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# Solution Presentation

## Slope Stability & Bridge Health

2026.05.12

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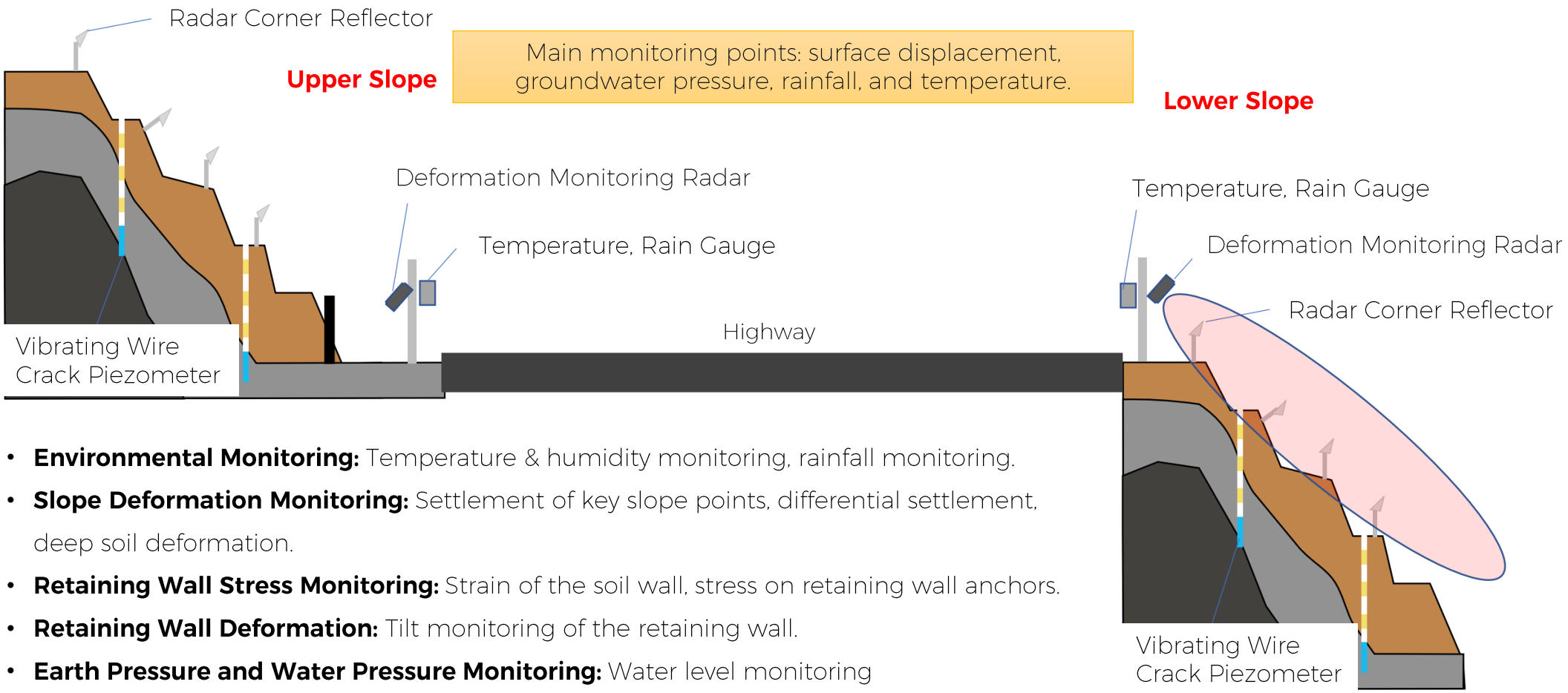
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# Slope Stability Monitoring

Real-time acquisition of quantitative data on the load-bearing capacity, structural response, and structural changes of key infrastructure such as bridges, tunnels, and slopes; real-time early warning and comprehensive data analysis.

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# Key Aspects of Slope Monitoring



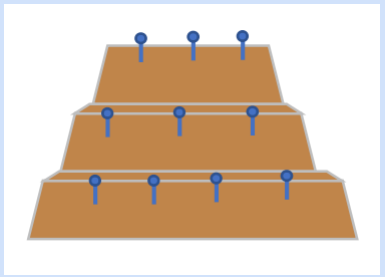
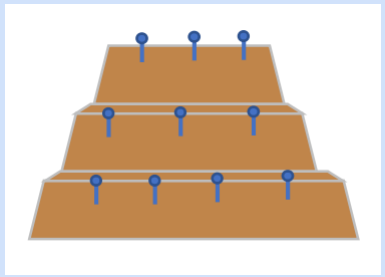
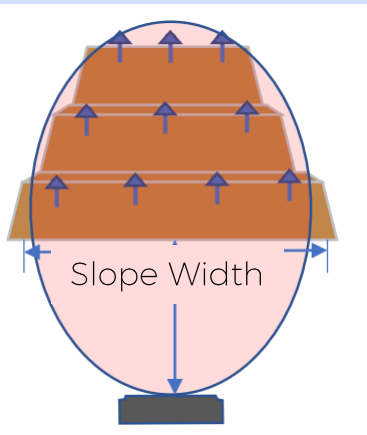
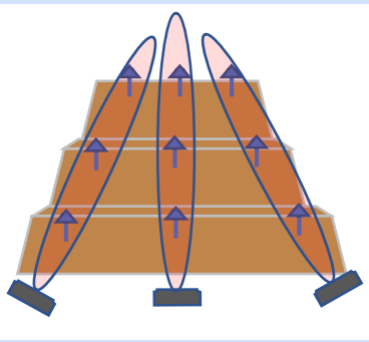
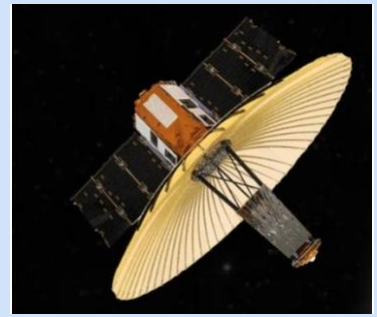

- **Environmental Monitoring:** Temperature & humidity monitoring, rainfall monitoring.
- **Slope Deformation Monitoring:** Settlement of key slope points, differential settlement, deep soil deformation.
- **Retaining Wall Stress Monitoring:** Strain of the soil wall, stress on retaining wall anchors.
- **Retaining Wall Deformation:** Tilt monitoring of the retaining wall.
- **Earth Pressure and Water Pressure Monitoring:** Water level monitoring

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# Comparison of Surface Displacement Monitoring Technologies

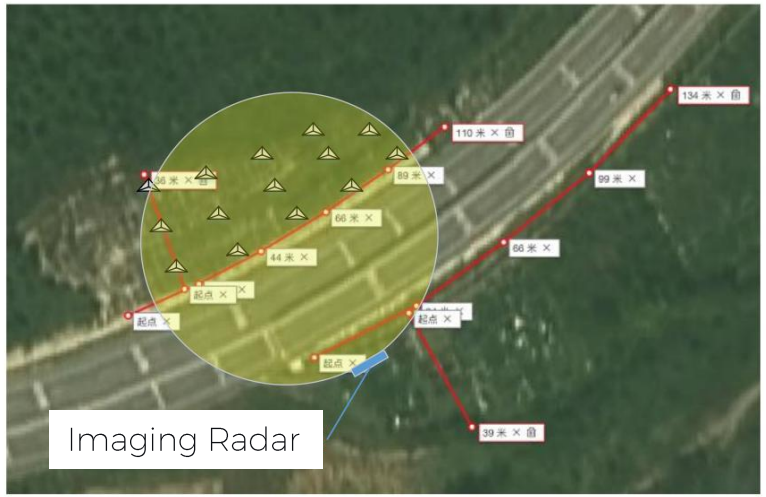
| | Inclinometer | Differential GPS | Imaging Slope Radar + Corner Reflector (SD1K) | Micro-displacement Monitoring Radar + Corner Reflector (MD10) | Satellite Radar Imaging + Corner Reflector |
|---|---|---|---|---|---|
| Principle | Using the inclination of monitoring poles to detect surface movement of slopes. | Measuring the absolute displacement of each monitoring point to track slope surface movement. | Monitoring surface movement by measuring the radial displacement of corner reflectors relative to the radar. | Surface movement is monitored by measuring the radial displacement of corner reflectors relative to the radar. | Microwave signals are transmitted from a satellite, and the reflected signals are received to generate high-resolution images. |
| Benefits | • Low cost<br>• Can be used in scenes with complex vegetation cover | Distributed and capable of operating in areas with complex vegetation coverage. | Large monitoring coverage with low equivalent cost per monitoring point. | Low cost; low equivalent cost per monitoring point. | Data can be acquired periodically to support long-term slope stability analysis. |
| Challenges | 1. Unable to measure sliding deformation of the slope.<br>2. It has been verified that slope landslides are dominated by surface translation in the early stage, and this technology cannot achieve landslide early warning. | High cost per monitoring point. | 1. Cannot operate in areas with complex vegetation cover.<br>2. Not suitable for scenarios with dense or complex vegetation.<br>3. The system cannot function properly under complex vegetation coverage. | 1. Cannot operate under complex vegetation cover.<br>2. Requires deployment of multiple units. | 1. Long revisit interval, typically 15–30 days.<br>2. Requires large corner reflectors, typically over 1 meter in diameter. |

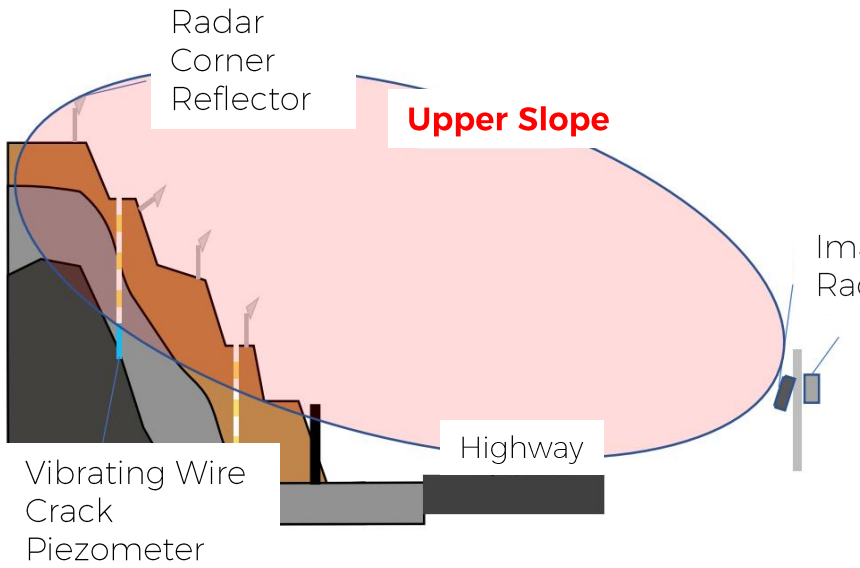
# Comparison of Surface Displacement Monitoring Technologies

