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Numerical Modeling of Magnetic Field Emissions from a Horizontal Directional Drilling Walk-Over Locating System

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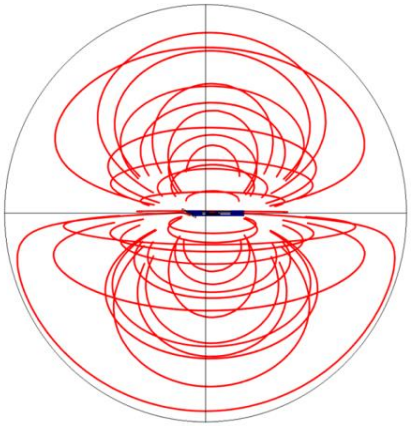

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Horizontal Directional Drilling (HDD)

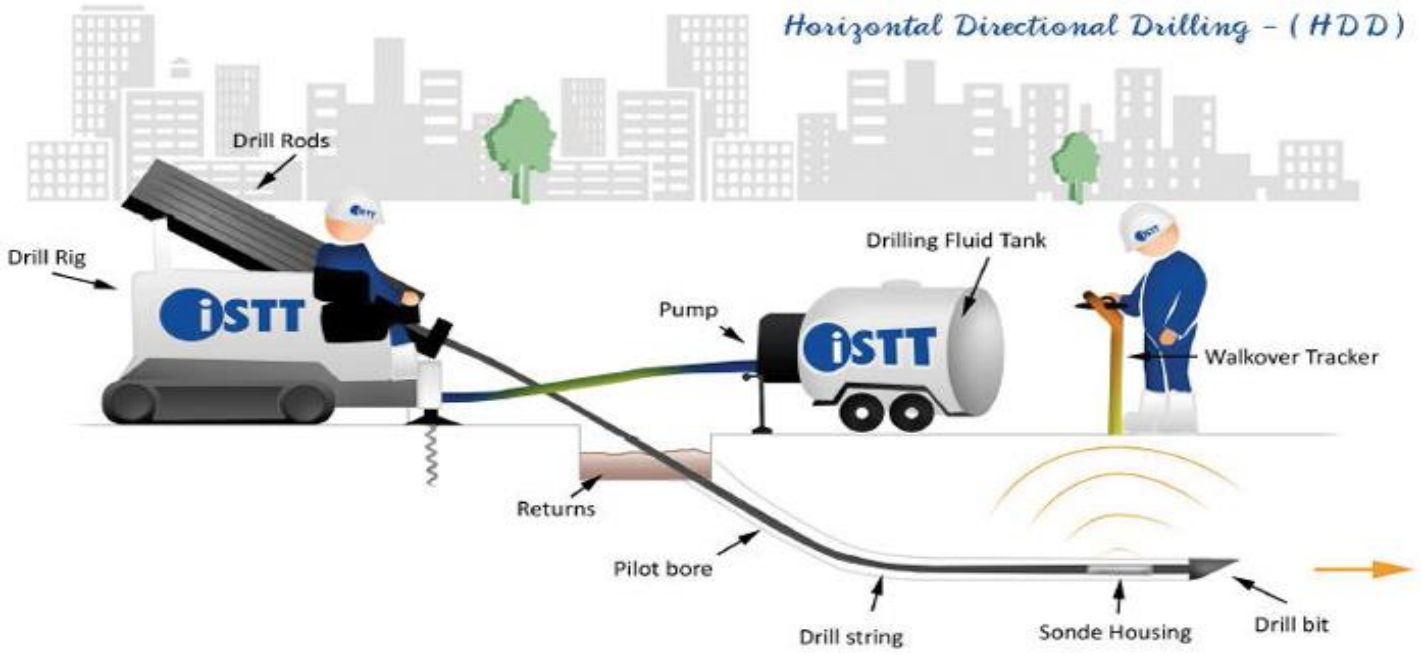

Image retrieved from http://www.istt.com/guidelines/horizontal-directional-drilling-hdd

