Deep, Controlled Source Electro-Magnetic Sensing: A Cost Effective, Long-term Tool for Sequestration Monitoring

Project Number DE-FE0012266

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Multi-Phase Technologies, LLC

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

August 12-14, 2014

Presentation Outline

- Benefits to Program
- Goals and Objectives
- Technical Status
  - Hardware and Software Modifications
  - System Tests
  - Model Study
  - Field Tests
  - Data Processing
- Accomplishments

Benefit to the Program

- The research is intended to develop and test a robust, cost-effective sensor array for long-term monitoring of CO_2 inventories in deep geologic formations using controlled source electromagnetic methods (CSEM) to measure the electrical properties of CO_2 reservoirs.
- This approach, which draws heavily on recent advances in marine CSEM, uses electrical and magnetic field signals created by transmitting electric current through borehole electrodes in or below the CO_2 reservoir. This technology contributes to the goal of accounting for 99 percent of injected CO_2.

Project Overview: Goals and Objectives

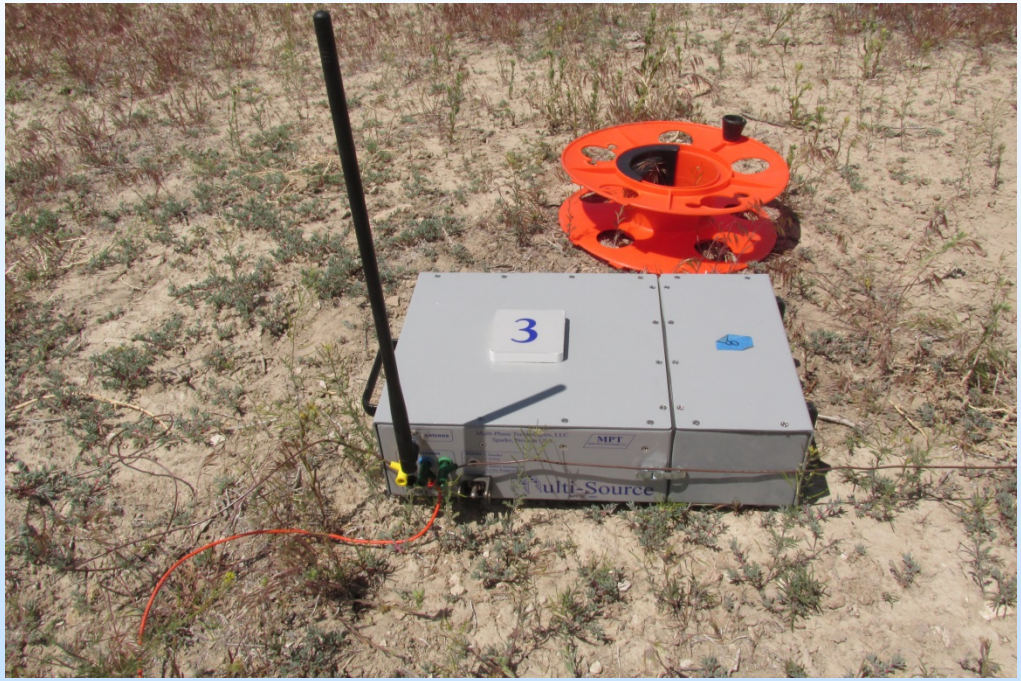
- Develop, cost-effective sensor array for long-term monitoring of CO2 (carbon dioxide)
- Use controlled source electromagnetic methods (CSEM) with a borehole source to measure the electrical properties of CO2 reservoirs
- Designed to operate as a permanent, autonomous monitoring and data collection system
- Provide much higher temporal data density than can be achieved economically with alternatives (3 D seismic surveys).
- Demonstrate System at Ketzin Site
- Post closure monitoring including simulation of release.
- Background and at least two follow-on surveys

Technical Status

- Hardware/Software Modifications
  - Implement Frequency Domain
  - Add Magnetic Field Sensors
- Hardware Tests (Astor Pass Nevada)
  - Test Modified Software
  - Compare Magnetic Field Sensors
- Field Tests: Ketzin Germany
  - Background
  - Post Extraction Data
  - Autonomous Operation
- Model Study
  - Provide Design Information
  - Test Feasibility

Multi-Source Tranceiver

- Internal TX
- Two Rx Channels
- Mux
- 3 Electrodes
- Multiple Units Can Transmit Simultaneously
- GPS Location and Timing



Magnetic Field Receiver

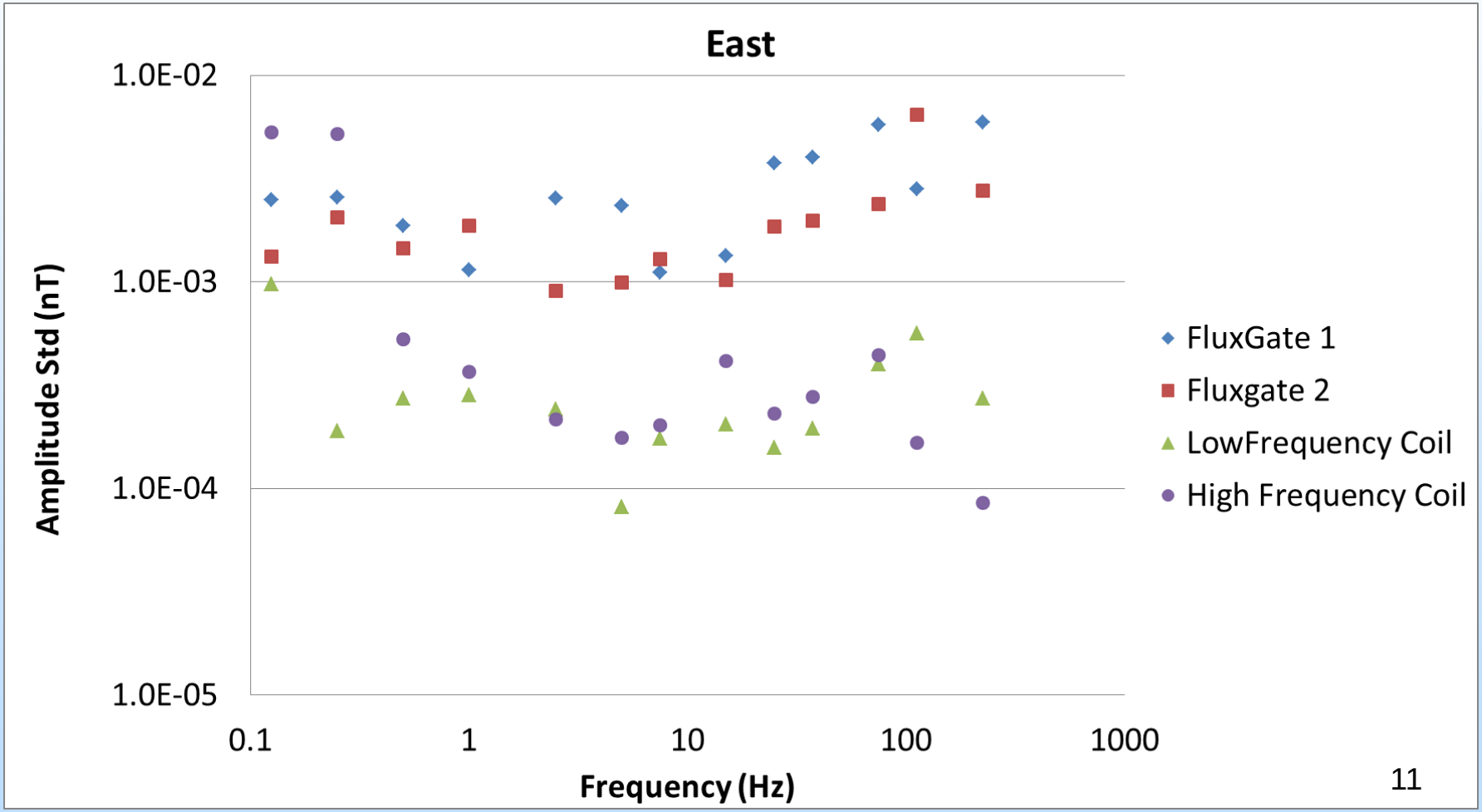
- 3 Rx Channels
- Internal Battery
- GPS Timing and Location
- 1/64 to 225 Hz

