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GPR and PIPELINE & CABLE LOCATOR DEVELOPMENT

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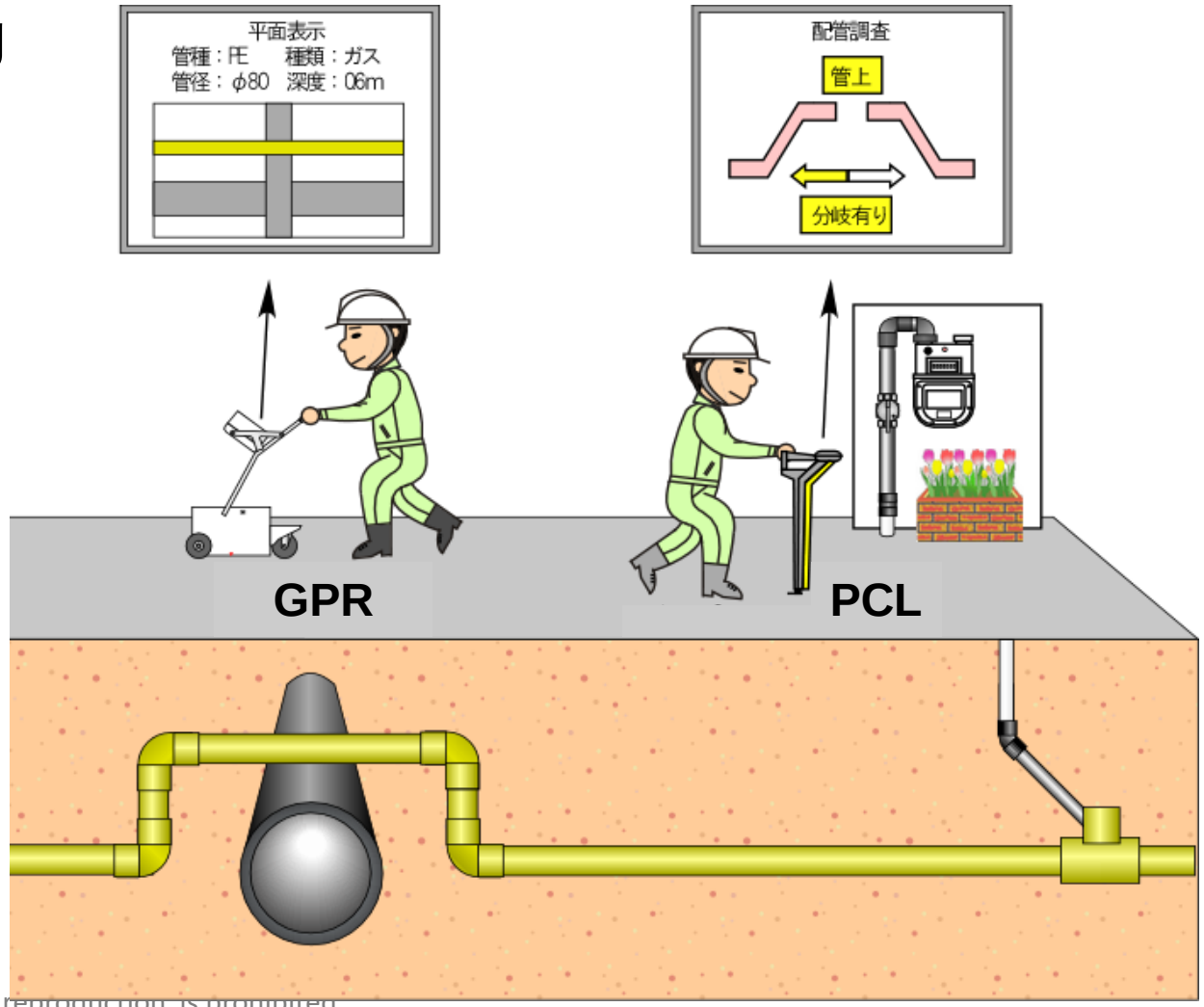
Pipeline Locating Technique

To avoid underground installation being damaged, gas company developed…

1) GPR: Ground Penetrating Radar System; Available for metallic, plastic pipe including foreign line(water, sewer, telephone, etc.)

2) PCL : Pipeline & Cable Locator System; Distinguish targeted metallic pipe & cable from other utilities.



Topics

1. Background
2. GPR Development
3. GPR Solutions
4. PCL Development
5. PCL Solutions
6. Conclusions

1. Background

- Pipeline Locating Technique for gas works

- Before the excavation or horizontal directional drilling work;
  It is important to identify pipes like gas, water and sewer, and locate the buried position.

(a). Survey before digging

(b). Survey before horizontal drilling

(c). Survey condition under road.

Survey method of Ground Penetrating Radar

1. Background

-To avoid being damaged…

◆ Need to detect gas buried pipeline carefully before construction work to prevent gas from damaging by heavy machine or boring machine.

Braked Situation

Gas pipe buried shallow was damaged by cutter.

Braked Gas Pipeline

Breakage Point

2. GPR Development

- History of GPR Development

- Commencement of research in 1980 and keep developing.
- More than half of them are used in Osaka Gas territory.

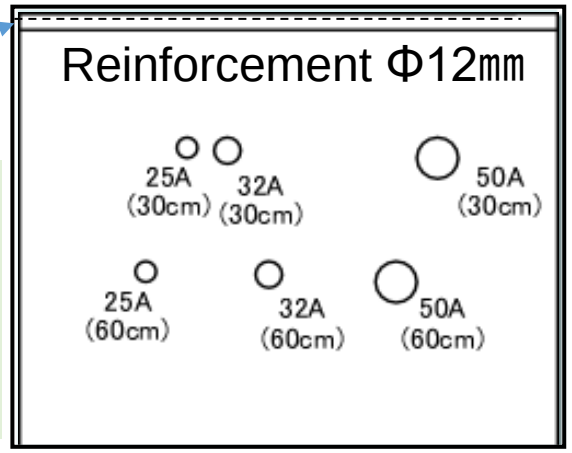
Name	Radar man (NJJ-61C)	Radar mini (NJJ-64)	Radaman M (NJJ-86,96)	Narrow-spot radar	Radar mini (NJJ-640)	Radar mini (GN-02)
Year	1989	1990	2002	2003	2007	2015
Nos.	16 units	80 units	3 units	10 units	142 units	45 units
Max. depth	2m	0.8m	3m	0.1m	1.0m	1.5m
Appearance						
Feature	Transmission wave: Pulse Receiving circuit: STC (Sensitive Timing Control Circuit)		Touch-panel Automatic Image Processing 3D (offline)	Ultra-small size for narrow space External antenna 3D (offline)	Advanced STC Touch-panel ・ Automatic Image Processing ・ 3D (offline)	Automatic Image Processing 3D(online) Transmission: Chirp wave

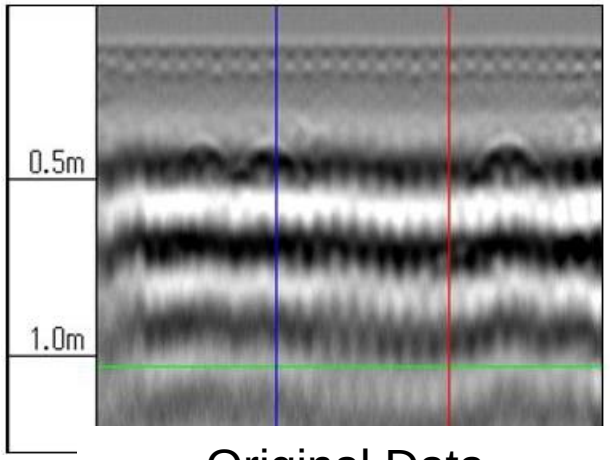
3. GPR Solutions

- New antenna design & Image Processing

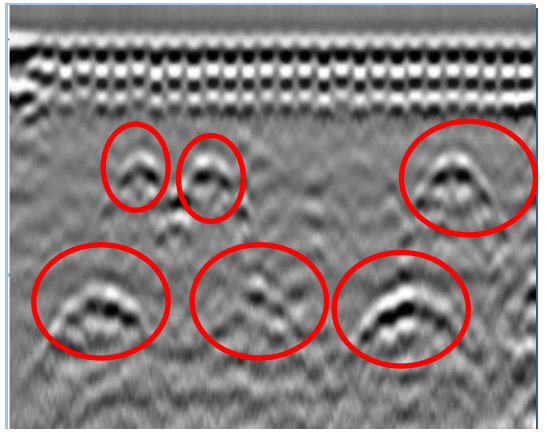
To make clear of shallow depth just under the reinforcement, new antenna design and image processing solutions are effective.

