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

Submission Title: [Meiji University UWB PHY Proposal for Body Area Network]
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Re: [This document is a response of Meiji University to the Call For Proposal from the IEEE P802.15 Task Group 6 on BAN.]

Abstract: [This document describes a PHY proposal with UWB-IR]

Purpose: [This document is intended as a PHY proposal for consideration in IEEE 802.15.6.]

Meiji University UWB PHY Proposal: Flexible UWB-IR PHY Proposal for Body Area Network

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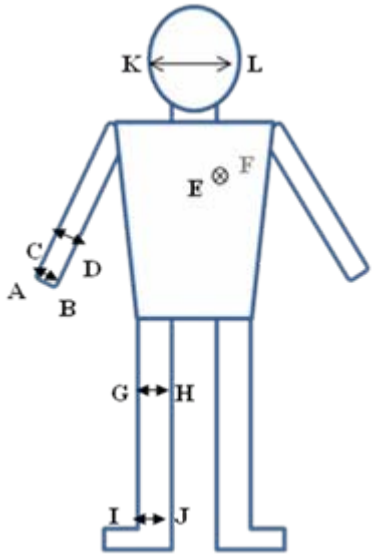
Presentation summary: UWB-IR with flexibilities

- Proposal for PHY only
- UWB-IR PPM-SS
- Scalable data rate
- Non-coherent detection
- Tx power can be reduced. Tx power may be less than -41.3dBm/MHz at short range, e.g. on-body to on-body
- Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible, for coexistence or avoiding interferences

On-body to on-body link may be kept with less transmitting power than on-body to external



Link	Description
A - B	Through the hand
C - D	Through the wrist
E - F	Torso, front to back
G - H	Through the thigh
I - J	Through the ankle
K - L	Left ear to right ear
M – N	Glucose sensor to Glucose pump

Why should we transmit maximal Tx power of -41.3dBm/MHz in shorter and lower data rate operation?

Can we reduce Tx power to coexist with other systems? YES!

Radio Regulation for Reduced Tx Power UWB

- In some regions, Tx power of lower than -41.3dBm/MHz UWB relaxes radio regulation in certain frequency band usages
- Examples: (P802.15-08-0034r10)