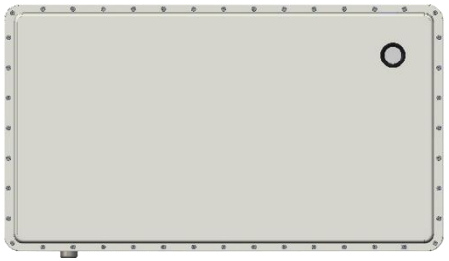
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|---|---|---|---|---|---|
| |  |  |  |  |  |

# Slope Monitoring: Imaging Radar

| Principle | Deployment | Specs |
|---|---|---|
| • The displacement of a corner reflector is determined by detecting changes in its position relative to the radar.<br>• Whether a corner reflector has moved is determined by analyzing the change in its position relative to the radar. | • Installed in opposite orientation, with the distance to the slope greater than the slope length.<br>• Corner reflectors installed at intervals of 10 m to 35 m. | • Maximum monitoring distance: 500m.<br>• Monitoring angle: Horizontal:±50°, Vertical:±8°.<br>• Ranging accuracy: ≤1mm.<br>• Data rate: 1fps. |



Imaging Radar
ClairWav-SD1K

# Slope Monitoring: Imaging Radar

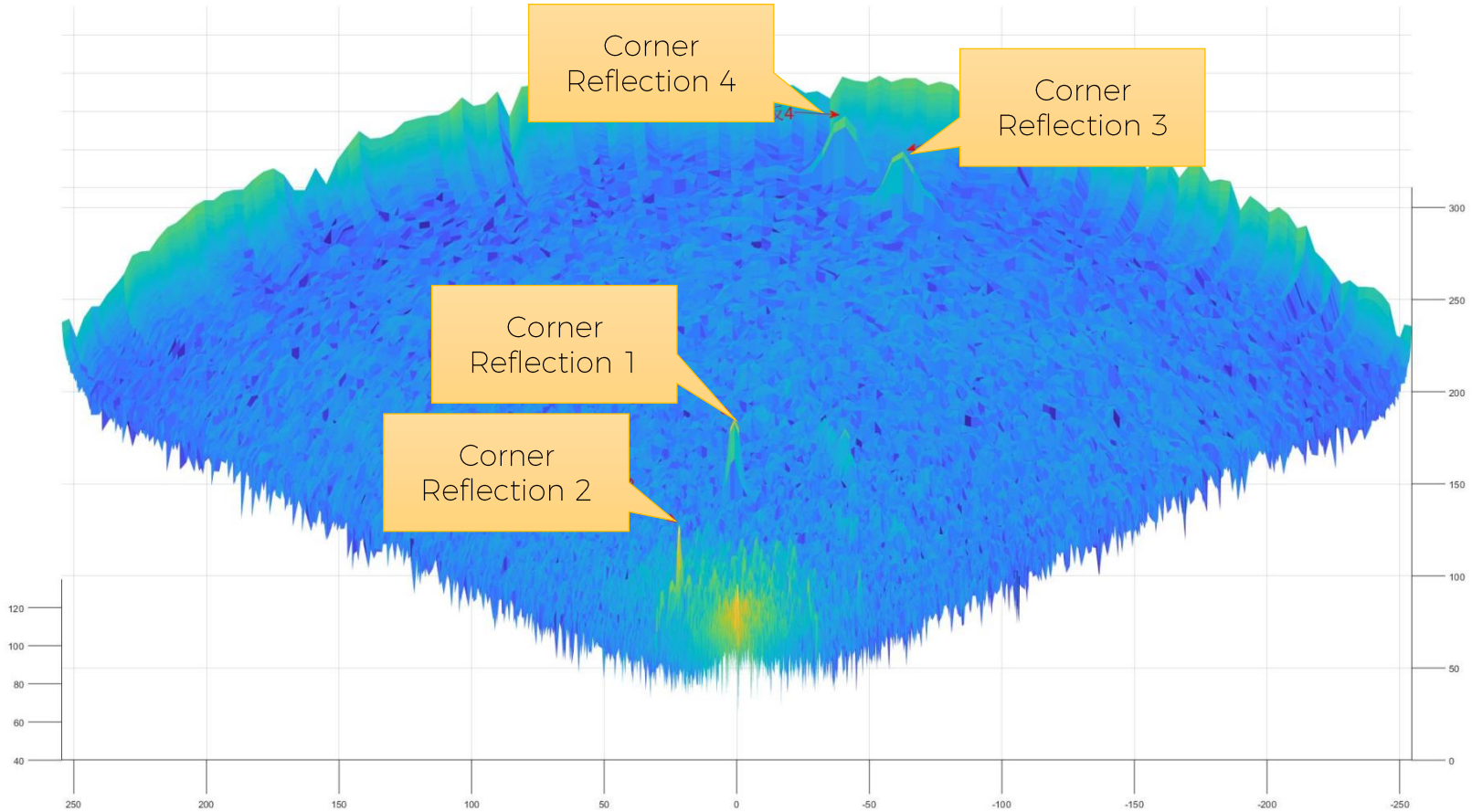
## Field Test 1: Weihe River Floodplain



Field test scenario on the Weihe River floodplain.

# Slope Monitoring: Imaging Radar

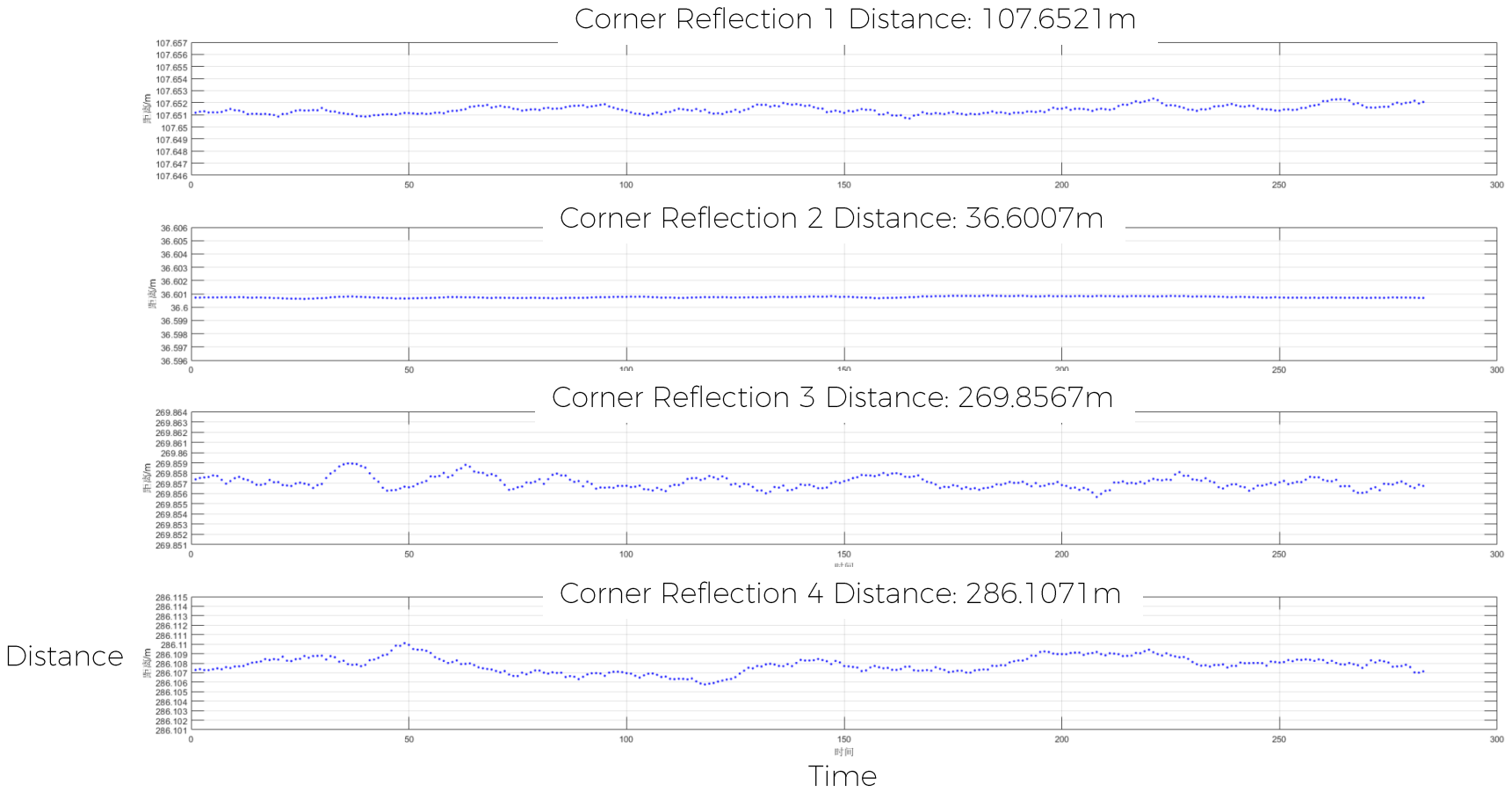
## Field Test 1: Weihe River Floodplain




Field measurement results on the Weihe River floodplain.

