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

Submission Title: [NICT's Narrow band PHY proposal for WBAN]

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Re: [Response to CFP]

Abstract: [The contribution illustrates a PHY for 15.6.]

Purpose: [To provide a narrow band PHY for WBANs.]

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NICT's Narrow-Band PHY Proposal for WBAN

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Summary

- Target data rate
 - Mandatory modes: less than 75 kbps (Bandwidth is less than 300kHz)
 - Available frequency bands:
 - MICS band (402-405 MHz)
 - WMTS bands (608-614, 1395-1400, and 1427-1432 MHz (US), 420-450 MHz (Japan))
 - ISM and other available bands (433 MHz (SRD), 868 MHz (EU), 902-928 MHz (US), 950-956 MHz (Japan), etc.)
 - Optional mode: up to 2.0 Mbps
 - Available frequency bands:
 - ISM bands
- PHY solution
 - GFSK modulation
 - The use of FEC code of (63,55)-RS over GF(2⁶) is optionally supported.

Why do we need a narrowband PHY solution?

Wideband PHY cannot be successfully applied to the medical-authorized frequency bands

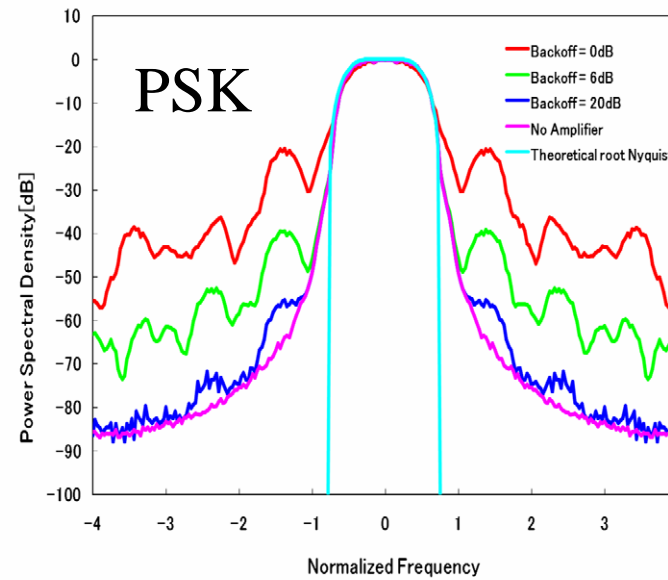
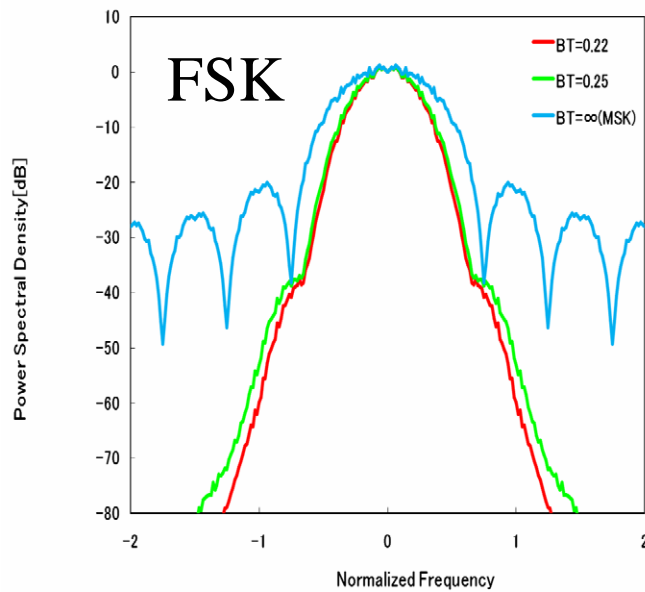
- Emission power limit
- Channel spacing
- Modulation type

Why do we employ GFSK?

