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Submission Title: [Outdoor Transmission Characteristics of IEEE 802.15.4 SUN FSK in the VHF Band]

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Re: [Wireless Next Generation, Long Range extension enhancements to 802.15.4-2020]

Abstract: Outdoor transmission characteristics of IEEE 802.15.4 SUN FSK in the VHF band are presented. A part of this contribution was supported from the commissioned research (No.05101) by National Institute of Information and Communications Technology (NICT) , Japan.

Purpose: Propose channel models to evaluate proposed systems for IEEE 802.15.4ad.

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Outdoor Transmission Characteristics of IEEE 802.15.4 SUN FSK in the VHF Band

Sept. 11, 2024

Hiroshi Harada and Jaeseok Lim

Background

- IEEE 802.15.4 SUN is a transmission scheme that can be used for all IoT applications, not just smart metering systems.
- The availability of OFDM for mobile communications was shown in Doc #390r2 to achieve the required packet error rate of IEEE 802.15.4 SUN OFDM even at speeds of several 10 km/h.
- Reception schemes for IEEE 802.15.4 SUN FSK in mobile environments have been presented in the literature [2][3].
- In order to transmit over a wide area of several kilometers using IEEE 802.15.4 SUN, it has been proposed to use the VHF band instead of Sub 1GHz. (Doc #50r2)
- In this contribution, the outdoor transmission characteristics of IEEE 802.15.4 SUN FSK in the VHF band are presented based on the literature [1].

Evaluation platform



BS transmission antenna

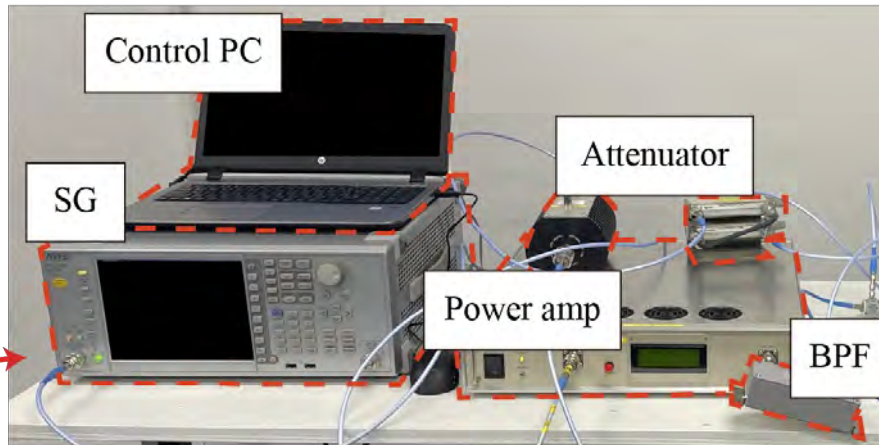


MS reception antenna

MS



MS receiver



BS transmitter

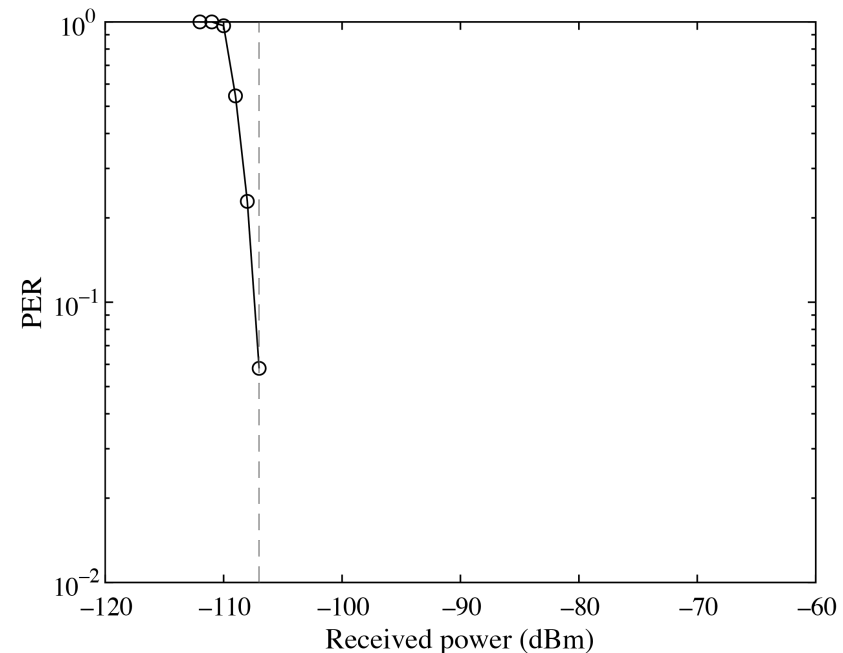
*BS: Base Station
MS: Moving Station
SG: Signal Generator
BPF: Band Pass Filter

