Monitoring oil and gas facilities: use of natural reflectors and artificial corners reflectors

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ALTAMIRA INFORMATION is an experienced earth observation company that provides ground movement measurements with millimetric precision using satellite images.
ALTAMIRA INFORMATION & CLS Group
Providing integrated services for industry, environment and security.
Altamira Information brings together a team engineers experts in InSAR technology. The company’s head office is in Barcelona (Spain), with branch offices in 14 other countries and expanding with agents in more areas.
Millimetric ground deformation measurements
Agenda

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Natural Reflectors and / or Artificial Corner Reflectors

Natural Reflectors : Characterisation, Advantages and Drawbacks

Artificial Corner Reflectors : Characterisation, Advantages and Drawbacks

Conclusion
What is a Radar Reflector?
Understanding the radar construction phase response within the resolution cell

\[ S = \sum_{\text{Pixel}} r(k) e^{i2\pi \frac{2\pi}{\lambda}} \]
What is a Radar Reflector? Understanding the radar construction phase response within the resolution cell

Changes in satellite position modify the pixel reflectivity
What is a Radar Reflector?
Understanding the radar construction phase response within the resolution cell

Temporal changes in the pixel modify the reflectivity
A PS is a target that keeps the reflection properties along the acquisitions. Its radar response is characterised by a reduced noise level allowing reliable phase measurements in repeat passes.

Temporal changes of the scatterer, different look angle (baseline), different sensor characteristics will make or not a pixel being a reliable measurement point.
Measurement technology adapted to site conditions

• Natural measurement points: using coherence of dry and arid surface conditions as measurement points

• Roofs, houses and buildings used as measurement points: they reflect the radar signal during period of analysis

• Installation of artificial corner reflectors to guarantee presence of measurement points

Site conditions determine which technique will be used for measurement purposes.
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Natural PS case study: CO₂ storage in Algeria

Gas injection monitoring: Desert Area

**Objective of the project**
- Historical study of ground deformation in the pre-injection phase to detect sensitive areas.
- Ground deformation monitoring during the injection phase.

**Analysis and results**

- Due to arid conditions is an ideal test site for the application of InSAR technology for ground deformation monitoring for CO₂ storage at 1900m depth.
- Injection phase: period of study (2003-2010).
- 46 images have been used.
- Areas of uplift (5mm/year) have been detected surrounding the injection wells. (Blue areas on the images).
- Areas of subsidence (2.5 mm/year) in the extraction area have been detected affecting gas field facilities.
**Natural PS case study: CH₄ storage in Germany**

**Uplift in west Berlin: Urban Area**

- **Objective of the project**
  - Detection and mapping of areas affected by uplift and subsidence movements, study using ERS images 1992-2001

**Analysis and results**

- Strong uplift in west Berlin is attributed to underground gas storage at salt pillow location (see zoom-in analysis graphics).

- Subsidence is visible at Teufelberg, an artificial debris mountain, caused by the compaction of debris. Uneven settlement is seen at the Egelpfuhl landfill site which is experiencing uneven compaction.

*“PSI is an efficient tool for vertical ground motion detection even if its rate amounts to parts of a mm per year.”* BGR
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Artificial Corner Reflector
Kinds of reflections for point targets

specular: \[ \sigma_{\text{max}} = \frac{4\pi \cdot a^2 \cdot b^2}{\lambda^2} \quad \theta_{3\text{dB}} \approx 0.5 \frac{\lambda}{b} \quad \theta_{\text{elevation}} \approx 0.5 \frac{\lambda}{a} \]

dihedral: \[ \sigma_{\text{max}} = \frac{8\pi \cdot a^2 \cdot b^2}{\lambda^2} \quad \theta_{3\text{dB}} \approx 40^\circ \quad \theta_{\text{elevation}} \approx 0.5 \frac{\lambda}{b} \]

trihedral: \[ \sigma_{\text{max}} = \frac{4\pi \cdot a^4}{3 \cdot \lambda^2} \quad \theta_{3\text{dB}} \approx 40^\circ \quad \theta_{\text{elevation}} \approx 40^\circ \]

Not all the reflections keeps signal rebound stable for different wide of incidence angle. Artificial Corner Reflector offers a measurement point, independent from satellite beam incidence and independent from the satellite used.
Reservoir Monitoring with Radar Satellite Images

1. Steam injection to dissolve heavy oil
2. Surface uplift as a consequence of steam chamber formation
3. Ground motion measurements using radar satellites
4. Measurement results: Uplift
5. Measurement results: Subsidence
Learning for ACRs use for O&G infrastructure monitoring

Monitoring with Corner Reflectors of SAGD (1/3)

Objective of the project

• Area of interest: SAGD steam injection area
• Measurement of ground motion should contribute to maximize steam injection efficiency with minimum risks for the extraction area

Analysis and results

• Installation of a network of more than 120 measurement points (double Aluminium Corner Reflectors)
• Reflectors are adapted to site conditions: snow and cold temperature
• Ground motion monitoring with satellite images, without any intervention at the site
• New image every 1-3 days, updated results every 15 days

*The project monitors ground motion with a very high frequency: Image update every 1-3 days and ground motion deliverables every 15 days.*
Learning for ACRs use for O&G infrastructure monitoring

Results of heavy oil ground motion monitoring (2/3)

After 2 months

After 5 months

After 7 months

Millimetric ground motion measurements are illustrated in isolines...
Results are presented in the form of a ground motion map, and for specific points of interest in time series with millimetric precision.
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Lessons learned: Natural Points versus Artificial Corner Reflector

Can we trust the behaviour of natural reflectors such as infrastructures? Altamira’s advanced process chain will search for “un-wanted” patterns on the motion.

<table>
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<tr>
<th><strong>Natural Measurement Points</strong></th>
<th><strong>Artificial Corner Reflectors</strong></th>
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<tr>
<td>• Existing radar signal reflection points: roofs, metallic structures, arid zones...</td>
<td>• Aluminium trihedral: installed to guarantee a measurement point</td>
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**Advantages**
- High measurement density (especially urban areas)
- Availability of historical ground motion studies if enough images in archive
- No installation required

**Disadvantages**
- Only possible if presence of natural measurement points (e.g. not possible in snow, forested area).
- Minimum 10-25 radar images required to determine the exact localisation of the measurement points
- Exact location and installation is chosen depending on what is to be monitored.
- Only 2-3 images are needed for first measurements

- In-situ installation of ACRs required.
- No historical measurements available, only measurements after installation of ACR’s

More than 500 Reflectors installed