

Successful Demonstration of Long-Distance Video Transmission Exceeding 30 km Using a VHF-Band Narrowband IoT Wireless System

Summary

A research group led by Professor Hiroshi Harada of the Graduate School of Informatics at Kyoto University (hereinafter referred to as “Kyoto University”) has developed a wireless system compatible with the VHF band (220 MHz band) for narrowband IoT communication systems, partially based on recommendations issued by the Information and Communications Council of the Ministry of Internal Affairs and Communications in December 2025. The developed system is based on the Wi-SUN system, which complies with the international standard “IEEE 802.15.4 SUN” and has a proven track record in applications such as smart meters. Using this system, the research group successfully demonstrated long-distance video transmission over approximately 34 km while utilizing a narrow channel bandwidth of only 400 kHz. Based on these demonstration results, the technology is expected to enable new applications involving video transmission in airspace, maritime environments, and outer space, where coverage by conventional mobile communication systems has traditionally been difficult.

Key Points

- Developed a narrowband IoT wireless system operating in the VHF band (220 MHz band), for which technical specifications were established in December 2025, based on the Wi-SUN system compliant with the international standard “IEEE 802.15.4 SUN,” which has a proven track record in applications such as smart meters
- Enabled wireless transmission of high-definition video over a narrow 400 kHz channel bandwidth through the use of highly efficient video compression technology
- Successfully demonstrated long-distance wireless video transmission between locations approximately 34 km apart

1. Background

In recent years, expectations for the IoT (Internet of Things) have continued to grow, particularly for applications involving the collection of environmental information through sensors, meters, and monitoring devices, as well as the remote control of various on-site equipment. As a result, a wide range of initiatives aimed at realizing IoT communication systems utilizing wireless technologies are currently underway.

Existing IoT wireless communication systems primarily utilize the UHF band (920 MHz band). However, because the maximum transmission power is limited to 250 mW, although numerical and text data can be transmitted over distances of several kilometers, it has been difficult to realize high-capacity communications, including video transmission, across wide areas spanning tens of kilometers. Against this background, research and development of narrowband IoT wireless communication systems utilizing the

VHF band—which enables wider area coverage—has been progressing. In December 2025, the Information and Communications Council of the Ministry of Internal Affairs and Communications issued a partial report defining the technical requirements for such systems. These systems utilize the lower frequency band (170.0–177.5 MHz) and the upper frequency band (217.5–222.0 MHz), enabling operation with a maximum antenna power of 5 W. As a result, they are expected not only to provide broad-area wireless coverage but also to support applications such as drone-based inspections of rivers and bridges, as well as transportation support for remote islands and mountainous regions. However, sufficient verification of the practicality and technical feasibility of VHF-band IoT wireless communication systems, including video transmission applications, had not yet been conducted.

2. Research Results

Kyoto University has developed a narrowband IoT wireless system operating in the upper VHF frequency band (220 MHz band), for which technical specifications were established in December 2025. Using the developed system, the university successfully conducted a long-distance video transmission experiment over a distance of approximately 34 km. The transmitting camera and radio station (hereinafter referred to as the “transmitter”) were installed at the observation deck of the summit station of the Katsuragiya Ropeway in Gose City, Nara Prefecture. The receiving radio station (hereinafter referred to as the “receiver”) was installed on the rooftop of the Kyoto University Kizu Farm in Kizugawa City, Kyoto Prefecture. The distance between the two sites was 33.6 km. Figure 1 shows the relative positions of the experimental sites and a cross-sectional view of the terrain between them.

