Influence of antenna polarisation on GPR signals of linear targets

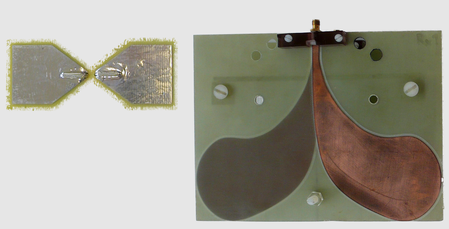
Jan Igel[1] & Kazunori Takahashi[2]

[1]Leibniz Institute for Applied Geophysics, Hannover, Germany
[2]Center for Northeast Asian Studies, Tohoku University, Japan

Introduction

- Linear objects like cables and pipes are common targets for ground-penetrating radar (GPR). The radar cross section (RCS) of such objects depends on antenna polarisation.
- Improvised explosive devices (IEDs) are a threat for civilians and the military and cause several thousands of victims per year. They are often triggered by command wires, which are difficult to detect by induction-based metal detectors.
- As GPR remains the only practical technique for IED detection, we investigate
  - ▷ the influence of antenna polarisation on the RCS of wires,
  - ▷ the difference between antenna near field and far field,
  - ▷ the RCS of wires compared to other targets (discs, spheres).

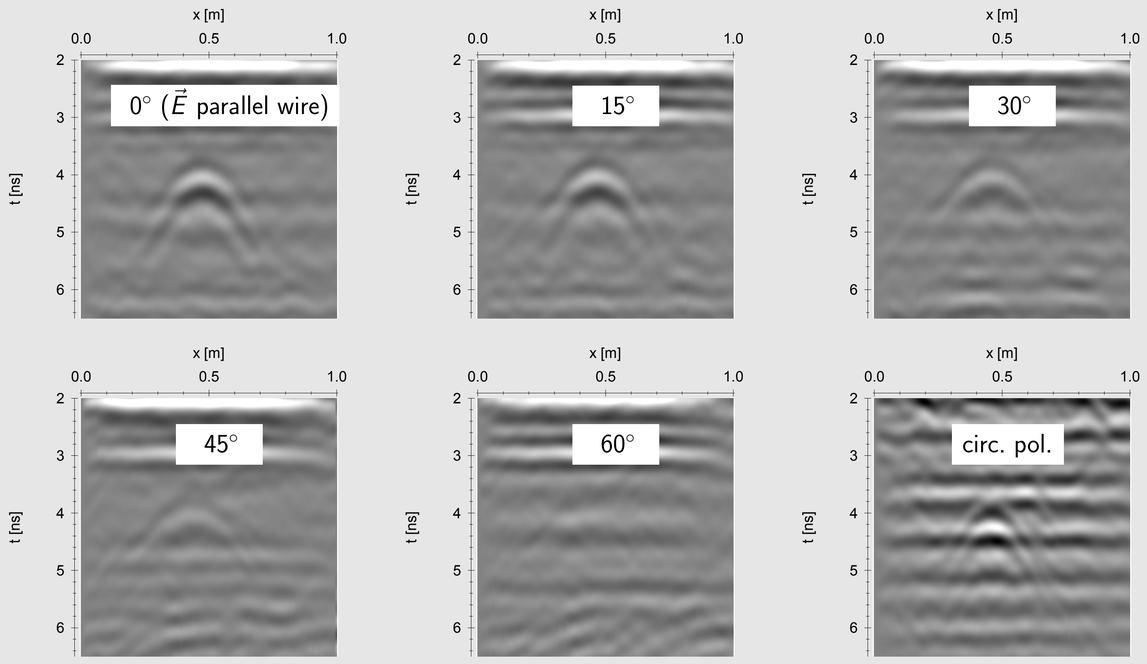
Antennas used in experiments



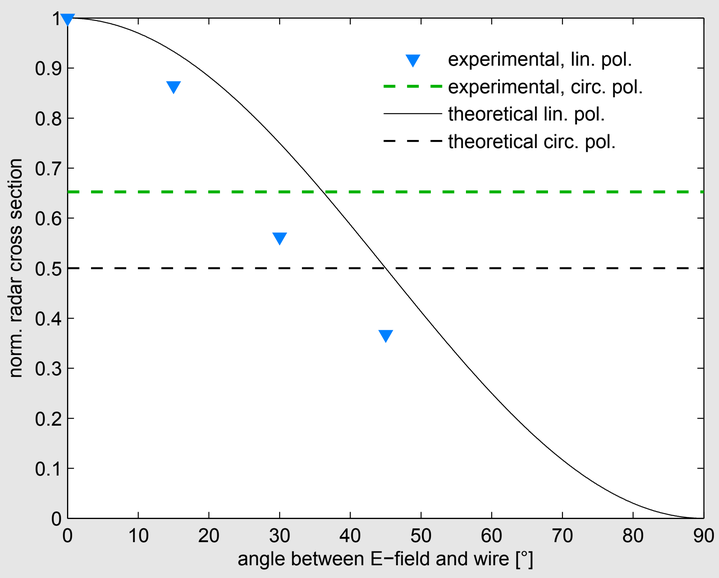
Bowtie & Vivaldi antenna (linear polarisation)

Spiral antenna (circular polarisation)

Wire in sandbox, polarisation



Radargrams over a wire buried 15 cm deep in sand. A Vivaldi antenna (2 GHz) was used with different orientations as well as a spiral antenna (2.4 GHz). The according RCSs are shown on the right hand side and analytical far-field approximation is given in black. The RCS for circular polarisation is supposed to be equal to the RCS for linear polarisation if the angle between $\vec{E}$-field and wire is 45°, i.e., half of the RCS for parallel orientation (0°).



Acknowledgements

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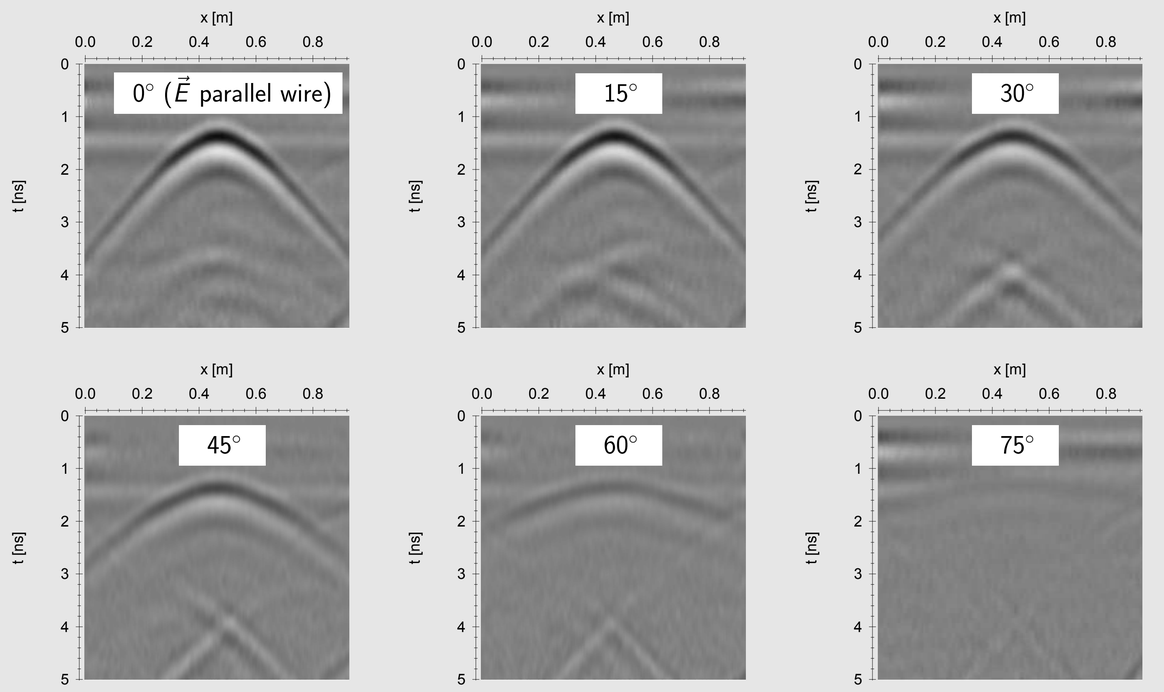
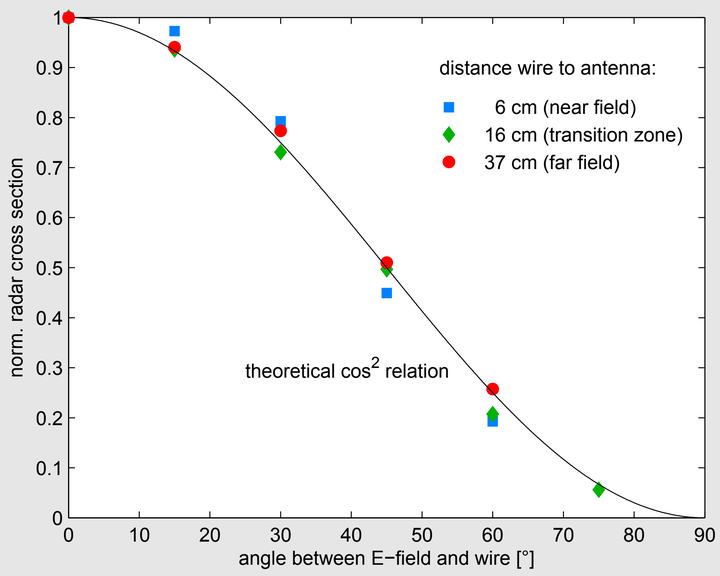
Conclusions