Parameters and Receiver used for the experiment

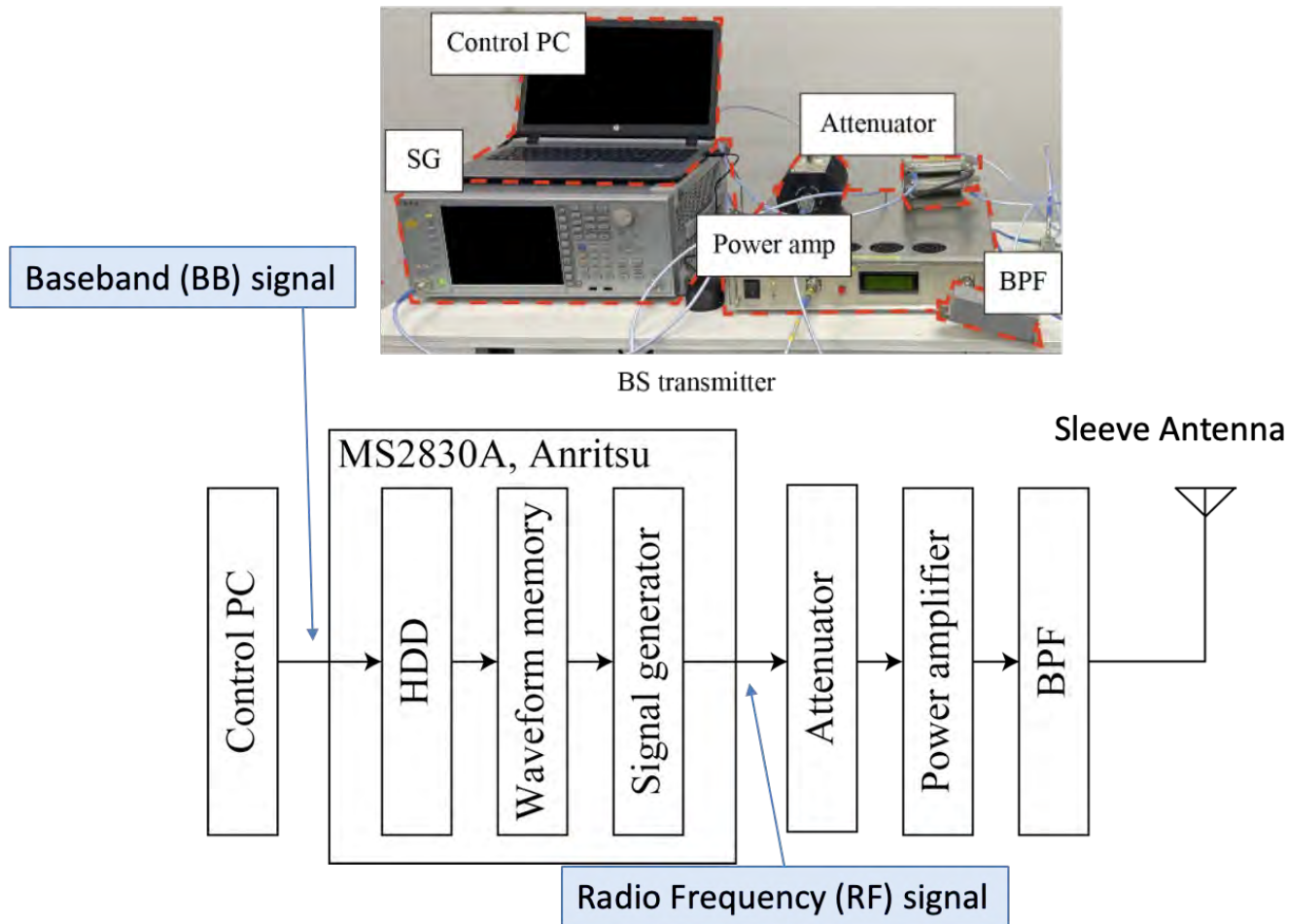
Parameter	Value
Base standard	IEEE 802.15.4
Channel bandwidth	400 kHz
Bit rate	100 kbps
Sample rate	800 kHz
Modulation scheme	2-GFSK
Modulation index	1
Gaussian filter BT	0.5
Encoding	RSC FEC
Coding rate	1/2
Constraint length	7
Decoding	Soft Viterbi
Packet size	Preamble sequence: 15 octets SFD: 2 octets PHR: 2 octets PHY payload: 250 octets
Estimation frame length	200 samples