Magnetic Sensor Comparison

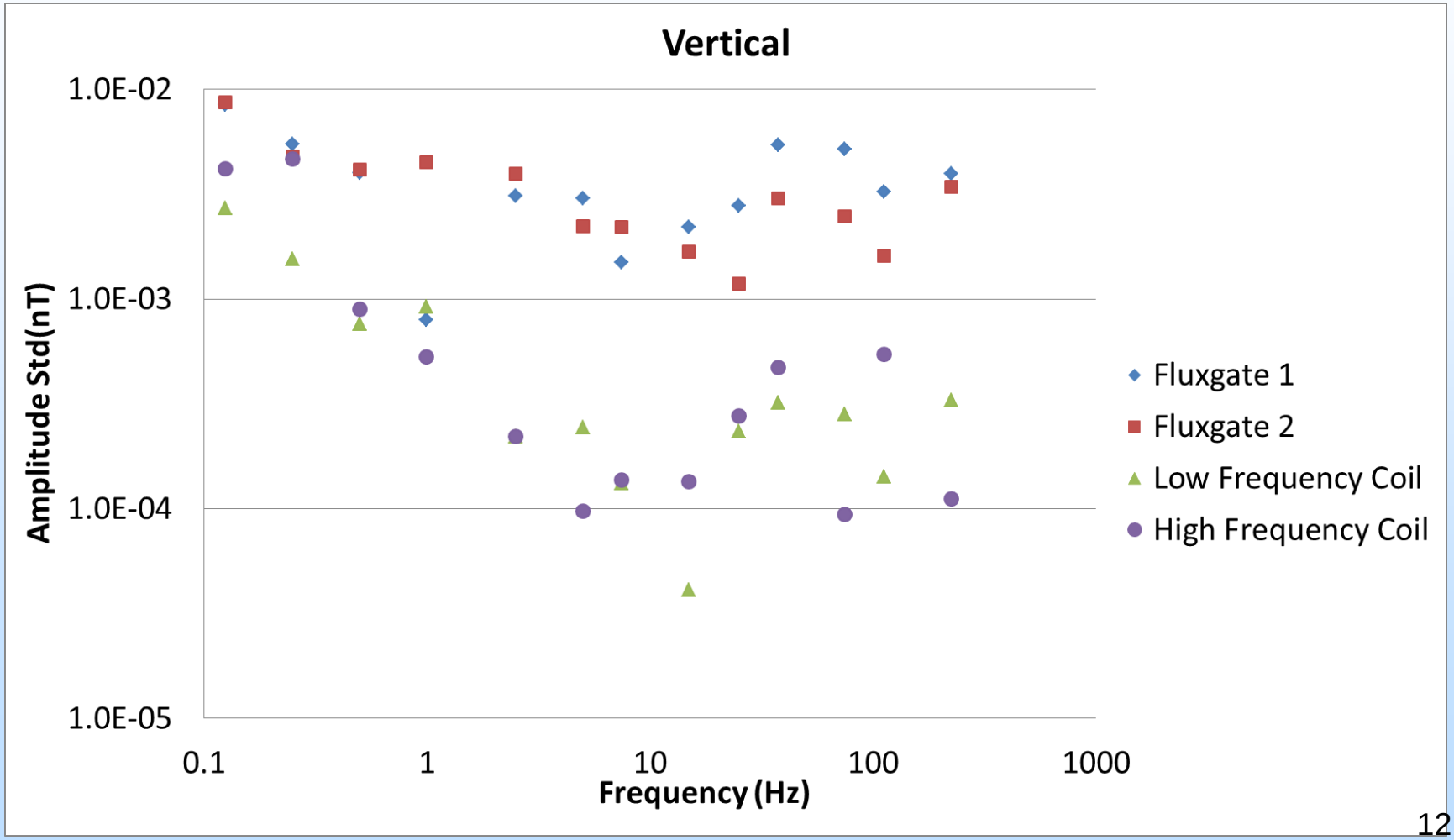
Placing Coils

SystemTests at Astor Pass, Nevada

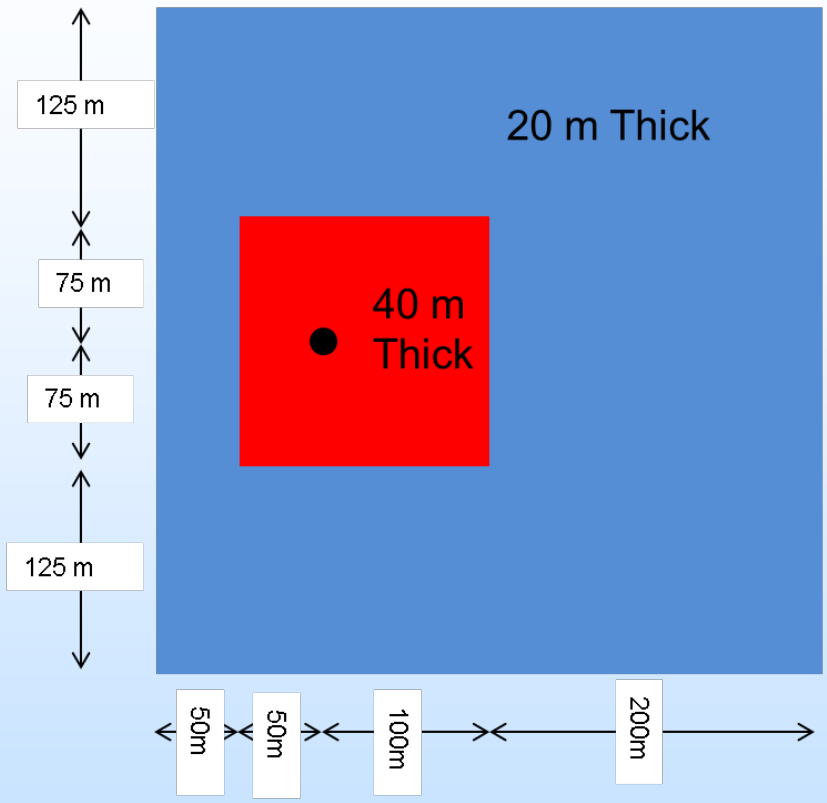
Data Standard Deviations From Repeated Short Stacks: Magnetic East Oriented Sensors



