# 40 R&D on Technologies for Collecting, Transmitting, and Processing Sensing Data of Civil Infrastructures (Underground Structures)

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## R&D Objectives and Subjects

Underground structures with severe communication environments can be monitored by collecting and using sensing data using wireless communication suitable for the environment.

**Objectives**

| | Conventional | Improvements achieved through our R&D |
|---|---|---|
| Inspection | ・Periodic inspection every several years<br>・Reports from residents and others | ・Installing and utilizing long-term maintenance-free sensors |
| Monitoring | ・Traffic blocking at manhole openings and closing and installing/removing work | ・No need for manhole opening/closing<br>・Automatic data collection by mobile and stationary APs |
| Diagnosis | ・Judgment only with the data at inspection<br>・Diagnostic variation due to workers<br>・Degradation diagnosis and prediction are impossible | ・Improved leakage detection accuracy by utilizing past data<br>・Workers' skill independent diagnosis<br>・Soundness evaluation of water pipes by constant monitoring<br>・Speed up response in case of disaster |

**Subjects**

| Technology | Contents of R&D |
|---|---|
| A) Sensing data collection and transmission technology | • Drive-by data collection: activation of terminals from running vehicles<br>• Static data collection: long distance data communications to APs |
| B) Sensing data handling technology | • Infrastructure facilities monitored data handling technology<br>• Techniques to lower power consumption of sensors |
| C) Optimal planning of water leakage monitoring systems | • Evaluating and determining leakage and accident risks in the area<br>• Optimizing the installation points of water leakage monitoring sensors |
| D) High sensitivity sensor terminal technology | • Economical data collection and operation methods<br>• High sensitivity sensor terminal technology over wide frequency bandwidth |

## Current Accomplishments (1/2)

### A) Sensing data collection and transmission technology

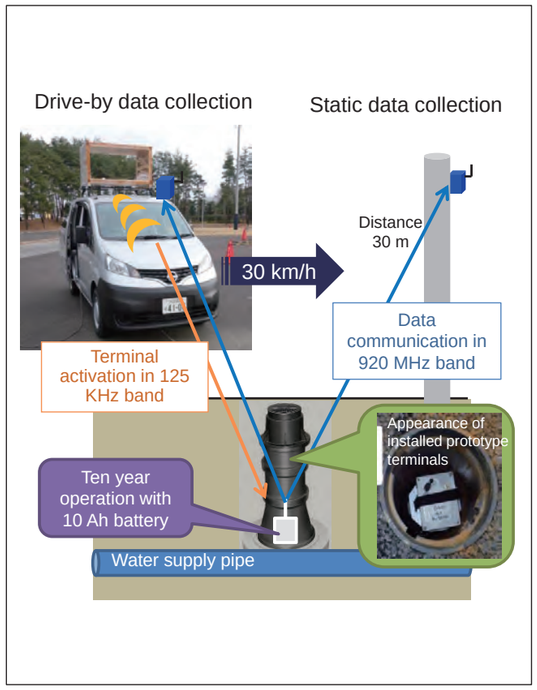
Established basic data transmission technology

(i) Link budget analysis

- Radio wave propagation characteristics clarified in multiple frequency bands by electromagnetic field analysis and water supply pipeline test bed verification
- Data transmission frequency band (920 MHz band) and terminal activation frequency band (125 kHz band) selected
- Link budget analysis completed by selecting modulation method, error correction method, antenna, etc.

(ii) Basic performance of data transmission technology evaluated

- Transmitter/receiver circuit for terminal activation/data transmission prototyped
- Static data collection method goal (30 m transmission) confirmed in test bed field between underground and ground. Drive-by data collection goal (running terminal activation and transmission) also confirmed
- Terminal activation and data transmission performance in actual field movements confirmed




### B) Sensing data handling technology: saving monitoring sensor power

Target (continuous operation for over 5 years) achieved

- Continuous operation for about 10 years with one battery (capacity 10 Ah) confirmed from power consumption evaluation performed through device circuit design and simulation

## Current Accomplishments (2/2)

### B) Sensing data handling technology: infrastructure equipment monitoring data processing technology

Usage of small/medium diameter metal pipes confirmed effectiveness of basic technology for water leakage

(i) Usage of actual data quantified water leakage determination task

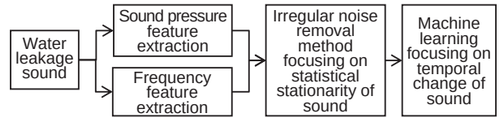
- Micro/fine water leakage sound characteristics propagating through pipes
- Water leakage sound characteristics due to pipe material, tube diameter, leakage volume, etc.
- Particular irregular noise for each place/time slot

(ii) Analytical methods designed to address problems

- Machine learning using multidimensional feature extraction focusing on sound pressure/frequency distribution
- Irregular noise removal method focusing on statistical stationarity of sound
- Individual learning model for each place focusing on temporal change of sound and location-independent common learning models

(iii) Measured data used to confirmed recognition rates of invented technology

- Learning models confirmed recognition rate of 98% plus for long water supply pipes of small/medium diameter. Models covered all verification data places including the actual environment. A common learning model independent of place is now being evaluated.
- Effectiveness of invented technology in various fields is now being evaluated.

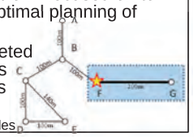



Process flow of invented analysis method

### C) Optimal planning of water leakage monitoring systems

Modeling and formulation established as mathematical optimization problem

- Facility location problem "k-median problem" focused on to formulate basic networks to examine optimal planning of leakage sensors
- Fundamental method evaluation completed by designing optimum installation points through weighting taking important risks in formulated networks into account



Formulated network examples

### D) High sensitivity sensor terminal technology

Design of high sensitivity sensor and integrated sensor terminal completed

- Pipes efficiently and effectively monitored through high sensitivity sensor terminal design completed over wide frequency bandwidth with doubled conventional sensitivity

Designed integrated high sensitivity sensor terminal

## Goals

### Final goals

Complete technical verification in actual water supply systems of local governments for social implementation. Complete the function expansion of data collection and analysis technology in conjunction with other themes to expand applicability domain.

| | |
|---|---|
| A) Sensing data collection and transmission technology | Development of transmission technology that can acquire long-term data without opening and closing manholes from sensors installed underground |
| B) Sensing data handling technology | Determination of leakage levels without dependence on worker's skill level by utilizing machine learning using multidimensional feature extraction |
| C) Optimal planning of water leakage monitoring systems | Development of priority evaluation system for optimum water leakage monitoring plan for water supply pipeline network |
| D) High sensitivity sensor terminal technology | Development of a practical level high sensitivity sensor terminal that can detect micro leakage sound on a long term basis. |

### Deployment image

| | |
|---|---|
| Domestic | Monitoring of water pipes to enable early detection and prevention of leakage |
| Overseas | Reduction in water leakage, development of water supply management projects, improvement in water supply infrastructures |