Refer to the literature [2] for error correction schemes and maximum ratio composite diversity schemes.

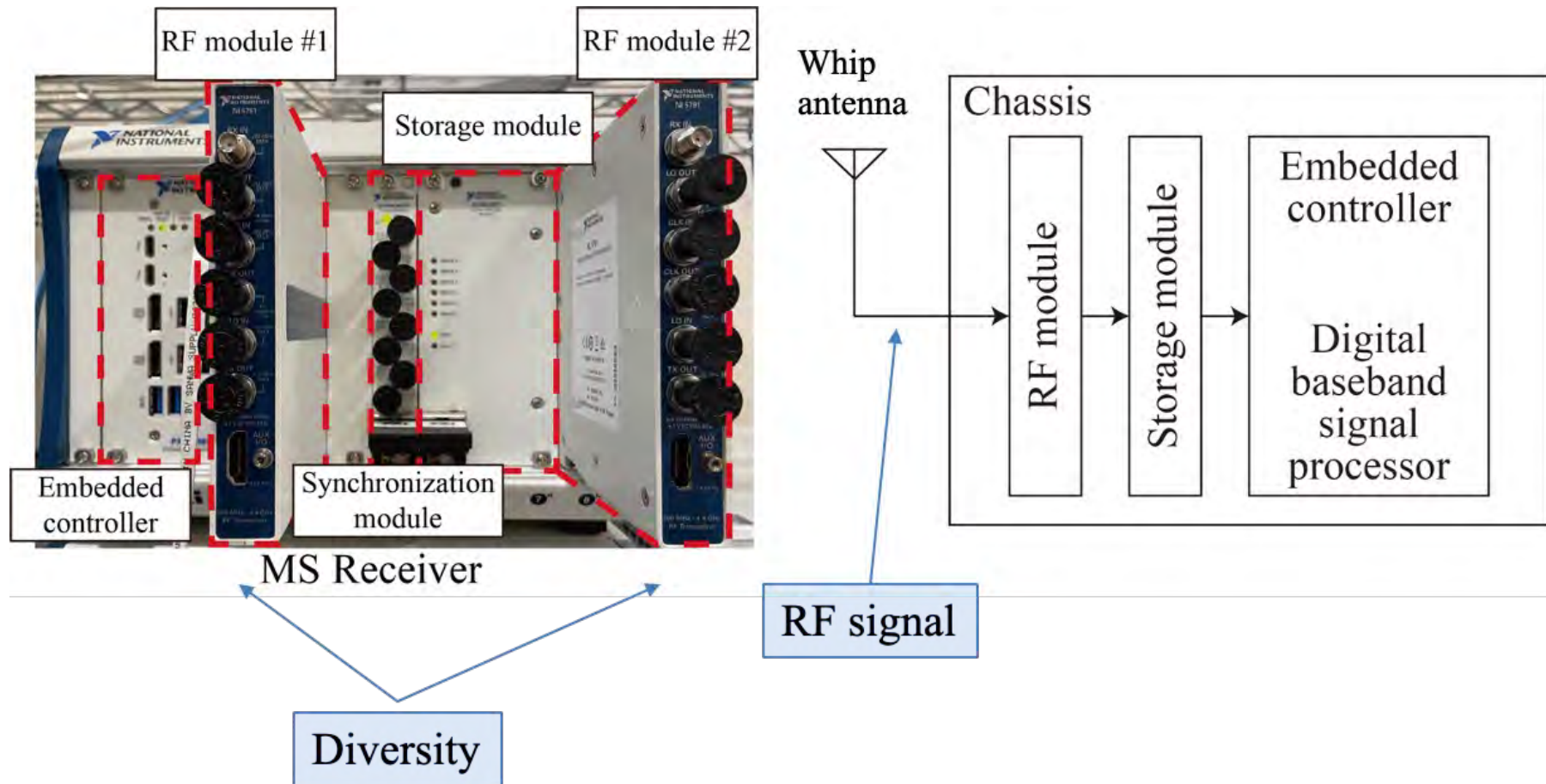
Parameter	Value
Base standard	IEEE 802.15.4
Carrier frequency	173 MHz
BS height	25.5 m
TX power	5 W (37 dBm)
TX antenna/Gain	Sleeve antenna/ 2.15 dBi
MS height	1.4 m
RX antenna/Gain	Whip antenna/ 2.15 dBi
Diversity	2-branch MRC