Concrete pavement 5 cm (Thickness)
Reinforcement interval 15 cm



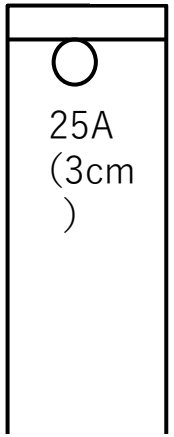


Original Data

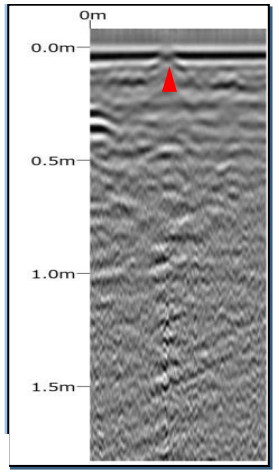


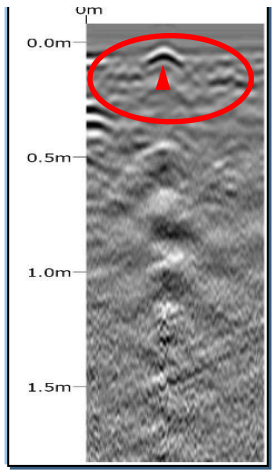
After Image Processing

5 cm thick asphalt pavement



Cross section view





3. GPR Solutions

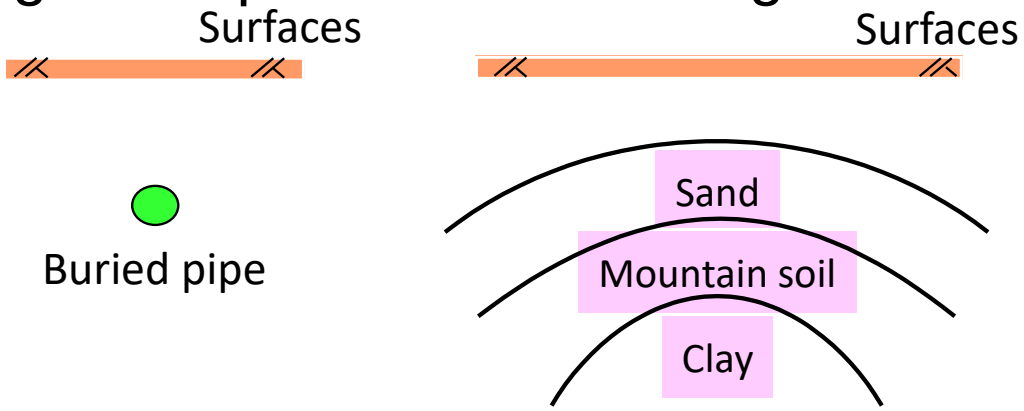
- New antenna design & Image Processing

◆ Can determine position and depth of buried pipe by comprehensively judging the soil type, echo bounce time, and propagation speed of electromagnetic waves.

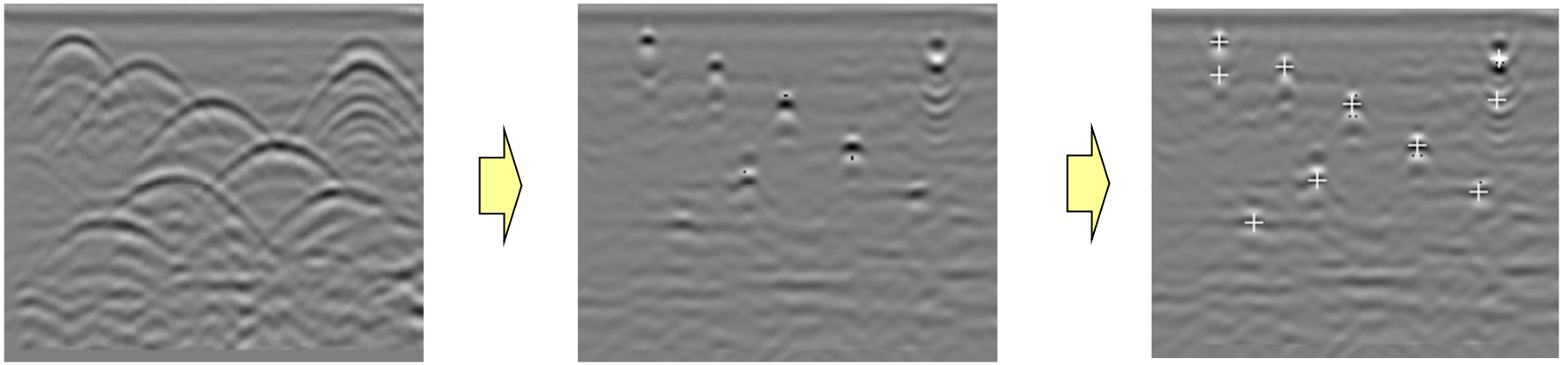
【XTV method】

Depending on the type of soil
There is a difference in the propagation speed of electromagnetic waves.

Depth ? = Reflection time × velocity?



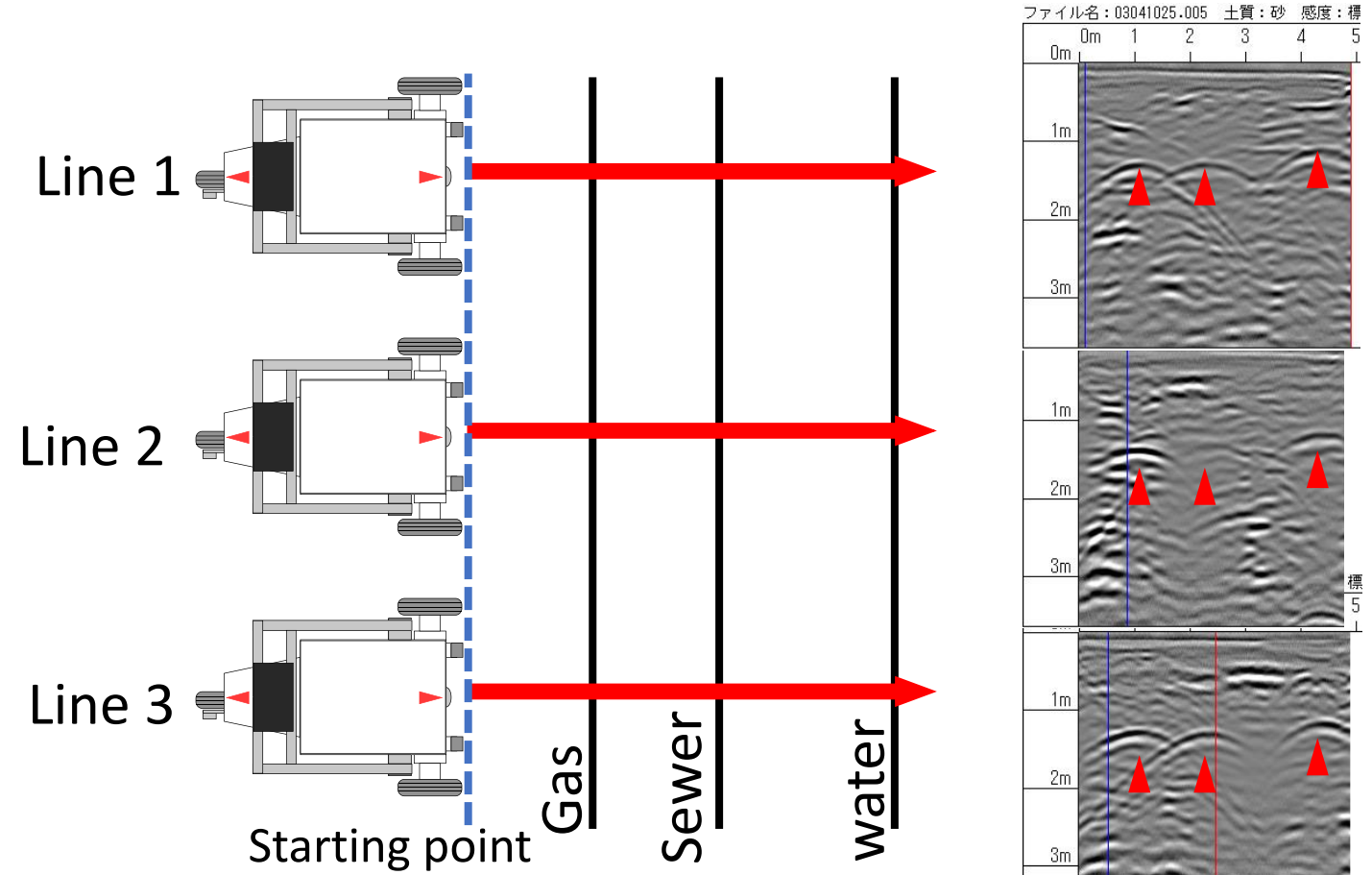
Exploration image → Speed Estimation & Migration → Automatic extraction



XTV method: Image Processing to estimate accurate pipe depth

Conventional judgment

- One-line data judgment: Difficult to judge due to excavation boundary, piece of rock, etc
- Three-line data judgment: Adjust the start position and if the echoes from the pipes are on the same x-axis, it is possible to judge.



