Leibniz
Universität Hannover

Institut für Transport- und
Automatisierungstechnik
Prof. Dr.-Ing. Ludger Overmeyer

Ground Penetrating Radar inside the BHA

A future MWD device?

Jan-Florian Höfinghoff

gebo Forschungsverbund Geothermie und Hochleistungsbohrtechnik

Niedersächsisches Ministerium für Wissenschaft und Kultur

BAKER HUGHES

Overview

- Project position within gebo
- Ground Penetrating Radar (GPR) – Technical overview
- GPR inside the Bottom Hole Assembly (BHA) – Possibilities and Problems
- Actual work
- Future steps/Conclusion

Project position within gebo

- Subproject within the technical projects of gebo
- GPR as a new “sensor” inside the BHA
  - Detection of layer boundaries
  - Detection of inhomogeneous material
  - Used for optimal way finding while drilling
  - Operating frequency in the range of 100 MHz – 1 GHz
- Basic research, which focuses on the feasibility
  - Antenna concepts
  - Integration concepts
  - Performance estimation
  - Prototypical implementation and field measurements

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- Detection of layer boundaries and inhomogeneities
- Penetration depth and resolution depend on chosen frequency
- Short pulse signal is emitted – reflections are detected and analysed
- Time/Depth conversion with known electromagnetic material properties

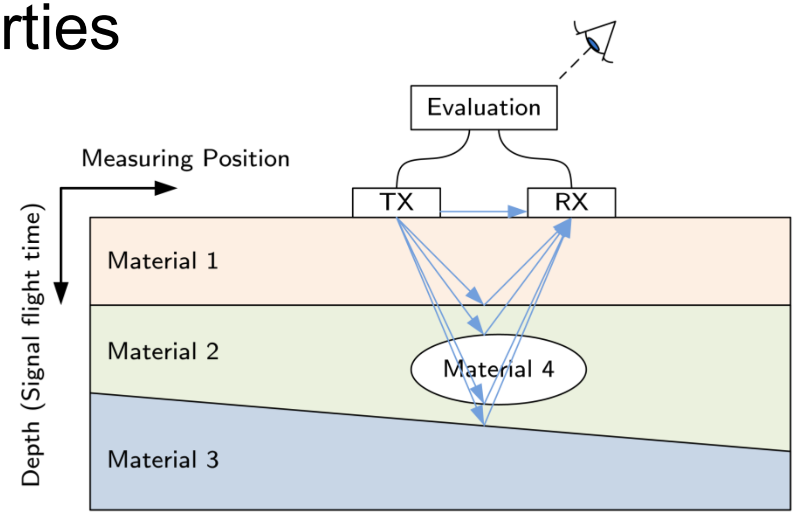

Figure 1: GPR principle

GPR – Technical overview

- Successful usage of GPR in various applications
  - Pavement/Building inspection
  - Archaeology
  - Mining
  - UXO detection (e.g. landmines)
  - Borehole applications
- Commercial borehole applications are limited so far to
  - Stand alone wireline tools
  - Low frequencies (loop antennas)
  - Plastic housing
  - “Measuring after drilling”

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The integration of a GPR inside the BHA offers some possibilities:

- Measuring while drilling
- New “control variable” for the drilling process
- Layer boundaries detection (e.g. for horizontal directional drilling)
- Inhomogeneities detection (e.g. for finding promising frac zones)
- Control of the frac process itself
- In-Situ scientific insight into deep rock structures

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But some problems have to be investigated and solved for a successful realisation:

- Little space available inside the BHA for GPR electronics and antenna
- Antenna suffers from small space and metal environment
- Antenna cover has to be out of non-metal material
- Harsh environment
- Mostly unknown in-situ electromagnetic material properties

Actual Work – Performance estimation

- Field measurements with commercial GPR for igneous rock
  - Penetration depth of up to 5 m for compacted wet Gabbro gravel of 2-5 mm diameter @ 400 MHz
- Measurement of electrom. properties of sandstone drill core from Genesys drilling
  - Consistency with literature
  - Used for further simulations
- Influence of the drilling fluid/formation water
  - Penetration of salt water layer with 10 mm thickness is possible
  - Gap between BHA and borehole wall can be minimized by proper engineering
  - Porosity of rocks is negligible at geothermal depths (gebo concept)

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- Integration of the electronics as common
- Integration of the antenna within the BHA wall
- Scraper and combined Fastening/Scraper for protection
- Antenna housing made of high strength plastic
- Antenna and housing are replaceable for easy repair