Data Standard Deviations From Repeated Short Stacks: Vertical Sensors



Model Study: Background Model



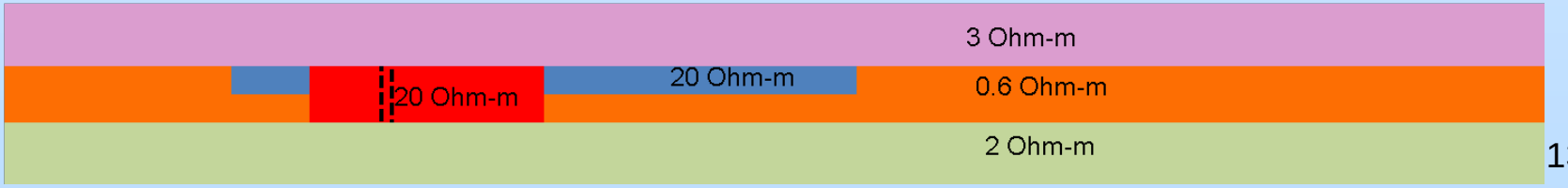
Map View of CO2 Thickness in Reservoir

Key

- Injection Well
- 20 m Thick CO2
- 40 m Thick CO2
- E & M Receivers

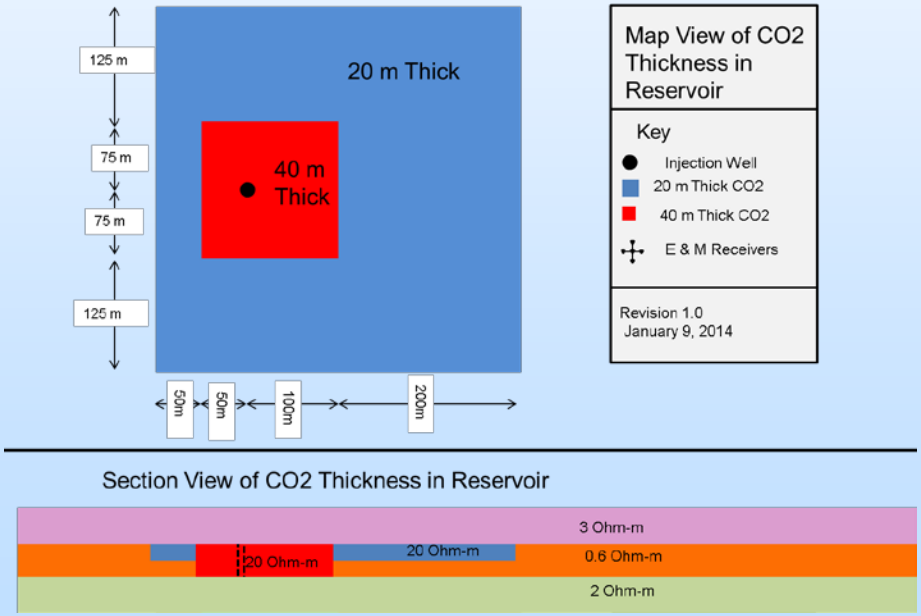
Revision 1.0
January 9, 2014

Section View of CO2 Thickness in Reservoir

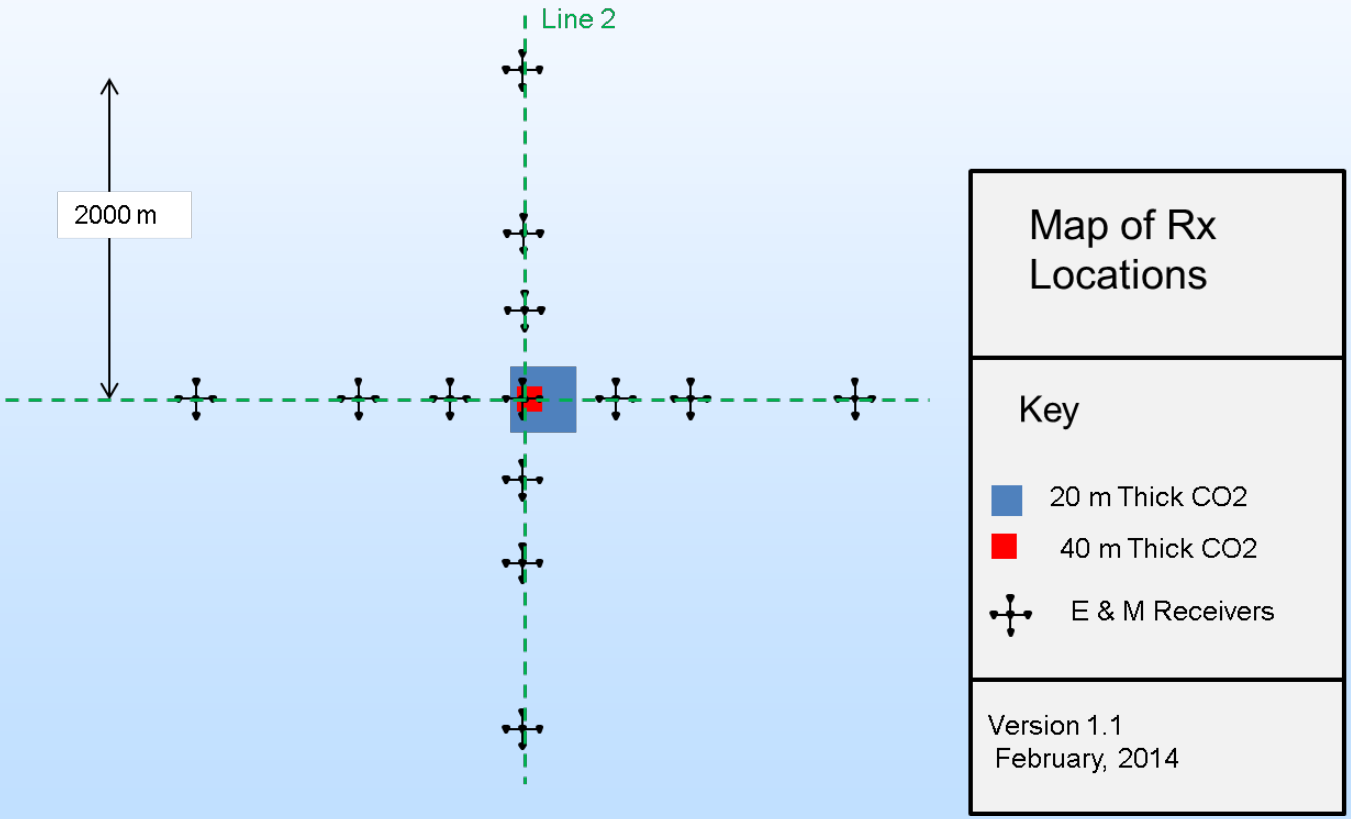


Models

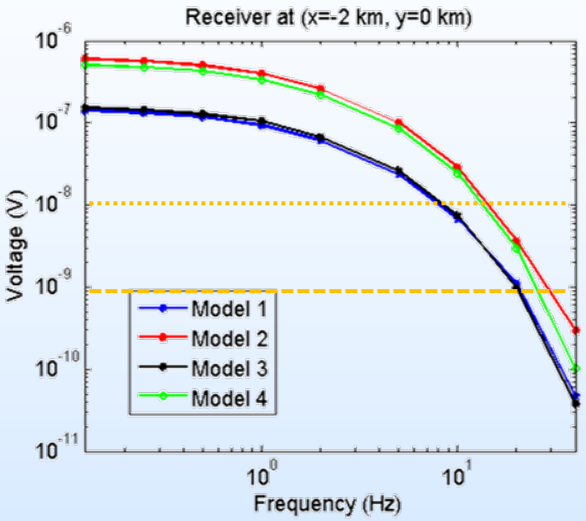
- Model 1: Background model (no CO2 plume)
- Model 2: Current estimate of CO2 plume
- Model 3: CO2 plume of a donut
- Model 4: 20m thick CO2 block

