

Development of Vehicle Intelligent Monitoring System (VIMS)

US-Japan Young Researchers Symposium on
Natural NSF, US, Japan Disaster Mitigation, 2005

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Background (1) : Metropolitan Expressway



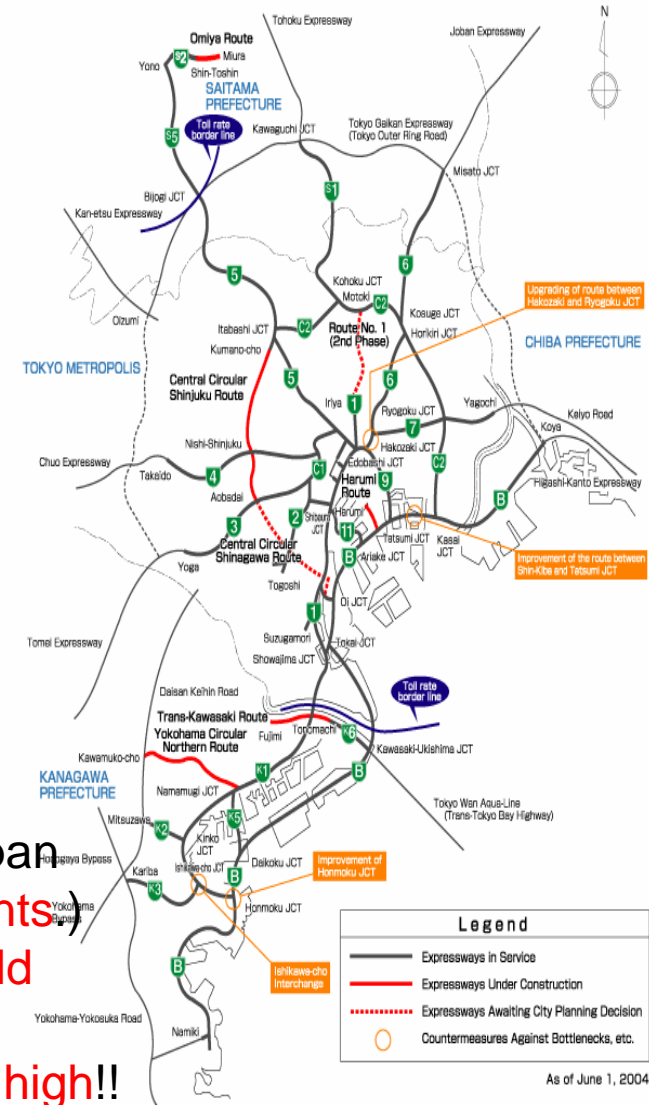
Urban expressway in Tokyo
(Metropolitan Expressway)

Total Length : 283.3km

Most of the structure types : Viaducts with a simple span
(So, there are **so many expansion joints**)

Years in service : About one third are **over 30 years old**

Traffic volume : About **1.12 million vehicles** per day
(About 9% are large vehicles) ...**very high!!**



Metropolitan Expressway Network

Background (2) : Damages of Metropolitan Expressway

Road surface condition →



← Expansion joint

often fail

difficult to inspect

(visual inspection from the patrol car is only way)

Maintenance of the urban expressway network is the biggest issue, now

Background (3) : Road profiler

Irregularity (unevenness) of pavement surface is measured.

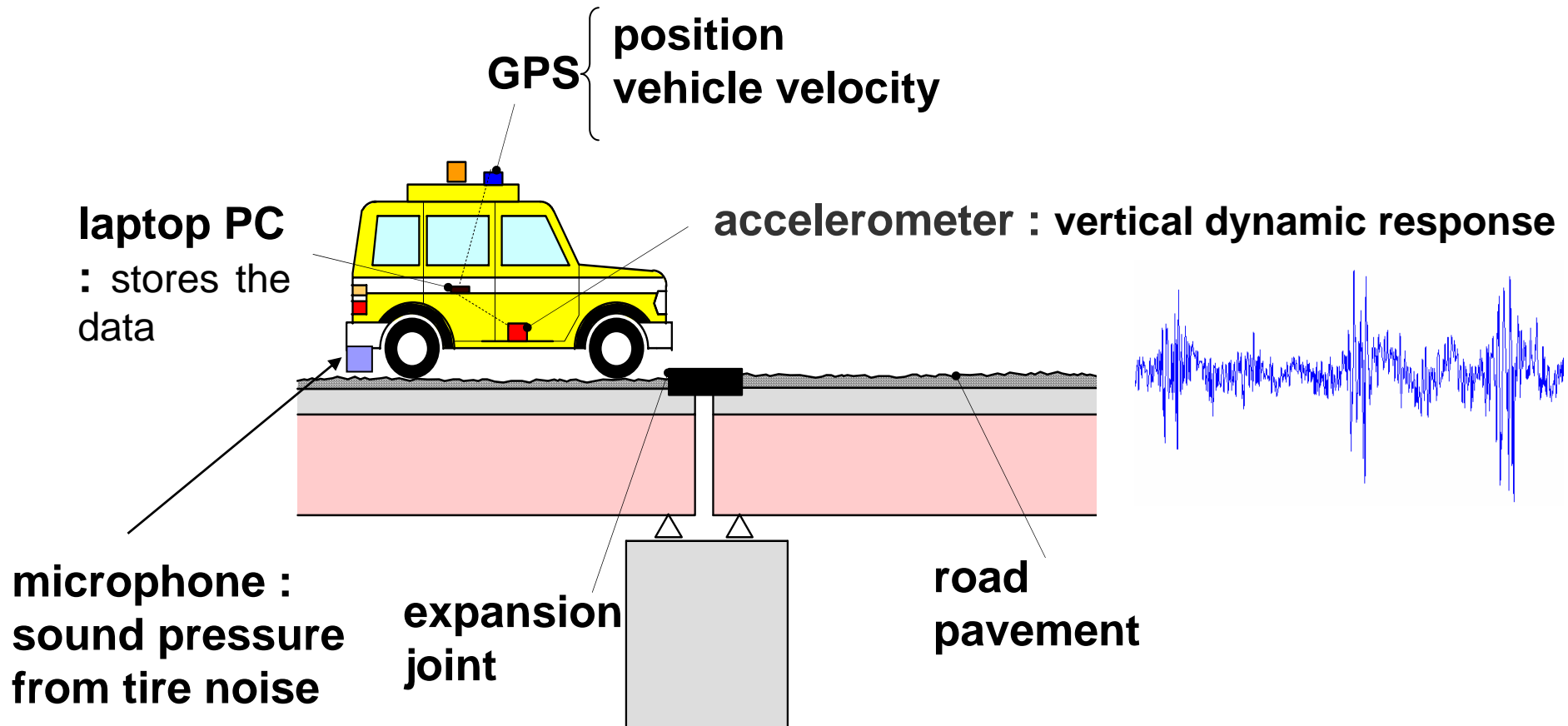
Accurate, but time (- 2 months to analyze) and cost (-few hundred thousand dollars) consuming

It cannot measure the condition of the expansion joints

To solve these problems, Vehicle Intelligent Monitoring System (VIMS) is being developed.



Concept of VIMS : a simple and inexpensive system



Data is collected automatically for several times per day by road patrol cars.
So slight change of the road conditions can be captured.



Positioning of VIMS

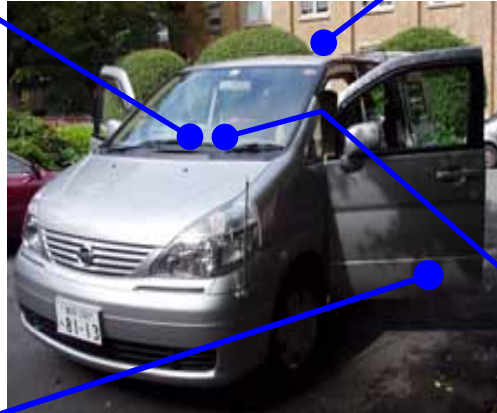
| Inspection method | Frequency of inspection | Operating cost | Time to analyze the data | How to assess |
|-------------------|------------------------------|----------------------------------|---|------------------------|
| Road profiler | Once every two year | Few hundred thousand dollars | 2 months | Quantitatively |
| VIMS | Several times per day | Almost free (only device) | Few minutes (bring the data and analyze by PC) | Quantitatively |
| Visual inspection | Once Every day | Almost free | Immediately | Depending on inspector |

VIMS will be the inspection method which positioned between road profiler and visual inspection.