- It is implementable with low cost and low power consumption with matured technology
- It is highly power-efficient
 - Can use a nonlinear amplifier at Tx
 - Can be non-coherently detected without PLL at Rx
 - Can shorten the length of preamble

Comparison between FSK and PSK

	FSK	PSK
Nonlinear amplification	OK	NG (larger out-band radiation)
Detection	Non-coherent (w/o PLL)	Coherent (w/ PLL)
Preamble length	Short	Long



Data rate

- Modulation: GFSK (modulation index $\beta = 1.0$, and $BT=0.5$)
 - Multiple sets of channel spacing/data rate
 - No specific band plan (No channelization)
- FEC: Optional RS code with (63, 55) over $GF(2^6)$
 - 16-bit CRC over a packet is mandatory.

Data rate R	Modulation	Modulation parameters	Channel spacing B	FEC	Mandatory	Target frequency bands
12.5 kbps	GFSK	$\beta=1.0,$ $BT=0.5$	50 kHz	Mandatory: None Optional: RS code (63,55) over $GF(2^6)$	No (A single channel spacing allowed in a frequency band)	MICS, WMTS (except for 608- 614MHz), ISM, etc.
25.0 kbps			100 kHz			
50.0 kbps			200 kHz			
75.0 kbps			300 kHz			
300.0 kbps			1.2 MHz			ISM
50.0 kbps	FH-GFSK (6 channels)		1.2 MHz		Yes	WMTS (608- 614MHz), ISM, etc.
2 Mbps	GFSK		4 MHz		No	ISM

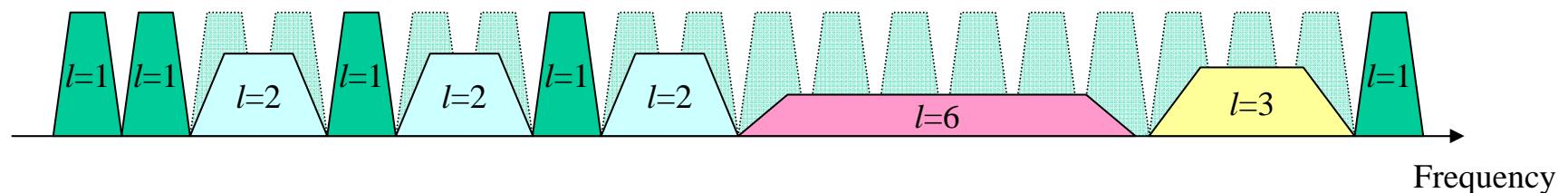
Accommodation of different data rates (channel spacings) in a given frequency band

- Base data rate (R) / channel spacing (B) :

$$R/B = 12.5\text{kbps}/50\text{kHz}$$
- Accommodatable data rate/channel spacing :