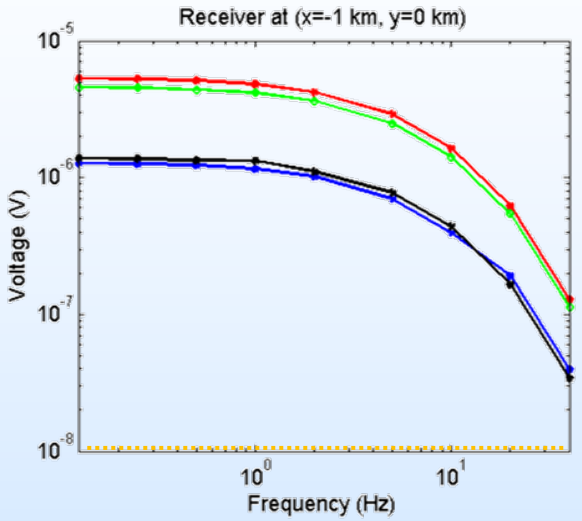


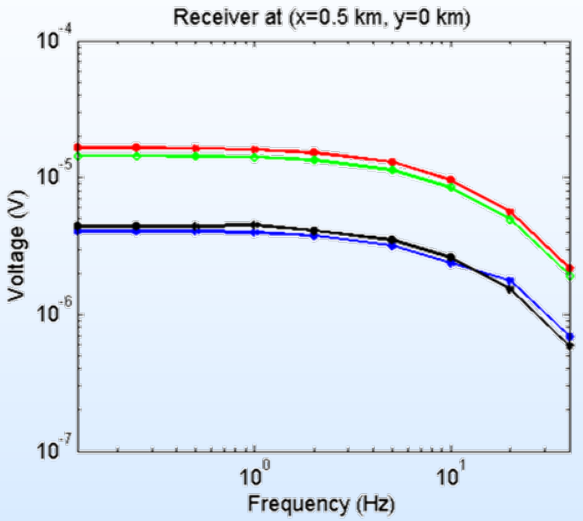
Model Study Background Model Continued

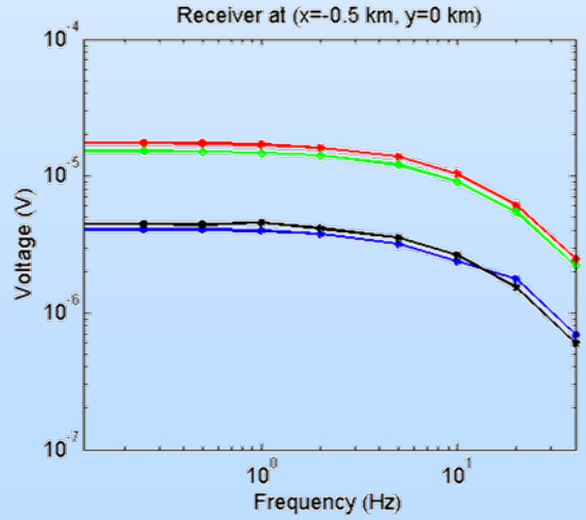


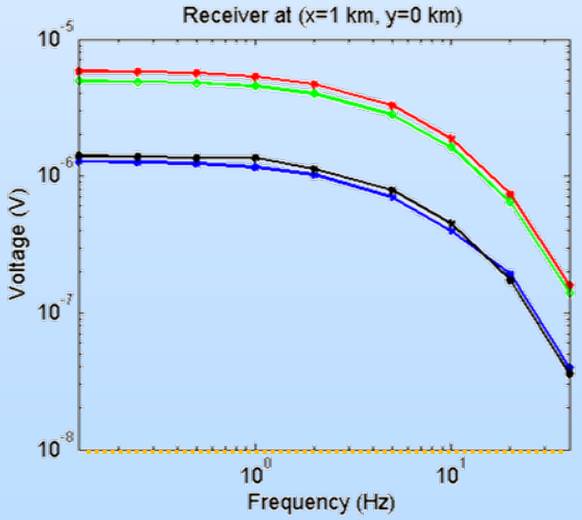
Line 1, Ex, Source 620 to 660 (Across Reservoir)

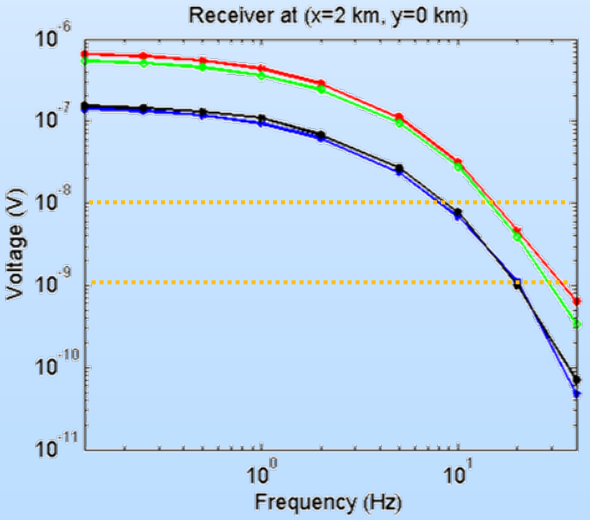












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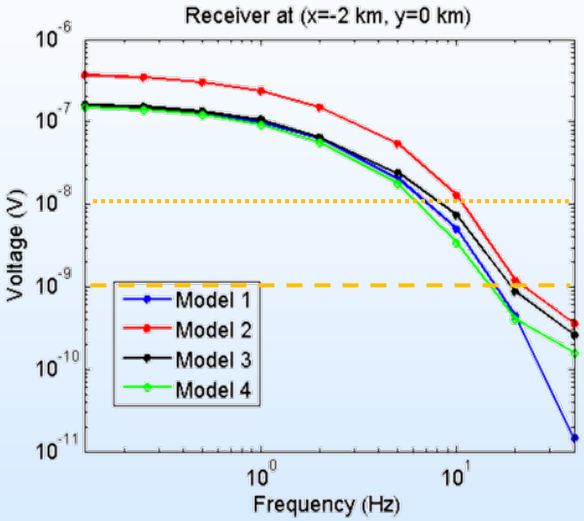