→ All three images are clear.

→ Although the sewer system is unclear, Identifiable by three-section evaluation

→ All three images are clear.

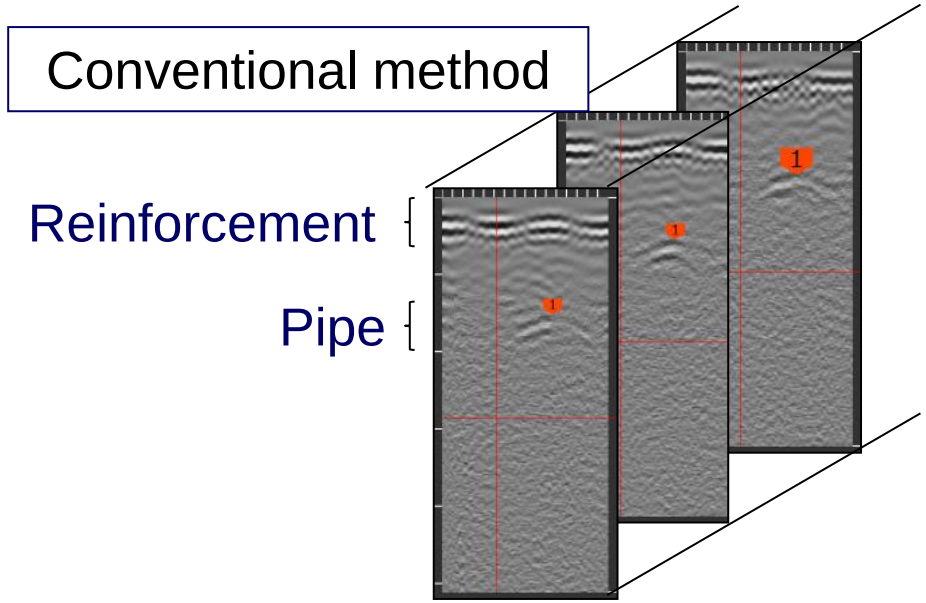
3. GPR Solutions

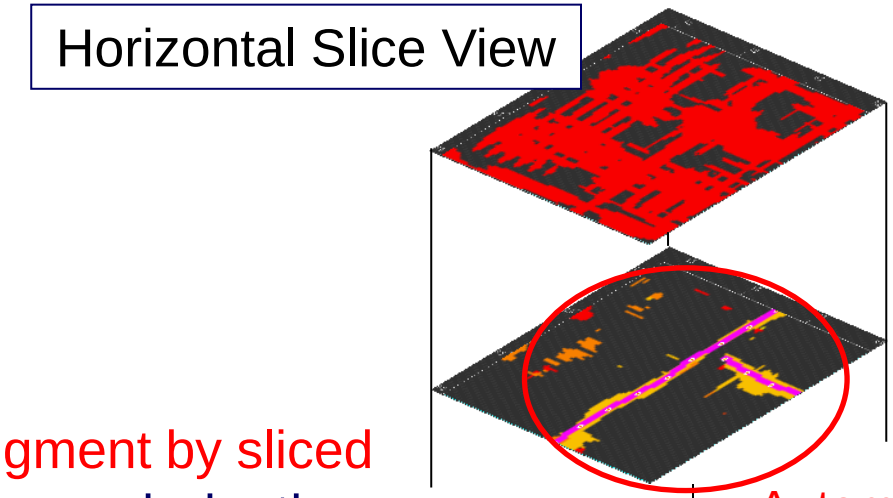
- Image Processing: Horizontal Slice View

Piping

- Conventional method: Must imagine continuous pipes from a few same x-axis position of the cross-sectional images. ⇒Beginner was difficult to judge..

- Horizontal Slice View: Can judge gas pipe easily even if reinforcement is used above gas pipe because it can slice horizontally and automatically judge continuity based on automatic pipe detection. Anyone can judge.





Reinforcement echos exist within 30 cm

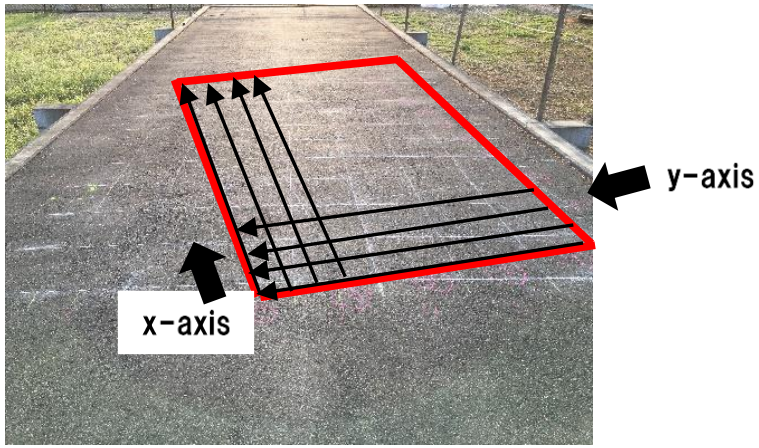
Easy judgment by sliced images by each depth range.

→Automatic Continuity Judgment

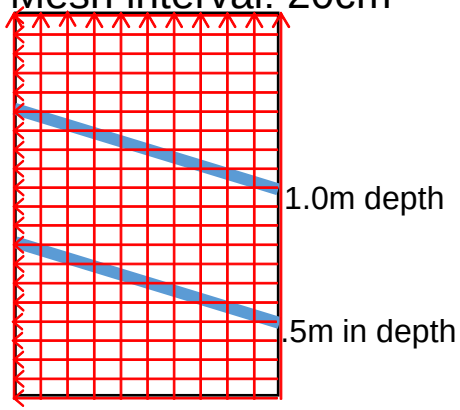
3. GPR Solutions

- Image Processing: Horizontal Slice View

◆ By probing in a lattice pattern, slanting pipe can be displayed accurately.

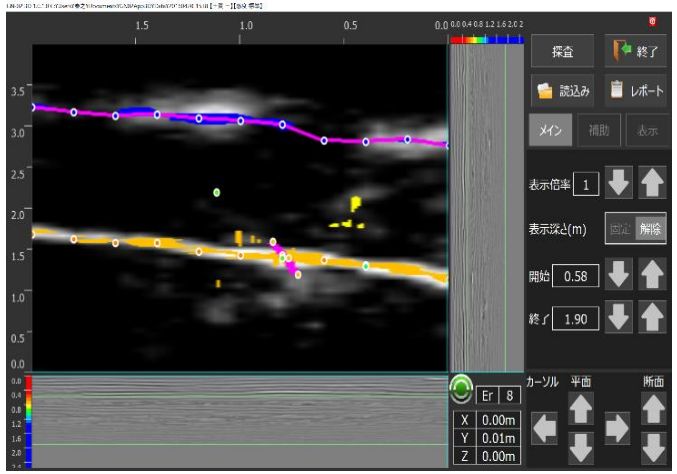


Mesh interval: 20cm



Plane view of operation route

Line measurement setting	x-axis	y-axis
Number of lines	11	21
Line mesh space	20cm	20cm
Area Range	2m	4m



→Automatic Continuity Judgment

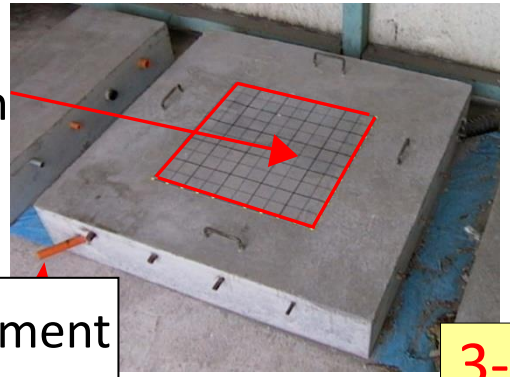
Plane view of GPR image processing result

3. GPR Solutions

- Image Processing: 3-D Visualization

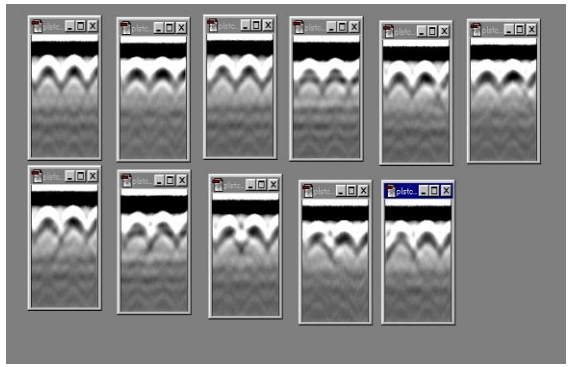
◆ Developed to locate gas pipe under the reinforcement by 3D visualization(online) thanks to PC processing capacity and image processing in 2015, so operator can detect more easily.

