Development of a data notification system using GEO-WAVE

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Abstract: The lack of cellular or radio coverage in mountainous regions drives a need for alternate communication or data transmission systems in such areas. We used our proprietary LoRa-based GEO-WAVE system to develop a system for monitoring remote wildlife traps (used for population control) and conducted field tests in a mountain region of Japan. The system achieved a maximum 160 km communication distance between a repeater and source device. Even in areas with poor line-of-site visibility, communication was widely successful due to the diffraction of radio waves. Other dead zones were easily eliminated by adding repeaters at strategic locations.

Keywords: LPWA, GEO-WAVE, LoRa, 920 MHz, Wildlife

Classification: Wireless communication technologies

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1 Introduction
Although wireless communication infrastructure in Japan has achieved a high rate of coverage for the overall population, radio network coverage is much lower [1]. This is a particular problem in mountainous areas where forestry, hunting, and surveying activities are conducted beyond the range of cellular phones, making communications difficult.

In recent years, damage to agriculture and forestry interests has become serious due to increasing populations of wildlife such as deer or wild boar [2]. Population control measures are becoming more common, but many capture sites are located in mountainous areas where checking traps and transmitting data are difficult. Although VHF or 3G equipment has been developed for this purpose, it is often impractical due to short transmission distance or inability to access mobile radio waves.

One solution to this issue is Low Power, Wide Area (LPWA) technology that enables long-distance communication; this is currently under development in various parts of the world [3], including systems intended for mountain climbers [4] and wildlife tracking and behavior analysis [5]. In this study, we developed a LPWA system called “GEO-WAVE” that allows the transmission of wildlife trap data over longer distances and verified the practical radio wave performance and implementation in the field.

2 System
We based our system on LoRa technology (Semtech), which excels at low-cost long-distance communication in the 920 MHz unlicensed frequency band. Assuming widespread use in mountainous areas, we increased the radio wave output to 250 mW and incorporated our proprietary “GEO-WAVE” standard that integrates relay and mutual communication functions (specifications given in Table I).

Table I. GEO-WAVE specifications

| Band           | 920 MHz |
|----------------|---------|
| Modulation system | LoRa/FSK/GFSK |
| Antenna        | External antenna (with U.FL connector) |
| Maximum transmission power | 250 mW |
| Receiving sensitivity | -137 dBm |
| Power-supply voltage (switchable) | External power supply: 6V (Range: 3.6 to 9 V) |
|                | Internal power supply: AA (cell) battery × 4 |
| Operating temperature | -30 to 75 °C |

The system consists of source, repeater, and gateway devices. The source can operate for about six months with four AA batteries; its function can be changed to a repeater via an internal switch. It is equipped with a GPS and magnet sensor; when the magnet is removed, an operation notification signal is sent to the repeater or gateway. Relevant information (time, captured notifications, location, radio wave conditions, and remaining battery power) is graphically
displayed via dedicated smartphone/tablet apps via the network server. The administrator can also check the status of all devices from the browser.

The repeater connects the receiver and gateway to facilitate information transmission; its coverage can be maximized by installing it in as high a location as possible. As this is always on to receive notifications from the source, it consumes more power than the source, requiring an external battery. In our field tests, it operated with an external power supply (20 D cell batteries) for about 5 months. Combining this with a solar power system could extend this span. In emergency conditions, it can operate for several days with four AA batteries.

The gateway sends and receives signals between the repeater or source and uploads information to the network server. It may be installed anywhere as long as it can communicate with the repeater; a waterproof case allows installation on a roof or other outdoor area.

### 3 Survey area and communication test

We conducted field tests in Japan’s Gifu, Aichi, and Nara Prefectures from April 2017 to December 2018.

#### 3.1 Gateway

The gateway was installed in a 3G or WiFi area, in a building window where AC power was available. Radio communication tests were conducted using different locations for the source device.