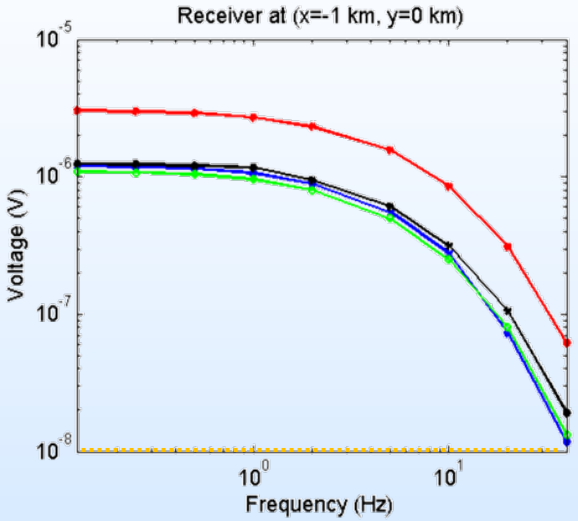

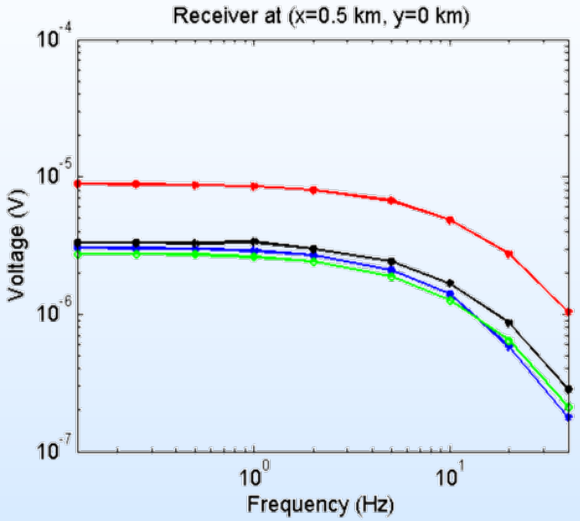

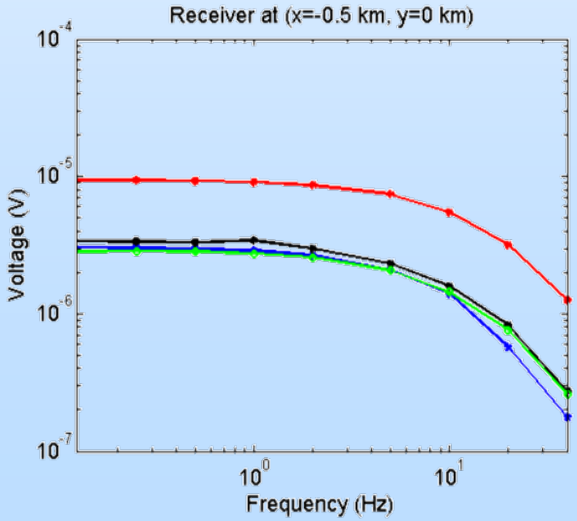

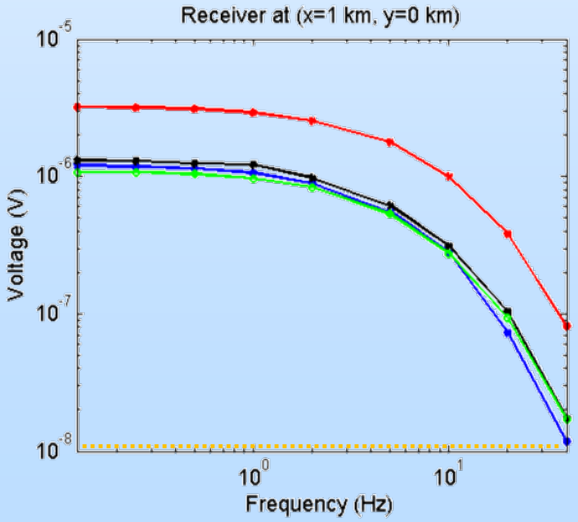

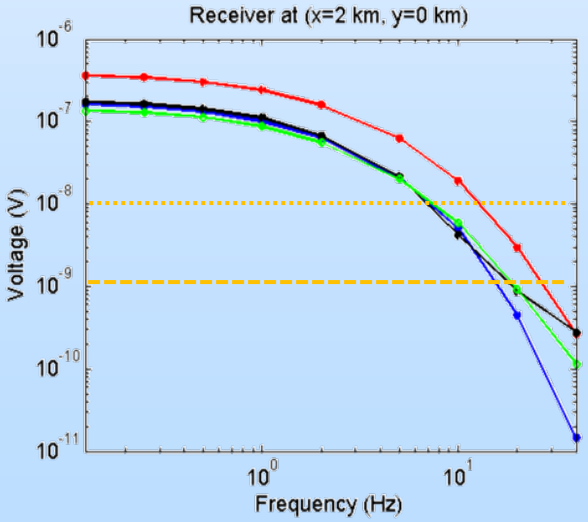

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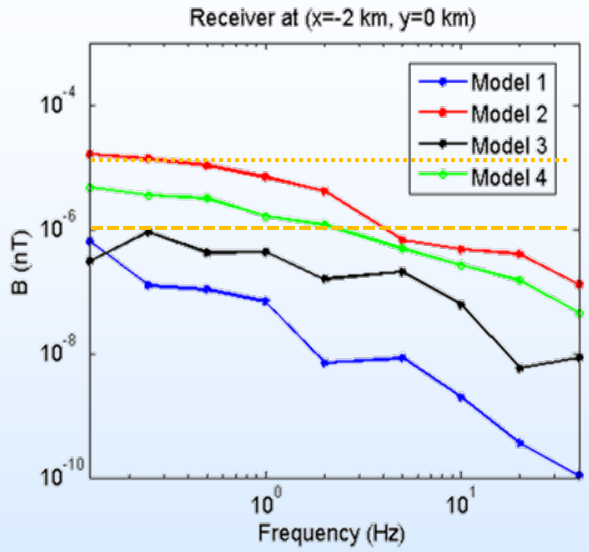