Range of exploration
50 cm square



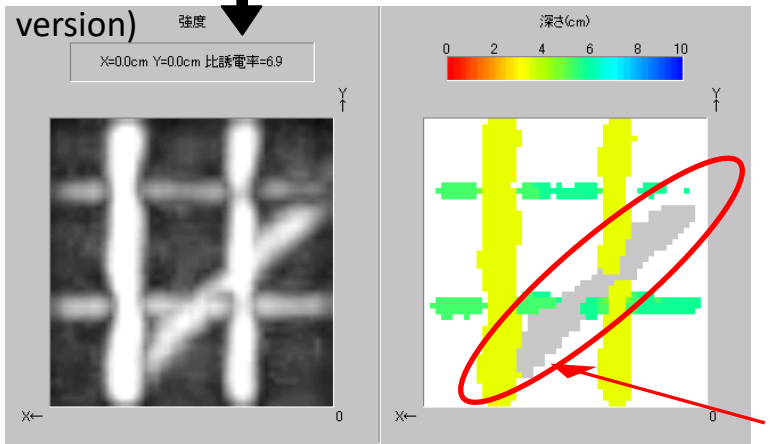
Below the lattice reinforcement pipe at an angle of 45 degrees

Conventional display(2-D)

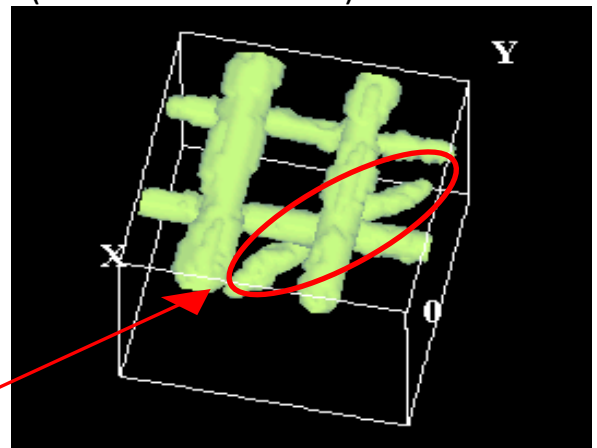


3-D visualization

(Light version)



(Professional version)



Pipe

Others; cooperation for police investigation

◆ Received a letter of appreciation from the Shiga Prefectural Police for corporation to find a drum can with a dead body by radar. (2001/Aug/30th)

遺体発見に協力の
大阪ガスに感謝状
県警

近江八幡市音羽町、土木作業員峠岡三治さん(47)の殺人・死体遺棄事件で、遺体をコンクリート詰めにしたドラム缶が埋められた場所を、地中探査機を使って特定した大阪ガス（大阪市中央区）などに、県警本部長から感謝状が贈られた。

探査機は同社の開発で、手押し車のように地面を転がすと地中の様子がモニター画面に映し出される仕組みで、埋設管を探す時に用いられる。

供述で得られた地点を掘ったがドラム缶がなかったため、県警捜査本部が同社に協力を依頼。七月三十一日、志賀町北小松の琵琶湖岸で検証に先立って探査し、最初に掘った場所から北へ約十七㍍の地中でドラム缶状のものが埋められていることを突き止め、発見に貢献した。

4. PCL Development

- History of PCL Development

- Commencement of research in 2000 and keep developing.

【New Function】

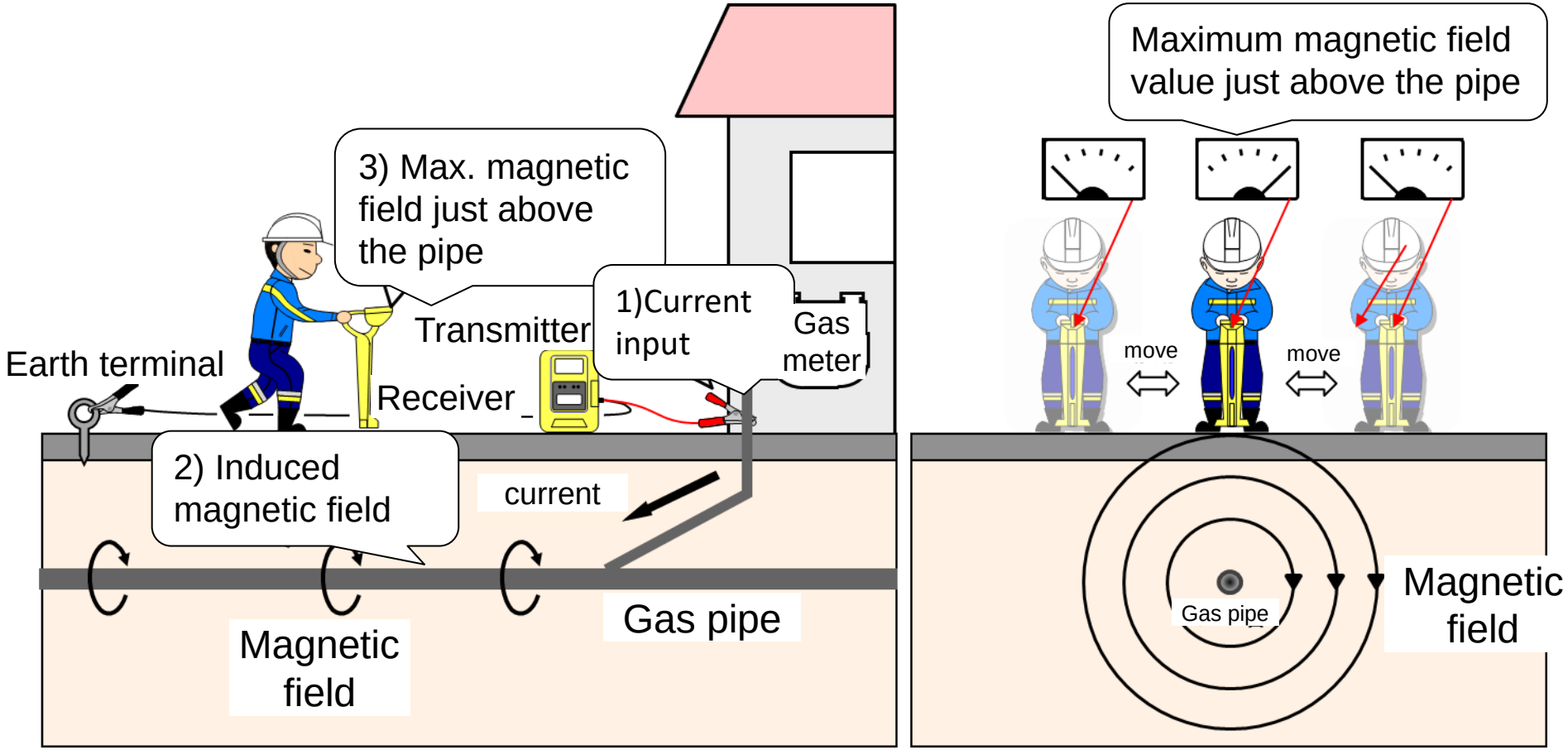
- Available for insulating joints
- Loop check function and transmitting frequency can be selected.