$$(R/B) \cdot l \quad (l=1,\dots,6)$$

l	1	2	3	4	5	6
R [kbps]	12.5	25	37.5	50	62.5	75
B [kHz]	50	100	150	200	250	300



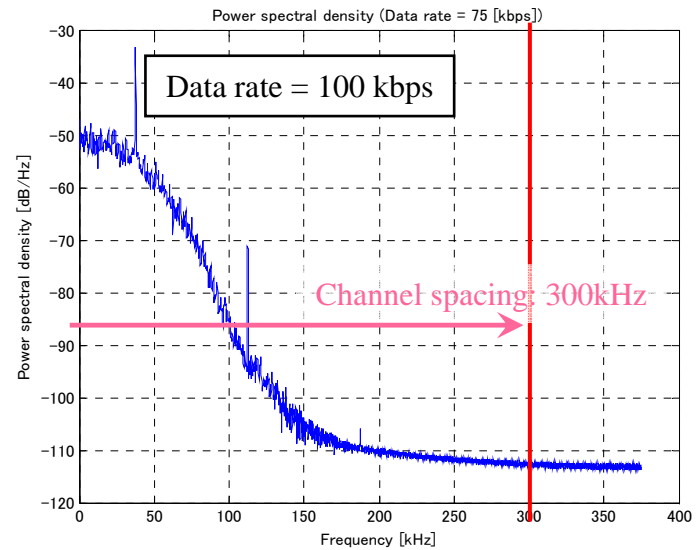
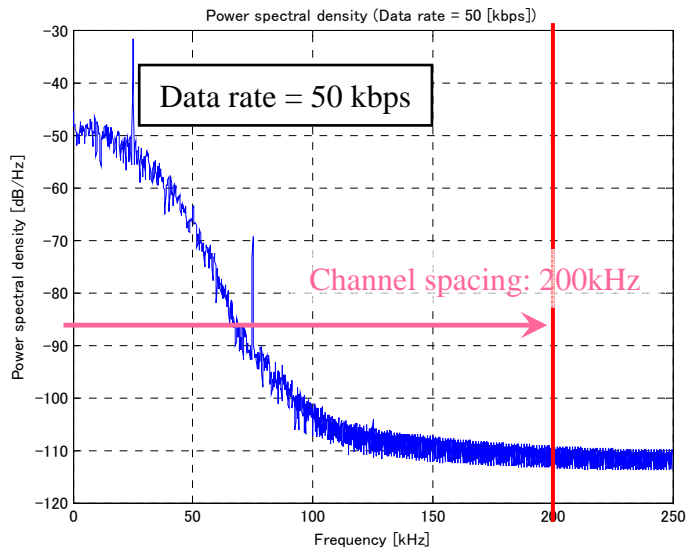
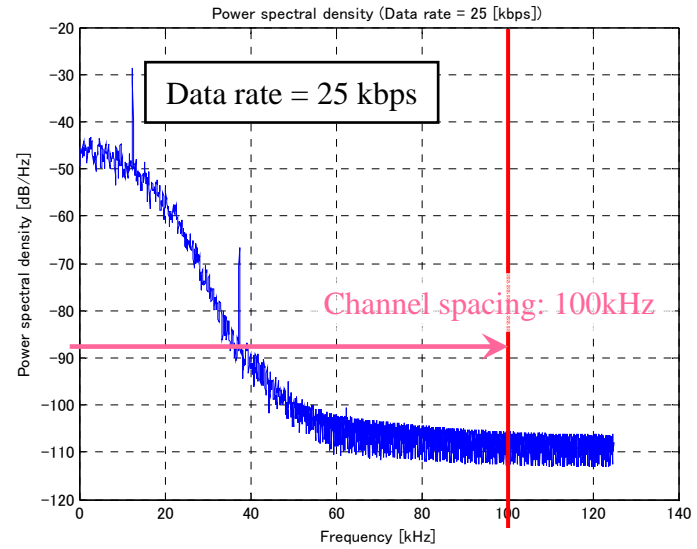
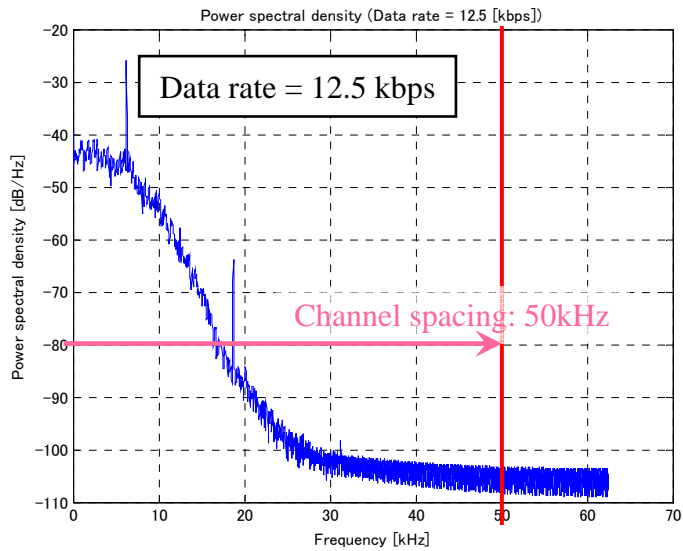
- In addition, $B=1.2\text{MHz}$ and 4MHz for broad band solution