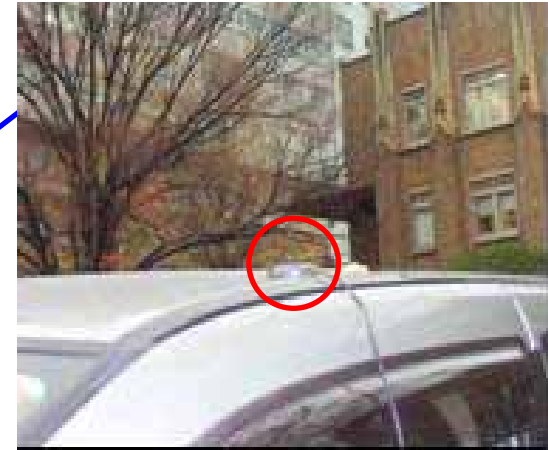
VIMS components



Laptop PC
(On the seat)



An ordinary car (for study)



GPS
(the roof of the car)



Accelerometer
(installed at the middle
of the body)



Microphone
(back of the rear left tire)

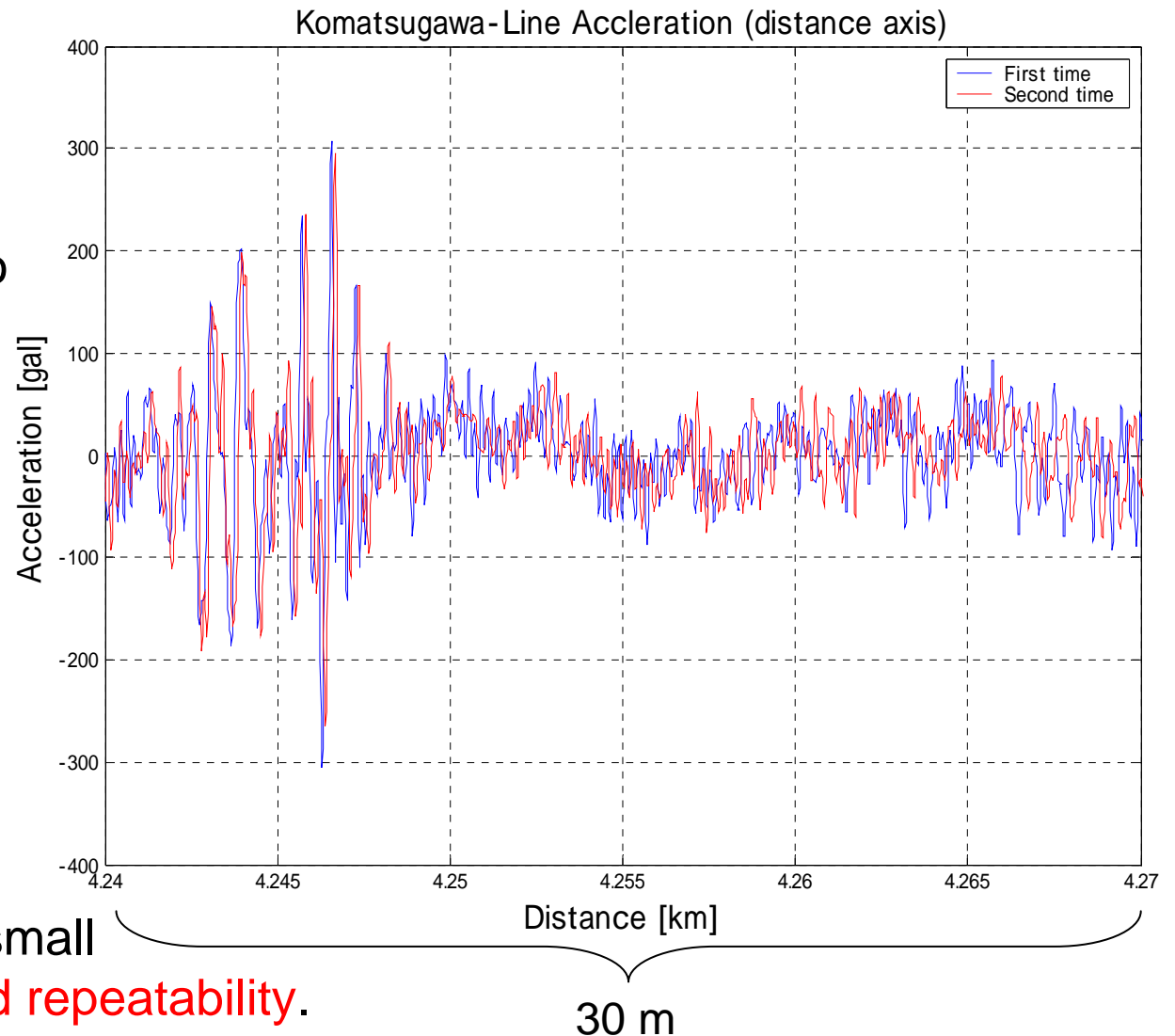
Measurement : once a week

Measured data (acceleration) : Repeatability

Time axis distance axis
by using vehicle velocity
from GPS

To compare more than two
data easily

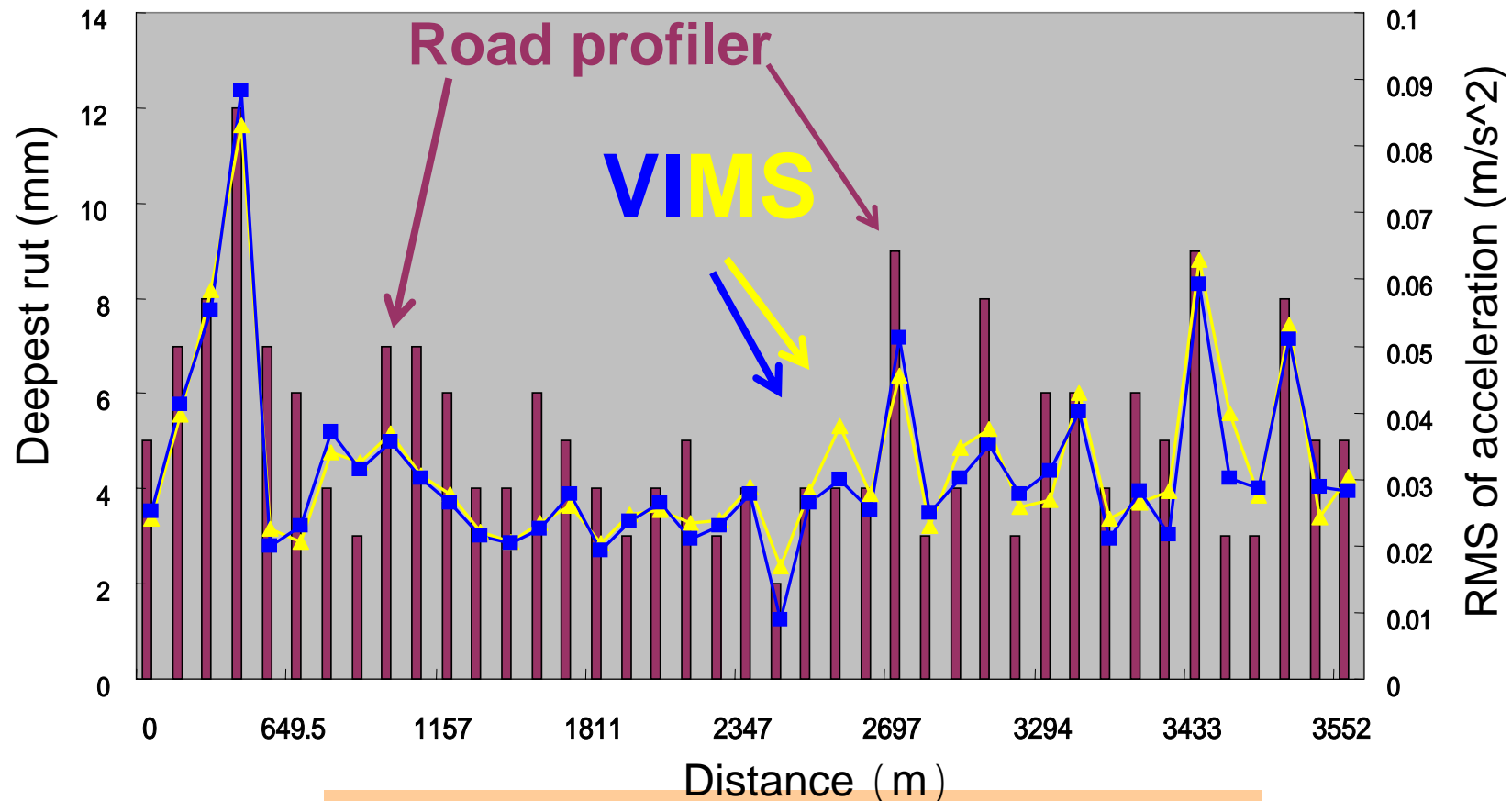
Two data measured on
the same date



The error of distance is small
We can understand **good repeatability**.

The correlation between RMS of acceleration and the deepest rut of road pavement

Dynamic response by VIMS reflects conditions of road pavement ?



Correlation coefficient = 0.8

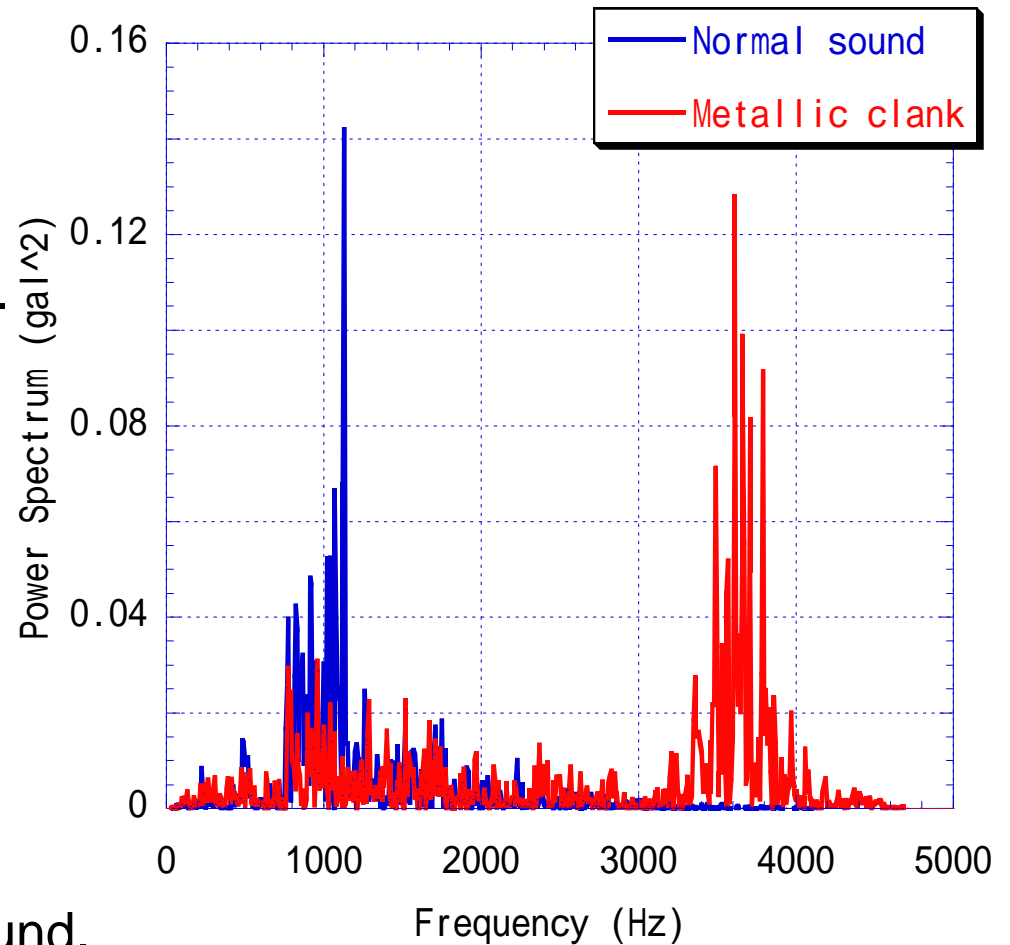
High correlation: VIMS can assess road surface condition.

Detection of abnormal sound

One expansion joint has metallic clank.

Metallic clank occurs from the breakdown of the anchor bolt.

The difference is clear!!



We can detect the abnormal sound.



Concluding remarks

- VIMS is developed for monitoring road surface condition.
- Although simple and inexpensive system, it can assess the condition very well

- For the future

Development of the diagnostic system

Comparing acceleration data between in NY and in Japan



| | Maximum gal |
|---------------------|-------------|
| Route 7 in Japan | Around 500 |
| Ouji route in Japan | Around 400 |
| Road in NY | Over 1000 |

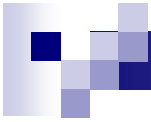
NY road is very rough.

What do you think about this result?