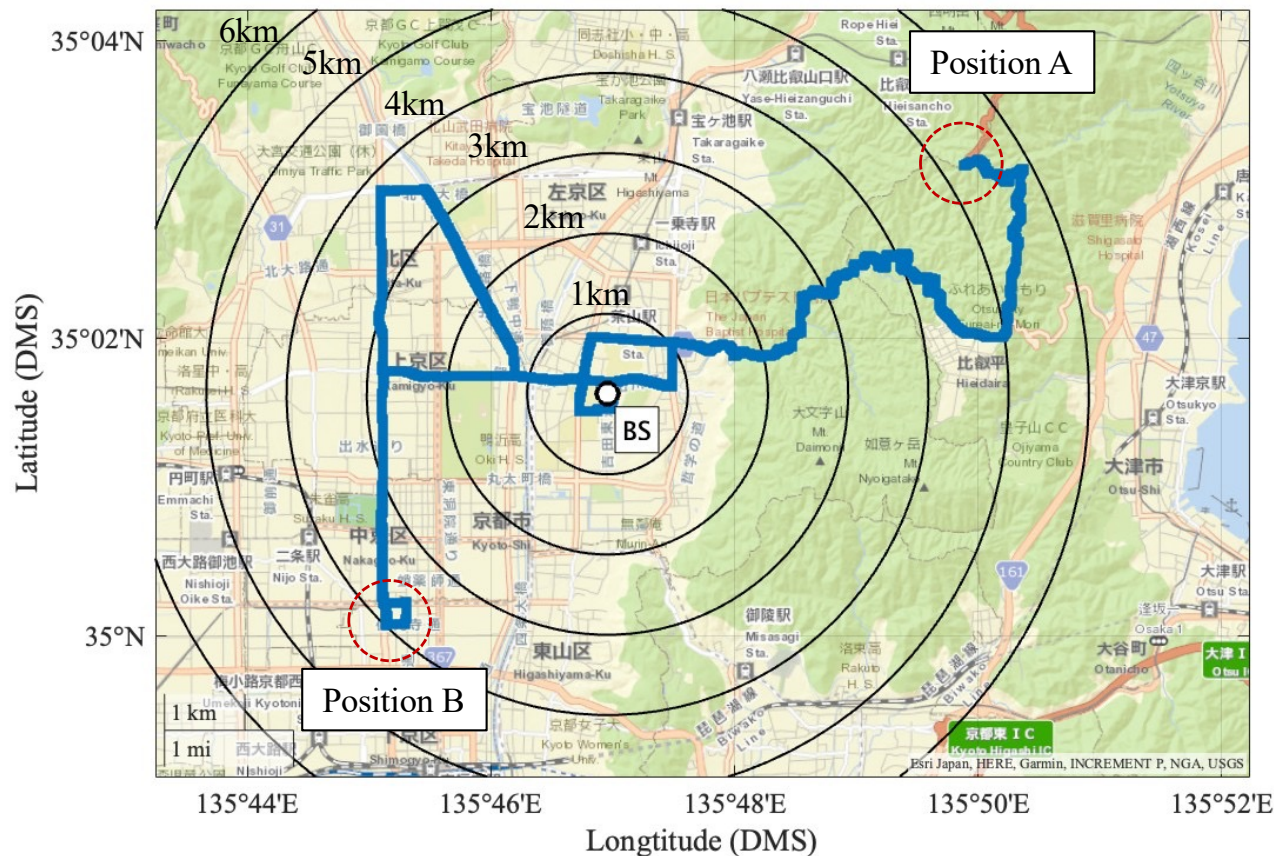
Evaluation platform: Transmitter



Evaluation platform: Receiver