Name	PL-960G	PL-1000	PL-900B (Easy locator)	PL-X	PL-G	PL-SD (Easy locator SD)	Simple earth terminal
Introduction Year	2002	2005	2009	2016	2017	2019	2012
Nos.	173 units	285 units	105 units	8 units	3 units		295
Depth	5m	5m	2m	5m	5m	0.8m	—
Frequency.	27,83,334kHz	8,27,83kHz	27kHz	0.5,8,27,83,128kHz	8,27,83kHz	250kHz	—
Feature		Peak hold	Low cost, single function	Automatic phase detection transmitor/receiver	Vibrator, Smartphone link function	Minimize and integrate transmitter / receiver	Sheet shaped earth terminal (Not required grounding)
Appearance							

4. PCL Development

- PCL Principles

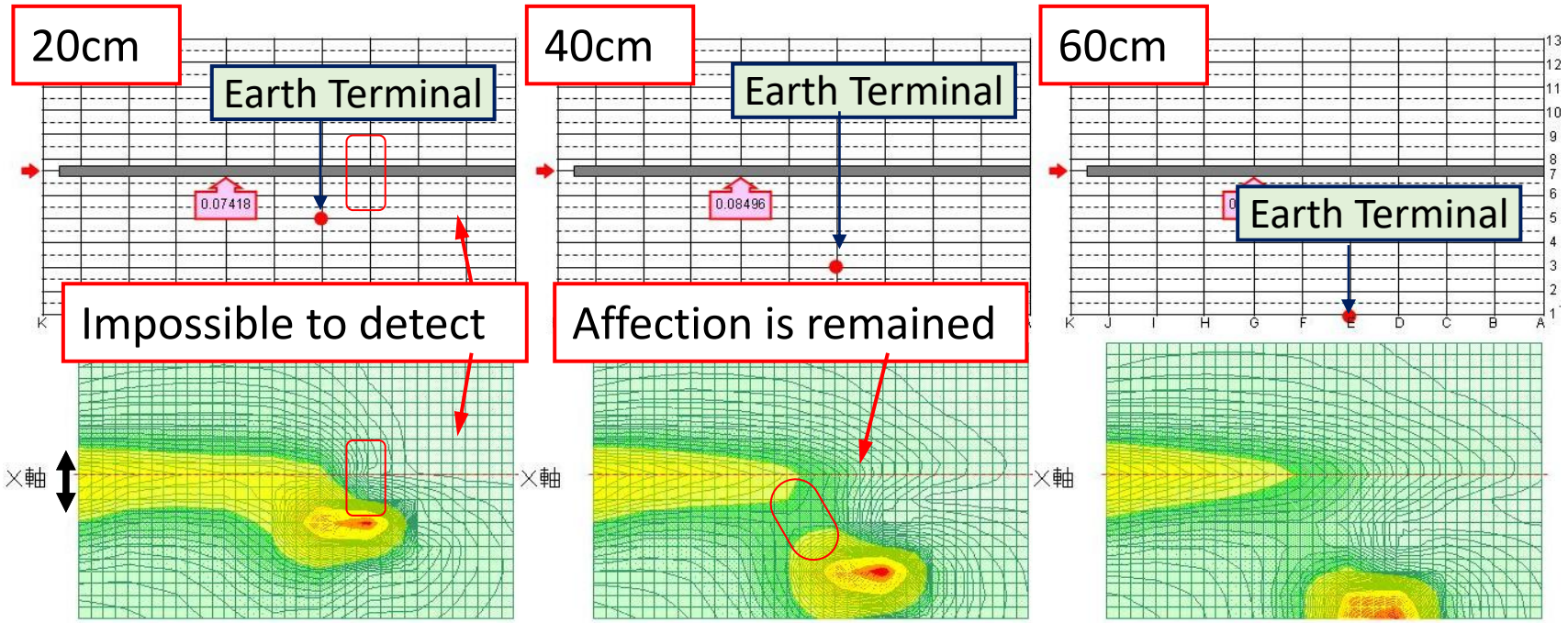
◆ Current is passed through the gas pipe, and the magnetic field is detected on the ground to determine the position and depth.



4. PCL Development

- Conventional PLC Function: Earth Terminal Point

◆ If the gas pipe and the Earth Terminal are close to each other, the exploration performance deteriorates. Since a strong magnetic field is generated around the Earth terminal.



Required to develop easy Earth Terminal

5. PLC Solutions

- New PLC accessory: “Earth Sheet”

- Materials with uniform electrical conductivity are required to realize Earth Terminal without fixing on the ground surface.
- Select the most suitable material for Earth Terminal from a variety of materials.

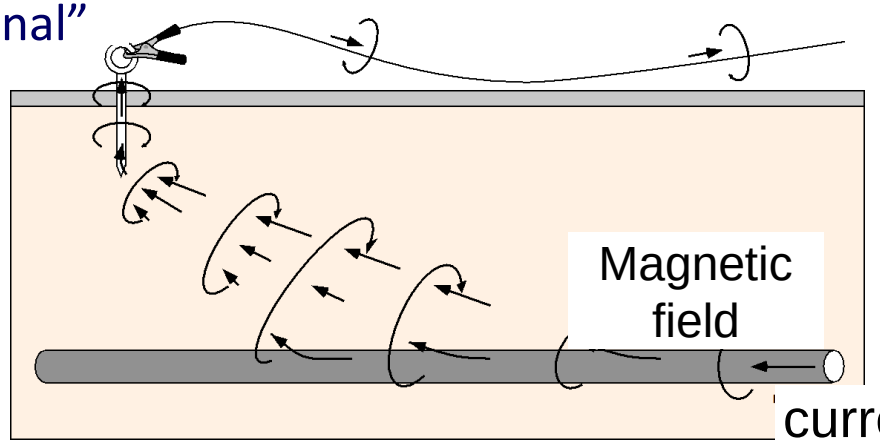
Conventional “Earth terminal”

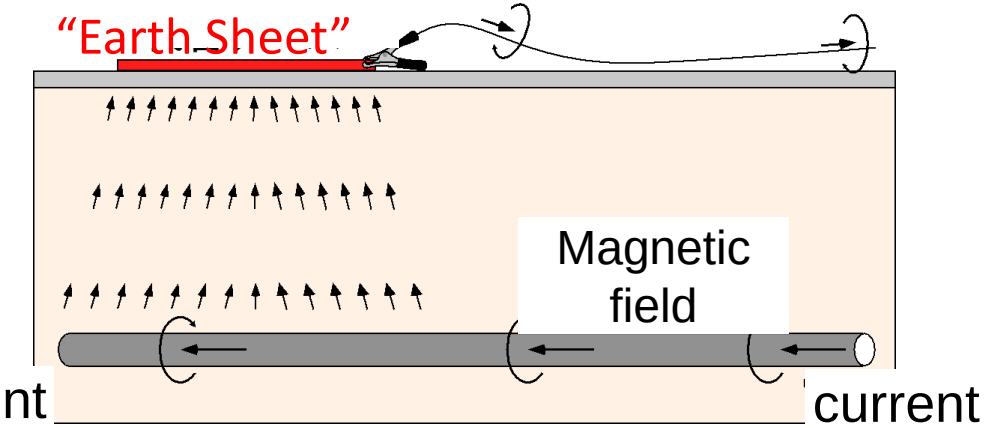
- Current is concentrated on the Earth Terminal rod.
- Generate a strong magnetic field
- Difficult to explore near Earth Terminal.

New “Earth Sheet"

- Distribution of current to alternative ground with area
- No strong magnetic field is generated.
- It is possible to explore near Earth Terminal.

“Earth Terminal”





5. PLC Solutions

- New PLC accessory: “Earth Sheet”

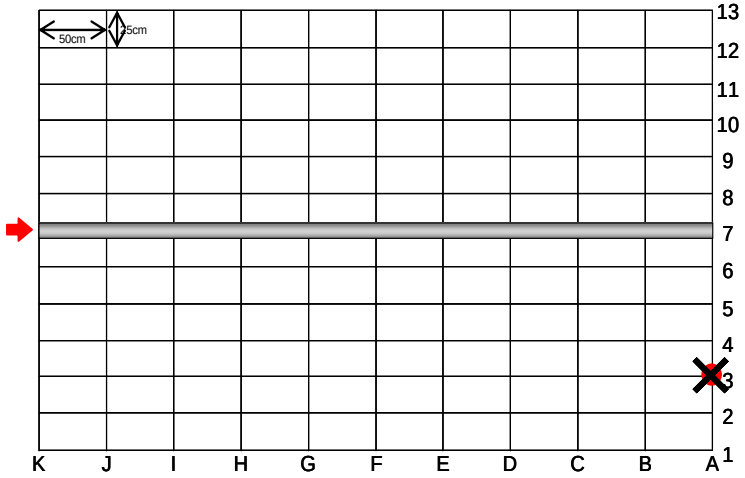
- Simply placing the new “Earth Sheet” to achieve better locating performance than Earth Terminal.
- Carbon material that blocks radio waves
- Characteristics: Since the carbon material of the conductive material is used, the Earth effect is large because the distribution of the electric current is uniform.