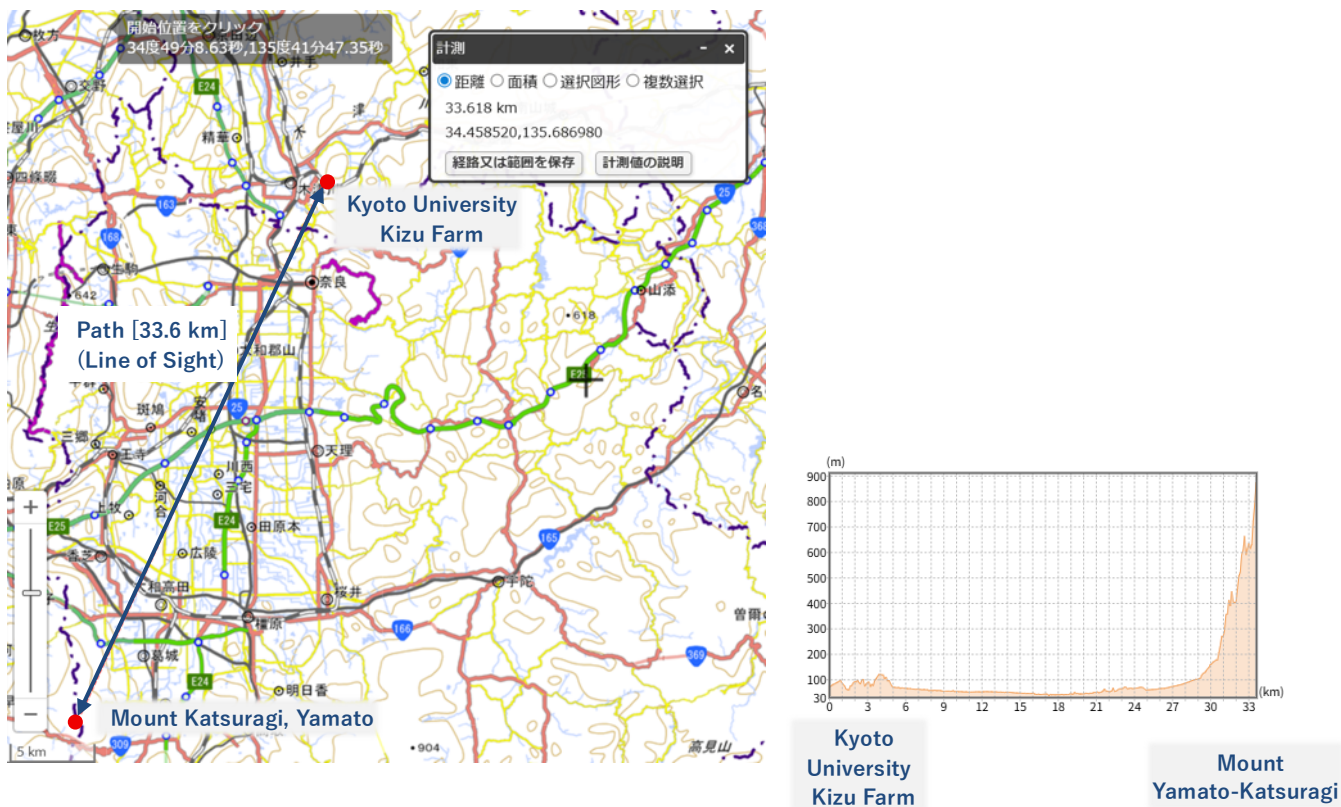


Figure 1: Route and cross-sectional view of the video transmission experiment (created by modifying a map

from the Geospatial Information Authority of Japan)

Figure 2 shows the wireless equipment used for the VHF-band (220 MHz band) narrowband IoT system evaluated in this experiment. The radio system was developed based on the Wi-SUN system, which complies with the international standard “IEEE 802.15.4 SUN,” a standard with a proven track record in applications such as smart meters. The system uses an occupied bandwidth of 400 kHz, FSK modulation, and a transmission rate of 150 kbps. In addition, a single omnidirectional whip antenna was connected to the transmitter, while a single directional log-periodic antenna was connected to the receiver. The receiver antenna was installed and aligned toward the transmitter. The video transmission equipment on the transmitter side consisted of a 4K camera and a 4K video encoder, while the receiver side consisted of a decoder and a display. The 4K video encoder is capable of efficiently compressing high-definition video using a high-compression technique. In this experiment, video transmission was conducted with an image resolution of 1920×1080 pixels and a frame rate of 5 fps. Figure 3 shows the transmitter-side wireless equipment, and Figure 4 shows the receiver-side wireless equipment. The specifications of the wireless equipment used in this experiment are summarized in Tables 1 and 2.