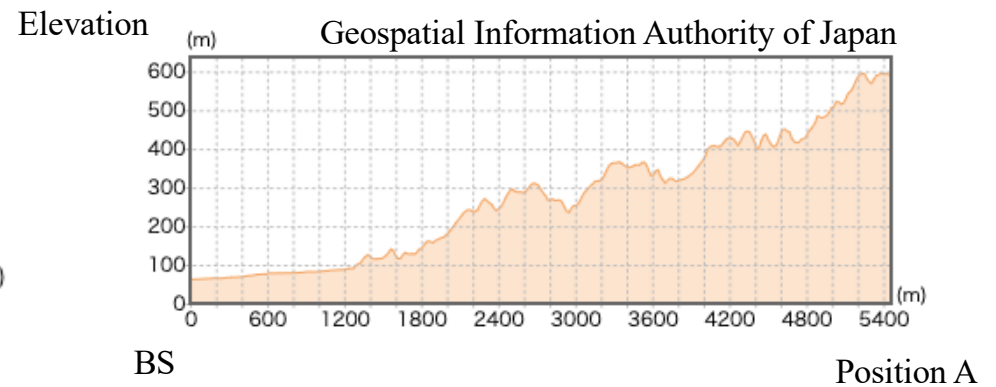
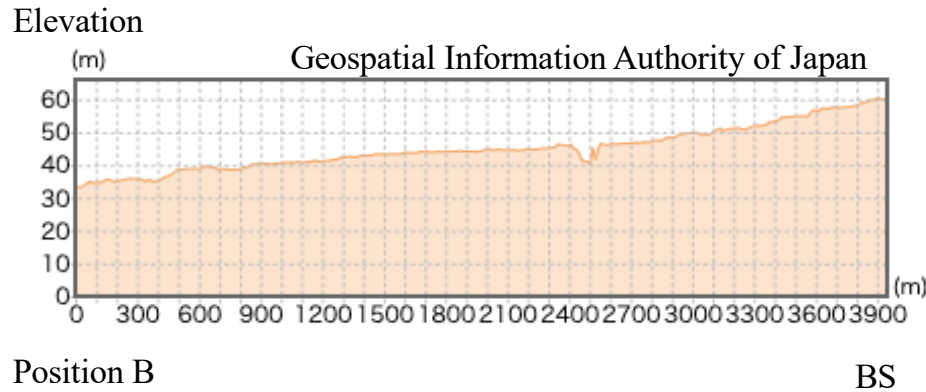
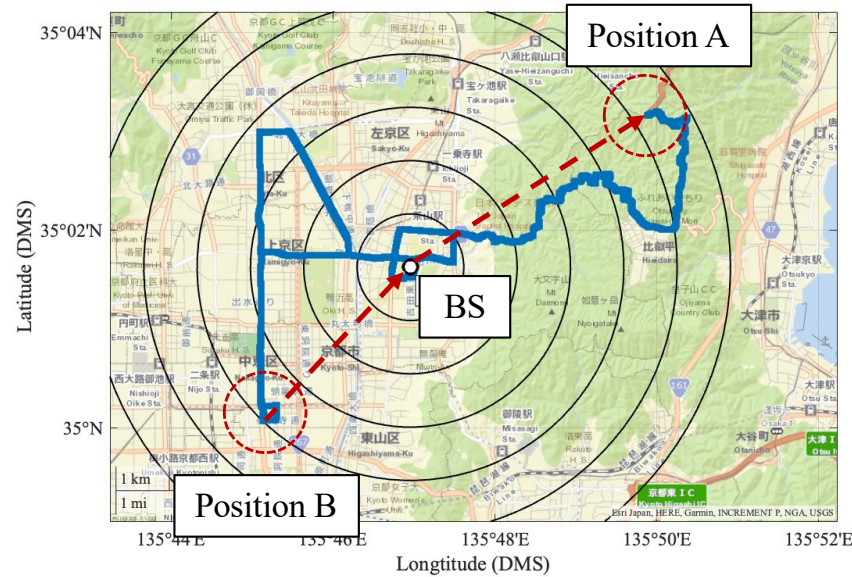