# Slope Monitoring: Imaging Radar

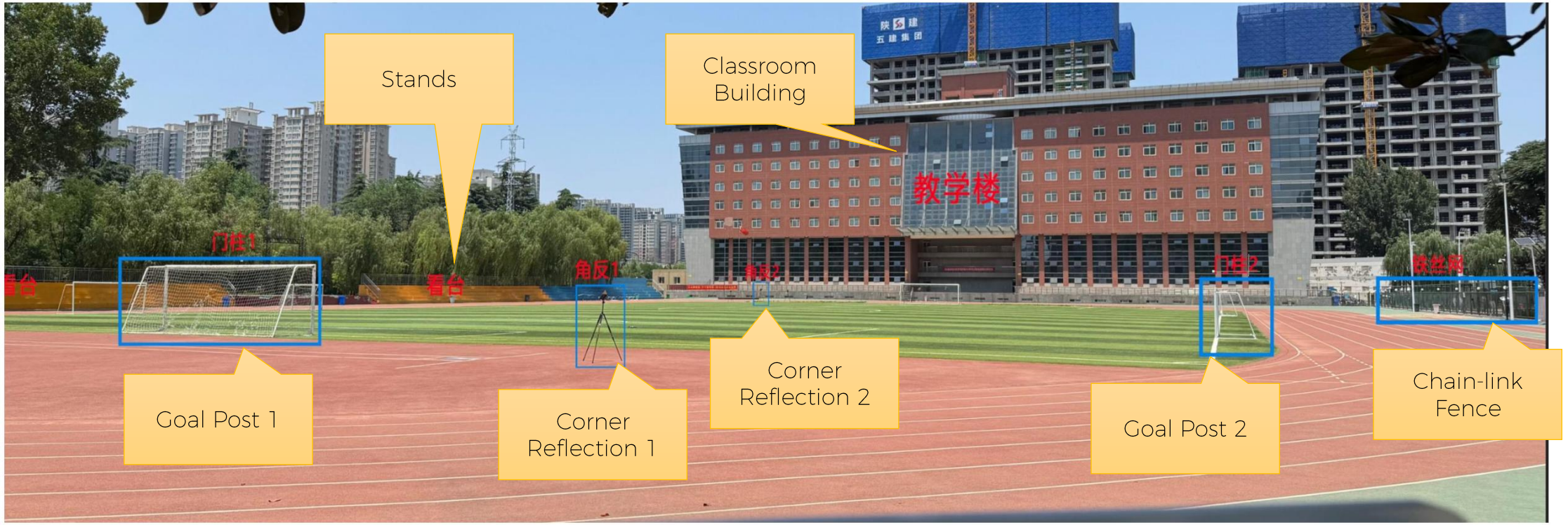
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Field measurement results on the Weihe River floodplain.

# Slope Monitoring: Imaging Radar

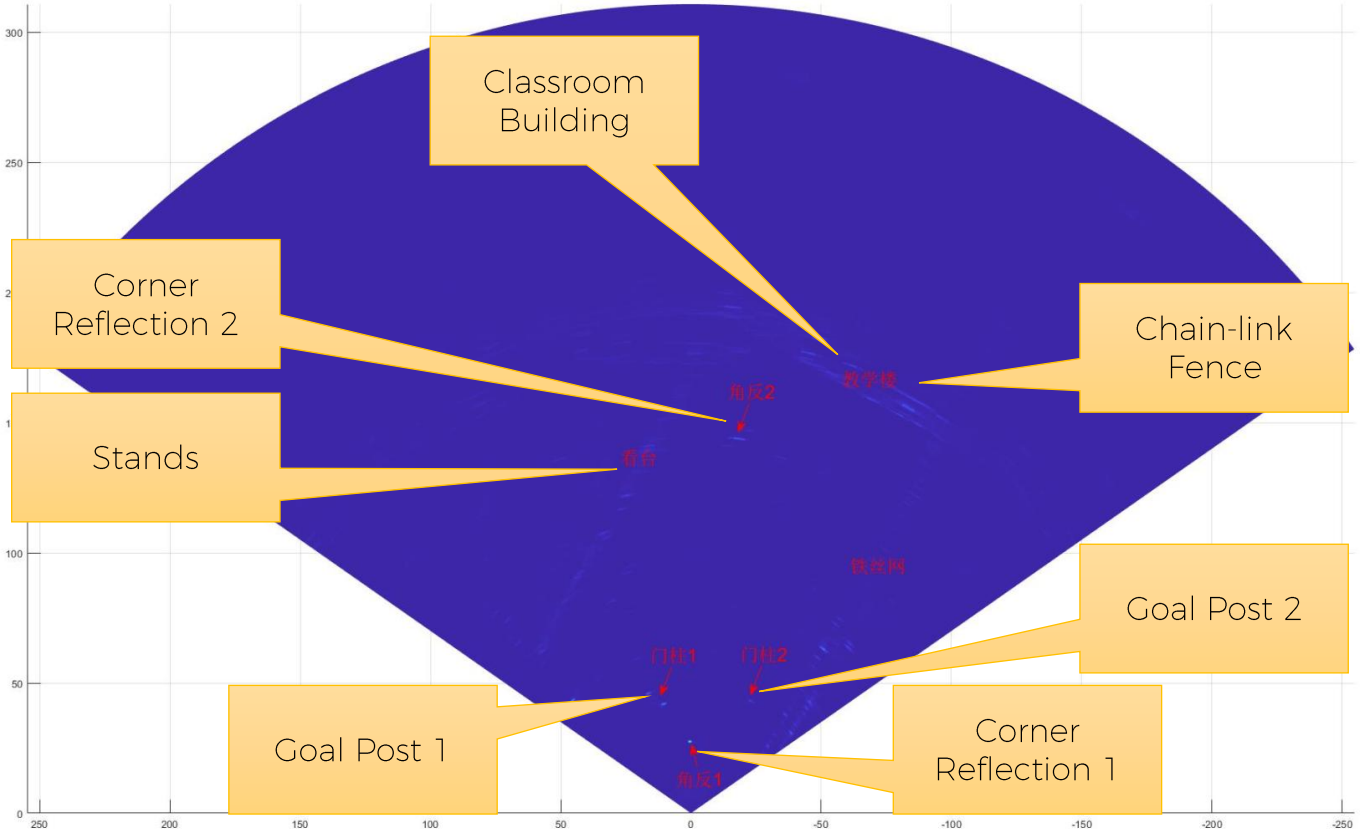
## Field Test 2: Sports Ground of a University




Field measurement scenario on the sports ground of a university of technology.

# Slope Monitoring: Imaging Radar

## Field Test 2: Sports Ground of a University

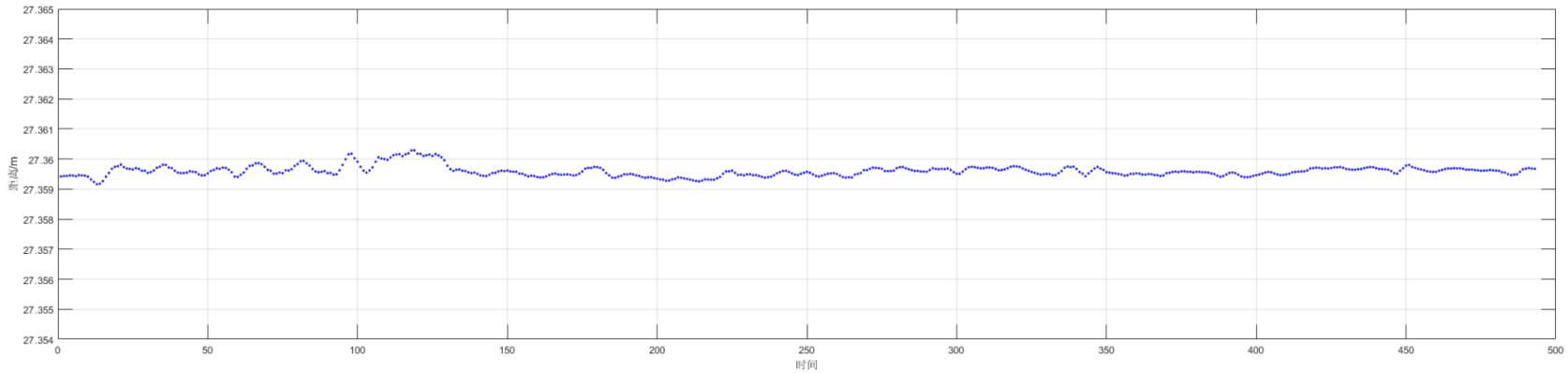



Field measurement scenario on the sports ground of a university of technology.

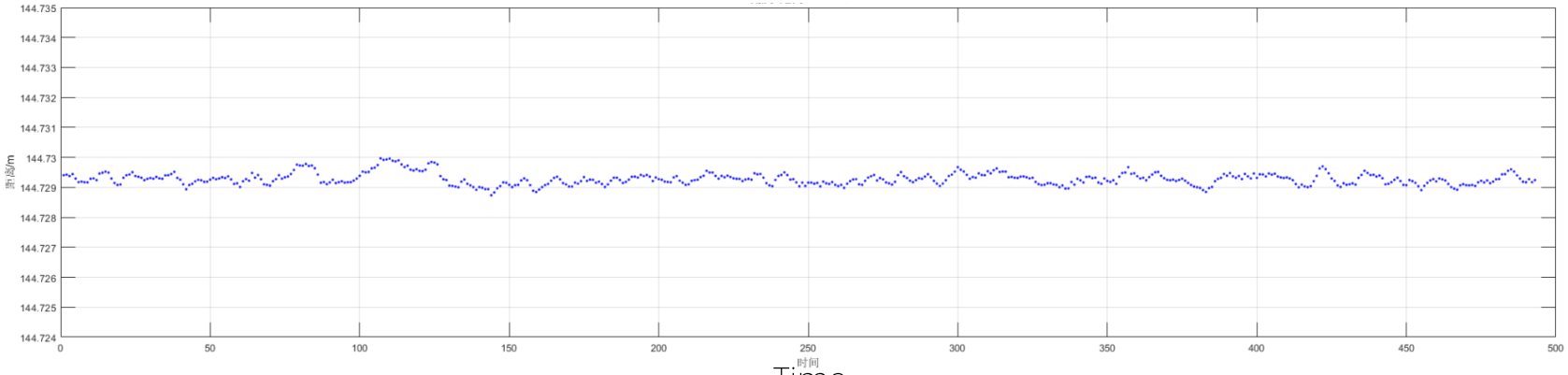
# Slope Monitoring: Imaging Radar

## Field Test 2: Sports Ground of a University

Corner Reflection 1 Distance: 27.3597m




Corner Reflection 2 Distance: 144.7294m




Distance

Time

Field measurement scenario on the sports ground of a university of technology.