- **Popular trenchless method to install buried utilities (water, gas, fiber optic and other utilities)**
- **First, a borehole is created using a cutting tool, and then the utility to be buried is pulled back through the borehole**
- **Precise tracking of the drill head is essential to create accurate 'as-built' drawings**

Drill head tracking: A review

Techniques used to locate and track a drill head

- Inertial sensors (e.g. accelerometers, gyroscopes)
- Magnetometers that measures the earth's magnetic field
- Wire-line locating systems
- Walk-over locating systems (most popular)

Handheld walk-over locators

- **Single axis (SA) receivers**
  - Measures one vector component (B_x, B_y or B_z) at a time using a single axis antenna
  - Often it is prone to errors due to 'ghost signals' (false signal peaks)
- **Vector sum (VS) receivers**
  - Measures all three vector components from which the total field strength is calculated

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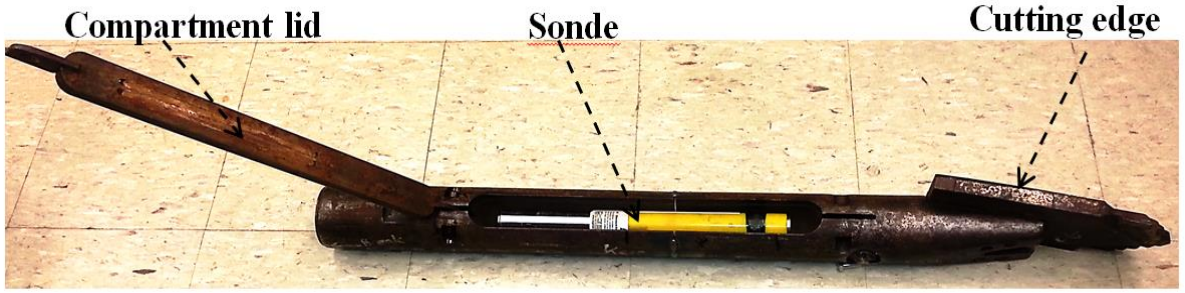
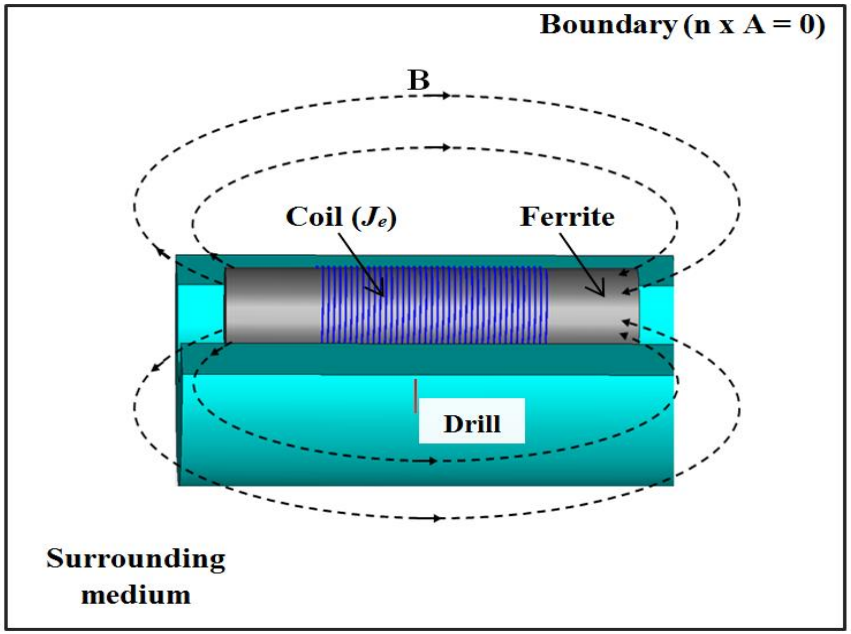
Mathematical description of the model