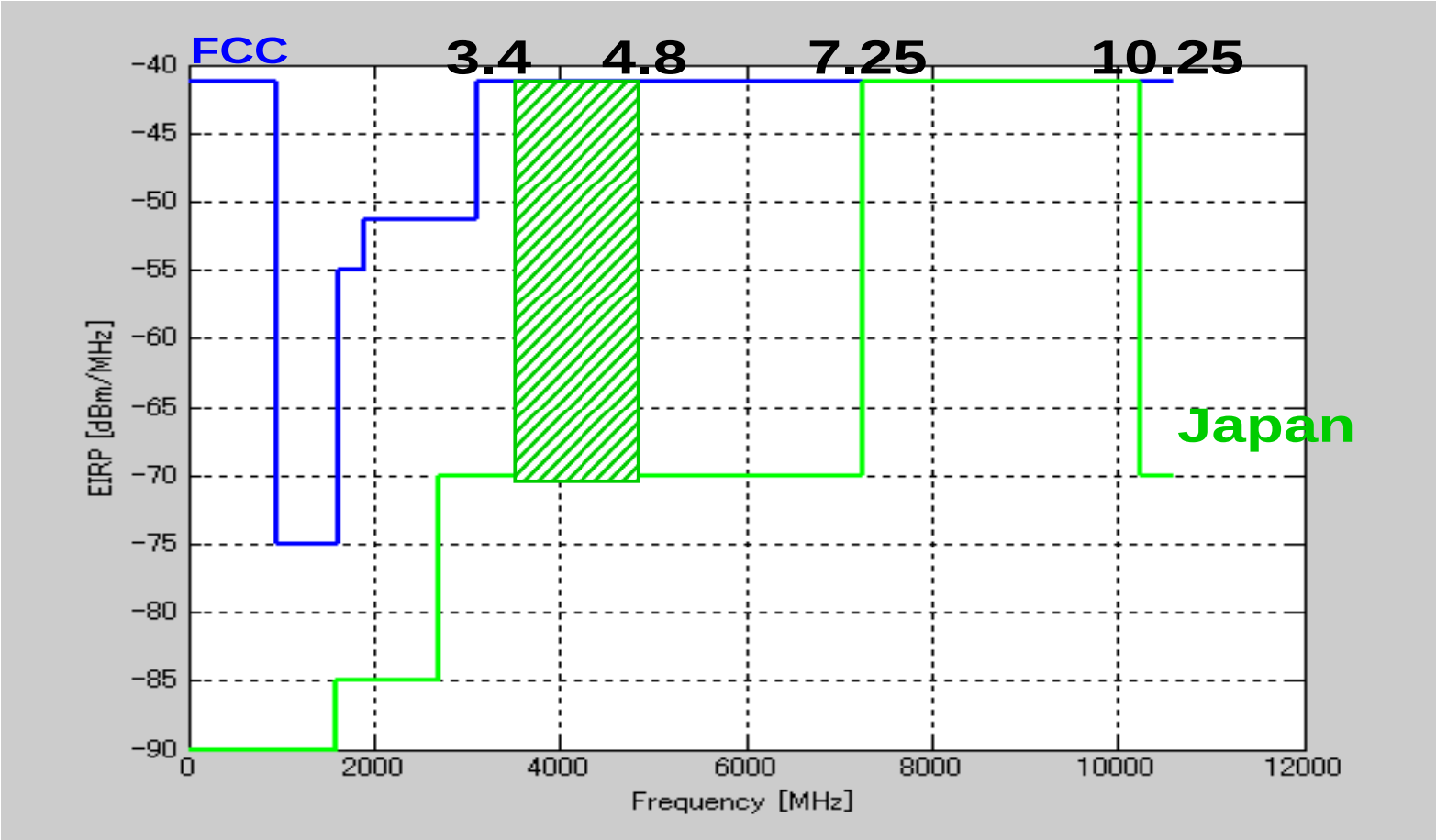
  3.1-6GHz for -70dBm/MHz or 8.5-10.6GHz for -65dBm/MHz in EU,