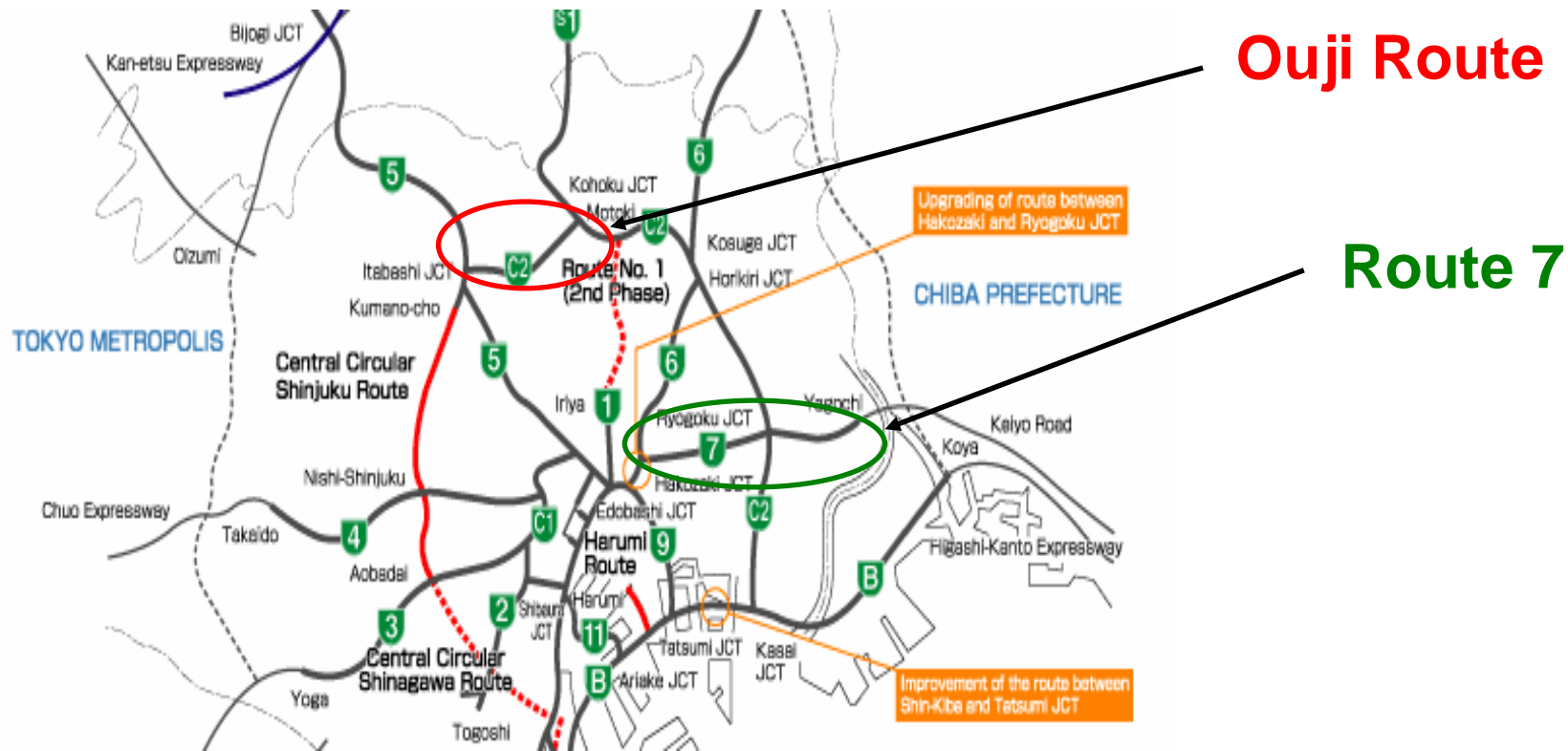


Thank you!



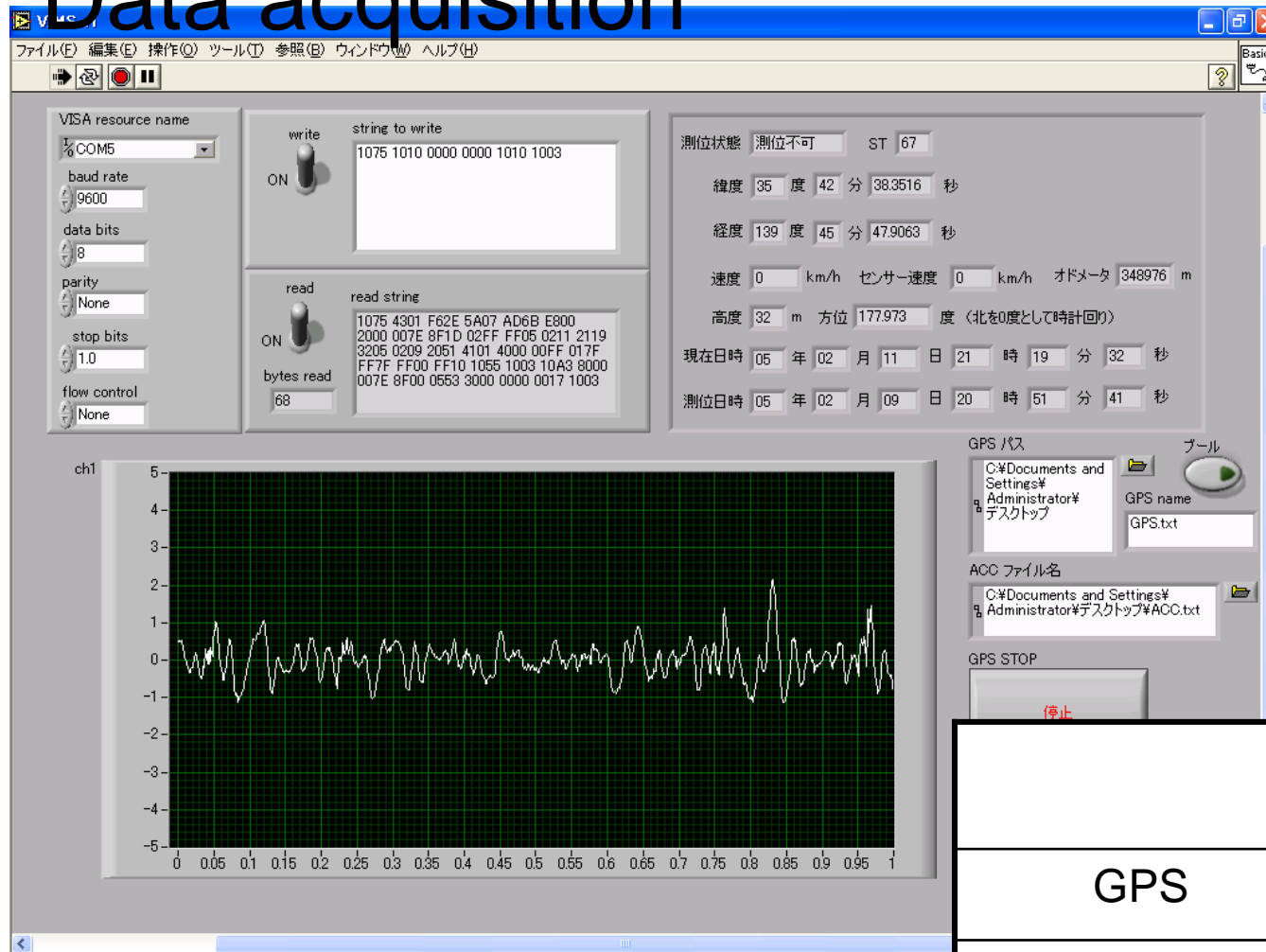


Measurement in Tokyo Metropolitan Expressway Network



Vehicle speed 60km/h

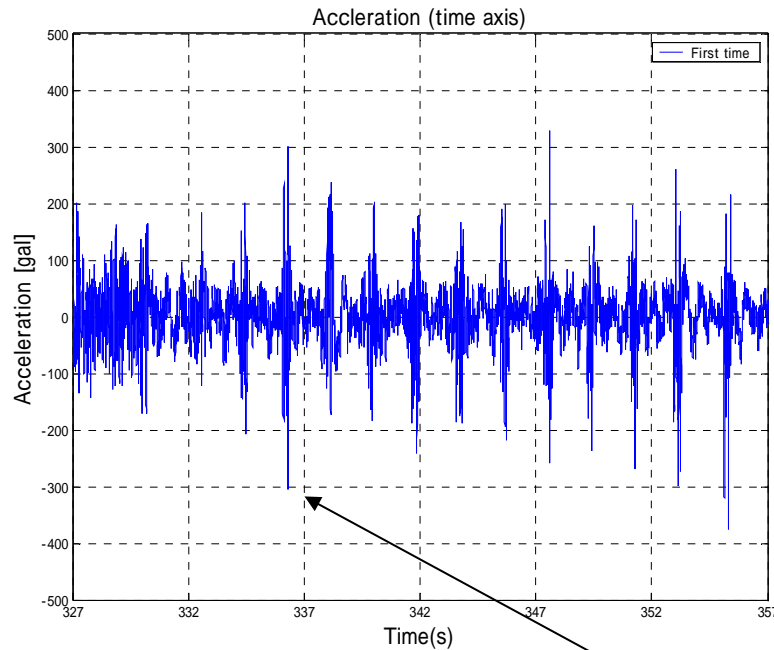
Data acquisition



LabVIEW (National Instruments)