A simplified sketch of the numerical model

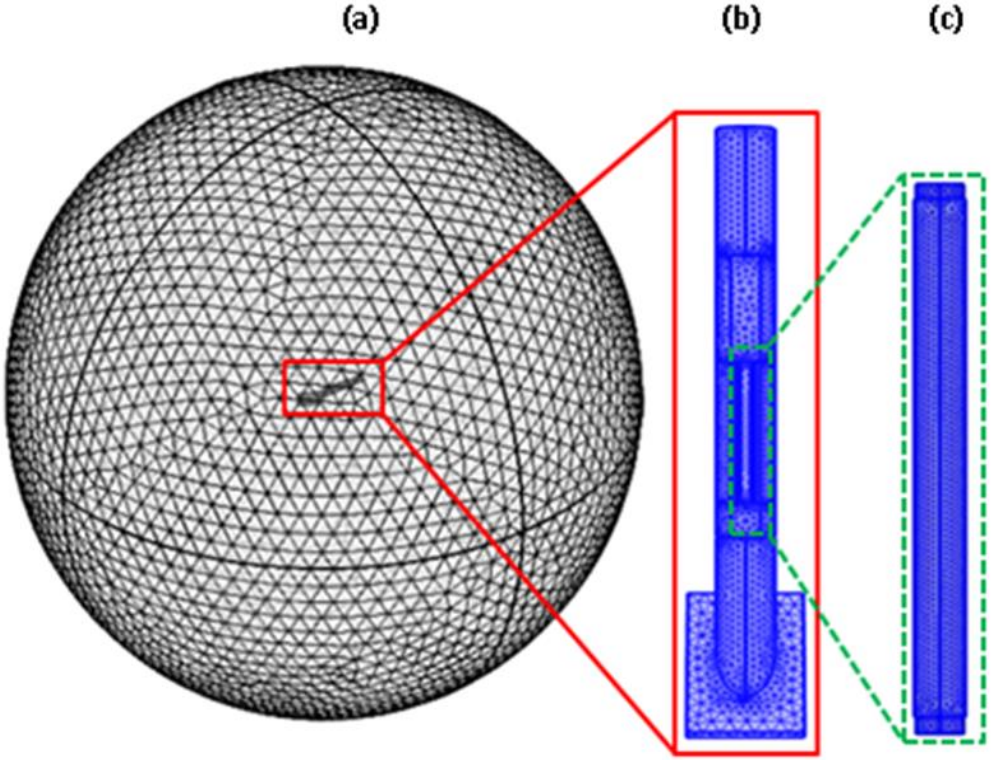
$$\left(j\omega\sigma - \omega^2\epsilon_0\epsilon_r\right)A + \nabla\, x\left(\mu^{-1}\nabla\, x\, A\right) = J_e$$

$$J_e = \frac{N\,I}{A}$$

A - magnetic vector potential
N - number of turns in the coil
I - coil current
A - cross-sectional area of coil
J_e - source current density

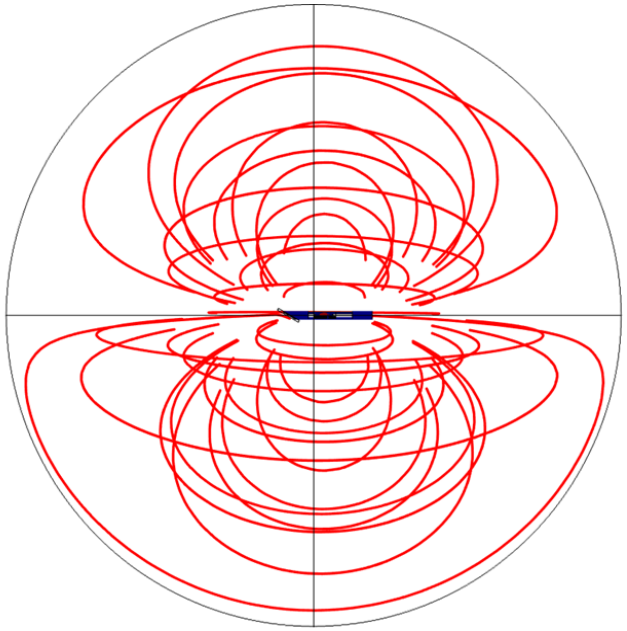
COMSOL Multiphysics model

- **AC/DC module with magnetic fields interface**
- **Frequency domain analysis (32 kHz)**
- **Model consists of ~923k elements ranging from 1 mm to 288 mm**