# Slope Monitoring: Imaging Radar

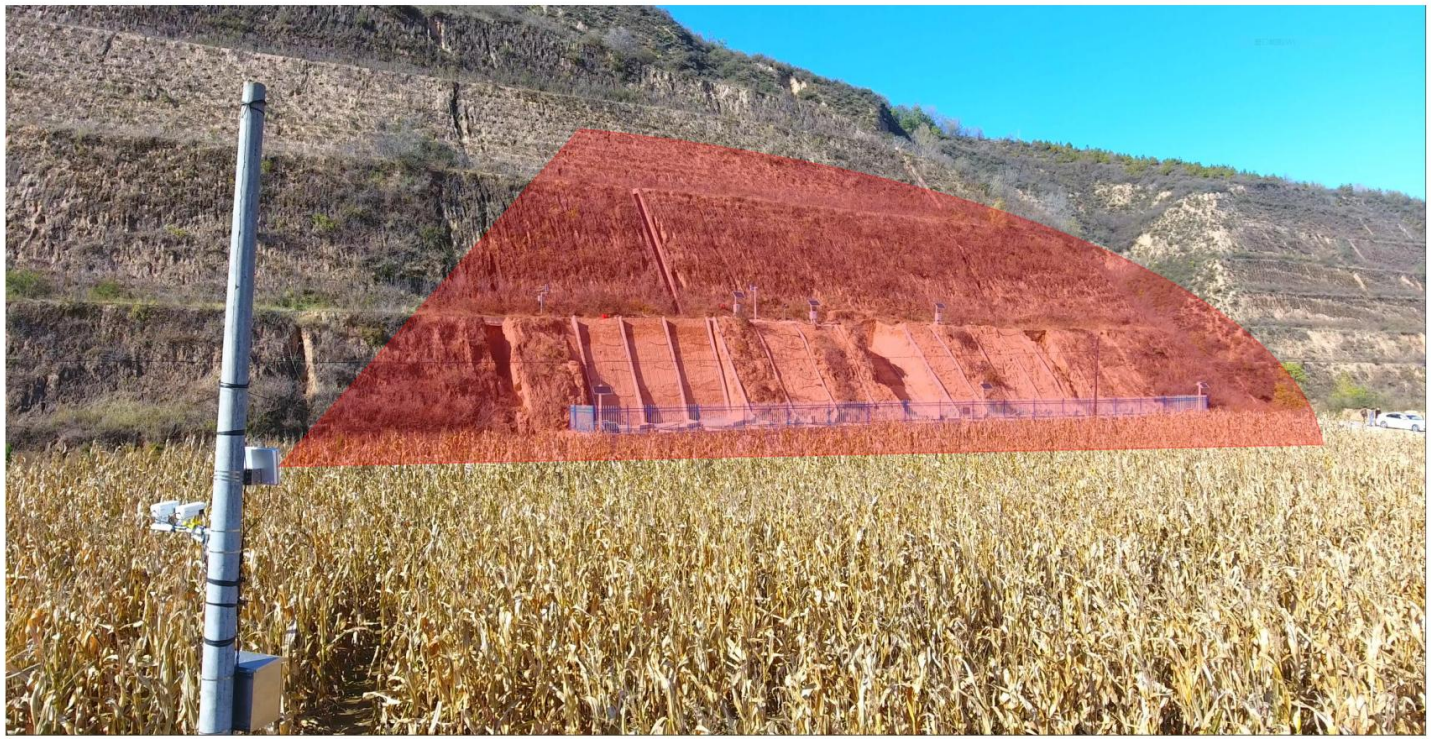
## Field Test 3: YanAn Field Test



Full View

# Slope Monitoring: Imaging Radar

## Field Test 3: YanAn Field Test



Radar View

# Slope Monitoring: Imaging Radar

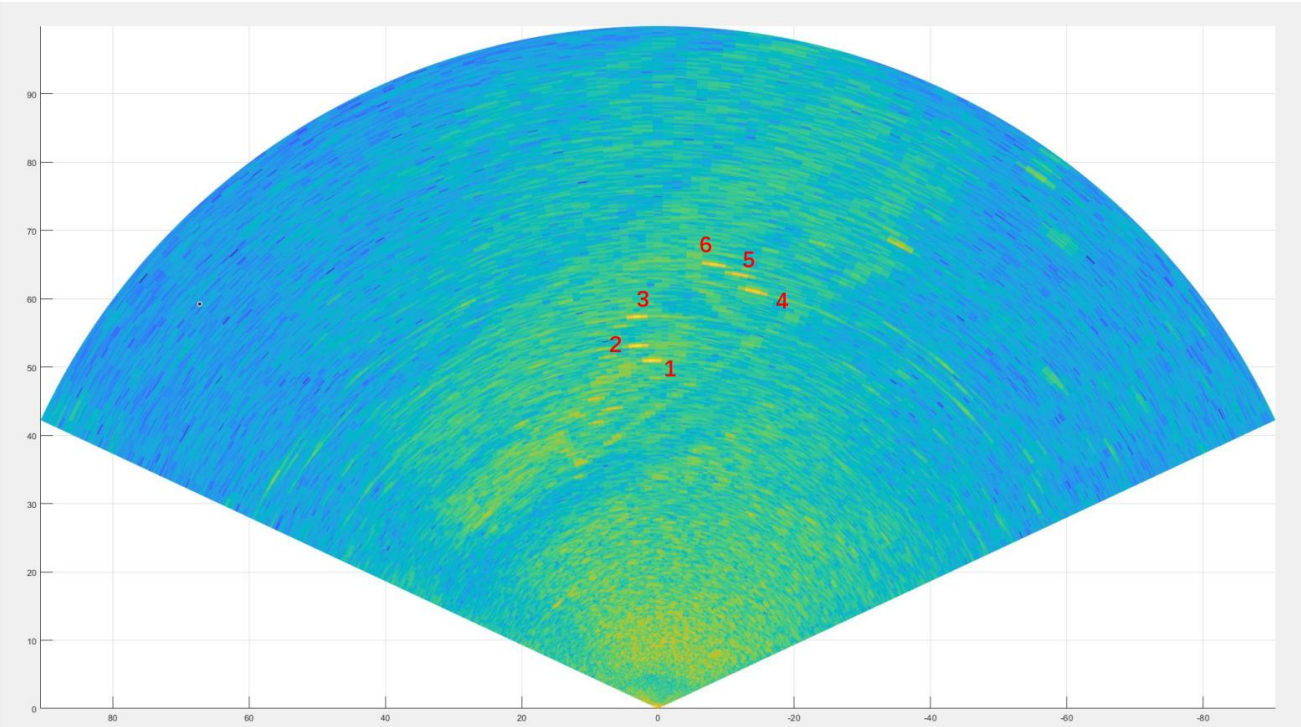
## Field Test 3: YanAn Field Test




Slope

# Slope Monitoring: Imaging Radar

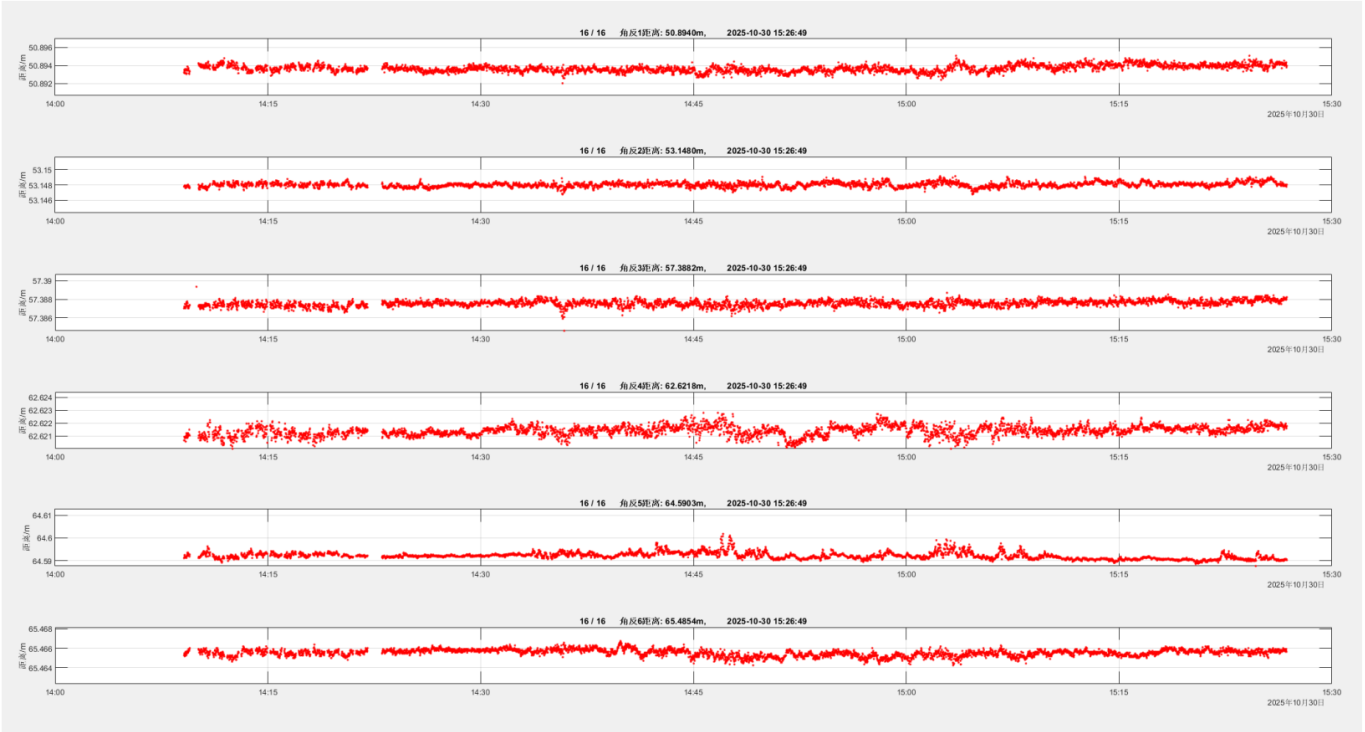
## Field Test 3: YanAn Field Test




Radar Imaging

# Slope Monitoring: Imaging Radar

## Field Test 3: YanAn Field Test



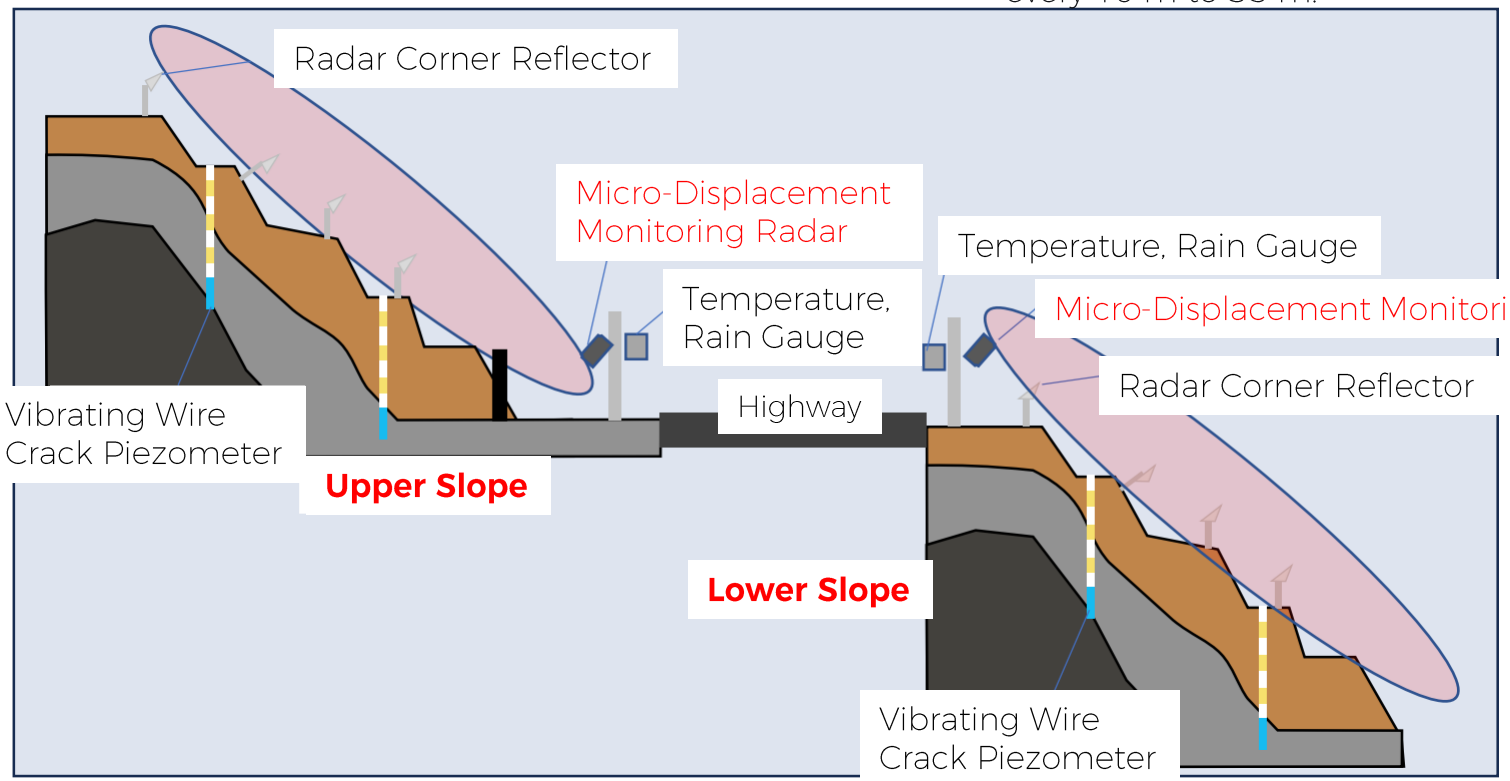

Corner Reflection Distance Detection Result

# Slope Monitoring: Micro-Displacement Monitoring Radar

**Principle:**

- By analyzing the changes in the relative positions between the radar and the corner reflector, determine whether the corner reflector has shifted.