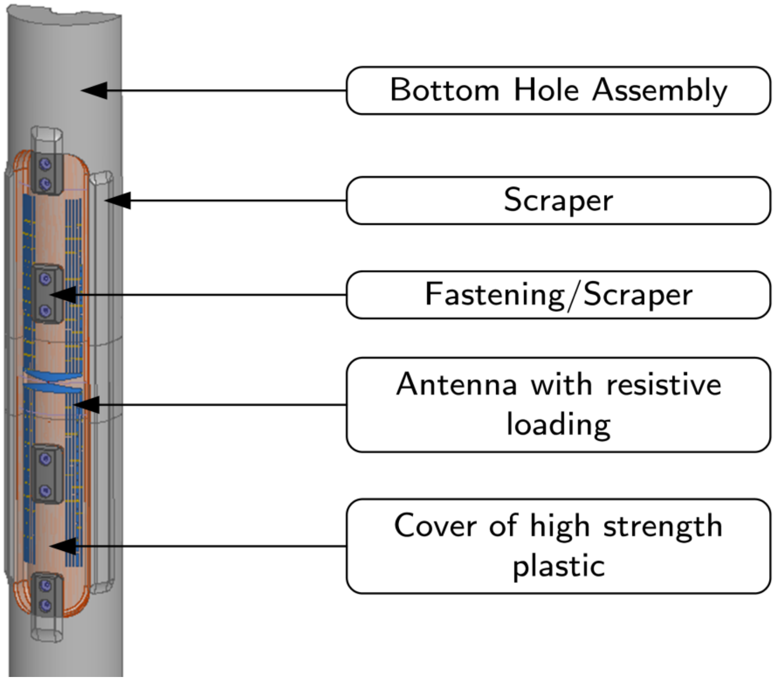

Figure 2: Integrated GPR antenna

Actual Work – GPR antenna

- Antenna design focuses on a good pulse radiating behaviour
- Reflections generate unwanted distortion (ringing) of the signal
- Main reflections are generated:
  - at the antenna ends
  - from the casing (metal BHA)
  - from the first ground reflection

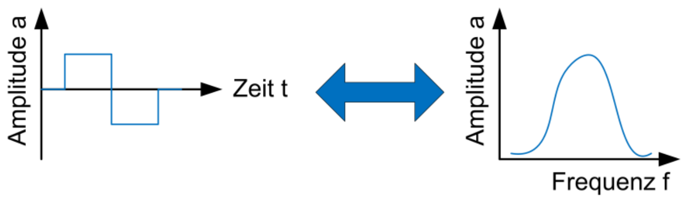

Figure 3: Time/Frequency correlation of a RADAR pulse

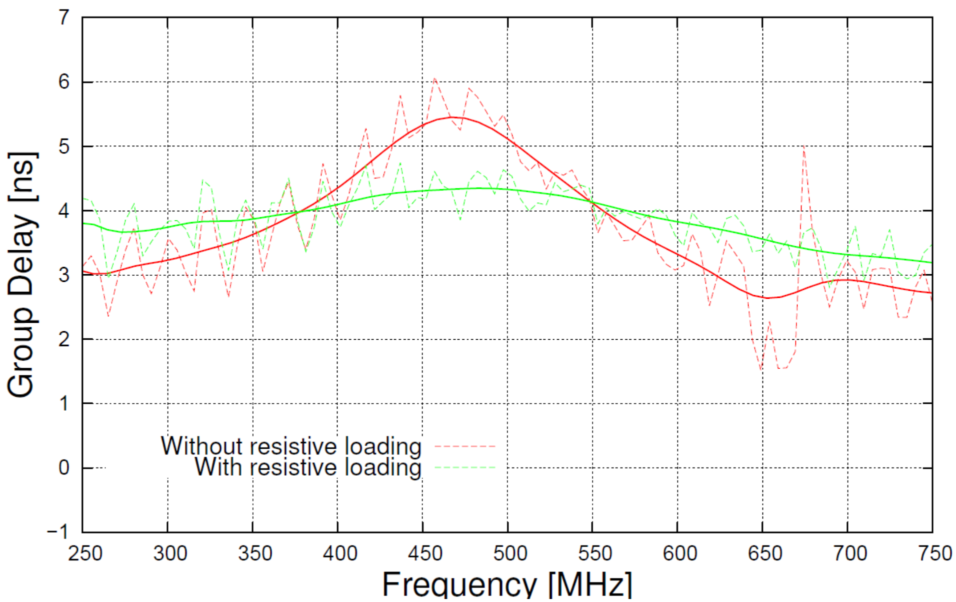

Figure 4: Antenna group delay with/without resistive loading

Actual Work – GPR antenna

- Metallic BHA housing produces strong reflections
- Antenna and housing geometries have to be tuned carefully
- Resistive loading has to be tuned in combination with geometry
- Pulse radiating behaviour:
  - can be optimized
  - will not be as good as without metal housing
  - suffers from small space inside the BHA