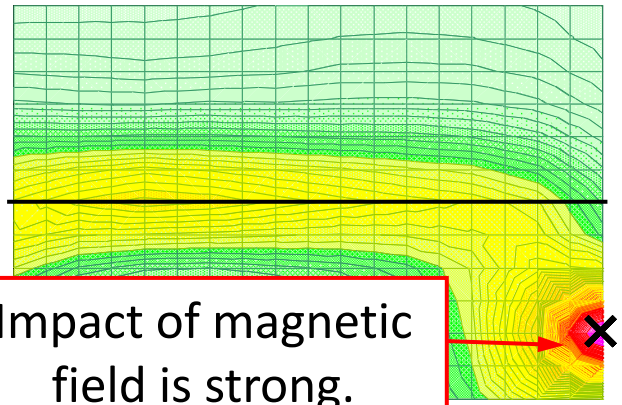
New “Earth Sheet”

5. PLC Solutions

- Earth Sheet impact

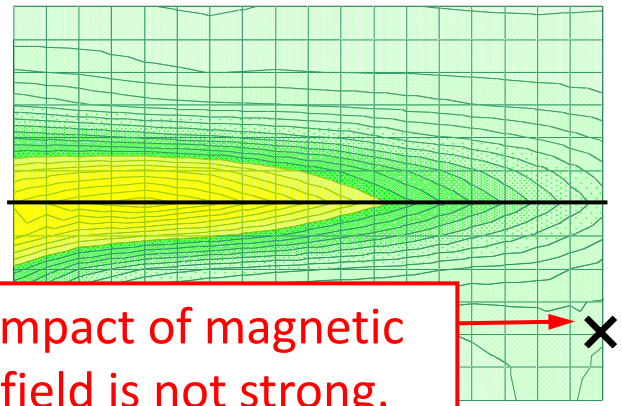
- No magnetic field near ground was generated in the water tank experiment, in case we put earth sheet.
- Earth effect can be obtained by simply placing the product in an optimum position for exploration.





Impact of magnetic field is strong.

Conventional Earth Terminal



Impact of magnetic field is not strong.

New “Earth Sheet”

5. PLC Solutions

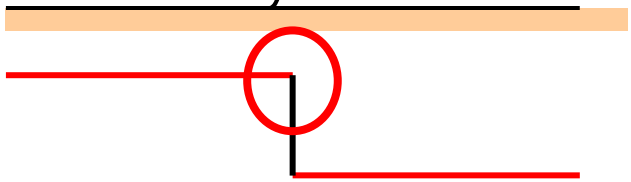
- Other problems to be solved

- Was difficult to detect branching, up/down
- Was difficult to specify gas pipes if there are adjacent pipes (to specify gas pipes).

Branching, vertical bend point

Conventional method

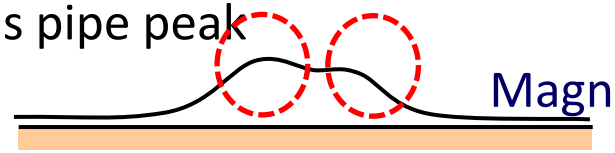
Vertical bend points cannot be detected accurately.

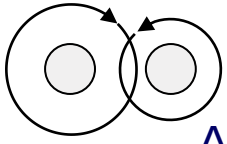


Target pipe to be searched

Conventional method

Difficult to distinguish the position of the gas pipe peak





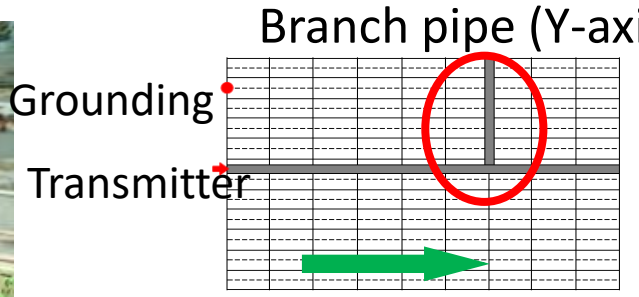
Requirement to detect the target position

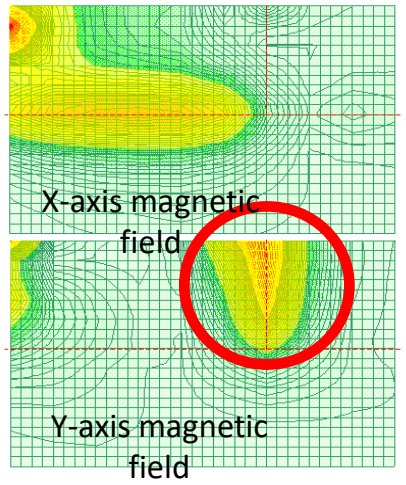
5. PLC Solutions

- Additional y-axis Sensor

◆Added another sensor (Y-axis) and can explore branch pipe.

Experimental scene





x-axis

Conventional sensor configuration

Additional sensor

Branch detection

- Explore the coil in the X-axis direction.
  → Explore straight pipes
- Explore the coil in the Y-axis direction.
  → Discover branch pipes

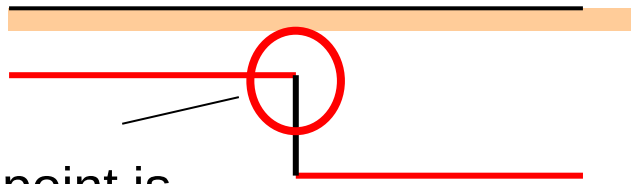
5. PLC Solutions

- Y-axis Sensor Improvement

◆ Conventional problem was solved due to the additional sensor(Y axis), so can detect branching and vertical bend point.

Conventional method

Only detection of horizontal magnetic field
→ Vertical bend points cannot be detected accurately.



Bending point is difficult to be located

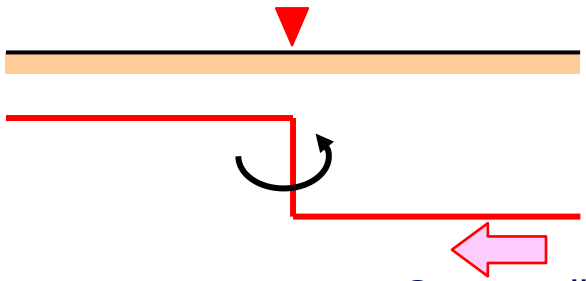
x-axis

y-axis

Additional sensor

Improved point

In addition to the horizontal magnetic field (x-axis), the vertical magnetic field (y-axis) is also detected.
→ It is possible to accurately detect bending points in the vertical direction.



Current direction

5. PLC Solutions

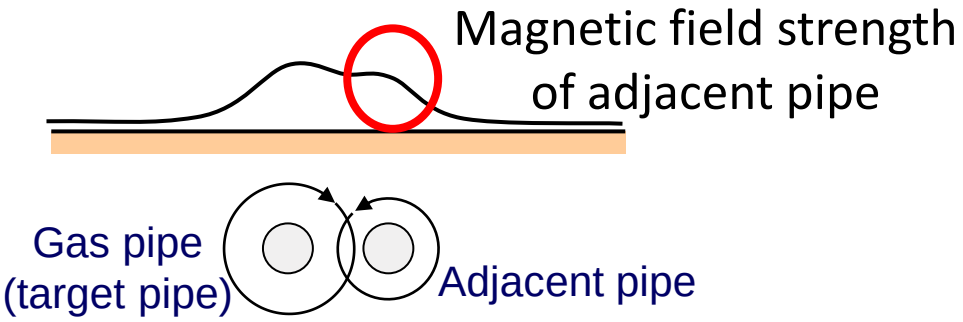
- Y-axis Sensor Improvement

◆ Conventional problem was solved due to synchronized system, so can distinguish the position of the gas pipe peak

Conventional method

The magnetic field of the gas pipe and the magnetic field induced in the adjacent pipe are synthesized.

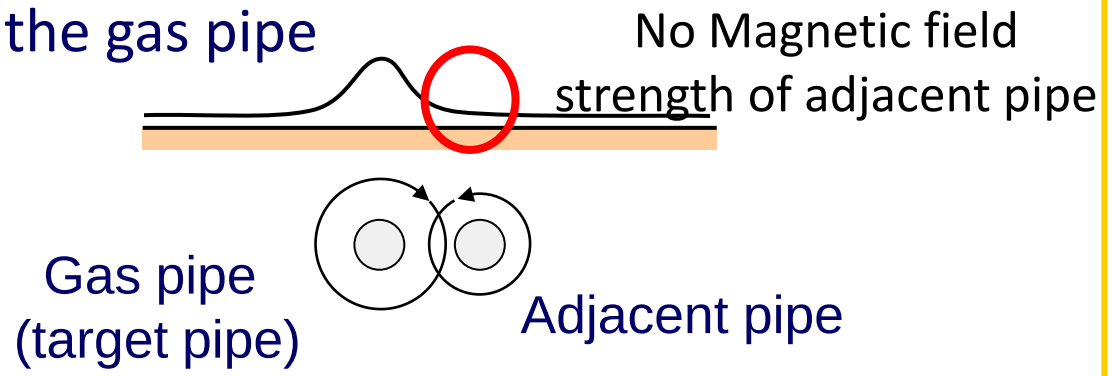
→ Difficult to distinguish the position of the gas pipe peak



Improved point

Available to cancel the induced magnetic field of the adjacent pipe because receiver and transmitter are synchronized.