VHF Band Basic Transmission Experiment



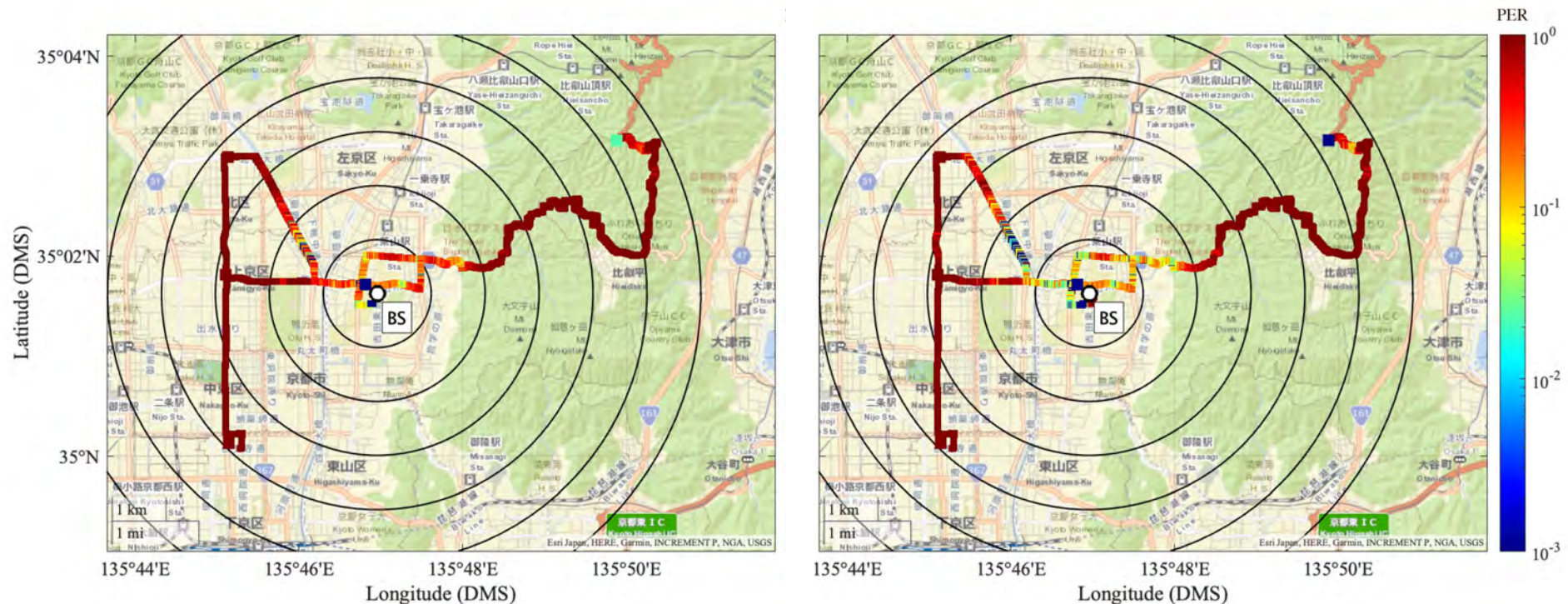
- Install BS on the rooftop of Kyoto Univ. (building 16.7 m, antenna 4.5 m, total **21.2 m**)
- Receive BS while driving within a **radius of 6 km**

VHF Band Basic Transmission Experiment



Packet Error Rate (PER)