  3.4-4.8GHz for -70dBm/MHz in Japan,

  can operate without DAA function

  DAA: Detection and Avoidance

UWB Spectrum Mask



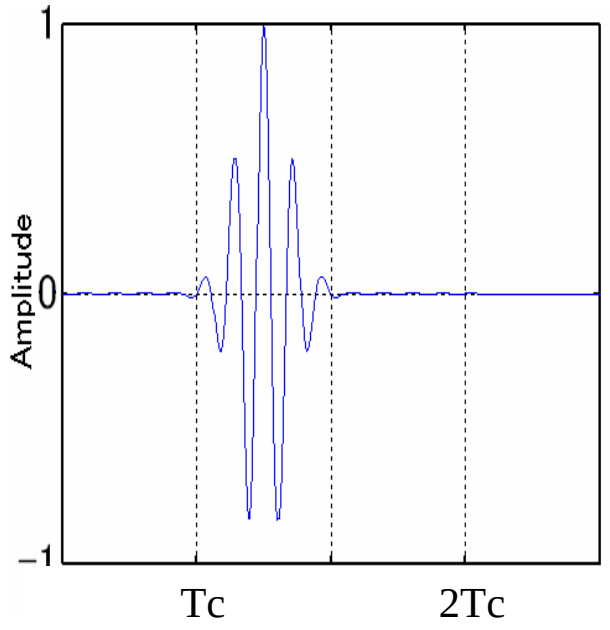
from P802.15-08-0034r10

Proposal PHY

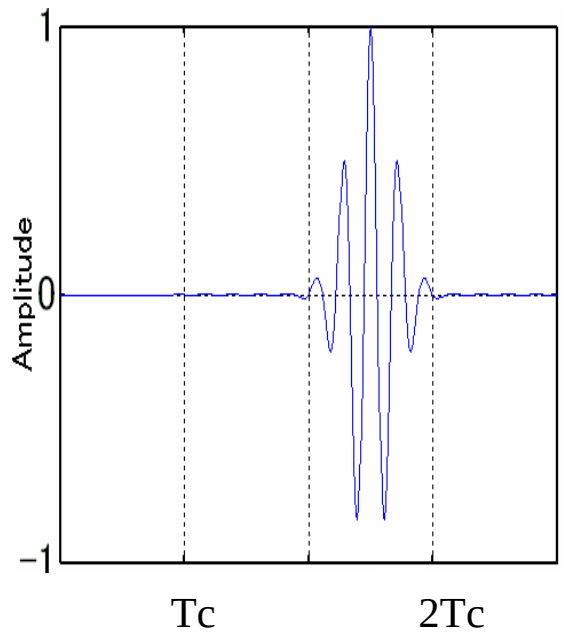
UWB-IR PPM-SS

- **Non-coherent detection**
- **Center freq.: UWB band(3.1GHz to 10.6GHz)**
- **Tx Bandwidth: 500MHz or wider**
- **Scalable data rate: 10kbps to 10Mbps**
- **Multiple piconets with SS codes and TX center frequency**
- **Tx power may be reduced for short range. Tx power may be less than -41.3dBm/MHz at short range, e.g. on-body to on-body ~ -70dBm/MHz**
- **Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible, for coexistence or avoiding interferences**