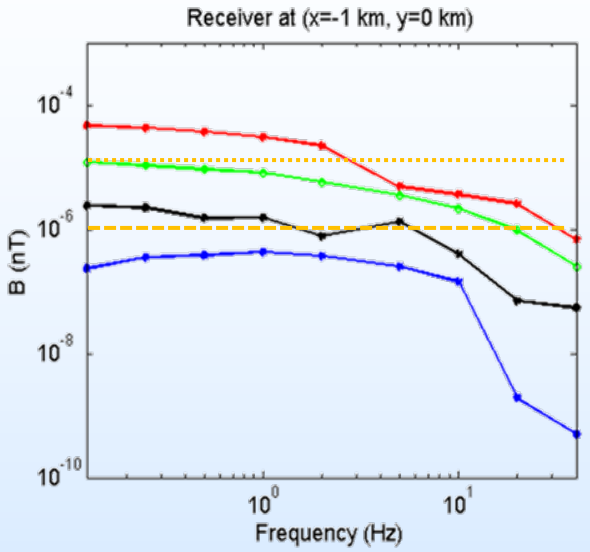

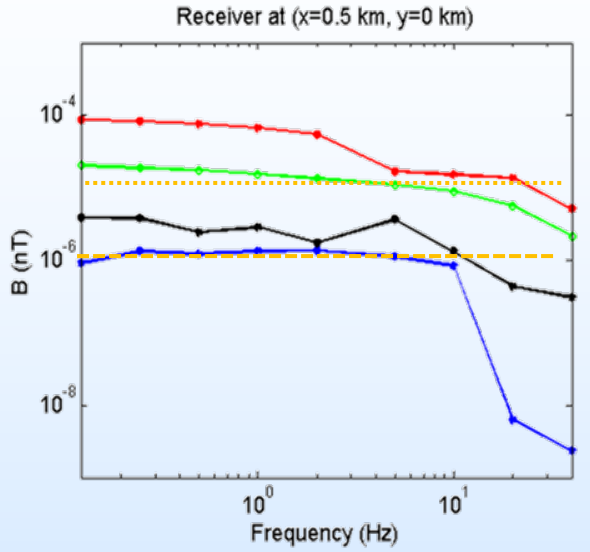

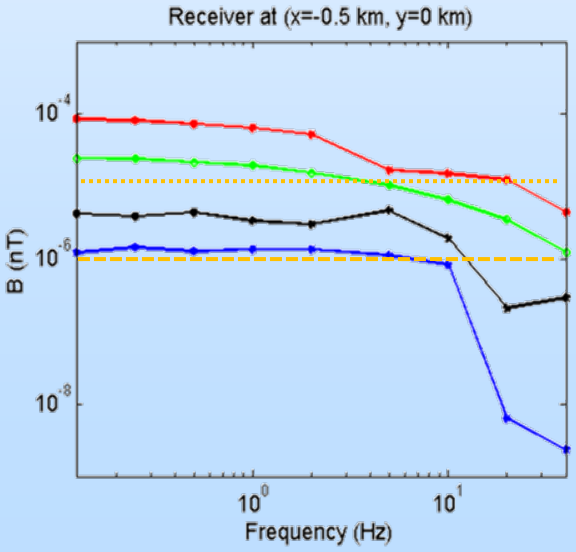

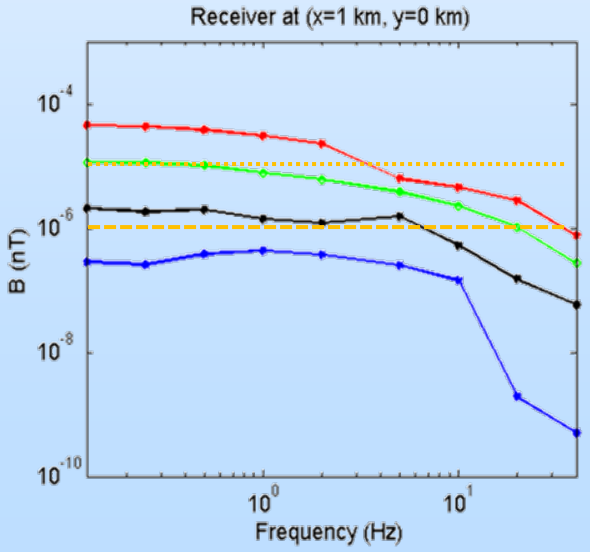

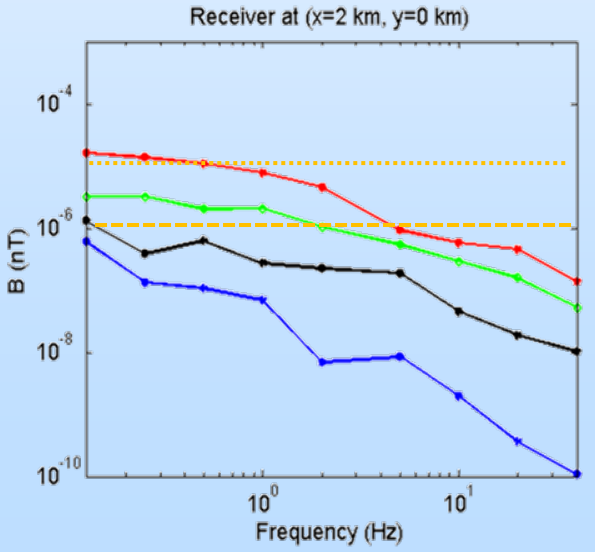

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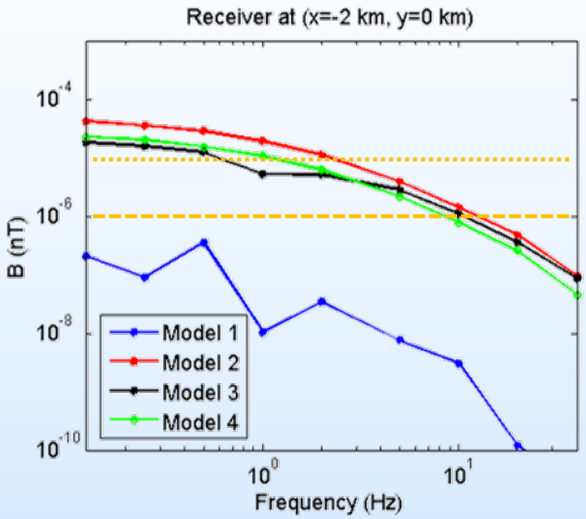
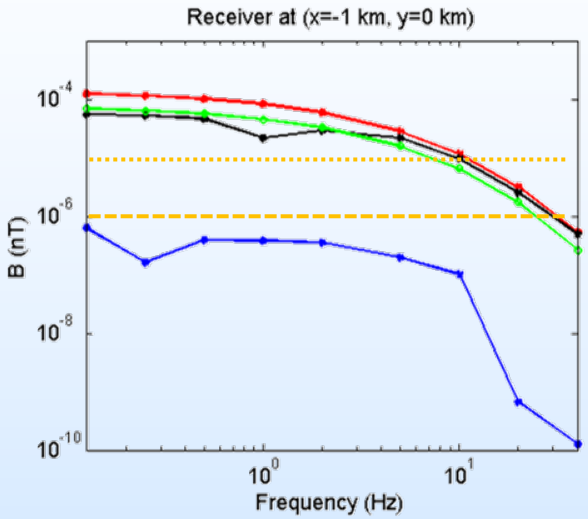
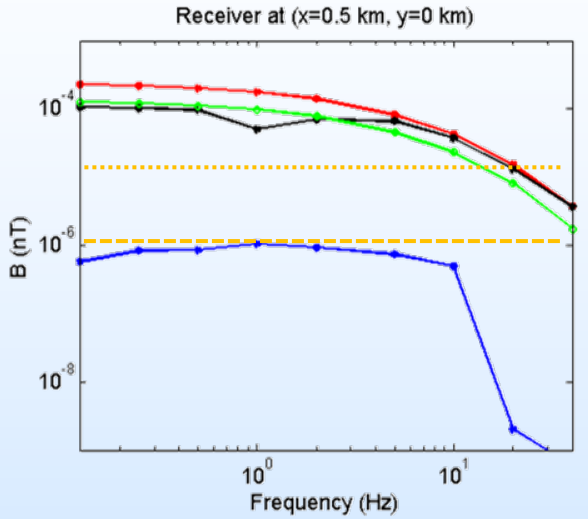