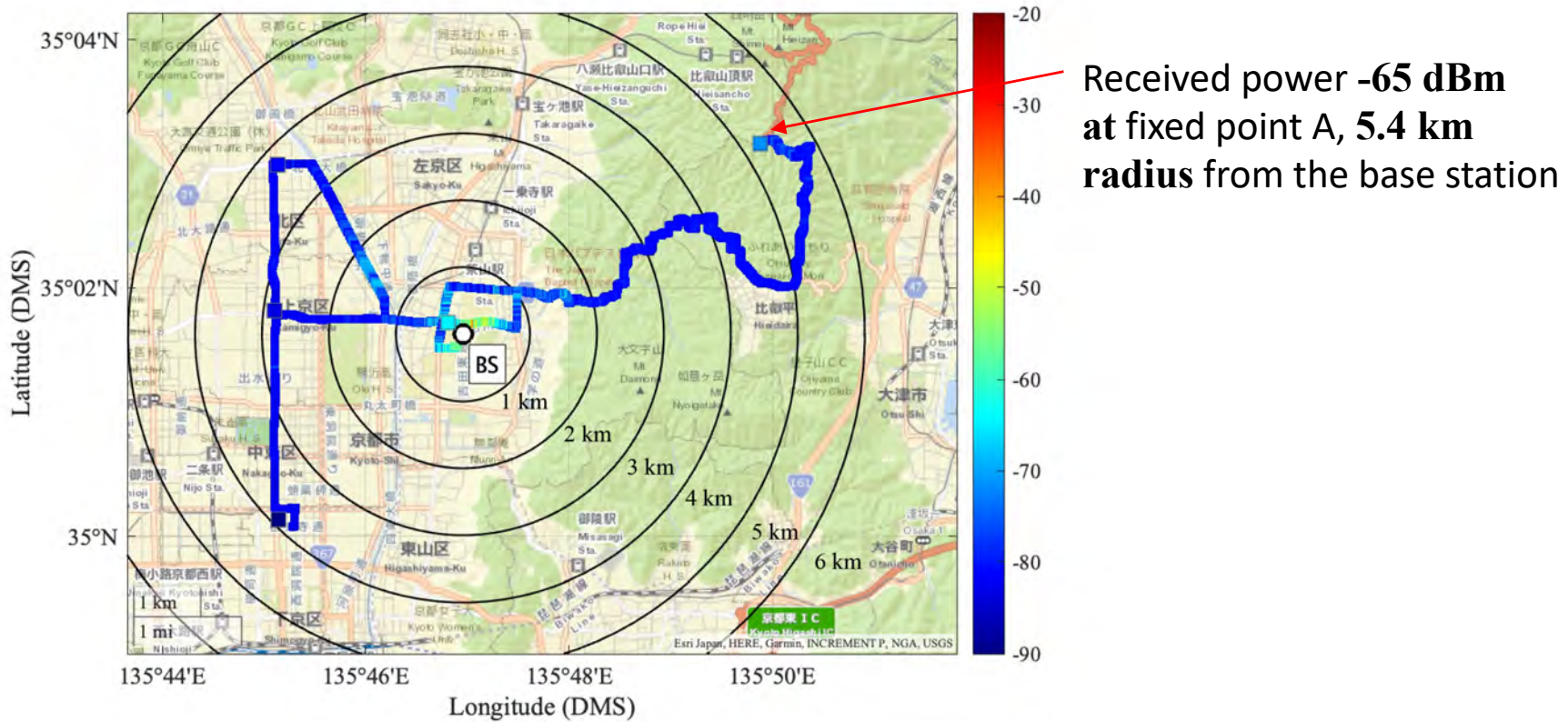
(mobile communication environment)



PER characteristics without (left) and with (right) diversity reception

- Increasing the number of sections within a radius of 2 km from the BS that achieve $PER = 10^{-1}$ even while moving.
- At fixed point A, **5.4 km radius** from the base station **$PER = 0$** is achieved

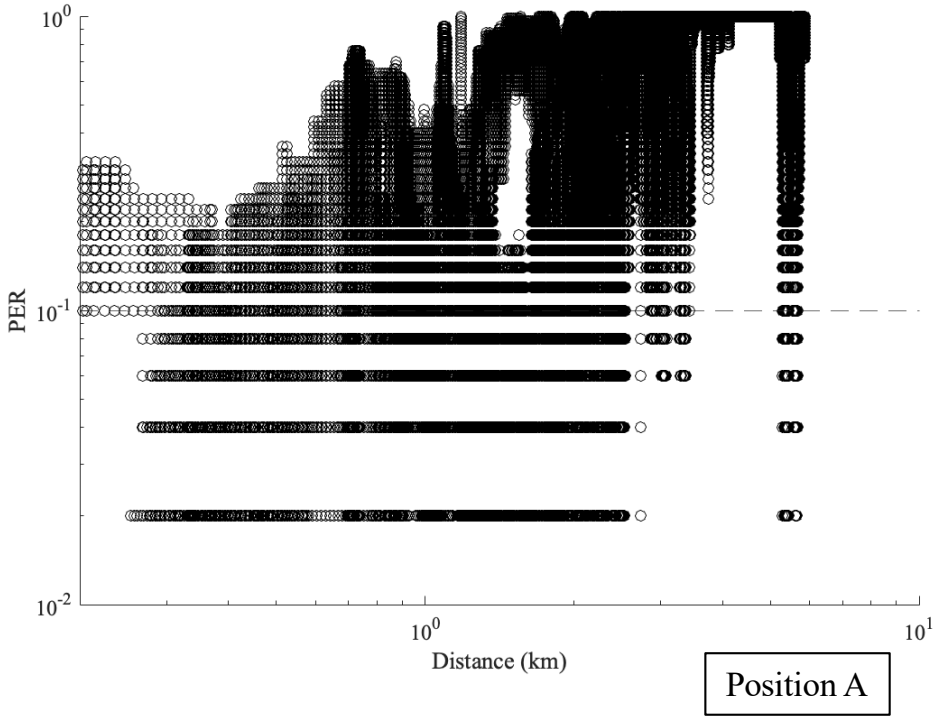
Received Power (mobile communication environment)