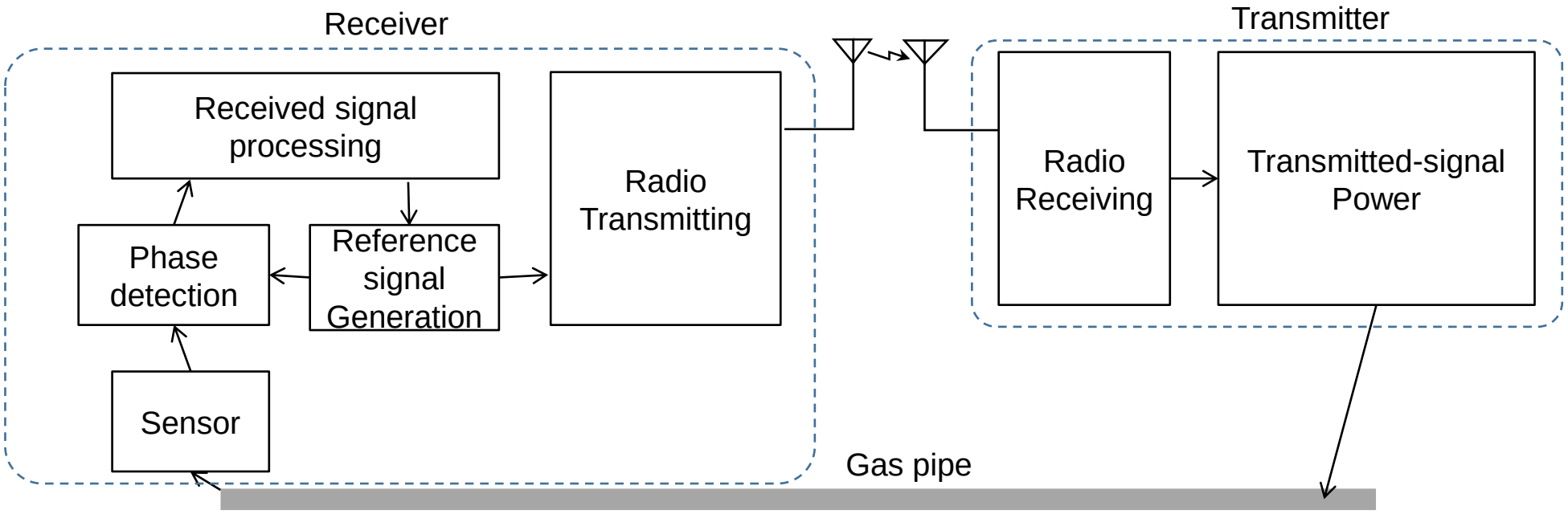
→ Possible to distinguish the exact position of the gas pipe



5. PLC Solutions

- Wireless Communication System for Synchronizing

◆ Wireless communication between transmitter and receiver, can determine the current direction of the gas pipe.→Can distinguish pipe even if it is buried close to another pipe.



6. Conclusions

1) GPR Development due to;

- New Antenna Design
- x-t-v 3-D image processing

Contributed for easy image recognition even under the reinforcement surface.

2) PCL Development due to;

- 'Earth Sheet' ;

  Earth terminal's impact can be improved.

- 'Target pipe identification function' using wireless phase detection;

  Only the target pipe can be identified.

- 'y-axis' sensor coils;

  The branched pipe position and the 90-degree elbow joint can be located.

As a result, above development have contributed to reduce the pipe damaging by third parties' excavation.

Contact : Osaka Gas

https://www.osakagas.co.jp/en/index.html

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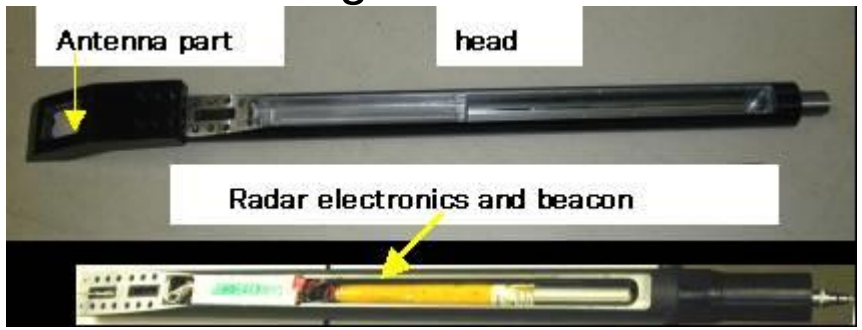
Shintaro (Shawn) Hiromori
E-mail:s-hiromori@osakagas.co.jp

(FYI)History of Small GPR Technique

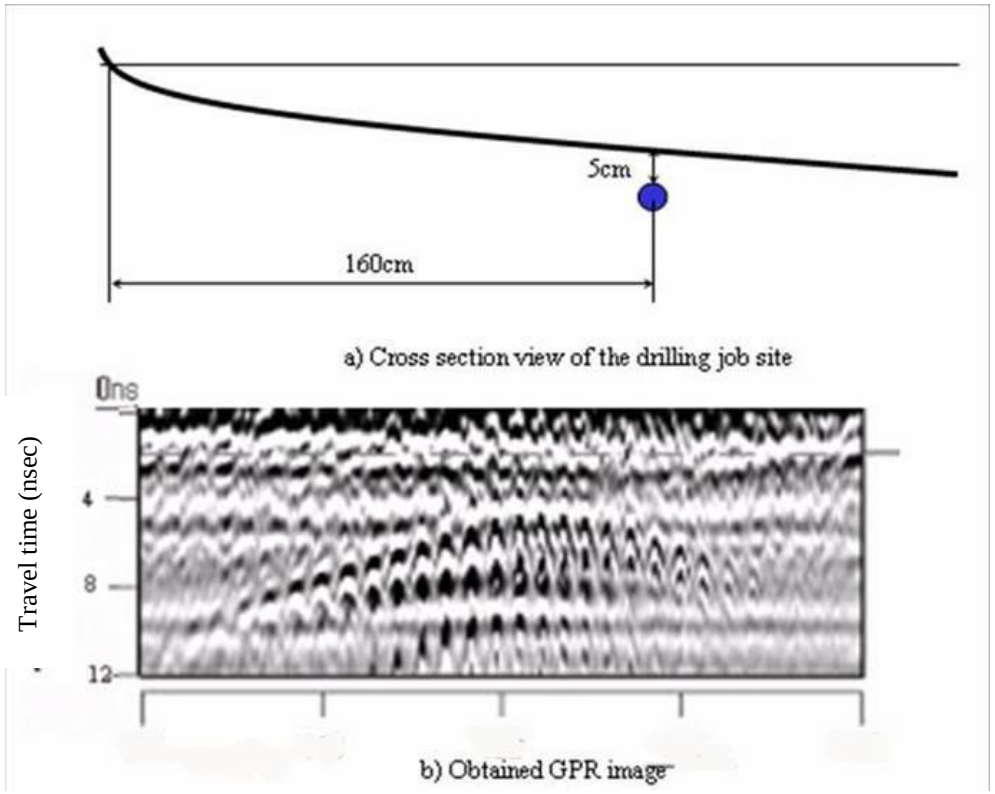
- Forward looking GPR for HDD machine 1998. (just for trial)



(a) GPR set on head of horizontal boring machine

(b) Controlling the boring machine

(c) Tip of the head with small antenna



Recommendation for PLC work

◆ Conventional PCL settings are difficult for non-skilled locating workers.

① Frequency Selection: Which frequency should be selected?

→ Select based on the effect of locating distance and pipe joint material.

- Standard (until insulating joints) : 27kHz
- Investigation beyond insulation joints : 83kHz
- Prolonged and deep surveys : 8kHz

② Transmission Power and Receiving Sensitivity:

- Which transmission power to be selected?
- Which receiving sensitivity to be selected?

→ Set the output constant as possible and adjust the reception sensitivity.

(Do not adjust the reception sensitivity frequently! Overlook the pipe ends, branches, etc.

③ Location of Earth: Where is the optimal ground location?

→ To check the maximum sensitivity when the receiver unit is just above the targeted pipe.

④ Distance of Earth point: How far should be separated from just above the pipe?

→ Preferable more than 50 cm.