BPPM-UWB in principle



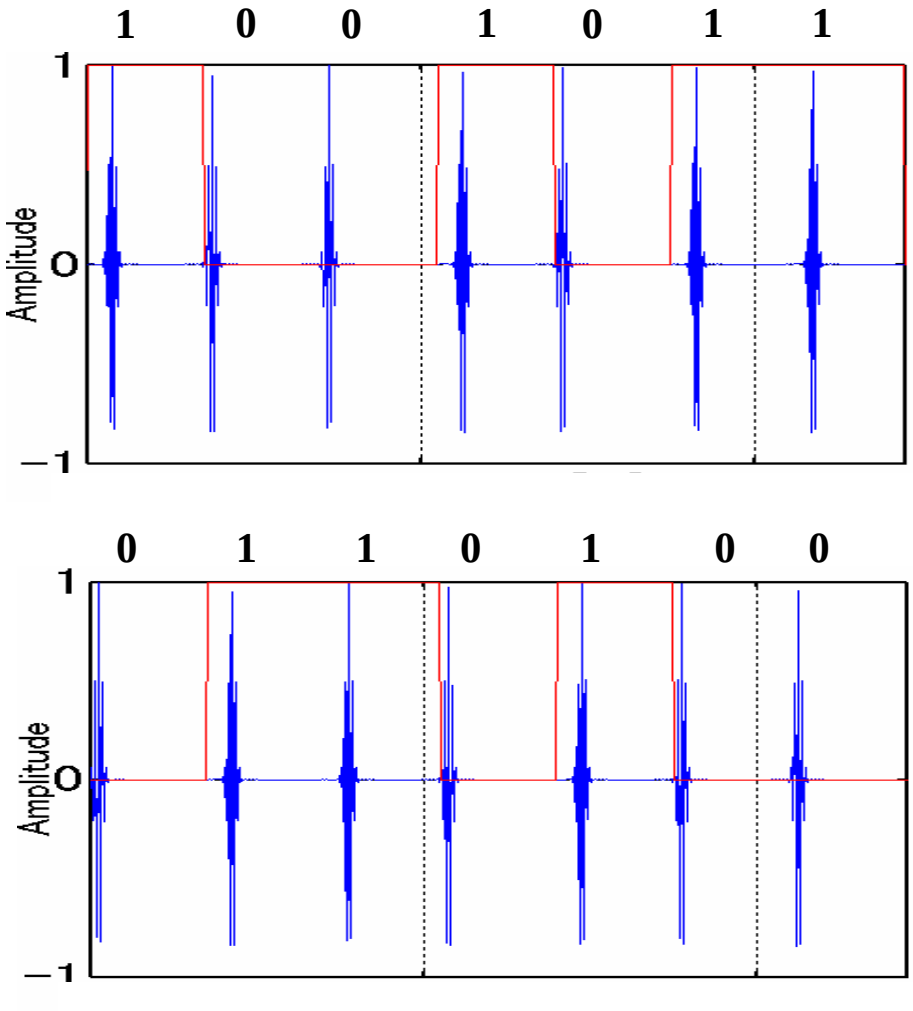
Data 0



Data 1

unit pulses are shifted Ts based on data “0” and “1”

Modulation: PPM-SS-UWB



Principle Explanation for SS code length L=7

Pulse train [1 0 0 1 0 1 1] corresponds data “0”

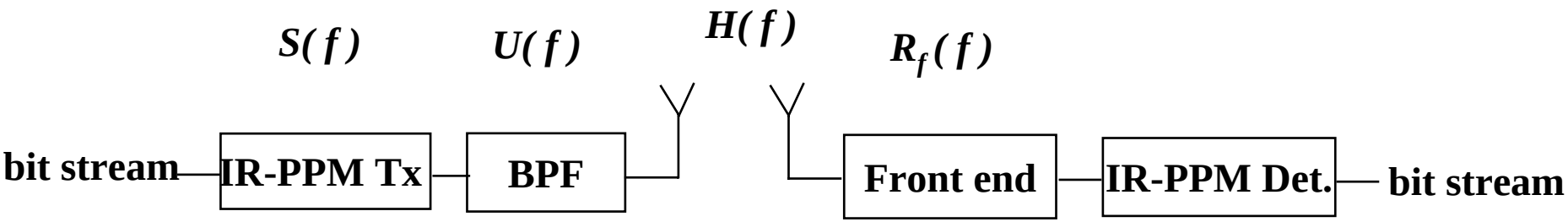
Pulse train [0 1 1 0 1 0 0] corresponds data “1”

Ikebe et.al, IWUWBT2005

UWB-IR : Bandwidth, center frequency and pulse shape of both Tx and Rx are flexible in principle

- When PPM with energy detection of pulse is employed,
- As long as correlation output of Rx produce a certain level for PPM detection, transfer function of Rx front-end or template waveform at correlator does not have to match the transmitted one.

Advantage of IR-PPM with Energy Detection



S(f): Tx UWB-IR PPM Pulse

U(f): Tx BPF,and Antenna

X(f)= S(f) U(f): Tx Signal

H(f): Channel including Rx Antenna

$R_f(f)$: Rx BPF, Template, etc.