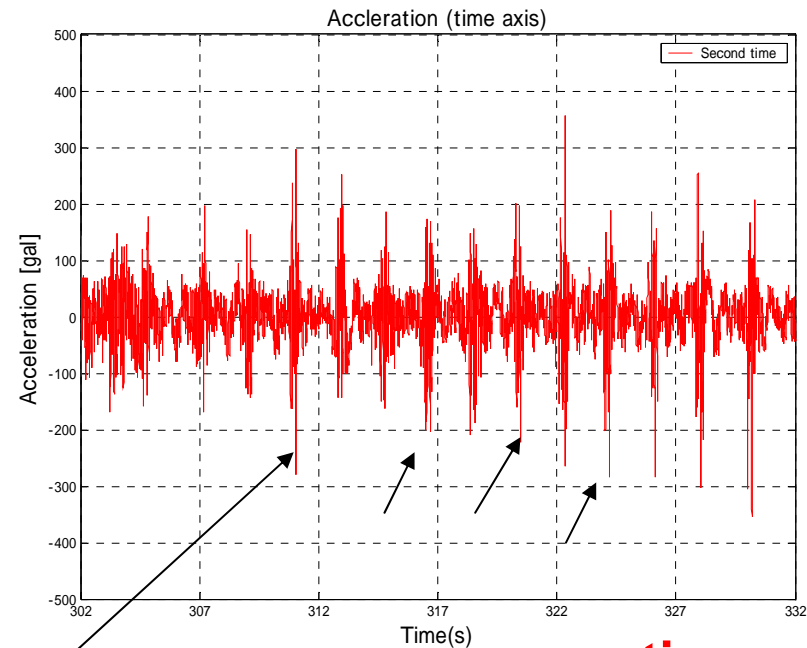
| | Sampling frequency (Hz) |
|----------------|-------------------------|
| GPS | 2 |
| Acceleration | 1,000 |
| Sound Pressure | 10,000 |

Two time history records (Route 7) : comparison



A time history of acceleration recorded at one road (60km/h)

time



Another time history of acceleration recorded at the same road (60km/h)

time

Bump due to an expansion joint

Need to relate the time to the distance

Position identified by GPS: 3m error, not accurate

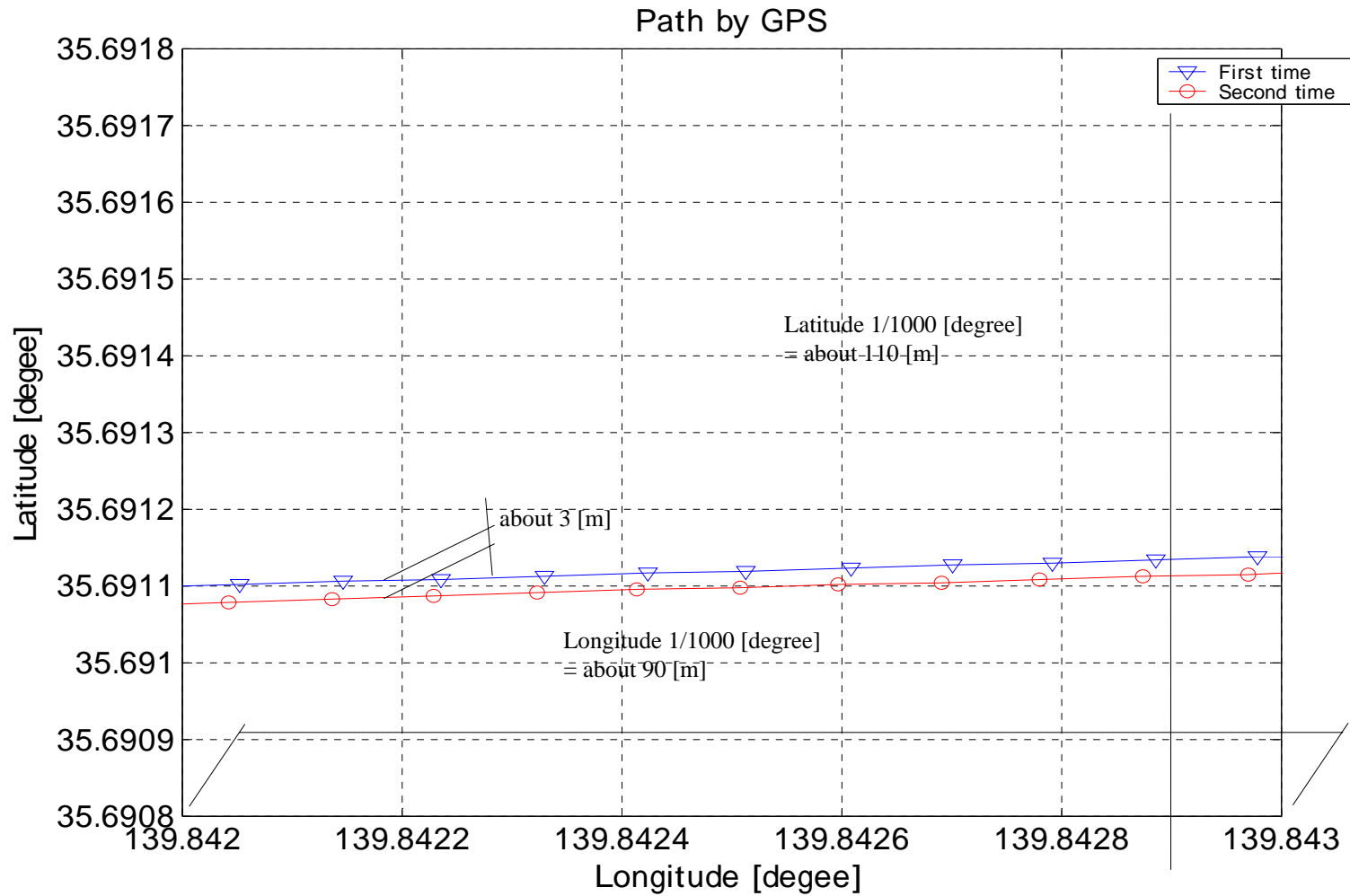
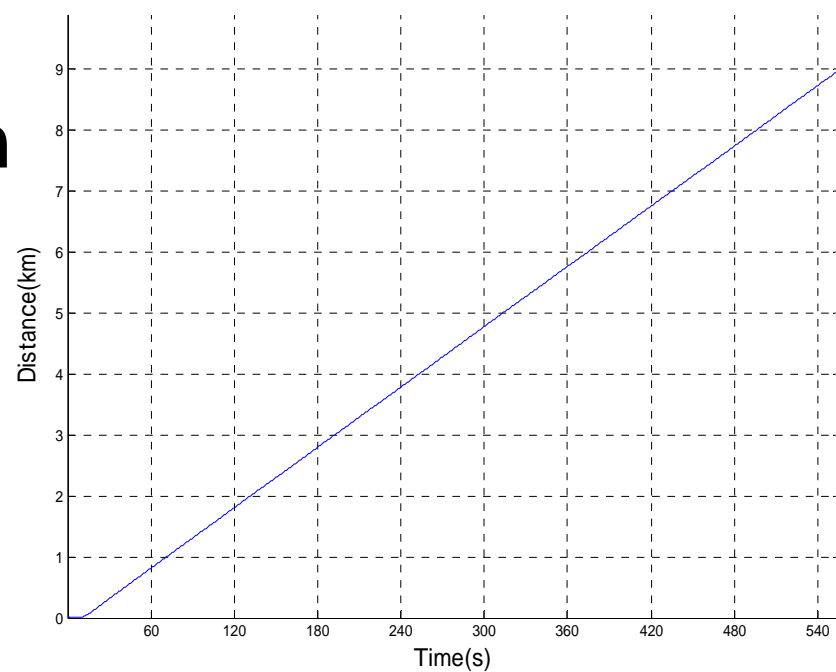
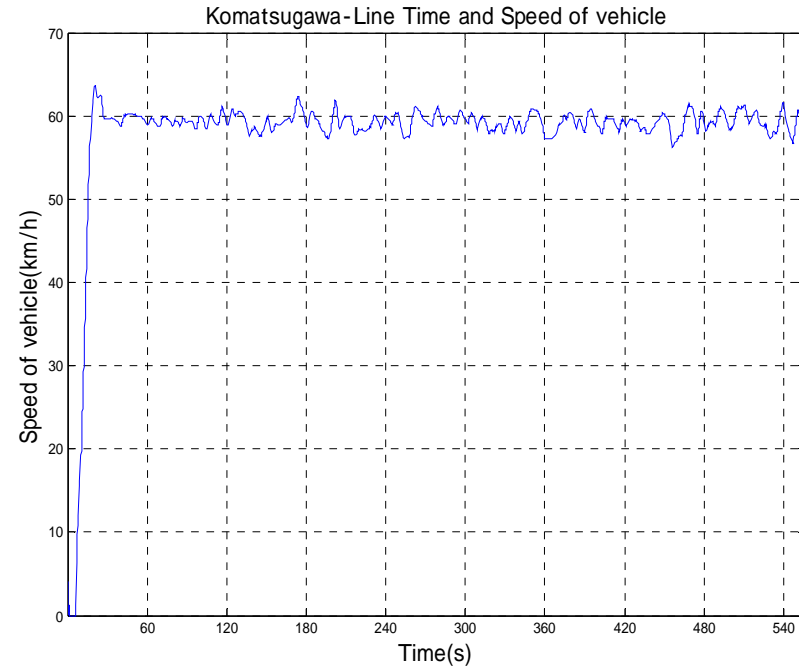