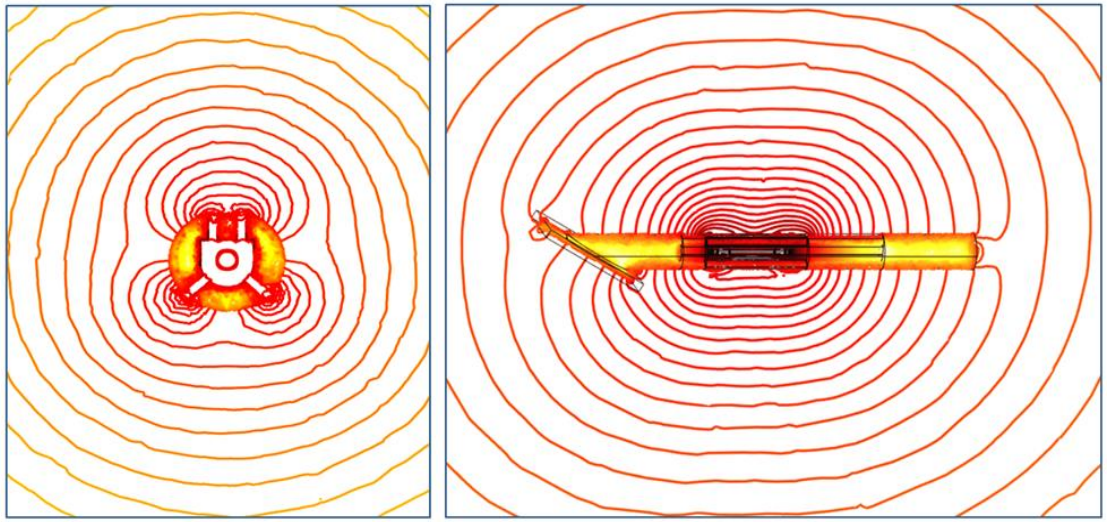


Mesh generated from the model: (a) fine mesh for medium surrounding the drill, (b) finer mesh for the drill head, and (c) extra fine mesh for the sonde.

Sample results



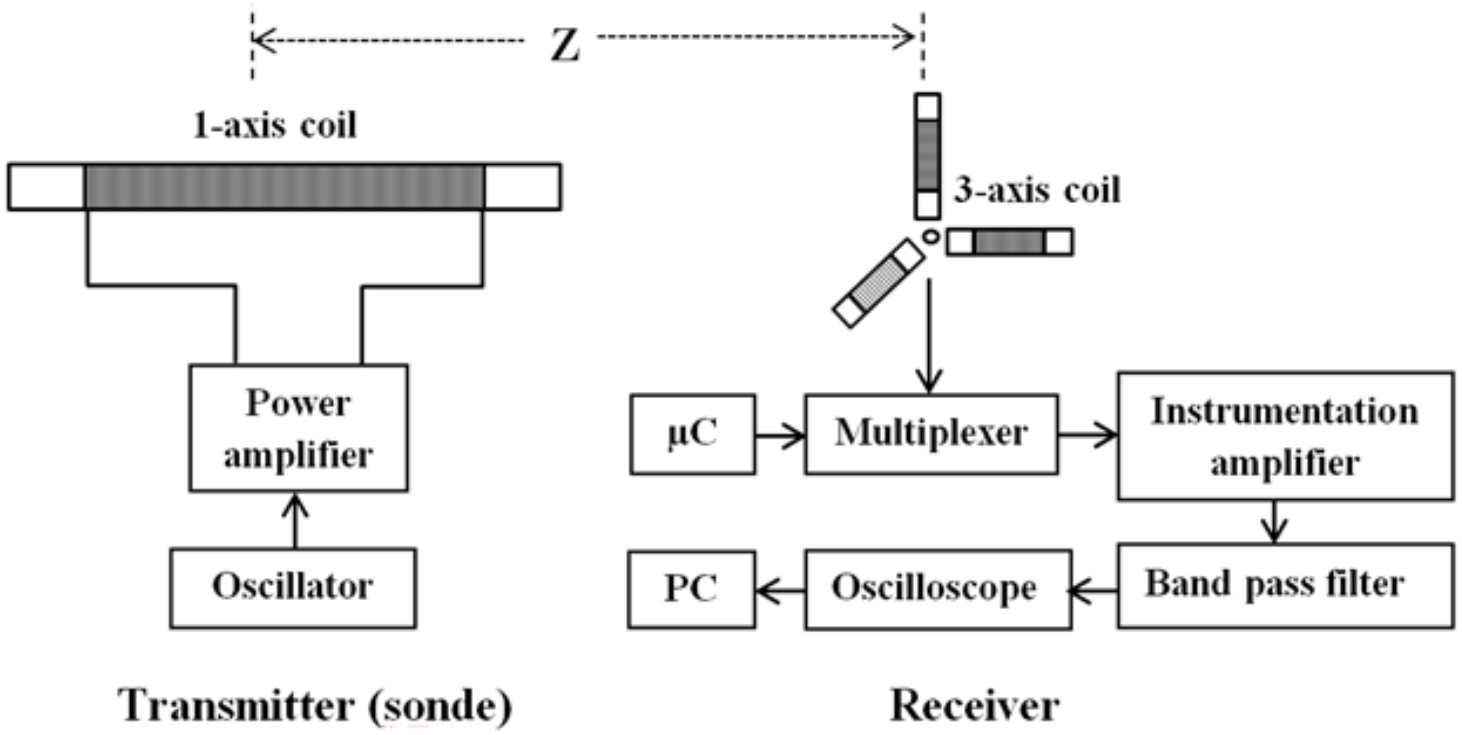
Screenshot from COMSOL model showing magnetic field lines emanating from the drill.