$R_f(f)$ does not have to match transmitted signal $H(f)X(f)$

We allow Tx-Rx mismatched filter. This eases UWB-IR design

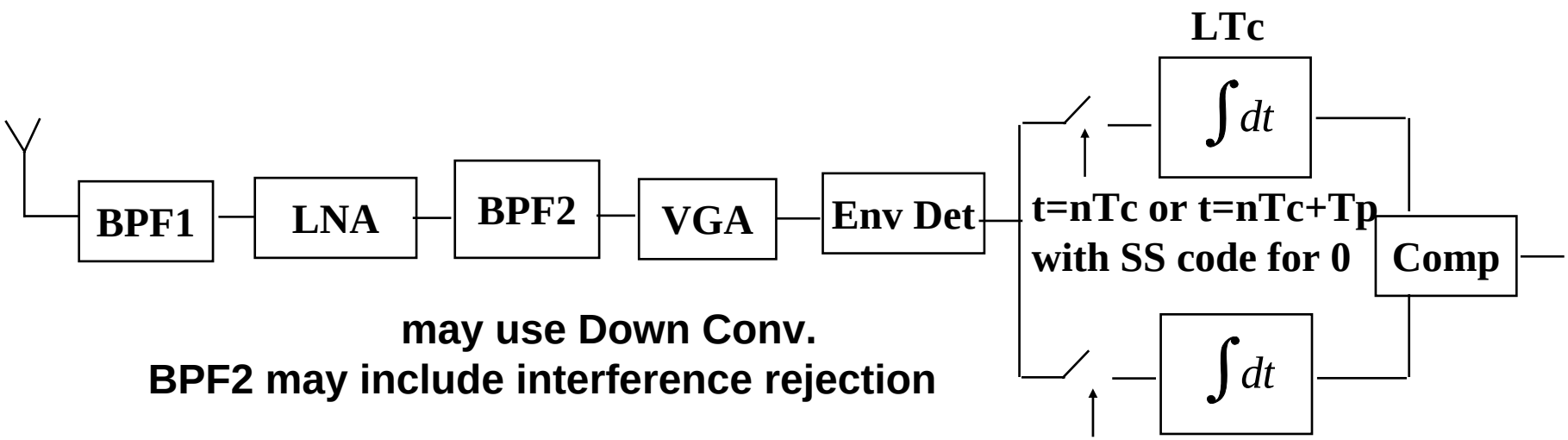
- **If we allow mismatch loss, receiver front end transfer function $R_f(f)$ does not have to match transmitted signal $H(f)X(f)$. $R_f(f)$ can be designed based on interference resistant manner [Ikegami, IWUWBS2003, Ohno, IEEE MTT2006].**
- ***H(f)*** **: transfer function of channel including Rx antenna**
- ***X(f)=S(f)U(f)***
- ***X(f)*** **: transmitted signal**
- ***S(f)*** **: transmitting UWB pulse**
- ***U(f)*** **: transfer function of Tx filter and antenna**

Base line PHY parameters for example

UWB-IR PPM-SS Non-coherent detection

- **Tx Center freq.: IEEE 802.15 4a like UWB band(3.1GHz to 10.6GHz)**
- **Tx Bandwidth: IEEE 802.15 4a like, 500MHz or wider**
- **Chip pulse repetition interval Tc: ~100 ns**
- **Chip pulse shape: raised cosine, Gaussian or other**
- **PPM pulse shift Tp: ~50 ns**
- **Number of chip pulse (SS code length) L for 1 bit: 11 for 1Mbps to 1024 for 10kbps**
- **Guard interval Tg: ~0**
- **Scalable data rate: 10kbps to 1Mbps (to 10Mbps)**
- **Multiple piconets with SS codes and Tx center frequency**
- **Tx power may be reduced for short range. Tx power may be less than -41.3dBm/MHz at short range, e.g. on-body to on-body ~ -70dBm/MHz**

Example Rx Block diagram



may use Down Conv.
BPF2 may include interference rejection

Tc: Chip pulse repetition interval

Tp: PPM pulse shift

L: Number of chip pulse per bit (SS code length)

Digital part can run at chip clock level, up to 10 ~ 20 MHz

Example Link Budget Analyses 1 (1m distance, Rx NF6dB)