Figure 11: Paths of two times measured by GPS

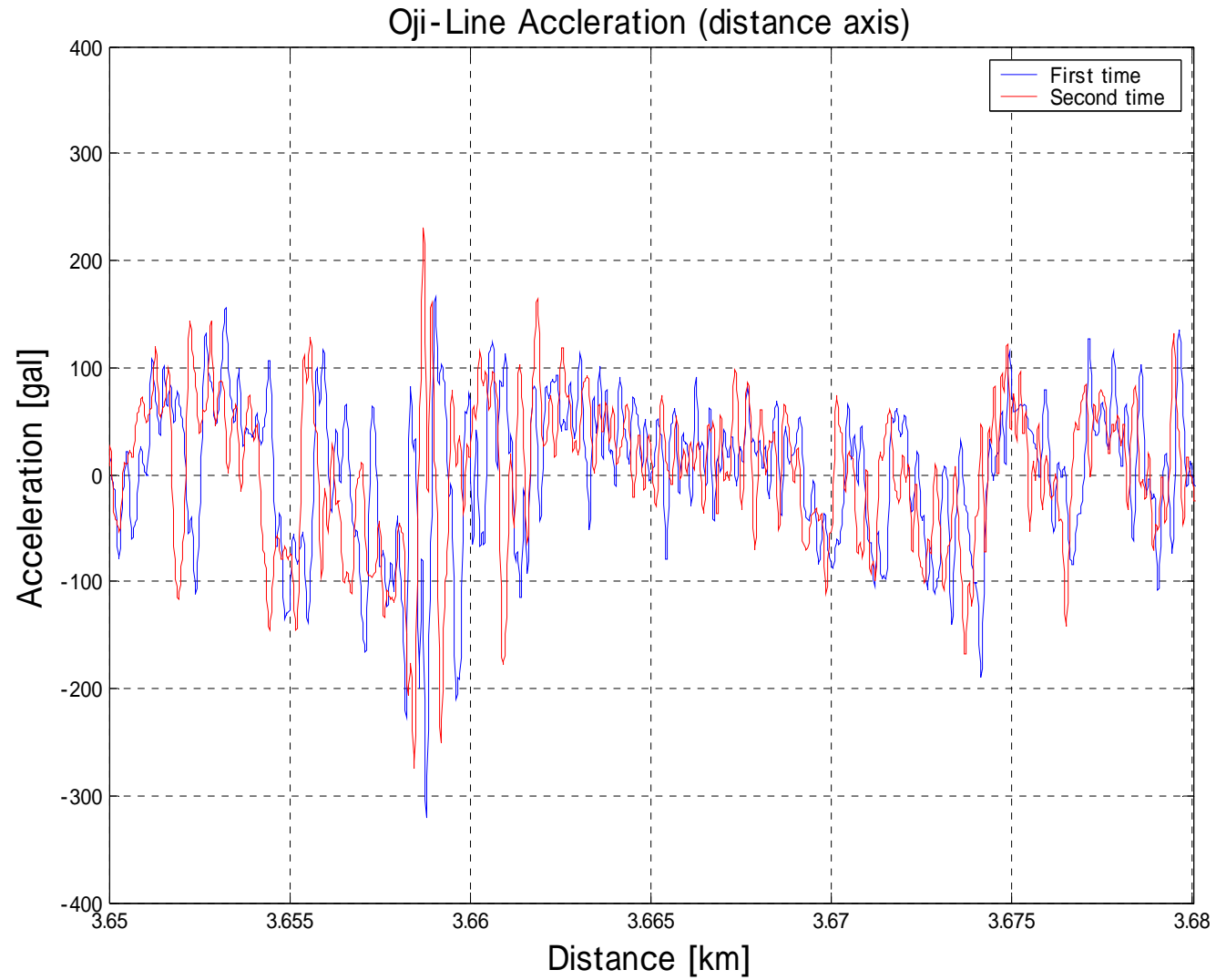
Speed obtained from pulses of vehicle

Integration yields distance.

Relation between time and location (distance from the origin)



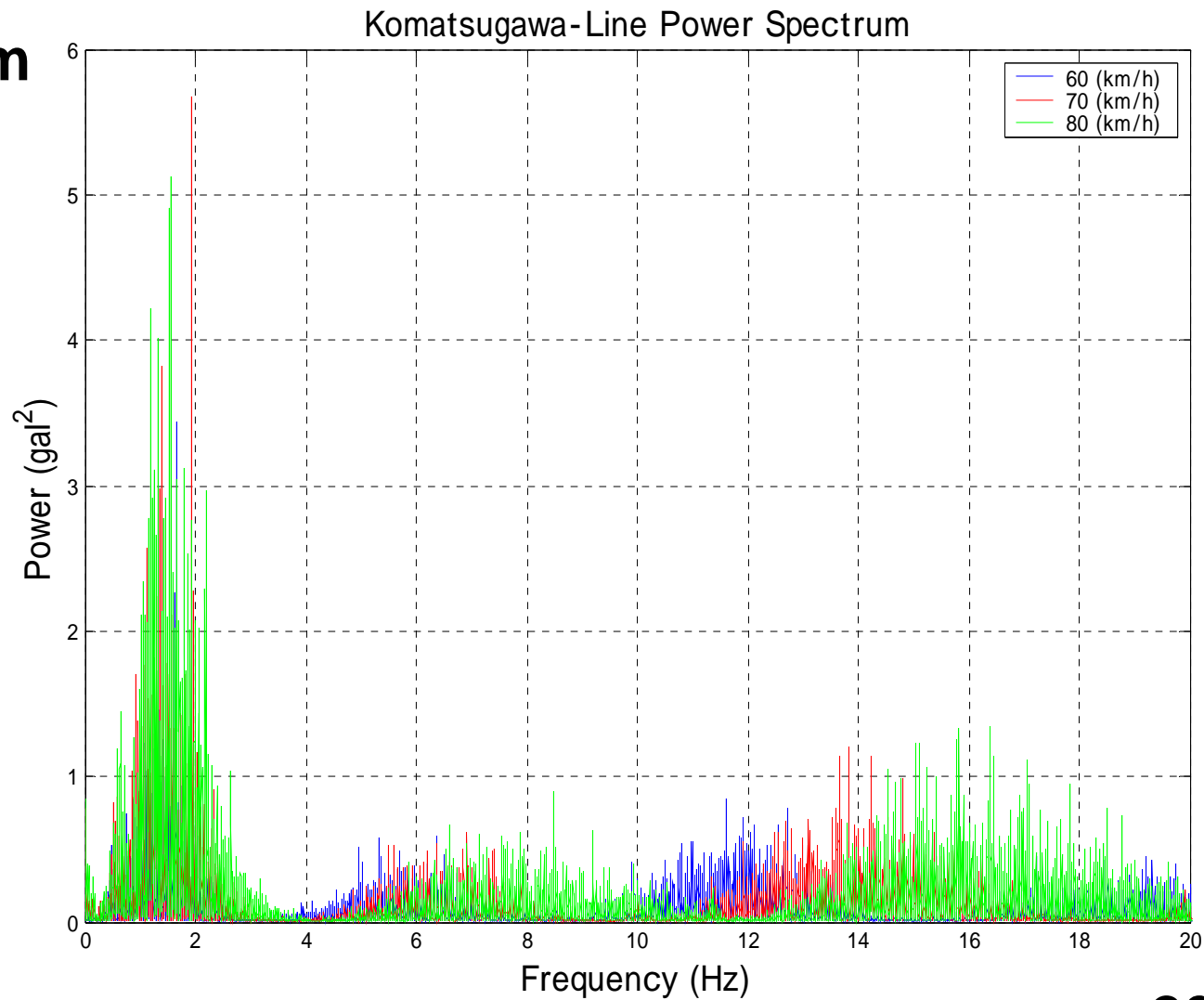
Repeatability(1): Route Uji-line 30m-length record