Interference and coexistence

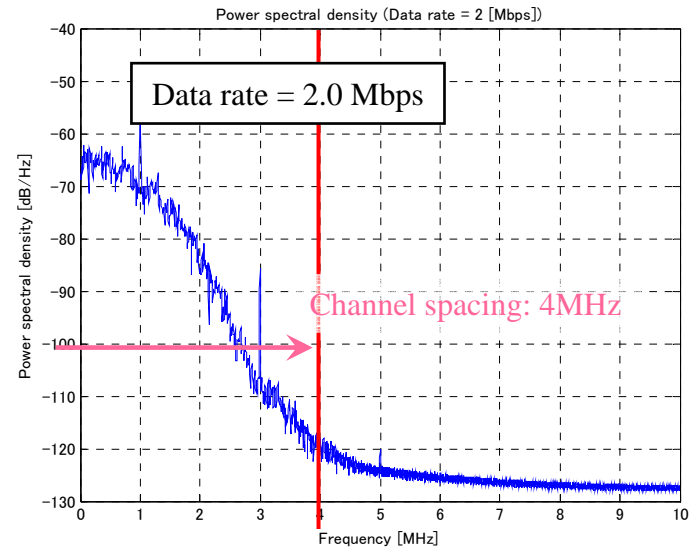
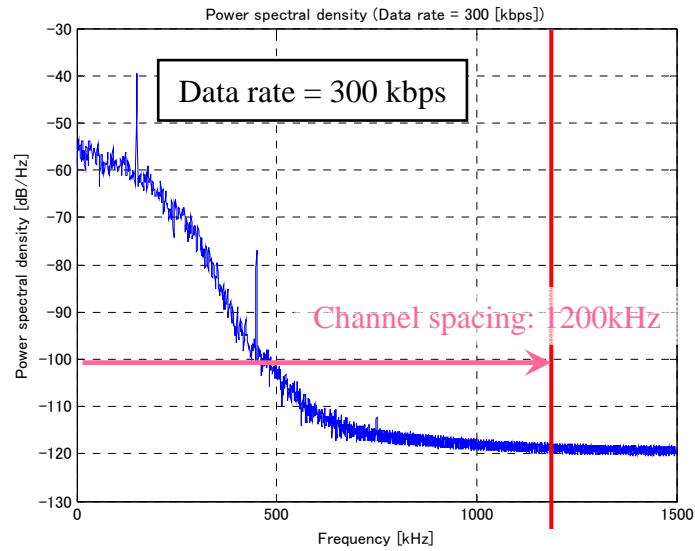
- MICS and WMTS
 - These are the frequency bands authorized for medical uses, in principle, with interference free
 - More than ten channels can be accommodated in a frequency band, so a BAN can be supported in a different frequency channel, in principle, with inter-BAN interference free

- ISM
 - More than ten channels can be accommodated in a frequency band, so a BAN can be supported in a different frequency channel, in principle, with inter-BAN interference free

Tx Spectrum (1)