PLC Function: Loop Check

◆ Connect the transmitter to the targeted gas pipe and determine whether the targeted pipe could be located or not.

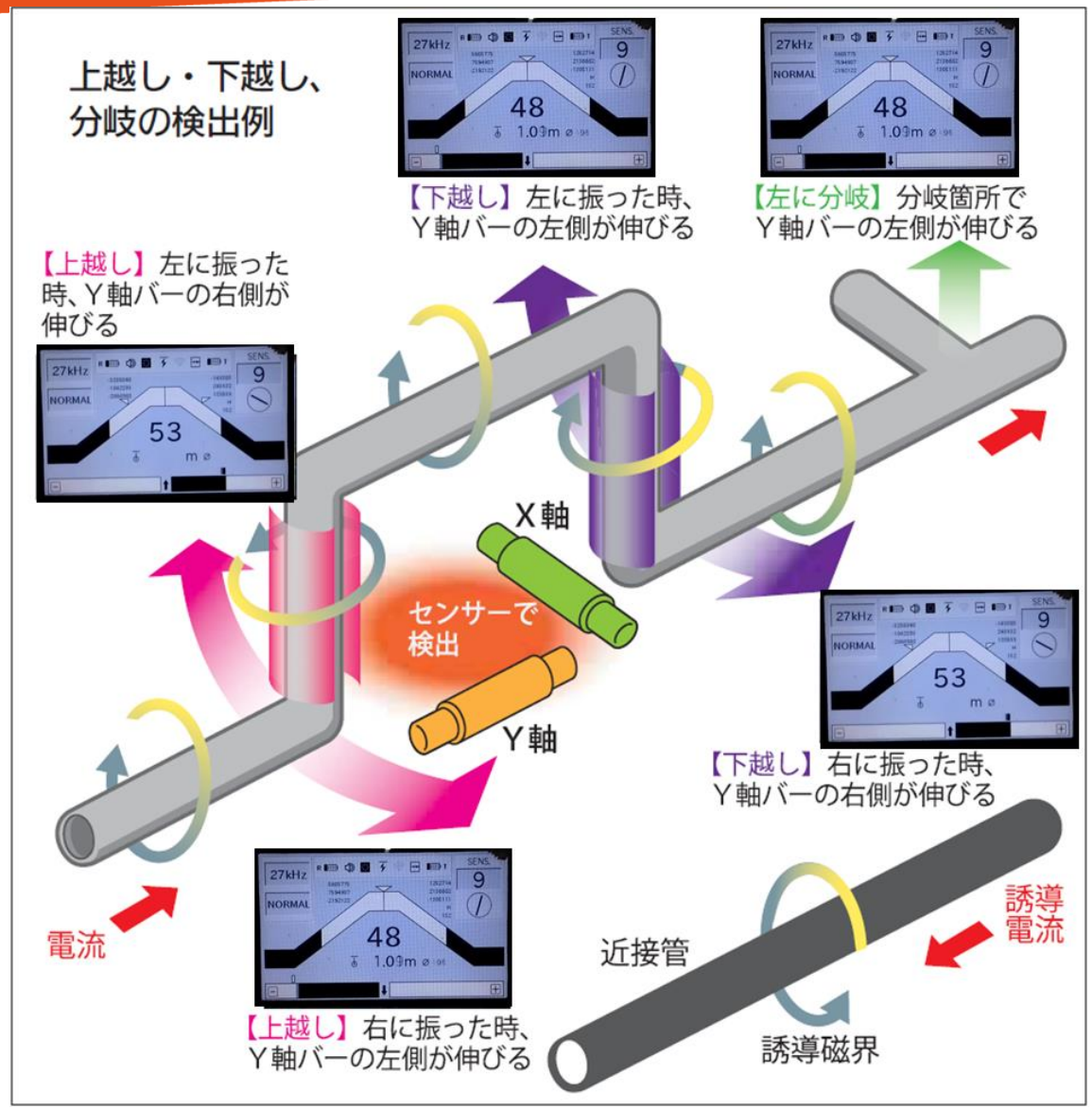
PL-1000 transmitter

[Resistance value 6-step display]

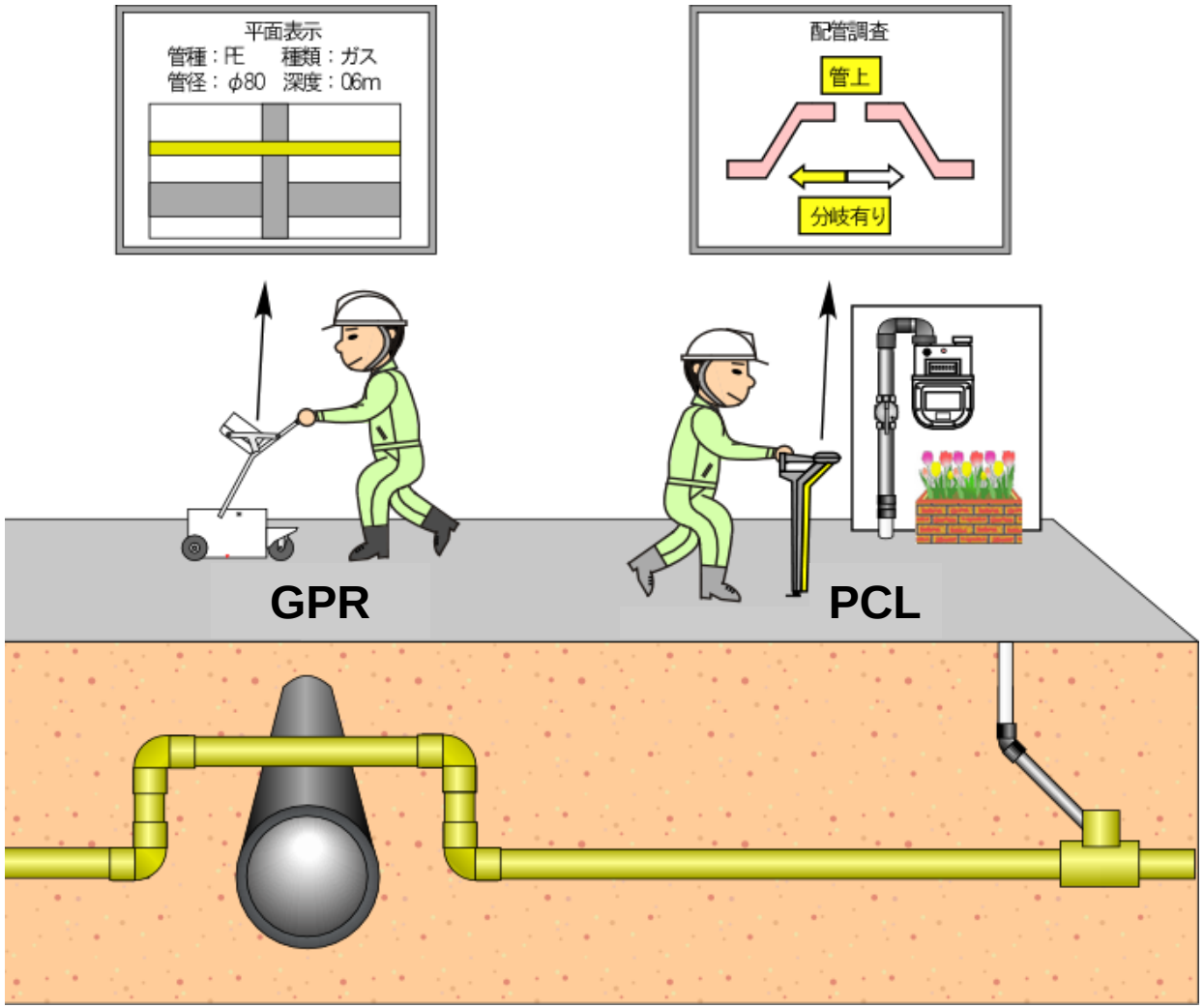
0~100Ω→1:■ ~ 680Ω→2:■■ ~ 1kΩ →3:■■■	Position and depth can be detected with high accuracy.
~ 3kΩ →4:■■■■ ~ 5kΩ →5:■■■■■	Position detection is possible, but depth accuracy is low level.
5kΩ~→6:■■■■■■	Undetectable (connection position should be changed)

※ Classification is based on the results of field tests and field investigations

What’s new for advanced PLC



Pipeline Locating Technique



To avoid underground installation being damaged, gas company developed…

1) GPR: Ground Penetrating Radar System; Available for metallic, plastic pipe and stray utilities.

2) PCL, Pipeline & Cable Locator System; Distinguish targeted metallic pipe & cable from other utilities.