- If the corner reflector disappears or its position changes, an alert will be issued.

- **Installation:**
  Roadside installation: radars are deployed along the expressway.
  A radar is installed every 25 m to 35 m.
  For the upper slope: the radar monitors upward.
  For the lower slope: the radar monitors downward.
  Along the radar's observation direction, radar corner reflectors are installed every 10 m to 35 m.






ClairWav-MD10
Micro-Displacement
Monitoring Radar



# Slope Monitoring: Micro-Displacement Monitoring Radar

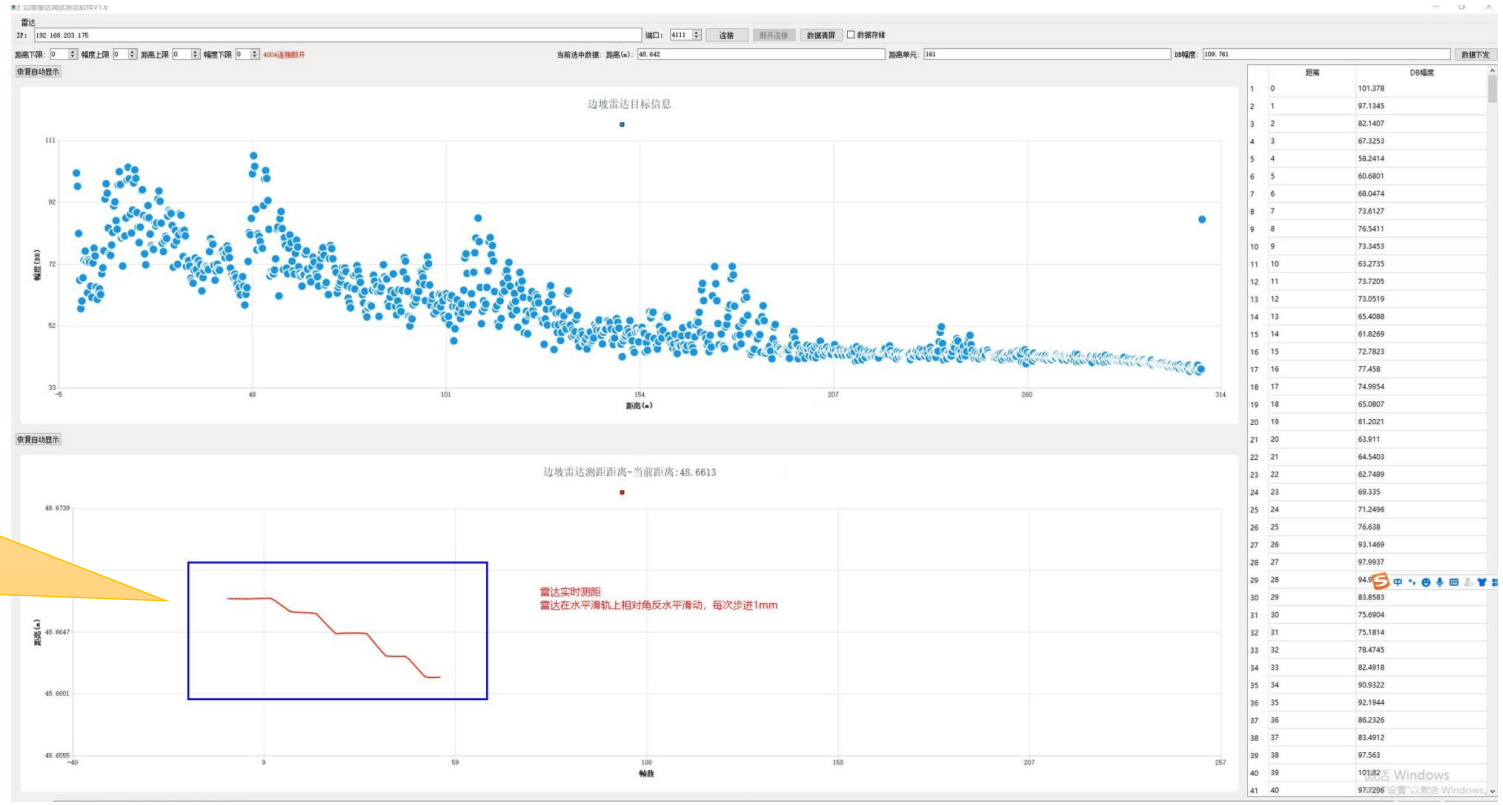
- Field Test 1



# Slope Monitoring: Micro-Displacement Monitoring Radar

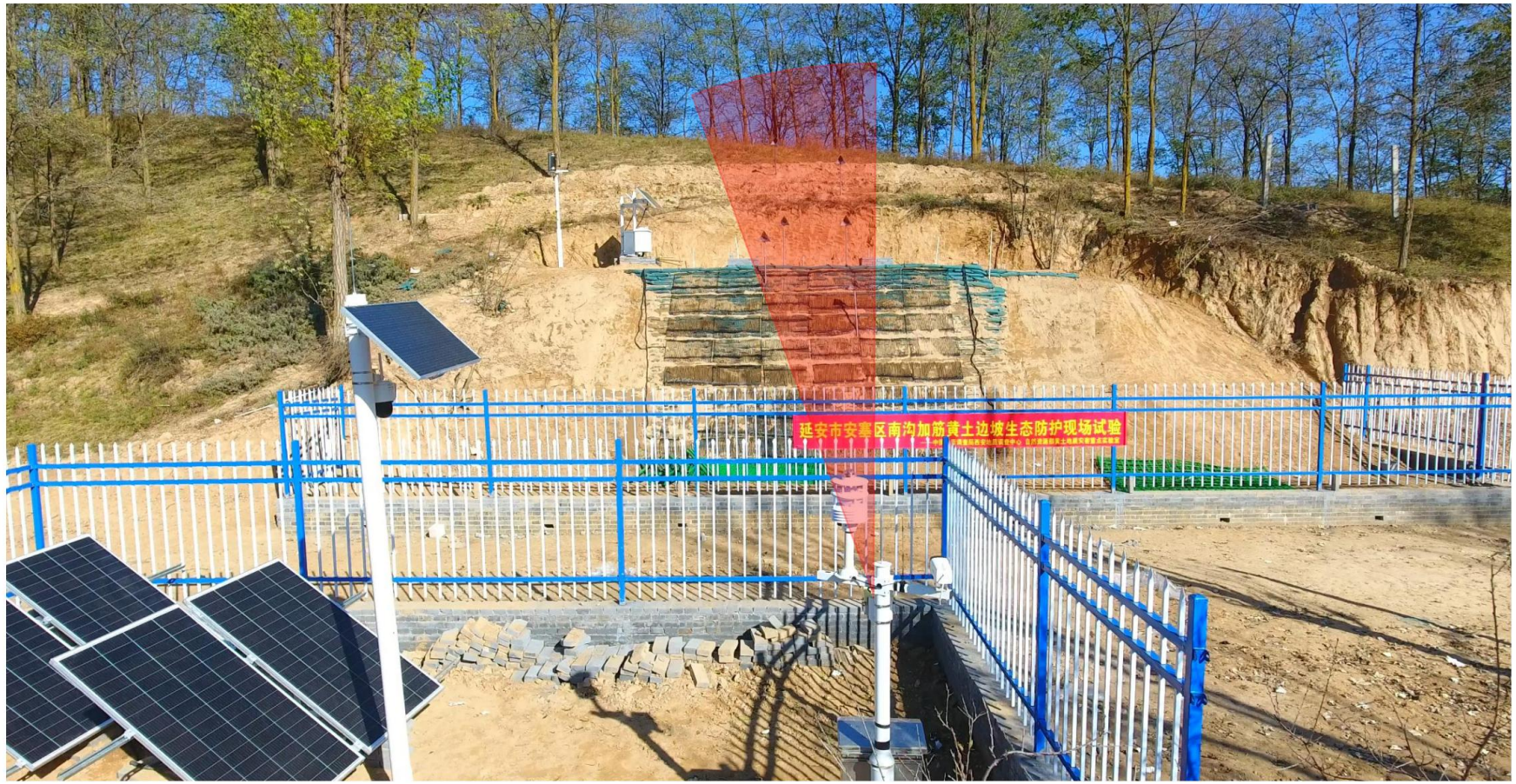
## Field Test 1: Test Result

Real-time radar ranging is performed. The radar slides horizontally relative to the corner reflector on a horizontal rail, with a step size of 1 mm per movement.