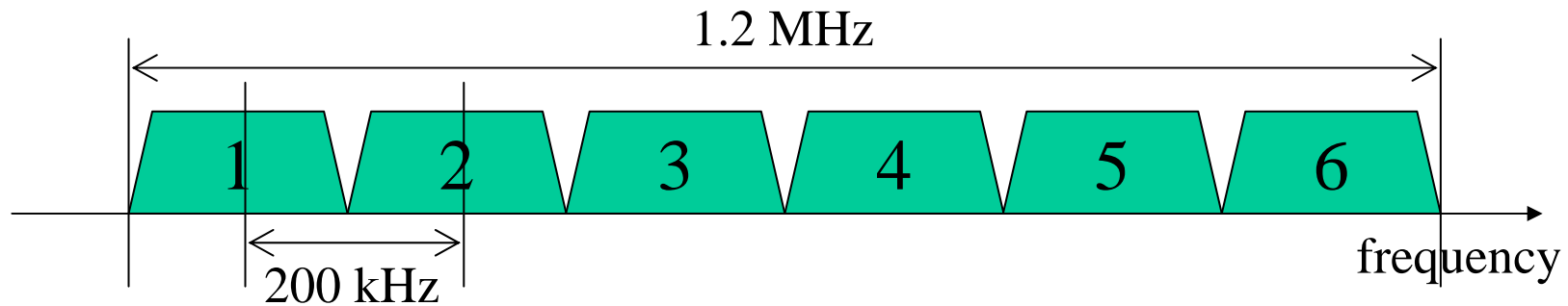


Tx spectrum (2)



Hopping Pattern in FH-GFSK

- 6 sub-channels in a BW=1.2 MHz channel



- Hopping patterns based on one coincident code are defined.
 - 6 WBANs are simultaneously accommodated.

FH_SEQ(1)	1	2	3	4	5	6
FH_SEQ(2)	5	3	1	6	4	2
FH_SEQ(3)	4	1	5	2	6	3
FH_SEQ(4)	6	5	4	3	2	1
FH_SEQ(5)	2	4	6	1	3	5
FH_SEQ(6)	3	6	2	5	1	4

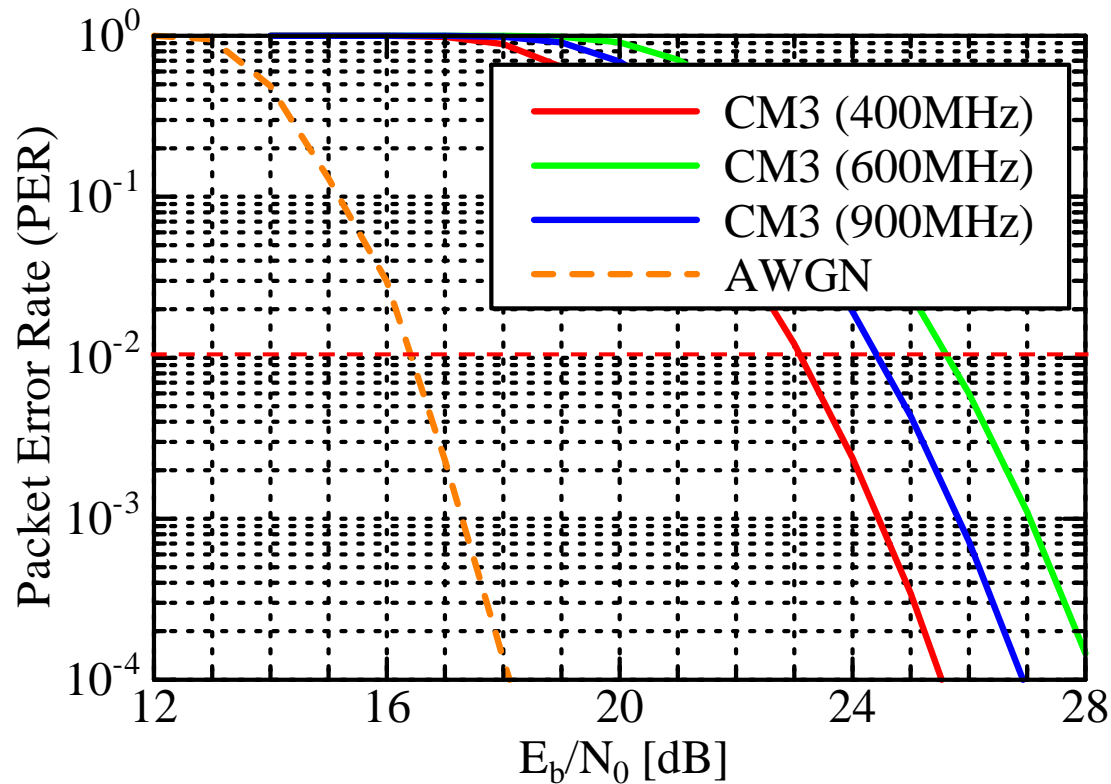
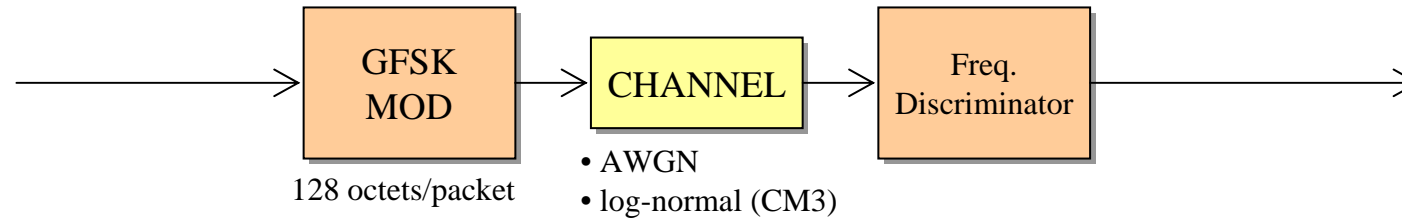
Packet format