	Free Sp	CM3	Low PSD	10kbps	Mismatch	8GHz
Center Freq [MHz}	4000	4000	4000	4000	4000	8000
TX BPF BW [MHz]	500	500	500	500	500	500
RX BPF BW [MHz]	500	500	500	500	100	500
TX PSD[dBm/MHz]	-41.3	-41.3	-70	-70	-70	-70
EIRP[dBm]	-14.3	-14.3	-43.0	-43.0	-43.0	-43.0
Free space path loss[dB]	44.5	44.5	44.5	44.5	44.5	50.5
CM3 Excess Path loss[dB]	0.0	16.0	16.0	16.0	16.0	16.0
Total path loss [dB]	44.5	60.5	60.5	60.5	60.5	66.5
N0[dBm/Hz]	-169.1	-169.1	-169.1	-169.1	-169.1	-169.1
C[dBm]	-58.8	-74.8	-103.5	-103.5	-110.5	-109.5
C/No[dBHz]	110.3	94.3	65.6	65.6	58.6	59.6
Bit Rate [Mbps]	10	10	0.15	0.01	0.01	0.01
Eb/No[dB]	40.3	24.3	13.8	25.6	18.6	19.6
Req. Eb/No[dB]	11.0	11.0	11.0	11.0	11.0	11.0
margin [dB]	29.3	13.3	2.8	14.6	7.6	8.6

10Mbps OK 150kbps OK margin 14.6dB 7.6dB 8.6dB

Example Link Budget Analyses 2 (3m distance, Rx NF 6dB)

	CM3	CM3	CM3	Low PSD	8GHz
Center [MHz}	4000	4000	4000	4000	8000
TX BPF BW [MHz]	500	500	500	500	500
RX BPF BW [MHz]	500	500	500	500	500
TX PSD[dBm/MHz]	-41.3	-41.3	-41.3	-70	-41.3
EIRP[dBm]	-14.3	-14.3	-14.3	-43.0	-14.3
Free space path loss[dB]	54.0	54.0	54.0	54.0	60.0
CM3 Excess Path loss[dB]	16.0	16.0	16.0	16.0	16.0
Total path loss [dB]	70.0	70.0	70.0	70.0	76.0
N0[dBm/Hz]	-169.1	-169.1	-169.1	-169.1	-169.1
C[dBm]	-84.3	-84.3	-84.3	-113.0	-90.4
C/No[dBHz]	84.8	84.8	84.8	56.1	78.7
Bit Rate [Mbps]	10	0.15	0.01	0.01	0.01
Eb/No[dB]	14.8	33.0	44.8	16.1	38.7
Req. Eb/No[dB]	11.0	11.0	11.0	11.0	11.0
margin [dB]	3.8	22.0	33.8	5.1	27.7
	10Mbps OK	150kbps	10kbps	10kbps OK	10kbps

UWB PHY, Rx is subject to interference, robust receiver design will be key (may be out of scope TG6 spec.)

- **Interference detection and rejection type receiver design**
- **Interference rejection by BPF or notch filter [Ikegami, IEEE IWUWBS2003]**
- **Interference rejection by receiver template waveform processing [Ohno, IEEE MTT 2006]**
- **UWB-IR type IEEE802.15.4a signal can be detected by simpler energy detector [Hasegawa, IEEE ICUWB2008]**
- **Use of chirp template to detect interferences [Ohno, IEEE ICUWB2008]**

Conclusion: UWB-IR with flexibilities

- UWB-IR PPM-SS
- Scalable data rate
- Non-coherent detection
- Tx power can be reduced. Tx power may be less than -41.3dBm/MHz.
- Bandwidth, center frequency and pulse shape of Tx or Rx template are flexible, for coexistence or avoiding interferences.

References

- Tetsushi Ikegami, Kohei Ohno “Effect of interference from other radio system to UWB impulse radio,” IEEE Proc. IWUWBS2003 June 2003.
- Takanori Ikebe, Kohei Ohno, Tetsushi Ikegami, “Interference Study for UWB using Envelope Detection,” Proc. IWUWBT2005, Dec. 2005.
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- Makoto Hasegawa, Masaki Kumazawa, Tetsushi Ikegami, Kenichi Takizawa,”A Study for possibility of detecting IEEE802.15.4a signals,” IEEE ICUWB2008, vol.1, pp.217-220, Sept. 2008.

Thank you for your attention.