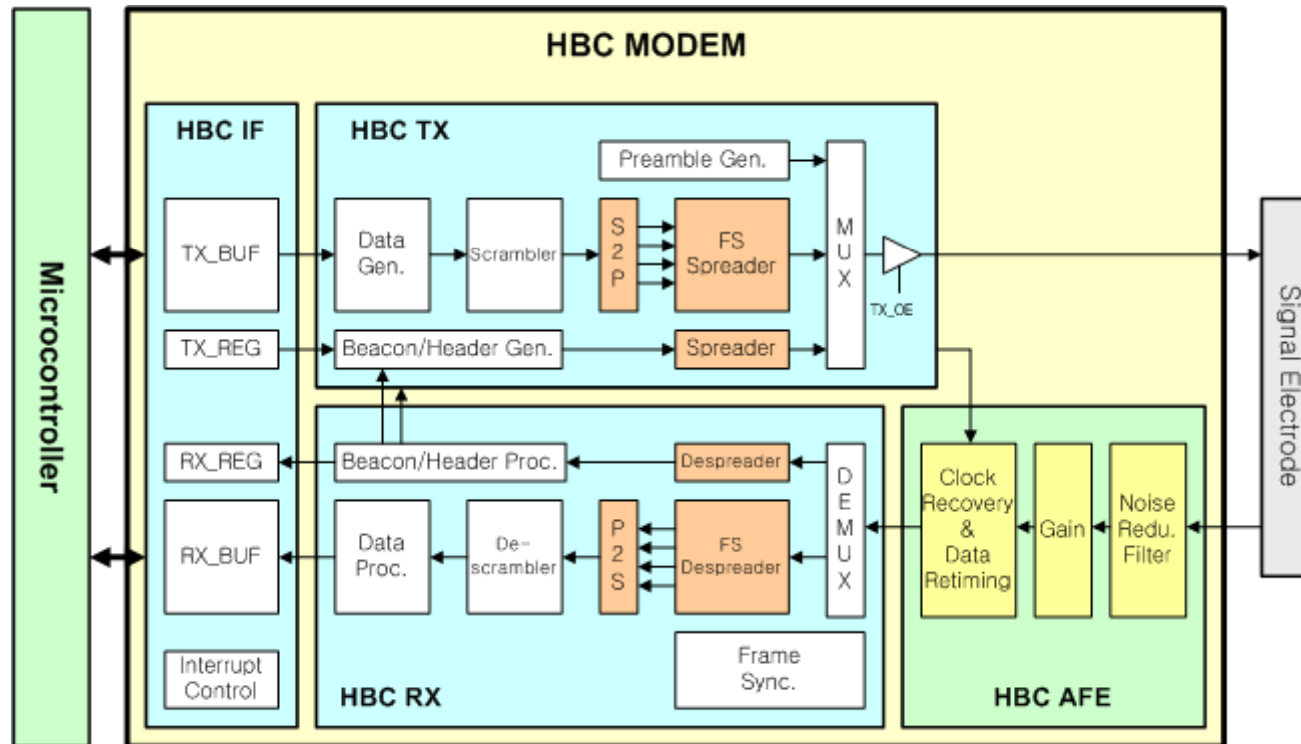
*FSBT: Frequency Selective Baseband Transmission*

# 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



# HBC System Overview



Simulation Parameters  
BER Performance Evaluation  
Link Budget

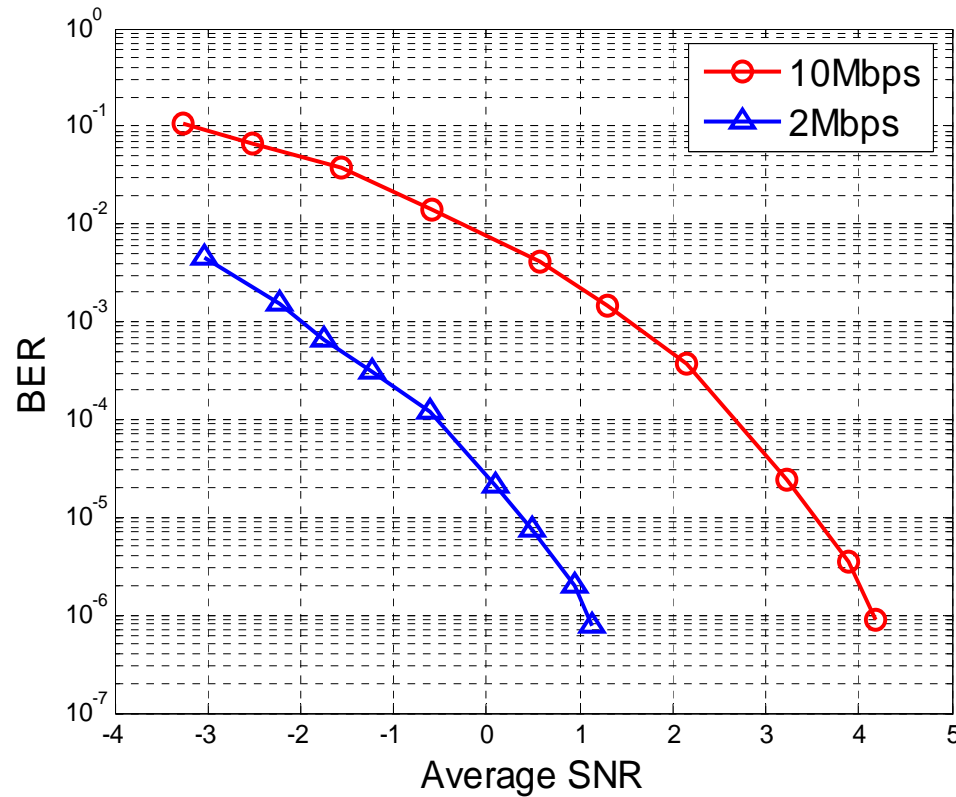
# PERFORMANCE ANALYSIS

# 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



Average SNR at BER 10<sup>-6</sup>

# Link Budget

Parameter	Value	
Information Data Rate [Mbps]	10	2
Tx Power [dBm]	-15.1	-15.1
Path Loss [dB]	55	54
Bandwidth [dBHz]	74	69
Rx Input Power ( $P_R$ ) [dBm]	-70.1	-69.1
Rx Noise Figure ( $N_F$ ) [dB]	10	10
Noise Power ( $N = kTB + N_F$ ) [dBm]	-90	-95
SNR Required ( $S$ ) [dB]	4.2	1.1
Implementation Loss ( $I$ ) [dB]	3	3
Rx Sensitivity ( $R = N + S + I$ ) [dBm]	-82.8	-90.9
Link Margin ( $M = P_R - R$ ) [dB]	12.7	21.8



# Power Consumption

- Normal Operation
  - 20 mW @ 10 Mbps
    - Modem: 14 mW
    - AFE: 6 mW
- Sleep Mode
  - Less than 10  $\mu$ W

# 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

- 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