Screenshot from numerical model showing B-field in transverse (left) and longitudinal (right) planes around the drill.

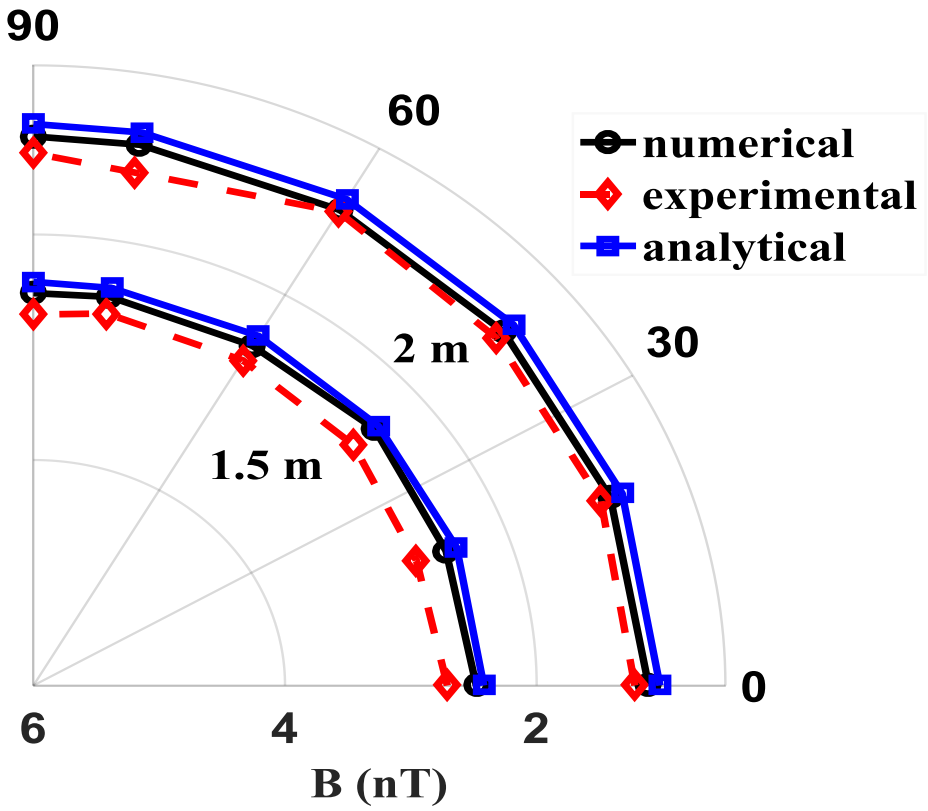
- **Contour lines generated shows distortion of field close to the drill**
- **A short distance away from the drill contour lines resemble the field from a solenoid coil**