Distance error is about 30cm

Effect of vehicle speed (60km/h,70km/h,80km/h)

Power
Spectrum
Intensity



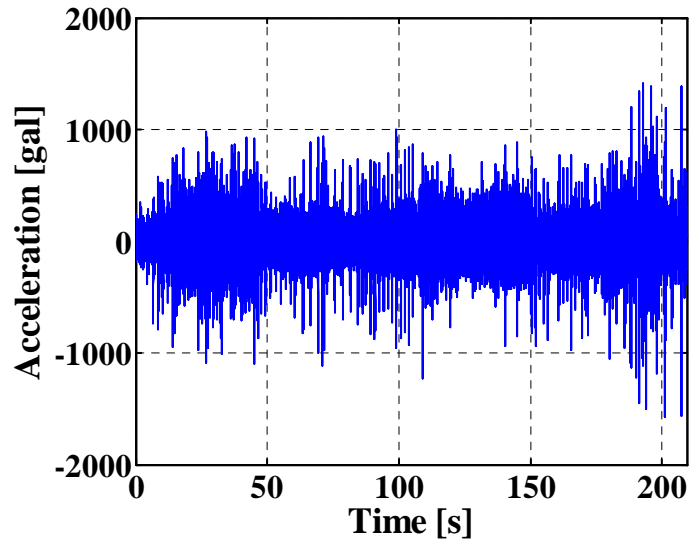
20Hz

RMS responses in pavement and expansion joints

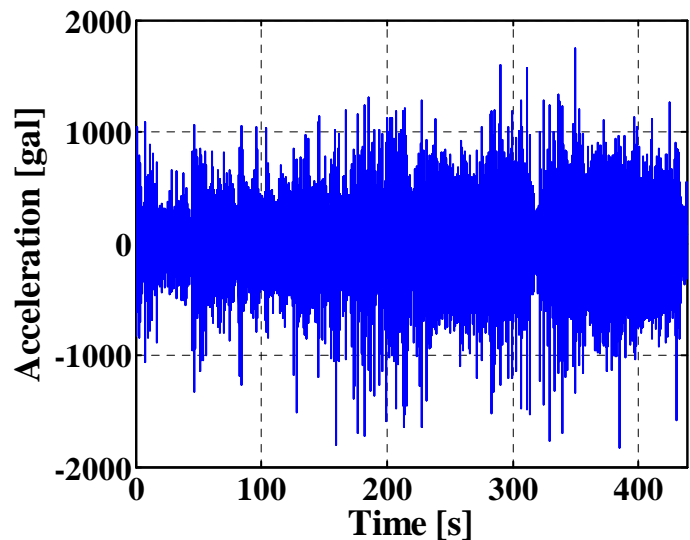
| measurement | | first time (gal) | second time (gal) | first/ second |
|-----------------|------|------------------|-------------------|---------------|
| Road pavement | Rd-1 | 31.3 | 28.0 | 1.12 |
| | Rd-2 | 35.4 | 36.0 | 0.98 |
| | Rd-3 | 28.5 | 29.0 | 0.98 |
| | Rd-4 | 31.4 | 30.4 | 1.03 |
| | Rd-5 | 32.7 | 33.7 | 0.97 |
| Expansion joint | Ej-1 | 109.9 | 101.4 | 1.08 |
| | Ej-2 | 101.8 | 97.8 | 1.04 |
| | Ej-3 | 78.6 | 77.3 | 1.02 |
| | Ej-4 | 101.6 | 95.1 | 1.07 |
| | Ej-5 | 86.0 | 83.8 | 1.03 |



1. Measurement in NY, Triborough Bridge



2. In concrete pavement



Maximum gal exceeds **1000 gal** and NY road is very rough.