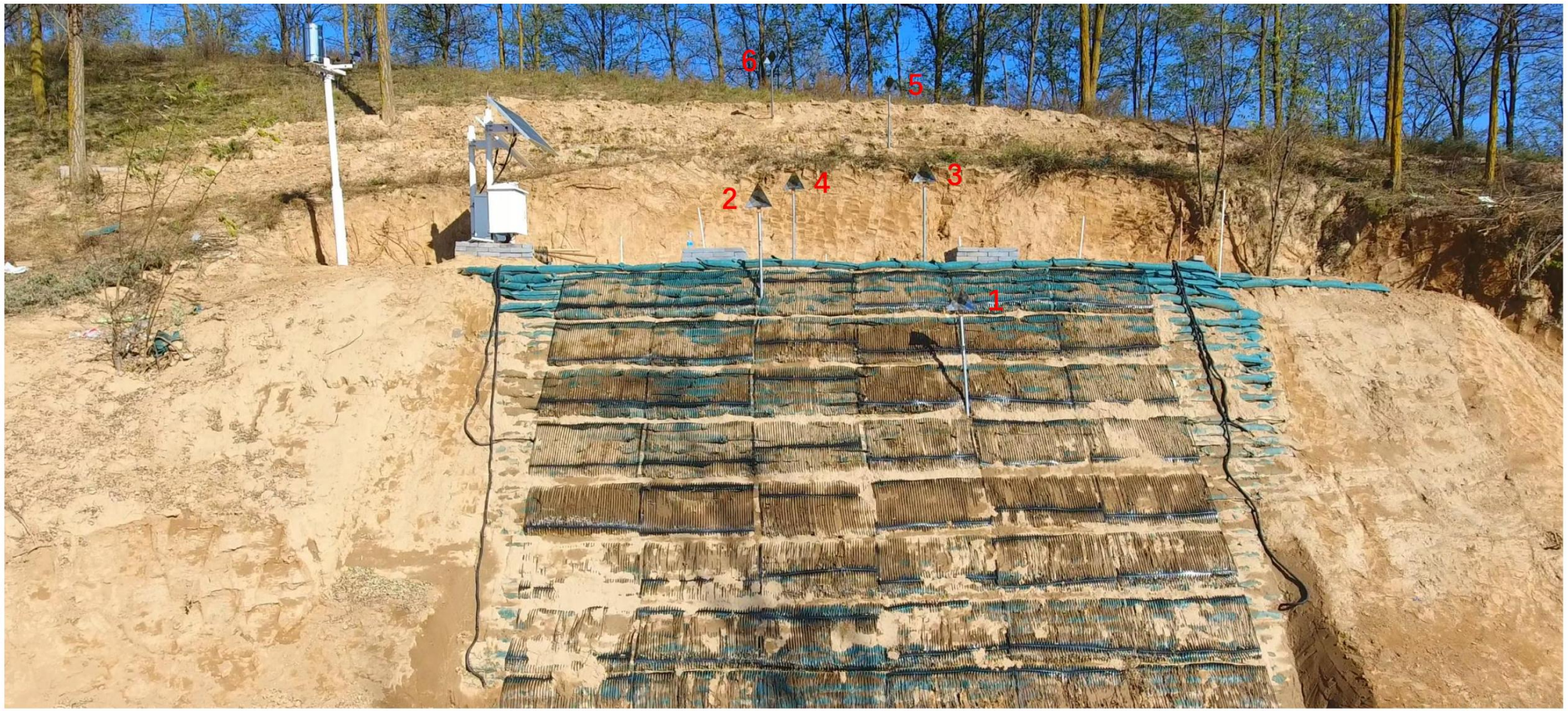
# Slope Monitoring: Micro-Displacement Monitoring Radar

## Field Test 2: Yan’an Test



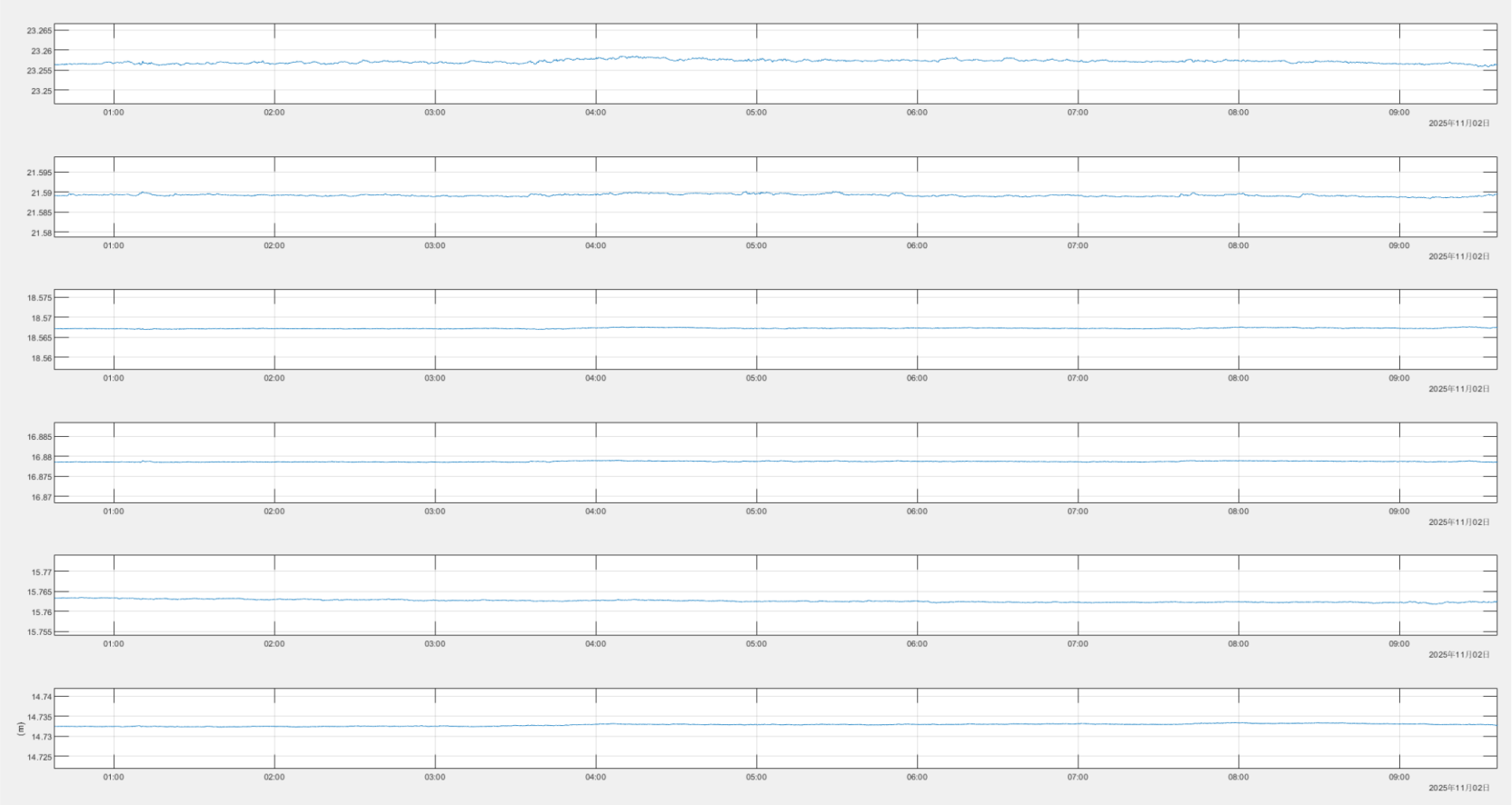
# Slope Monitoring: Micro-Displacement Monitoring Radar

## Field Test 2: Yan'an Test



# Slope Monitoring: Micro-Displacement Monitoring Radar

## Field Test 2: Yan’an Test Result

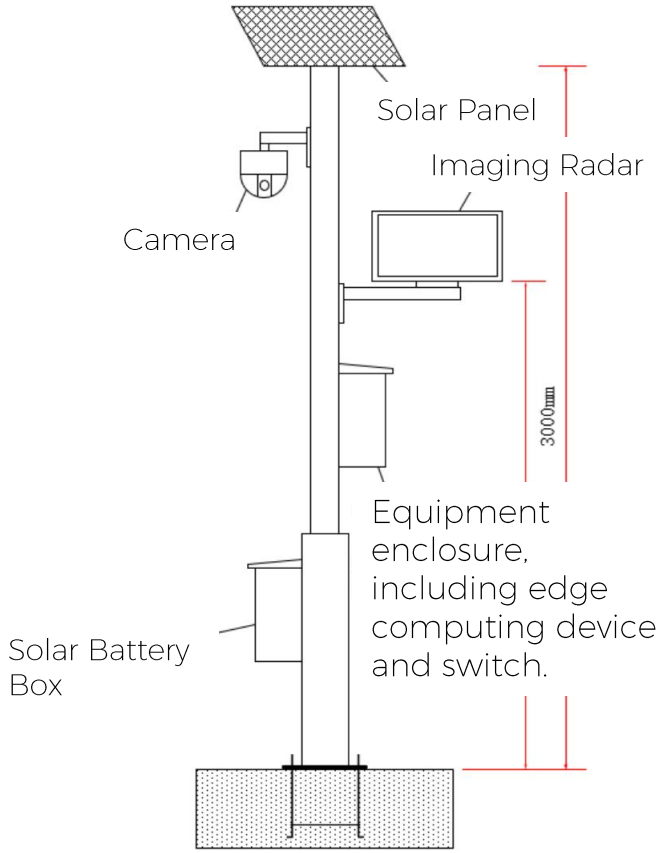


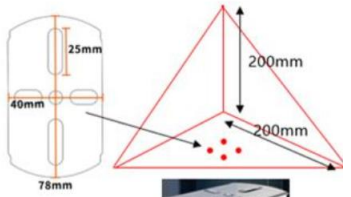
# Solution Benefits

| 1 | 2 | 3 |
| --- | --- | --- |
| Low average cost per monitoring point, all-weather real-time monitoring, automatic graded warning. | Easy to install (no installation depth required), easy to maintain. | Installed along the line, with convenient access to power and network supply. |

# Deployment Plan

## Imaging Radar

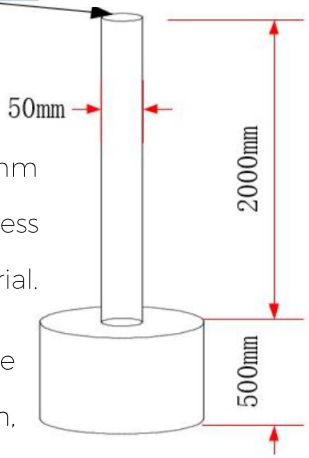



Corner reflector: made of three isosceles triangular iron plates with a right-angle side of 200 mm, welded, stainless steel material, wall thickness 2 mm. Holes are drilled at the bottom as shown in the left figure, and it is fixed to the universal joint using M6 screws and nuts.