Figure 2: Wireless equipment for the VHF band (220 MHz band) narrowband IoT wireless system

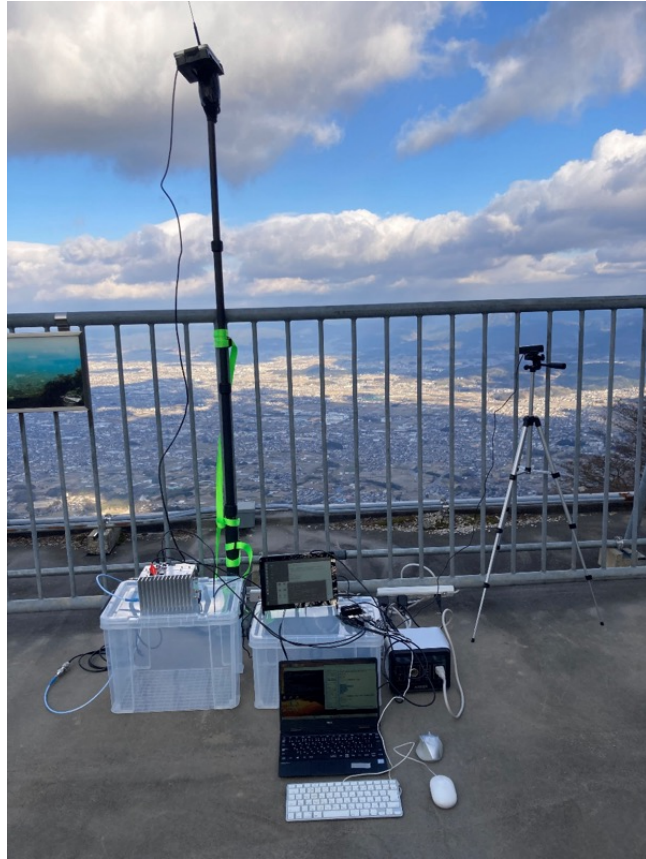


Figure 3: Transmitter (Katsuragiya Ropeway Observation Deck)



Figure 4a: Receiving-side device (Kyoto University Kizu Farm)
Control and video processing unit



Figure 4b: Receiving-side device (Kyoto University Kizu Farm)
Radio



Figure 4c: Receiving-side equipment (Kyoto University Kizu Farm) Antenna

Table 1: Radio Specifications

Frequency	Output	Bandwidth	Modulation Scheme	Error Correction	Data Rate
220 MHz band	5 W	400 kHz	FSK	None	150 kbps

Table 2: Antenna Specifications

Location	Type	Gain (dBi)
Transmitter (Mt. Katsuragi, Yamato)	Whip Antenna	2.15
Receiving side (Kyoto University Kizu Farm)	Log-periodic antenna	11.0

Figure 5 shows the video received at Kyoto University's Kizu Farm from transmissions sent from Mt. Yamato-Katsuragi along the route shown in Figure 1. In this experiment, the video quality was verified by slowly changing "rock-paper-scissors" hand gestures within the transmitted video. As a result, we confirmed that video transmission using a narrow bandwidth of 400 kHz is possible even over a long-distance communication environment of approximately 34 km. At the Kizu Farm receiver site, the received signal level was -75 dBm, and the packet error rate was 0%.