- Preamble
 - length: 4 octets (0xAA)
- SFD (start frame delimiter)
 - length: 1 octet
- PHR
 - type of data content, such as medical or non-medical
 - length: 1 octet
- PHY payload
 - length: 8~128 octets

SHR		PHR	PHY payload
Preamble	SFD	Reserve	PSDU
4 octets	1 octet	1 octet	

Performance evaluation

- No FEC



Channel model	Required Eb/N0 for PER of 10 ⁻²
AWGN	16.4 dB
log-normal CM3 (400 MHz)	23.1 dB
log-normal CM3 (600 MHz)	25.6 dB
log-normal CM3 (900 MHz)	24.3 dB

Performance evaluation

- Wearable WBAN (Channel model: CM3)
 - 400 MHz

Data rate	Modulation	Rx BW	NF +IL*	FEC	Tx power	Required Eb/N0 (PER = 10 ⁻²)	Path loss (3m)	Margin
12.5 kbps	GFSK	50 kHz	20 dB	None	0 dBm	23.1 dB	45.0 dB CM3	68.6
25 kbps		100 kHz						65.6
50 kbps		200 kHz						62.6
75 kbps		300 kHz						60.9
300 kbps	GFSK	1.2 MHz	20 dB	None	0 dBm	23.1 dB	45.0 dB CM3	54.9
50 kbps (FH)	GFSK	1.2 MHz (200kHz x 6)	20 dB	None	0 dBm	23.1 dB	45.0 dB CM3	62.6

*: NF (Noise figure) and IL (Implementation loss) of 20 dB is tentative value.

Performance evaluation

- Wearable WBAN (Channel model: CM3)
 - 600 MHz

Data rate	Modulation	Rx BW	NF +IL*	FEC	Tx power	Required Eb/N0 (PER = 10 ⁻²)	Path loss (3m)	Margin
12.5 kbps	GFSK	50 kHz	20 dB	None	0 dBm	25.6 dB	57.6 dB CM3	53.6
25 kbps		100 kHz						50.6
50 kbps		200 kHz						47.6
75 kbps		300 kHz						45.8
300 kbps	GFSK	1.2 MHz	20 dB	None	0 dBm	23.1 dB	45.0 dB CM3	38.8
50 kbps (FH)	GFSK	1.2 MHz (200kHz x 6)	20 dB	None	0 dBm	25.6 dB	57.6 dB CM 3	47.6

*: NF (Noise figure) and IL (Implementation loss) of 20 dB is tentative value.