Universal joint: The base is welded to the top of the cylinder. The upper part is connected to the base of the corner reflector.




Vertical column: 2500 mm × 50 mm cylinder, wall thickness 2 mm, stainless steel material.

Installation hole: Drilled using a water drill, hole diameter 100 mm. After inserting the vertical column, the hole is filled with concrete to a depth of 500 mm.

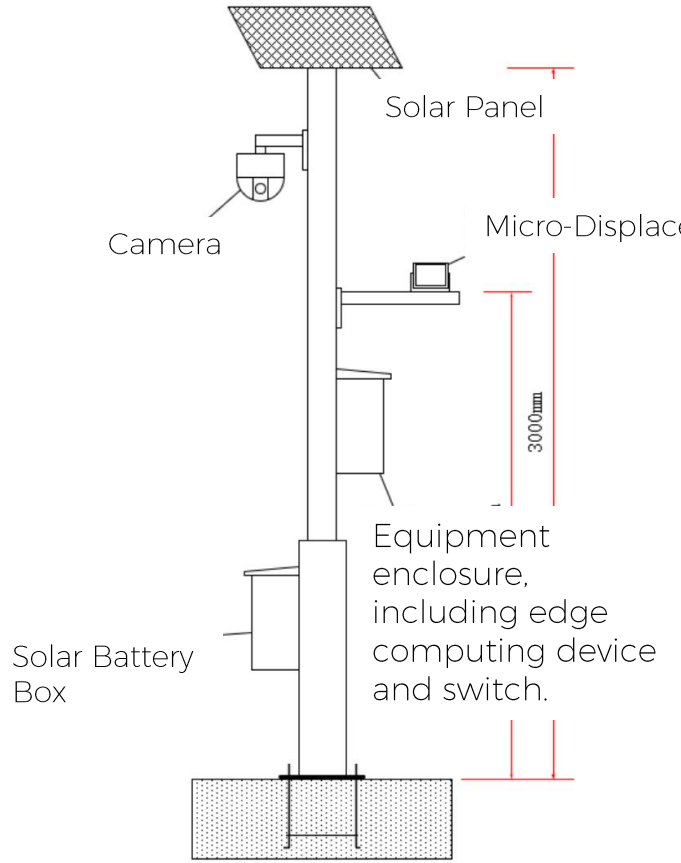
# Deployment Plan

## Imaging Radar

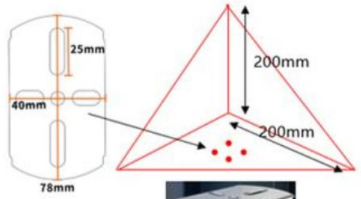


# Deployment Plan

## Micro-Displacement Monitoring Radar



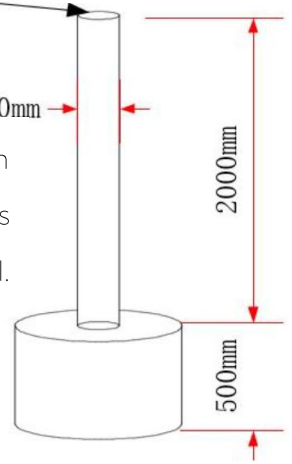

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# Deployment Plan

## Micro-Displacement Monitoring Radar



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# Bridge Health Monitoring

Real-time acquisition of quantitative data such as load-bearing capacity, structural response, and structural changes of key infrastructure including bridges, tunnels, and slopes, enabling real-time warning and comprehensive data analysis.

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# Bridge Health Monitoring Solution

## Key Inspection Points

- Bridge Deck Deflection
- Bridge Deck Vibration
- Pier Inclination Angle
- Expansion Joints

## Principle

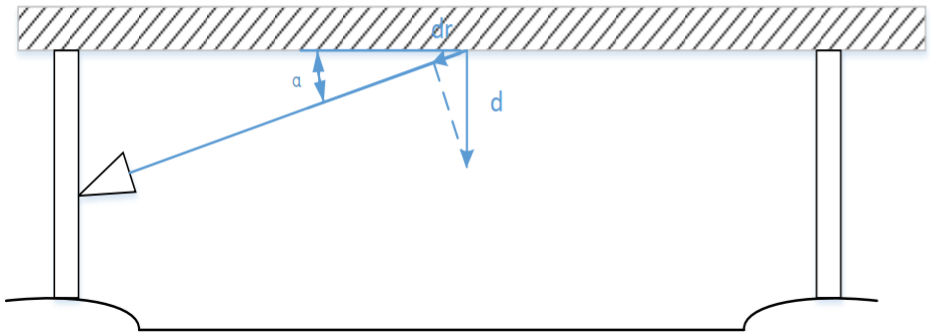
- Corner reflectors are installed on the underside of the bridge deck. Radars are installed on the bridge piers to detect the micro-displacement of the corner reflectors relative to the radars. The bridge deck deflection is then obtained through conversion. Bridge vibration can be monitored simultaneously.

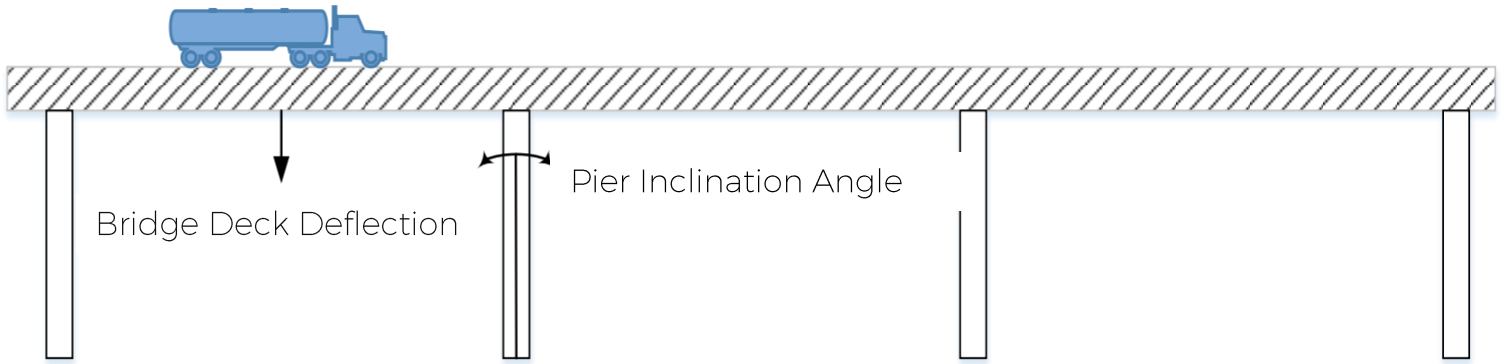
## Deployment

- The radar is installed on the bridge pier, and the angle between the line of sight to the measurement point and the bridge deck is greater than 30°.
- Corner reflectors are arranged on the underside of the bridge deck and can support more than 20 measurement points.

## Specs

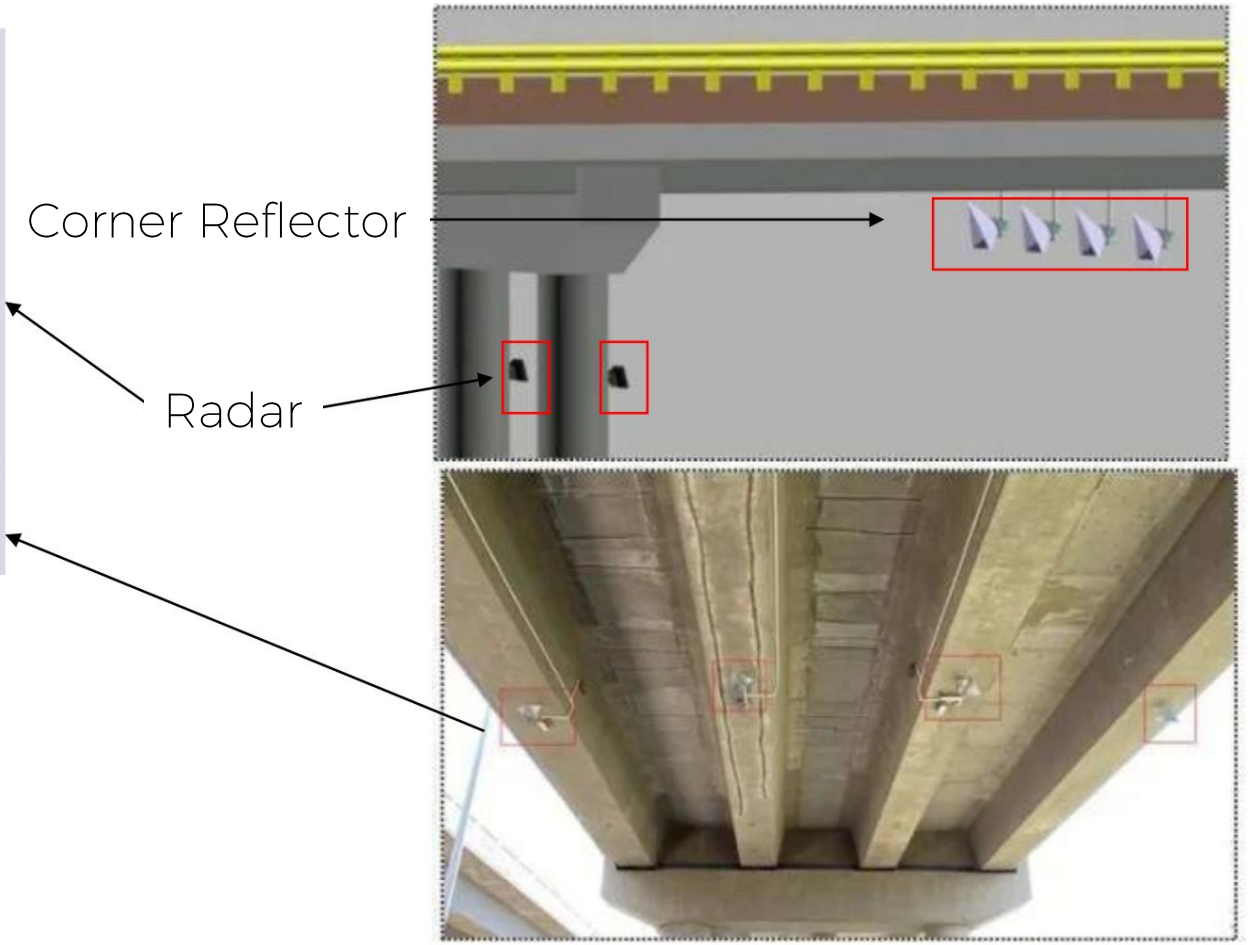
- Maximum monitoring distance: 100m.
- Monitoring Angle: 4°-10°.
- Displacement measurement accuracy: ±0.5mm.
- Data rate: 10-20fps.