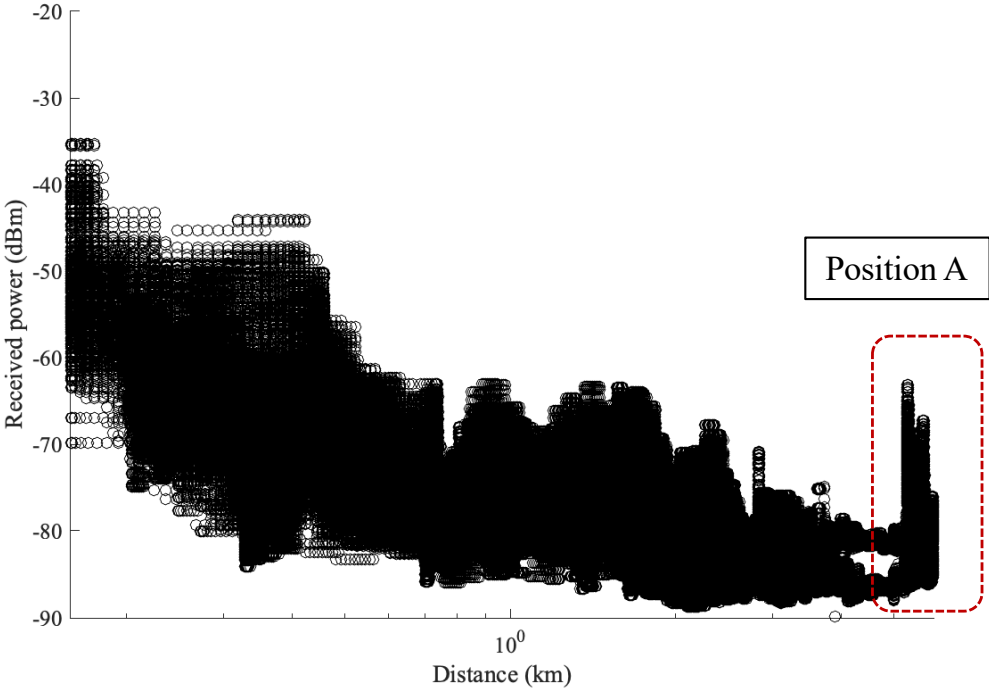
- Received power -65 dBm at a fixed point with a 5.4 km from the base station

Transmission performance

Packet Error Rate



Received power



Reference

- [1] Jaeseok Lim, Keito Nakura, Hiroko Masaki, Norichika Ohmi, Hiroshi Harada, “SDR-based Fundamental Transmission Experiments of IEEE 802.15.4 SUN FSK Using VHF-band,” IEICE Tech. Rep., vol. 123, no. 436, SRW2023-45, pp. 1-6, March 2024. (Japanese)
- [2] Jaeseok Lim, Keito Nakura, Shota Mori, Norichika Ohmi, Hiroshi Harada, “Software-Defined Radio-Based IEEE 802.15.4 SUN FSK Evaluation Platform for Highly Mobile Environments,” IEEE Open Journal of Vehicular Technology, Aug 2024. (Accepted)
- [3] Jaeseok Lim, Keito Nakura, and Hiroshi Harada, “Super-large Coverage IEEE 802.15.4g-FSK-based Wireless IoT System in VHF-band”, 2023 IEEE World Forum of Internet of Things(WFIoT), Aveiro, Portugal, Oct. 2023.