Performance evaluation

- Wearable WBAN (Channel model: CM3-A)
 - 900 MHz

Data rate	Modulation	Rx BW	NF +IL*	FEC	Tx power	Required Eb/N0 (PER = 10 ⁻²)	Path loss (3m)	Margin
12.5 kbps	GFSK	50 kHz	20 dB	None	0 dBm	24.3 dB	59.2 dB CM3	53.3
25 kbps		100 kHz						50.3
50 kbps		200 kHz						47.3
75 kbps		300 kHz						45.5
300 kbps	GFSK	1.2 MHz	20 dB	None	0 dBm	23.1 dB	45.0 dB CM3	39.4
50 kbps (FH)	GFSK	1.2 MHz (200kHz x 6)	20 dB	None	0 dBm	24.3 dB	59.2 dB CM 3	47.3

*: NF (Noise figure) and IL (Implementation loss) of 20 dB is tentative value.

Performance evaluation

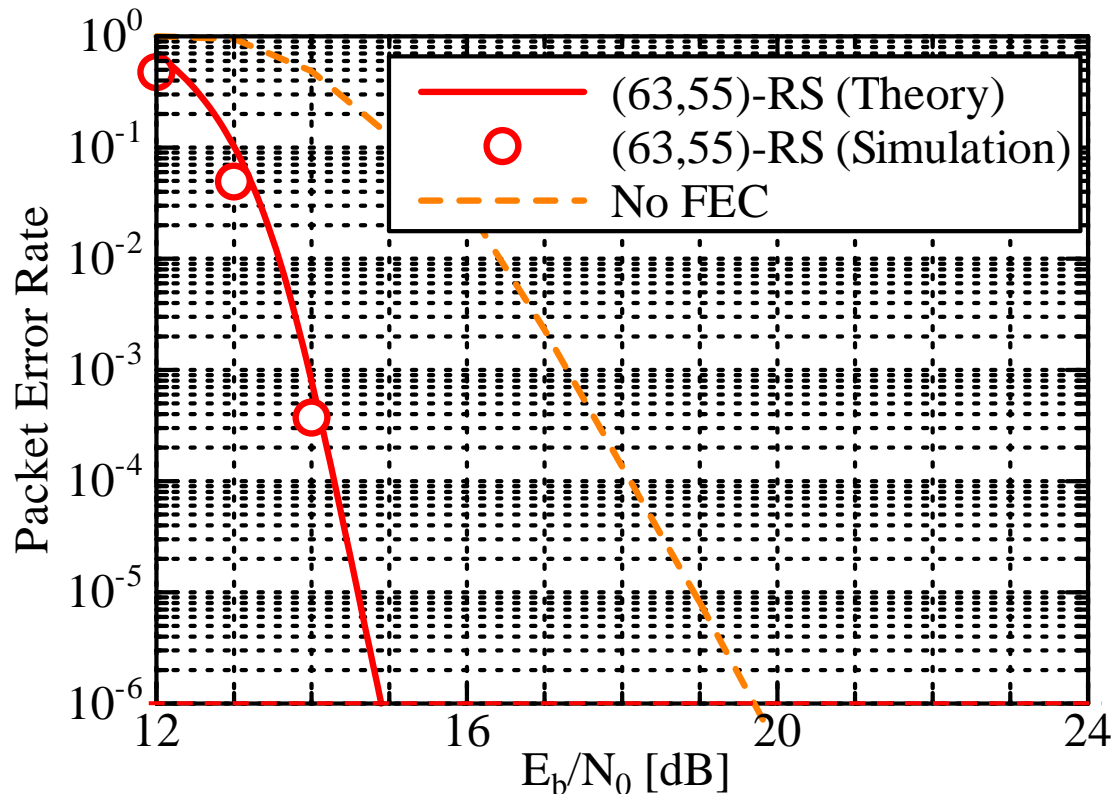
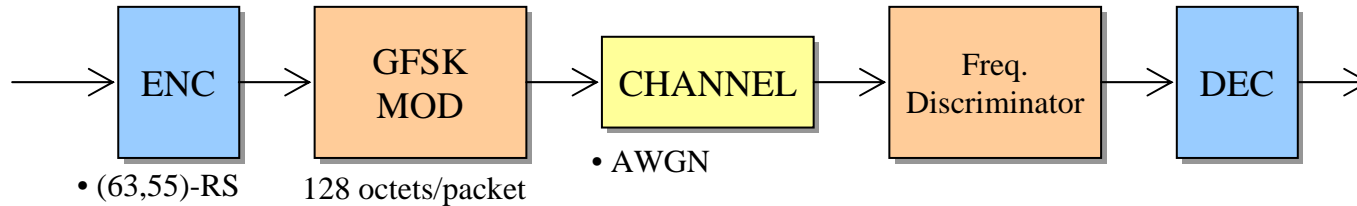
- Implantable WBAN (Channel model: CM1)