# Bridge Health Monitoring Solution






**Deployment**

- The radar is installed on the bridge pier, and the angle between the line of sight to the measurement point and the bridge deck is greater than 30°.
- Corner reflectors are arranged on the underside of the bridge deck and can support more than 20 measurement points.

# Bridge Deflection Monitoring – Scheme Comparison

| | Detection Method | Detection Accuracy | Acquisition Frequency | Suitable Scenarios |
|---|---|---|---|---|
| Contact-type | Mechanical dial gauge (0.001 mm resolution) | 0.001mm | Static | Small measurement range, manual reading |
| | Mechanical dial gauge (0.01 mm resolution) | 0.01mm | Static | Small measurement range, manual reading |
| | Connected pipe (dynamic level or static level) | 1mm | Dynamic/Static | Measurement range less than 300 m |
| | Cable-extension type | 0.1mm | Static | |
| | Electronic deflection meter | 0.001mm | Dynamic/Static | |
| Non-contact-type | Laser ranging | 0.1mm | Dynamic/Static | Measuring distance of 50 m, vertical measurement point |
| | Visual displacement monitoring | 100mm | Dynamic/Static | Measuring distance of 500 m |
| | Total station (theodolite) | 1mm | Static | Various types of bridges, measuring distance less than 2 km |
| | Leveling instrument | 1mm | Static | Bridge deck measurement with obstructed line of sight |
| | GNSS | 10mm | Static | Ultra-long-span bridge |
| | Microwave Radar | 0.1mm | Dynamic/Static | |

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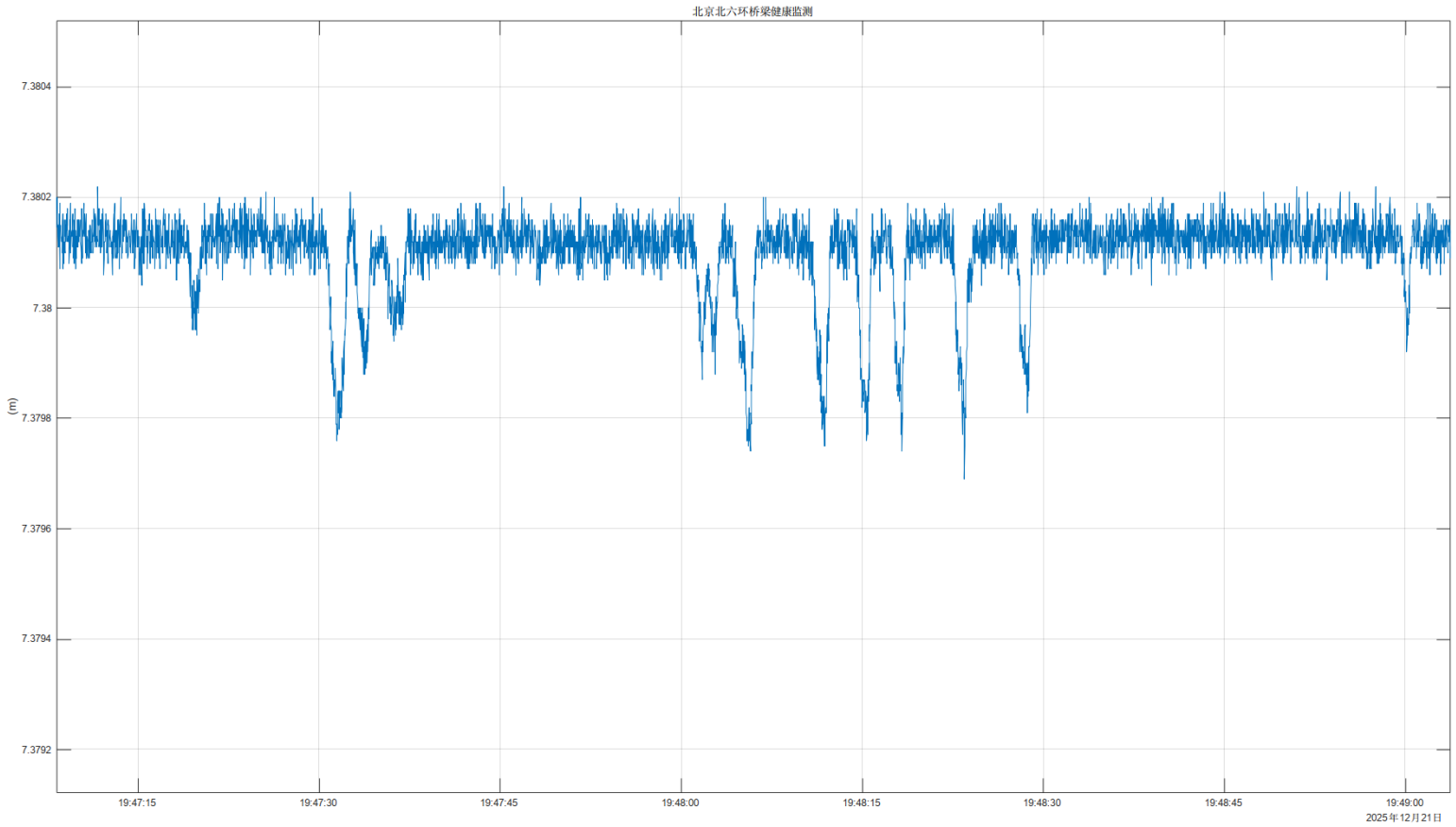
# Bridge Health Monitoring Solution

## Beijing North 6 Ring Bridge Pilot



# Bridge Health Monitoring Solution

Bridge deck deflection curve under a passing vehicle

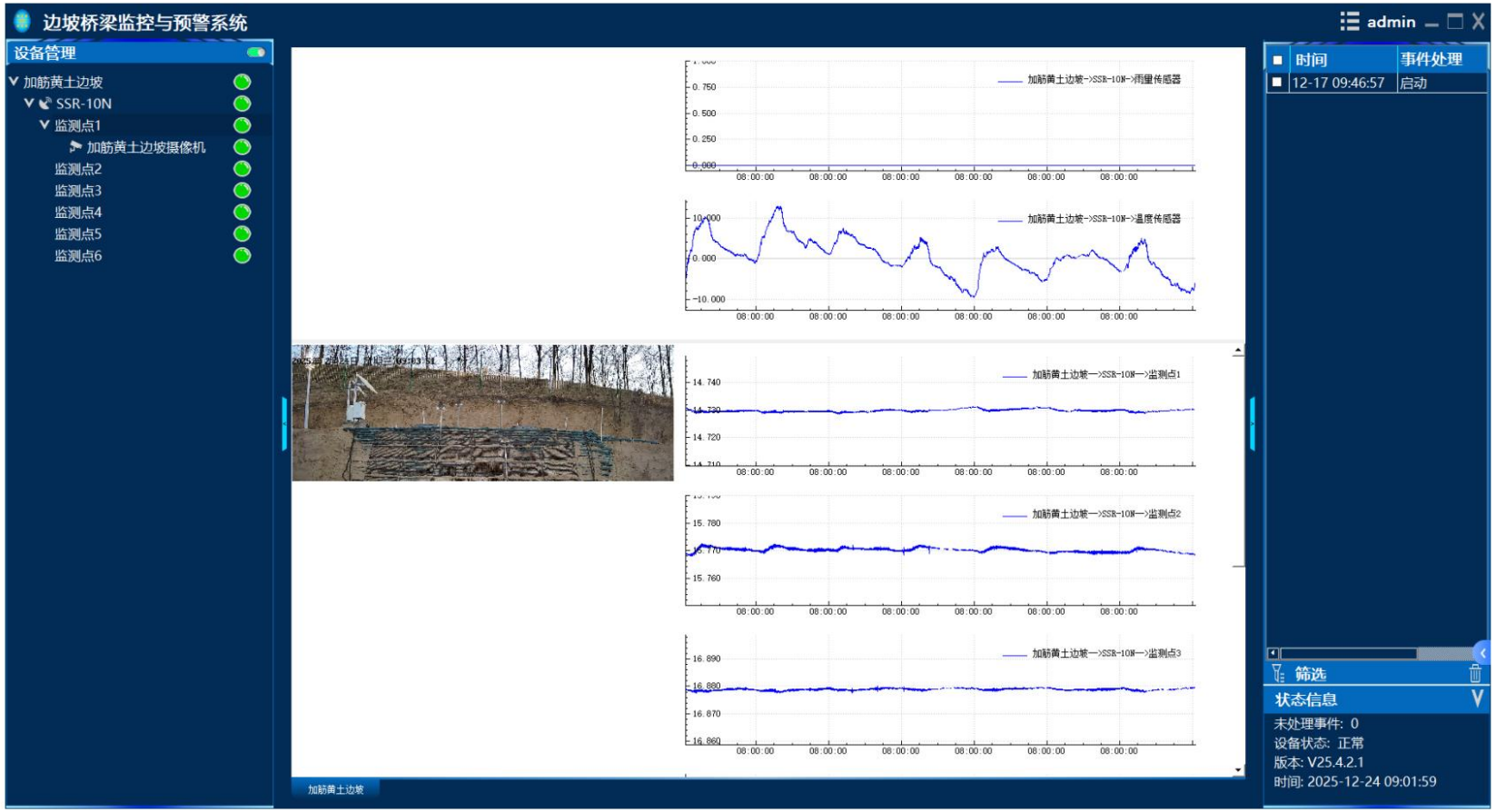


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# Intelligent Monitoring Platform

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# Intelligent Monitoring System Platform for Slopes and Bridges




**Major Functions:**

- Capable of monitoring multiple slopes simultaneously
- Real-time preview of data from each monitoring point
- Historical data storage and playback
- Capable of integrating multiple sensors for data fusion and analysis
- Automatically generates monitoring reports
  Supports configurable warning strategies for intelligent assessment and alerting

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# Thanks

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