# Evaluation test of tilt sensor using LPWA

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## Introduction

The mountainous area occupies approximately 70% of the country`s land in Japan and frequently sediment-related disasters have occurred due to natural disasters such as typhoons and heavy rain, earthquakes, flood, landslide, debris flow and others. In order to reduce the damage caused by sediment-related failures as much as possible, it is necessary to establish a monitoring system to observe soil movement and deformation. It is important to construct an installation that combines wireless technology and a tilt sensor that can measures movement of the soil and send the information through communication wireless[1)]. The system which has been conventionally used, have been using a wired cable to the power supply and data transmission to the equipment. However, the issues of this system are difficult to maintenance and monitoring[2)]. This system should be easily installed by placing tilt sensors on the top of the pile and by driving the pile into the soil. In this work, we have evaluated the radio wave propagation and examined the measurement error of the tilt sensor due to temperature change. This experiment also studied the configuration and problems of the deformation monitoring system.

## Radio Wave Propagation Methods

In this work, the transmitters were installed on the Tateyama mountain to examine the radio wave transmissivity. There are ten units (A to J) to set the tilt sensor on the top of the piles at the site. The transmitter placed at each point and confirmed whether the radio waves could be received by receiver that was set up at the Observatory of Shinkouzan. The measurement results of the reception sensitivity at A to J are shown in **Table 1.**

**Table 1**: Reception Sensitivity at Observatory of Shinkouzan

| Point | Measure of value [dBm] | Median Value [dBm] |
|---|---|---|
| A | -123 ～ -118 | -120.5 |
| B | -105 ～ -100 | -102.5 |
| C | -129 ～ -121 | -125 |
| D | -125 ～ -120 | -122.5 |
| E | -121 ～ -105 | -113 |
| F | -130 ～ -126 | -128 |
| G | -124 ～ -131 | -127.5 |
| H | -- | -- |
| I | -124 ～ -118 | -121 |
| J | -125 ～ -118 | -121.5 |

## Results

It confirmed that RSSI values at point B shows the highest value, however for H point it was difficult to find the position at the site. From the table, when the transmitter was installed at A to J, the RSSI values range from -100 dBm to -131 dBm, and it turned out that it received without problems at Observatory of Shinkouzan. For the second experiment, the receiver was installed at the top of the radio tower, it was expected that there was higher possibility of receiving radio waves with sufficient height. The results of the experiment show that the RSSI values of all the points (from A to J) range from -70 to -90 dBm. Based on that, it is considered that the radio tower at Observatory of Shinkouzan is the most suitable place to receive radio wave communication from the transmitter.

## Evaluation Performance of Tilt Sensor Methods

To develop the slope monitoring system, it is necessary to understand the characteristic of a tilt sensor. The tilt sensor used in this experiment adopts the magnetic flux with combination of an amplifier and hall element. To investigate characteristic of the tilt sensor, the performance of the sensor due to the temperature change must be evaluated[3)]. The sensor was set in a transmission box (shown at **Figure 1**) made by plastic along with thermocouple, Arduino UNO as the transmitter, a mobile battery and then put into drying oven and raising and lowering the temperature.

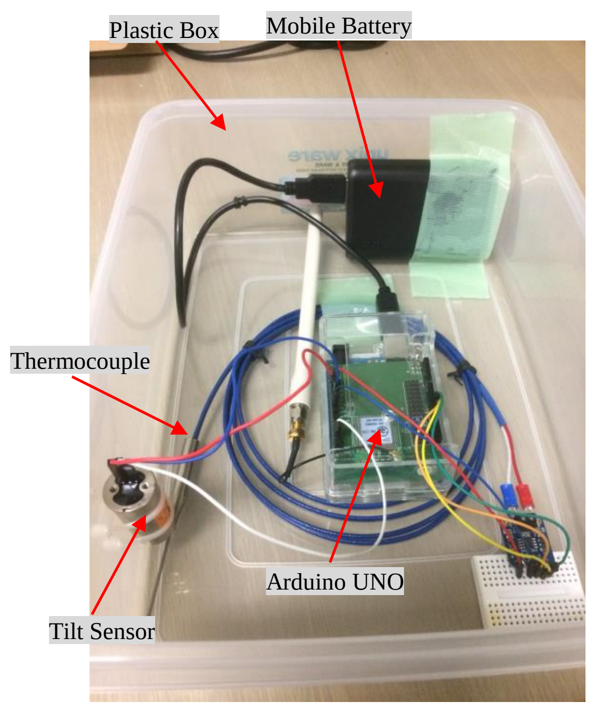


**Figure 1**: Composition of transmission box

The experiment was started at 17ºC and it was increased until maximum temperature at 56ºC and then decreased until 16.50ºC. The angle of the tilt sensor at the starting point is 0.00 º, when at the highest temperature it become 0.53 º. It is shown at **Figure 2**.