- Simplified analytical solution, method of moments calculation and experiments with different antennas show very good agreement, even if the wire is within the near field of the antenna.
- Thin cables show a strong signature in GPR data compared to other objects like discs and spheres.
- Wires with arbitrary orientation can be detected by GPR using
  - ▷ circularly polarised antennas
  - ▷ two perpendicularly oriented antennas with linear polarisation.

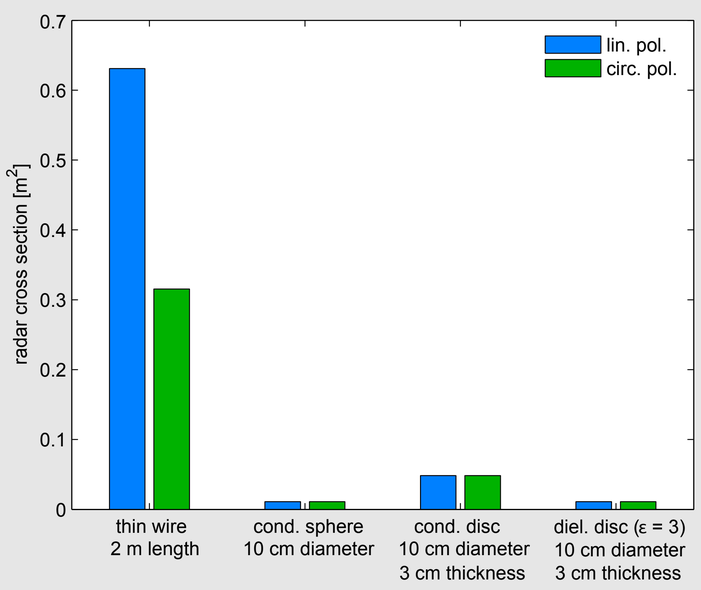
Wire in air, near field & far field



Radargrams over a wire in air with 1.5 GHz bowtie antenna depending on antenna orientation (angle between $\vec{E}$-field and wire). The RCS ($\propto$ peak-to-peak amplitude of hyperbola apex) is shown on the right hand side for different distances between wire and antenna. The analytical far-field approximation is given by a $\cos^2$ function.



Numerical simulation



Method of moments (MoM) calculation of RCS for different objects in air. An incident plane wave with linear and circular polarisation is used, frequency is 2 GHz. Note the high RCS of the thin wire (parallel to $\vec{E}$-field) compared to the other objects.