#### 3.2 Repeater

We used a nylon band to attach the repeater to a tree near the top of Mt. Omo (453 m above sea level) in Motosu City, Gifu Prefecture, then conducted radio communication tests from 236 different source locations (Fig. 1a). Topographic shielding (such as from an intervening mountain) could disrupt communication, but this remained possible when the distance between the source and repeater was low. In addition, the presence of an electrical transformer nearby could disrupt the signal.

#### 3.3 Maximum sensing distance

Communication was confirmed at a distance of about 160 km from the repeater to a source device on Mt. Hidegatake (altitude 1695 m) near Ohdaigahara in Nara Prefecture. Although this was beyond visual range, detection was likely aided by both points’ locations on high peaks.

#### 3.4 Comparison of visible map and actual measurements

We demonstrated that the communication coverage area can be effectively determined in advance by making a visibility map (Fig. 1b); the simulated sensing area and the actual sensing result were nearly identical. As such visibility maps can be easily created without special skills, using free software, they are an effective means for assessing device placement locations for long-distance communication.
(a) Received signal strength indicator (RSSI) of source locations.

Blue: stable (+13 to -100 dBm); yellow: slightly stable (-101 to -120 dBm); red: no connection; white square: repeater on Mt. Omo.

(b) Comparison of simulated visibility and actual measurements; pink shading indicates regions visible from the repeater on Mt. Omo (white square) within an 88 km radius. Visible map created in Kashmir 3D based on the 50 m mesh altitude published by the Geospatial Information Authority of Japan.

Fig. 1. Field testing of the GEO-WAVE system in Gifu and Aichi Prefectures.
4 Mountain diffraction of GEO-WAVE

The GEO-WAVE system has a higher radio wave output (250 mW) than commonly used LoRa systems (20 mW) in order to produce a more reliable communications environment. The field test measurement results confirmed that mountains resulted in radio wave diffraction, but it was not clear to what extent this occurred. Therefore, to better constrain the effects of mountain diffraction on the GEO-WAVE system, we extracted 12 sensitive points and 7 insensitive points near the border of both areas. The diffraction angle was calculated using the peak of the mountain ridge as the angle between the two devices (Fig. 2). The angle of mountain diffraction decreased as the distance between the devices increased; when this exceeded about 15 km, wraparound by mountain diffraction became difficult. Depending on the environmental conditions, such as maximum sensing distance, it may deviate from this linear approximation. Of course, the angle does not matter if the distance between the source and repeater/gateway is sufficiently close. In the non-sensing area, it is possible to stably cover a wider area by arranging repeaters appropriately while considering mountain topography, for example by installing another repeater on another mountain.

![Fig. 2.](image)

Distance between selected measurement points and angle of mountain diffraction for GEO-WAVE. Circles indicate sensitive areas and triangles indicate non-sensitivity. The linear approximation was calculated from the eight points (asterisks) nearest the boundary.
5 Conclusion

Our proprietary LoRa GEO-WAVE system enables bidirectional long-distance data transmission with a maximum detection distance of approximately 160 km. Within a certain distance, it can also be propagated through blind areas by mountain diffraction or by arranging repeaters appropriately. This system provides a useful tool for managers and workers in fields such as wildlife and forestry that require long-distance monitoring and data transmission, as it enables communications over wider and more topographically rugged areas than previous systems. This system is being marketed as the Ori-Wana System and has been installed and verified at 50 sites in Japan since April 2018. In the future, we plan to verify the performance limits and social convenience of this system. We are currently developing other systems using based on GEO-WAVE, such as text-chat systems and animal behavior tracking systems. The GEO-WAVE system described here, and the knowledge and skills acquired during its testing, will greatly contribute to further technological improvements in the Internet of Things for diverse applications in areas beyond cellular or radio coverage.

Acknowledgments

We thank Motosu City for its cooperation in this survey. This study was funded through the “Land of Clear Water Gifu: Forests & Environment Tax”. We would like to thank Editage (www.editage.jp) for English language editing.