Sound level of expansion joints

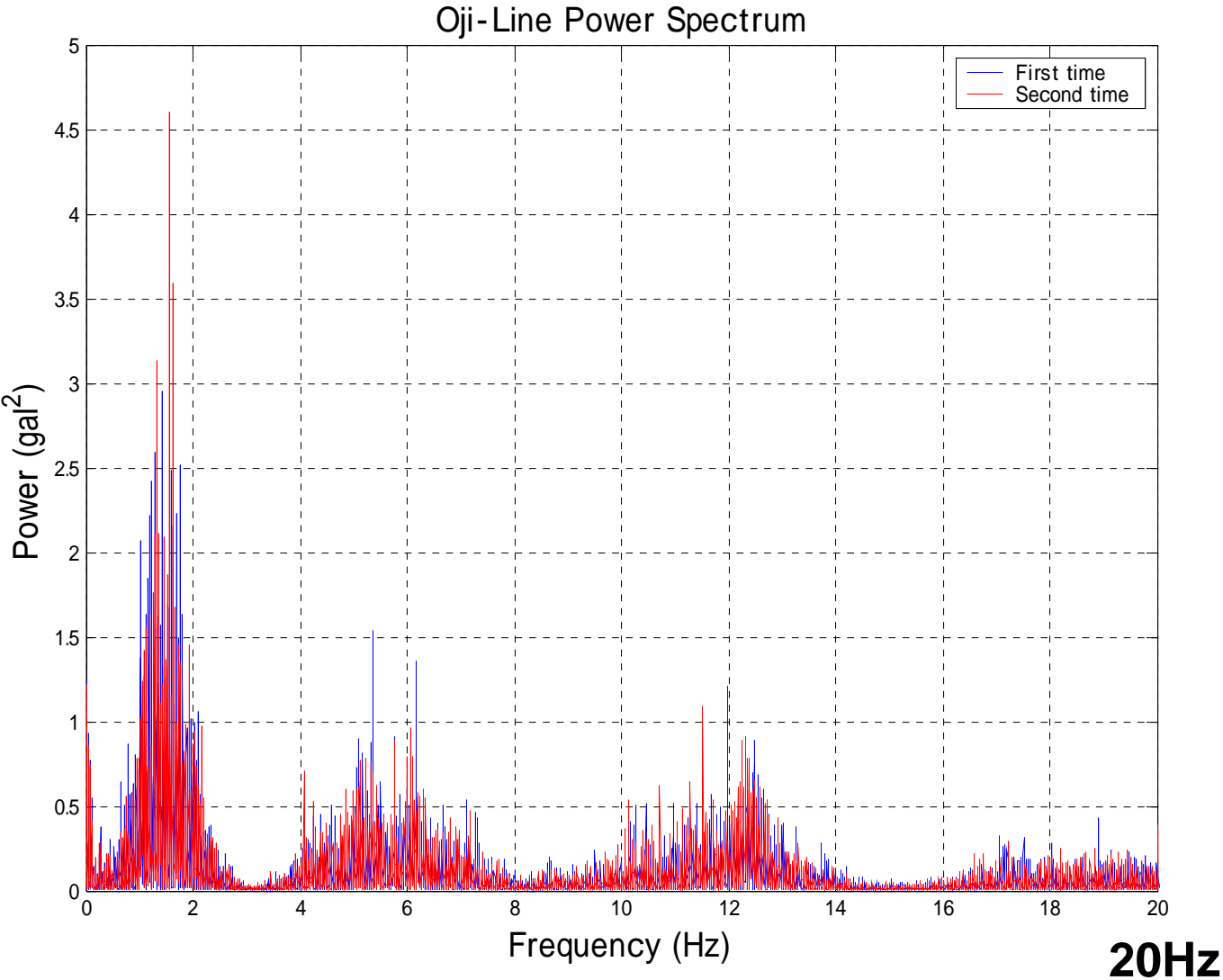


Route 7 is larger than Uji route
加速度応答と対応していない

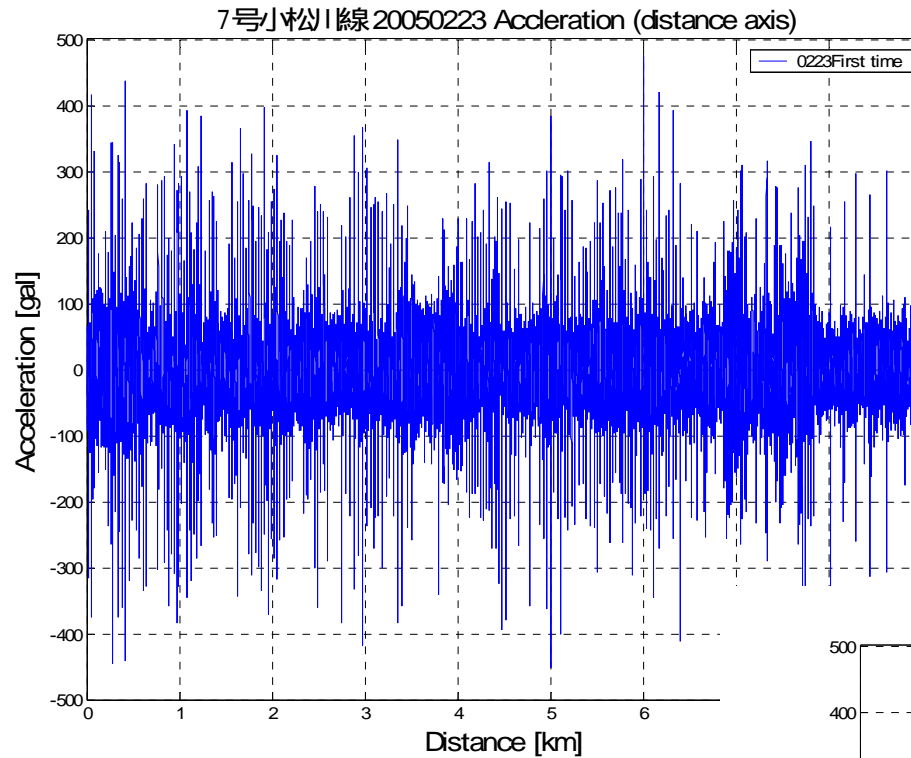


Power spectrum of acceleration (0-20Hz)

Good repeatability



20Hz

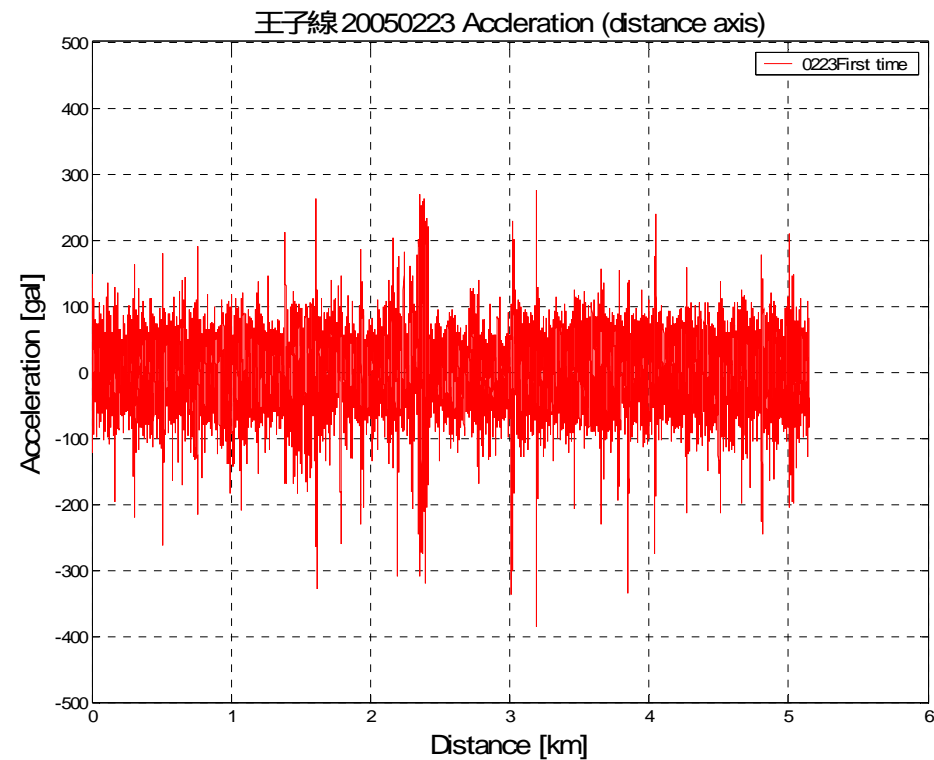


Route 7

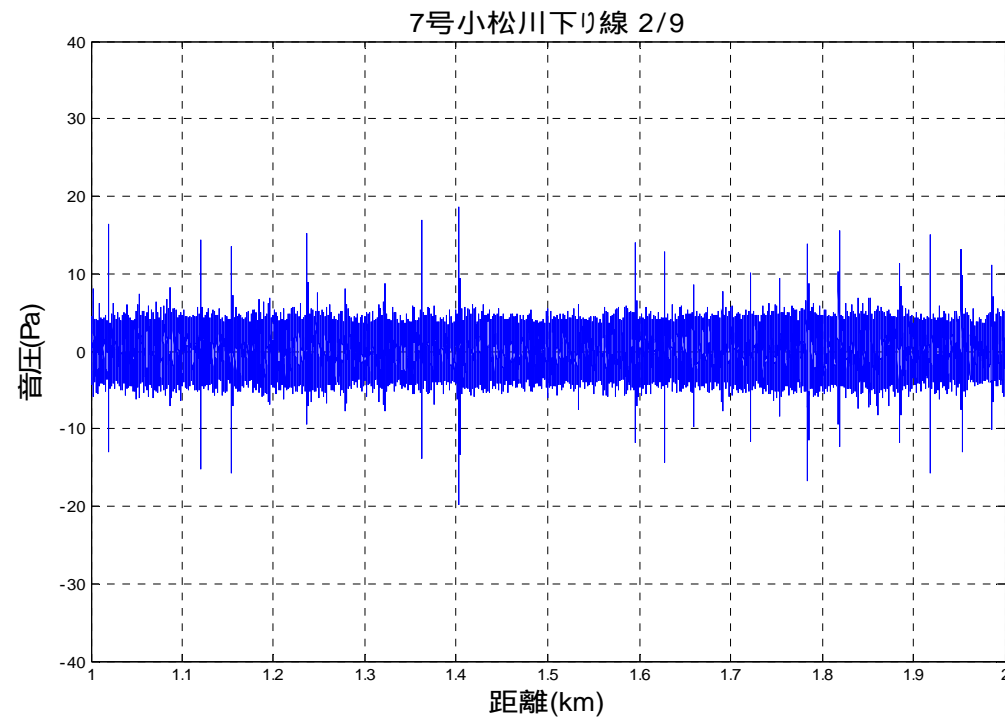
Maximum : 500 gal
30 years old

Ouji Route

Maximum : 400 gal
A few years old



Data from the microphone



Sound level of expansion joints

Change sound pressure (Pa) to sound level (dB)

Route 7

Average 103.7dB



Ouji route

Average : 98.8dB



Route 7 is larger than Ouji route