Data rate	Modulation	Rx BW	NF +IL*	Duty ratio	FEC	Tx power	Required Eb/N0 (PER = 10 ⁻⁶)	Path loss		Margin
								In-body (150 mm)	Outside (2.85m)	
12.5 kbps	GFSK	50 kHz	20 dB	5 %	None	-16 dBm (MICS)	19.6 dB	64.7 dB (CM2, deep tissue)	33.6 dB (free- space)	13.2 dB
25 kbps		100 kHz								11.1 dB
50 kbps		200 kHz								7.1 dB
75 kbps		300 kHz								5.3 dB
300 kbps	GFSK	1.2 MHz	20 dB	100 %	None	-10 dBm (eg. ISM)	19.6 dB	64.7 dB (CM2, deep tissue)	0 dB (body surface)	18.9 dB
2 Mbps	GFSK	4 MHz	20 dB	100 %	None	-10 dBm (eg. ISM)	19.6 dB	64.7 dB (CM2, deep tissue)	0 dB (body surface)	23.7 dB

*: NF (Noise figure) and IL (Implementation loss) of 20 dB is tentative value.

Performance evaluation

- With optional FEC (for implantable WBAN)



FEC	Required Eb/N0 for PER of 10^{-6} *
No FEC	19.6 dB
(63,55)-RS	14.9 dB

*: Implantable WBAN requires lower PER than wearable WBAN.

Performance evaluation

- Implantable WBAN (Channel model: CM1, with (63,55)-RS)

Data rate	Modulation	Rx BW	NF +IL*	Duty ratio	FEC	Tx power	Required Eb/N0 (PER = 10 ⁻⁶)	Path loss		Margin
								In-body (150 mm)	Outside (2.85m)	
12.5 kbps	GFSK	50 kHz	20 dB	5 %	None	-16 dBm (MICS)	14.9 dB	64.7 dB (CM2, deep tissue)	33.6 dB (free- space)	20.6 dB
25 kbps		100 kHz								17.6 dB
50 kbps		200 kHz								14.6 dB
75 kbps		300 kHz								12.8 dB
300 kbps	GFSK	1.2 MHz	20 dB	100 %	None	-10 dBm (eg. ISM)	14.9 dB	64.7 dB (CM2, deep tissue)	0 dB (body surface)	33.4 dB
2 Mbps	GFSK	4 MHz	20 dB	100 %	None	-10 dBm (eg. ISM)	14.9 dB	64.7 dB (CM2, deep tissue)	0 dB (body surface)	28.2 dB

*: NF (Noise figure) and IL (Implementation loss) of 20 dB is tentative value.

Conclusions

NICT's GFSK-based narrowband PHY

- A straightforward, simple and efficient solution for satisfying the requirements in medical scenes
- Supported by matured technology