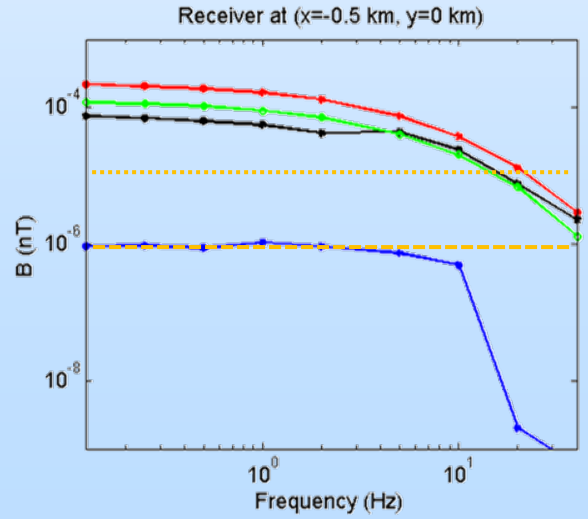
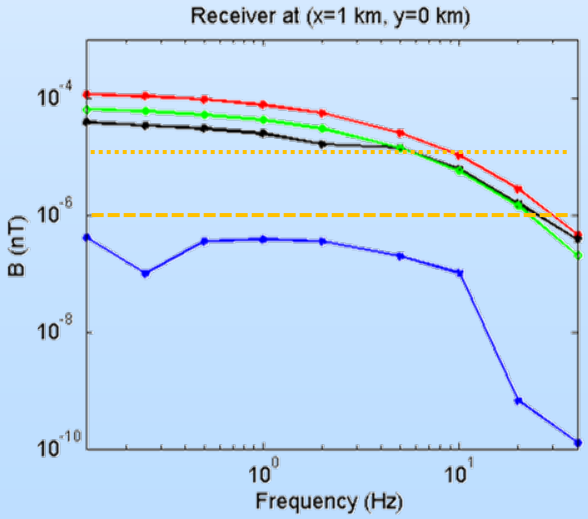
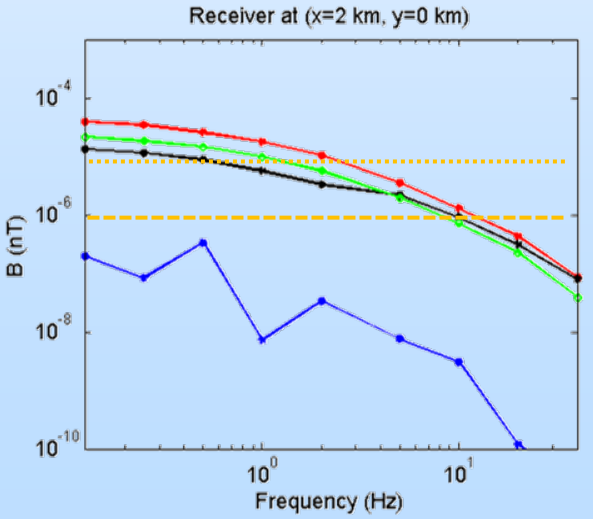












Accomplishments to Date

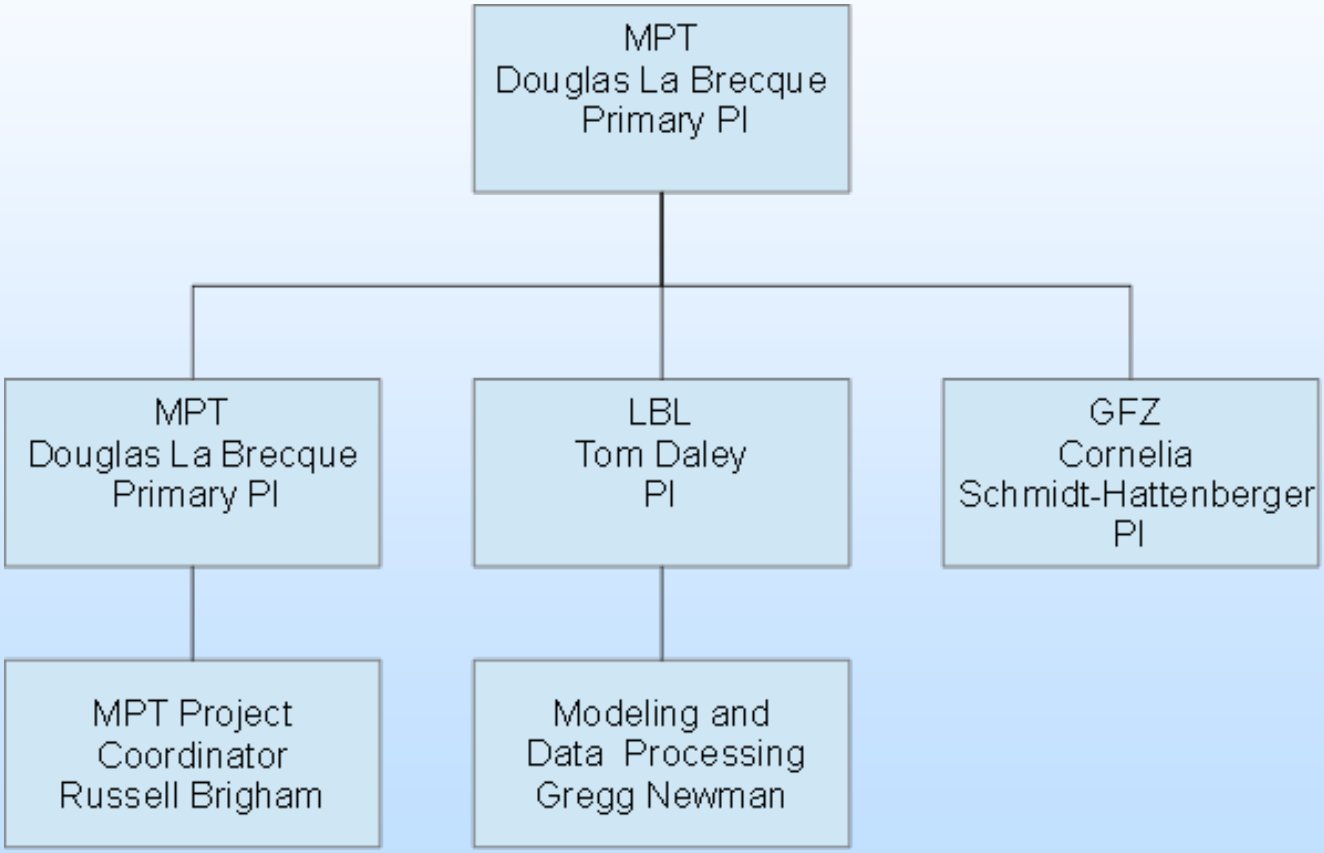
- Completed Hardware and Software Modifications
- Completed Model Study
- Completed Magnetic Field Sensor Comparison
- Completed System Tests Trials