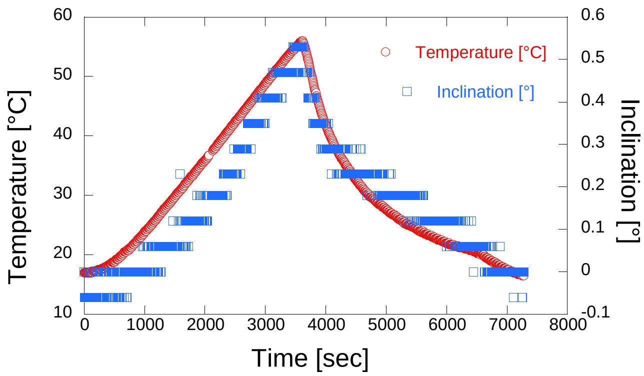


**Figure 2:** Chart relation between inclination, time and temperature

Because the slope deformation monitoring system works outdoor, the transmission box was installed outdoor to observe under actual temperature conditions. During the experiments, the lowest and highest temperatures were 4.50ºC and 26.25ºC, respectively. When the minimum temperature occurred, the tilt angle became -0.18º. For the highest temperature the tilt angle was 0.42º. The range between the lowest and the highest point was 0.60º. It is shown at **Figure 3**.

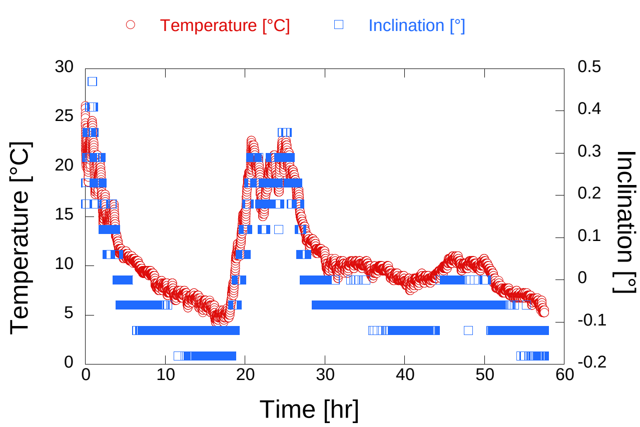


**Figure 3:** Chart relation between inclination, time and temperature

## Results

When comparing the results between indoor and outdoor experiment, there was amount of change with then angle of the sensor during raising and lowering temperature. The other hand there is damage error during the outdoor experiment due to the heavy rain and strong wind. In the case of outdoor experiment during winter season, it needs to considered when the temperature during highest temperature at Summer season.

There are several problems in operating the slope monitoring system using LPWA. When the heavy rain occurs, the interval time between transmitter to receiver becomes ten minute slower. It is caused the consumption energy more and mobile battery life would be shorter than it expected.

## Conclusion

The results of radio wave propagation experiment possible to receive radio waves from the tower at the Observatory of Shinkouzan. When we put the gateway on the top of the tower, the received signal strength indication (RSSI) becomes -70 dBm to -90 dBm, higher reception sensitivity than the observation platform was confirmed

For the experiment to test performance of tilt sensor, it was found when the tilt sensor put inside drying oven with temperature changes from 15ºC to 55ºC, the inclination angle changes by 0.06 º as the temperature changes by about 4.80ºC to 5.40ºC. In the experiment at the outside temperature between 0 ºC to 25 ºC, the inclination angle changes by 0.06 º as the temperature changes by about 2.10ºC to 2.60ºC. From these results, it was confirmed that the amount of change in the tilt angle depending on the temperature

In this system, the sensor unit is attached to the upper part of the single pipe, it has to be assembled separately from the sensor unit, and there is a disadvantage because the cost becomes higher . Therefore, by using a sensor built-in plastic pile, further cost reduction and efficiency improvement could be expected. The future task is important to gather more operational data and to create management standard values the represent the risk of slope collapse.

## References

1) Young, Shin Minato, Ozawa Satoshi, Tsuchida Hiroshi: Tilt measurement using bubble tube images for disaster prevention development of equipment, Journal of Society of Civil Engineers, G (Environment), 69 (5) , I - 73 - I - 77 , 2013 .

2) Aoki Hiroshi, Steven D. GLASER, Ikegawa Yojiro, Shoda Banda, Kazuhide Miki: Soil of the ground development and application of wireless sensor network to owned management monitoring, measurement and control, 46 Vol. 2 No., Pp133-136 , 2007 .

3) Green Instruments Co., Ltd .: Technical information, www.midori.co.jp/technical/index.html