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- Final simulation model:
  - Integration concept modelled with Autodesk Inventor
  - Field simulation of the imported model with Ansoft HFSS
  - Simulative iteration of geometry and electronic values
- lead to an optimal prototype design for evaluation

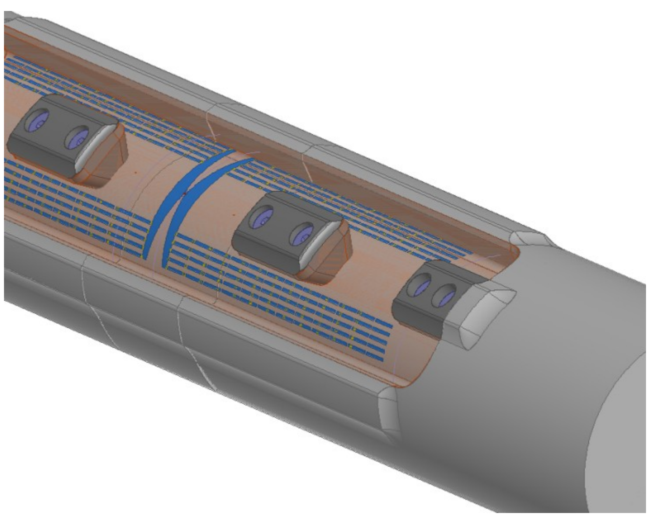

Figure 5: HFSS simulation model

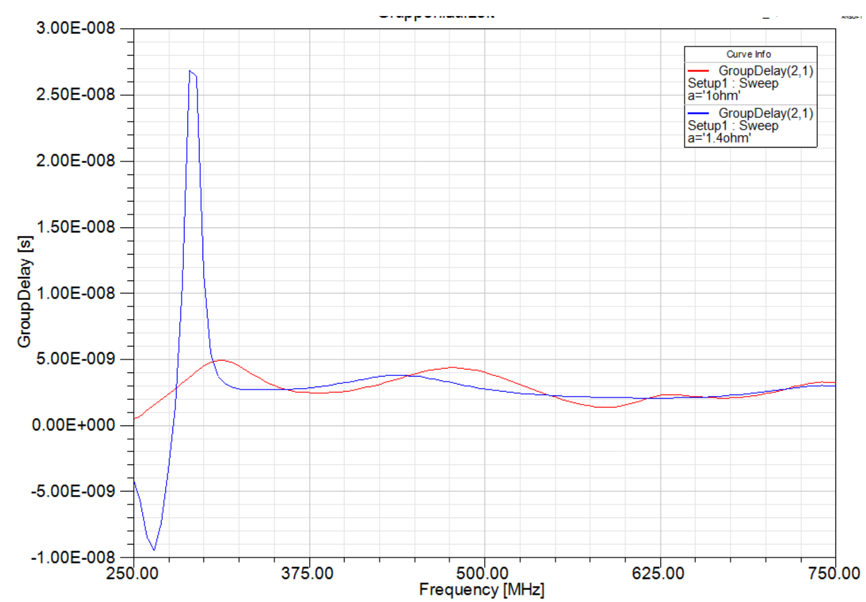

Figure 6: Group delay behaviour

Future steps/Conclusion

- Development and integration of a final antenna design
- Construction of a full size prototype
- Field measurements for the evaluation of simulation results

GPR inside the BHA is a promising approach.
For a final judgment a fully operational prototype and its evaluation is necessary

For further questions please contact:

Prof. Dr.-Ing. Ludger Overmeyer
Tel. +49 511 762-3524
Fax. +49 511 762-4007
Ludger.Overmeyer@ita.uni-hannover.de

Dipl.-Ing.(FH) Jan-Florian Höfinghoff
Tel. +49 511 762-18173
Fax. +49 511 762-4007
jan-florian.hoefinghoff@ita.uni-hannover.de

ITA
Leibniz Universität Hannover
Institut für Transport- und Automatisierungstechnik
An der Universität 2
30823 Garbsen
http://www.ita.uni-hannover.de