Experimentation



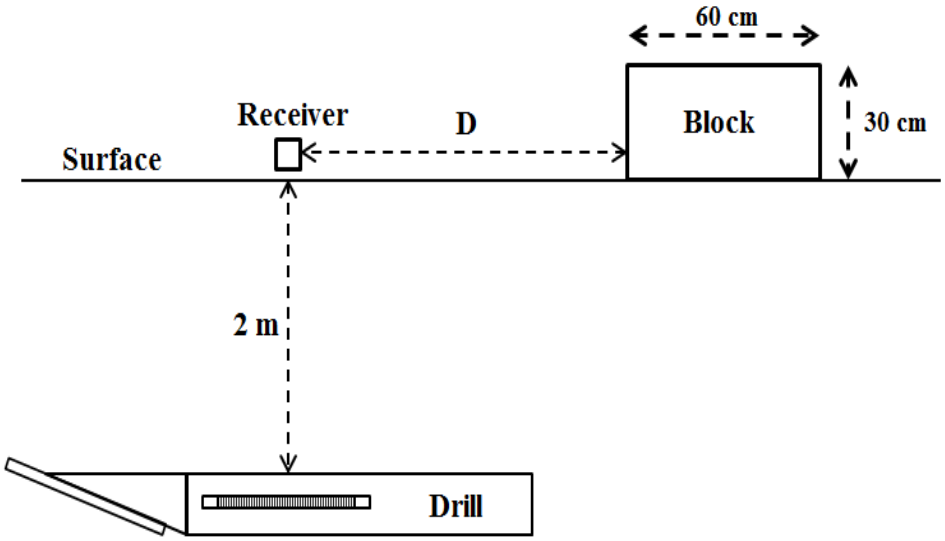
Schematic diagram of the experimental setup

Validation of numerical results

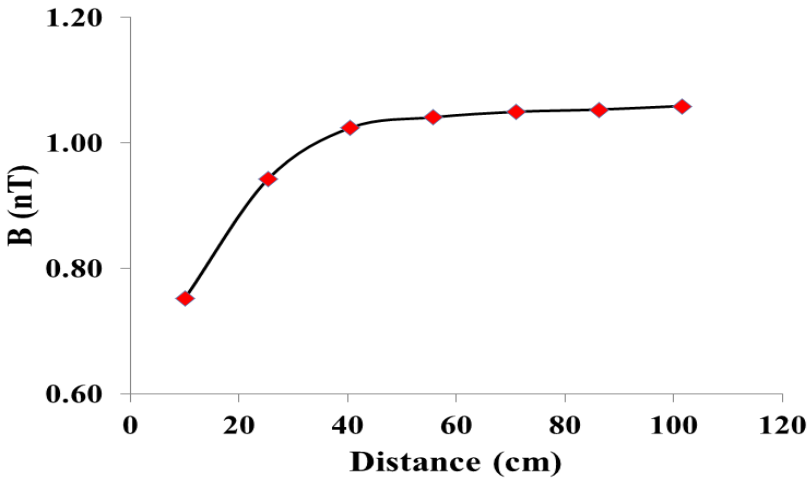


Magnetic flux density transverse to the drill

Walk-over locator operating in an environment with magnetic interferences



A ferrous block located close to a walk-over locator



B vs. distance D

Conclusions

1. **Numerical modeling of the magnetic field emissions from a HDD walk-over locator was carried out**
2. **Numerical predictions were compared with experimental data and closed-form solutions**
3. **This model could be used to simulate a walk-over locator operating in a noisy real-world environment**
4. **As a example, influence of a ferrous object located near the locator was studied**

Thank you