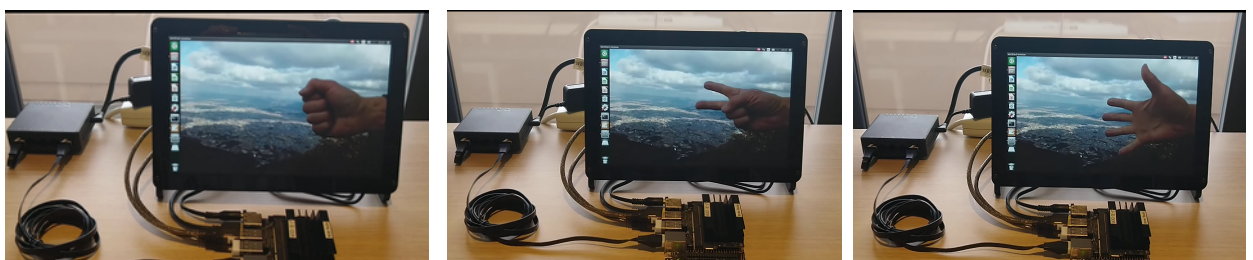


Figure 5a: Video from Mt. Katsuragi, Yamato (Rock) **Figure 5b:** Same as above (Scissors) **Figure 5c:** Same as above (Paper)

3. Future Developments

We have demonstrated that the narrowband IoT wireless system developed for the VHF band (220 MHz band) enables video transmission over distances exceeding 30 km, a communication range that has been difficult to achieve using conventional mobile communication systems. We plan to conduct communication experiments using the OFDM method, which is expected to support wider-bandwidth transmission, in order to further explore the potential of video-based applications in airspace, maritime environments, and even outer space.

4. Acknowledgments

We would like to express our sincere gratitude to Kintetsu Railway Co., Ltd., including the Katsuragi Ropeway Line (Mt. Katsuragi Ropeway), and the Kyoto University Graduate School of Agriculture Farm (Kyoto University Kizu Farm) for providing the experimental sites used in this study. Part of this research was conducted under the National Institute of Information and Communications Technology (NICT) project entitled “Research and Development of Ultra-Coverage Beyond 5G Wireless Communication and Video Coding Standardization Technologies through Japan-U.S.-Australia International Collaboration (JPJ012368C05101)” and the Ministry of Internal Affairs and Communications project “Research and Development for Expanding Radio Frequency Resources (JPJ000254).”

<Glossary>

1. VHF Band Narrowband IoT Wireless Communication System
Within the VHF band made available through the transition from analog to terrestrial digital television broadcasting, the frequency ranges 170.0–177.5 MHz and 217.5–222.0 MHz have been allocated for IoT (Internet of Things) applications such as disaster response, river monitoring, infrastructure monitoring, drone communications, public safety, and wide-area sensing. Although the available bandwidth is smaller than that of mobile communication systems or Wi-Fi, the system leverages the propagation characteristics of low-frequency bands to enable wide-area and long-distance communications, even in mountainous regions and disaster situations. Furthermore, because wide-area coverage can be achieved with a relatively small number of base stations, the system is also expected to serve as a backup communication infrastructure when conventional mobile networks are unavailable.
2. IEEE 802.15.4 SUN (Smart Utility Network)
IEEE 802.15.4 SUN is an international standard for the wireless transmission layer (physical layer) required for applications such as energy management and smart cities. It is designed for

implementation in outdoor sensors, meters, and related devices. The standard supports communication distances of up to approximately 1 km and enables low-power transmission of data such as IPv6 packets. It was established by the IEEE 802.15 Working Group in the United States.

3. Wi-SUN (Wireless Smart Ubiquitous Network) System

Wi-SUN is a wireless communication system developed by the Wi-SUN Alliance, an international industry association that develops interoperable wireless communication standards based on the IEEE 802.15.4 SUN standard. By integrating IEEE 802.15.4 SUN with other open international standards, Wi-SUN enables a wide range of applications, including energy management, disaster prevention, and industrial systems. Wi-SUN includes multiple profiles (technical specifications) optimized for different applications. For example, the “Wi-SUN HAN (Home Area Network)” profile, which enables communication between smart meters and Home Energy Management Systems (HEMS), has been adopted by electric utilities throughout Japan. For details, please refer to the official Wi-SUN Alliance website: <https://www.wi-sun.org>.