Summary

- Key Findings
  - The Model Study Showed Significant Changes in Both Electric and Magnetic Field Responses Between Model Scenarios and Transmitter Types
  - Measuring the Magnetic Field Components With Sufficient Accuracy Will Be Challenging Particularly for Long Offets and High Frequencies
  - The Fluxgate Magnetometers are Not Sufficiently Sensitive For CSEM Measurements At This Scale
- Future Plans
  - Background Measurements Will Be Collected in Late September
  - The Initial Post-Extraction Measurements Will Be Collected in Late October or Early September
  - Data Inversion Should Start in November

Appendix

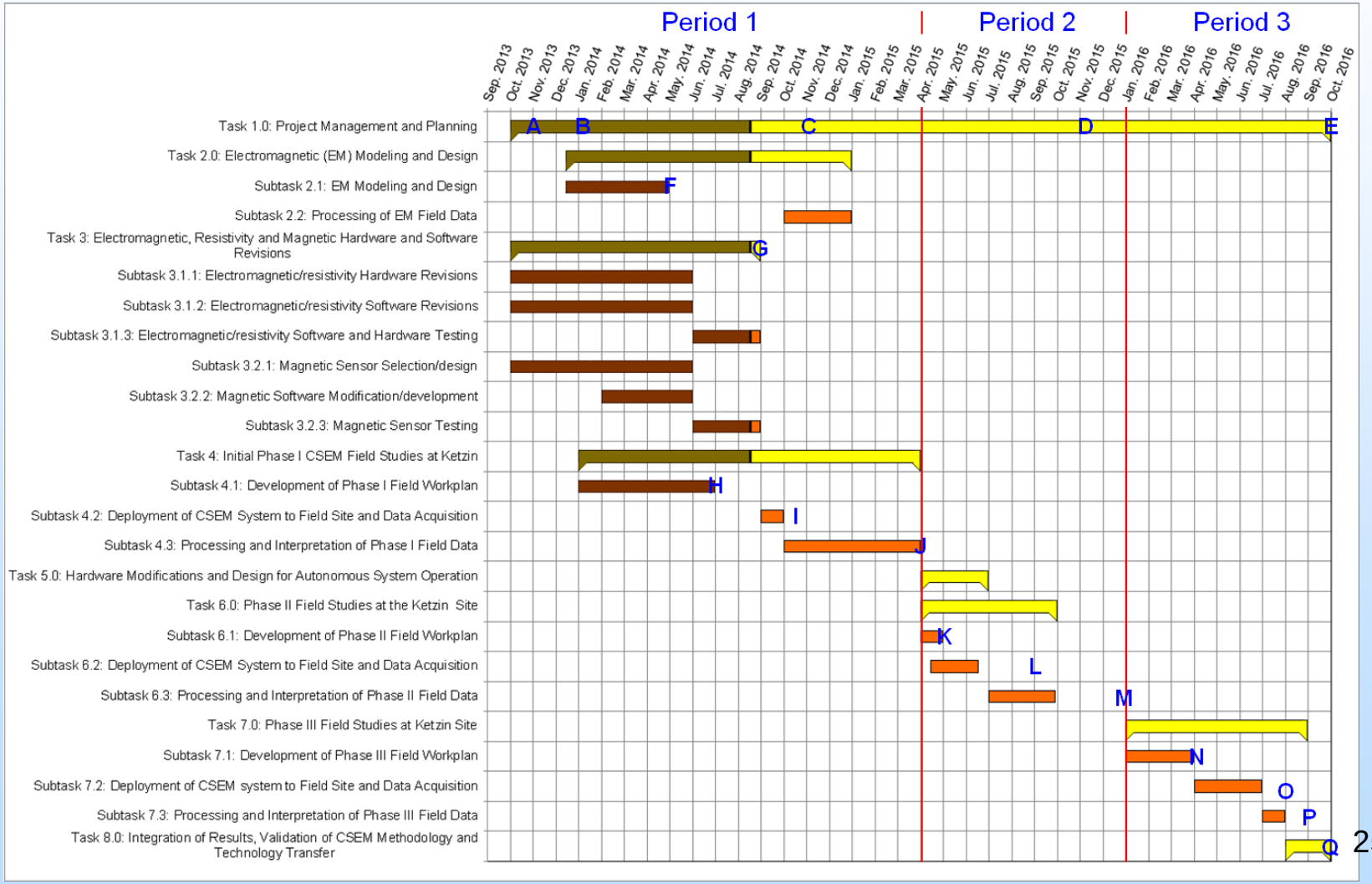
Organization Chart



Organization Chart

- Dr. Douglas LaBrecque from Multi-Phase Technologies, LLC (MPT) is the primary PI. He will be in charge of staff at MPT and coordinate the project with Lawrence Berkeley National Laboratory (LBNL), and the German Research Centre for Geosciences (GFZ) in Potsdam, Germany.
- Tom Daley from LBNL is a Co-PI and the primary point of contact for modeling and lab operations at LBNL.
- Dr. Cornelia Schmidt- Hattenberger from GFZ is a Co-PI and the primary point of contact for field operations at the Ketzin site.
- Russell Brigham from MPT will be the Project Coordinator and will assist Dr. LaBrecque.
- Gregg Newman from LBNL will be responsible for modeling and data reduction.

Gantt Chart


Period 1
Period 2
Period 3
Sep. 2013
Oct. 2013
Nov. 2013
Dec. 2013
Jan. 2014
Feb. 2014
Mar. 2014
Apr. 2014
May. 2014
Jun. 2014
Jul. 2014
Aug. 2014
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Feb. 2016
Mar. 2016
Apr. 2016
May. 2016
Jun. 2016
Jul. 2016
Aug. 2016
Sep. 2016
Oct. 2016
Task 1.0: Project Management and Planning
Task 2.0: Electromagnetic (EM) Modeling and Design
Subtask 2.1: EM Modeling and Design
Subtask 2.2: Processing of EM Field Data
Task 3: Electromagnetic, Resistivity and Magnetic Hardware and Software Revisions
Subtask 3.1.1: Electromagnetic/resistivity Hardware Revisions
Subtask 3.1.2: Electromagnetic/resistivity Software Revisions
Subtask 3.1.3: Electromagnetic/resistivity Software and Hardware Testing
Subtask 3.2.1: Magnetic Sensor Selection/design
Subtask 3.2.2: Magnetic Software Modification/development
Subtask 3.2.3: Magnetic Sensor Testing
Task 4: Initial Phase I CSEM Field Studies at Ketzin
Subtask 4.1: Development of Phase I Field Workplan
Subtask 4.2: Deployment of CSEM System to Field Site and Data Acquisition
Subtask 4.3: Processing and Interpretation of Phase I Field Data
Task 5.0: Hardware Modifications and Design for Autonomous System Operation
Task 6.0: Phase II Field Studies at the Ketzin Site
Subtask 6.1: Development of Phase II Field Workplan
Subtask 6.2: Deployment of CSEM System to Field Site and Data Acquisition
Subtask 6.3: Processing and Interpretation of Phase II Field Data
Task 7.0: Phase III Field Studies at Ketzin Site
Subtask 7.1: Development of Phase III Field Workplan
Subtask 7.2: Deployment of CSEM system to Field Site and Data Acquisition
Subtask 7.3: Processing and Interpretation of Phase III Field Data
Task 8.0: Integration of Results, Validation of CSEM Methodology and Technology Transfer
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Bibliography

No papers have been completed in the three quarters of this project.